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Preface to the fourth edition

I had considerable pride in being asked by the publishers to produce this fourth edition. *Technology of Biscuits, Crackers and Cookies* has been continuously in print since 1982 when the first edition was published and thus is very well known throughout the industry worldwide. It has been improved and extended twice with a second edition in 1991 and a third edition in 2000. By 2011 this reference text will have been around for 30 years! I think this success can be attributed to the practical relevance to students of biscuit manufacturing. To mark the long-term value of this book the title has been changed to ***Manley's Technology of Biscuit, Crackers and Cookies*** so I hope that the text will continue for many years yet.

There is a limited amount to add to the Prefaces that I wrote for the previous editions and I recommend you to read these to follow how the text and its aims have developed over the years.

In 1982 personal computers and the Internet were not available so books were the main sources of information. Surprisingly, books are still very popular as reference texts but the value of the Internet should not be underestimated. By searching, lots of additional pockets of information can be found, including coloured pictures of different types of biscuits, but I hope that this text will be regarded as a valued reference for biscuit technology. This book is now available as a digital text and can be purchased either as individual chapters or as the whole book from Woodhead Publishing.

Not to be left out on the Internet, in 2006 I produced a website of biscuit technology, The Biscuit Doctor, www.thebiscuitdoctor.com This is a précised version of this text with the addition of coloured pictures and a large section addressing common problems. In 2010 an on-line Technology Course was added to provide a convenient facility for students to study the subject and to achieve a Certificate of Achievement.

I have worked in biscuit manufacturing for more than 43 years and wish others to enjoy it as much as I have. Having now worked in more than 100 biscuit factories in about 40 countries (mostly as an independent consultant) I have, I hope, helped

owners to improve their businesses and taught very many people some of the critical aspects of manufacturing and product development. This has given me much pleasure as I have enjoyed teaching younger people not only how to do things but also the reasons behind what they have to do to make good biscuits profitably. I still have a number of clients that I have known for many years and whom I help on a retainer basis, but as I have got older I have reduced my travelling so have recently had less hands-on involvement in production. I am aware that there are some areas that have developed that I do not know enough about and this is why I have decided that there should be other experts, with more specialist knowledge, contributing to this new edition to keep it comprehensive and relevant. The text remains valuable to those who want to make biscuit manufacturing a profitable business.

Biscuits were the first long-life convenience foods. Many of the older and larger biscuit companies have amalgamated and passed into the ownership of large international companies. However, this does not mean that small companies no longer exist. New businesses are continually being formed, not only in developing countries but also for specialist products in Europe and other strongly industrialised countries. In the larger companies the emphasis has been on large-scale production with mechanisation and automation to reduce costs. Computerisation and instrumentation have aided this greatly but it does mean that the opportunities for individuals to learn the technology have been reduced. Computers only do what they are programmed to do so, if measurements are not correctly correlated, process control will be unreliable. Understanding the basic technology is an essential starting point. This book aims to help.

Duncan Manley, 2011
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Woodhead Publishing now has a prominent position in food technology books. Wherever relevant, reference has been given to their other publications where other aspects of food manufacturing may be useful.

Preface to the third edition

It is now 17 years since the first edition of this book and 9 years since the second edition. Throughout this time I have acted as an independent consultant and have visited very many companies in about 34 countries. This has given me the chance to discover what things people want to know, what problems commonly occur and where assistance and information is commonly needed. I am very aware that few biscuit technologists have been able to see inside other biscuit factories and thereby learn or even confirm that what they are doing is correct or the best. I hope that this book will help in this area. It has been a privilege to see that in most of the companies I have visited there is a copy of my book! In many it has been the first edition that I have seen so unfortunately there has not been the thought that the later edition might be worthwhile! However, both the second edition and this one have major additions and improvements. In preparing this edition all the text has been completely reviewed and revised. I have tried to include useful and practical data and ideas that have come my way over the period of my career.

This book may be used for various purposes but I have tried to be practical rather than academic. In the end technology should be used to make biscuits efficiently. Thus the concepts and operations of production and product development need to be detailed systematically. It is hoped that the management chapters which have been extensively revised and enlarged will be useful in this respect.

Since producing the second edition in 1991 I have organised and run a series of annual teaching seminars known as the Cambridge Biscuit Seminars. There were three seminars, a Biscuit Processing Technology Seminar, a Practical Seminar in Biscuit Making and a Biscuit Development Seminar. They were held two or three times a year from 1991 to 1998 and were attended by delegates from 109 companies in 42 countries. Discussion and feedback from these delegates greatly enhanced the contents of the lectures and has also influenced this new edition of the book. There was particular interest in details of the functions of ingredients and mechanisms of processes. The practical rather than academic approach that I took seemed to be particularly appreciated. Meeting the delegates at my seminars has led to much consultancy work to mutual benefit.

Another benefit from the seminars has been to endorse the fact that it is not until you have to stand up and teach a subject that you find out what you do not know or not understand satisfactorily. I have been through this and am now much clearer on why things happen and what needs more research! You will see that I have indicated this at times in the text.

I have also written and had published a series of manuals on biscuit technology which are designed as training aids for factory staff. They are complementary to this book in that they contain additional practical information such as troubleshooting guides and diagrams of process mechanisms which help the operator to understand what is happening and how he should tackle problems.

Biscuit manufacturing is an engineering enterprise. Factory operators and managers must have a sympathy for the function and control of machinery and engineers must have a good understanding of the processes that are mechanised. It is hoped that all involved in the biscuit manufacturing industry will gain knowledge and guidance from this book. It is designed to be both a training aid and a reference text.

As a consultant I have maintained independence and have not received any financial reward from suppliers as a result of recommendations or introductions. I am continually being asked for recommendations on suppliers of ingredients and machinery and I do my best to point people in the optimum directions. I have broken with tradition in this edition by allocating a section at the end to displays from some of the suppliers that I regularly recommend. These displays have been paid for by the suppliers and they are provided as useful references for the reader and starting points for more information and quotations.

It is impossible to acknowledge all the help I have had resulting in this new edition but I should like to single out Dr Karl Tiefenbacher of Haas in Vienna for his contributions on the chapter on wafers.

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Preface to the second edition

Technology and engineering have changed the face of biscuit manufacturing from busy, noisy, labour-intensive enterprises where team work and craft skills were essential, to quieter, cleaner and very much more efficient businesses with workers more isolated and less involved in the biscuits they are making. Managers and supervisors have also become more isolated and are being required to become more involved with paper work.

Strangely, automation is reducing this isolation because people are coming together in control areas and are discussing their relative problems more. Computers are reducing the drudgery and allowing managers to decide more quickly and based on better information. However, there are still significant gaps between scientific knowledge and craft skills, and the biscuit industry is in a critical stage where craftsmen are now few and process understanding is incomplete.

It is hoped that this book will encourage many to understand more of the technology of biscuits and to make their own contributions to technical advancement.

This was how I concluded the first edition of this book, and it would seem that most of it is still true today. That was eight years ago!

It took me some time to write that book and the print is now sold out. I thought that rather than have a reprint I should make the effort to produce a second edition.

This edition therefore contains some additions and alterations and has a revised format. I remain pleased with the concept of the first edition, so much has not been altered.

The preparation of the first edition involved a typist deciphering my writing and unfortunately the publishers did not compile the type electronically. My company has, in the meantime, invested in Apple Macintosh computers and much use is made of the word processing facilities. However, the prospect of retyping the book in order to be able to make use of the marvel of word processing was not attractive! Fortunately I was introduced to the OCR (optical character recognition) available

for the Macintosh, and with very little trouble all of the book was scanned into word-processable form. The saving in time was incredible.

Thus, this second edition I view as an update similar, in a way, to an updated version of a satisfactory computer program. Errors have been removed, useful new parts added, but basically it is the same book, better now and easier to use.

Continuing with the software analogy, I have introduced the idea of a Reader's Registration Card. I have for some time been concerned that, with textbooks, there are such long periods between writing, publishing and reprinting or rewriting that errors become cast in stone, and interesting new information cannot be communicated to the readers. It is my intention to send periodical updates to those readers who register, thus making the book constantly more topical and relevant. I hope you will avail yourself of this service by sending back the card, which you will find at the back of the book. The service will be available to individuals only, not to libraries.

The first edition has been translated into Spanish and this is still available. I myself used the book as the basis of the first Practical Course in Biscuit Technology at the ZDS College in Solingen, Germany, and I still see it as a reasonably comprehensive *single* volume reference book for technical management in a biscuit company or for those aspiring to such a position.

Duncan Manley, 1990

Preface to the first edition

Biscuit making is a substantial sector of the food industry. It is very well established in all industrialized countries and is rapidly expanding in the developing areas of the world. The major attraction of biscuits is the very wide variety of types that are possible. They are nutritious convenience foods with long shelf life. The main disadvantage for some countries is that biscuits as we know them rely upon wheat flour for their manufacture and this cereal may not be cheaply available.

Biscuit manufacture has lent itself to extensive mechanization and is now entering the realms of automation. Its development from a craft to a science is not yet complete, so understanding of processes and experience are still very important at all levels of management. However, during the last decade or so the industry has seen the retirement from the older companies of most of their long-serving and experienced craftsmen/ managers. Modern life, where educated people tend to move jobs in the course of their careers, combined with a drastic reduction in staff numbers in biscuit factories, has caused a problem in the training, technical competence and solid experience of much of the staff. It is now very difficult to learn slowly and surely the tricks of the trade because it is not so possible to work near to those who do know. Whilst mechanization has made it possible to reduce labour costs and to eliminate many of the hard, dull and repetitive jobs, it has also thrown a great emphasis on the importance of the engineer and maintenance mechanic. Engineers have assumed very important roles and not least the electronic engineers. Unfortunately we frequently see in these people an appalling lack of interest and understanding of the processes their machines are involved with.

In developing countries there is an understandable desire to invest in good, efficient machinery with which to make biscuits in their new factories. There is a common wish to copy well-known European biscuit types despite the fact that their local raw materials may be more suited to other products. The problems of technical understanding in these virgin factories are very great and need gentle and lasting attention.

In line with other industries around the world there is a desperate need in biscuit manufacturing to improve production efficiency, to reduce waste and conserve power. Inadequate understanding of processes and the functions of raw materials has hampered both operators and management in their attempts to run plants smoothly. Unfortunately, there are very few formal courses for training biscuit operatives and managers and most of the courses are of very short duration or lack adequate practical content. Furthermore, although much information is published in various technical journals about particular aspects of biscuits, there are surprisingly few textbooks comprehensively covering the biscuit manufacturing processes and the business in general. Notable texts have been *The Manufacture of Biscuits, Cakes and Wafers* by Fritsch & Grosppierre in 1932 [1], *Biscuit and Cracker Production* by Bohn in 1957 [2], *Cookie and Cracker Technology* by Matz in 1978 [3], *The Biscuit and Cracker Handbook* in 1970 by the Biscuit and Cracker Manufacturers Association, Chicago [4], *Biscuit Manufacture* by Whiteley in 1971 [5] and the two-volume magnum opus by W. H. Smith in 1972 [6] entitled *Biscuits, Crackers and Cookies*. Only Whiteley and Smith are significant on fairly recent British techniques; the rest specialise in USA methods which are rather different.

This book is designed to offer information in a practical way for those whose business is the making of biscuits. Particular emphasis is placed on creating awareness of opportunities and possible difficulties in the hope that forward planning will avoid trouble. Hopefully help will also be found for those already in trouble! Thus the information is structured for senior and technical management, purchasing and production management and senior operatives.

In Part I important characteristics of the common raw materials and wrapping materials are described, followed in Part II by descriptions of principal biscuit types with a few typical recipes and their manufacturing processes. Part III includes considerations of production equipment, and processes. Part IV is oriented towards production efficiencies through technology and techniques. There is particular emphasis on the role of a technical manager and effective quality and process control. Recommendations are made for the development of management control systems and for the integration of technical and new product development policies with staff training and personnel development.

Technology tries to be precise, but we are living in a world of people. While people have personal skills and great flexibility, they also have prejudices which are as much a problem as materials and methods. In an industry that stems from ancient crafts and hallowed traditions it is important to consider a framework of precise scientific fact which can accommodate personal skills and can preserve them lest they be lost in a coming age of automation. It is important to balance the value of a trained person with his problems of mood, variable concentration and need for periodic breaks, but flexible awareness and skills, with the untiring reliability of an instrument that has no flexibility and may not be able to check itself. It is always important to question what ought to be done and what can be done and what would be best. The design of plant and its control must include people and not just instruments and computers. Thus the information and ideas offered here are the result of a long felt need to be comprehensive in one book. They are based on many years of personal experience as a scientist in flour milling, as a senior manager and director in a medium-sized biscuit company in London, as a research manager for a major biscuit machinery manufacturer and currently as a private consultant to the industry.

As textbooks tend to be out of date by the time they are published, an attempt has been made to show where the industry is heading, particularly in the areas of process control so the information should be of value to ambitious and less advanced manufacturers alike.

Very often new ideas and the application of new technology is disseminated to senior management of biscuit companies by the visiting sales representatives of major machinery suppliers keen to make a sale. It is hoped that the information provided in this book will provide a sound basis of fact against which new claims can be judged or tested. It is also hoped that the need will be demonstrated for at least a small technical department in all companies. The functions are various, but particularly they should aid senior management to keep abreast of relevant technical developments which may be of benefit and to initiate requests for equipment which suit a particular requirement.

There is considerable excitement and satisfaction to be had from the challenges in the biscuit industry and this is enhanced if one has confidence in one's techniques and understanding of processes. It is hoped that this book will allow others to share what I have found and to avoid some of the frustrations.

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The Biscuit Doctor is designed and owned by Duncan Manley.
Duncan Manley is the author of several books on Biscuit Technology including
Technology of Biscuits, Crackers and Cookies
and was the principal lecturer at the Cambridge Biscuits Seminars

1

Setting the scene: A history and the position of biscuits

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Abstract: Biscuits are a very significant part of the food industry in most countries of the world. This chapter describes what biscuits are and briefly outlines the history of their commercial manufacture. Early biscuits were simple but with industrial development a wide range of tasty products were mass produced. Chocolate coating and cream sandwiching heralded luxury treats and advances in packaging greatly increased shelf life.

Key words: biscuits, crackers, cookies, wafers, mechanisation.

1.1 Introduction

The word biscuit derives from *panis biscoctus* which is Latin for twice-cooked bread and refers to bread rusks that were made for mariners (ships biscuits) from as long ago as the Middle Ages. The dough pieces were baked and then dried out in another, cooler, oven. They were very unattractive being made more or less from flour and water.

What are biscuits now? They can be staple foods, snacks, luxury gifts, dietary products, infant foods, dog and cat foods, and with additions of chocolate and cream, etc., they borderline with confectionery. They are all made with flour (usually wheat flour) and all have low moisture content and thereby long shelf life if protected from moisture and oxygen in the atmosphere. They are the original ‘convenience’ manufactured food.

The word ‘biscuit’ is an all-embracing term in Britain and several other countries. It includes items also known as crackers (a term derived from the USA for thin, non-sweet, products that made a noise of cracking when broken), hard sweet or semi-sweet biscuits, cookies (which is a name that originated from the Dutch *Koekje* meaning a small cake) and wafers which are baked between hot plates from a fluid batter. The name cookie was adopted in North America where the term ‘biscuit’ can be confused with small soda-raised breads or muffins. In other countries the term cookie is used principally for wire-cut products of rather rough shape that often contain large pieces of various ingredients like nuts and chocolate. Thus the British tend to use the term biscuit for everything and the Americans do not use the word

biscuit for any of these items. Technically the difference between bread and biscuit is the level of enrichment with fat and sugar, and the moisture content. Between cake and biscuit the difference is that of dough consistency, and again the moisture content. In general, biscuits can be baked on a flat surface but cakes must be baked in containers because the dough is softer.

It is claimed that the only way to understand the present is to understand the past. So let us briefly consider the early history of biscuit making. It is perhaps appropriate that the author, as a British person, should be the one to write about the biscuit industry because it started in Britain and many biscuit types that were first developed and produced in Britain are still made and enjoyed all round the world. Britain led the industrial revolution which involved the design and construction of machines and can thereby also claim to be a leader in developing the biscuit industry. However, little seems to have been written about the history of biscuit manufacturing and this account will centre very largely on the situation as it developed in Britain.

The word biscuit in the English language is certainly old. Dr Samuel Johnson in his dictionary, published in 1755, gives a primary definition as 'a kind of hard dry bread, made to be carried to sea', and a secondary one of 'a composition of fine flour, almonds and sugar, made by the confectioners'. William Shakespeare also refers to ships biscuits in his play *As You Like It* written about 1600. The first biscuits, in terms of mass production, were of an unsweetened type relating more to crackers in modern parlance.

Although the first biscuits were dried-out rusks, useful as long-life food for sea journeys, early cooks making confections with fat and sugar would have found that if little dough pieces are baked in a typical hot oven and taken out when they have a good colour and a stable structure they would not have been dry enough to be entirely crisp. Putting them back into a somewhat cooler oven to dry them out improved their eating qualities and also their shelf life. Baking from the start in a cooler oven for a longer period allows drying but results in less colouration and structure development. (The idea of separate moisture control from the development of texture and colour is a technique that has been returned to relatively recently with modern electronic technology as part of the baking process.) However, the term biscuits was applied originally to dried bread pieces. These were also sweetened and flavoured with spices. Other products like our modern biscuits were made but called by more cake-like names. For example, shortcake and shortbread, short dough types are very ancient. In 1605 there is reference to puff pastry made by placing butter between sheets of rolled out dough. 'Wafers' are probably the oldest types of biscuits; ancient records show that they were widely used in religious ritual. As a type of baked flour product they were introduced into Britain by the Normans from France (c. 1100). They were made on special wafer irons not only by bakers but also by wafer makers and at home. The products must have been cake-like similar to the *gaufres* of France today and not the thin crisp sheets we call wafers now. Wafers are made from batters and the recipes, used at least in France, were often enriched with eggs, wine or cheese. In 1605 there is reference to rolled wafers, i.e. wafers with enough sugar in the recipe to allow them to be rolled off the baking plate after baking. They would have been similar to the brandy snaps and rolled wafers of today.

Biscuits are a very significant part of the food industry in most countries of the world. Their success can be attributed to at least four key factors:

1. their relatively long shelf life
2. their great convenience as food products
3. the human liking and weakness for sugar and chocolate
4. their relatively good value for money.

1.2 The beginnings of biscuit manufacturing

The early biscuits, as Johnson's dictionary definition indicates, were for mariners on long journeys and were formed from just flour, salt and water. In America they were known as pilot biscuits and later, hardtack. They were very laborious to make, were very hard to eat and in fact had to be soaked in a beverage or soup to make them palatable.

Biscuit manufacturing concerns, firstly, the invention of machinery to reduce the labour required. The first machines were for mixing and forming dough pieces followed by a mechanical oven for baking continuously. Later attention was given to mechanising the movement of dough and biscuits within the factory and later still to packaging.

Practically no mechanisation is recorded before the beginning of the nineteenth century, this had to wait for the use of steam to provide motive power. Water power, so important for the development of flour milling, textile manufacture, etc., seems never to have been used in the biscuit industry probably because early biscuit bakeries were at the sea ports where harnessing water power is more difficult. Electricity was not used until near the end of the nineteenth century, it offered transmittable power and lighting so important to modern factories.

At the end of the eighteenth century there are reports that dough mixing was done initially by hand then was finished off by the mixerman jumping into the trough and treading it with his bare feet! A certain amount of mechanisation was introduced to form a rough sheet of dough but the pieces were then cut out by hand as rectangles which were in turn worked by hand into circles and dockered (holes pierced through the dough piece) before baking. The sheeting machine was known as a brake. A dough brake is a pair of rolls where the gap between the rolls can be opened or closed. It had more than one function; it kneaded the dough, as a supplement to mixing, and permitted a clear sheet to be formed giving a smooth surface. The brake could also be used to laminate the dough with or without the inclusion of flour or fat between the sheets. Brake machines are still occasionally used for fermented, puff and mechanically developed doughs. The first commercial biscuit dough mixer seems to have been a barrel with a shaft through it driven from a steam engine. The shaft had a number of blades attached and when the dough was mixed it was removed through a door underneath. There was no mechanical development of the dough and the crumbly mass was then pressed together to form a sheet. (It is interesting that this technique is still used in some factories for Water biscuits where the dough is relatively dry and where a wetter dough would produce a much harder baked product.)

There was a report of a travelling oven built in 1810 which used a moving belt of wire mesh but this was not successful. However, travelling ovens were introduced into British biscuit factories around 1849–51 but were not generally accepted till near the end of the century. This is contrasted with the first reel oven, not so efficient as a travelling oven, which was claimed to have been invented in the USA in 1859. Reel ovens were standard in the USA until about 1930!

The early ovens were fired by coal but the travelling ovens were firstly heated with superheated steam through tubes running along the length of the oven. Later ovens were fired directly with gas and electrically heated ovens appeared much later. Also in the 1849 era there were great developments in mixing machines and new types of cutters. They were pioneered not so much by machinery suppliers as by entrepreneurs setting up biscuit factories. People like George Palmer, who had practical knowledge of baking, were able to design machines. Most of the early mixers were vertical spindle machines and the cutters were reciprocating, as they copied the way the task was done by hand. Incidentally, the first rotary cutter was invented in 1890 (another was patented in 1900 by Thomas L. Green & Co., USA) but it was a long time before such cutting was generally accepted. Drives for the forming machines were by layshafts driven from a large steam engine. It was not until the 1880s and 1890s that electricity was introduced but still the power was delivered through layshafts, gearboxes and belts to individual machines, meaning that speed adjustment was difficult. These factories were relatively dangerous places to work! There is some dispute about who set up the first biscuit factory using continuously running and integrated machinery. It may have been Jonathan Dodgson Carr in Carlisle when he invented a cutting machine in about 1831 (copying the principle of the printing press of the time) or Thomas Grant in the victualling yard at Gosport in 1829 but certainly we know a lot about the enterprise of George Palmer and his partner Thomas Huntley when they established, in 1846, the biscuit factory at Reading, west of London. This factory was the first to use continuously running machinery for making fancy biscuits, effectively the start of a completely new consumer industry.

As a result of this enterprise, and their very successful export business, British biscuits became known in most countries of the world. The biscuits were packed mostly in tins or tin-lined boxes of 40, 28 or 5 lb (about 18, 12 or 2.5 kg) capacity and this solved the problem of keeping the product fresh. As it happened, the brother of Thomas Huntley had an ironmongery business where the tins were made! Most of these tins were returnable so the handling, washing and relabelling was a major operation. In those early days, distribution in Britain was mostly by canal and water transport greatly reduced damage that vibration would have caused if transportation had been by road.

By 1870 the biscuit, principally cracker, market in the USA was well established but there were substantial imports of British biscuits. Machinery was also imported from Britain thus emphasising the role of the UK in the early growth of the biscuit industry. T&T Vicars in Liverpool was established in 1849, A M Perkins and Son in London in 1851 and Joseph Baker and Son in 1876. Perkins and Baker amalgamated in 1920 to form Baker Perkins.

Some of the earliest biscuits took the form of various fermented crackers such as cream crackers and soda crackers. The digestive biscuit was introduced by Alexander Grant in 1892. In 1898, Huntley and Palmer, then the largest biscuit manufacturer in the world, was producing about 400 varieties of biscuit. The surprising point is that many of the most popular biscuits today were being sold over 100 years ago.

Tunnel ovens remained relatively short until about the 1950s. Initially the bands were chains upon which baking trays were placed and then removed after they emerged from the oven. Later, as rolled steel in long lengths became available (in the early 1930s) continuous bands were introduced. Initially, these bands were 24

inches wide and were only steel but soon the standard became 32 inches (about 800 mm) and wire meshes of various forms were used for certain types of products. Although 1 metre and 1.2 metre oven bands are the standard now, it is rare to find wider ones. This is probably because it is still considered necessary to be able to reach over the band manually. Wider plants are now being offered but they are not yet that popular.

In the case of lean, low fat doughs the production of a sheet of dough that had a clear smooth surface suitable for gauging to a thickness for cutting out dough pieces, was a tedious matter. Manual reversing brakes were used. The result was a pile of roughly square, thick, sheets which were then fed into the first of a series of gauging rolls prior to cutting. These brakes could also be used to introduce fat or flour between the sheets for cracker and puff products. It was not until the use of chemicals and enzymes was introduced that it was possible to form a satisfactory sheet directly with a series of three rollers. Later complicated synchronised machines, consisting of series of rollers and conveyors, were developed to emulate the work of the hand brakes. These machines were called laminators. Laminators were introduced in the USA in the late 1930s or early 1940s but were not used in the UK until around 1950. By 1968 a cream cracker plant with a direct gas-fired oven of 1 metre width and an oven 232 feet (70 m) long was producing biscuits in 2.5 minutes.

During early mechanisation, short doughs were formed into sheets with three-roll sheeters and the dough sheet was cut in the normal way with or without a cutting device, to emboss a deep pattern on the surface of the dough pieces. Only in about 1930 was the compact and extremely efficient rotary moulding machine introduced. This machine forms dough pieces with any desired surface pattern directly from mixed dough.

Having achieved the mechanisation of simple biscuits, it was not long before the embellishments and secondary processes were also mechanised. In 1903 the first chocolate-coated biscuits were introduced. The process of icing biscuits and cream sandwiching was mechanised around the turn of the century. Full mechanisation of stencilling-type cream sandwiching machines (see Section 41.2.3) was first achieved with the Salerno type machines in the USA. The first patent for a multi-row sandwiching machine of this type was taken out in 1900 by Joseph Baker and W. T. Carr. In the late 1930s this design was developed by Baker Perkins into their 14BW machine. The extrusion with wire cutting of the cream deposit type of sandwiching machine originated with a patent by Baker Perkins in conjunction with Robert Macfarlane (of Macfarlane, Lang & Co. now absorbed into United Biscuits) in 1928. It was described as a continuous horizontal creaming machine. It was called the 'Streamline' and had a vertical rotating hopper stencil system that was later developed into the Quality machines that are still in use today.

In the early days biscuits were packed in barrels or tin boxes and were dispensed into paper bags in grocers' shops. One can see therefore that freshness was a problem. Conveniently sized packets of biscuits (half and one pound, about 250 and 500 g) were introduced from 1901 and sales increased dramatically as a result. The wrapping film was mostly waxed paper and so not very moisture proof. The packs were formed by hand. During both world wars, biscuits were again packed mainly in reusable tins and in fact this form of packing persisted until the 1950s in Britain. Coated cellophane was invented in the 1930s. This represented a great advance as it could be heat sealed and was very moisture proof compared with waxed paper. Polypropylene film was introduced in 1964.

Biscuit manufacture was the first of the food industries to be mechanised and it will be appreciated that there has been a continuous improvement in productivity in biscuit manufacture as the result of reducing the amount of labour needed and speeding up production lines. Labour in the mixing and dough-handling areas was the first to be reduced but it is only in the last 40–50 years that the numbers of people employed in the packing area have been reduced to relatively small numbers.

1.3 Ingredients and formulation development

Clearly, the availability and handling of ingredients has had its effects on the development of the industry. Good white wheat flour became available as roller mills were introduced after 1880. Prior to this the flour was stone ground and the separation of the bran from the endosperm was much less successful. Roller milling also permitted the separation of the germ and this resulted in a much longer rancid-free life for flour.

The fact that early biscuits were cracker types, low in fat and sugar, was no coincidence. The only fats in common use were butter and lard which did not offer good shelf life under the conditions in which they were used and the storage facilities for biscuits. There was no refrigeration and fat that has started to become rancid deteriorates very rapidly. Although sugar refining is a relatively old process, it is interesting to note that sugar was an expensive commodity. Following the Crimean War in 1857 the duty on sugar in Britain was reduced but it remained taxed until about 1870. The reduction in cost of sugar at that time greatly helped the developing biscuit and confectionery businesses.

With time, the quality control of the major ingredients improved, vegetable oils became available and flavoursome syrups were used more and more. The use of spices, cocoa, etc., as flavourings is very old but the development of flavour extracts and synthetic aromatics and colours added new dimensions to formulation. Food technology has shown how non-nutritive additives can be useful for processing and product stability. Unfortunately, we have come full circle now and there are consumer pressures to remove unnatural ingredients in the belief that natural is always best.

During the 1920s and 1930s there were technical advances in the handling and storing of ingredients. For example, liquids were bulk handled and metered by pumps. The biscuit industry was one of the first food industries to bulk handle ingredients. It was not until 1960 that the first automatic mixing and bulk-handling scheme was installed in the Huntley and Palmer factory in Reading. It was equipped with a centralised mixing room with control panel. Dough was carried by fork-lift trucks from the mixers to forming machines thus allowing flexibility for mixers serving more than one plant.

All flour confectionery is developed from human skills in baking and a great deal of research has been directed to improving our knowledge of the science of what happens when flour is hydrated, mixed with other materials and baked. It is this research that has been the main driving force in the development of the biscuit industry. It is therefore correct to say that without science there is no innovation and without innovation there is no competitiveness.

1.4 Engineering

Clearly, engineering has been the key to the development of the biscuit industry. Powered machines have allowed a great reduction in labour, considerable increases in production speeds and as a result biscuits are first-class foods at very good prices. As electricity came to be the power source, synchronisation of speeds became more precise and electronic sensors of various types have permitted even greater progress through improved process control. Probably the most significant developments have been in high-speed wrapping machines and the automatic feeding of biscuits to them. From 1955 there has been great growth in the SIG company of Switzerland and others who produce automatic packaging machines which are set at the end of the production lines. This has allowed massive reductions in labour but has made even greater demands for product size control.

Unfortunately, the value of the power of microelectronics is only as good as the information supplied. We are still in the phase of perfecting sensors to measure continuously product variation and to investigate the sources of product variations. In some cases enough experiments have been conducted to allow models of processes to be made. From this information much more reliable closed-loop controls can be developed. However, there is a stage before closed-loop control. It is better to reduce or eliminate the variation than to devise control loops which compensate for variation. It is often from these studies that methods and processes are challenged. Perhaps the traditional processing methods are not now the most appropriate.

Machines were originally developed to replace tasks undertaken by hand. It is still the case that there are very few biscuit types which cannot be made by hand with only simple tools. The mechanisation has been based principally on the different requirements of hard and short doughs. The former have low sugar and fat contents allowing the formation of a continuous structure of gluten by hydrating and mechanically working the flour proteins, the latter have unlimited levels of fat and sugar with little or no gluten structure. Short doughs offer a much greater variety of product. In either case the dry and crisp baked products may be further embellished with secondary processing involving chocolate, fat-based creams, jam, etc. At the packing end of the production line, mechanisation has allowed feeding to wrapping machines. Where assortments are packed, robotic assemblies have been designed.

Throughout, biscuit machinery has been built very solidly. With moderate maintenance it lasts a very long time. Often when one factory finishes with it another buys it second hand. Thus, incremental improvement in design has been a lot slower than in other industries such as cars and household machines.

We have now reached a stage where developments concentrate in two major areas:

1. ultimate process control to get the maximum yields of product from ingredients in minimum time
2. the search for novel products to excite consumers.

The first of these involves questioning whether traditional methods are the optimum and therefore demands critical appraisal of processes and the machinery being used. It also involves the use of large dedicated plants with the maximum of automatic control.

The second involves a blend of food technology, creativity and engineering skills to produce products with interesting textures and other eating qualities. The discipline of design ensures that technical features are combined with attractive appearance and convenience of consumption which has throughout been the unique position of all biscuits. By definition new products will, at least for a while, have limited consumer demand; they are ill suited to large plants and require the plant control to be mostly manual until the line is well established (if ever!). Thus not all of the processes in the biscuit factory will be automated.

Most raw materials can be accepted and handled mechanically at the factory and their critical properties can in many cases be measured electronically. Mixing and forming machinery responded to the touch of a button but even so, critical decisions must still be made by *people* in control.

Unfortunately, problems have arisen in the training of biscuit factory staff. It used to be that production staff had plenty of opportunity to learn first hand the effects of ingredients in doughs and the finer points of oven control on the qualities of biscuits being produced. The adjustment of the machinery was relatively crude but was easy to understand. Modern machinery is very complex and control systems very sophisticated. The blend of experience in doughs and baking and engineering is not good, one is either a baker or an engineer. In fact good bakers are becoming rare because factory operatives have less chance to learn by the practical experience of trial and error. Also, a typical biscuit factory uses too much of their engineers' time in troubleshooting and dealing with breakdowns to allow them to do planned maintenance or to contribute to new machinery designs. We have nearly reached the stage where a factory can be controlled from a central room but to do this there must be a new breed of staff who are technically competent in both engineering and biscuit technology. This is the point that should be borne in mind when considering the development of biscuit manufacturing.

Biscuits also contribute to the dietetic and functional food areas with special formulations for those with dietary needs. There is concern about heart disease and the relationship to diet. Although obesity is probably the most important factor for heart disease, it has also been suggested that certain fats contribute more than others. The types of fat that are suspect are those commonly used in biscuits, the saturated fatty acid types and 'tropical oils' and because of their physical characteristics it is almost impossible to get away from them. Sugar, sucrose, is another major component of biscuits which the health pundits dislike because of tooth decay and 'empty calories', but if you cut out fat and sugar the diet becomes either dull or very expensive!

It is perhaps surprising that the biscuit industry has survived so well when the nutritionalists have attacked it so much. Eventually it will be understood that there is nothing wrong with biscuits, in fact they are good foodstuffs, if eaten in moderation and as part of a mixed diet. Biscuits have never been staple food. With the exception of those that need accompaniments, such as butter or cheese, like plain crackers, biscuits have been eaten principally between meals or for the outdated 'afternoon tea' occasion. There is some evidence that they are belly fillers, especially for children arriving home from school, but basically biscuits are eaten because it feels good to eat something! They are tasty and very convenient for this. We are beset with non-logical habits (smoking, drinking, shopping trips) and biscuit eating is one of these. This is probably why biscuits have survived the 'not good for you' onslaught of recent years.

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2

The role of the technical department in biscuit manufacture

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Abstract: The need to know and understand biscuit technology has never been greater. The technical department is a service department and is responsible for the technology resources of the company. Activity must be both proactive and reactive. You can only afford to be lazy if you are efficient. There is always a better way to do things.

Key words: technology management, technical support, training, managing innovation and improvements.

2.1 Introduction

Biscuit making has progressed over the past half century from a very labour-intensive craft-based industry to the relatively efficient and well-mechanised semi-science-based industry today. Plants have become bigger and faster. This has meant that in countries with a long tradition of biscuit manufacturing, productivity has increased greatly and, because sales have not increased as fast, biscuit companies have merged and many factories have been closed. In the larger factories there has been a concentration on high-output products and less on specialities that have to be sold at higher prices. Specialist, relatively low volume, products are more the province of small manufacturers and there is a continual establishment of new business at this end of the market. At the same time many new biscuit factories have been set up and expanded in developing countries. Biscuits are now made in nearly all countries in the world, even those where wheat, to produce wheat flour, is not grown or is not the staple cereal food.

Much biscuit-making machinery was so well built that it has functioned adequately for a long time and in terms of sophistication, is now out of date. To keep up with competition it is necessary to have better machinery and to choose this with care and an eye for future products. The need to know and understand biscuit technology has never been greater. It is needed in the design of products and processes, to deal with problems of manufacturing and to guard the company's reputation with high-quality and safe foods. We are now being thrust into a new era which is offering great opportunities but also great strains on the management of the biscuit industry. The technical factors causing these strains include:

- the advent of cheap electronics offering enormous potential for process control and improved efficiency of production
- uncertainty of the technology of making biscuits which is hindering the fitting of sensors essential to the harnessing of electronics for automatic control
- a shortage of people with enough process understanding, because experienced, craft-based, operatives are being lost from the industry due principally to retirement; younger people are not learning the business so well because long production plants inhibit easy appreciation of cause and effect; there is not the same tradition among workers to stay with the same industry for most of their working lives; there is very inadequate opportunity for formal training in biscuit technology; a trained member of staff may feel that opportunities are better elsewhere
- consumers are demanding much higher standards in food, information about age of product and nutritional values.

Most who read this book will be involved with some technical aspect of the manufacture of biscuits, crackers or cookies. You may have started in a junior position and will not be sure how far up the ladder you will get or, at the other extreme, you may be the chief executive of your company and will be delegating technical duties to your subordinates. In both cases you should consider the structure and responsibilities of the technical department. If you are a junior member of staff the aim here is to show how your efforts may fit into the overall responsibility of your department and if you are the chief executive the aim is to outline a structure that may be useful for integrating the technical responsibilities and progress within the company.

Books on food manufacturing traditionally start with accounts of the ingredients and packaging materials then progress to the more interesting subject of product types and how they are made. As has been explained in the preface, the aim of this book is to provide a reference handbook for technologists working in the industry. For them, although the raw materials are very important, it is the organisation of what they do that would seem to be more important. 'You can only afford to be lazy if you are efficient!' Efficiency involves excellent planning. Experience has shown that many of the problems found in a biscuit factory are related to inadequate attention to planning. Planning is a key task for all management. It involves not only what should be done and when but also who should do it and the development of personal skills to allow people adequately to complete their tasks.

The demands on the technical department have increased greatly. It is the focus of most technology aspects of the manufacturing business which are not administered by engineering management. The technical/technology department does not normally include engineering responsibilities. The technical manager therefore has a very important contribution to make to the responsible management of the company because the sale of safe and wholesome food is of paramount importance on moral, legal and company survival counts.

The biscuit market in most countries is dynamic, demanding new products or changes in packaging and at the same time is very competitive. New product development can be very expensive and must be carefully managed to produce what is wanted when it is wanted. Most of the new product development activity is the responsibility of technologists and falls within the scope of the technical department.

The following sections and chapters in this part of the book will describe the responsibilities of technical management and suggest how the tasks should be organised.

2.2 The requirements of the technical (or technology) department

The technical department is a service department and is responsible for the technology resources of the company. Activity must be both proactive and reactive. It is most important that the technologists are not seen as policemen intent on finding fault. They must work in the management team to promote efficiency and prevent problems and errors from occurring. The services will include services for the marketing and sales department for

- product development
 - new product creation
 - product improvement
 - legislation and labelling
 - product specifications
- administering a total quality programme with the aims of
 - ensuring product safety
 - ensuring only correct quality items are produced for sale
 - promoting continuous improvement in all areas
 - managing process control and incidents records, such as complaints from customers, so that they are used to further a policy of prevention rather than cure.

The technical department will also provide services for the production and purchasing departments. These services come under the broader scope of the particular quality management system in operation. They should include

- quality control checks on ingredient and packaging materials
 - laboratory services
 - liaison with suppliers and the purchasing department
- process control techniques
 - process development
 - assessment and calibration of monitoring instruments
 - testing and assessment of new production machines
- advising and monitoring factory hygiene arrangements
- support for training
- support for troubleshooting.

In order to provide these services adequately the technical manager or director must ensure that he is up to date with 'state of the art' biscuit technology, has the right equipment, the right staff and enough laboratory, test, bakery and office space. He should also know where professional assistance is available and organise the training of his own staff.

It is normal for the technical department to have accountability directly to the top management of the company. It is not so satisfactory for it to be part of the production or engineering departments. However, as has been indicated in the lists above, there is now a strong belief in teamwork to achieve an efficient and progressive business and the technical manager should be considered as a partner in a complex operation rather than a subordinate of another departmental manager.

The role of the sales and marketing department is also very important in the technical development of the company. It is often thought of as a non-technical department but its staff should be encouraged to understand the processing and

quality aspects as much as possible because it is often from this department that ideas arise and plans for the product mix are decided.

With the background of a quality programme that involves all staff, it may be useful to outline where particular responsibilities for product quality normally lie. The sales and marketing department is responsible for

- market research
- co-ordinating strategic and tactical product development
- product specifications
- sales and promotion
- sales forecasting
- customer relations, including complaints handling.

The manufacturing or production department is responsible for

- line management
- manufacturing against specification which includes product safety
- manufacturing against stock requirements
- manufacturing at minimum cost
- engineering, purchasing, warehousing and distribution
- training of production staff.

Being a service department it is reasonable for the technical department to be classed, in financial terms, as a business overhead and therefore it may be viewed as a luxury! If this happens the attitude is very short sighted because inadequate staffing could lead to inefficiency of processing in the factory and shortage of confidence in the marketplace. The tasks of the production department are very demanding without having to deal with specialist technical problems and commercially there is a need for a company to show that it has well-defined procedures for quality and food safety under the control of qualified competent persons. Also the technical department should be a source of new ideas which, by careful investigation, lead the company to new strengths and lower production costs. It should be regarded as a very important investment for the company and the Board should see that it is funded and managed properly.

2.3 Selection of staff for the technical department

2.3.1 The skills required of a technical manager

The technical department is only as good as its leaders. Thus it is necessary to consider carefully the skills needed in these leaders or to ensure that potential leaders are well trained. It is no longer appropriate to view the manager as the chief chemist suggesting that the department is laboratory based. The most important skills required of the manager include

- a basic education in applied natural science, particularly food science with emphasis on baking and flour confectionery
- knowledge of factors that affect food safety and, as appropriate, the analytical procedures for testing for food safety
- experience in identifying projects that will benefit from technical investigation and be cost effective; this is a skill requiring an analytical mind that is good at identifying priorities, and it is probable that this experience can only be

acquired by working in an industrial environment, not necessarily in biscuit manufacturing

- dynamic management of project teams, formed from company employees or commissioned from agencies; this is very largely a personality skill and requires an alert and logical mind combined with great enthusiasm for the job in hand
- management of skill and career development of technical staff to the benefit of both company and individuals; this demands the ability to plan ahead and be sensitive to the needs of the company and the potential of individuals
- personality to promote the technical and creative competence and awareness of the company combined with the ability to sell one's ideas and pride in the company
- excellent communication so that colleagues in other departments will know about developments that may affect them and can react appropriately; like the other personality skills this cannot be proved with an academic qualification.

2.3.2 Support staff

The key words in industrial management today would seem to be involvement and motivation. Too many workers from middle management right down to the new recruit are not sufficiently involved with the aims and technology of their business and so lack correct motivation. It is true that personal ambition can accelerate a situation of greater involvement, but there is predominantly a need for greater communication and teamwork. It is suggested that nowhere is there a greater need for communication than from the technical department.

It has been shown that this department should be an important function in a biscuit business; therefore poor communication could mean that it hinders company progress and is poor value for money. Selection of staff for the technical department is, therefore, critical.

A young technician or technologist coming into the food industry probably happens on biscuits and will decide to make his or her career with these products only if the initial experiences and conditions are good. The range of products in each biscuit company differs considerably and the equipment used to make and pack these products also varies in its type and age. It is difficult for anyone to build up a comprehensive knowledge of all sorts of biscuit technology by working in one factory. There is a great lack of formal teaching courses in biscuit technology so often the basics are not learnt either. It is, therefore, to be expected that an ambitious technologist will wish to move from company to company (or at least factory to factory if it is a group company) in his career towards senior management. If each person takes all his knowledge and expertise with him when he moves on, an individual factory will be greatly hindered in its technical advancement. The structure and management of the technical department must be designed to cope with these probable staff movements, and to capitalise on them rather than suffer loss.

It is suggested that it is necessary to have a department of sufficient size that individual losses are less critical. Documentation of work and attention to thoughtful logical filing of reports is essential and this information must be stored safely with appropriate security systems in place.

It is best to have different individuals responsible for and leading small teams for quality control, process control support and new product development. The staff working in these teams should be moved around at intervals to extend their

experience. The author found it useful to use the technical department as a training ground for key personnel in other areas of the business, a point that will be taken up again later.

It is not possible to be definitive about the academic qualifications each should hold because it is very unlikely that anyone will come qualified in biscuit technology before working in a biscuit company! In selecting a new member of staff it is essential that they should have a good basic education involving general science but in addition should be able to demonstrate an inquiring interest in what things do and how they work. A great problem for many technologists is an inability to identify the important things and to prioritise their work programmes. The training given to food process engineers or chemical engineers is probably nearest to the ideal. Subsequent experience and general personality are very important as has been discussed already. There is a particular requirement for at least one qualified electronics and instrumentation engineer because understanding the physics of measurement and the principles of control are now very important. Whether this particular person should be a member of the electrical engineering staff or the technical department must be decided on an individual company basis.

The technical department staff should be responsible for collecting and collating technical information within the company and they should be encouraged to give formal and informal talks on technology to various groups within the company. They should explain what is happening, what could happen and what the current technical plans are.

Throughout the company, visits to suppliers' factories and exhibitions should be encouraged, but everyone who makes one of these visits should be asked to submit a report outlining points of interest. Distribution of this information and its filing should be the responsibility of technical department staff. More consideration is given to the needs of a food designer or test baker in Section 6.3.2.

2.4 Facilities for the technical department

2.4.1 The test bakery

In order to do the necessary practical work for product development, either new concepts or improvements to current products, a test bakery is needed. There are of course limitations on what can be achieved in the test bakery but to rely on factory mixing and baking facilities makes the progress of development much slower and considerably more costly. Time and other resources in the factory should be used only when modifications to the formulation or processing have been tried on a small scale. As a minimum the test bakery will need a mixer, accurate balances for weighing both large and small ingredients, dough piece forming equipment and an oven. The equipment should be of a sufficiently high standard to allow accurate and reproducible work which can then be scaled up for factory trials.

For large companies a pilot plant with a travelling oven offers the possibility to make larger trials with a view to investigating process control techniques or for making market research samples. A pilot plant is a large investment and much careful thought is needed to make sure that enough mixing and forming equipment is available to feed the oven for these longer trials. A pilot plant also needs at least two or three people to run it so there are staff considerations also. A fuller consideration of test bakery facilities is given in Section 6.3.1.

2.4.2 The laboratory

An analytical laboratory is needed for most of the quality control checks. The size and scope of this laboratory depends very much on the sophistication of the products that the company manufactures. Emphasis is given to doing a minimum of laboratory work and to relate the tests to the use that can be made of the results. Under a total quality programme much reliance should be placed on suppliers for the quality of ingredients and packaging materials. The equipment should be chosen carefully and as far as possible should be industry standard so that results can be compared with suppliers or other laboratories as necessary.

Process development technologists will need laboratory facilities as many of the monitoring instruments to be used to provide better process control will need to be calibrated.

Tasting tests form an important part of both quality control and product development assessments so facilities to conduct these formally and methodically should be provided.

2.4.3 Information handling and dissemination

Emphasis is given to good communications from the technical department. Collation, recording and results of analyses were traditionally done in books or on cards. We are now in the era of inexpensive computers and these permit exceptional efficiency and presentation of reports. It is no longer a luxury for technologists to use personal computers to make databases from which specifications can be updated and printed for various groups of data. The search, sort and computation facilities allow instant access to ingredient lists, nutritional information and histories of incidents. Graphics software permits very neat and detailed process audit diagrams. The technical department should also house the company's library of reference books and trade journals.

2.5 Liaison with other technical establishments

It is impossible and uneconomic for a company to have facilities to cover all its possible requirements. It is therefore necessary to build up contacts and relationships with other expert resources. It is a duty for the technical staff to be aware of establishments such as

- technical libraries
- environmental health authorities (factory inspectors, etc.)
- independent analytical laboratories
- technical consultants
- technical trade associations
- pest control specialists
- specialist laboratory facilities
- locations for training technicians on short courses
- research units capable of undertaking sponsored projects.

The Internet is now a most valued source of all sorts of technical information.

2.6 Support for purchasing

Under the organisation that is detailed above, support for purchasing is a service to the production department. The importance of good liaison between quality control staff and the ingredients and packaging materials buyer will be discussed in Chapter 4.

As the company develops, it will be necessary for new plant, new materials and new instruments to be acquired. At each stage additional specialist knowledge is needed and it is impossible for any one factory to know all that is necessary. Unfortunately, suppliers often do not know exactly what is required by their customers. Thus the business of involvement and co-operation comes in. Having decided what new equipment or materials are of interest or are needed, the technical department should devise a programme to ensure that adequate time and resources are allowed for in-house assessment or commissioning, maybe working alongside staff from the supplier. In this way decisions on suitability or acceptability can be made wisely and quickly and critical control aspects defined.

2.7 Support for training

This is also a service for the production department and is usually provided in conjunction with the personnel department if it has responsibility for staff training. The purpose of a company is to make a profit for its owners, the shareholders. In a biscuit company the manufacture and sale of biscuits is the means to this end. It is necessary to combine human skills with available raw materials and machinery. Unfortunately, a common fault of management is neglecting the development or maintenance of personnel so that their full potential is not utilised. However, it should not be forgotten that people are very expensive and also the company's most valuable assets. Unlike machines, people are very versatile and, handled properly, they will appreciate in value to the company whereas machines will only depreciate. Therefore in any consideration of development policies, the attention to and investment in people, the staff, should be considered first. Robens [1] described the development of staff as 'human engineering'. He included the following points as key factors to better utilisation of staff:

- Workers should be encouraged to work out how they can achieve goals by personal skill and speed of reaction to an adverse change.
- People will work if they are paid, they will work better if the physical conditions are right and they will work better still if their jobs provide the means to their mental refinement and growth.
- No-one works well in a sprawling bureaucracy in which the individual loses his sense of identity and purpose and his awareness of the overall pattern of operations.

As will be discussed later under the continuous improvement aspect of total quality, as many workers as possible should be involved in determining their work practices. It is commonly the case that staff of the technical department can help significantly in teaching production staff what is involved in processing so that they have a better chance of contributing to an efficient factory.

It is well known that you do not really understand a subject until you have to teach it, so communication of technical matters is useful experience in itself for technical staff. However, one must balance against this the importance of using good teachers. It is therefore suggested that technical matters should be taught by a combination of own staff and part-time teachers (such as consultants).

Biscuit making is a very technical business and factory managers and supervisors should be given the opportunity to assimilate a broad spectrum of the technology of manufacturing. Practical experience has shown that there is much value in seconding factory personnel for six-monthly periods to the technical department and also rotating jobs within the department as much as possible to improve their understanding and range of skills.

2.8 Management of technical developments

From the lists given in Section 2.2, it will be seen that developments are a key function for the technical department. *Everything* can be improved with enough thought. There is always a better way to do things. Some improvements are more obvious or easier to do than others. The philosophy of continuous improvement means that change has to be managed efficiently. This involves prioritising change and monitoring results. Executing change requires planning. All of this is an attitude of mind and a requirement for awareness.

Development planning should be in the job specifications for all managers and there is nothing basically special about the management of technical development. The driving force for change must come from the top management and much attention must be given to motivation. Properly motivated technical people, organised in a manner that fosters co-operation and good communication, are essential to the growth of a manufacturing enterprise.

Review of the company's three- or five-year development plan should involve two-way communication. Summaries of progress and achievements against targets should be prepared at least every six months (to relate to the overall review) and there should be clear indications of possible new objectives which may offer potential for advancement or savings. Each department, group or individual should be encouraged to consider its potential for improved performance or efficiency. Managers should give priority to the time they spend on decision making and delegating rather than information collecting and travelling. Accuracy and speed are the essential requirements and here computers are providing untold benefits. It is surprising how much benefit to morale and motivation can be given by managers visiting all parts of the factory regularly and taking an interest in the performance and attitudes of the staff.

It is unlikely that many companies can cope unaided with all the necessary technical developments and the technical manager must decide how to get the help he needs. In many cases he can draw on assistance by being a member of a technical or research association. He may also sponsor projects at universities or colleges. There is the possibility of contracts with agencies or consultants. These contracts may be for specific short periods to aid in particular problems or developments or they may be over longer periods on a retainer basis. The advantages of specialist help are to reduce overall costs compared with recruiting and training staff combined with the benefits of wide experience.

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3

Quality management systems and hazard analysis critical control point (HACCP) in biscuit manufacture

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Abstract: The business of manufacturing biscuits involves ensuring that the company survives by it making a profit. The public demands attention to food safety. Failures in quality control may be disastrous for the reputation of a company. Establishing and maintaining an effective quality management system is a team task and the responsibility of the technical department.

Key words: quality management, hazard analysis critical control point (HACCP), product safety.

3.1 Quality management

As a result of good management in biscuit manufacturing we want

- high productivity with minimum production costs
 - maximum production speeds
 - minimum down time
 - minimum labour costs
 - lowest material prices
 - minimum pack over weights
- zero defects
 - high quality
 - no rejects
 - safe and wholesome food products
- a climate of continuous improvement through involvement of all staff
 - in quality and process control
 - in production efficiency
 - in the working environment.

The key to achieving these objectives is the philosophy of continuous improvement. It all starts by defining a product, which is a best guess of the product's measurable characteristics (its quality) and the means by which it should be made. After a while this specification may be changed as a result of feedback from marketing and

production; the product and knowledge about its efficient production has improved. Later even more improvements may be discovered. In most cases the route to these improvements has been found to lie 80% with input from observant and involved people, mostly production staff, and only 10% each from production systems and technology.

Firstly, what do we mean by quality? Quality is ultimately defined by the customer. A product will delight a customer if it is

- what he wants (e.g. size, appearance, taste, value for money)
- how he wants it (e.g. pack size, easy to unwrap, adequate shelf life)
- when he wants it (e.g. delivered on time, available for purchase at specified times and places, easy to display on a shelf)

The customer is not necessarily the person who eats a biscuit, he may be a retailer or an agent.

The terms 'high' or 'low' quality should refer to how near a product is made to its intended specification. Thus, a poor-looking or tasting product may have been specified like that for a particular customer. If it is made correctly, it is of high quality even though other similar products look or taste more attractive to other customers.

Consumers, through the activity of the media, are becoming more and more aware of hazards to health as a result of contamination and the composition of the food that they eat. There is growing knowledge about the relationships between food ingredients and health problems such as heart disease and allergies/food intolerances. They are also becoming much more intolerant of substandard food as a result of contamination and deterioration during storage. There are therefore many aspects to consider when a product is being designed to 'delight' a customer. The business of manufacturing biscuits involves satisfying our customers and ensuring that the products are safe, otherwise the company's reputation may be harmed. The company must also ensure that it survives by making a profit.

We are also having to become much more responsible for protecting employees from accidents and factors that affect their health at their places of work. Safety guards on machinery have to be in place and training must be given to encourage people to be aware of dangerous situations.

There have been a number of management initiatives aimed at improving control during manufacturing. Quality circles are usually groups of 4–12 people coming from the same shop floor area who voluntarily meet on a regular basis to discuss work-related problems and solve them at that level. Other problems may be identified for upward referral. In this way quality consciousness is emphasised and involvement encouraged.

BS 5750 [5] (a British Standard) was originally issued in 1979 principally for the engineering industry. Since then it has been seen to be applicable to most other industries and in 1987 the international standard for quality systems, the ISO 9000 series, was published and this endorses BS 5750. ISO 22000 is a further directive for harmonisation of food standards and guidance. ISO is short for International Organisation for Standardisation. BS 5750 in essence is a pro forma upon which management and all employees may write their script of how to operate their particular business. It creates an atmosphere of 'right first time' rather than the inefficient system of sorting out rejects. Accreditation and regular verification by external examiners is an integral aspect of BS 5750 and ISO 9000. Hazard analysis critical control point (HACCP) is described in Section 3.2.1.

All aspects of production management are involved in a quality management system (QMS). A comprehensive management system is a culture that aims to satisfy the customer and eliminate problems on an on-going basis. It requires education to get people to work together, think about what they are doing, to look at problem-solving techniques in a global context, not just at the particular level, and to gain a deeper understanding of the processes and systems with which they have to work. The trouble is that most do not know enough about the global situation and do not care enough about their colleagues. This is why a team approach is essential for a successful QMS.

By committing all business procedures to paper and detailing requirements, there is much less confusion, and better understanding of where attention to problem solving and improvement should be focused.

The demand for a QMS must come from the boardroom, the highest management level of the company, but its administration is best centred within the technical department. A QMS integrates product design, product safety, quality control, process control, production efficiency and good manufacturing practice; in fact much of management practice.

The cost of product failures can be very great. The brand value and even the company's reputation may be damaged but there may also be substantial losses as a result of stock write-off, product recall and market relaunch operations. The provision of a QMS must be taken very seriously.

3.2 Management of product safety

There is a moral responsibility for any food manufacturer to take all reasonable steps to ensure that the food that he is offering to consumers is safe to eat within any time constraints that are stated on the pack. The company must also take care to label its products accurately and correctly so that it is not guilty of giving misleading information.

In the event of a post-production fault being discovered, it must be possible to identify the packs involved and to recall them if necessary. It will be possible to trace every pack if it has a code printed on it. This code could also be the 'best before' guide for the customer.

The legal situation relating to food safety is, in many countries, becoming very demanding. There is a requirement to comply with laws about composition, labelling and of course safety and hygiene. Also there is the requirement for a manufacturer to prove that he is taking all reasonable precautions and exercising 'due diligence' in order to defend a prosecution for a food safety violation. Therefore to install a metal detector may be regarded as a reasonable precaution but to check regularly that it is working is due diligence.

Prosecution is one thing to fear because the fine may be large but worse is the adverse publicity that such an incident may attract. This could ruin a manufacturer's business or severely damage consumers' perception of a brand.

Today's manufactured food is the safest it has been in human history. It is much more likely that food poisoning arises in domestic kitchens because of lapses in hygiene control than in prepared food. However, manufacturers must set up monitoring and control systems in their factories to ensure food safety. One formalised

and internationally recognised system is that known as the hazard analysis critical control point (HACCP) concept.

3.2.1 Hazard analysis critical control point (HACCP)

The HACCP system was started in 1959 when Dr Howard Bauman of The Pillsbury Company in the USA was asked to work with the National Aeronautics and Space Agency (NASA) on the specifications of food for space journeys. He worked on physical aspects related to eating in zero gravity but particularly on the long-term safety of food to be consumed by crews. It was essential that risks from pathogenic micro-organisms were reduced to an absolute minimum. Since then the HACCP approach has become internationally accepted as the most effective system for food safety and quality control.

HACCP was developed particularly to ensure microbiological safety of foods. Fortunately, all biscuits are effectively sterilised as a result of baking temperatures and nearly all biscuits, even those subjected to secondary processing, have a water activity which is well below the point where microbes can grow. This means that safety hazards in biscuits are only likely to fall within the categories of inclusions (foreign bodies) and contaminations, principally chemicals (for example cleaning materials or lubricating oil). Not all foreign body inclusions can be regarded as affecting the safety of biscuits but, of course, they represent a serious failure of quality control. For this reason defects in products of this nature can best be avoided by installing a HACCP system. The use of a HACCP approach for control in biscuit manufacturing is rather more limited than one where short shelf life and perishable foods are involved. The effective use of HACCP has increasingly raised standards and awareness of risks over the past 20 years but its successful implementation demands a culture by manufacturers.

'Hazard' is defined as 'a biological, chemical or physical property which may cause a food to be unsafe for human consumption'. 'Hazard' implies 'risk'. Unfortunately there is no such thing as 'no risk' when it comes to health. So in searching for hazards there is inevitably the need to make risk assessments, quantifying the probability and the implications of something going wrong.

In the category of biological hazards we are principally concerned with microbial contamination arising from human, rodent, insect and bird transfers (these are dealt with in more detail under good manufacturing practice (GMP) in Chapter 4). There is also a concern about the safety of genetically modified plants used as food ingredients, changes brought about by irradiation and allergens from certain products that affect a few people. These later aspects involve much uncertainty and are very technology based. In order to advise on these points the technical manager must ensure that he keeps up with modern literature and knows whom to consult to be confident that usage and labelling of products is accurate and sufficient.

Chemical hazards include contamination by cleaning chemicals, poisons used to control rodents and insects, lubricating materials, etc., within the factory and these are considered under GMP. We are also concerned with hazards to health caused by toxins from previous microbial growth, pesticide residues on raw materials, fumigant chemical residues, heavy metals from water supplies, excessive amounts of certain fats in the diet, salt, sulphur dioxide and leaching from wrapping materials. The technology is very complex and often controversial but the technical manager ignores it at his peril!

Physical hazards are much less controversial and possibly the greatest cause of problems in biscuit manufacturing. They include the unfortunate inclusions of fragments of glass, metal, wood, human hairs, buttons, pieces of plastic, stones, flakes of paint, etc., most of which will arise from within the factory. All these matters are discussed under GMP.

The HACCP approach first of all implies consideration of the rational organisation of premises and production flows. All stages should operate in accordance with the 'forward motion' principle: all soiling or risk of contamination is gradually removed in the course of the product's journey to the packing stage. The seven principles of a HACCP system may be summarised as

1. Hazard analysis. Prepare a list of steps in the process where significant hazards occur and describe preventative measures. This is an extension of the process flow diagram which can be constructed, as described in Chapter 5, to record all aspects of the process. A major part of doing a hazard analysis is knowing what to look for and questions to ask and how to use the information after it is obtained. Hazards may arise in bought-in materials. A supplier quality assurance (SQA) system will be needed which, in effect, means that the suppliers are applying the HACCP system. Hazards may not affect consumers of the food, they may relate to operatives in the factory.
2. Identify the critical control points (CCPs) in the process. Define all the control points, decide which have most effect and are therefore the critical ones.
3. Establish critical limits for preventative measures associated with each identified CCP. These will define when the product must be rejected or the process/production stopped until the problem is resolved.
4. Establish CCP monitoring requirements. Establish procedures from the results of monitoring to adjust the process and maintain control. In biscuit manufacturing safety problems/hazards are mostly to do with contamination by foreign bodies. Thus the results of monitoring are mostly to do with product rejection and searches for the sources of the contamination.
5. Establish corrective action to be taken when monitoring indicates a deviation from an established critical limit. This principle has little application in typical biscuit manufacturing in the field of product safety.
6. Establish effective record-keeping procedures that document the HACCP system. All 'finds' must be recorded in detail, along with 'finds' reported by customers. Any articles of contamination should be kept, if possible, as reference for the future in case the incident is unresolved and it happens again.
7. Establish procedures for verification that the HACCP system is working correctly. A control system is not good enough unless it is regularly reviewed and improved.

By using the HACCP system all product is traceable so that if something unfortunate is found it is easy to identify all production that may have been affected and to withdraw or recall it. The effective use of HACCP has increasingly raised standards and awareness of risks but its successful implementation often requires a real culture change by manufacturers. After reading the sections on GMP, quality control and process control it will be appreciated that the design of HACCP and its implementation is not distinct from other control operations. HACCP is part of a quality management system.

It is beyond the scope of this book to detail all the elements involved in establishing a HACCP system relevant to a company or manufacturer. It is hoped that the above outline of the culture and what is involved will prompt more detailed study. HACCP is a *preventative* system of food control.

3.2.2 Traceability

The EU General Food Law Regulation 178/2002 defines 'traceability' as 'the ability to trace and follow a food, feed, food-producing animal or substance, through all stages of production, processing and distribution.' This regulation makes traceability compulsory for all food businesses. It is therefore essential to include it in any quality management system. The traceability works in two directions: being able to follow an ingredient from source through to product offered for sale and being able to trace back any ingredient in a pack to the source before the product was manufactured. Keeping all the necessary records is quite challenging!

3.3 Useful reading

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4

Quality control and good manufacturing practice (GMP) in the biscuit industry

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Abstract: In the biscuit industry, with its particular problems of flour variation, defining specifications and controlling processes requires regular reappraisal. Being prepared for problems, even of the more unusual types, protects the company reputation when something does go wrong. Quality control is about vigilance. All personnel who visit a factory must be aware of the hygiene needs for a food factory. A manufacturer must be concerned with both the safety of his customers and his staff.

Key words: product inspection, specifications, liaison with suppliers, safety.

4.1 Principles and management

The need for a culture of a quality management system and an outline of what is involved has been given in Chapter 3. It is the all-embracing structure that oversees control in manufacturing. For the purposes of discussion it is convenient to divide the system into sections. Management of product safety by means of the HACCP system has already been introduced. It is convenient to consider control activities that centre on materials/products before and after production, which we shall call quality control, and those that occur at the time of production, functions concerned with the dynamics of processing, which we shall call process control. The distinction is based on the nature of monitoring and measurement activities and therefore those who should be responsible for doing them. Quality control inspections and testing can, mostly, be carried out when convenient and therefore specialised staff are used, whereas process control inspections must be carried out continuously at defined intervals during the production processes and, given the right instruments and training, must be performed and supervised by production workers.

The scope of quality control and process control operations covers quality control preproduction and involves the inspection of ingredient and packaging material deliveries, inspection and monitoring of materials in storage, and factory hygiene arrangements and conditions. Process control involves materials processing operations, metering, mixing, dough holding and handling, dough piece forming, baking, biscuit cooling and handling, secondary processing operations and packaging. Quality control post production involves the inspection of packed product, and monitoring goods in finished product storage and distribution conditions.

In this chapter typical quality control procedures are described and good manufacturing practice (GMP) will be included. GMPs centre on the factory environment and people and are not specific to the manufacture of a particular product. In the biscuit industry, with its particular problems of biological raw materials, defining specifications and controlling processes is much more difficult than, for example, in chemical industries.

The principles for quality control must be to

- identify where variations in ingredients and packaging materials will affect the product quality or the processing operations
- quantify these variations and define the permissible limits in terms of measurable/described characteristics
- agree the product specifications with suppliers and agree how significant variable properties can be monitored
- agree with suppliers the procedures for timely communication should faults or defects occur
- do enough checking to have confidence that all is well but not to waste time and money on tests that cannot lead to useful recommendations to the benefit of the company
- give great importance to timings for reporting the results of checks
- ensure that results and conclusions from checks are statistically sound
- record all out-of-specification incidences for the benefit of monitoring and supplier reviews.

A good quality control manager will identify problem areas and direct his efforts and resources appropriately. He will ask himself the following questions

- What happens if we do not do the checks?
- Can we afford not to do the checks?
- Will the records from the checks be enough to support our policy of continuous improvement and lead to a reduction in the number of checks needed?

The aim is reduction of variation and prevention of problems rather than testing and rejection. In many cases instrument-based measurements are not very satisfactory or take too long. He will therefore have to rely on the sensory perception of his staff in terms of their eyes, nose and taste as much as on scientific instruments. People are expensive so it is essential that they are selected for the necessary degree of intelligence and with senses that are sufficiently keen to perform the tasks allotted to them. It is wise to check that they are not colour blind and do not have other permanent physical disabilities impairing their senses. The staff should be constantly reminded of their value and cost to the overall business and given adequate information and training to allow them to perform to the best of their abilities.

The requirement is for the company to make products to agreed specifications. Quality control staff will be involved in defining these specifications because they will know and understand the properties of the materials used and thus the limitations to accept. It is probable that the product (and materials) specifications will be reviewed periodically in line with a policy of continuous improvement. As the product specifications affect marketing, processing and costing they should not be altered without general agreement. There is no such thing as 'high' or 'low' quality in the way that quality is being considered here. The product, and hence its quality, is defined by a specification which must allow for some variation. Quality control

therefore implies 100% adherence to specification, it cannot be high or low in that respect.

4.2 Quality control tasks for finished product inspection

It has to be admitted that it is not possible completely to define and test for all the characteristics that make up a biscuit product. It is therefore necessary that quality control staff are sensitive to variations that do or might occur in the processing which may affect the product quality and to make checks as appropriate. It is this understanding that will decide the frequency of sampling and checking. Under a quality management system (QMS) culture quality control staff will be informed promptly by production if there are difficulties that may affect the product quality. Through co-operation the correct actions will be agreed.

A view must be taken on how finished products should be adequately monitored bearing in mind that all the control systems in the factory should be aimed at preventing variation and contamination. As a result of spot checks the extent of some problems can be estimated with a view to tightening up controls earlier in the process. These may include checks on

- pack weights and examination of process control pack weight records
- pack appearance, correctness of coding/overprinting
- storage tests to check pack performance and product shelf life
- incidences of broken biscuits within packs
- organoleptic checks on biscuit texture and flavour
- metal detection facilities, review of 'finds'
- warehouse conditions, e.g. stacking and rotation of stocks
- procedures for loading of trucks and damage due to distribution
- storage conditions and stock rotation at depots.

The single most important property that affects biscuit quality is the individual biscuit weight. If the weight is higher or lower than specified both the colour, moisture content, size and eating quality may be affected. If the biscuit size is wrong the pack may be too heavy or too light and this affects the pack performance and the economics of production. Instruments may be installed to monitor pack weights and the records from these will be of great value. The instruments, usually known as checkweighers, need to be calibrated and checked for correct performance at regular intervals.

Metal-detecting instruments also must be checked for correct performance regularly. Organoleptic tests are discussed in Chapter 6. It is becoming more common for biscuits to be sold with precise claims of nutritional value. Where this is the case quality control must take adequate samples and make assays by approved methods to substantiate claims on the labels.

Analysis of results from these quality control checks over a number of days or weeks may reveal shortcomings of packaging materials or various machines. It is the duty of the quality control manager to spot these points and to communicate with process control, engineering, product development, etc., staff to see if improvements can be made or whether a development project should be instigated.

Discovery of substandard packed stock requires urgent and logical management procedures. What is done depends on the nature of the problem and the attitude of

the sales director. Just occasionally it may be necessary to recall stock that has left the factory and even got as far as the retailing shops. It is very important that thought is given, before an incidence occurs, to what to do in these circumstances. The press media have an unfortunate skill in humiliating managements that are unprepared in incidents that cause public concern even though they may be very rare. A good discussion on product recall policies and procedure was given by Stewart [1].

4.2.1 Customer complaints

Customer complaints are an early warning that all may not be well in the quality control system. Many companies have a freephone number printed on the package to encourage customers to let them know of problems and concerns. Customer complaints will normally be addressed to the sales and marketing department but quality control should take a significant position with respect to these and in particular about foreign matter in biscuits. Prevention of foreign matter in biscuits is mostly about good manufacturing practice (GMP) which is discussed in Section 4.4.

Customer complaints are mostly about stale biscuits but the most serious complaints are about foreign matter inclusions. Here prompt, responsible, action is imperative. If a consumer is sufficiently concerned to notify a complaint, he or she will become aggressive if not assured that the matter is being treated properly. The aggression may take the form of recourse to the authorities or a court of law which could involve the manufacturer in considerable expense and bad publicity. Not all customer complaints are justified and there are rogues whose main aim is free supplies. However, with good record-keeping and keen observation of technical matters it is often possible to spot the hoax complainers. No complaint should be treated lightly as it may be an indication of an extensive or serious problem.

4.3 Quality control tasks for ingredient and packaging materials

The starting points for materials quality control are the specifications, understanding of the critical characters in relation to where the material is to be used and the capabilities of the supplier. This means that the quality control staff must maintain a good liaison with the company purchasing department, process technologists, and product development staff. It is essential that substandard materials found as a result of quality control checks are reported not only to manufacturing but also to the buyer.

In Part II of this book details will be found about the types and functions of most of the materials needed to make packed biscuits. Basic specification requirements for these materials are indicated but suppliers can often reduce variations in some of the material properties to suit their usage. There will always be strong reliance on the supplier to send materials within the agreed specification.

It is recommended that the liaison with suppliers extends to visits so that processes and facilities can be fully appreciated. Specifications should be mutually agreed between supplier and user in terms related to the use and against reasonable analytical procedures. The quality control department should be able to make analytical checks using similar methods to those in the supplier's laboratory. There is often a problem of operator error which must be taken into account before faults

are declared as a result of tests. From time to time collaborative tests should be made on a selected set of samples to ensure that both laboratories are in agreement. Where facilities for tests are not available at the user's laboratory, the quality control manager must establish connections with independent analysts to enable him to have the tests made for him. The tests to be made, and their frequency, will be decided as a result of hazard analysis and risk assessments related to usage of each material.

The quality control of raw materials starts when deliveries are made. The condition of the consignment on the vehicle is important because damage or contamination may have occurred here. In the case of bulk deliveries, it is wise to see, smell or taste a sample from the vehicle before discharge commences. It is unlikely that all the necessary tests can be made before the material is accepted, so an initial assessment combined with discharge into a separate silo or bin is desirable. The sample taken from the vehicle should be more than large enough to do all the tests, or likely tests, and should be stored in a clean and airtight vessel. This sample should be labelled and kept in the laboratory for the duration of the time that the rest of that consignment is in store. This provides a reference should unforeseen difficulties appear during use of that consignment.

Glass jars and bottles are a serious hazard in food factories as dangerous splinters can get into product should a vessel be dropped and broken. Therefore, samples of ingredients should be kept only in tins or plastic containers if they are ever to be taken outside the laboratory. The storeman is responsible for raw materials and other supplies before they are needed for production, but quality control staff should check storage conditions for temperature, humidity, infestation and cleanliness. Note also the labelling to ensure correct rotations are adequately and correctly administered. All stocks should be checked and/or tested as soon as possible after delivery and again as necessary while they remain in store. Some system should be set up to ensure that the storeman does not release goods for production until cleared by quality control. In cases of doubt about material quality, the buyer should at once be told. It may be necessary to reject the materials or to use some, out of rotation, for production and to critically monitor results before it is decided whether to accept or not.

The question of a representative sample should always be considered. There are various procedures which may be followed in order to obtain a 'good' sample but as these tend to be complicated it is usually necessary to be critical only if the first sample taken is poor or borderline in quality.

4.3.1 Procedures for taking alternative materials

The idea of reducing processing difficulties by using a single supplier of an ingredient brings with it commercial vulnerability. A wise buyer will never be content with a sole source of supply however good it is. Thus, in collaboration with the quality control and product development technologists the buyer should plan for alternative sources of supply.

Before material is taken from a new supplier there are a series of technical as well as commercial actions to be taken. The supplier should be asked to supply against a specification, he should be visited so that his facilities and control procedures may be examined. He should then be asked to supply a representative sample large enough for one or more full-sized trial mixings in the factory. With the aid of

process technologists, production staff should be asked to use the material instead of the standard ingredient and the results throughout the processing will be carefully monitored. It may be necessary to make small adjustments to plant settings and these must be recorded. If the product looks satisfactory, organoleptic tests should be made and only then will it be possible to accept a trial consignment for prolonged trials and eventual acceptance.

4.4 Good manufacturing practice (GMP)

Good manufacturing practice includes aspects of factory hygiene and product safety. It is, of course, strongly involved with a HACCP system. Hygiene is not strictly within the compass of biscuit technology, but as this is an aspect of great importance in a biscuit factory and the technical department is usually asked for advice, some discussion of the principles, practices and techniques is not really out of place. Poor attention to GMP can lead to foreign matter getting into product and for this reason it is of particular concern to quality control.

Much of what is to be said should not need stating as it is common sense where preparation of food is concerned. The problem is that cleaning and attention to details that ensure that food is wholesome and safe involve extensive labour-intensive operations which are not in themselves profitable to the business. Thus attention to hygiene is all too frequently neglected and slack behaviour and poor supervision soon becomes the norm. This can lead to a bad example for new staff and complacency with unhygienic conditions. The principles are based on the moral and legal responsibility of the food manufacturer to produce food that is safe and wholesome for consumers.

Factors causing danger to health or revulsion to consumers are associated with the decomposition of food by bacteria and moulds, contamination by animals, that is, rodents, birds, insects and humans, contamination with 'foreign' bodies such as glass, metal, paper, stone, plastic and fibres, and contamination with chemicals such as insecticides, detergents, bleaches, mineral oils and grease.

Legislation in different countries varies considerably on these aspects, but codes of practice are continually being developed that all should endeavour to follow as closely as possible. The following is an attempt to summarise this code of practice in sections.

4.4.1 Sources of contamination

4.4.1.1 People

From people may come contamination by micro-organisms on their hands. Hairs, buttons and pieces of jewellery may fall off their bodies and clothes and articles may fall from pockets. The most important requirement is that all those who handle or are likely to handle food should observe basic rules of personal hygiene. Disease may be quickly spread if food handlers are negligent about hand washing following visits to toilets. It is very unpleasant to have food contaminated with grease or other dirt from unwashed hands.

At all food premises good, clean washing facilities must be provided with continuous supplies of hot and cold water, non-scented soap and disposable towels. Cold

water with no soap and communal towels are not adequate. Soap should be from fixed dispensers not as tablets that could be stolen or lost into dough, etc. Hand washing sinks and facilities must be separate from those used to wash equipment. All food handlers must ensure that their hands are washed and clean before handling food and it is particularly important that their hands are washed after each visit to the toilet. It is a wise procedure to insist that everyone entering a production area washes his or her hands *every time*, even if the time outside has been short and not involving a visit to toilet.

Employers should provide clean overalls and hair coverings for all personnel. These are to be worn only in the food factory. No personal food, drink containers, loose money, pins, jewellery (other than plain wedding rings), watches, radios, books, newspapers and smoking tackle should be allowed into the production areas. Hair should be *completely retained* in the headgear and hair brushing or combing, necessitating removal of headgear, should be forbidden in production areas. In this way the possibilities of contamination by loose articles is significantly reduced.

Smoking involves the hands becoming contaminated with saliva and the by-products, matches, ash and cigarette ends, are particularly repulsive. Smoking apparatus must not be brought into a production area even in the pockets of users. No smoking should ever be allowed in the production areas.

Operators who have cuts, abrasions or skin infections, particularly on the hands or arms, should be especially careful. Bandages or dressings should be of good quality and be, at least partly, brightly coloured and easily detectable should they be lost. In those premises where metal detectors are available for product scanning, it is additionally useful for the bandages to contain metal strips that will be automatically found should a bandage be lost into the product.

Food handlers suffering from intestinal complaints such as diarrhoea or other contagious diseases should be required to keep away from production areas until they recover. It is frequently necessary for operators to carry certain small articles with them in the course of their duties. Articles such as pens, pencils, gauges and various tools should not be carried in top pockets in case, while bending over, they should fall into the product or machines. Overalls provided with no top pockets remove this possibility! Where gloves are needed either of fabric type (as for chocolate handling) or waterproof, they require regular washing and drying both inside and out. Gloves should not be shared by more than one person and they should be replaced when damaged.

4.4.1.2 Emptying containers

When bags or boxes are opened and emptied there is a great potential for contamination. Pieces of string or paper removed in the opening process must be placed in rubbish bins and not on the floor. Before inverting a bag, box or other type of container, ensure that it has not collected floor or surface dirt that could fall into an unwanted place. Dispose of the empty container in a responsible way so that spillage or dust is avoided as much as possible and it is not a danger to other workers.

4.4.1.3 Small items of equipment

In most biscuit factories it is necessary to use bowls, beakers or trays to carry and weigh ingredients or dough. These should be of metal or plastic because glass is particularly dangerous by way of splinters or small fragments if broken. Glass containers must never be taken into production areas.

Where ingredients are delivered in glass containers they should be dispensed into unbreakable containers in specially designated rooms away from the production areas. Colour coding of containers is better than labels which may fall off. Elastic bands provide particular hazards due to their tendency to fly off in unexpected directions and become lost. All utensils should be stored, full or empty, on special clean platforms or shelving so that they are off the floor. This is to ensure that when inverted no floor dirt can fall from them onto the product or into a mixer. After use all containers should be washed in hot water, with detergent as necessary, and left inverted to dry.

Cleaning equipment such as cloths, brushes, mops and scrapers should be stored and dried after use on specially provided racks, hooks or rails, off the floor. Detergents used for cleaning equipment must be of approved types and stocks must be stored separately away from ingredients or dough containers. Office equipment such as elastic bands, paper clips and particularly pins should be forbidden in the factory environment.

4.4.1.4 *Plant machinery*

At the end of each production run all machines should be cleaned immediately so that build-up of dough or other materials does not become hard, mouldy and an attraction for insects. In any case it is usually easier to clean machines while dough, etc., is fresh.

Hidden recesses in some machines are particularly difficult to clean and thought should be given to this when the purchase of new machinery is considered. Jowitt [2] is a useful reference where hygienic design of machinery is concerned. As a basic principle, all food machinery should be mounted off the floor so that the floor can be thoroughly swept or washed at regular intervals.

Covers for the moving parts of machinery should be properly fixed at all times and kept in good repair. All surfaces should be wiped down regularly and washed with warm water and detergent if necessary.

Fabric conveyors should be checked regularly to watch for frayed edges or seams. If necessary these should be trimmed with a sharp knife or the conveyor replaced. If a machine is not to be used for some time it should be covered with a dust sheet. Drip trays and other catch containers must be emptied and cleaned regularly, but certainly at the end of each production run. Particular care should be taken that mineral lubricating oils and greases do not contaminate food. Leaking motors, gearboxes or bearings should be reported without delay for engineering maintenance.

Where it is necessary to climb up to high parts of machines or where bridges or ladders are needed to get over machines, special walkways with adequate guarding should be provided to prevent floor dirt, carried on footwear, dropping onto dough, products or food surfaces. No string should ever be used to attach wires or other articles in production areas and fibrous or loose insulation materials should be covered and fixed securely to prevent disintegration. Nowhere in production areas should wood be used. This is easily splintered and pieces find their way into ingredients or dough.

When machinery is replaced or obsolete it should be completely removed from the production area and stored (preferably in a reasonably clean condition) in a store remote from the factory. In many factories the machinery graveyard is an ideal home for marauding rats, mice and insects. It is ideal from their point of view

because it is dry and undisturbed. Food can be taken there and breeding can take place in relative comfort! The convenience of such a home should be denied within the production environment.

Much closer attention is now being given to the design of plant machinery in respect of hygiene in all food factories. The demands are not so strong in a biscuit bakery as in dairy and meat establishments as there is little 'wet' processing and all the dough is baked and therefore effectively sterilised before packing. Nevertheless much biscuit machinery is currently very difficult to clean easily and a number of aspects are now receiving engineering attention. These include mounting all the drive and control components outside the main frames of machines (to reduce places where materials can collect in difficult to see and reach places) and eliminating dirt traps, for example where a guard is fitted to a frame or motor. Rounded structural members collect less dirt than square sections. We are not yet at the hosing down stage for biscuit machinery but the move to make it easy to clean off scraps of dough and layers of dust from all parts of machinery is clearly a good direction to be taking.

4.4.1.5 Buildings and general factory areas

A major source of contamination is from insects, animals and birds. Also dirt or loose particles falling from overhead areas offer potential hazards. Flying insects and birds must be excluded from the factory by using screens over ventilation fans and windows which open. Traps such as high-voltage grids incorporating an ultraviolet light to attract insects may be useful for catching flying insects that have found entry into the factory. They are not 100% effective and preventing the insects getting into a building is better. Open doorways should have plastic strip or air curtains to prevent entry of insects and birds. Doors to the outside should fit closely to the floor so that animals cannot enter at night or at other times. Rodent control systems should be regularly maintained and any bait must be placed only in specially designed and sited containers which are clearly marked. Damaged bait containers should be disposed of immediately and safely.

Trunking for wiring and other services should be well sealed to reduce the chance of dust accumulation followed by insect infestation. High ledges and roof supports where dust can collect should be of sloping construction and be cleaned regularly. Good lighting should be maintained in all production areas and plastic screening, where appropriate, used to prevent glass falling onto the product should light bulbs or tubes be broken.

It is a requirement that all food workers are aware of these potentials for contamination, and report to management without delay any aspects that do not seem satisfactory.

4.4.2 Safety of people

In most countries employers are required to ensure that the machinery employees use and the areas in which they work are safe. However, if employees are negligent in reporting faults or in cleaning operations, etc., it is possible that an otherwise safe situation becomes unsafe.

4.4.2.1 Floors

Dirty floors that have become wet or greasy are slippery. Clean up as necessary.

4.4.2.2 *Machine guards*

Moving parts, especially those where a nip is involved, must be guarded to prevent hands or clothing becoming trapped. It is particularly dangerous to run a machine with these guards removed. Experience shows that accidents involving machines occur more often to 'experienced' operatives. They become over confident and try to overcome problems by running machines with guards removed or take risks 'because they got away with it before'!

4.4.2.3 *Electrical connections*

Most machinery is driven and controlled by electricity. For safety and other reasons the connections and other electronic components are housed in cabinets or under guards. The danger of electricity cannot be seen so it is very dangerous to remove guards. Faults with electrical apparatus must be reported to management or responsible engineers.

4.4.2.4 *Strain injuries*

Back strain is a very common injury experienced by factory workers. It is unpleasant for the person who suffers it and a potential cost and inconvenience to the employer due to the need for sickness leave. Back strain derives from physical effort performed incorrectly or carelessly. Employees should be encouraged to think before moving and lifting bags, boxes or pieces of machinery. If they are too heavy they should get help, if the floor is slippery they should take extra care. Do not try to lift something too high without help. Do not expect a colleague to help you if he or she is not clear what is expected or is not strong enough to do it.

4.4.2.5 *Dust*

Dirt is defined as material in the wrong place! Dust soon becomes dirt. It is unpleasant, may be dangerous to health and it may accumulate and fall into containers containing food or ingredients. Things should be arranged to cause as little dust as possible and any produced must be cleaned up without delay.

4.4.2.6 *Engineering and building work*

Maintenance or alteration work performed by non-production staff requires particular vigilance as engineers and builders are not used to the hygiene standards required of food factories. Fitters and machinery maintenance workers should never place feet on surfaces which will come into contact with food and if *in situ* drilling or filing is needed, magnets should be placed to catch metal swarf. It is good practice to have high standards of housekeeping in the engineering workshops so as to remind staff that high standards are required in the factory. Metal swarf can easily be carried into the factory on engineers' footwear from the workshops so everything possible should be done to reduce this hazard.

Nuts, bolts and small machine parts should be collected in containers, not left on ledges on machines for fear that they should be forgotten or fall into important parts of machines. Where cutting of walls, floors or ceilings is necessary, the whole area should be sheeted up so that fragments of brick, stone or mortar do not fly into food areas. Good cleaning up should follow such activities. Loose mortar, broken doors or bad cracks should be attended to without delay as, in

addition to the hazards of falling particles, they also afford shelter for insects and vermin.

4.4.3 Supervision and execution of cleaning operations

Even if all the basic precautions detailed above are observed, there is the fundamental problem of organisation and supervision of cleaning and factory housekeeping. This problem should be addressed under the QMS and HACCP systems. Hygiene is everyone's responsibility.

It is wise to appoint a full-time hygiene officer to oversee and organise all cleaning operations, but cleaning should be the responsibility of area production supervision. Operators should clean their machinery regularly and at the end of production runs. Where necessary one or more full-time cleaners should be appointed to work with these production workers. This arrangement instils an attitude of team responsibility in areas and prevents a careless worker shifting responsibility to others whom he may not know or see. The exceptions are for space cleaning, in-depth, of walls, overheads and some floors. These are probably best tackled by cleaning teams equipped with suitable mechanised equipment. The cleaning team should also be able to deal with emergencies such as large spillages, blocked drains or local floods.

Responsibility for the cleaning team is with the hygiene officer and he should also ensure that the outside areas of the factory – the yards, waste disposal containers and drains – are properly maintained and cleaned. The hygiene officer should also understand the value of various detergents, insecticides and sterilising chemicals and be responsible for stocks and safe storage away from foods and wrapping materials. He should arrange cleaning schedules and techniques with the production management and ensure that cleaning equipment is adequate and in good condition. He should also organise instruction for all production and maintenance staff at regular intervals and arrange special induction talks to all new recruits at a very early stage in their employment with the company.

He should liaise with specialist companies for the control or eradication of insects and rodents and it is wise for the company to have a rodent-control contract with one such company so that appropriate baiting and infestation control techniques are used. Cleanliness and good housekeeping are the responsibility of all food factory staff, but the hygiene officer should be sufficiently qualified to understand the technical and micro-biological techniques to be employed and above all be a good and fastidious organiser. He should also maintain a close liaison with the technical department.

If staff making food ingredient deliveries to the factory, or their vehicles, are not up to hygiene standards, a complaint to the supplier should be made at once in writing saying that future consignments will be rejected if attention is not paid to hygiene requirements.

4.5 Hygiene surveys

Under the HACCP system regular monitoring of hygiene and GMP in the factory will be programmed. The task of making hygiene surveys can be given to many

different members of staff as it encourages thoughtfulness about what is and should be done.

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Process and efficiency control in biscuit manufacture

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Abstract: Biscuit manufacturing involves a series of processing events that are dependent on the preceding one. Constant monitoring either manually or with instruments is essential to keep production running smoothly. Inadequate process control leads to out-of-specification product and waste of materials, power, labour and time.

Key words: specifications, instrumentation, process audit.

5.1 Process control and efficiency

There is a requirement for the manufacturing team to make food that is fit for consumption and meets product specification at the lowest output cost. Increasingly in the biscuit industry there is overcapacity and continuing pressures on profit margins. This occurs in a marketplace where there appears to be a limited appetite for big new product launches. This has led to a commodity type mentality where manufacturers have the capability to make generic products represented in the marketplace. There is a clear advantage in being a low cost producer.

The relative high density of biscuits, unlike the salty snacks market, makes it viable to distribute product over long distances increasing competition for manufacturing across regions.

The Biscuit, Cake, Chocolate and Confectionery Alliance (BCCCA) (now part of the Food and Drink Federation (FDF)) commissioned a European benchmarking study looking at manufacturing efficiency (phase 2 Janette Macpherson *et al.*) which was reviewed at the BCCCA conference in March 2001 [1].

A key business measure examined was overall effective efficiency (OEE) which measures the overall efficiency of manufacturing plant. It reveals quality output as a percentage of what the plant can produce if there was no downtime, waste or loss of production. Compared with a world class manufacturing standard of 86%+, the report showed an availability average of 81% (made up of 3.9% changeovers and 15% downtime), performance of 87% (87% of output rate) and quality of 98% (2% waste). This gave an OEE of $81.1 \times 87 \times 98 = 69\%$ in the food industry represented by the BCCCA where $OEE = \text{availability} \times \text{performance} \times \text{quality}$.

The benchmarking process considered training and operational skills as well as the business measures to get a measure of the 'health' of the industry. Clearly, certain business measures such as scheduled downtime and changeovers are affected by commercial issues as well as technical ones. However, it is clear to see that manufacturing efficiency and business profitability is impacted on by the choice of plant and the ability of the manufacturing team to get the best from it. Process control plays a major role in managing the equation.

Since the publication of this report there has been an increased focus on energy usage as industry responds to the need to reduce its 'carbon footprint'. This is an additional driver of technical change whose scope goes beyond the financial savings that can accrue. Improving energy efficiency is a core driver of research and development in the biscuit industry.

In order to make to product specification at high OEE, there needs to be a consistent raw material specification, a well maintained plant and a workforce that understands the critical control points that can be adjusted in order to make product within specification. The emphasis in today's manufacturing is on 'right first time'. This demands a rigorous focus on quality assurance where variations in key product parameters can be continuously monitored and adjustments made when necessary. This then means the end to the process of quality control where final product can be rejected on the basis of routine assessment of finished product.

To the biscuit manufacturer, the requirements to meet success are

- getting biscuits into packs
- getting the correct weight and numbers of biscuits into each pack
- meeting the product specification (as written down)
- reducing waste and inefficient running of plant.

It would be wrong to believe that the factory aims for product excellence as viewed by the consumer. Their requirement is to meet the product specification, as written by the technical team which is not as easy as might be believed when reading quality management systems manuals.

Biscuit ingredients, particularly flour, are agricultural materials that are variable. Ingredient specification can account for some of the variation seen in product characteristics but not all. Wheat flour is not easy to characterise. A test baking procedure where a biscuit is made under controlled conditions is still the most consistent way of testing the function of ingredients in a given recipe.

This makes automatic feedback control of the unit processes difficult to manage because small changes to dough character can lead to process adjustment down the line which can lead to product characteristics cycling whilst the process is being regularly altered in an attempt to re-establish control. Product consistency is often best maintained by establishing dough consistency and using the levers of control of piece weight and oven setup to maintain the stack height, colour and moisture to ensure compliance with specification.

As a rule of thumb, high fat doughs tend to be more tolerant or 'forgiving' and therefore make less demand on the process control system. However, there is a requirement to keep the nutritional composition of products under review with particular reference to fat and salt. It is not currently topical to produce biscuits where fat reduction is claimed. There is sufficient history to suggest that consumers do not like the trade off with eating quality that reducing the fat content of biscuits

brings. Reducing fat in biscuits therefore increases the importance for process control in managing OEE.

5.1.1 Making to specification – continuous product improvement

A lot of discussion about process control takes the manufacturing specification as a given. This is correct on a day-to-day basis. However, the specification should reflect the product standard documentation which is usually owned by marketing as the brand owner and reflects the consumer attributes that make the product irresistible. There is much evidence to show that having a preferred product and continually striving to maintain it boosts the underlying rate of sale once advertising and trade marketing are removed. The level of innovation is closely linked with consumers' perception of quality and an increase in perceived value leads to increased market share [2].

The problem is that manufacturing specification and marketing requirements are not always written in the same units. Take one example of a snack biscuit:

Desired consumer attributes

- Cheesy
- Shape/regularity
- Crisp crunch & melt/clears the mouth quickly
- Substantial without being heavy
- Good balance of flavour
- Golden yellow colour.

Manufacturing standards

Moisture	2–3%
Colour	67–71
Breakage	≥8%
Malformed biscuits	0%
Stack height	50/200 mm
Piece weight	750/kg

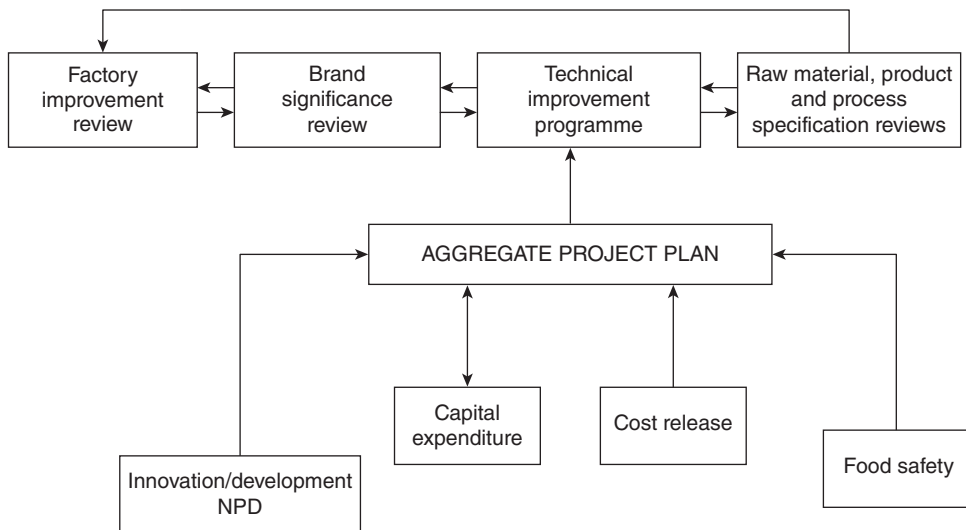
There is no clearly defined linkage between the marketing required standard and the manufacturing specification. Indeed there is no specific language that can form the basis for a means of improving the consumer appeal of the product and communicating those changes back to the consumer.

There are some more complicated techniques such as quality function deployment that can be used to understand how consumer attributes can be linked to manufacturing specification. However, there are some more simple techniques that can be employed that can inform the continuous improvement process.

One such technique is a factory sensory assessment made during each shift. In this evaluation the product is scored for appearance, flavour, aroma and texture on a three-point scale, with 3 indicating that the product met consumer expectation in full and 1 that the product was unacceptable (Table 5.1). A score of 2 is the more interesting in that it represents a product fault that falls short of rejection. Any score of 2 requires the tester to give a reason which is then collated and potentially used to drive an improvement programme. The same assessment can then be repeated

Table 5.1 Quality attributes for a wholemeal biscuit

Attribute	3 – Meets consumer expectation in full	2 – Improvement required	1 – Unacceptable
Appearance	Even baked colour (chart reference) Clear emboss, smooth surface, no breakage, uniform round shape		Burnt/under baked No emboss or illegible emboss Breakage post wrapping
Flavour	Baked wheaty, low salt after taste		Bitter, salty, stale
Aroma	Baked wheat		Stale/off odours
Texture	Initial crisp, crumbly texture. Good mouth clearance		Soft, very crumbly or gritty

**Fig. 5.1** A continuous product improvement chart.

with product purchased in the marketplace. This assessment provides a consumer perceptive on product quality and identifies three key issues:

- sub-standard product not to specification
- quality changes post manufacturing, i.e. shelf life and distribution
- consumer view at variance with specification.

It provides a valuable key performance measure for consumer satisfaction that is not complaints driven. Together with photographic standards, process measurement and process audit data, this forms the basis of a product file which is the 'How to make' guide for each product type and represents a core competence of the business.

A review of the product standard and the manufacturing specification should be part of the innovation process of regular meetings and activity involving the technical development team, manufacturing and marketing as described in Fig 5.1. The key elements are:

- Factory improvement review – regular performance review against key quality indicators held by manufacturing team.
- Brand significance review – review of specification issues and opportunities of improved profitability often as part of sales and operational planning.
- Specification review – annual formalised review of raw materials process and product specifications including consumer and functional relevance
- Technical implementation plan – links to all technical projects including those outside scope of the factory team

5.2 Process audit

A biscuit manufacturing line is usually a set of continuously running unit processes fed by batch mixers. As previously mentioned, being a food product made from natural raw materials, variations occur in the dough which require the operators to make adjustments to the unit processes to maintain specification. These changes are based on experience of what is still an underlying craft-based industry.

On occasion, a line may operate in a suboptimal way that requires a reappraisal of the whole line. Historically, this often occurred at change of flour harvest, before the significance of degree of damaged starch to control of biscuit character was understood. On these occasions it is necessary to run a process study or line audit to measure and record data at all the critical control points of the operation. Referencing previous audits, modifications to recipe, mixing forming and baking can be proposed.

As well as recording measurements down the line, it is important to make measurements across the band from the control side to the non-control side of the line. Forming and baking process can deliver variances that manifest in different product height, colour and moisture.

A process audit sheet can be constructed as in Fig 5.2. This will form part of the product file for continual reference. Increasing sophistication in continuous measurement techniques has allowed for better understanding of unit process operation, particularly baking. The principal use of these measurements is to inform technologists about optimal ways of running the equipment rather than being used as a means of automated process control.

5.3 Process control checks and records for plants with no continuous monitoring sensors

As a result of thought and experience the critical control points will have been established. At these points measurements and records should be kept. There may be other control points where records need not be kept.

The first opportunity to decide whether baked biscuits are to the correct specification occurs at the oven exit. It is, therefore, usual to sample and make measurements of weight, size, colour and moisture at this point. The one most important parameter is the biscuit weight. If this is wrong then it is likely that the other characters will also be wrong. Therefore there should always be good facilities for checking biscuit weight as they come from the oven and this should be the first check to be made. If faults are found, as a result of measurements at the oven exit, instructions can be signalled to adjust the forming machinery or oven and, if necessary, to

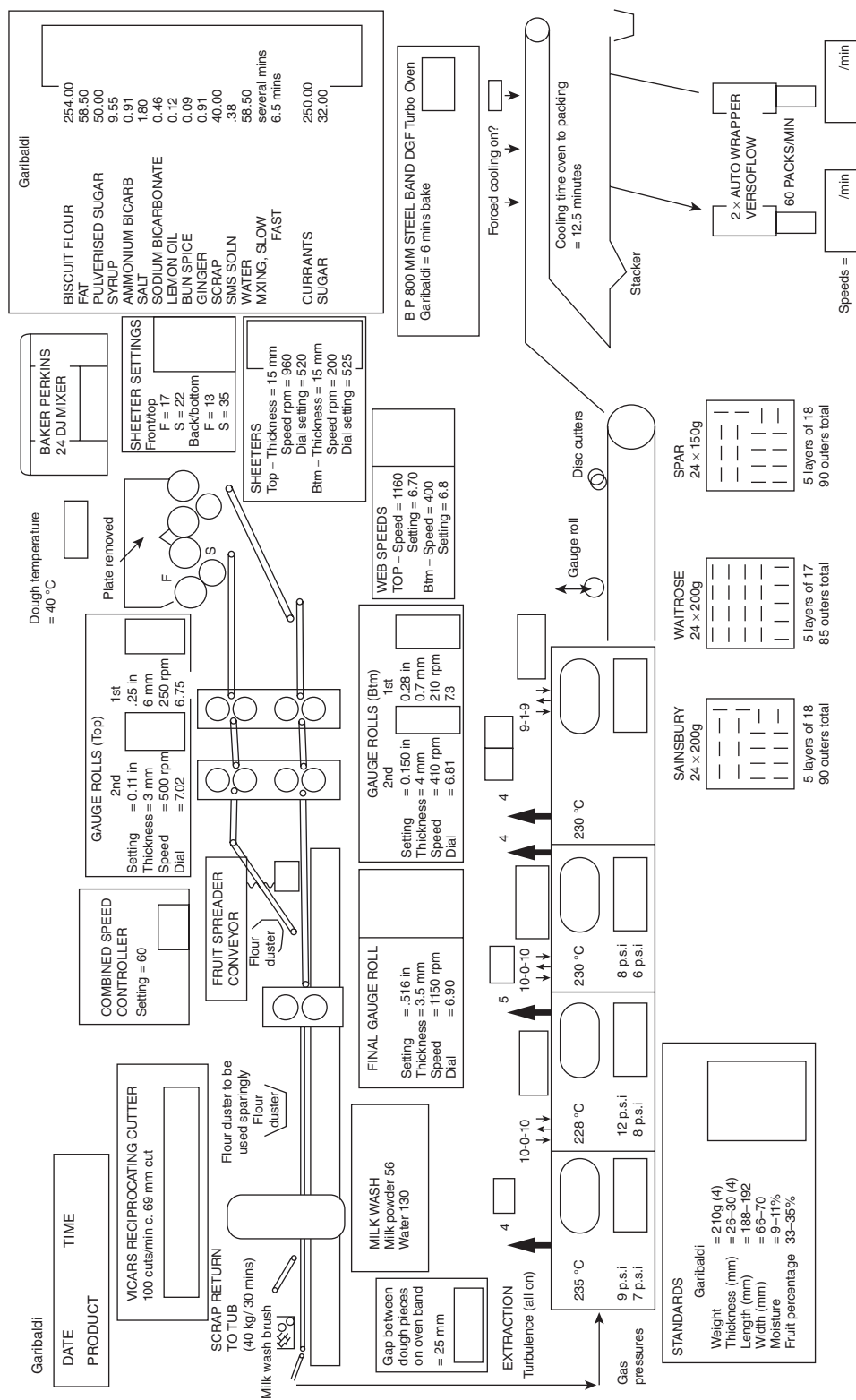


Fig. 5.2 Example of a process audit diagram.

stop further feed into the oven. Signals can also be sent forward to warn those responsible for packaging that substandard product is coming.

As a preliminary check on the quality of dough from a new mixing it is sometimes the case that a small sample of this dough is introduced by hand at some place in the forming machinery so as to produce biscuits ahead of the main mass of this dough. This is useful for detecting, in a timely manner, serious errors of formulation of the dough. However, it is not a satisfactory means of being critical about the quality of the biscuits that will be produced when that dough has aged and been through the complete range of forming equipment.

It is essential that records are made of the measurements taken from samples taken at the oven exit so that the progress of the day's production may be considered retrospectively. In many factories the measurements are checked against go/no-go limits and the values are recorded on a chart against time. On this sort of chart it is not uncommon to find that provision is made to record values at 15 or 30 minute intervals and some space should be left for a few relevant notes (see Fig. 5.3).

There are many deficiencies in this type of record keeping. For example, if an out of specification measurement was recorded, was the sampling repeated and if so what was the new reading and how long had the bad production continued? There is no space to record this activity. The production manager subsequently visiting this part of the factory cannot know whether a slight or large problem existed and whether the trouble lasted for many minutes or only a few. Trend charts are to be preferred and these, based on probability (statistically constructed process control charts) are much better and more informative (see Fig. 5.4).

It can be seen that this type of chart allows marks to be made to record as many measurements as were made. It can be expected that sampling and measurements will be more frequent at times of trouble. This type of recording chart allows immediate visual comparison with targets and limits and the pattern of the records of measurements allows appreciation of trends. Trends give everyone a better idea of how long the trouble had been growing and may suggest causes and hence where attention should be focused. Operators, managers, process technicians, etc., can all make measurements and record results with different colours or shapes of marks.

Sampling a group of, say, 25 biscuits from a continuous production where many hundreds are being produced every minute can give only a vague estimate of any parameter. The principle of statistical sampling is that short-term variability is accepted as a fact so that if a single sample falls within predetermined limits it is probable that the whole population is satisfactory. If, however, the sample is not within the limits, a second sample should immediately be taken and if this is also bad then there is a probability that the whole population is not correct. Thus, the process control chart shows a central mean value line, and on either side a pair of warning limit values and then further away a pair of action limit values (see Fig. 5.4).

5.3.1 Construction of process control charts

This type of process control chart is known as a Shewart chart. Details are described in BS 2564 [3] and in several other handbooks on statistical methods for quality control.

It is firstly necessary to find the positions of the inner and outer control limits from the target mean. This is done by measuring sets of biscuits taken over a very

Date

Plant no.

Biscuit type

STANDARDS

Thickess gauge length

Number of biscuits to fill gauge

Filled gauge weight

Biscuit length

Biscuit width

Biscuit colour, top

Biscuit colour, bottom

Biscuit moisture

Rows per minute

Baking time

Time	Filled gauge weight (g)	Number of bisc. per gauge	Biscuit length (mm)	Biscuit width (mm)	Biscuit colour top	Biscuit colour bottom	Moisture %	Stoppages From	Stoppages To	Reason for stopping General comments
0800										
0830										
0900										
0930										
1000										
1030										
1100										
1130										
1200										
1230										
1300										
1330										
1400										
1430										
1500										
1530										

Fig. 5.3 Chart for recording measurement values against time.

Rows per minute	(std)
Baking time	(std mins)

Plant number

Biscuit type

[illegible]

Fig. 5.4 Trend chart.

short time interval to establish the range of the short-term variability of the means. The range of the means is then multiplied by two factors to give the positions of the limit lines. The inner limits are given by the equation $\bar{x} \pm A_{0.025}w$ and the outer limits are given by the equation $\bar{x} \pm A_{0.001}w$, where $\bar{x}$ is the target mean and w is the mean range from the test samplings. These limits are used to show that when the record of a measurement of a sample is entered into the chart only 1 point in 20 will lie outside the inner limits when the process is in control, so a second sampling, done at once, can be expected to confirm this, and only 1 point in 1000 will lie outside the outer limit when the process is in control. Thus a record outside the inner (warning) limit should be confirmed with a second before action takes place but a record outside, the outer (action) limit should be acted upon immediately.

In collecting the data to construct the chart it is important to remember that sampling of biscuits should be done in the same way each time and in the same manner as the production worker. Also, the sampling should relate in numbers of biscuits and position on the oven band to the way that the biscuits are collated for a packet. For example, if packs of 200 g are being produced containing, say, 30 biscuits, the sample should be of 30 biscuits. The target (centre line) of the chart should be drawn by placing the warning limit at the maximum (or minimum) for the weight, width, thickness or length as required or limited by the wrapping machine tolerances.

It is recommended that control charts like that in Fig. 5.4 are used for all production plants. Biscuits are commonly packed in column packs where the thickness of individual biscuits determines how many are contained in a pack. The packs are, of course, sold by weight so extra biscuits (because they are thin) mean heavy packs. In some cases manufacturers like to control the biscuits by volume but as the volume is very much related to the biscuit weight this approach is not recommended.

5.3.2 Temporary recipe change and mixing procedure records

From time to time it is necessary to make slight alterations to the dough recipe or its mixing in order to keep the biscuits within specification. The most common alteration is to the dough water quantity which adjusts the consistency as a result of flour or temperature change. Changes to the quantities of aeration chemicals may also be necessary. It is important that a reliable means of recording these changes is in place. The changes should be authorised only by a manager or supervisor and at the time the authorisation takes place a signature should be obtained to show the change and the time that it happened. It is a duty of the process control staff periodically to review the changes that have taken place, for each of the lines, because it may be that a permanent change should be made to the product formulation or some process investigation should take place to establish why changes, which suggest process instability, were needed.

5.4 Making process control measurements

It is strongly recommended that oven exit measurements be made and recorded by the plant operatives and not by special process control staff. Management and process technologists should be encouraged to make occasional checks in addition and record their results on the chart with distinctive marks. The operators should

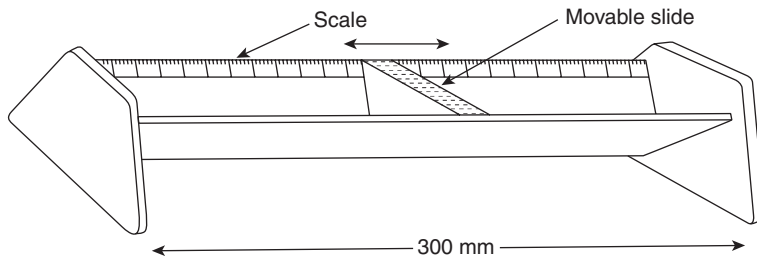


Fig. 5.5 Gauge for measuring biscuit thickness, length and width.

be encouraged to note all their measurements honestly because it is important to know the nature and size of variations. Line staff have been known to mark the chart after an adjustment in the mistaken thought that management would rather see less variation. The measurements are the basis of plant adjustments to maintain control and also, in the longer term, the basis for changes in process or plant if excessive variations and difficulties continue to be recorded.

Process technologists should be responsible for the construction of the charts bearing in mind appropriate sampling techniques and relationships between oven exit biscuits and those that have cooled and been handled before packaging. A different chart will be needed for each product and in conjunction with production management, process technologists should ensure an adequate supply of the charts so that a new sheet can be used for each production run.

The gauges and instruments used for measurement should be as simple and easy to use as possible, bearing in mind the precision that is required. Figure 5.5 shows a typical gauge for measuring thickness, length and width. It is simple and robust. It can be used in a near vertical position for thickness measurements, so that a standard pressure is exerted on the column, and horizontally for length and width measurements. It is recommended that a stated multiple of between three and five biscuits be laid adjacent for length and width checks so that any errors are multiplied for easier appreciation. The values actually measured should be recorded on the process control chart so that no arithmetical errors occur. For biscuits that are supposed to be square or round, the length and width records should be made on the same part of the chart with different symbols so that their concurrency or otherwise is immediately obvious. Electronic laboratory type balances with digital readout to the nearest 0.1 g should be used for weighing biscuits.

Measurements of biscuit moisture and colour (both top and bottom surfaces) at the oven exit can now be made extremely rapidly with electronic instruments. Process technologists should ensure that these instruments are regularly calibrated and the procedures for using them are clearly communicated to operators. Similar measurement and recording facilities must be established at other places where the product characters are critical, for example, where surface oil, sandwich cream or chocolate is applied.

Determining the moisture content of biscuits is a long test if done according to internationally agreed standards. However, there are other methods which give good, but approximate, results in shorter times. Of particular value is the infra-red absorption technique. This type of instrument must be calibrated for different biscuits because it is also sensitive to fat content but, having been calibrated, readings are instantaneous on crumbs from ground-up biscuits.

5.5 Action procedures as a result of product measurements

If the control charts are designed and used correctly they will prompt action by operators. These actions will probably be adjustments of machinery. It is important that communication of the need for adjustments is made promptly and appropriately. The most common action will probably be in respect of biscuit weight. As biscuit plants are long, some sort of signal must be passed from the oven exit to the forming machine (where the weight can be changed) and acknowledgement of this signal made. Commonly a tick-tack form of hand signal is used, but this can fail if the appropriate operator is not visible at the time. A simple system which involves lamps and alarms to indicate increase or decrease with acknowledgement cancelling is useful and this system can incorporate a timer so that having adjusted the dough piece weight another signal can be sent from forming machine to oven exit which alarms as the adjusted biscuits emerge from the oven. It is not usually necessary for records to be kept of dough piece weights, etc., but some indication on the oven exit charts that action had been taken is useful.

5.6 Instrumentation for monitoring

The aim of process control is to maintain steady state conditions. It will be appreciated that even with the aid of statistical assessment, sampling at intervals is laborious and gives only an intermittent picture of the progress of production. Sensors, which can be used as monitors, now exist that are capable of measuring continuously, or at very frequent intervals, most of the product and machine variables with which we are concerned. However, great care should be exercised in fitting the sensors to ensure that they do, in fact, see the parameters they are supposed to see and are not influenced in their read-outs by other things such as heat, dust and vibration. Assessing the performance of these sensors is a major task for process technologists. If possible the sensors should be self-checking and covered by a maintenance and calibration programme.

All instruments should be capable of transmittable signals so that the readings can be viewed remotely and can be recorded electronically for later use. One of the main hindrances to greater understanding of process cause and effect has been the geographical disposition of the various parts of a biscuit production line. Instrumentation has allowed the centralisation of information so that a plant supervisor can see, displayed in his control room, the state of product and plant throughout its length. This area of technology has seen considerable advancement through the development of SCADA (supervisory control and data acquisition) systems. Sensors are linked to a computer system which offers a control and monitoring capability for management of the line from one location.

5.7 Efficiency and integrated plant control

Efficiency promotes efficiency. Inefficiency is infectious and tends to contaminate everything around. Efficiency of production is related to the amount of saleable product made from a given quantity of materials in a given time and with a given number of people. The major causes of inefficiency in biscuit production are

- slow reaction to measurements of out-of-specification product parameters
- stops due to excessive variation of dough or biscuit qualities causing difficulties with the wrapping machines
- excessive settling down time following plant changeover or at the beginning of a shift.

5.7.1 Investigating excessive variations and process optimisation

The value of continuous monitoring of a variable parameter like biscuit colour is that patterns of variations can be seen so much clearer than from spot checks. This often gives a clue to the cause or source of the variation. It is much more satisfactory to prevent variation than to compensate for it. Collecting data from suitable monitors and then processing it using correlation statistical methods make it possible to build up models of the process which are both qualitative and quantitative. The ultimate is to be able to record, adjust and optimise a process automatically by using enough sensors and a computer as the 'brain'.

Process modelling has four distinct stages:

1. qualitative measurement (what affects what)
2. advisory control (how much to alter a primary variable to get a desired effect)
3. predictive control (includes interactions from other than primary effects)
4. closed loop (process relationships understood to a 95% confidence limit).

The 'state of the art' is that no biscuit production line has yet been equipped to allow complete remote/automatic control. The reasons are that there are so many process variables and so much difference between products that the development and design of such a plant has not represented an economic proposition. The sensors and programs are available but the task of modelling processes is formidable. There are few totally dedicated plants, making only one product, and those that are dedicated have not been designed with automatic control in mind. There are too many potential control points.

If one accepts that variation in baked colour, for example, can be caused by oven temperature control, recipe variation, dough piece weight and some other factors, it can be seen that the introduction of a simple control loop which alters the oven conditions, based on a reading of just biscuit colour, could lead to problems rather than an improvement. It still remains best to have good display of the variables and to use human experience to make adjustments. There is still a lot of craft in biscuit making.

The classical technique for process modelling is to make statistically designed experiments with deliberate variations. This approach cannot often be tolerated on a production plant and the use of a special pilot plant has shortcomings and is a luxury that very few can afford.

5.7.2 Improving the efficiency at startup or at changeover

The multiplicity of potentials for adjusting a plant or process is often the cause of slow startup and much waste of time and materials. Few factories have bothered to commit to paper all the settings of all the machinery and all the measurable variables of ingredients and dough, etc., relating to all of the products. It is left to the skill and experience (and memory!) of individuals to get things right at startup and

the length and complexity of most plants means that this often takes considerable time. Compilation of process audit diagrams, such as the simplified one shown in Fig. 5.2, is essential for the process technologist. The data is first collected when a plant is running as smoothly as possible. It forms a basis for further investigation of process optimisation and most importantly as a reference for operators to set the plant prior to a startup.

It is recommended that a plant is started, adjusted and run empty before the first dough is mixed. If there are any mechanical or electrical problems these can be fixed before dough is wasted or left to stand for excessive time. Much modern machinery is equipped with sensors that give electronic displays of settings. It is possible to record these settings and to program a computer to reset a complete plant at the touch of a button. This is a considerable aid in an efficient startup. As production proceeds and further adjustments are necessary, these can be recorded on a time base and related to variations observed in the measured parameters of the baked product. This is a significant stage towards understanding the process and optimising it.

5.8 Outline of the instrumentation that is available

Sensors exist for most process variables but not all have been developed with the biscuit industry (or even the food industry) principally in mind. It is, however, much better to aim to use proven instruments rather than try to develop new ones.

5.8.1 Measurement of ingredient qualities

Ingredient quality in store is the responsibility of quality control and is dealt with in various specific sections. Variations to line operation can be influenced by changes in raw materials that are used. A change in key ingredient performance can result in changes to biscuit quality outside the oven which can trigger adjustments to the process which may then alter again when the next dough is used causing unsettled operating conditions. It is therefore important to ensure monitoring of the key ingredients that may cause variations in dough performance.

- *Wheat flour.* Test baking is the only reliable way of comparing flour performance. However, data on damaged starch (Farrand units, particle size, protein content and water absorption) are helpful. Nabisco went a stage further using diagnostic solvents to characterise flour performance (AACC Method 56–11).
- *Fat.* The solid fat content of votated fat is important (particularly for short doughs).
- *Sugar.* The particle size of powdered sugar and the brix content of syrups will affect biscuit properties.

5.8.2 Ingredient metering

This is probably the most important area of process control. Faults in metering can cause all sorts of problems later in the production. Solids are usually batch weighed and choosing an appropriate system allows good accuracy which is significantly better than a continuous metering system. The management of scrap is

also important. Techniques and discussions of the various merits can be found in Section 33.5.

5.8.3 Mixer instrumentation

When ingredients are mixed a number of functions are performed. A homogeneous blend is required, which is time dependent on the type of mixer and the load it contains. Overfilling a mixer can severely jeopardise good blending. Some ingredients will dissolve in the liquids present and others may become hydrated. These functions are time, temperature and agitation dependent. Thereafter other changes may occur such as the development of gluten from the hydrated wheat flour proteins. These would appear to be shear and compression dependent and hence related to the mixer action. Power consumed by the mixer is liberated as heat. Mostly this is absorbed by the dough but also by the fabric of the mixer itself.

This subject is dealt with in more detail in the section on mixing in Chapter 34, but in searching for means of obtaining dough of uniform quality from successive batches, various types of instrumentation have been used. The key difference in measurement is whether a dough is a short one or gluten developed. With a gluten developed dough the end point is temperature and work input (joules/g). Time is less important than ensuring the correct amount of energy in the dough which is indirectly measured by its temperature rise. The end point for a short dough is for a mixed crumb that will form a dough piece on compression. Here, work input is less important other than checking that the batch has not been over mixed. Also there is less of a temperature rise and so mixing time becomes more important. It is relatively easy to monitor dough temperature if a probe is designed into the mixer. It is usual for power meters to be attached to the mixers so that mixing power curves with time and temperature curves can be recorded centrally. Such an instrument is very useful for detecting when an unusual situation has occurred during the mixing of all doughs. Figure 5.6 shows what tends to happen to the peak power level in a typical semi-sweet dough when progressively more water is added. It will be appreciated that low power values can occur when both too much and too little water is added in typical high-speed biscuit mixers. Much can be read from the shape of the power curve but the interpretation must be related to particular mixers and particular recipes. It is important to remember that the power curve is very mixer-load dependent so variations in quantities of scrap dough, etc., can affect it significantly.

The size of the mixer is also important. For gluten developed doughs there needs to be stand time to allow the dough to relax, whilst in short doughs the consistency of the dough changes all the time as moisture equilibrates. This can lead to variations in key parameters such as stack height.

5.8.4 Forming machinery instrumentation

5.8.4.1 *Hoppers of three-roll sheets, rotary moulders, wire cut and depositing machines*

The height of the dough in the hoppers of these primary forming machines significantly affects the thickness of sheets produced or weights of pieces formed. Many simple proximity or optical instruments exist to detect and control the height of dough in the hoppers. It is best to keep the dough level as low and even as possible.

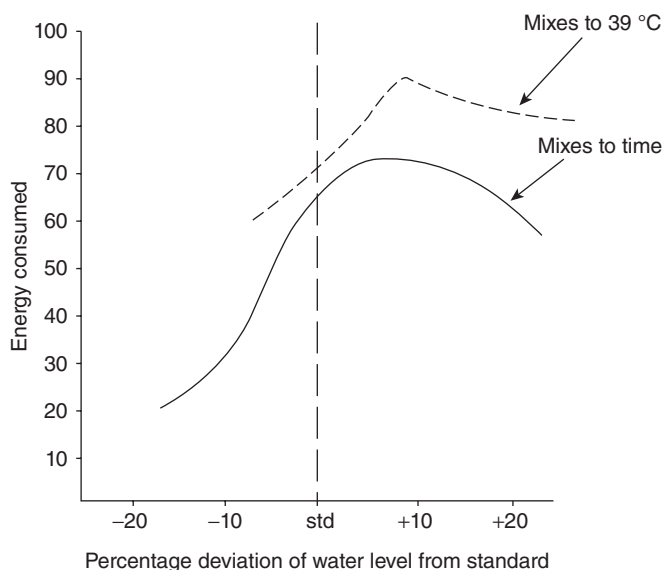


Fig. 5.6 Effect of dough water level on total energy consumption of a Rich Tea dough mixed to time and to temperature.

5.8.4.2 Dough metering in a sheeting/forming machine

A three- or two-roll sheeter does not meter dough evenly for reasons which include height of dough in the hopper, variations of dough consistency and placement of scrap dough. Furthermore, the cutting machine operator has great difficulty in setting precisely the feed rate from the sheeter into the first gauge roll due to the low linear speed of the dough sheet. Figure 5.7 shows how the dough sheet may be floured, rippled, incomplete, etc., between the sheeter and the first gauge roll. If the dough pulls or overfeeds at the first gauge roll, control further down the plant is affected. An optical gauge or a trailing shoe gauge can, in most cases, be a valuable device to control the feed to gauge rolls by speeding up or slowing down the conveyor. The optical gauge maintains a set position of the dough surface as it tends to rise and fall as shown in Fig. 5.8. Alternatively, a simple but less sensitive control system uses the torque of the first gauge roll to modify the speed of the sheeter and subsequent feed conveyor. The operator sets a reference level based on a normally set condition and the feed is automatically controlled to this value.

Therefore the first gauge roll is used to meter the dough mass through the plant. Similar dough feed control arrangements can be used on all gauge rolls if necessary, but it has been found that the first gauge roll after a sheeter and after a laminator are the optimum positions to effect control.

The principle of the optical thickness gauge to effect similar control is shown in Fig. 5.8. If the position of the gauge is altered by knocking, vibration or pushing by a mass of dough, the observed dough surface position is affected. Also flour dust can adhere to the window, due to static electric charge, blinding the optics. Laser technology is now available for online measurement and feedback of dough thickness.

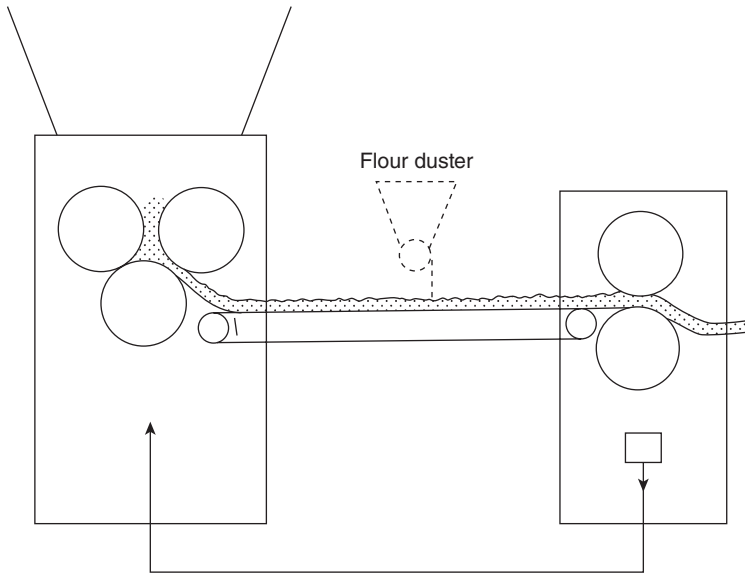
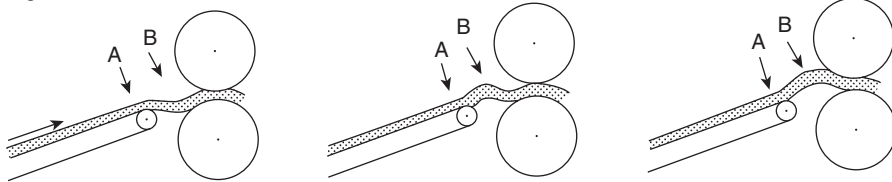
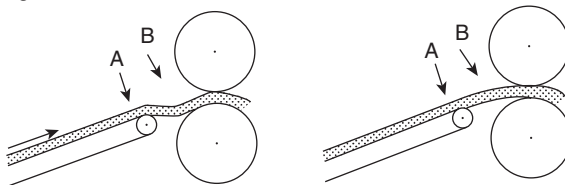


Fig. 5.7 Dough metering system using a mass flow sensing device.

Progressive increased feed



Progressive under feed



At position A the dough thickness is affected by changes in tension.
At position B the whole dough sheet moves as a result of changes in the feed situation

Fig. 5.8 Position of a dough sheet feeding a gauge roll.

5.8.4.3 The weight of dough pieces cut from sheets

Biscuit size is affected more by weight than by any other single factor. However, at the time of writing there is no entirely satisfactory commercially available in-line scale for monitoring dough pieces. The best compromise is to infer weight by measuring dough piece thickness. This assumes constant density (this is a reasonable assumption). An optical gauge has been used to measure either the dough sheet

thickness just before cutting, or of dough pieces after cutting. There are, however, a number of difficulties worth mentioning.

- Measurement of the dough sheet is only proportional to cut piece thickness if there is no appreciable displacement of dough by the cutter. Where two-roll rotary cutting is used, the first roll docks and patterns the dough and also pins it to the cutting web, the second cuts out the shape. If the first roll is not at a perfect height for the surface of the dough, either the dough is not pinned down or some displacement into the surrounding scrap areas occurs.
- Measurement of dough piece thickness is severely complicated by the distance that the sensor must be from the cutter due to the mechanism of the scrap lift apparatus. A small amount of tracking can cause the sensor to scan at different positions on the piece from time to time and due to the pattern and docker hole positions the average thickness may appear to alter. Dough pieces are often plucked from the cutting web which affects their apparent height.
- The dough sheets or dough pieces are characteristically between 2 and 3 mm thick. Weight variations of $\pm 2\%$ are significant so the gauge must be capable of detecting less than 0.05 mm. In practice, although the gauges are capable of better than this, the variation in thickness of the cutting web and its vibration make such precision very difficult to achieve with confidence.

On the subject of dough piece weight variation, it is worth recalling that one reason why dough pieces may vary, given precise dough metering on the cutting machine, is uneven relaxation following final gauging. This could be because the dough quality is varying and in turn is probably due to either dough age or temperature or to uneven cutter scrap inclusion. All these factors can be reduced to a minimum if dough handling is carefully controlled.

5.8.4.4 The weights of dough pieces formed with a rotary moulder

There are various adjustments for rotary moulders which affect the dough piece weights (see Chapter 37). Optical gauges have been used to monitor the thicknesses, and hence weights of moulded pieces, while still on the moulder web, but difficulties have been encountered similar to some of the reasons stated for dough pieces cut from sheets. There remains the fact that control of the dough consistency and height in the moulder hopper are better means of preventive control than later compensatory adjustment.

5.8.4.5 Gauge roll settings

It is possible to monitor gauge roll gap settings with proximity gauges sensing the positions of the roll shafts. Servo motors to adjust the gaps through the normal worm gears can then be used to maintain constant gaps independent of load or bearing wear. Such systems also allow remote gap adjustment down the plant from the central control room. Obviously this instrumentation is most valuable for controlling the final gauge roll settings.

5.8.4.6 Dough piece row counters

The production rate is fundamentally determined by the speed of the cutter, but rows per minute at this point are not necessarily indicative of the production going to the oven since there may be no dough under the cutter or for various reasons the whole of the dough sheet may be deflected to the scrap return system. A row

counter over the pieces entering the oven will, therefore, give production information and can be computed to show the total production for the shift or day. It is worth remembering that the speed of the oven, the useful baking time, is not a fundamental indicator of production speed. This is because the spaces between the dough pieces can be varied at the point where they are transferred from the cutting machine or rotary moulder.

5.8.4.7 Sugar, salt and nut garnishing applications

Many types of biscuit are decorated and garnished with sugar, salt or nut pieces before baking. The quantities of these materials affect product appearance, weight and cost, so control of the amounts added is highly desirable. In practice, it is rare to see much attempt at control and often the application is irregular due to blockages or low hopper levels. By using a loss in weight or hopper level sensor combined with a product row counter, computations of weight per cent (or other units) can be made at regular intervals and displayed or recorded as required. It is then a simple matter to incorporate alarms should the rates be higher or lower than preset limits.

5.8.5 Baking instrumentation

In 1988, Peter Wade [4] wrote that ‘there is probably more Black Art concerning baking than about any other part of the biscuit-making process’. This was despite a major development in the technology of travelling ovens that occurred over the previous 30 years. At the time there were still discussions that linked variations in oven performance to the weather. At a more technical level it was stated that it was not possible to replicate the Carr’s Water Biscuit when trials were carried out on a metal oven rather than the traditional brick ovens built for the purpose. This was about to change following some pioneering work carried out by United Biscuits Research and Development leading to a patent [5].

The baking process has several key functions. In biscuit making, water acts as a processing aid in that it is added to the ingredients to make a dough and is then removed by the baking process. Before this occurs, the dough structure has to develop and set to the right colour. This has led to ovens being structured to have three discrete zones where conditions can be optimised to allow the structure to be set, colour developed and product dried to specification in the shortest time.

There are different types of oven that have been developed according to the way they provide the heating environment. The principle choice is either direct gas fired or indirect fired based on whether the naked flame is present in the baking chamber or is used to heat the air that is blown into the ovens. Regarding control of the oven process, the type of oven makes little difference. Ovens have a heating means which is profiled along the length to optimise the requirement of the biscuit at each stage of development and a control by dampers of the exhaust air which carries away the moisture and which is replaced by further heated air.

Peter Wade recognized the importance of different types of heat in baking and of the effect of humidity but explained that it was not possible to measure it.

5.8.5.1 Heat flux

There are three modes of energy transfer that impact on a dough piece in an oven cavity:

- conduction – through oven band and mesh
- convection – via air currents
- radiation – from surfaces of the oven cavity.

Heat flux is the amount of heat energy passing through an imaginary surface of cross-sectional area per unit time in units of W/m^2 . It is the rate of energy transfer during a heating or cooling process into or from the dough piece. It incorporates variables such as temperature, air movement, mode of heat transfer and oven design, etc., into a useable measurement.

Figure 5.9 shows the heat flux recording and temperature trace through an oven. It can be seen that at a stage in the oven whilst the temperature is recording optimal temperature there is a fall off in heat flux which measures the heat transfer to the biscuit and therefore the degree of baking. This highlights the fact that oven temperature cannot be a perfect measure of baking performance.

Heat flux therefore replaces temperature as the key oven measurement and, by virtue of being a better measure of the heat a biscuit 'sees', opens up a range of opportunities to the biscuit manufacturer. It adds to a process technologist's knowledge and understanding of the baking process and helps in troubleshooting when an oven performance is thought to be suboptimal. It can highlight causes of cross-band variation leading to effective remedy as well as general faults in burner or damper operation. This can lead to efficiency and cost savings as oven profiles can be reconsidered. It can also help to optimise product quality by supplying optimal energy to meet the requirements of the different stages of baking. It also allows profile comparisons between different lines enabling product transfers and making product developments more effective. Heat flux dataloggers called Thermaflux are made under license from United Biscuits by Digitron (see [29]).

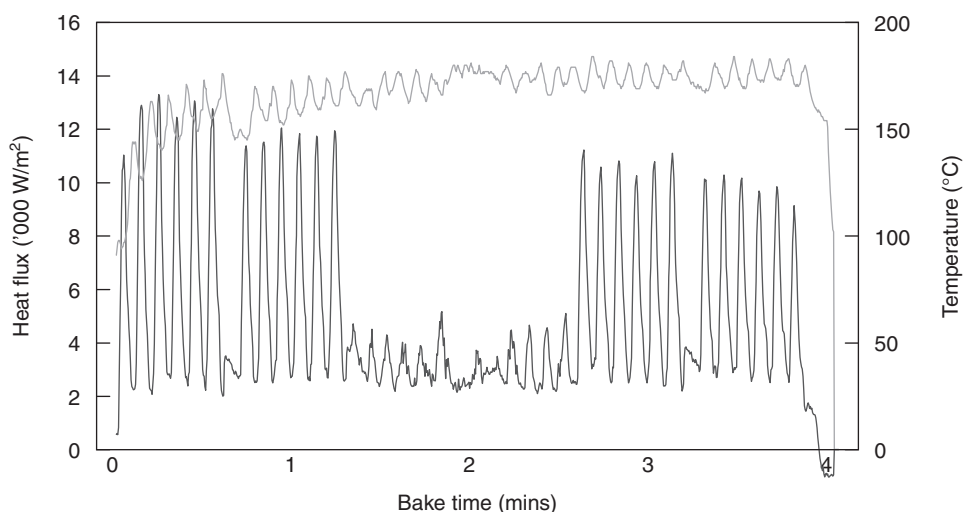


Fig. 5.9 Spooner forced convection oven. Ineffectiveness of air temperature alone (courtesy of Digitron Ltd).

5.8.5.2 Humidity control

Because the temperature in a biscuit oven is greater than the boiling point of water, it cannot be measured as relative humidity. Moisture in the oven as a function of the drying process or from the products of combustion can be measured as dew-point. This is the temperature at which the moisture in the air will condense on a surface.

The importance of humidity in control of the baking process is well known but, 'Unfortunately defining the humidity in a biscuit oven atmosphere is not the same as measuring it' [4]. Crackers have been considered to be of improved quality when baked in a direct gas fire oven where the humidity due to products of combustion is higher in the first zone. It is postulated that higher humidity will reduce evaporation leading to more rapid temperature rise of the dough and that the setting of the structure will be affected. That will impact on stack height and biscuit consistency. In addition with a controlled level of humidity the baked appearance can be enhanced with brighter and deeper colour. Hygrox PTM made by McQueen Cairns Technology [28] enables continuous humidity and temperature information to be monitored along the length of the oven. In addition to helping oven performance optimisation and efficiency it can be used as a diagnostic tool for oven burner and damper faults.

5.8.6 Post-oven instrumentation

As the biscuits emerge from the oven, checks are made on weight, size, colour and moisture. Normally these are made on samples of up to 30 biscuits taken manually from the band at intervals of 15 to 30 minutes. In order to obtain a more detailed idea of product variation, sensors have been used to measure one or more of the product parameters continuously or continually. Usually this involves scanning only one lane of biscuits so across the band variation is not monitored.

In time data capture with instruments will become the norm. This will relieve operators from regular sampling for process control. The analysis of captured data will use essentially the same principles as Shewhart charts but with most of the error potential, analysis and presentation time taken out. The computed data can be used to trigger alarms for an operator or to automatically make plant adjustments through control loops [6].

Optical non-contacting sensors can measure all important parameters except weight and so far in-line band weighers are not available for biscuits at this point. Automatic estimates of biscuit weight involve removal and subsequent replacement of samples from the biscuit conveyors. Mechanisms for this are necessarily rather complex (see Wade and Watkin [7]). With most products, moisture content is the only sensor generally used. Online colour measurement is available but moisture data plus operator experience is usually sufficient to maintain product specification. Signals from post-oven measurements can be used to drive control loops altering oven conditions and the dough piece forming machinery (sheeting but not rotary moulding). However, the shape, thickness, length and width of biscuits is affected by complex interactions of the effects of dough quality, dough piece weight, tensions in the dough at the cutter and oven conditions. The biscuit colour is affected both by dough piece weight and oven conditions and to a lesser extent by dough moisture content.

There are examples of control loops where on line moisture measurement is linked to gas pressure in the oven as a means of control. These systems lack

popularity because there is a significant fitting cost to established lines and the equipment needs a level of technical skill and regular calibration which adds to the factory burden. When performing a prime cost evaluation for biscuits, the major cost to production is in raw materials and energy. The cost of labour is often insufficient to justify capital spending that would be required to achieve a realistic payback. A means of monitoring biscuit or dough piece weights automatically and with minimum disturbance to them as they are conveyed along the plant would enable an accurate assessment of reasons for variation in product dimension after baking. With advances in computational measurement that goal will be achievable in the future. Again the largest drawback will be whether the cost of the equipment and its payback can be justified.

A long programme of control engineering based on post-oven biscuit monitoring was conducted at a London biscuit factory under the supervision of staff from the Flour Milling and Baking Research Association (FMBRA) at Chorleywood (which later became part of the Campden and Chorleywood Food Research Association, now Campden BRI (see Lawson and Jabble [8])). It is fair to say that progress was hindered because of a lack of suitable oven instrumentation and thereby insufficient knowledge of optimum conditions for baking. This was a successful attempt at creating a fully automated line and was commissioned in the late 1970s. For all its technical excellence it failed in part because certain unit processes were not infallible. So breakdowns that occur in packaging machines, for example, would result in large amounts of dough wastage since in order to keep steady state in the plant, it had to be kept running. It was probably a lesson of the day that seeking technical excellence cannot succeed without a full examination of all the cost and staff training implications. Its pioneering of process control linking checkweights and height scan data yielding biscuit weight data that controlled back to dough thickness was ground breaking but not repeated.

5.8.6.1 In-line biscuit moisture measurement

Biscuit moisture content is an important aspect of quality. It has a bearing on shelf life and, for certain types, whether 'checking' may occur. Productivity demands the fastest possible baking and the limitation is invariably moisture removal. As is indicated in Section 39.5.2, the use of a post-oven electronic drier may be very useful to aid in this.

In most factories, biscuit moisture measurement is made using online measurement as supplied for example by NDC Infrared Engineering. Only one lane is regularly measured unless there is knowledge of major moisture differences across a line. An exercise measuring moisture variation across a line is important so that the line monitored can represent an average of variation that occurs. Loss in weight techniques involving heating crumb from crushed biscuits on a special balance have been consigned to use in checking calibration. Calibration is most important as moisture content is such a vital part of the specification. It is outside the scope of this text but it is essential that a reference method of moisture measurement and what it actually measures is understood and then used both in setting up the product standard requirement and the specification. The most practical method for a biscuit plant at present is that based on infra-red absorption [27]. This works on the principle of differential absorption of two wavelengths in infra-red light. Unfortunately, the light does not have a good penetration power and as the wettest part of the biscuit is at its centre this cannot be sensed. It takes a few hours for moisture at the

centre of a freshly baked biscuit to equilibrate through the product, and it is usually only 10 minutes or so before baked biscuits are packed. Checking or cracking of biscuits is still an issue for the industry. A means of detecting moisture gradient in a freshly baked biscuit would be a popular development.

As was mentioned in Section 5.4 the same type of meter may be used to estimate moisture content in ground-up samples of biscuits in an off-line mode. The moisture monitor is particularly useful for scanning fresh wafer sheets. Here the sheets are more translucent to the light beam and the moisture gradient is in any case very low across a wafer sheet.

5.8.6.2 Dimension measurement and colour

Measurement of length and thickness can be made with a vision system which works on the principle that an inclined beam of light reflects at a different place on a photosensitive array as a product passes beneath it. The thickness is the computation relative to the substrate, e.g. the oven band. The time between the large movements of the reflected beam is computed to give the biscuit length. Laser displacement sensors have largely replaced white light height scan systems which pioneered this field. Investment in this technology depends on what is done with it. Continuous improvement in control of biscuit height and dimension would enable wrapping machine function greatly. Measurement of biscuits in one lane would require an assumption that it was illustrative of other lanes. It is not clear how an operator with the information can use it to directly improve process control. Although it provides useful data, a lot more investment would be required to improve biscuit wrapping function through control of biscuit shape and dimension. Linkage to biscuit weight at the checkweigher would give an estimate of biscuit weight. With biscuit weight being a key determinant of moisture content this could form the basis for a control loop. Online colour measurement is used in the snack industry as a means of rejecting overcoloured product. It is not regularly used in the biscuit industry since an understanding of the relationship between oven performance and moisture content plus visual inspection enables specification to be maintained. Colour is monitored offline using measurement such as the tristimulus method of HunterLab Colorimeter [26].

5.8.6.3 Instrumentation for secondary processing

Most secondary processing of biscuits involves increases in weight, for example, oil spraying, creaming and chocolate enrobing. In-line weighing, except of packets, remains to be perfected, but the special cases of liquid additions offer possibilities for measurement and indication if not control. Both oil spray application and chocolate pick up can be calculated through loss in weight monitoring, in the feed reservoir, computed against biscuit throughput counting. Chocolate must be tempered before it is applied to a biscuit. An in-line temper meter is available to check that the chocolate being used is in the correct condition.

5.8.6.4 Post-wrapping instrumentation

5.8.6.4.1 Checkweighers

Every-packet checkweighers positioned after wrapping machines have been used successfully for many years. Prior to the introduction in the UK of average weight legislation, the checkweighers in the UK were used mainly to reject packets below the acceptable minimum gross weight. Modern legislation, related to average

weight-packing systems, requires detailed records to be kept of pack weights during a production run. Checkweighers allow statistically calculated records to be made and displayed as frequently as needed from the checks of weight on every packet. This information is very valuable not only to satisfy legal requirements but also to review the progress of any period of production. It has also been possible to set up short feedback control loops to automatic length metering feeders to the wrapping machine. A length metering feeder selects a column of biscuits and places it into the feed of the wrapping machine. The relationship between column length, biscuit volume and weight varies during production so some adjustment of the number of biscuits selected for a pack can limit the incidence of lightweight packs and the overall give away. Packet checkweighers are not ideal as a means of overall production line control. They provide information too long after the dough piece was cut to allow satisfactory feedback systems. They are affected by the number of biscuits in a pack, where this is determined by column length and they may be affected by extra biscuits introduced into the production line from previous production when 'traying up' prior to wrapping had been necessary. However, checkweighers provide a useful record on the effectiveness of other process control efforts.

5.8.6.4.2 Metal detection

Metal contamination is not unusual and must be controlled. Even small pieces of metal contained in dough can do serious and possibly permanent damage to a cutter or moulder. It is therefore wise to install a metal detector across the dough feed to machines. If metal is detected the dough containing it is rejected and must be disposed of carefully. Metal detection in packed biscuits is very routine and is a key part of quality control and product safety. The detector instrument is usually placed next to and in line with a checkweigher.

Having detected contamination it is very important that the dough or biscuits containing metal are isolated from other products. It is also worth the trouble to search out the offending metal fragments and to identify their origins. It may be that this will prevent reoccurrence or indicate where engineering maintenance is needed. A spade striking a hopper side or dough tub is a common source of metal fragments.

Metal detectors work on the principle that a metal object drawn through an electromagnetic field causes fluctuations in the current which can be sensed and used to operate alarms or rejection mechanisms. They work best with ferrous metal but non-ferrous metal can also be detected as slightly larger masses. The sensitivity of the detector is greatest if the cavity through which the packet must pass is as small as possible. Modern designs of metal detectors allow detection of ferrous and non-ferrous particles in aluminium foil or metallised film packs.

5.8.6.4.3 Foreign body detection

Despite all efforts at hygiene maintenance and total quality management during biscuit manufacture, it is unfortunately the case that occasionally some unwanted matter other than metal fragments will become included in the biscuits and therefore could injure or offend a customer. Metal is a relatively straightforward material to detect with an instrument. Glass and plastic are much more difficult to find. X-ray machines are available but are more costly than metal detectors. A risk assessment is required to determine whether there is a threat from foreign bodies other than metal to justify the cost of installation.

5.9 Troubleshooting

It has been shown how pressures for improved efficiency in biscuit manufacture, the development or adaptation of suitable process sensors and the potentials available from microelectronics for calculation and data storage are focusing attention on the process control technologist. There is always a better way to do something. This is particularly the case in biscuit manufacturing because, so far, we have not done enough to fully understand the processes.

Although process control is getting much better, it is not uncommon for things to go wrong. At this stage all relevant people in the company are brought in, often with some degree of panic, to solve the problem. This problem solving is often called troubleshooting. What are the skills needed to be a competent troubleshooter?

- Be a good observer. Look carefully at the manifestations of the problem, look at all the records that led up to the problem and see if there are patterns or circumstances that could be related.
- Try to understand the process mechanisms, with the aid of a chart if possible. Follow all the mechanisms that have a relevance to the observed problem.
- The problem is not always what it at first appears to be! Try to think of all the relevant facts and possibilities before following one route too single-mindedly.
- Make changes in a methodical and logical manner. If too many things are changed at once the real cause and the real solution can be lost in the muddle.
- Record, in detail, each trial and the results obtained from it. These will be important in the final considerations and also for the future. Maybe the results will not be useful but if they were not recorded they cannot be reviewed! Negative results are often as important as positive ones.
- When the problem has been solved, or resolved as far as seems possible, reconsider the product specification and try to design out the weaknesses that resulted in the 'out of control' situation that arose.

Understanding process mechanisms and basic troubleshooting activity is not only the province of the process technologist. Every day we look to the plant operators to be observant and to make corrections for the deviations that they encounter. Mostly this is the control and adjustment of machinery. With this in mind the author has published a set of six *Biscuit, Cookie and Cracker Manufacturing Manuals* [9] which are designed to be teaching and reference aids for plant operators. Included are process mechanism charts which should be useful both for understanding what happens and also during troubleshooting. The mechanism charts are not repeated in this book but cause and effect are discussed in the later sections when types of biscuits, processes and processing machinery are described. The mechanism charts can also be accessed in Manley's The Biscuit Doctor website [10]. Knowledge, understanding and the building of competence can be further supported by the Biscuit, Cake, Chocolate & Confectionery Association's range of Open Learning Modules, CABATEC [11]. Originally government sponsored, these are self-study programmes which include several biscuit manufacturing unit processes (Introduction to Biscuits, Recipes, Mixing, Baking and Chocolate Enrobing & Moulding). There are also modules covering key raw materials, chocolate manufacture, quality assurance and technical transfer. There are also many useful suggestions and advice associated with common faults and problems encountered during manufacturing on Manley's The Biscuit Doctor website [10].

The prospects are very exciting and offer many challenges for logically minded food scientists and process control engineers.

5.10 Energy efficiency

Most food companies have social responsibility policies that include consideration of environmental issues. Energy use and its impact on the environment is therefore topical in baking where large ovens are in continual use. In the UK, legislation was enacted in 2001 in the Climate Change Levy which applies to energy used in industry and provides a financial incentive for businesses to use less energy. The levy which is charged by the energy suppliers can add up to 10% to the energy bill. There are enhanced capital allowances for the purchase of energy efficient equipment and under the Climate Change Agreement; energy intensive users can receive an 80% discount on their levy in return for meeting challenging targets for reducing their energy needs.

With advances in process control via heat flux and humidity measurement, there are opportunities to focus in on meeting energy reduction targets by examining ways of reducing energy whilst maintaining quality products. From Fig 5.10 the efficiency of energy used is given as 46% with the largest loss being via excess air.

This has led to exercises looking to re-profile ovens using heat flux measurement. Baker Perkins describe the use of smaller air jets that yield a similar heat flux at

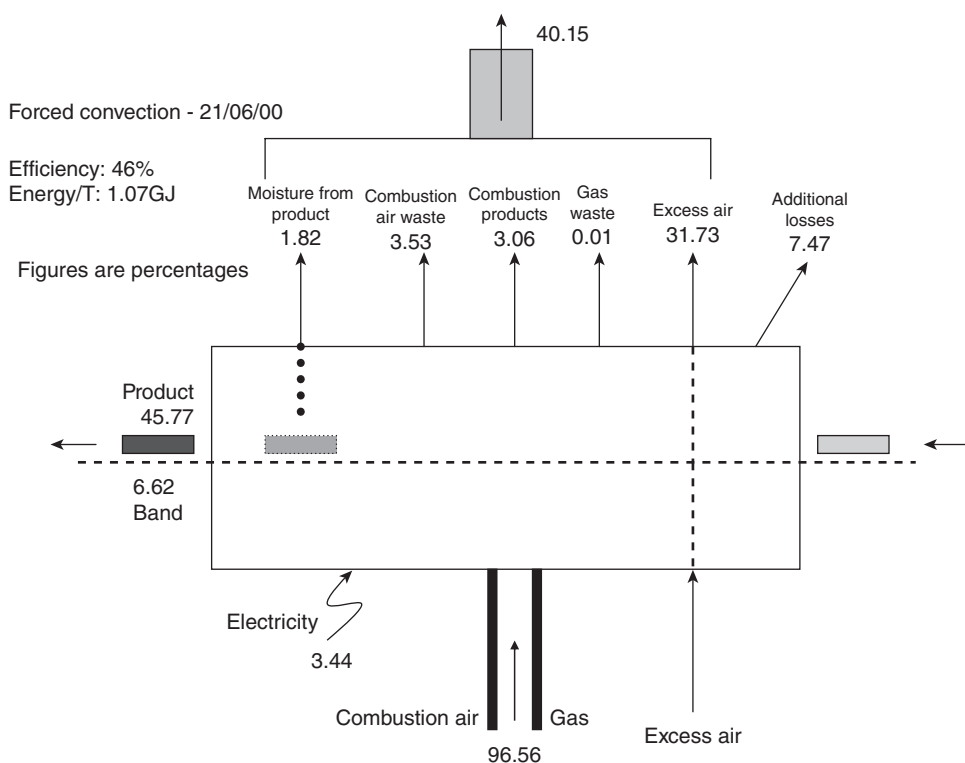


Fig. 5.10 Estimates of ratios of heat losses (courtesy of Digitron Ltd).

a reduced air temperature. Increasing air turbulence and reducing extraction are other approaches that can be monitored via humidity measurement to ensure sufficient removal of moisture in the oven.

Exploring burner design has also been successfully exploited. Gas usage can be reduced by employing burners whose turndown ratios are 20:1 which use little energy when not required. Additionally changes to burner design, such as Enviro mont from Mont Selas, replace traditional ribbon strip burners with a wide Nitmesh flame medium. They claim energy efficiency by additional radiant heat provided by the hot surface of the Nitmesh material which can become incandescent as opposed to the gas flame on a ribbon burner which provides only a limited amount of radiant heat due to its low emissivity.

There are also opportunities for higher capital spend with payback benefits mentioned through the Climate Levy such as energy recycling of the exhaust gases and enhanced oven insulation if possible.

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Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.

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6

Product development in the biscuit industry

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Abstract: New products are not necessarily totally new. There is always a place for 'improved' versions of existing products. New products are considered the lifeblood of any company. Product design is where vision and circumstance meet. Managing creativity is always a team task. Facilities are needed to make new products and to assess them. Product assessment, consideration of shelf life and the need for critical path planning are also covered.

Key words: innovation, product development, food design, lateral thinking, product assessment, shelf life, water activity.

6.1 Introduction

At the beginning a product was conceived, the process was developed and production started. With time, improvements were made and more products were manufactured. Those products that delighted customers and consumers continued to be made, those that struggled for sales were considered for their suitability for the market and the cost of production. It is important to understand that the term 'product' here is a complete item, not just the appearance and taste but also its packaging and its condition when it reaches the consumer. This is the case for every company and the activity that drives product conception, development, improvement and suitability for the market happens as a result of a product development team. It is a large and complex operation and can be performed successfully only by a team. The suggested structure of this team is given in Section 6.6.1.

It is a lot easier to write about product development than to do it successfully! It can be very tedious, very frustrating and, when it comes to disappointing sales, an apparently very inexact science. However, by experience it has been found that a logical approach is essential and if all members of a development team read this chapter and communicate fully it is probable that success and job satisfaction will be more likely.

The list or portfolio of products that are made and sold by a company is the responsibility of the marketing department. Marketing should ensure that each product has a recognised place in the market and that it is made and packaged as nearly as possible to the ideal for its role. As we become more affluent we do not spend more on food compared with other goods and leisure. We can only eat so

much – too much in many cases. We live to eat and do not stop to think that too much is unhealthy. Marketing of calorie-reduced foods is never the same as that of more delicious food!

It is important that the product list is reviewed regularly and that additions, deletions or changes form a positive programme of marketing development. New products are not necessarily totally new. There is always a place for 'improved' versions of existing products and in many cases it is easier to achieve placements in retail outlets with changed existing products than with something new which has an unknown sales potential. Product development is considered an extremely important factor in the growth and image of a company. Although the market situation is always important there are sometimes other factors like under-utilised production facilities that have to be considered in the development programme.

6.2 Product development

6.2.1 Product maintenance

It is essential that products already being manufactured are regularly reviewed and modified. There are several reasons why a change may be considered, for example:

- a change to the pack size or graphics will heighten consumer interest or place it in a different market position
- the use of a different ingredient or a change in the formulation in order to 'improve' flavour, appearance or cost
- a recommendation from process control technologists to allow improved production efficiency or less variability
- a change in a competitor's product that has to be countered
- shelf life tests or bad experience about product damage has prompted a change to the packing system or materials used.

It is rare that a change turns out to be simple to execute! There are usually several aspects that need attention, not least an assessment of the effect on the consumer. It is therefore necessary to plan ahead carefully and to make a critical path analysis as described in Section 6.6.3.

6.2.2 Copying competitors' products

An essential aspect of marketing and product development is to remain aware of competitors' products. It is quite common for companies to decide to follow a 'me too' policy, but be warned: to exactly match an existing product on a different plant with different ingredients can be extremely difficult or impossible. In order to match an existing product start by examining it closely to ascertain which processes and equipment are being used. If ingredient and nutrition lists are provided some calculations may suggest a likely formulation. Some simple analytical tests will reveal the type of fat, percentage of the major ingredients, etc. Trials will then be made but only experience will tell whether it is formulation, processing or production facilities that need alteration.

6.2.3 New products – the source of ideas, encouraging creativity

6.2.3.1 *What is wanted?*

New products are considered to be the lifeblood of any company. Changes in the marketplace are occurring at an ever-increasing speed and this demands and permits many new products. A company must have a positive policy and programme towards new products and most companies do not invest enough in new product development. Product development requires creativity and innovation.

In an ideal world someone will draw up a detailed product brief and then it is a technical/practical matter to decide how the product can be made. This rarely happens except when a copy of an existing product, either a competitor or from another country, is what is wanted. As has been explained above, this may not be an entirely satisfactory development route to follow. The best ideas arise as a blend of creativity from marketing, technical, engineering and production personnel. Therefore there needs to be a period of creative thinking long before a product brief is established.

Innovation suggests a major change of direction from the thinking that came before. Innovation starts with an idea but the idea is no good unless it is tamed to suit completely the occasion. This taming is known as ‘design’; the marrying together of an idea and its application.

- A meeting of vision and opportunity.
- A meeting of vision and circumstance.

The first stage is to search for a product concept. The concept may be suggested in a number of ways, for example:

- a product made by or a technique used by a competitor
- the availability of a new ingredient offering consumer interest
- a new process or machine
- a trend in consumer interest in an aspect of nutrition
- a gap in the market for a product to be eaten at a specific time or with certain other food
- a gap in the market for a particular age group of consumers
- a new packaging style.

The product concept has to be constrained by factors such as production facilities, in-house skills and experience, finance and time-scale. The best ideas are likely to have as few constraints as possible.

6.2.3.2 *How do ideas arrive?*

An idea is the solution to a problem. If you do not know about the problem you cannot have an appropriate idea or if you do you will not recognise it.

- Ideas are the basis of development which is in effect a series of problems.
- Ideas are the result of creativity.
- Ideas will only come to those who are looking for them.
- Ideas will only come to those who are aware of the needs and potentials that relate to the problem.
- Ideas are elusive, note them down when they appear.
- Ideas are thought processes and are therefore very cheap.

Ernest Rutherford said, ‘When money is short there is no alternative but to think.’
Albert Einstein said, ‘Imagination is more important than knowledge.’

When we are asked to have an idea, to solve a problem, we draw on our experience, observation and knowledge. We all have an immense amount of each but the difficulty is in being able to organise our thoughts to find the appropriate connections. Usually our thinking is evolutionary, vertical thinking, yielding ideas based on what has already happened elsewhere or are prompted by developments in related environments. Some examples of vertical thinking in biscuit development are responses to the trend towards lower fat consumption and the trend towards small snack packs. The cream-filled cookies from Italy known as *Grisbi*, made on Rheon co-extruder type plant, were prompted by the dual dough cookies in the USA in the mid 1980s.

We learn about trends by observation and experience. There is a serious possibility that evolutionary ideas will come to other individuals first! A less common way of thinking is to stimulate the direction of our thoughts by asking the question 'what happens if?'. This is called lateral thinking and involves the repeated use of hypotheses – viewing from very different angles and being receptive to possible solutions. Creativity is something that a computer cannot yet master because it involves exploring unknown territory and viewing things through experience.

6.2.3.3 *Encouraging and trapping ideas*

There is a tendency to think of creativity as the product of specially talented individuals who have a greater than normal ability to have flashes of inspiration. This is probably because we marvel at the pictures of certain painters, compositions of well-known musical composers and astonishing leaps forward by a few scientists. The important thing to realise is that we can all be creative and most already are.

- There are geniuses of creativity but they are rare and sometimes unacceptable people!
- Creativity can be developed in people so creativity is not a matter of chance.
- Large jumps of innovation are much rarer than small ones. The small ones are often important, exciting and valuable.

All ideas are related to other things. Your brain stores patterns of information. When presented with a situation or problem you automatically, and extremely rapidly, run through those patterns in your memory. The brain is incredibly efficient at recognising things (just as well for a golfer who is searching for his ball!). There then follows a period when you try to rearrange the information as you search for a solution or a new idea. If you do not find it quickly you tend to give up and think about something else.

How can you prolong that search and give your brain a better chance of coming up with a solution? Many books have been written on nurturing creativity but there are two that are commendable. *Drawing on the right side of the brain* by Betty Edwards [1] presents the idea that the rearrangement of information resulting in new combinations – ideas – occurs principally in the right half of your brain. Because the left side works in a very dominant and logical way, you have to train yourself to 'listen' to the right side. The right side may put up useful ideas at times when the left side is relaxing, for example when driving or showering (bathing in the case of Archimedes). This is the basis of the Eureka phenomenon. An idea suddenly pops up when you were not expecting it or even thinking about the problem. The other is a book called *The use of lateral thinking* by Edward de Bono [2] which describes how the art/science of lateral thinking can be developed. This presents different

patterns to your brain which may stimulate it to sort out useful new combinations which are the source of solutions.

A joke is a technique for seeing a pattern from a different angle. A comedian was addressing a group from a small town. He told of a survey that had found that 90% of women in that town had been unfaithful to their husbands. The Pope in Rome heard about this terrible situation and decided to write a letter to all of those who had been faithful, to compliment them and show his support. 'Do you know what he wrote in that letter?' the comedian asked one of the women. 'No' she replied. 'Well there you are' he said! Viewed from the different angle it is a quite logical pattern.

In the ideas business there is no substitute for experience but it must be combined with an inquiring mind. Product developers are most likely to be people with a good training and who exhibit widespread interests and the wish to travel. They should be actively encouraged to widen their experience, to report back on what they have found and seen and to give opinions on how things could be improved.

In summary, product development is encouraged if a team of people appreciate what is wanted, they are allowed to share their ideas freely and in this way develop lateral thinking. They will be aware of the requirements (the problem) in their subconscious and should be ready to spot a useful idea whenever it is presented or occurs to them. By working together and stimulating each other, perhaps through brainstorming sessions where no one must be embarrassed about suggesting anything, many brains can be encouraged to search for ideas.

6.3 Facilities for process and product development

6.3.1 The test bakery

In order to do the necessary practical work for product and process development, a test bakery is needed. It is extremely difficult and much more expensive to do adequate practical development work on full-size factory plant. The test bakery will need storage facilities for ingredients, mixer(s), balances, dough piece forming equipment and an oven as a minimum. Also the facilities for storing trial samples should be well thought out. The equipment should be of sufficiently high standard to allow accurate and reproducible work which can then be scaled up for factory trials.

For large companies a pilot plant with a travelling oven offers the possibility to make larger trials with a view to investigating process control techniques or for making market research samples. A pilot plant is a large investment and much careful thought is needed to make sure that enough mixing and forming equipment is available to feed the oven for these longer trials. A pilot plant needs at least two or three people to run it so there are staff considerations also.

6.3.1.1 Equipment, ingredient storage and handling

The ingredients should be as near as possible in the same condition as those to be used in production. This means that care must be taken to ensure that the fat is in the correct plastic condition, at the right temperature and is fresh. If the particle size of the sugar is likely to be critical, this ingredient should be collected from the mixing department of the factory where it is delivered after passing through the bulk-handling system. If ingredients are likely to deteriorate with time either they

should be acquired fresh or they should be stored appropriately, for example, in dark containers, or in a refrigerator for liquid flavours.

6.3.1.2 *Metering*

Metering is very important and should be performed very accurately with appropriate balances. Measure all ingredients to two decimal places in grams. Measure all liquids by weight, including water, and for small liquid ingredients where volumetric measurement is best, use disposable syringes.

6.3.1.3 *Mixing*

The choice of mixer is difficult. Ideally one should have a small version of the type to be used in the factory but as scale-up of mixing causes more problems than most other aspects of scale-up it is difficult to be too particular about the type of mixer that is best. It must be powerful enough to make the dough and be able to handle the variety of quantities that may be involved at both cream-up and final mixing stages. A Z-blade mixer is potentially better than a planetary type. A removable bowl mixer does not offer satisfactory jacket temperature control. You may wish to record the power curve during mixing. If possible have a temperature sensor located in the dough so that the temperature can be monitored while mixing.

In many cases a dough should be rested or fermented before forming and baking. If the temperature needed is elevated, a cupboard should be available.

6.3.1.4 *Forming*

For laminating and general sheeting and gauging a reversing brake is needed. There are several good makes. Good calibration of the roll gap is essential but automatic reduction programmes, etc., are a luxury. Look for driven conveyors each of at least one metre in length.

It is also possible to gauge short doughs with a brake if the dough is passed through the rolls between greaseproof paper or canvas webs. Laboratory scale rotary moulders are available which give good uniform dough pieces. Cutting should be done with appropriate cutters. With the transition to rotary cutting it is now becoming very difficult to get appropriate hand cutters.

6.3.1.5 *Baking*

Without a travelling oven, baking can often present very great difficulties. There is no static oven that can reproduce the variations of heat application possible in a travelling oven in the short period of baking that most biscuits require. The best compromise is a forced convection oven where a given even temperature is quickly achieved after the door has been opened and the product introduced. It is necessary to have a variety of different types of baking trays which use the wires and steel sheets which are found in your factory. Stainless steel trays are not recommended.

6.3.1.6 *Cooling and packaging*

Some sort of racks are need to cool the baked product and then packing should be in flexible film bags of OPP (oriented polypropylene, an excellent moisture barrier material) which are heat sealed. Labelling must be good.

6.3.1.7 *Product measurement and testing*

Clearly the product must be physically measured. Instruments are required for this. Often organoleptic testing is also needed. Facilities for this must be provided and

the test baker or his manager will be very much involved in the programme of testings. (See Section 6.4.1.)

6.3.1.8 *Trial records*

Records of trials are a major investment for the company. Trials build up experience that may need to be accessed after many months or even years. It is important that they are done conscientiously. This means that the test baker must have a desk within the bakery area and a satisfactory filing system that all understand!

6.3.2 **The food designer/test baker**

The test baker needs to be a creative person. Maybe he is the food designer of the development team. If not he must work very closely with the food designer. Let us now consider his personality and personal needs.

Creative people are artists, not all artists paint pictures but no artist can paint a picture without loving the feel of putting paint onto canvas. No fashion designer can create a new look without loving clothes and handling fabric. No food designer can create a new product without wanting to taste a wide range of foods with different flavours. This means that the job cannot be only 9 to 5 Monday to Friday. Opportunities have to be taken to try out new food and to play around with ingredients. The 'what happens if?' attitude must be prominent. In short, a food designer and test baker have to love food. However, an artist or designer must also be technically competent. In the case of a biscuit developer, he or she must have a good education in food science, hygiene and process technology combined with enough experience to be able to include some craft aspects to his or her work. It is not sufficient to have only craft training which used to be the main requirement in the baking industry. A scientific training is needed to ensure a careful and critical approach and an inquiring mind about cause and effect. It is this combination of technology and imagination that seems to be rather rare. Science tends to develop an exact and logical mind. Creativity demands lateral thinking.

In order to be able to link all the aspects of development a designer has to have experience. Experience can (unfortunately) only be gained with age! Experience feeds a creative mind. The experience gained by different jobs, foreign travel, living alone, bringing up a family, and being able to eat in different restaurants is invaluable. The opportunity to acquire different ingredients and experiment with them is of utmost importance. Experience also improves one's perception of the needs of the consumer, but this perception will only be good if you are interested in people and can relate to the way they live and respond.

We see the blend of personality and qualifications for a food designer or test baker as being somewhat complicated and specialised. It is a senior position but not one of line management. Food Designers are consultants so why not employ them as such. Use them as much as is required. Creative people need to be constantly challenged and to be stimulated so to take them away from their creative role and involve them in quality control or other everyday problems is not the best use of their talents. To keep a creative person fully occupied with your company's current development plans is not always possible. A good creative person should be able to conceive and organise the development of many more ideas in one year than can be coped with by the average company.

Success feeds enthusiasm so do not kill it with changes to plans that delay progress. It is probable that you should try to organise your product development department with a food designer as a manager who has day-to-day contact with the test baker (who may be more junior) but the food designer must regularly be intimately involved with the practical aspects of the product development.

6.3.3 The laboratory

An analytical laboratory is needed for many of the quality control checks. The size and scope of this laboratory depends very much on the sophistication of the products that the company manufactures. Emphasis is given to doing a minimum of laboratory work and to relate the tests to the use that can be made of the results. Even so the equipment should be chosen carefully and as far as possible should be industry standard so that results can be compared with suppliers or other laboratories as necessary.

Process and product development technologists will need facilities as many of the monitoring instruments to be used to provide better process control can be developed and checked in the laboratory. It may be expedient to send product for analysis out to contracting laboratories rather than trying to justify having your own.

6.3.4 Relations with other departments and organisations

It is impossible and uneconomic for a company to have facilities to cover all its possible requirements. It is therefore necessary to build up contacts and relationships with other expert resources. It is a duty of the technical staff to be aware of establishments such as

- technical libraries
- environmental health authorities (factory inspectors, etc.)
- independent analytical laboratories
- technical consultants
- technical trade associations
- pest control specialists
- specialist laboratory facilities
- colleges for training technicians on short courses.

There is no better or quicker way to search for information than via the Internet. All those working in product development should have free access to computers not only for Internet access but to keep records and reports that can be viewed by others in the team.

An essential element of any development is research. Research means knowing what others have done before trying to reinvent something. Access to published work is essential. Membership of a trade association or trade research organisation is very valuable. Knowing where to find information is a critical skill in this technological age. Few developers do this part of their work adequately.

Each company should maintain a good library, books are expensive but cheap compared with wasted time. Books that have been bought should be read and kept available for all to consult. Communication is the other critical skill. The product development meetings are a main source of communication but developers should

be encouraged to visit other departments of the company, ingredient and equipment suppliers, etc., to talk over ideas and problems.

6.4 Assessing products

6.4.1 Presenting product for hedonic assessment

There are several stages when a developing product should be assessed using groups of people. These include:

1. initial checks to control the direction of the development with a view to establishing the product specification.
2. at market research.
3. presentation to retail customers.

Cases 1 and 3 will be discussed here. Each assessment will probably involve tasting and is so important that it should be planned very carefully for maximum efficiency of the project. Presentation is very important.

6.4.1.1 *Environment for the in-house assessment test*

This important stage in a development programme is often conducted badly. You may be familiar with a situation like this. The development team assembles with the usual merry banter and comments about the problems that each has just left behind and concern that there should not be a crisis develop during the course of the meeting! The chairman calls the meeting to order and an agenda, which probably includes several products, is commenced. At some stage it is necessary to taste samples of a particular product and sample tins or bags are opened and are passed round. There may or may not be plates to put the uneaten samples on and provision of water to clear the palate tend to be the source of additional fuss and bother because they were not provided at the outset. Someone attempts to record a consensus of the expressed opinions which are offered spontaneously and therefore probably influenced by previous utterances.

At the meeting is probably the leader of the project but not the test baker. He or she becomes emotionally involved with criticisms passed, tries to remind individuals that different comments were made last time and this was why the product is now as it is. Unless time is drawing near for the next stage in the project it is probable that the chairman will conclude with the decision that some changes are needed and that there will be another assessment at the next meeting. Motivation of the test baker is reduced and frustration is rife. Perhaps this is an exaggeration of the situation as it occurs but it is not unusual and is very unsatisfactory. So, how should the test be done?

6.4.1.2 *Introduction*

The chairman or the test baker should introduce the test by saying what is to be tasted and making any comments about the stage of the practical development and reminders of what were the conclusions from the previous tests. Each member will then be given forms, one for each sample to be tasted, which have been labelled with the appropriate sample reference code or number. The forms are for recording all findings and comments. The panel will be reminded that no talking is permitted until all have completed the tests and written their comments. There shall, of course,

be no smoking, no interruptions like telephone calls and fooling around to cause distraction. The test is important and must be taken seriously.

Each person will also be given a plate and a glass for water. Bottles of cool carbonated water or jugs of lime juice water will be placed in easy reach of each person. Receptacles will be provided for discarded samples.

6.4.1.3 *Samples*

Only when these preliminaries have been completed will the samples be produced. These should have been stored in ideal conditions so that they are a few days old but not softened by moisture pick-up. Immediately before the tasting starts they should be put on attractive plates and placed in the centre of the table around which sit the panel members. Each plate will bear the sample reference code. It is unlikely that more than five samples can be tasted critically at one sitting. The samples should represent small variations on either side of some predetermined characters so that the effect of some changes can also be appreciated by the tasters.

Results must be recorded on a form which will have been designed to record findings based on some type of hedonic scale. Typically a hedonic scale describes points in a continuum of characteristics. There are no absolute values that can be recorded, merely a collection of statements of likes or dislikes. In no case will there be a question which invites the answer Yes or No.

Figure 6.1 is an example of an assessment form. It will be seen that the assessor is taken systematically through the visual, textural and flavour qualities. There are two methods of scoring, a 5 just right scheme allowing one to show how far from the ideal characters are and a 0–10 scale, where 10 is best, for overall assessments. A final score is requested to show, despite the personal values recorded, how the taster feels that the product would do commercially for the company. Results from this sheet give a good impression of how acceptable a product is and which characters need changing or attention during a subsequent stage of development. Very often tasters in a panel will give very different preferences. This information is useful because it suggests that there is not an ideal position for those attributes.

There may be a need to consider other aspects of the product such as opinions about pack configuration and presentation within the pack. Comments about pack artwork or labelling are not appropriate at this testing time. There will also be places to record acceptability for the purpose in question and comments related to changes that would be worth considering.

It may be that a product is being designed to be eaten with other food such as butter and cheese, in which cases these foods should be provided along with cutlery so that the eating experience may be as realistic as possible. If the product is to be a match with or a contrast to a competitor's product, the other product should be provided as well. If a close match is the aim then the tasting test should be of a different type (see Section 6.4.2).

6.4.1.4 *Discussion and conclusions*

When all have completed the tastings there should be a round-table review of the findings and opportunities for open discussion. The forms will later be collected and, maybe, the results will be analysed for breadth and strength of opinions. At the conclusion there should be a consensus of opinion recorded about the future course of development and the product characteristics that are considered important or unique and should form part of the product specification. It may be that further test

INSTRUCTIONS

Mark the line at the appropriate position to correspond with your view of the characteristic under discussion, e.g.

Size (too small) -10 - - - - X - - - - | - - - - +10 (too large)

NAME OF TASTER

NAME/REFERENCE OF PRODUCT

VISUAL APPEAL

(just right for me)

Colour	(too pale)	-10 - - - - - - - - +10	(too dark)
Thickness	(too thin)	-10 - - - - - - - - +10	(too thick)
Size of biscuit	(too small)	-10 - - - - - - - - +10	(too large)
Ingredient size	(too small)	-10 - - - - - - - - +10	(too large)
Design concept	(unattractive)	-10 - - - - - - - - +10	(attractive)

General overall visual impression mark (out of 10) (10 = PERFECT)

COMMENTS**TEXTURAL QUALITY**

(just right for me)

Too soft	-10 - - - - - - - - +10	too hard
Insufficiently crisp	-10 - - - - - - - - +10	too crisp
Too crumbly	-10 - - - - - - - - +10	too dense
Insufficient interest	-10 - - - - - - - - +10	too bitty

General overall texture mark (out of 10) (10 = PERFECT)

COMMENTS**FLAVOUR**

(just right for me)

Main ingredient delivery – too weak	-10 - - - - - - - - +10	too strong
Insufficiently sweet	-10 - - - - - - - - +10	too sweet
Insufficient spice	-10 - - - - - - - - +10	too spicy

AFTER-TASTE

Too transitory	-10 - - - - - - - - +10	too strong

Is the after-taste:- Pleasant/Unpleasant?

General overall flavour mark (out of 10) (10 = PERFECT)

General overall after-taste mark (out of 10) (10 = PERFECT)

COMMENTS**COMMERCIALPOTENTIAL**

Average potential

Below average	-10 - - - - - - - - +10	above average

Fig. 6.1 Tasting test form for preference testing.

bakery trials are needed to change certain characteristics or it may be felt that the time is correct for the preparation of a large number of samples to be taken to market research or a larger in-house panel.

You are trying to establish whether the product approaches the product brief and also whether the product will be suitable/acceptable to the market. Development implies trying to practically match a concept and to modify the brief in the light of results obtained. It is important that the tasting helps to drive the project to a successful conclusion and this means that the aims can be changed a little but not so much that the project becomes a camel because it was a horse designed by a committee. One needs to comply with key product attributes.

6.4.1.5 Presentation to customers

Selling can fall down because the presentation to the customer is done poorly. There are two possible scenarios. First, samples are taken to the buyer. Try to make the occasion as attractive as possible. Try to make an appointment and ask for facilities to be provided when you present the samples, with the aid of other staff, and make a formal occasion of it. It is very important to you and it should seem so to the buyer, even if he is apparently rather casual.

The other scenario is that samples must be submitted to the retailer and at some stage an assessment is made in your absence. From the manufacturer's point of view this is far from ideal because he has no idea of the conditions under which the product is viewed and eaten. The important point, and really all that can be done, is to make sure that the packaging is as attractive as possible and that the samples will be in excellent condition even if they are stored for some days.

Assessment is an extremely important stage in biscuit development and should be treated very seriously. Everyone is swayed by personal impression, we do eat with our eyes, so think about the presentation at a tasting and make the tasters as comfortable and as enthusiastic as possible in order to get the best and most responsive results.

Do not present a product that is too fresh! Remember that changes occur during storage. The most rapid change is within the first few days and it is unwise to get the customer excited with a very fresh product which, a little later, will become what the consumer will find. If the customer notices this short-term change he may be inclined to suggest a very short 'sell by' period which will give production/distribution/product rejection problems.

6.4.2 Critical tasting tests

There is no substitute for tasting tests in assessing overall biscuit quality; after all, that is how the consumer will judge the product. Unfortunately, reliable tastings require a considerable amount of planning and administration. Hasdell [3] gives a comprehensive account of taste panel work which underlines both the values and difficulties. There are two types of tasting test. There is the type which aims to detect differences between samples that are supposedly similar and another type is used to record preferences and/or individual opinions about aspects of the product.

A common form of the difference test is the triangular test. This involves presenting three samples, two of one biscuit and one of the other. The tasters are asked, 'Can you detect a difference?' 'Which two are alike?' and 'Can you describe the difference?'. Clearly, the reason for the difference will be valuable only from those

who correctly selected the odd sample. Often the two types of biscuit being tested have some visual difference in addition to the eating quality difference. When this is the case it is necessary to conduct the tastings either blindfolded or with illumination that obscures the visual differences.

Some tasters may guess the odd sample; it is therefore necessary to analyse the results statistically. Roessler *et al.* [4] give details and showed, for example, that if there were 10 tasters, difference would be proved at the highly significant and very highly significant levels ($P = 0.01$ and $P = 0.001$) if 8 and 9 of the tasters, respectively, were correct. With 20 tasters the numbers would be 13 and 14 respectively. It is the triangular type of tasting test that quality control will use mostly in monitoring product quality.

In the early stages of product development it is people's opinions that are required from tasting tests. A great deal of literature has been published about scaling and ranking methods in these types of tasting tests. The size of the literature reflects the difficulties presented. An assessment, as was described in Section 6.4.1, is recommended. For preference tasting it is not so important to have trained tasters. Some people are more perceptive tasters than others, but with the principle of business involvement in mind, it is wise to seek interest and co-operation from all levels and types of staff in the company on matters involving the quality of its products.

6.4.3 Shelf life considerations

6.4.3.1 Definition of shelf life

General definitions of the shelf life of a food product, offered for sale under normal or prescribed storage and distribution conditions, are:

- the period of time from the date of manufacture or packaging while the product remains safe to eat
- the period of time when we can be certain that the desired eating and visual characteristics remain satisfactory
- the period of time when the claims on the label in respect of nutrition remain valid.

What is the importance of knowing and declaring a shelf life for biscuits? It is a legal requirement, at least in the EU, to datemark foods, particularly those with a durability of less than 18 months, with a 'best before' date. (A 'use by' date is required for microbiologically perishable foods.) If the product fails any of the above criteria,

- there will be consumer dissatisfaction which could result in lost future sales, a complaint or even a legal charge if the nutritional information is incorrect
- the reputation of the company will be tarnished which could affect other products
- if the shelf life is understated it will mean that product runs must be more frequent than they could be and there could be difficulty for the retailer in that the product does not sell before it must be withdrawn from the shelves. Thus for economic and marketing reasons the shelf life should be estimated carefully and made as long as possible.

It is the manufacturer who must decide the shelf life period for each of his products. He will aim for periods at least similar to those of competitors' products being

offered for sale close to his. There is a difficulty in both determining and defining the shelf life of a product as the changes are mostly to do with eating quality and these are very subjective. Well-made and well-packaged biscuits can have a long durability. The questions that are frequently asked are, how can a shelf life period be estimated and how can it be increased?

6.4.3.2 *The shelf life position of biscuits*

For the purposes of these considerations biscuits can be divided into two groups. Those with very low moisture contents and those employing caramel, jam or fruit paste, etc., that have a higher moisture content. The vast majority of biscuits fall into the first group. These are microbiologically stable and although they deteriorate with time never become unsafe to eat. The changes during storage affect the crispness, flavour and sometimes the appearance. The changes are typically very slow so the consumer gains the impression that biscuits will remain good for some time after purchase. Very few know how long the shelf life is from date of manufacture. This is why the term 'best before' is better than 'sell by'.

Those products with higher moisture contents must be carefully formulated or specially packed to ensure that conditions prevent the growth of moulds. It is very unlikely that pathogenic organisms will grow so we do not have to be concerned with the safety of these products. The higher moisture contents will affect the rate of deterioration of flavours so the shelf life periods are often shorter than for dry biscuits. This group is considered later. The period during which a product retains the desired characteristics is related to the formulation, processing and design of the packaging. Thus the shelf life is a critical aspect of the product development programme and important to monitor as part of the quality control procedures.

6.4.3.3 *Factors affecting the shelf life of low moisture biscuits*

Deterioration during storage can manifest itself by changes in physical and chemical characteristics. The changes can be referred to as staling or spoilage mechanisms. Physical changes include the following.

- *Loss of crispness due to moisture uptake.* Biscuits are very hygroscopic. They typically have an equilibrium relative humidity (e.r.h.) of about 30% so in most cases must be protected from the atmosphere to prevent, or at least delay, moisture pick-up. Loss of crispness is the most likely characteristic noticed by consumers and therefore forms the main aspect of shelf life. There is a stage at which the crispness is unsatisfactory and this is related to total moisture. Clearly this point will be reached as a result of too high a moisture content after baking, before packing or as a result of pack performance.
- *Fat migration.* Fat is a mixture of glycerides of different molecular weights and different crystallising temperatures. With changes in temperature during storage of the biscuits, there is often a movement of the liquid fat fractions. This can result in the development of crystallisation on the surface of the biscuits which is called fat bloom and can be seen as a paling of the surface colour. Fat migration will cause softening of a chocolate coating and sometimes the separation of biscuit from a sandwich of cream.
- *Loss of surface colour.* Fat bloom may be the cause but this can also be related to moisture pick-up through a chemical change in the brown colours developed

through the Maillard reaction during baking. This mechanism is not fully understood.

- *Flavour migration.* This may result in a dilution of the flavour sensation of a cream or topping by the movement of the flavour throughout the biscuit. Migration may result in the blending of flavours where several different types of biscuit are packed as an assortment.

Chemical changes include:

- *Development of off-flavours.* Unpleasant flavours develop as a result of oxidation, particularly of fats. This is known as oxidative rancidity. The speed of development of this type of rancidity is particularly related to the presence of moisture, certain metal ions and certain wavelengths of light. Rarely, there may be some hydrolytic rancidity associated with fats and moisture, especially in alkaline conditions. This is in effect a soap formation. In biscuits it is almost always caused by enzymic action which means that ingredients that have not been heat treated are involved, for example nuts in creams.

Off flavours may derive also from reversion of natural or added flavourings or certain fats. They can also derive, by migration, from packaging materials, especially cardboard. Odoriferous materials are often very soluble in fats and oils. It is therefore important to ensure that biscuits are stored away from other domestic items such as perfumed soaps, detergents or disinfectants.

- *Certain additives like vitamins deteriorate with time.* Thus nutritional supplement claims must be monitored in terms of time and storage conditions. Most chemical reactions are affected by temperature. The higher the storage temperature the faster will be the change.

6.4.3.4 Predicting shelf life

As it is the manufacturer's responsibility to determine the shelf life period this is clearly an essential part of the new product development programme. Tests must be initiated early in the development as soon as a concept product has been made. The initial test will be used to spot the directions of deterioration. The results will affect the design of the product in terms of satisfactory ingredients and packaging. Reliance is principally on organoleptic assessments and this means that tasting tests need to be very well controlled.

Design and organisation of tasting tests is described above. Typically the changes are very small and slow and the human senses are usually more sensitive than instruments even for hardness and crispness. Describing the changes in numerical values is thus difficult. As increase in biscuit moisture content is the main reason for deterioration of biscuit quality during storage, it is recommended that biscuit hardness as measured with a sensitive penetrometer or other instrument, is related to moisture content (or water activity). Thereafter the limit of moisture pick-up during storage can be more realistically related to the stage when a biscuit is too soft for acceptable eating.

Although there are some techniques for accelerating product changes that happen under storage, there is in fact no substitute for storage under expected conditions. This means that the product development time-scale and projected launch date should be such as to allow ample time for shelf life assessment. Samples must be taken at all stages in the development culminating with samples from the stage of scaled-up manufacture.

There is a problem in defining the expected storage conditions. Packs spaced on a shelf with air circulating all around them, perhaps in a well-lit area, will be more vulnerable than packs enclosed in a box used for distribution and warehouse storage. Additionally, one has to contend with variations in consumer handling. Unfortunately, there is very little published information on consumer handling of biscuits therefore we have to decide what is the end point of a product's life and we must include a clear margin of safety to take into account variations in pack performance and consumer handling. From a product specification and quality control point of view, it is therefore necessary to have two standards, a specification at the time of packaging and properties that determine the end of a product's satisfactory life. Neither is easy to define. The aim is to ensure that all changes are as slow as possible. Hence packaging that is well sealed and has moisture, oxygen and light transmission rates as low as economically possible are used.

6.4.3.5 Setting up shelf life tests

Predicting shelf life is a matter of monitoring change. Except for moisture pick-up, which can be assessed by increase in weight, monitoring relies entirely on comparison with control samples. Preparation of the control samples requires attention to the selection of typical ingredients and then storage in conditions designed to reduce the deterioration to an absolute minimum. We have seen that moisture, temperature and oxygen are the major factors affecting deterioration of biscuits. It is recommended that control samples are kept at a uniform low temperature, say 4°C, and hermetically sealed against humidity, oxygen and light. Metal tins offer the best conditions. It has been shown that biscuits stored in soldered tins will maintain satisfactory eating qualities for very long periods. Tests against these controls should be designed to emulate the conditions that the product will experience throughout its life from manufacture. Typical boxes, warehouses and distribution journeys should be involved.

In nearly all cases it is the packaging that limits the shelf life. It may be imperfectly sealed at the time of wrapping, damaged by handling into the outer box, perforated by sharp edges of sugar crystals, a corner of a plastic tray, or possibly by exposure to very low temperatures that cracks the barrier film (this is more likely to be the case with cellulose-based films than plastic).

6.4.3.6 How can the shelf life be increased?

- Ensure that the product is in prime condition at the time of wrapping. Of particular concern here is how the product is handled before wrapping. In many cases the product is stored in containers exposed to the factory atmosphere for long periods before wrapping. This is particularly the case where secondary processing is not done in-line. The speed of moisture pick-up during a cool humid night is surprisingly fast. Crispness and oxidative deterioration starts then.
- Heavy or double wrapping reduces moisture and oxygen transmission rates.
- Controlled atmosphere packaging and the use of antioxidants in the formulation delays the effects of oxidation but none is as effective as the use of good stable ingredients and baking to the correct moisture levels.

6.4.3.7 Products with higher moisture contents

There has been a great increase in consumer interest in biscuit-like products with softer and dual textures. A new biscuit straight from the oven is more crisp on the

edges than in the centre. This is even more marked if there is a filling of fruit or jam. Soft or chewy textures offer a welcome choice from typical crisp biscuits. These softer textures are achieved by having higher moisture contents. The free moisture is there as a concentrated solution, a syrup of some sort. The problem is that at higher moistures moulds and other organisms may grow. In most cases moisture will migrate from a wet place to a drier one. This can be through the vapour phase; the two parts do not have to be in contact.

One is forced to consider a physical characteristic of the product known as the water activity (a_w). Water activity is a measure of the amount of available water in a food. Water activity values are numerically equal to the equilibrium relative humidities divided by 100. Therefore water activities are in a range from 0 to 1. Values below 0.65 will not support the growth of moulds and yeasts so this is the area that we should aim for in order to achieve long shelf life of soft products. The concentration of the solutions in the product determines the water activity. The more concentrated the solution the lower the water activity. Furthermore, the smaller the molecules that make that solution the lower will be the water activity. Therefore a 70% solution, by weight, of invert syrup will have a lower water activity than a 70% solution of sucrose. The problem is that in order to get a water activity below 0.65 we are near to the limits of sugar solution concentrations; higher concentrations will crystallise and the remaining solution is then less concentrated. There are some other soluble substances that can be used to lower the water activity in biscuits such as salt and glycerol. Products that are soft and microbiologically stable can be seen to be usually very sweet.

Products coming from the oven have reached temperatures that destroy all but a few mould spores. If they could be packed hot and before picking up spores from the atmosphere even at higher water activities, they would remain sterile and thus microbiologically stable. It is not practical to pack hot products and the packaging would have to be sterile also. Even one mould spore falling on the product before packaging, given favourable conditions, will grow and multiply. If the water activity of a soft product is above about 0.65 it is necessary to package in a special way to prevent the growth of spores landing on it. A propionate salt can be included in the formulation to retard the growth of the moulds. The product and package can be surface sterilised with intense ultraviolet light but this is practical only if the surface is very smooth and there are no crevices where a spore could hide. Another way is to introduce some alcohol into the pack; an alcoholic atmosphere is excellent at retarding mould growth but this ingredient can be expensive and needs to be declared on the ingredient panel. If one could be sure that there is no oxygen in the pack, most moulds cannot grow, thus flushing the pack before final sealing with carbon dioxide or nitrogen or by introducing a sachet of an oxygen scavenger, the oxygen can be eliminated. Finely divided iron is an effective oxygen scavenger and the product called Ageless from Japan works in this way. Refrigeration also retards mould growth.

Even with these precautions it is likely that high water activity products will have shorter shelf lives in terms of flavour change than drier products. However, the strong flavours of syrups, jams and fruits may mask these changes to a certain extent. The Campden BRI (formerly Campden & Chorleywood Food Research Association) developed a computer program called the Cake Expert System that can predict the mould-free shelf life of semi-moist baked products from details of the formulation and final moisture content. This is not generally useful for biscuits but it may be applicable if they are cake-like.

6.4.3.8 *Shelf life monitoring, routine shelf life testing*

The tasting tests needed to monitor shelf life changes have been mentioned above. As moisture uptake is the principal limiting factor for most biscuits, pack performance testing is the first aspect of quality control testing that should be monitored. There are various simple methods that can be used to check the moisture barrier properties of a pack, for example, blowing on the seals to see if the pack can be inflated, inflation under water to locate a hole in the packaging and storage at elevated humidities and noting the gain in weight over a number of days. These tests are relative and give only a rough indication of shelf life as determined by long-term storage. However, they may be useful for showing how packs compare from day-to-day production or with those of competitors.

6.5 **Establishing the product specification**

All products are manufactured to specifications. The specification determines what the product should look like and how it should taste. This is the product quality. The concepts of high quality and low quality are not appropriate except that a small range must be allowed in the specification to accept natural variations. Quality control implies adherence to the product specification. The detailed specification must be written and agreed by all parties. In particular the size of the variations must be accepted and agreed. It is recommended that as much as possible of the written specification should be in diagrammatic form like the process audit diagram (see Fig. 5.2). In the course of time, for one reason or another, the specification may be altered or the size of acceptable variations changed. Such changes must not be taken lightly or unilaterally. There are important customer satisfaction and company economic considerations involved in the product specification.

The quality is defined primarily by the formulation and the nature of the ingredients but the processing technology very much affects the product so this must be included in the specification. Many companies state that the processing parameters on the product specification cannot be finalised until at least three full production runs have taken place. This means that aspects such as the reincorporation of cutter scrap, etc., have been fully taken into account. All product specifications must become part of the company's quality management system.

Specifications should include as many details as possible about the ingredients and the steps in making, handling, packing, storage and shelf life of each product. Critical control points must be identified and the nature and frequency of process control checks defined. There is a difficulty in recording and monitoring the organoleptic attributes as these are very subjective, but it is normally the case that if all the ingredients, processing and product parameters that can be measured, like size, weight and colour are correct, then the eating qualities will be satisfactory also. This does not mean, however, that the product should not be checked by critically tasting at regular intervals.

Creating the product specification is the responsibility of the product development team. Typically the specification evolves through the stages of development and is refined as a result of full-scale production. This late stage when a product is first made on the full-size plant intended for production is usually referred to as 'scale up'. The product character is often different from that which was expected at

scale up and the skill and experience of technologists and production management are critical to be able to adjust the processing to achieve the desired product.

6.5.1 Plant trials and early production of new products

A project is not finished until the new product has been manufactured satisfactorily at least once. The food designer, and probably other members of the project team, should be involved at the plant trial stages so that none of the critical characters of the product is compromised in production and help and advice can be given if difficulties are encountered. Some of the factors that must be viewed critically at scale up are:

- ingredients
 - temperatures
 - condition of the fat (temperature and solids content)
- mixing
 - determination of the end point
 - consistency and physical appearance of the dough
- dough handling
 - time-scales
 - temperature during use
- dough piece forming
 - plant speeds
 - pressures exerted on the dough
 - how the cutter scrap is handled and incorporated with fresh dough
- baking
 - the temperature and air velocity profiles when in a steady state
 - biscuit size, colouration and moisture.

Very often new processing plant is needed for a new product – a significant investment for a business. There will be occasions when management will wish to delay this investment until the success of the product has been confirmed. In these cases, or when there is a long delay before the new facilities can be commissioned, it is usual to consider commencing manufacture in another factory under contract. If this route is taken there are even more demands on the food designer and other technical staff of the technical department. Trials and subsequent process and quality control are much more difficult to manage than in one's own factory.

6.6 Management of product development

The staffing of the technical department has been discussed in Chapter 1 and it is suggested that product development (PD) is too important to staff on a casual part-time basis. The possibility of using contract help is well worth considering because it can bring in special skills and force the programme speed better than in house where there are always other pressing management problems to deal with.

There is often a personality problem of a 'them and us' variety when marketing and production staff sit at a meeting. This is not helpful when product development is involved and understanding of the problems of both sides must be encouraged by good communications. A food designer, leader of the PD section, should provide

an effective link between the marketing and manufacturing functions and can encourage each side as appropriate through the medium of a development team. It is important that the designer is in at the beginning of a project and there to the end. It is probable that a designer, appropriate to the project, brought in from an outside organisation will be more effective than an in-house member of staff with a bias to a particular department of the company. The designer should be a catalyst in the development team and an interpreter between the company and its customers.

6.6.1 Suggested structure for the development team

- Champion of marketing
- Food designer
- Board director
- Champion of technology group
- Champion of manufacturing
- Champion of purchasing.

The team does not have to be made up of senior management (managers approve plans not products!) but each member must have experience of his or her function area. Innovation is the province of everyone not just specialists. The term 'champion' is better than 'representative' as it suggests involvement and responsibility rather than just an appendage of a department.

All team members should have similar status in this team so that nobody 'pulls rank' and thus inhibits the flow of ideas. Stimulation is of utmost importance so the team must have product 'ownership' to maintain their enthusiasm to the completion of the project.

6.6.2 The duties of each team member

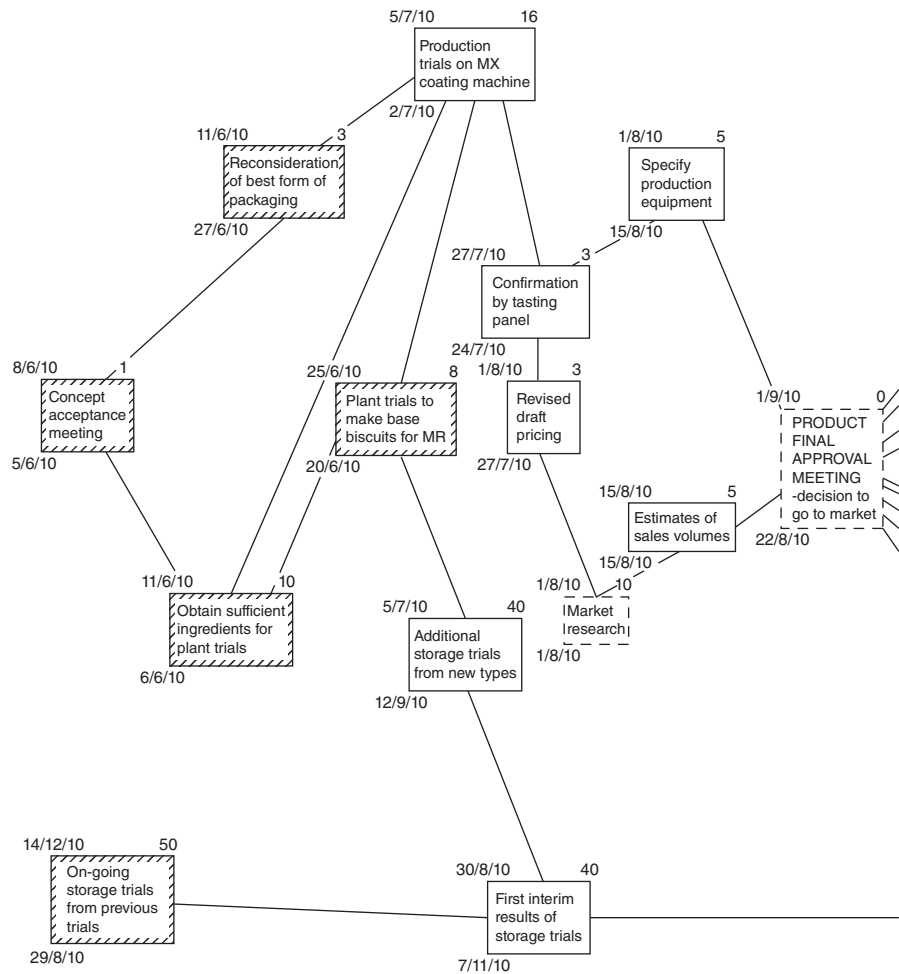
- *Champion of marketing* (the team leader or product champion)
 - to control the definition of the brief
 - to contribute information on marketing opportunities as he and his department see them and thus to control the scope of the project
 - to define the market segment which seems the most appropriate to the project
 - to introduce time and cost parameters to the project
 - to control the project financially
 - to organise activities and maintain liaison with market research, sales and advertising
 - to keep detailed minutes of team meetings and to distribute them as appropriate
 - to call team meetings frequently to ensure constant action
 - to bring comparable products to the team's attention so that they can eat them and analyse their strengths and weaknesses
- *Food designer*
 - to communicate his or her vision of customer needs relative to the products in question
 - to motivate the team in creativity and to encourage lateral thinking linked to customer wants

- to integrate innovation with design within the specified parameters but to see that the team does not fall in love only with the first good idea
- to form a link between commercial ideology and production conservatism
- to supervise or personally make product samples for initial assessments
- to refine product characteristics in the light of assessments of product samples
- to define product specifications for manufacturing with particular attention to permissible limits
- to oversee manufacturing trials to ensure that no important compromises are made to the characteristics of the product as a result of process scale-up and packaging.
- to organise or aid the product champion to produce and progress the project plan and critical path
- *Board director*
 - to feed support for company development through new products
 - to contribute commercial experience
 - to inform the Board of the project activity so that financial and other company resources remain compatible
- *Champion of technology group*
 - to contribute appropriate technical experience
 - to investigate processing techniques, raw materials, packaging materials/ systems and feasibilities generally
- *Champion of manufacturing*
 - to contribute appropriate manufacturing experience
 - to investigate manufacturing implications in terms of plant, skills, process control, packaging systems and manufacturing costs as potential new product ideas crystallise
- *Champion of purchasing*
 - to contribute appropriate purchasing experience
 - to investigate costs and availabilities of all bought-out ingredients and made up items
 - to investigate contract manufacturers if appropriate.

6.6.3 Project management

In any new product venture, the sequence of activities should be planned carefully in advance. Particular emphasis should be given to the timing of each step and the overall timetable should be prepared. It is very important not only to the marketing effort but also to the overall cost of a project that the launch date for a product is known well in advance. The launch takes place only if all the interrelated tasks are completed smoothly and on time.

There are graphical project management programs for personal computers which will display the critical path for the project and also allow ready appreciation of the demands on resources both human and financial. Figure 6.2 is a very simplified new product development project chart. Each box is a task which can be ascribed an earliest start date, latest finish date, duration, etc. The computer calculates the critical path and one can 'play games' of 'what happens if?' with the computer by altering dates or durations to see how the overall programme is affected. Each task requires personal and financial resources and the computer can summarise the time and money needed at each stage totalising with time. There are milestones, shown as



Critical path. Delicious Biscuit Company product G110 version A4

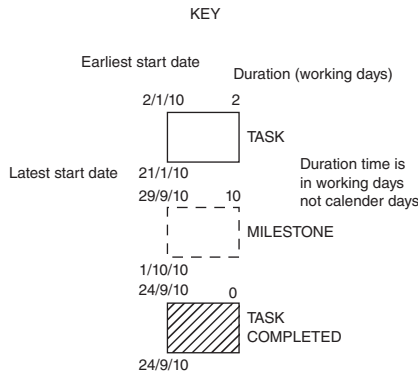


Fig. 6.2 Project management program, showing critical path.

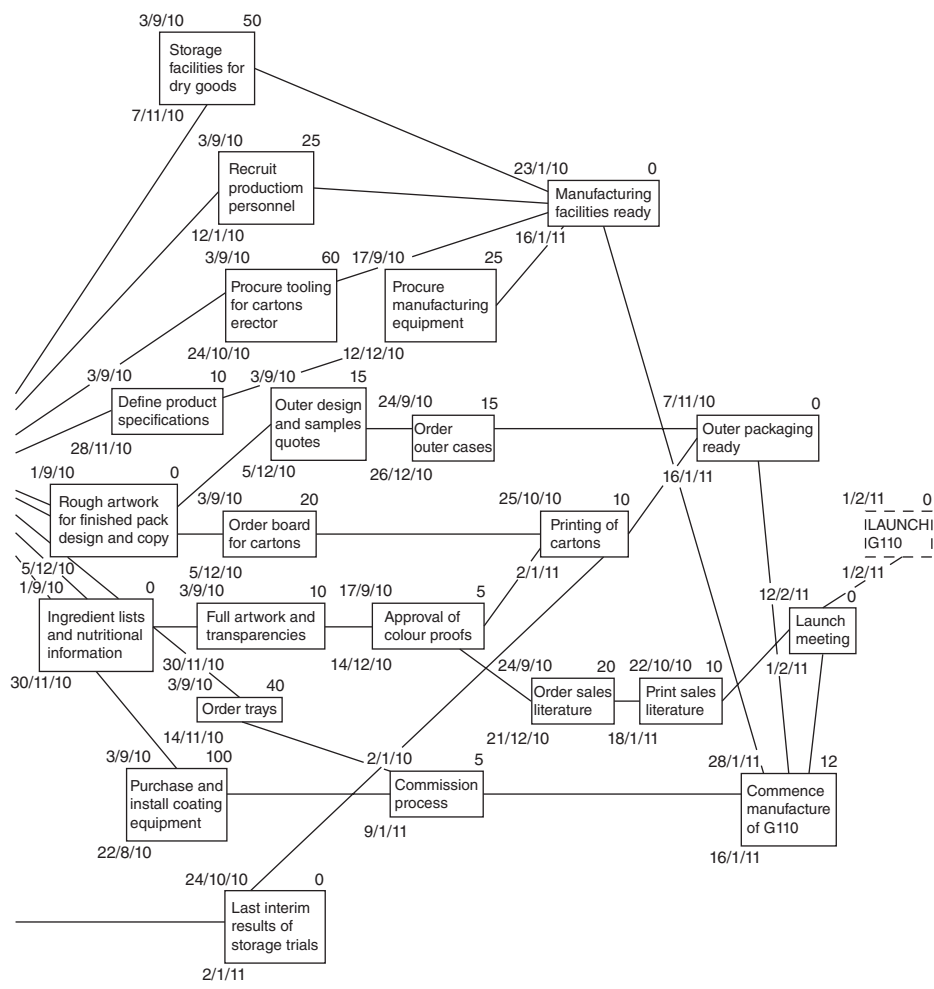


Fig. 6.2 Continued

boxes with dashed edges, which can be considered as reassessment times so that the project does not drift on to an unsatisfactory stage without the opportunity to cancel or divert it. The advantage of a well-managed project is that the enthusiasm of all is maintained because all feel involved and can see the project progressing.

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7

Sustainability in the biscuit industry

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Abstract: This chapter discusses factors affecting sustainability in the biscuit industry. It includes information on a range of potential drivers for action to improve sustainability and how they are affecting manufacturers. It also includes information on a number of actions that businesses can take to improve sustainability.

Key words: environmental sustainability, carbon emissions, water use, waste reduction, sustainable sourcing.

7.1 Introduction

In the last few years sustainability and focusing on ‘green issues’ has grown from an area that businesses could dismiss as the domain of cranks and hippies to one that is fundamental to business success. The vast majority of science now supports the theory of global warming and the need to take action to reduce the damage carbon emissions are doing to the planet.

The global food industry faces a double challenge. On the one hand, climate change is creating weather volatility, which in turn affects crop yields and raw material pricing. On the other hand, the global population is rising steadily, thereby increasing the need for food. To make matters worse, the countries where the population seems to be rising the fastest are often the poorest, relying on staple crops and least able to adapt to the changing climate and water shortages that are forecast to accompany them. The world population has tripled in the last 50 years and water demand has increased sixfold.

Improving the sustainability of a business is imperative as it is the ‘right thing to do’ and is expected by customers, consumers and employees. International conferences, for example at Kyoto and Copenhagen, have also brought sustainability to the forefront of government planning. Stretching international long-term targets have been discussed and will be implemented with varying degrees of success around the world. It is an area that businesses must address and, given the long-term nature of the issue and the likelihood of global success, the expectation must be that the measures taken to drive sustainability within the global economy will become increasingly stringent.

While governments will endeavour to drive the right behaviours through a combination of incentives, taxation and levies, businesses can take proactive action that

will generate substantial benefits in terms of cost saving and improved efficiency as well as environmental benefits. It is also an area that employees expect their employer to embrace. Employees will – with varying degrees of enthusiasm – support sustainability activities, even if changes cause them some inconvenience in their working day. As global citizens they recognise that action must be taken to protect the environment and they typically want to work for businesses that are playing their part in what will probably become the major challenge of the twenty-first century. They may also recognise that if their business does not embrace sustainability, they risk competitors gaining an advantage by taking early action, affecting their job security.

7.2 Key drivers for sustainability in the biscuit industry

The main drivers for taking action on sustainability are as follows:

- consumer demand
- customer demand
- industry bodies
- government agencies
- government requirements
- employee demand.

Whilst several are inter-related, these are dealt with separately below.

7.2.1 Consumer demand

While the majority of consumers support the broad sustainability argument, there is no evidence that this is a major factor driving consumer behaviour in the purchase of biscuits. Price, brand, health and convenience are the main driving factors in helping consumers make purchasing decisions, as evidenced by the fact that marketers continue to focus their activities in these areas. Where manufacturers in other categories have experimented with sustainable labelling, it has not made a noticeable difference in sales. For example, Walkers/Pepsico trialled carbon footprint labels on certain flavours of crisps in the UK but the impact was minimal and has not been extended by them to other flavours or been taken up by their competitors.

Very few enquiries from consumers are received by manufacturers about the sustainability of products. Where questions are asked, these are often about individual ingredients, e.g., does the product contain palm oil and if so has it been produced sustainably? Very few comments are made about the sustainability of the product as a whole. Excess packaging may also generate occasional enquires but on the whole the packaging of biscuits compares favourably with other categories. For example, the roll wrap film of a 400 g packet of biscuits will typically weigh less than 3 g. The exception to this is the selection box segment of the category where the quality, decoration and opulence of the packaging forms an integral part of the purchase appeal – for example a colourful biscuit tin of products bought as a gift. This provides a greater challenge for the manufacturer – to maintain the packaging as an indication of the indulgence and luxury of the product inside whilst at the same time reducing its impact on the environment.

Looking ahead, there is increasing interest, particularly from governments, in introducing carbon footprint labelling on each individual product so that the consumer can see the carbon generated in its manufacture. The aim of this labelling would be to include all carbon generated by the product, not just that from the manufacturer. This means that the carbon label would include all carbon emissions from the planting of the seeds of the raw material to the disposal of the finished product. The aim is to give consumers more information to drive their purchasing decisions and encourage manufacturers and their supply chains to greater effort in sustainability. The hope is that this would increase consumer demand as a driver for sustainability.

The French government has already considered legislation along these lines although other governments are currently holding back. To be effective it is essential that there is a consistent means of measuring carbon emissions in all products or this concept will be devalued and create more confusion than clarity for the consumer. A common carbon measuring template called PAS2050 has been produced in the UK by a group led by the Carbon Trust (a UK government sponsored body). This aims to cut the cost calculating carbon emissions and ensure that all manufacturers are working on a level playing field. The level of accuracy of such a measure is critical to its success. If it is not sufficiently detailed then consumers will feel it is of little value and it will offer little incentive for companies to improve their supply chain as they will not be able to demonstrate the benefit. On the other hand, if it is too detailed it will be prohibitively expensive, for example if a certain ingredient has several sources depending on the season, the labelling would need to be changed every time the source changed.

Carbon labelling is still at an early stage but notwithstanding its lack of progress to date, its development is likely to proceed as it is a means for governments and regulators to pressure industry to reduce carbon emissions across the entire supply chain. For biscuits, the bulk of the carbon value of the product is generated from the production of the raw materials. As most biscuits use a combination of similar raw ingredients and packaging, there is unlikely to be striking differences between the carbon footprints of similar biscuits. The change in consumer behaviour is therefore likely to be less in the biscuit category than say the fresh fruit or meat categories where the contrast in carbon values should be more striking.

The primary drivers of consumer purchasing decisions are likely to remain price, brand, health and convenience, but sustainability will be added to this list – with visibility through carbon labelling – and may be a deciding factor where other drivers are considered equal.

7.2.2 Customer demand

While sustainability is not currently a major purchasing factor for most consumers, they do say that it is important to them in research. Approximately 50% of US consumers consider at least one sustainability factor when selecting consumer packaged goods items and choosing where to shop for those products, according to a survey conducted by Information Resources, Inc. The 22,000 US consumers surveyed were asked to determine the impact of four key sustainability features in their product and store selection: organic, eco-friendly products, eco-friendly packaging and fair treatment of employees and suppliers. One-fifth of those surveyed were determined to be 'sustainability driven', taking at least two sustainability factors into account when making their selections.

Stating that they will 'take sustainability into account in purchasing decisions' is not the same as actually always buying the most sustainable product. However, there is pressure on retailers to highlight the sustainability of their range – ideally demonstrating that their core products are sustainable and not just specialist 'green' brands. To achieve this most, if not all, major retailers will run comprehensive corporate responsibility programmes.

As well as responding to consumers' stated preferences – even if this is not always matched by buying behaviour – retailers are also responding to the same pressure from the environmental movement with carbon reduction targets, taxation and levies as mentioned earlier for manufacturers. Their environmental programmes will typically incorporate various sustainability goals and often these are quite stretching. For example, Tesco, the largest retailer in the UK, aims to be a zero carbon business by 2050 (source: Tesco website).

Understandably, with these ambitious goals, retailers will use their purchasing power to encourage their suppliers to support them. The focus of this support is primarily around the sustainability of packaging and the use of environmentally sensitive ingredients. However, with the advent of carbon labelling there is likely to be increasing pressure from customers to reduce carbon footprints to demonstrate improving sustainability to consumers. Retailers are keen to understand what sustainability programmes their suppliers have in place and to encourage environmentally friendly activity. Some are even keen to share in joint environmental projects, for example sharing transport networks with a supplier to reduce empty running and unnecessary road miles.

7.2.3 Industry bodies

Many manufacturers will be members of industry bodies such as the Food and Drink Federation in the UK. They look to work with government agencies and ministers to represent and co-ordinate the environmental activities of manufacturers. Some such bodies will agree their own environmental targets in conjunction with a majority of members to demonstrate that the industry as a whole is playing its part in protecting the environment. There will obviously be pressure on all food manufacturers within such an industry body to meet or exceed the benchmarks that a relevant industry body has set.

Support from industry bodies will go much further than target setting and they play a key role in representing manufacturers collectively on critical environmental issues, such as negotiating around carbon measurement labelling and interacting with government bodies to ensure consistency and avoiding confusion for the consumer. Individual manufacturers cannot act alone on such issues. The cost of calculating the carbon footprint of every product would be prohibitively high – and meaningless if every manufacturer calculated according to their own formula. For effective comparison a collective formula is essential and much more cost effective for the manufacturer. With increasing legislation on environmental issues, industry bodies also are in a stronger negotiating position than individual manufacturers to achieve changes that manufacturers need.

Industry bodies also encourage the sharing of best practice and can even support co-operation between competing manufacturers in a way that helps them work together to improve the environment while still competing on the shelf.

7.2.4 Government agencies

Government agencies are those organisations that are in some way supported by governments and government departments to help achieve their environmental goals. Typically they will focus on just one area of the sustainability agenda such as packaging, water saving or carbon emissions. This single focus means that they can stridently push businesses on this one issue, issuing reports, proposals, recognition exercises and league tables to encourage action. However, with several agencies the advice can conflict and particularly in times of government cost cutting, agencies can compete with each other over the same territory, which can make life difficult for manufacturers. The situation can become particularly testing when a manufacturer operates over a number of different countries and is seeking to co-operate with a number of different agencies supported by national and regional governments, such as the European Union. In such circumstances, close liaison with national and regional industry bodies can prove helpful.

7.2.5 Government requirements

Driven particularly by international agreements on carbon emissions, governments will look to drive the environmental agenda within their own territories.

- For carbon emissions this could mean carbon trading schemes, taxes on emissions, carbon reduction, targets for industry, etc.
- For water this could involve incentivising water reductions, increasing restrictions on usage of boreholes and other natural water resources.
- For packaging this could result in some form of packaging tax or levy on packaging issued by a business for their products. National governments may look to support local government departments and councils in raising local rates to support improvements to local recycling facilities.

7.2.6 Employee demand

Last but not least is employee demand. Employees see a wide range of media highlighting the danger from global warming, climate change, water shortages and not surprisingly they want to play a part in protecting the planet. This is particularly the case with younger employees who have often been educated with environmental messages and are facing more significant change during their lifetimes. Consequently, when seeking employment they value companies that are taking their sustainability responsibilities seriously. Many companies now feature corporate responsibility activities in brochures that are sent to prospective new employees and in recruitment events.

Once in employment many remain willing to support environmental initiatives, contributing ideas to suggestion schemes and accepting small inconveniences when they can see an obvious benefit, such as the replacement of single bins with a range of recycling facilities to minimise waste to landfill. By directing and engaging this enthusiasm, major progress can be made and substantial costs savings achieved. For example, one biscuit manufacturer doubled their recycling rate, reduced water by 17% and reduced food waste by 16% in just the first year of their sustainability initiative – saving millions in the process. Sustainability is not necessarily a cost; it can be a key tool to improve employee engagement as well as generating substantial savings.

7.3 Carbon emissions and energy use

The obvious first place to look when managing carbon emissions in a biscuit manufacturing business is the ovens. They use a large amount of energy but are essential to the manufacturing process and so it makes sense to use them as efficiently as possible. Effective energy management systems for ovens are essential to manage their efficiency. These systems should enable the accurate measurement of energy used by line and by shift so that managers and engineers can be held accountable for the energy used by the equipment under their control. Energy use can then be tracked between different areas of the site and between different sites to highlight best practice and quickly identify when energy is being wasted.

Other factors that should be considered include:

- adjusting oven switch-on times to the minimum necessary at the start of the shift/production run
- organising production runs where possible to get the most production through the oven over the shortest possible time to minimise the time the oven is left on with no product
- setting realistic time-scales for fault fixing – so that if the oven cannot be fixed promptly – i.e. within its shutdown and start up time, it is switched off until repairs can be effected. A delayed spare part causing prolonged empty running of an oven can quickly impact the emissions per tonne of product of a manufacturing site.

Other more innovative solutions can also be explored. Some manufacturers have experimented with new oven burners that retain more heat in the oven – although this does require adjustments to the heat settings at the various different stages of the oven. Much of the oven heat escapes up the flues and chimneys and some manufacturers are experimenting with heat exchangers to try and recover this energy and use it for cooling, e.g. to reduce air conditioning in areas around the ovens. In addition to ovens, other energy management activities include: ensuring that other line equipment is not running when not required; ensuring that the controls for the heating and air conditioning systems are aligned and the systems are not wasting energy fighting each other; and replacing standard equipment such as lighting with low energy systems.

Looking ahead to carbon labelling there is likely to be an increased focus on carbon emissions in the supply chain which will represent the bulk of the emissions of the finished product. Until the measurement process for product carbon labelling has been finalised it will be difficult to judge what action is necessary. However, in the future procurement will have a key role to play in improving the perceived carbon efficiency of a business, identified through the carbon labelling of its products.

7.4 Reducing water use

Water is not a major ingredient in most biscuit products and therefore the scope to reduce its use is primarily in the better management of hygiene measures. Particularly in countries where water is not regularly in short supply, there is a tendency to use it abundantly. With climate change, rainfall patterns are changing and water

looks set to become an increasingly scarce resource in some parts of the world. In some areas with projected seasonal changes, wetter winters are forecast but this water has to be conserved through drier summers. While many countries have taken water availability for granted until recently, it may become a precious commodity in the future – and where water is already scarce, the situation could worsen. Already major infrastructure is being built with China constructing a new canal to supplement reservoirs serving Beijing, which is the equivalent length to a canal stretching from London to North Africa.

Governments and industry bodies are now encouraging the conservation of water. Against the louder clamour for carbon reductions, some agencies have tried to calculate a carbon footprint for water savings, but for most people it is easier to understand water savings in terms of cubic metres of water. Water is also becoming increasingly expensive and with projected shortages, this price increase is likely to escalate. This provides a further incentive to business to reduce water use where possible – without compromising the necessarily high hygiene standards of a food manufacturer.

7.4.1 Steps that can be taken to reduce water use

- Facilities in areas of at least moderate rainfall will have good supplies of ‘grey water’, i.e. rainwater that can be collected from roofs of facilities and used in replacement of clean water from the mains. Obviously this cannot be used safely for drinking or hand-washing without some form of treatment but can be used for things like toilet flushing and vehicle washing. Regulations concerning the use of grey water will differ by country but not to use it is to allow an increasingly valuable resource to go literally straight down the drain. The costs for setting up separate plumbing systems to collect rainwater and then deliver it where it is required, e.g. for toilet flushing, can be expensive for existing buildings but the payback period is likely to get increasingly shorter.
- Simple water management measures such as reducing the flush of toilet cisterns by putting bricks or other more tailor-made devices in them and by fitting trigger spray valves to the end of hosepipes can achieve significant savings. Trigger valves on hosepipes usually increase the pressure of the jet, improving cleaning effectiveness and only allow water to be used where it is required. Spray nozzles can also be fitted to normal hand-washing taps and waterless systems can easily be installed into urinals.
- If water is used in the production process then sensors can be used to cut off water when production is not running and water can be recovered and re-used, if for example washing ingredients.
- Sub-metering can be considered to more closely monitor where water is used around the site and target areas for improvement. The principle of ‘if it is not measured, it will not get done’ is valid and if people know that profligate use of water will be detected they are more likely to try to avoid it. Healthy competition between parts of a site will also encourage teams to play their part in water conservation – and in other sustainability activities.
- Education of staff can also play a key role. While most employees are aware of the risks of global warming, particularly in countries with high rainfall, it is important to educate employees on the importance of conserving water.

7.5 Reducing waste

Whereas in the above-mentioned areas of sustainability, reducing carbon emissions and water, a small group of individuals – usually engineers – can have a big impact on reducing waste, it is critical to have wide-scale involvement of all employees. Every single employee will have a part to play in reducing the waste of the business and unless they are engaged in the cause, substantial progress will not be made.

The good news is that waste is a physical thing that can be seen and touched, unlike carbon emissions, and it is much easier for employees to see the size of the challenge and the progress they are making. A key starting point is challenging any culture of acceptable waste levels. There are essentially two different types of waste: food waste and non-food waste, and these are dealt with separately below.

7.5.1 Food waste

Where in the past people may have been relaxed about seeing product shoot off the end of a line into a waste bin because of a fault in a process, awareness of waste levels should have been raised. Most biscuit food waste will be recycled as animal feed and as the business is still selling it in this form, it is sometimes not seen as 'proper' waste. However, biscuit manufacturers are not aiming to be in the animal food business and all employees should have an awareness of the price differential between finished goods and waste sold as animal feed. Sometimes equating the food waste output of the total factory to the output of a line of a factory will illustrate more clearly the scale of the problem. Calculating the value of replacement ingredients required to replace the volume of waste also brings home to all employees the benefit of reducing the volume of food waste.

At least one large biscuit manufacturer has found that by concentrating attention on reducing food waste their quality measures have improved. Employees focusing on increasing standards of work to minimise waste have as a consequence improved standards of quality more generally elsewhere too. There is no simple formula to reducing food waste as all production processes are different, but a starting point should be a review of where in every line waste is generated.

By taking a 'zero tolerance' approach to food waste, issues can come to light that have been creating small amounts of waste over long periods of time and which can be easily fixed. Where possible, food waste can be re-introduced into production and healthy competition between sites and lines can encourage all employees to reduce food waste on a previous period. Other ideas to explore include making product from food waste. A classic example is the Filipino biscuit now made by Kraft. This is a ring shaped biscuit, normally covered in chocolate and was developed by an earlier owner of the brand. They looked at the bits of dough cut out from the centre of the rings and decided to cook them as they were and coat them in chocolate and sell them as Filipino Holes – which proved very popular. Waste biscuit products can be used for a variety of purposes, such as filling for confectionery bars or biscuit crumb for cheesecake bases.

7.5.2 Non-food waste

While the price for recycled materials is generally low, the rising charges levied for dumping waste in landfill makes reducing waste to landfill a significant cost reduc-

tion for any major manufacturer. The savings can be substantial: one major manufacturer reduced their waste to landfill by approximately two-thirds over just three years.

A comprehensive approach is required looking at the entire manufacturing process from raw materials coming in to finished product going out the door. Analysis of waste initially destined to landfill will give a good indication of the scope for recovery. The following should be seen as essential steps:

- Review recycling facilities on every site – are there recycling facilities for all major components of landfill that can be recycled?
- Is it clear what can be recycled and what goes in each bin – particularly for items that have to be broken down into components?
- Are the bins located near where the waste occurs and ideally nearer to hand than the landfill bins?
- Is the level of recycling being monitored, are employees incentivised to recycle, e.g. through an inter-site competition to raise recycling levels?

Another key element is looking at where the waste comes from – a lot will be delivered in the form of surplus or unnecessary packaging. It is essential to involve suppliers as often packaging arrangements are historical or presumptions of what the manufacturer wants. By exploring needs with the supplier, often both parties can save time and costs by reducing unnecessary material or by switching to recyclable or reusable containers.

There will always be some elements of waste that cannot be recycled, particularly composite items that are made of different materials, for example hairnets that are made from a form of paper and elastic. Other options can be explored to replace these items such as reverting back to cloth caps that can be laundered or looking at disposal through incineration in a way that generates energy.

A number of businesses have set ‘zero to landfill’ targets and in these circumstances solutions need to be found for all types of waste, and incineration will inevitably feature for the final residual waste. But it is important to ensure that all recycling opportunities are explored first and that waste is not routinely shipped off for incineration before being sorted. This would mean missing out on revenue from the sale of recycled materials, but as there are currently only a few energy generating incinerators, it would also mean generating carbon emissions by trucking unnecessarily large amounts of waste lengthy distances to incinerators.

7.6 Packaging

By weight the vast majority of a biscuit manufacturer’s packaging is likely to be recycled, being in the form of cardboard cases and pallets that are delivered to supermarkets who routinely recycle these items. Packaging that reaches the consumer is much less likely to be recycled, particularly plastics. Local authority capability for recycling plastics varies from one region to another and it is difficult for consumers to distinguish the types of plastic that can be recycled from those that cannot.

Compared with other categories in a supermarket the amount of biscuit packaging compared to the product is very low. A typical weight for a roll wrapped packet of biscuits is around 2–3 g compared to 400 g of biscuits. However, the plastic film

in this roll wrap packaging is not normally recyclable. The biscuit industry faces a number of challenges in the move to recyclable packaging for consumers.

The key issue for packaging and sustainability is the need for the packaging to act as an effective barrier to avoid food waste. The greenhouse gas emissions resulting from the waste of one digestive biscuit is the carbon footprint equivalent of 48 biscuit wrappers. Trials on biodegradable packaging with polymers such as cellulose and polylactic acid have been disappointing with a 50% reduction in shelf life combined with an estimated 300% increase in packaging costs. (Barry Pamplin, European Packaging Technology Controller, United Biscuits)

Biodegradable plastics can also contaminate other plastics when used for recycling so that the integrity of the product made from the recycled material is affected.

Rather than replace the type of packaging, work to reduce packaging has so far concentrated in two areas:

- Improving the pack fill of individual product packs, multibags and cases by reducing surplus packaging. As well as saving packaging this also enables more compact packing product on pallets and in trailers generating further savings for haulage costs.
- Reducing the thickness of packaging while maintaining its barrier properties. Many primary wrappers are now less than 40 microns thick – that is less than half the thickness of a human hair!

Looking further ahead there is an expectation that local authorities will be able to improve their plastic recycling capabilities so that they will be able to recycle the plastic films that predominate in consumer biscuit packaging.

7.7 Other options for improving sustainability

7.7.1 Transport

Transport and logistics provide further opportunities for reducing carbon emissions and reducing costs. In addition to improving the case and pallet fill mentioned earlier, leading food manufacturers are working with suppliers, customers and even competitors to share transport networks and reduce empty running. For example, Nestlé and United Biscuits have won awards for their transport sharing arrangement, showing that while companies can compete on the supermarket shelves, they can co-operate together to save costs and emissions. United Biscuits generates over £1m a year in revenue from its transport sharing operations.

7.7.2 Sourcing

Consumers are increasingly interested in the sourcing of key ingredients for the products that they buy. Research shows that an increasing number are able to recognise the symbols for things such as Fairtrade and Rainforest Alliance that certify or endorse ingredients. Research also shows that while consumers value these things, they feel that they should come as standard and are reluctant to pay a premium for them.

For biscuits, consumers take for granted that most key ingredients, such as wheat, are produced sustainably. The ingredients that environmental/social campaigners are most concerned about in the biscuit sector are palm oil and chocolate.

The palm oil industry has been heavily criticised for rainforest clearance, the burning or draining of peat reserves and the destruction of the natural habitat of the orang-utan. To address this, the Roundtable for Sustainable Palm Oil (RSPO) has been established and includes both palm oil plantation owners, manufacturers and some campaigning bodies. The RSPO has established a certification system for sustainable palm oil and from 2009 volumes of certified sustainable palm oil have started to be delivered to western manufacturers. Some manufacturers are committing to using this sustainable product faster than others and while one biscuit manufacturer is using it already, most companies have committed to using it by 2015.

The chocolate industry provides an even greater challenge for biscuit manufacturers in sourcing terms as instead of large corporate owned plantations, the majority of chocolate is produced in very small family farms in West Africa. Even where this chocolate is then processed through larger cooperatives it remains extremely difficult to accurately gauge working practices on the ground. Even organisations such as Fairtrade struggle with auditing at individual farm level given the number of farms involved and poverty levels in the region. The focus from campaigners has been on confectioners but there is increasing pressure on biscuit manufacturers to seek some form of certification to give assurance that their chocolate has been sourced in a responsible manner.

8

Choosing materials for biscuit production

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Abstract: Can you identify the critical attributes of the material? There should be good liaison for ingredient supply between the buyer and the technical department.

Key words: ingredient specifications, labelling of supplies, critical attributes

8.1 Introduction

Selecting ingredients and packaging materials involves evaluation of both technical and cost aspects. It therefore requires liaison between the technologists and company buyers so while reading the following chapters on the various materials used in biscuit manufacture, technologists should remember that they should be able confidently to argue the case for a particular item with the commercial side of the business. It is probable that the purchasing manager may find the details described for materials helpful in his choice of supplier.

8.2 Important technical aspects

For each ingredient or packaging material the technologist should be able to answer the following questions:

- Does the specification of the material match the use(s) for which it is intended?
- Can you identify the critical attributes of the material?
- Will the material require special storage conditions?
- What will be the maximum storage life of the material, taking into account the packaging and storage conditions, that can be given at the biscuit factory?
- How will the material be used, is the form of packaging important to aspects of lifting, metering or resealing after some is used?
- What would be the ideal quantity to have delivered at each occasion and what should be the style of packaging?

8.3 Important commercial aspects

For each ingredient or packaging material the buyer should be able to answer the following questions:

- Who are the possible suppliers?
- Do the suppliers have experience in supplying this material and do they have adequate technical competence?

8.4 Programme for the meeting with a supplier

If at all possible both the buyer and the technologist should visit the supplier to see their facilities and thereby to better understand the service they can give. However, this may not be possible or practical at the first meeting. The meeting should aim to cover the following points which have a technical base.

- Discuss the material needed and how it is to be used.
- Communicate the desired specification.
- Communicate the problems that may arise if variations in the ingredient/material should occur.
- Understand the variations that are likely to occur either as a result of expected causes or through the supplier's processing limitations.
- Discuss the supplier's quality control procedures, including the tests and equipment used.
- Strike an agreement on what is required and what can be supplied.
- Agree to collaborate on standardising critical tests in each other's laboratories.
- Agree a material and packaging specification.
- Agree labelling of the material or documentation that will accompany bulk deliveries.
- Understand production code labelling.
- Agree procedures on both sides in the event of difficulties and situations of out-of-specification consignments.

Ask for a visit to the supplier's processing plant or store. At this time it will be possible to complete a working understanding of the process used and to form an impression of production management effectiveness and hygiene conditions.

Quality and process control management should work on the principle that if one starts right one is more likely to stay right. A careful consideration of what is wanted for smooth processing and selection of the most suitable and most reliable materials will make a considerable contribution to the efficiency and hence profitability of the biscuit factory.

Wheat flour and vital wheat gluten as biscuit ingredients

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Abstract: Wheat flour is the major component of nearly all biscuits. Its properties and, hence, suitability for biscuit making depends on the type of wheat used, on season to season variations within the same sort of wheat, and on the settings of the wheat mill. Generally soft wheat flour with mellow gluten properties is used for biscuit making. This chapter deals with wheat, the milling process, wheat flour and its constituents and highlights some important aspects for the miller and the biscuit manufacturer.

Key words: wheat, flour (constituents), starch (damage), gluten protein, arabinoxylan, ash.

9.1 Introduction

Wheat flour is the principal component of nearly all biscuits and major advances in technology of flour milling coincided with the development of biscuit manufacturing. Before the invention of roller milling for flour, the wheat was milled between stones. From this meal, it was difficult to separate the bran so the flour was dark and coarse in quality. The first roller flour mill was built in the 1840s in Budapest and the first in Britain was built by Henry Simons in 1875. At about the same time, silk bolting cloths were introduced so it was possible to separate the bran from the white endosperm (the white starchy centre part from which flour is derived) much more completely. The result was much whiter flour. Roller milling also enabled the germ to be separated better. The germ is the embryo of the wheat and is rich in oil. Milling liberates enzymes that break down the fat and cause it to become rancid. Thus, roller-milled flour has a much longer rancid-free shelf life than stone-ground flour.

The properties of wheat flour vary not only as a result of the type of wheat used to make it and from season to season variation from supposedly the same sort of wheat, but also depend on the settings of the wheat mill. The importance of wheat flour in world nutrition has resulted in a massive literature on the subject of wheat and wheat flour. Much of this literature refers to flour in its relationship to bread (see [1] for a review), where the influence of fats and sugars in the dough is minimal.

The properties of wheat flour in relation to biscuits are complex, so will be dealt with in some detail. In order to put the subject into perspective, only biscuit doughs

will be considered in detail and references will be cited for important accounts of the main analytical methods. Emphasis will be on 'weaker' flours, traditionally deemed most suitable for biscuit making, but other flours and means of tailor making special flours will be mentioned to give the biscuit technologist a broader idea of what is available.

9.2 Flour from the viewpoint of the miller

9.2.1 Wheat types

According to FAOSTAT [2], wheat is the second largest cereal crop grown in the world. While typically 820 million tons of maize are harvested yearly, the yearly wheat harvest can be estimated at about 690 million tons, which is comparable with that of rice (~685 million tons). Wheat grows everywhere except the arctic regions.

Of all the cultivated cereals, flour from wheat is almost unique in that it forms a dough. The only other flour where this happens, and not to anything like the same extent, is rye. The reserve proteins from wheat, i.e. the gluten proteins, are responsible for the dough forming capacity of wheat flour. Gluten permits the retention of gas bubbles during baking of a dough to give open textured and pleasant eating products.

There are a very great number of species and varieties of the genus *Triticum* (wheat), but we shall be concerned exclusively with varieties of *Triticum aestivum* known as common or bread wheat. *T. durum* (durum wheat) from which the best quality pasta is manufactured, is not included in the present discussion.

Where the climate is not too extreme and, particularly, where the winter is usually not too cold, winter wheat is sown. The seed is drilled in the autumn and some growth occurs before the ground freezes. However, in areas of more continental and extreme winter temperatures, the wheat is usually sown in the spring and is known as spring wheat. The difference is important because winter wheat varieties tend to have softer grains with lower protein content than spring wheat varieties.

Plant breeders continually produce new varieties of wheat. This has resulted in a constant change in types available for milling. Each new variety tends to maintain its superiority for only a few years. This is either because it succumbs to disease or is replaced by an even higher-yielding variety. Over the last decades, there have been spectacular improvements in the wheat yields per acre, in resistance to disease and in protein content and quality.

British wheat flour was traditionally considered to be ideal for biscuits because it had low protein content, which produced weak extensible gluten. This type of flour is not suitable for making good bread. Europe, until about 1960, imported Canadian and other high-protein wheats to make bread flours, a practice which has largely become obsolete since the increase in the cost of good bread wheats from North America in Europe.

Over the years, the quality of flour has been changing as a result of the wheat-breeding programmes. The aims of these programmes have been high yields and higher protein contents because these maximise farmers' profits and make the flour more suitable for bread doughs rather than having characteristics that suit biscuit doughs. Fortunately, as a result of adaptations of biscuit-making technology, there are still very good biscuit flours available but, as will be shown later, care must be

taken to ensure that a consistent quality of flour is used for any particular process. Whereas wheats can be classified as millable (or otherwise) and suitable for different end-product applications such as bread or biscuit making, an important point is that, on top of this classification, each variety shows further variation in its properties depending on the growing and harvesting conditions. Thus, from farm to farm and year to year, it is impossible to be certain what quality of flour will be obtained from any particular wheat variety.

Milling wheat can be described as hard, medium or soft, based on the physical characteristics of the wheat grain. Hard types tend to have high protein contents (10–14%), are in most instances spring wheats and have vitreous endosperms. When milled, the grain shatters and the starch granules are often damaged (see Section 9.2.6) resulting in high water absorption characteristics (i.e. the amount of water needed to give a standard consistency of dough). In contrast, soft wheats produce a more fluffy type of flour with less damaged starch and with lower water absorption. Their protein levels are typically low or very low (8–11%) and their protein gives gluten that is less elastic and resistant to deformation and more extensible before being broken. The position of medium wheat is evidently intermediate.

Canadian and American hard red spring (HRS) wheats are good examples of hard wheats. European winter varieties and some Australian and American soft red winter (SRW) wheats are examples of soft wheats. American hard red winters, Plate (South American), Russian and some Australian wheats are in the medium category.

The wheat grain, botanically known as a caryopsis (but often referred to as a berry) because the seed wall is fused with the wall of the ovary, broadly is composed of three parts: the bran, the endosperm and the germ (Fig. 9.1). From a botanical point of view, the term ‘bran’ refers to the outer layers of the wheat kernel, which are generally brown or reddish and preferably removed during milling. These outer

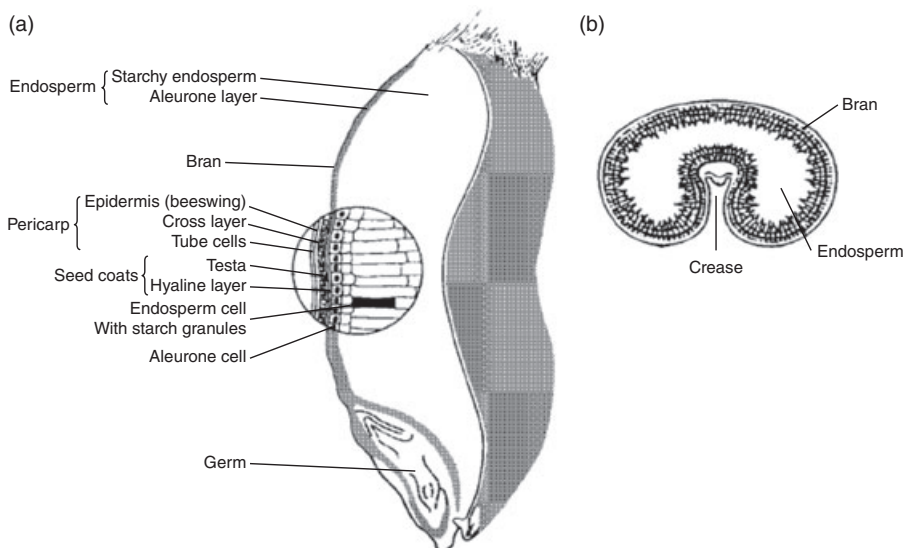


Fig. 9.1 Wheat grain: (a) longitudinal section, (b) cross-section.

layers are, from the outside to the inside of the kernel, the pericarp, the seed coat and the nucellar epidermis. The pericarp itself consists of several layers: the epidermis, the hypodermis, the cross cells and the tube cells. The total pericarp consists of about 6% protein, 2% ash, 20% cellulose and 0.5% fat [3]. The seed coat and the nucellar epidermis are, in fact, part of the seed itself, the former being firmly joined to the tube cells and to the nucellar epidermis. From a botanical point of view, the aleurone layer, which is generally one cell layer thick, is the outermost layer of the endosperm and, thus, is not part of the bran. However, because it is removed during milling, it has been referred to as part of what the miller calls 'bran' [4]. Indeed, commercial wheat bran comprises both the botanical bran as well as aleurone tissues. Wheat bran typically contains 45–50% dietary fibre, which is largely water-unextractable. The most important components of this fibre fraction are cellulose and water-unextractable arabinoxylan (WU-AX) [5]. The white or yellowish centre is called the endosperm and the minute embryo plant is known as the germ. Only the endosperm is useful as flour. One of the objects of milling, to produce white flour, is to separate the endosperm as completely as possible from the bran and germ. However, due to the form of the grain, which has an indentation down one side (known as the crease), complete separation is exceedingly difficult. Other grains like rice and barley do not have such a crease, so, in their case, a process known as pearling (peeling off the bran) is possible, but this technique is hardly used for wheat.

9.2.2 Production of flour

The milling of wheat is a very complex mechanical process aimed at optimum separation of its three components. The grain is first conditioned. This involves adding water and holding for a few hours so that the total moisture content is about 15%. The bran layers are then slightly wetter making them tough and less inclined to break up into small particles during milling. Then, the grain is nipped apart with grooved rollers (known as break rolls) running at different speeds. The aim is to keep the bran pieces as large as possible and to expose the endosperm which is subsequently pulled off the bran pieces in large particles. The larger and lighter bran pieces are separated by a combination of sieving and aspiration, and the endosperm pieces are then reduced progressively in size, by grinding with smooth rolls (reduction rolls), to the powder we know as flour. The particle size distribution of flour is important and is discussed below.

Depending on the nature of the wheat and the skill of the miller, flour which is more or less contaminated with bran is obtained. The germ is soft and richer in fats than either of the other two parts and during reduction of the endosperm to flour becomes rolled into flakes, which facilitates its removal by sieving. It is, however, inevitable that a small proportion of the germ particles also find their way into the flour.

As a rough guide, the bran comprises about 12% of the grain, the endosperm about 85.5% and the germ about 2.5%. If the extraction of the endosperm were perfect, the yield (extraction rate) of flour would thus be 85%, but this is never possible. The inclusion of minute particles of bran in the white flour makes the latter greyer in colour and spoils some of the dough-making attributes of the flour. For example, the gluten becomes less elastic and less 'lively'. In practice, therefore, biscuit flours have extraction rates between 72 and 76%. Whiter flours have only

70% extraction rates. Wholemeal flour is, by definition, almost 100% extraction. Such flours are very 'brown'. Intermediate flours, known as wheatmeals, are produced at other extraction rates (typically 84%). Except when made by stone milling, it is usual for all these brown flours to be made by adding bran back to white flour. In this way, a particular bran size range is controlled.

During milling, flour is obtained at a number of different places in the mill because the aim is to take away the milled endosperm as early as possible before it becomes contaminated with bran particles. Each mill stream of flour has a particular name and the miller can collect these separately or combine them all together before storing the flour. If the whiter fractions are stored separately, the rest of the flour is of lower quality. For most biscuit applications, 'straight run' flour, that is a complete set of flour fractions, is blended. The more recent interest in higher fibre contents in our food has greatly increased the use of wheat bran mostly in the form of brown flours. Bran is very high in dietary fibre and is a very good source of such fibre [6, 7].

During milling, particles of all sizes are formed. The fine particles are separated from the coarse and the coarse are sent to another set of rollers for further reduction. This means that, in normal milling, the range of the particles produced cannot be controlled. However, the maximum size can be determined by the size of the screens used to separate the flour. The maximum size of flour particles may vary from mill to mill and it is useful to know the effects of flour particle size on biscuit parameters. Clearly, the finer the particles, the higher will be the specific surface area and therefore the higher the water absorption. As biscuits are baked to low moisture levels, it can be assumed that less water in dough will save energy during baking. However, the effects are different for developed doughs, such as for hard sweet biscuits, and short doughs. Finer flour for hard doughs tends to give biscuits with a higher density and less development during baking, whereas finer flour for short doughs gives biscuits with lower density, more development during baking and less spread on the oven band (see Section 28.7). The mean particle size for most biscuit flours is around 50 μm with less than 10% more than 130 μm .

9.2.3 Wheat flour constituents

9.2.3.1 Starch

Starch is the most abundant component of wheat flour (*ca.* 70–75%). It occurs as granules and consists mainly of the two glucose polymers amylose (AM) and amylopectin (AP). AM is an essentially linear polymer, built up of α -(1,4)-linked D-glucopyranosyl units with a degree of polymerisation between 500 and 6000 glucose residues [8]. Its molecular weight (MW) ranges from 10^5 to 10^6 and only few (<1%) α -(1,6)-linkages are present. In contrast, AP is a highly branched polysaccharide with a MW of 10^7 to 10^8 , which has been reported as one of the highest known amongst naturally occurring polymers. It consists of chains of α -(1,4)-linked D-glucopyranosyl residues joined through α -(1,6)-linkages. There are three types of AP chains. The A-chains are outer chains and do not carry branches. The B-chains, in contrast, carry A-chains and/or other B-chains. Finally, there is one single C-chain per molecule which contains the only reducing residue. Nowadays, the cluster model for AP is widely accepted [9]. The AM/AP ratio differs between starches, depending on the botanical origin. For common wheat starch, AM contents from 17 to 29% have been reported [10].

Next to AM and AP, wheat starch also contains 1–2% minor components, which occur either at the surface of or inside the granule. The main minor components are lipids (0.8–1.2%) and proteins (<0.6%). The lipids associated with the starch are generally polar and prevalently occur inside the starch granules. The predominant classes are lysophospholipids, especially lysophosphatidylcholine, and free fatty acids. They can occur either free or as amylose-lipid (AML) complexes. The starch surface lipids are mainly glycolipids and triacylglycerols [11]. Starch associated proteins occur mainly at the surface of the starch granules, although starch granule internal proteins have been reported. Some of the starch surface proteins, the so-called puroindolines, have received special attention, because they are believed to play an important role in wheat kernel hardness [12] and, hence, in its milling properties. Mineral fractions are only present in very limited levels except for phosphorus present in the phospholipids and nitrogen (<0.05%) originating from enzymes involved in starch synthesis [3].

Starch in wheat flour, when undamaged (see Section 9.2.6), occurs as semi-crystalline granules that are present as such or make up part of the flour particles when they are embedded in gluten. In wheat, two types and sizes of starch granules can be distinguished. The large, lenticular (A-type) granules have dimensions of ~25–40 μm , while the small, spherical (B-type) granules have a diameter of typically up to ~10 μm . Native starch granules show birefringence when they are microscopically viewed under polarised light. This feature can be observed as a typical Maltese cross which indicates a highly ordered arrangement of the macromolecules within the granule. Additionally, the typical X-ray diffraction (A-type) pattern of native wheat starch granules indicates partial crystallinity (ranging from 20 to 40%), due to the orderly packing of adjacent branches of the AP components.

When sufficient water is added to starch at room temperature, the insoluble starch granules can absorb up to 30% of their dry weight of water and, thereby, swell slightly (*ca.* 5% volume increase). Below a characteristic temperature, known as the gelatinisation temperature, this process is reversible. When the starch suspension is heated at or above this temperature, the molecular order of the granules is irreversibly destroyed by a process termed gelatinisation [8]. The structural changes that occur during gelatinisation include changes of shape and size of the granules (swelling), water absorption, melting of the crystallites and the progressive solubilisation of the starch. For a single starch granule, these changes, leading to loss of birefringence, occur within a narrow temperature interval (<1°C), while for a population of starch granules, they occur over a much wider temperature range (7–10°C), indicating that gelatinisation takes place granule per granule.

The events that occur following starch gelatinisation during further heating are referred to as pasting. These include further swelling of the granules, granule distortion, AM leaching out of the granules and continued water uptake by the granule remnants. These phenomena contribute to a significant viscosity increase. It is said that a starch paste is formed. During starch gelatinisation and pasting, the presence of free starch lipids may give rise to AML complex formation.

During cooling of the amorphous starch paste, the starch polysaccharides reassociate to a more ordered (or even crystalline) structure. After few hours, very stable AM crystallites are formed between the AM molecules that were leached during pasting (gelation). The recrystallisation of AP side chains, often referred to as retrogradation, is a much slower process requiring several days or weeks and takes place within the gelatinised granules or granule remnants.

9.2.3.2 *Proteins*

Soft wheat flour, used for cookie making, typically contains 8–11% proteins. Based on their functional properties, the flour proteins can be divided into two distinct groups: gluten and non-gluten proteins. Fractionation of wheat proteins in many instances is done using Osborne-type procedures [13].

The non-gluten proteins (~15–20% of total wheat protein) form a highly heterogeneous group containing albumins (water-extractable) and globulins (unextractable in water, but extractable in dilute salt solutions). These are mainly monomeric proteins with a MW lower than 25 000, although a significant proportion has a MW between 60 000 and 70 000 [13, 14]. Most non-gluten proteins are physiologically active (enzymes or enzyme inhibitors) or structural proteins. Albumins and globulins are generally found in higher levels in the aleurone cells, bran and germ and in somewhat lower levels in the wheat endosperm. They are relatively high in lysine, tryptophan and methionine [3]. The gluten proteins (~80–85% of total wheat protein) are the major storage proteins of wheat. They occur in the endosperm of the mature wheat grain where they form a continuous matrix surrounding the starch granules. They show very low solubilities in water or dilute salt solutions, due to their low levels of amino acids with ionisable (charged) side chains and high hydrophobicity. Gluten proteins are characterised by rather high levels of glutamine (~35% of the total protein) and proline (~14% of the total protein) and can be divided into gliadins and glutenins [15, 16].

Gliadins are a highly heterogeneous mixture of monomeric proteins with a MW between 30 000 and 80 000. They are readily extractable in aqueous alcohol solutions (e.g. 70% ethanol) and are, therefore, the main components in the Osborne prolamin fraction. Based on their electrophoretic mobility, three types of gliadins are distinguished: α - (α/β -), γ - and ω -gliadins [16, 17]. They either lack (ω -gliadins) or have three (α -gliadins) or four (γ -gliadins) intramolecular disulfide bonds [18].

Glutenins are a heterogeneous mixture of polymers with a MW up to several millions. They are unextractable in aqueous alcohols but extractable under dilute acid conditions. The glutenin polymers are made up of disulfide-linked glutenin subunits (GS) which can be released with reducing agents such as β -mercaptoethanol or dithiothreitol [14, 18]. GS are biochemically related to the gliadins and extractable in aqueous alcohols. Two types of GS can be distinguished based on their electrophoretic mobility in SDS-PAGE: high molecular weight GS (HMW-GS) with MW from 65 000 to 90 000 and low molecular weight GS (LMW-GS) with a MW ranging from 30 000 to 60 000 [13]. So far, more than 20 different HMW-GS have been detected in different wheat varieties. Generally, three to five of them are found in a single common wheat variety. LMW-GS make up ~60% of the glutenin and are more hydrophobic than HMW-GS. More than 40 different LMW-GS have been detected in different wheat varieties. The estimated number of different LMW-GS in a single wheat variety varies from 7 to 16 [14].

The structure of glutenin, as an essentially linear and polydisperse protein, has been the subject of many studies. It is generally assumed that both LMW-GS and HMW-GS are involved in the glutenin structure and that (nearly) all sulfhydryl moieties are involved in disulfide bonds. Also, it has been postulated that the association of the different GS is not random but leads to a rather linear polymer with some branches in the structure [19].

9.2.3.3 *Minor constituents*

9.2.3.3.1 Non-starch polysaccharides

For cereals, the term non-starch polysaccharides generally refers to cellulose, arabinoxylan (AX), β -D-glucan and arabinogalactan peptides (AGP). They differ from starch in that they are not present as insoluble granules, in their building blocks and/or the way the latter are linked to each other. Cellulose occurs in cereal pericarp, but is (mainly) absent in wheat endosperm and, hence, in wheat flour.

The other non-starch polysaccharides are often referred to as hemicelluloses. They are present in the cell walls of the endosperm and bran tissues [20]. In wheat flour, AX are predominant (1.5–2.5%) and are either water-extractable (WE-AX, typically 25–33% of the 1.5–2.5%) or WU-AX. Although they both form a polydisperse group of molecules, a general structure applies. This enforces the belief that the WE-AX are building blocks or precursors for the WU-AX. AX are made up of a backbone of β -(1,4)-linked D-xylopyranosyl residues, which can be substituted with monomeric α -L-arabinofuranoside at the C(O)-3 or C(O)-2 position. Ferulic acid can be coupled to the C(O)-5 of arabinose through an ester linkage [21]. An important parameter of AX is its arabinose to xylose ratio, which typically averages 0.5–0.6 for the WE-AX population. The fine structure of WU-AX after alkaline extraction (AS-AX) basically resembles that of WE-AX, with only slightly higher MW and arabinose to xylose ratios for AS-AX than for WE-AX.

AX has unique physico-chemical properties. WE-AX and AS-AX yield highly viscous solutions, the viscosity of which depends on AX chain length, substitution degree, substitution pattern, degree of cross-linking (through oxidative gelation with coupling of ferulic acid moieties) and whether or not they interact with proteins present in the extract [21]. WE-AX would also stabilise protein films against thermal disruption, a phenomenon which has been attributed to increased liquid viscosity and mediation of interactions between proteins in the absorbed layer. WU-AX, on the other hand, have a strong tendency to absorb water and swell [22]. Thus, while WE-AX directly influence dough liquor by increasing viscosity, WU-AX rather indirectly impact dough viscosity by their high water-binding capacity.

Wheat flour AGP has a MW of ~23500 and is present in wheat in lower concentrations (~0.3%) than AX. A structural model for AGP has been put forward [23].

9.2.3.3.2 Other minor constituents

Wheat flour contains approximately 2% lipids with comparable levels of polar and non-polar lipids present. In flour from the starchy endosperm, they can be divided into starch granule associated lipids (see above) and non-starch lipids [24]. The non-starch lipids comprise ~75% of the flour lipids and consist predominantly of triacylglycerols, as well as of other non-polar lipids, glycolipids such as digalactosyl diacylglycerols, and phospholipids.

Wheat flour also contains small levels (<3%) of mono-, di-, and oligosaccharides such as glucose, fructose, sucrose, raffinose and glucofructans.

Wheat is also a good source of vitamins B1 (thiamine), B2 (riboflavin), B6 (pyridoxine), niacin, pantothenic acid and tocopherol as well as of iron and zinc. However, because most of these fractions are concentrated in the aleurone layer, a significant proportion is lost during milling [3].

9.2.4 Ash content and colour of flour

A primary classification of flour can be based on the level of bran it contains. As seen from the chemical compositions of the major wheat components in Table 9.1, bran contains more mineral matter than the other fractions, making ash content a means to define flour types. In mainland Europe, flours are classified by ash content which evidently relates to extraction rate (Table 9.2). It can be seen that the classification for German flour relates to average ash percentage $\times 1000$. The method for assessing ash has been described in Kent-Jones and Amos [25].

Importantly, classification based on ash content does not reveal much about the flour performance which is closely related to protein quantity and quality. Since the ash constituents of wheat originate from the minerals of the soil, it is evident that both the total mineral content as well as that in the bran will depend to a certain extent on the soil and climatic conditions during growth. As regards assessing the ash content of flour, the situation in the UK, for example, is further complicated because there is a legal requirement to add minerals to flour (see Section 9.2.10) so determination of natural ash content is not possible. An alternative and much simpler test for quality is to measure the brightness or reflectance of a flour-water slurry with a 'colour' grader. The Kent-Jones grader [25] gives values ranging from less than 0 for the brightest flours to around 8 or 9 for wheatmeals of 85% extraction. Figure 9.2 shows the approximate relationship between ash content and grade value of flour. Grade values of 1–2.5 are typical for bread flours and 2–6 are common for most 'white' biscuit flours.

Table 9.1 Composition of endosperm, germ and bran (commercial samples) [26]

	Endosperm (%)	Germ (%)	Bran (%)
Moisture	14.0	11.7	13.3
Protein	9.6	28.5	14.4
Fat	1.4	10.4	4.7
Ash	0.7	4.5	6.3
Carbohydrate by difference	74.3	44.9	61.4
Starch	72.0	14.0	8.6
Hemicellulose	1.8	6.8	26.2
Sugars	1.1	16.2	4.6
Cellulose	0.2	7.5	21.4
Total carbohydrate	74.1	44.5	60.8
Recovery of fraction	99.8	99.6	99.4

Table 9.2 Classification of flours in mainland Europe

European Union flour type	German flour type	Ash (% on dry basis)	Approx. extraction rate (%)
1	405	<0.50	Up to 55/60
2	550	0.51–0.63	Up to 65/70
3	812	0.64–0.90	Up to 75/80
4	1050	0.91–1.20	Up to 80/85
5	1600	1.21–1.80	Up to 90/95
6	Whole wheat	Approx. 2.0	100

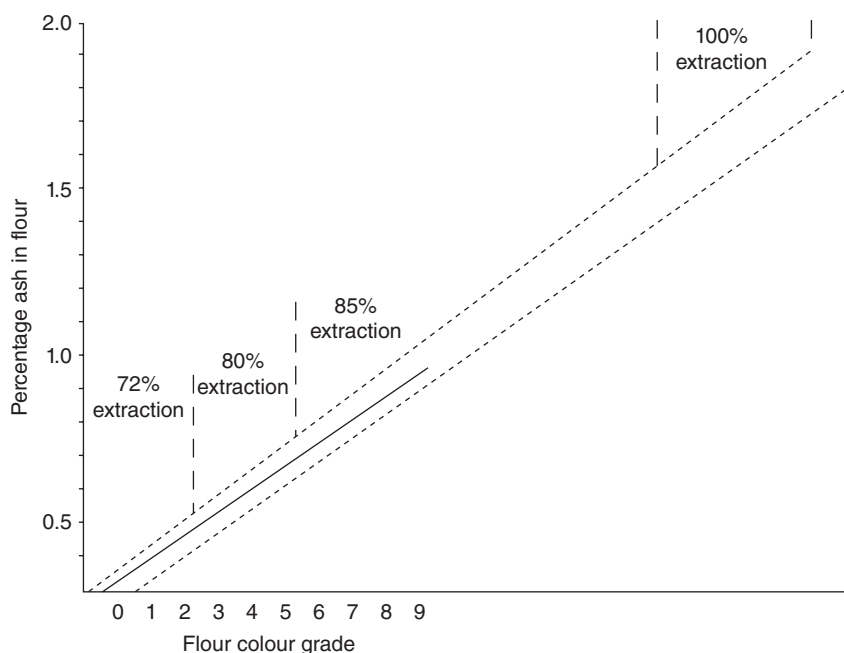


Fig. 9.2 Diagrammatic relationship between ash content of flour and flour colour grade.

The ash value is determined by a combustion test which takes several hours, the colour grade is determined by measuring the reflectance from a flour-water batter and takes only minutes. More recently, an instrument known as Branscan has become available which measures the bran in a flour sample by image analysis. The instrument measures the number and size range of dark specks in a dry flour sample [27].

9.2.5 Protein content of flour

Much importance is attached to the flour protein level, though the quality of the gluten that this protein gives in a dough is probably of more importance for biscuits (see Section 9.2.11). By blending wheats it is theoretically possible for the miller to obtain almost any desired protein level between 8 and 13%. The meaning of this protein level should be viewed with caution because the way in which it is calculated is important. The nitrogen content of protein from the endosperm is about 17.5% of the protein, so multiplication of the nitrogen value determined by Kjeldahl testing [25] or Dumas combustion analysis by 5.7 will give the total protein level. Tkachuk [28] suggested multiplication factors of 5.6 for flour and 5.7 for whole wheat, respectively, but the generally recognised factor is 5.7. The protein concentration in flour can also be estimated by near infra-red reflectance (NIR). The protein in the outer branny layers, which does not form gluten, has a lower nitrogen content and a factor of 6.25 or 6.30 is used to estimate protein in branny materials for animal feed.

Some idea of the gluten quality may be obtained by washing away the starch from a flour-water dough. This leaves a ball of gluten which can be manipulated to

give a rough indication of the extensibility and resistance qualities. The weight of gluten obtained from a given weight of flour in this way, known as wet gluten, is not a reliable estimate as the efficiency of starch washing and the water content of the gluten are indeterminate variables. However, protein determined by the Kjeldahl method (the standard method) on a sample of flour can be related to the wet gluten value by multiplying by a factor of 2.6–2.9. Multiplying the wet gluten value by 2.2–2.5 will give an estimate of the protein content of the flour on a dry basis. ‘Wet gluten’ values should be used with great caution, but it can be seen that good biscuit flour should have a wet gluten value of about 26%.

9.2.6 Starch damage in flour

It has been found that, in the process of milling, as the endosperm is fractured and then crushed, some of the starch granules are physically damaged. Starch damage has a profound effect on the water absorption behaviour of the flour when a dough is made. This is because, with an excess of water present, the protein absorbs twice its weight of water, undamaged starch grains 33% of their weight and damaged starch grains exactly their own weight of water. Thus, both the protein level and the level of damaged starch have a large effect on the water-absorbing properties of the flour.

The miller can change the level of starch damage in flour as it is being produced by increasing the grinding pressure on the reduction rolls. The starch is most easily damaged in hard vitreous wheats (least suitable for biscuit making) and the level of damage is of great importance to bread making. For biscuits, since the finished product must be almost completely dry, the amount of water used to make the dough should be a minimum, so flours of low water absorption and hence low protein and low starch damage are to be favoured. As it happens, it is more difficult for the miller to change the level of starch damage in soft wheat flours. The condition of the mill machinery and the form of the mill have some influence and, for this reason among others, there is a strong case for always obtaining flour for a particular product or process from the same mill to improve the chance of consistent quality.

Determination of the level of starch damage is based on the fact that fungal alpha-amylase enzymes, under standardised conditions, can attack only the damaged granules of starch. This fact is of great significance to bread makers, but is not of much significance for biscuit manufacturers except where wet doughs like cracker sponges are left to stand or ferment for long periods.

9.2.7 The skill of the flour miller

The miller is required to produce flour of a particular type or quality with characteristics as consistent as possible from day to day or mill run to mill run. He achieves this by blending many different parcels of wheat whose properties he has tested so that the protein content of the flour is as required. The mixture of wheats is known as the grist. Using his skill in dampening the wheat, he will produce a flour of correct moisture content even allowing for differences in atmospheric humidity that will affect the stocks as they pass through the mill. By setting the mill correctly, he can achieve a desired extraction rate (economically important) with flour of correct ash content or colour, and starch damage value.

Bread and biscuit flours have very different specifications, so when a mill is changed from one to the other, many factors must be changed and flour produced over the period of change (mills run continuously) will be of intermediate properties for some time.

9.2.8 Flour moisture

The moisture content of wheat and, subsequently, flour is important for a number of reasons. If the grain is not dry enough after harvesting, it will sprout or rot in store. It may heat up and spoil as a result. In conditions of poor harvest, grain must be dried and if the temperatures experienced by the grain are too high, the protein will denature such that, when part of flour, it will not hydrate to produce gluten. Such grain is unsuitable for milling. The miller can test for the presence of heat-damaged wheat. If the grain has sprouted in the field or after harvesting, there will be a dramatic increase in the enzymatic activity. This will pass into the flour if the wheat is used for milling. High amylase (and peptidase) activity is unsatisfactory in flour that is to be used for fermented doughs.

By accepted definition, the moisture content of wheat, flour, biscuits, etc., is that water which can be driven off if a sample of about 5 g is heated at a temperature between 100 and 105°C for at least 5 hours. After drying, it is necessary to cool the sample in a desiccator. The weight loss is determined with an accurate balance. In practice, it is unlikely that a moisture estimation accurate to better than 0.1% can be achieved. More rapid methods have been devised. In addition to shorter times in warmer ovens, there are electronic methods which involve measurement of changes in, for example, electrical conductivity, dielectric properties, absorption of infra-red light, that occur as the moisture content changes. They are mostly non-destructive and more or less instantaneous. It is important to remember that all alternative methods for moisture estimation must be calibrated against the standard oven-drying method and that they generally are somewhat less accurate than the standard oven-drying method.

The miller will aim for moisture contents in the flour of ~14.5% and he will obtain good flour at acceptable extraction rates if the flour falls within the range 13–15%. Obviously, the miller might aim at 15% moisture. However, very damp soft wheat flour will not flow well in the mill pipework and blockages may occur. Also, flour that contains over 14.5% moisture will not store well for more than a week or two. The reason is that mustiness due to mould growth will develop. Flour around 13% has the best storage properties under cool dry conditions, but it is usual to use flour at around 14%. Figure 9.3 shows the relationship between flour moisture and the equilibrium relative humidity (ERH), or a_w (see Section 41.4.1). If the conditions are at a humidity significantly different from the ERH for a sample of flour, loss or gain of moisture will occur.

It is possible to find flour dried to much lower levels than 13%. These are made specifically for long-term storage. If lower than 10%, it is necessary to store the flour in moisture-proof containers, otherwise it will absorb moisture from ambient damp air.

Figure 9.4 shows the difference in moisture content between successive 15-tonne road tanker loads of two biscuit flours arriving at a biscuit factory. The two flours were from two different mills but each was supposed to be of consistent quality. It can be seen that a very large number of the deliveries differed by less than 0.4%

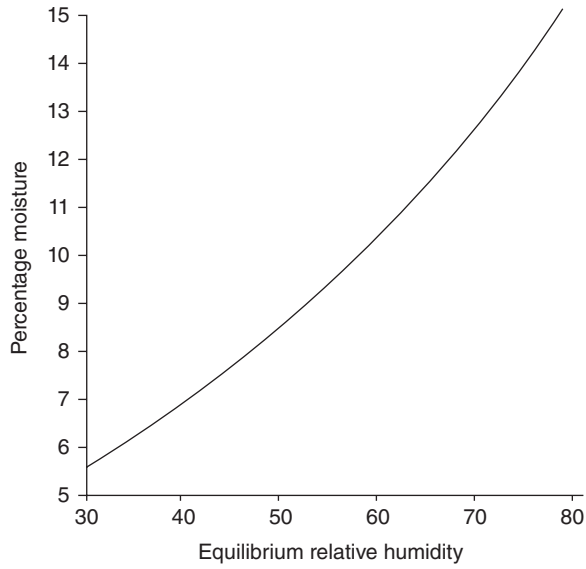


Fig. 9.3 Relationship between flour moisture level and the equilibrium relative humidity.

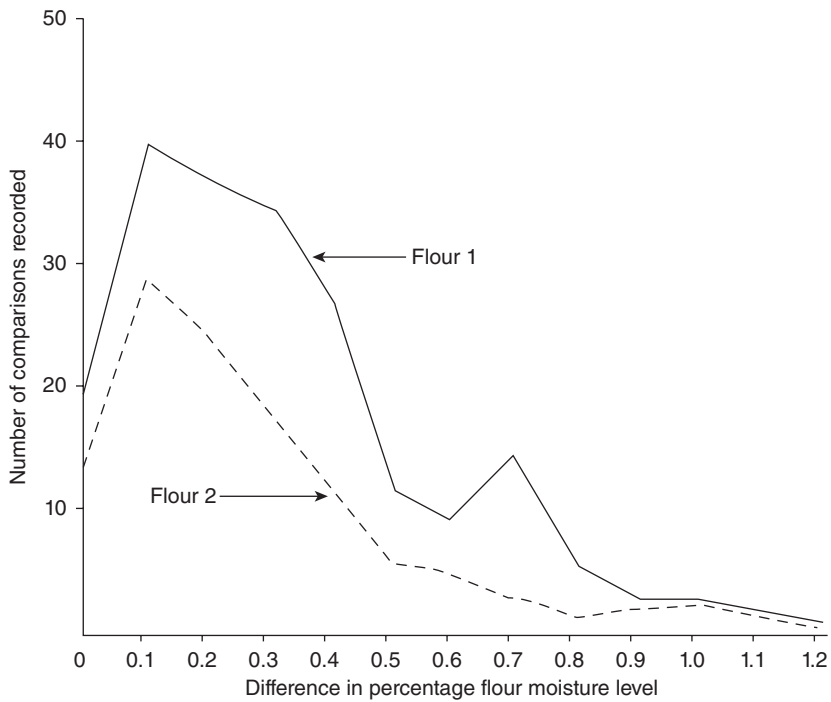


Fig. 9.4 Differences in flour moisture level between successive pairs of tanker deliveries.

moisture content which would have had a negligible effect on the water level needed to give doughs of uniform consistency. For normal systems, it is doubtful whether the variations caused by flour moisture changes are significant compared with inaccuracies in the precision of water and flour metering.

9.2.9 Different flour types

In addition to changes to the flour that the miller can achieve by adjusting the blends of wheat both from the point of view of protein content and hardness of the grains, there are other technologies of tailoring flours for special purposes.

By selecting the best flour from the head of the mill, a very bright flour with minimum bran is obtained. This is known as patent flour. Flour with heat-treated germ added (the germ is heat-treated to inactivate the lipase) gives the well-known Hovis and Vitbe type flours. Chlorination of flour impacts both its protein and its starch. As chlorine is absorbed by the flour, the pH drops and it is by measurement of the acidity that the level of chlorine treatment is controlled. Slightly chlorinated flour is widely used in the USA but cannot be used in EC countries. It controls the spread of short doughs in the oven. The use of chlorine also effectively increases the water absorption characteristics. Flour that has been heated or milled from heated wheat also has (part of) the protein and enzymes denatured. Such flour was developed for thickening soups where strands of gluten and high micro-organism counts are undesirable. There has been an increased use of heat-treated flour as an alternative to chlorinated flour for high ratio cakes and in certain biscuits. Heat-treated flour may be called 'inactivated flour'. The treatment may be severe, denaturing all the protein, or just gentle thus modifying the properties of the flour a little. Flour with baking powder added is called self-raising flour.

Figure 9.5 shows the particle size range of a typical biscuit flour. It is important to note that the particle size distribution is not normal in statistical terms. This is

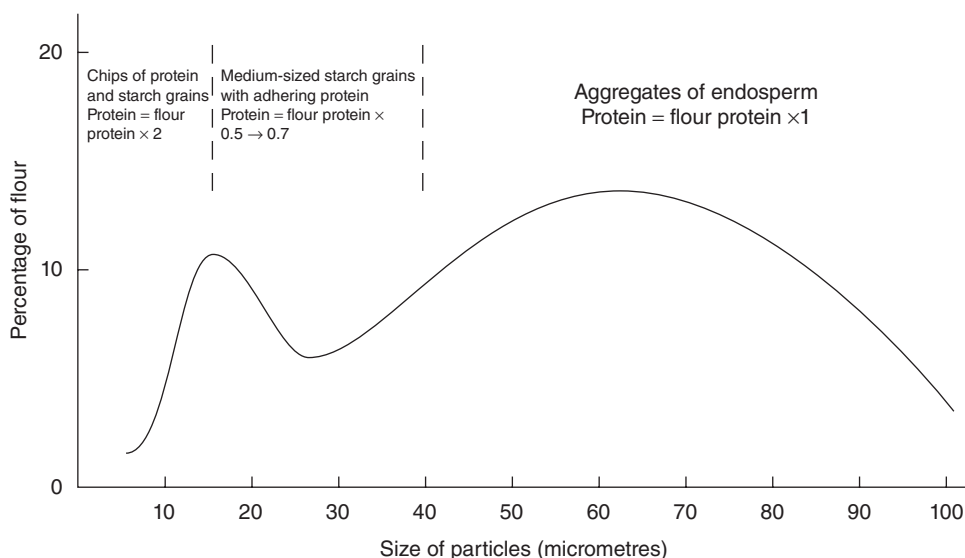


Fig. 9.5 Flour particle size distribution of a typical biscuit flour.

because, as was explained earlier, the flour also contains free starch granules. In principle, the particle size range can be altered by the miller by changing the screens used to take the flour. However, it is not a realistic option to ask a miller to provide flour with a specific particle size range that is different from his norm. There is a case for using coarser flours for short dough biscuits, as will be described in Section 28.7, but the effects are best achieved by other means than the coarseness of the flour.

Air classification is a technique for obtaining flour fractions of higher or lower than normal protein content. The process involves blowing flour through a centrifuge so that the differential air drag allows the collection of flour particles in specific size ranges. The flour particles are indeed conglomerates of starch granules embedded in a protein matrix. In the production of flour, the smallest particles are rich in chips of the matrix and individual starch granules (particles with a size range of about 0–15 µm). The protein level in this fraction is about twice that of the parent flour. Particles between 15 and 40 µm are rich in medium-sized starch granules with a little adhering protein. The protein level of this fraction is only about 50–66% of that of the parent flour. Above 40 µm, the particles consist of pieces of the endosperm as it is found in the wheat berry. The starch is still embedded in the protein matrix so the protein level here is the same as that of the parent flour. It will be appreciated that by air classification the miller can adjust his flour protein level up or down.

9.2.10 Flour treatment

In addition to the very special treatment with chlorine gas to make cake flour, various other additives and processes may be used in the mill to change the flour or to comply with statutory requirements. Most of these treatments are associated with bread flours and as the legal situation is changing, the reader is referred to other sources for current permissibility.

Of particular interest is the legislation in Britain dating from nutritional requirements in the Second World War. The flour in Britain must be fortified with finely powdered chalk – called *creta preparata* – at the rate of 2.35–3.90 g per 1000 kg flour. In practice, it is very difficult to achieve an absolutely homogeneous blend of this material with flour. Also in the UK, it is required to add 16.5 g iron (as ferric ammonium citrate or ferrous sulphate), 24 g of thiamine and 16 g nicotinic acid per 1000 kg flour. It will be appreciated that, with these additions, it is not possible for British flour to be tested with an ash test to determine basic quality. Certain other countries also require additions to flour for nutritional reasons.

Freshly milled flour changes in its physical dough-making properties during the first one to two weeks. This is due to oxidation and is an effect which is less desirable for most biscuits. There is not much that can be done about this, but the fact should be remembered that very fresh flour and the same flour stored for a couple of weeks will have different properties.

9.2.11 Protein quality

This is the factor of most interest to biscuit makers in the context of flour quality and unfortunately the characteristic that causes most difficulties as it is so difficult to define and test. Protein from different wheat varieties, and even from the same

variety grown under different conditions, exhibits considerable differences when it is hydrated and formed into gluten. The gluten may be strong and difficult to stretch, but very elastic, or weak and easy to stretch, extensible but not very elastic. The former is preferred for bread and some crackers, the latter for biscuits. There is a tendency for the high-protein flours to have strong gluten and for the low-protein flours to have weak gluten. By using oxidising or reducing agents, it is possible to respectively strengthen or weaken gluten a little. The use of peptidase can also result in weaker gluten, but the chemistry is different as is described in the section on enzymes in Chapter 16.

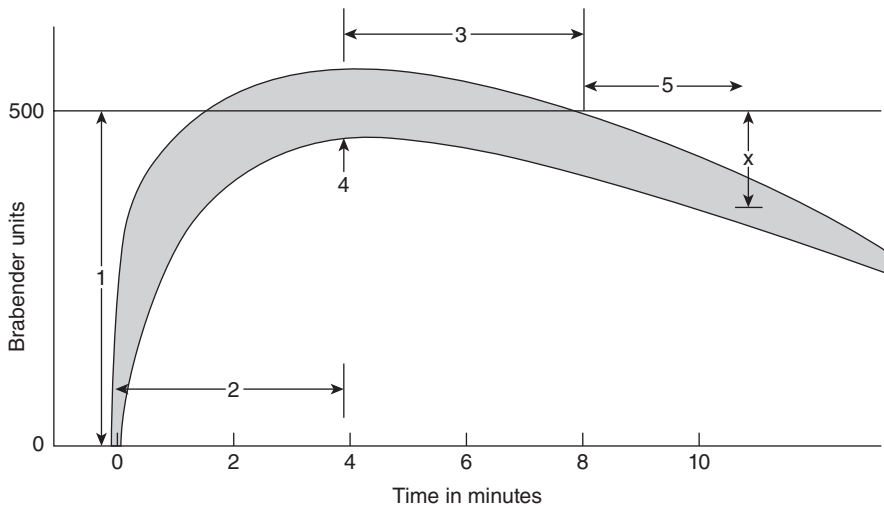
Practically, the quality of dough and the gluten contained in it can be tested with a variety of rheological instruments. These fall into three main groups. Those that show the effect of water on the dough consistency are used to determine the flour water absorption, those used to stretch a mass of dough to measure its resistance and extensibility until the strand breaks and finally, and those involving heat which measure the slackening of a dough or batter and hence give a measure of the enzyme activity of the dough.

Bread has a very simple recipe of flour, water and salt and maybe a little fat. The water absorption of bread flour is of great importance, not only because the correct water level gives the best rise in the oven, but also because it affects the final moisture of the loaf. Biscuits have significant additions of sugar, fat and other ingredients that affect dough consistency. Unfortunately for biscuit makers, nearly all the research on flour quality by rheological testing has been done with simple flour/water/salt systems which are not easy to relate to biscuit recipes.

It is useful to know what one can measure by using a Brabender Farinograph and Extensograph or a Chopin Alveograph. These instruments are well described by Kent-Jones and Amos [25]. It may be that the use of one or more of these instruments may be useful for quality control of flour in a specific biscuit recipe, but there is very little published work on this. In general, the research from these instruments cannot be used as a basis of process control in biscuit making. They may, however, still be useful for monitoring changes in the quality of flour from deliveries or suppliers or through a year. The Brabender equipment is widely used, but the Chopin instruments are favoured principally in France. The Brabender equipment, particularly the Farinograph, is a much more universal piece of dough-testing equipment. It is used widely for bread doughs, but is not commonly used for testing biscuit doughs.

Figure 9.6 shows a typical Farinogram (a result from the Farinograph) and Fig. 9.7 shows the shapes of curves from strong and weak flours. It will be seen that the change in dough consistency during mixing at a controlled temperature gives information about the development and stability of the characteristics. Similar curves can be obtained with biscuit doughs which include other ingredients, such as sugar and fat, and, from these, some information can be gleaned about optimum mixing times.

Manley at Baker Perkins [29] developed a mixer power monitor which can be used on any type of mixer with an appropriate current transformer. The purpose of this instrument is to follow the development curve of dough mixing. To a certain extent, it is possible to correlate the mixing of biscuit recipes on a small laboratory mixer with a full-size mixer in the factory. Best comparisons are made when mixers of different size but similar action are used. Even then, mixer size and beater speeds have large effects in scale up.



1. Dough consistency, Brabender units
2. Dough development time, minutes
3. Dough stability time, minutes
4. Dough elasticity, Brabender units
5. Dough weakening time over x Brabender units

Fig. 9.6 Analysis of a Farinogram.

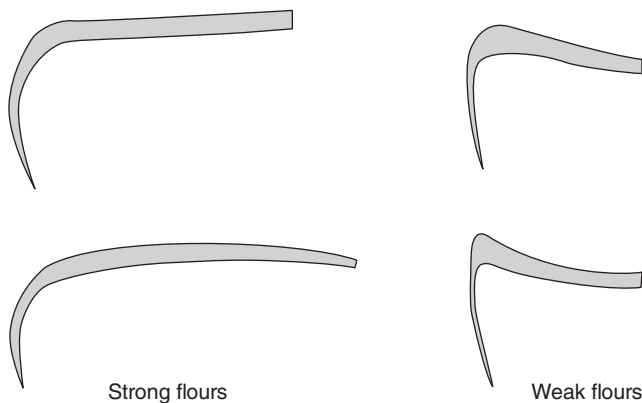


Fig. 9.7 Typical Farinogram outlines to show extremes of differences between flours.

The principal reasons for wanting to know about flour quality in biscuit doughs are firstly to produce repeatable consistencies, appropriate to the forming method and machinery, and, secondly, to give satisfactory biscuits. This application of dough-testing is hardly likely to be of interest to the miller since he can reasonably argue that he has control neither over the other ingredients in the recipe, nor over the effects of baking.

9.2.12 Foreign matter in flour

Unfortunately, flour is by no means sterile and free from foreign matter. The nature of wheat, the conditions of harvesting, storage and cleaning prior to milling, all have a bearing on what 'extras' can be found in it. It is as well to be aware of what might or will always be present.

Bacteria and fungi abound in astronomical numbers in soil, and as dust from the fields is present on the wheat, it is not surprising that wheat is rich in microflora as well. Sieler [30] has carried out several surveys on the size and nature of the microbial population in flour. He has shown that the counts are greatest in new crop flour and decline somewhat through the season. This is particularly the case for fungal spores. Baker [31] showed that flour milled from washed wheat is not significantly different in respect of micro-organisms from flour from unwashed wheat. It is reasonable to assume that all flour will have a very rich microbial population and this has a bearing on doughs that are stood or fermented for long periods.

Wheat that has been stored badly may attract infestation in the form of rodents, birds and insects. It is extremely difficult for the miller to remove all the products of this infestation and traces will therefore probably be found in the flour. The USA introduced a test for this type of contamination, known as the Filth Test (although it is really a purity test!). The test method is given in Kent-Jones and Amos [25] where there are some good photographs of the things that may be retrieved and seen with a microscope. Limits were set such that any flour or baked products imported into the USA must have fewer than specified numbers of rodent hair, insect and bird feather fragments. It is felt that the legislation was somewhat harsh and probably made more so with a view to political than public health considerations. However, it does point out some important facts. Firstly, unpleasant or pathogenic organisms are common in most flour, so it should not be eaten without baking. Secondly, contamination occurs wherever wheat is stored, throughout a flour mill and possibly where flour is stored. It is not possible, therefore, for a miller to offer any sort of assurance in respect of the Filth Test unless he knows the history of the harvested wheat and he is always attending to the condition of his wheat and mill.

More important in respect of infestation of biscuit flour is the occurrence of insect eggs, particularly of the Mediterranean Flour Moth, weevils and mites. These may be picked up in an infested mill and will pass on with the flour. Most millers use a machine known as an entoleter at the final flour stage. This flings the flour from a disc against the machine wall and thereby destroys the insect eggs. Whether this is 100% effective or not can well be questioned because it is still common to find moth and sometimes other insects developing in flour stored in an otherwise clean flour store at a biscuit factory.

Infested flour is, at the very least, unpleasant and much care should be taken to prevent infestation by storing flour for minimum periods before use, cleaning out all dead spaces in the flour system regularly, fumigation at frequent intervals with safe insecticides and rejection of all deliveries or stocks found to be infested. Infestation will quickly spread to sound stock if these procedures are not followed. It is almost impossible to sterilise flour which has become infested without affecting quite drastically its quality for baking.

9.2.13 Packaging, storage and delivery

Flour from the mill is usually stored in silos which contain many tons. In many cases, the temperature of this flour is typically about 22–25°C and it is very difficult to

raise or lower it. The miller will have obtained the desired quality of flour by blending wheats, but sometimes blending of flours also occurs. This is carried out between the silos and at the point of bagging or discharge into bulk tankers for delivery.

Flour is usually bagged off in multiwall paper sacks which are sealed by sewing. The bulk of flour is taken from the mill in bulk via a road or rail tanker. These containers are filled by gravity immediately before dispatch from the mill. The flour is transferred at the factory pneumatically using a blower mounted either on the tanker or in the factory buildings. The density of flour is referred to as packing density for it is inevitable that some air is included. The packing density is around 487 kg per cubic metre (31 lbs per cubic foot), but this varies greatly due to the different way in which flour settles. Strong flour from hard vitreous wheat has a higher density than weak flour and standing in a silo or as the bottom bag in a stack results in increased packing density.

9.3 Flour from the viewpoint of the biscuit manufacturer

9.3.1 Function of flour in biscuits

Flour is the main ingredient in most biscuits. It does not contribute much flavour, except perhaps where bran is included. It does contribute strongly to the baked texture, hardness and shape of biscuits. The nature of these effects differs for different biscuits related to the enrichment with fat and sugar and to the way in which the dough has been mixed. More details will be given where the different types of biscuits are described, but the principal property of flour of interest to biscuit makers is the quantity and quality of protein and thus of the gluten that is formed when the flour is mixed with water.

Most biscuits can be made from flour that has a low quantity of protein and gluten that is weak and extensible. Thus, flour with a protein level of less than 9.0% is best and levels of more than 9.5% often create processing problems. The exceptions are fermented cracker doughs and puff doughs where a medium strength of flour is needed, with protein values of 10.5% or more. If the ash content of a white flour is too high, the function of the gluten during baking is impaired and the biscuit may look grey. To a certain extent, the quality of the gluten can be adjusted by additives and processing techniques.

The problems of specifying flour quality for biscuit making have already been described. They rest very much on the recipe of the product and the effect on the baked biscuit. An important aspect to the baker is the consistency in quality of the flour he uses. What a baker does not like is varying flour and, for this reason, it is strongly recommended that a close liaison is maintained between miller/supplier and baker so that each understands and is informed of the other's problems. It is best to keep to one grade from one mill for each biscuit recipe and not to chop and change even for financial reasons. Significant difficulties can be expected where deliveries of flour from widely different sources is the norm. Some dough and baking problems related to flour are considered in the sections on specific biscuit types and also in *Manual 1* by Manley [32].

9.3.2 Flour specification

The purpose of a specification is to agree with the supplier on measurable parameters of a material which are relevant to the use for which the material is to be put.

In the case of flour for biscuit making, this presupposes that critical parameters are known in relation to the function of the flour in different processes. A specification is of no use if both the supplier and the user cannot agree measurement techniques or if it is beyond the capability of the supplier to consistently meet the limitations required for each parameter.

There may be some specific characteristics for flour for a special purpose but, in general, a typical specification for a biscuit flour to be used for chemically aerated biscuits, i.e. not fermented doughs, will include some or all of the characteristics and values shown in Table 9.3.

In the USA, it is common to specify a spread factor as determined by the Cookie Spread Test [33]. This is a baking test for short dough cookies. The miller can reduce the dough spread factor by treatment of flour with chlorine gas.

9.3.3 Checks and tests on flour deliveries

It is advisable to sample flour from each delivery and to retain a good sized quantity until all of that delivery has been used. Before the delivery is accepted, an attempt should be made to check that the flour is of the grade required since a gross error as, for example, the acceptance of a bread flour instead of a biscuit flour, will give enormous problems in disposal if the flour has been transferred to a silo.

The best quick check is a colour test. This can be made either with a Kent-Jones colour grader, a Pekar test or with a Branscan. The Pekar test involves smoothing a small dry sample of the flour adjacent to a reference flour with a polished metal spatula and then carefully dipping the flour into some water. A skin forms on the flour surface and observation by eye immediately allows comparison of the colour and size of the bran particles. If the new flour and the reference are very different, further investigation should proceed at once. Other tests, such as moisture and any rheological or baking tests, may be made before the consignment is released for use

Table 9.3 Typical specification of flour used for chemically aerated biscuits

Wheat type	A maximum content of soft wheat varieties	
Moisture content	14.0%	±0.5%
Smell	Free from mustiness (moulds), no taints from paint, detergents, hessian bags, etc.	
Protein ($N \times 5.7$)	9.0%	±0.5%
Colour grade figure (Kent-Jones)	3.5	±1.0
or ash content	0.46–0.55	
Particle size range		
Particles greater than 250 μm	Less than 1%	
Particles greater than 50 μm	40%	±5%
Simon Research values 100E/R	7.5	±1.0
or Alveograph values		
W (baking strength)	140	±10
P/L or Brabender Extensograph values	1.8	±0.3
Resistance, Brabender units	330	±50
Extensibility, cm	15.6	±1.0
Statutory additives	As applicable	

in the factory, but it is not normally practical to make such tests before accepting a delivery.

If possible, a new load of bulk flour should be put into an emptied silo. This ensures correct rotation of the flour and effective quality control. Unfortunately, flour silos are usually larger than the bulk tanker so more than one consignment is placed against another. Problems may arise because silos rarely discharge in a systematic first in, first out fashion. If this happens, it can mean that old flour will become lodged and may be compacted around the silo sides and bottom corners. A procedure of regular emptying must be maintained.

Flour delivered in bags should be marked prior to storage to ensure correct rotation of stocks. Any damaged bags should be used early as spillage is both wasteful and a hazard to general infestation. Bagged stocks should always be stored on pallets at not more than about 10 bags high. The flour store should be cool, well ventilated and rodent, bird and if possible insect proof. If the stock is to be kept for prolonged periods, arrangements should be made with the miller supplier to have moisture contents around 13% or below.

9.3.4 Conveying, screening and weighing

Bulk flour is normally conveyed from the silo by air. A rotary seal at the base of the silo delivers flour into an air stream provided by pumps. The volume of air to flour is normally considerable and, due to the way in which the flour falls into the rotary seal, the delivery from the silo is usually somewhat irregular. A rotary seal beneath a silo is not a reliable way of metering flour. The temperature and humidity of the conveying air may have an effect on the flour moisture content.

It is wise to pass the flour through a screen, either planetary or rotary, prior to metering into a mixer. In this way, any lumps or unfortunate larger pieces included with the flour are removed. It is wise to check daily what tails over these screens as it may indicate problems. Flour may be weighed above, or in a mixer, or even remotely and then passed to the mixer. The latter system may be more economical on equipment but is likely to result in less accurate metering. The biggest variation in mixed dough consistencies is likely to be due to poor metering of ingredients and that of flour is usually the worst. The subject of ingredient metering is discussed in more detail in Section 33.5.

Flour from bags presents another set of problems. In opening bags, it is easy for string, labels or paper to fall with the flour. Hygiene considerations at the flour bag tipping point are never wasted. As for bulk flour, it is wise to include a sieving system between bag tip and mixer/weighing.

9.3.5 Overcoming flour variations

It is fair to say that we have not reached the stage where the ability to measure meaningful properties of flour quality allows feed-forward for process control. It is therefore necessary to do all that is possible to reduce variations in supplies of flour. The best means is to blend. A flour miller reduces the effects of wheat variation by blending loads of wheat and the same can be done in the bakery by blending several different flours. Care should be taken that the blending is well planned, otherwise even more variation can be experienced because variable quantities of each constituent are arriving at the mixer.

A problem occurs annually with new crop wheat. The freshly harvested wheat always produces a different quality of flour. The wheat also changes gradually in store from the time that it is harvested. To overcome the effects of this, the baker should insist that the proportion of new crop wheat in the grist at the mill is increased slowly over at least four and ideally more weeks. This will ensure that the amount of very fresh wheat is at a minimum and will allow adjustments to be made gradually in the bakery. The miller supplier should communicate the percentage of new crop wheat being used so that the baker can at least be prepared.

Changes in biscuit flour properties can be demonstrated as the flour is stored, even for a few weeks. The changes affect the protein and generally the effect is to make the gluten less extensible. No way is yet known to overcome this, so it is important to store the flour for minimum or uniform periods. Flour hung up in blind spots in silos can be a cause of variation for this reason.

9.3.6 Brown flours

If brown, wheatmeal or germ enriched types of flours are used, there are other considerations to be made. Contamination of white flour with bran at the biscuit factory spoils the efforts of the miller so, unless a large amount of brown flour is to be used, it is unwise to put it into a bulk-handling system shared with white flours. Usually, the bran particles are of significant but uniform size (about 2–3 mm in diameter), so sieving will tend to separate the bran from the white flour. Screening before use is therefore not desirable. Brown flours are usually fed to the mixers from bags or are handled in dedicated bulk systems. The other option is to create brown flour in the mixer by using a specific grade and quantity of bran with white flour.

9.3.7 Dusting flours

These are used in relatively small quantities to aid the passage of dough through the forming machinery or to dry the surface of an oven band. The important quality of dusting flour is excellent flowability so that a thin even coating can be produced from the dusting machine. Weak flours or damp flours do not flow well, so strong bread type flours are often used. Air classification (see Section 9.2.9) can result in coarser flour with the fine fractions removed. Passage through the air classifier also tends to reduce the natural moisture content and this improves the flow characteristics. As a rough guide, if a handful of flour, when squeezed tight, remains in a ball when the hand is opened, it is unlikely to form a good dusting flour.

9.3.8 Developments in flour types

The development of levels of heat treatment to affect the texture forming properties or the spread during baking has been mentioned above. However, the most interesting developments in 'flours' are associated with the introduction of pieces and increases in the fibre content. The developments have been motivated by the demand for more dietary fibre and, hence, the use of more bran. By heating, steaming, chopping or rolling wheat, various flakes and soft pieces of whole wheat can be made. Incorporation of these into flour allows biscuits to be made with different eating textures. The pieces may also be of rye, oats or barley (see Chapter 10).

9.4 Vital wheat gluten

The use of vital wheat gluten has been of most value for making bread in countries where there is a scarcity of high-protein wheats and thus a need to import stronger wheats. There are certain biscuit types such as cream crackers and puff biscuits where higher protein flours are required. Vital wheat gluten has been extensively used as an economical method of obtaining these stronger flours.

Vital wheat gluten is produced in a number of different countries, for example, Australia, Argentina, Belgium, France, The Netherlands, USA, and the UK. Typically, it is a light tan fluffy powder but its colour depends on the quality and extraction rate of the base flour. That from Australia is usually the palest in colour; that from the UK the darkest. As will be appreciated, it is composed of the water insoluble protein complexes of flour, collectively known as gluten (see Section 9.2.3 for gluten composition).

The method of drying used to produce the vital wheat gluten tends to decide the particle size of the powder. Spray-dried material usually has a finer granularity than flash dried. This does not matter particularly, but it is most important that the powder should be well dispersed into the flour before it is wetted and a dough is mixed. If vital gluten is wetted undiluted it forms tough rubbery balls that cannot subsequently be dispersed properly through a dough.

A typical gluten analysis shows:

Protein ($N \times 5.7$)	73.0%
Starch	16.0%
Fat	1.0%
Ash	1.2%
Fibre	0.8%
Moisture	8.0%

When checking a specification for dried gluten, it is important to note whether the protein content is quoted on an as-is or a dry basis. Protein contents which range from 70 to 80% are usual at moistures between 6 and 10.5%. The packing density of vital wheat gluten is about 650 kg per cubic metre.

The gluten powder should absorb a minimum of 1.5 and typically 2.0 times its weight of water within about one minute. It should be possible to stretch the cohesive, elastic and tough hydrated mass some distance without breaking. There should also be obvious elastic properties. The total protein content of a flour/gluten mix can be calculated simply but, as a guide, for cracker doughs, additions of 1 or 2% of gluten to a base flour can show significant baking improvements.

Most of the literature on vital wheat gluten is concerned with its use as a supplement for bread doughs but a paper by Benson [34], another by Collins [35], and a more recent one by Xu *et al.* [36] are useful.

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10

Meals, grits, flours and starches (other than wheat)

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Abstract: Although wheat flour is by far the largest cereal material to be used in biscuits, there are other cereal meals and flours that may enhance the eating qualities and stimulate interest.

Key words: oats, maize, malt, rye, soya flour.

10.1 Introduction

In most biscuits of all sorts, white wheat flour is the major ingredient. This is because of the unique position of wheat protein that forms gluten upon hydration and mixing. In many types of biscuits significant amounts of wheat bran (or as whole-meal flour) is included to give a rougher eating texture and to increase the dietary fibre content. In some types, quantities of other meals or starches may be included to give special flavours or structural properties. There would seem to be scope for more development of biscuits richer in flours, other than wheat, especially in countries where wheat is not grown so this ingredient has to be imported either as flour or as wheat for local milling. Most of the materials described in this chapter are therefore included to stimulate interest in their use rather than to suggest that they are important ingredients at present. The types of non-wheat starchy materials are very extensive but the major ones will be considered under the headings of cereal and non-cereal.

It is worth mentioning the growing technology of snack foods which are produced with an extrusion cooker or via deep fat frying where high gelatinisation of starch allows a structure which is largely or totally independent of protein. For these, non-wheat starchy materials can be used. These highly expanded products are extremely profitable because of their very low packing densities.

Extensive investigation into the use of non-wheat starchy materials in baked goods, and particularly bread, was carried out by the Tropical Products Institute of London in what was called the Composite Flour Technology Programme [1]. Most of the research was directed to the levels of inclusion that are possible in basically wheat flour bread doughs but perhaps there will be interest in extending the work to biscuit-like products which are more economical but acceptable to local tastes.

There are some unfortunate individuals who are intolerant to certain cereal proteins. In the worst cases the condition is known as coeliac disease and it is defined as an inability normally to digest the proteins found in wheat, barley, rye and oats. So much of the Western diet contains wheat products that these people are severely limited in what prepared foods they can eat. It is, however, possible to make types of biscuits and cookies free from gluten by using some of the materials to be described here. For further information about the coeliac condition, the reader is referred to literature from The Coeliac Society in London [6]. Some other information about food intolerances is given in Chapter 31.

10.2 Cereal-based materials

10.2.1 Maize (corn on the cob)

This is known as corn in America and is the cultivated grass *Zea mays*. Maize is one of the heaviest yielding cereal crops and is found as several significant varieties. When milled in the more or less traditional way like wheat, a yellowish flour is produced but more significantly a semolina-sized powder or 'grit' can be obtained. Although the protein content is around 9% on a 13% moisture basis, this protein does not form gluten. The flour is not commonly used in baked products. As the flour has a yellow colour, blends with wheat flour do impart a rich appearance to baked goods suggesting the inclusion of egg. Such wheat/maize flour blends are also said to reduce the tendency for shrinkage in certain pie pastry.

Maize 'grits' are an important raw material for extrusion cooked products. The size of the grit should be chosen to suit the application for which it is used but the main criterion is the flowability of the material. By a process of wet milling, the maize starch is separated from the protein and oil germ components of the grain and after drying a very fine flour which is almost pure starch is obtained. This is known as cornflour in Europe and cornstarch in America, a point of nomenclature that should be watched. This starch is the raw material for a number of industrial uses such as, for example, the production of glucose syrups, dextrose and dextrin powders by acid or enzyme hydrolysis (see Section 11.4).

Function. Cornstarch may be used as a minor ingredient in hard sweet biscuit recipes to improve the surface sheen of the biscuits. It also makes the texture somewhat more delicate. Also, with the increasing protein content of biscuit flours giving tougher, less extensible gluten, cornstarch may sometimes be useful to 'dilute' the biscuit flour. This helps to make the dough less tough and easier to sheet. Up to 10 or 15% of the flour can be replaced with cornstarch. Too great an inclusion gives a noticeable and rather unpleasant dryness to the biscuit flavour. (The use of heat-treated wheat flour has also been shown to have useful texture modifying effects without the flavour disadvantages; see Section 9.2.8). Cornstarch is a useful filler for dry premixes and may be used as a minor ingredient in biscuit and wafer sandwich creams.

Cornflour can have moisture contents as low as 1–2% but levels of 5% are common. The purity of the starch and the absence of oil makes the material very resistant to deterioration in store. There is a large technology of chemically modified cornstarch which should be researched if the reader is interested in using starch as a thickener rather than as a simple component in a dough.

10.2.2 Oats

This is a cereal of cool temperate climates. The plant is *Avena sativa*. The fat content is 2–5 times as high as in wheat but the protein content is about the same. This protein does not produce gluten though the nature of the protein is detrimental to those suffering from coeliac disease (see Section 10.1).

Function. Oats, in one form or another, have been extensively used in biscuits for flavour, textural benefits and appearance. (This suggests that much more use could easily be made of other cereals like sorghum and millet in the countries where they are grown.)

There are two important forms in which oats are used in baked products. Oatmeal (sometimes known as groats) which is a branny flour, and oat flakes which are also known as rolled oats. These are relatively large and thick particles made by rolling knibbed pieces of the grain. In all cases considerable attention is given to the cleaning and removal of the outer husk layers of the grain before milling. This is because the husk is particularly hard and sharp pointed. Oatmeal is often milled between stones and the separation of bran and endosperm is never as complete as in wheat flour production.

Oatflakes are produced from cut pieces (knibs) of cleaned grain which are graded to ensure an even sized production of flakes in the following rolling process. In biscuit making it is important to specify the flake size and thickness required. Typically the flakes are about 0.45 mm (0.018") thick and about 8 mm (0.3") in diameter. Other flakes used in biscuits can be as much as 0.8 mm (0.03") thick.

The high fat content of the oatmeal causes problems with oxidative rancidity in store. To overcome this problem a technique of heat treatment of the grain before milling, known as stabilisation, has been developed. This inactivates the enzyme lipase and considerably extends the shelf life of the meal or flakes.

Oatmeal biscuits are dense and short, rather friable, biscuits with a distinctive but not unpleasant flavour. They are usually made by mixing oatmeal with roughly its own weight of wheat flour and then processing as for short dough biscuits. It is possible to make oatcakes (these are biscuit-like) without wheat flour but they are very fragile (Fig. 10.1). It is important not to over bake as a bitterness quickly develops from burnt oatmeal.

Oatflakes are very attractive in cookie or wire cut biscuits. Here again, the dough is short and particular attention should be paid to the dough consistency as oatflakes have a very slow water absorption and often different deliveries have marked differences in absorption. This is probably associated with the conditions of the stabilising process at the mill. The author devised a simple water absorption test in order to try to predict the dough water level requirements associated with different deliveries of oatflakes. This involved the mixing of a sample of oatflakes with three times its weight of water at controlled temperature to form a slurry. After 10 minutes standing the dropping time of this slurry, through a wide mouthed funnel, was measured. The test is repeated after 20 minutes standing time. Values of between 50 seconds and 130 seconds were recorded, a difference which showed the amount of variation that can exist. Oatmeal or oatflakes have a protein content of about 12%, fat of about 7% and moisture between 9 and 10%.

Important claims have been made about the ability for oat bran in the diet to reduce the levels of blood cholesterol and hence the incidence of heart disease. Biscuits form a very acceptable way of eating oats or oat bran. Oat meal and oat-



Fig. 10.1 Thin oatcakes.

flakes are always supplied in paper sacks. They should be stored and handled under similar conditions to wheat flour and bran.

10.2.3 Rye

This cereal, *Secale cereale*, is the only other commercially available cereal whose protein forms a gluten in dough. It is an important cereal crop of the colder parts of north and central Europe and Russia. It is milled in the same way as wheat but the flour is much darker and has a strong flavour.

Function. Rye flour is used as an ingredient in gingerbread or Lebkuchen, small fatless sweet products usually made with a rotary moulder. Otherwise it is used principally to make a rather dense bread and finds a major use in the manufacture of crispbreads (see 32.2.1).

From a nutritional point of view there is practically no difference between rye flour and wheat flour. The gluten which is produced when the flour proteins are hydrated is plastic but not very elastic. Therefore, whereas in wheat flour doughs the gas cells formed during fermentation are enclosed in an elastic, extensible medium, fermenting rye doughs essentially possess the nature of a foam in which the main problem is to prevent the collapse of the gas cells.

Rye flour crispbreads have established an important position in slimming diets and according to Kent and Avers [2] this is because the pentosans gelatinise and swell in the stomach, giving a feeling of satisfaction and the hydrolysis of the polysaccharides is slow, so the blood sugar level rises slowly, but is maintained for 5 or 6 hours, thereby controlling the appetite. Rye flour has a protein content of around 6.7%, fat 1.3% and moisture of 15%. The grains have a tendency to germinate rather easily so rye flour is usually fairly high in amylase activity. This property combined with the naturally higher levels of pentosans make the doughs very sticky to handle. It is usual to improve the dough handling quality by mixing rye flour with about 25% of wheat flour.

10.2.4 Sorghum

Sorghum vulgare is an important crop of tropical and sub-tropical areas. Dry milling produces a greyish flour or meal and as for maize, a large particle product or grit is commonly produced. In dry milling there is generally a problem of germ removal, so the flour or grit has an appreciable oil content (around 2.5%) and this means that it is susceptible to oxidative rancidity in store. When the meal is baked the enzymes are destroyed and the tendency to rancidity is thereby significantly reduced. The protein content is around 9% but this does not form gluten.

Wet-milled sorghum produces a low protein starchy material as for maize but the germ content is usually appreciable giving stability problems. Another process where the outer layers of the grain are removed by a scouring or abrasive process results in pearled sorghum. This gives small round particles of largely uncracked endosperm.

10.2.5 Millet

This grain is derived from a range of cultivated grasses which resemble sorghum. Ragi or finger millet is *Eleusine coracana*, Bulrush millet is *Pennisatum typhoideum*, common millet is *Panicum miliaceum*, Japanese millet is *Echinochloa frumentacea*. They are crops of mainly tropical areas and locally are extremely important sources of food. The grains are small and round, as for sorghum, and the production of meal or flour is almost the same as for sorghum. However, the protein content is considerably higher than for other cereals, often as high as 22–23%. The amino acid composition of this protein is much better balanced for human nutrition than sorghum so unlike maize and sorghum about 85% of the millet crop is used for human food.

The meal is usually rich in germ and this means that the storage stability is poor, especially in hot climates. It is important to obtain supplies of meal from local mills as and when it is required. It seems that it is more difficult to remove the germ and protein from millet than from sorghum and maize.

10.2.6 Rice

This cereal, obtained from the plant *Oryza sativa*, is one of the world's two most important food crops, the other being wheat. The protein content is rather low (starch content high) and again no gluten is formed. The grains are consumed mostly in the form of whole grains but it is also milled after polishing to remove the dark outer layers (which incidentally also removes much of the important nutritional

components) to form flour and grits which are very clean and white, and because they are low in oil have good storage properties. Fine rice grits are also known as rice cones and this material has found widespread value as a dusting material to prevent dough pieces adhering to one another and to oven bands.

Function. The flavour of rice flour is very bland. It is not commonly used in biscuits (except for rice crackers in Japan) but if used as a minor substitute for wheat flour it gives a softer texture and will reduce the rise during baking. Very occasionally it is used to thicken batters for wafers. As for the other flours already described, there would seem to be little reason why more could not be made of it in biscuits.

Rice paper made from a rice flour batter is used for bottoms of products particularly prone to sticking to the baking band such as macaroons and meringues. Silicon-coated paper has now commonly replaced the use of the edible rice paper as it is reusable though much more expensive. Rice wafers made in a similar way to rice paper are used in churches for Holy Communion.

10.2.7 Barley

Meal or flour from this cereal, *Hordeum distichon*, is rarely used in baked products although a certain amount of barley meal and pearl barley is used in soups, etc. The main value of barley is in the production of malt, although this is also obtained from wheat. Germinated grains are dried and then roasted to give a good flavour to the mixtures of dextrins and maltose sugar present. Following this, either a malt extract produced by leaching with water, or a malt flour is prepared. Due to the very hygroscopic nature of maltose and dextrins, malt flour is difficult to handle and malt extract is usually sold as a thick viscous syrup of about 80% solids.

Malt flour is produced from the dried unroasted germinated grains. This has an extremely high amylase activity and may be used to boost this property in flour for fermented doughs. Recent development in the production of standardised fungal or bacterial enzymes have tended to replace malt flour for this purpose. Due to the roasting process prior to the production of malt extract, the enzymes are of course destroyed. Enzymatically active extract is also available and this is known as diastatic malt extract, whereas the other is non-diastatic (that is, contains no enzymatic activity). Non-diastatic malt extract may be used to give a natural and pleasant flavour to biscuits.

10.3 Non-cereal flours and starches

Most of these, with the exception of soya flour, are starches, which are washed out of plant tissues, in a more or less pure state. They differ in their starch grain size, composition and flavour, although the latter is usually very mild. Sometimes a sweetness of flavour is present due to the presence of small amounts of sugar. The behaviour of different natural starches is a large subject which is more important for fermentation and extrusion cooked processes than for baking.

These materials are, however, important because they form the major food sources for many parts of the world. Where the protein, vitamin and mineral

contents are low, there is much malnutrition if these starches are not combined with other foods in the diet.

10.3.1 Cassava starch

This plant, *Manihot utilissima*, grows extensively in the tropics worldwide. It is a shrub which grows 2–3 metres high with woody stems and swollen tuberous roots. From these roots, cassava starch is prepared. It is also known as tapioca or manioc. Use of this starch in biscuits seems to be very rare but the reasons are not technical except for the limitations expressed for other starches.

10.3.2 Arrowroot

Another tropical plant, a herbaceous perennial, *Maranta arundinacea*, has swollen roots from which the starch is extracted. This was used in a particular variety of British semi-sweet biscuits to weaken the flour and give an improved smoothness to the palate. The combination of a world crop failure in the 1960s and the availability of cheaper starches with almost identical properties has effectively precluded its use in biscuits now. It is worth noting, if only because it gives an idea of the usage level, that a Code of Practice was formulated in Britain following the Second World War which stated that a biscuit could not be called Arrowroot unless at least 10% of the biscuit was arrowroot starch.

10.3.3 Starch from sweet potatoes and yams

Sweet potatoes come from the plant *Ipomoea batatas* and yams from a number of plants of the genus *Dioscorea*. There is confusion because one or other of these names is often loosely applied to almost any tropical root crop. Mostly they are eaten by boiling but starch can be extracted, dried and sold commercially. As with other starches, the general importance of yam starch has been a shadow of cornflour but peculiarities of flavour are prompting its consideration in snack products.

10.3.4 Potato starch

Potato, *Solanum tuberosum*, is an extremely important vegetable crop of temperate climates. Many snack foods such as crisps, chips, etc., are based on potato or potato starch. Under suitable conditions, potatoes yield a higher food value per hectare than any cereal but their principal disadvantages are their high water content and shorter storage life than cereals.

Inclusions of around 5% of potato flour with wheat flour will give textural and flavour differences in a similar way to other starches. No doubt high substitutions of wheat flour could be tolerated and acceptable biscuits produced.

10.3.5 Soya flour

This, *Glycine max*, is a plant grown principally as an oil-producing crop but the protein-rich meal remaining after oil extraction is an important and valuable food raw material. The protein is of high quality because the balance of amino acids is more suited to human nutrition than that found in cereal proteins. The latter are

short of lysine and soya protein is especially high in this. By a process of reforming and texturising the soya protein, meat analogues have been produced which offer a much cheaper high-protein food than meat from large mammals. (Gluten washed from wheat flour can also be used in this way.)

Function. In addition to the nutritional qualities of debittered low-fat soya flour, many claims have been made for the value of this material in baking. It is a major source of high protein for dietary biscuits. There is a small level of lecithin which is a natural emulsifier. It may reduce the elasticity and increase the extensibility of doughs. However, claims that biscuits using about 3 or 4% of soya flour based on the wheat flour content have better appearance, better eating quality and longer shelf life should be viewed with caution. The fat and lecithin (emulsifier) contents undoubtedly will contribute to enhance quality but the water-binding action of soya flour may not be ideal for biscuit dough except that the consistency is tightened. There is probably some value in considering soya flour as a replacement for egg in a recipe and for this purpose blends of soya flour and egg albumen have been prepared for use, for example, in wafer batter.

There are many different soya flours which vary in their protein, fat and moisture contents. The reason for their use in any particular biscuit recipe should be considered before a grade is selected. Typically the protein contents vary between 45 and 62% (as is) and the fat from 1 to 20%. Protein levels are usually based on $N \times 6.25$ and not $N \times 5.7$ as in wheat flour specifications and it is possible to obtain soya protein isolates with protein values as high as 98% on a dry basis. Naturally the price of the flour is directly related to the protein content. The moisture content is between 5 and 9%.

Soya protein does not, of course, produce gluten. It is, however, worth noting that this is a major source of non-animal protein that is acceptable to sufferers of coeliac disease who are unable to tolerate wheat and other cereal proteins. Digestion of significant quantities of soya products often give gastro-intestinal problems in the form of excessive flatulence. Soya bran which is a flour milled from the outer coating of the soya bean, is particularly high in dietary fibre so finds a use in dietary and health food biscuits.

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11

Sugars and syrups as biscuit ingredients

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Abstract: Sugars and syrups are major and important ingredients of most biscuits. In addition to their sweetness they are structural and flavour modifying and enhancing substances. Specifications for crystalline sucrose are detailed and also the types of glucose syrups.

Key words: sucrose, reducing sugars, glucose syrups, honey, invert syrup.

11.1 Introduction

Sweetness has always been a popular characteristic in foods. Honey was probably the first source of sugars used by man. Many plants have sugars in their tissues but only sugar cane, *Saccharum officinarum*, and sugar beet, *Beta vulgaris*, have been used to extract sugar in commercial quantities. In both cases the sugar is sucrose. There are reports that sugar from sugar cane was in common use as early as 1700. Sugar from sugar beet was first extracted in about 1798 and the sugar beet industry first became important in France and Germany. Napoleon encouraged its development as a means of boycotting cane sugar from the British colonies. Sugar and cocoa were the first commodities to be processed by industrial methods. White sugar was being processed by 1850. In the refined state there is very little difference between sucrose from cane or beet.

As starch is broken down other sugars are formed most of which have sweetness. This breakdown happens naturally by enzymic action and this is how malt is formed, when cereals germinate. The technology of starch conversion is now well advanced and by combinations of enzyme and acid hydrolysis sugars and mixtures of not so sweet carbohydrates can be prepared to order from starch. The glucose syrups are an example of this. Other intensely sweet compounds have been made, including saccharine, aspartame, cyclamate, etc., and these are mentioned in Section 18.7.

11.1.1 The function of sugars in biscuits

Sugars are major and important ingredients of most biscuits. In addition to the sweetness they are structural and flavour modifying and enhancing substances.

11.1.1.1 *Sucrose*

Sucrose in biscuit doughs dissolves, or partially dissolves depending on the amount of water present, and then recrystallises or forms an amorphous glass (a supercooled liquid) after baking. In this way it strongly affects the texture of the baked biscuit. If the quantity of sucrose is high the biscuit is hard. The size of the sucrose crystals, and therefore their rate of dissolution as the dough piece warms in the oven, affects the spread of short doughs as they bake and affects the appearance and crunchiness of the baked biscuit.

As sucrose dissolves it contributes to the liquid phase of the dough so, to the point where the sucrose solution is saturated, the amount of sucrose depresses the amount of water needed in a dough. Sucrose shifts the starch gelatinisation point to a higher temperature thus allowing the dough more time to rise in the oven. It has been claimed to be an antioxidant in biscuits and thus contributes to shelf life by retarding fat rancidity. In doughs which are fermented with yeast, sucrose provides a yeast food and so enhances the rate of gas production. Finely milled sucrose is a major bulking agent in fat-based creams.

In its various crystal forms and sizes sucrose can be used as a surface decoration for biscuits. In certain cases a surface dusting of sucrose will melt during baking, cooling afterwards as a glass thus giving an attractive gloss or glaze.

Sucrose is a major component of chocolate, jams, jellies and caramels where its concentration affects the water activity and thus the stability against microbial growth and the consistency. Sucrose is the major component of icings which are used to coat some biscuits after baking. The by-products of cane sucrose refining are syrups with strong, and mostly pleasant flavours, which have considerable value for biscuits. Burnt sugar is known as caramel. It has a bitter taste and is dark in colour. Thus caramel may be used in biscuits for both its colouring property and its flavour.

11.1.1.2 *Reducing sugars*

Sucrose is a disaccharide, that is, it is made up of two molecules of the basic sugar structure. If sucrose in solution is hydrolysed (a process known as inversion) the molecule is split into its two components giving the monosaccharides dextrose and fructose (laevulose). All monosaccharides are reducing sugars, that is, they react with Fehlings solution to change its colour due to the precipitation of brown-red cupric oxide. In addition to monosaccharides, like dextrose and fructose, the disaccharides maltose and lactose are also reducing sugars. Reducing sugars combine with amino acids (from proteins) in the Maillard reaction which occurs during baking and which is the way in which dark and attractive surface colours are formed. Primarily for this reason usually between 10 and 20% of the sugar used in a biscuit dough is a reducing sugar.

Mixtures of reducing sugars and sucrose in solution affect the crystallisation in jams and jellies. Fructose gives a much sweeter eating sensation than sucrose and both fructose and dextrose in powder form give a cool sensation as they dissolve in the mouth. Both these characteristics have their values in formulations for some biscuits or the components of biscuits.

11.1.1.3 *Syrups*

Syrups are solutions of sugars, usually reducing sugars or mixtures containing reducing sugars. They typically have a concentration of 70 or 80%, any higher and the sugars would start to crystallise at ambient temperatures. Some syrups are used, at

relatively low levels, in biscuits for their distinctive flavours. They are also used as humectants (materials that prevent the loss of water from food) and, as such, prevent the baked textures being too hard and brittle. Syrups are a convenient way of introducing reducing sugars into a formulation and thus enhancing the Maillard reaction during baking.

Sugars are readily absorbed in the human gut and are valuable sources of energy in our food. There is concern in some places that we consume too much sugar and sugar-rich foods contribute to dental caries. However, it will be seen from all the functions of sugar in biscuits that attempts to reduce the levels that are typically used will probably have a significant effect on texture and other eating qualities.

11.2 Common sugar, sucrose

Common sugar is chemically known as sucrose and derived almost exclusively from sugar cane or sugar beet. In its pure state it is normally available as white crystals, but it can also be bought as liquid sugar, which is a solution in water. Impure sucrose, crystals with coatings of syrup which are dark in colour, are known as 'brown sugars'. Sucrose is a disaccharide and a non-reducing sugar.

11.2.1 Crystalline white sugar

Crystalline white sugar is available in a variety of sizes and is a very pure substance. Table 11.1 gives a typical chemical specification for crystalline white sugar. The crystal size is determined at the sugar refinery at the time of crystallisation from the mother liquor. This means that there is always a range of crystal size. The range of the size may be reduced by sieving but this is not a normal part of the manufacturing process. The commonly available grades are 'granulated' and 'caster'. 'Icing' sugar is very fine in particle size and is produced by milling a coarser grade. The crystal size range is usually expressed in terms of mean aperture (MA), and coefficient of variation (CV). The mean aperture is the sieve aperture size (expressed here in micrometres, μm) which will pass 50% of the sample; it is the average particle diameter. The coefficient of variation is related to the standard deviation (SD) of particle sizes as shown in the formula:

$$\text{CV} = \text{SD}/\text{MA} \times 100$$

Typical specifications for particle size are:

Table 11.1 Typical chemical specification for crystalline white sugar

Polarisation	99.8	min
Invert sugar	0.3%	max
Moisture content	0.04%	"
Sulphated ash	0.04%	"
Copper	1.0 ppm	"
Lead	0.5 ppm	"
Arsenic	1.0 ppm	"

Coarse granulated	MA = 940–1000 μm	CV = 20 to 30%
Granulated	MA = 570–635 μm	CV = 26 to 30%
Caster	MA = 276–300 μm	CV = 16 to 26%

There may be a great range in the size of granulated sugar from different refineries, and MAs of up to 670 μm and as low as 475 μm can be expected.

Icing sugar is produced by milling and screening a coarser crystal sugar. Because it is very fine and hence difficult to sieve into many different sizes, it is normal to express the particle size by, for example, maximum held on a 100 μm sieve = 6% and maximum held on a 60 μm sieve = 13%. The smaller the crystals the faster the sugar will dissolve in the mouth. Particles greater than 40 μm will feel gritty between the teeth and particles more than 20 μm can be detected by the tongue. To aid the free flow character of icing sugar it is common to add a little tricalcium phosphate. If present, this should be declared, and the quantity is usually up to 1.5%.

11.2.1.1 *Calculation of mean aperture and standard deviation of a sample of crystalline sugar*

A sample of the sugar is gently sieved through a series of sieves of different mesh size. The nominal width of the sieve apertures is usually embossed on the sieves. The sieves may have numbers related to the British Standard Sieve Series BS410. The relationship of these numbers to the nominal width of aperture in microns, μ , (1/1000 mm) is shown below:

No. 16	1000 μm
No. 22	710 μm
No. 30	500 μm
No. 44	355 μm
No. 60	250 μm

Figure 11.1 shows this relationship graphically.

After sieving, the mass of the sample retained on each sieve is found by weighing and also that passing through the finest sieve. The cumulative percentages passing through successively coarser sieves are entered on probability graph paper. It is assumed that the range of crystal sizes either side of the average is 'normal' in statistical terms, so by plotting the results of the sieving on probability paper a straight line will be created. If the plot of the cumulative percentages is not a straight line, it can be assumed that the sample is either from a mixture of two or more 'makes' of sugar, or from a sugar that has been sieved to alter the natural range of crystal sizes. For example, a sugar may have been roughly milled but some of the dust or coarse particles have subsequently been removed. Such a sugar will not give a straight line plot on probability graph paper.

Having obtained a sieving analysis from a sugar sample, it is possible to compare this with the supplier's specification. To take an example, the specification of some granulated sugar is MA 570–635 μm , CV 26–30%. Firstly calculate a table of values from the equations $\text{CV} = \text{SD}/\text{MA} \times 100$ or $\text{SD} = (\text{CV} \times \text{MA})/100$. This will give:

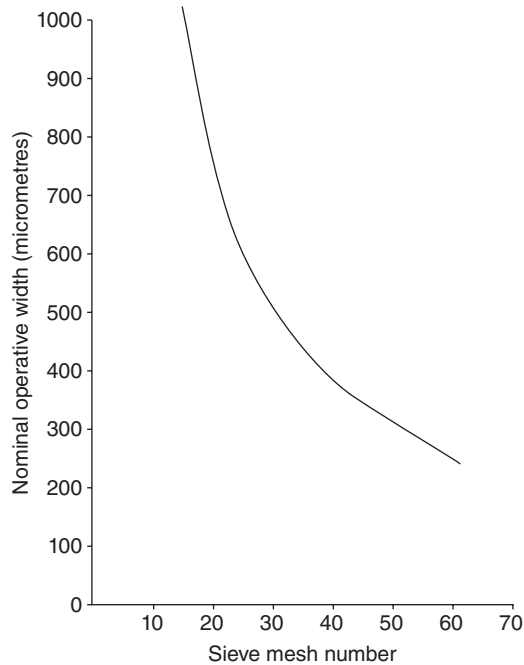


Fig. 11.1 Relationship between sieve aperture and mesh number (from British Standard Sieve Series BS 410, 1962).

CV	MA	SD	MA - 1.96s	MA - s	MA + s	MA + 1.96s
	(50%)	(s)	(2.5%)	(16%)	(84%)	(97.5%)
26	570	148	280	422	718	860
30	570	171	235	399	741	905
26	635	165	312	470	800	958
30	635	190	263	445	825	1007

Plot these values on probability paper as shown in Fig. 11.2. In effect, there are four normal distribution curves shown by the four straight lines, and the specification defines that a sample will fall within the area contained by these four lines. A typical sample may have the sieving analysis:

Tails of	16 mesh = 0.5%	Cumulatively,	16 mesh = 99.5%	1000 μ m
	22 = 23.5%	throughs of	22 = 76.0%	710 μ m
	30 = 50.0%		30 = 26.0%	500 μ m
	44 = 20.5%		44 = 5.5%	355 μ m
	60 = 4.3%		60 = 1.2%	250 μ m
Throughs	60 mesh = 1.2%			

These cumulative percentages have been plotted in Fig. 11.2. The mean aperture of this sample is read off on the 50% line, and it can be seen to be 600 μ m.

Figure 11.3 shows a typical specification for caster sugar with a plot from a sample of milled (powdered) sugar. It can be seen that the milled sugar has a mean aperture of 235 μ m (50% line) and standard deviation of $235 - 20 = 215$. This means that

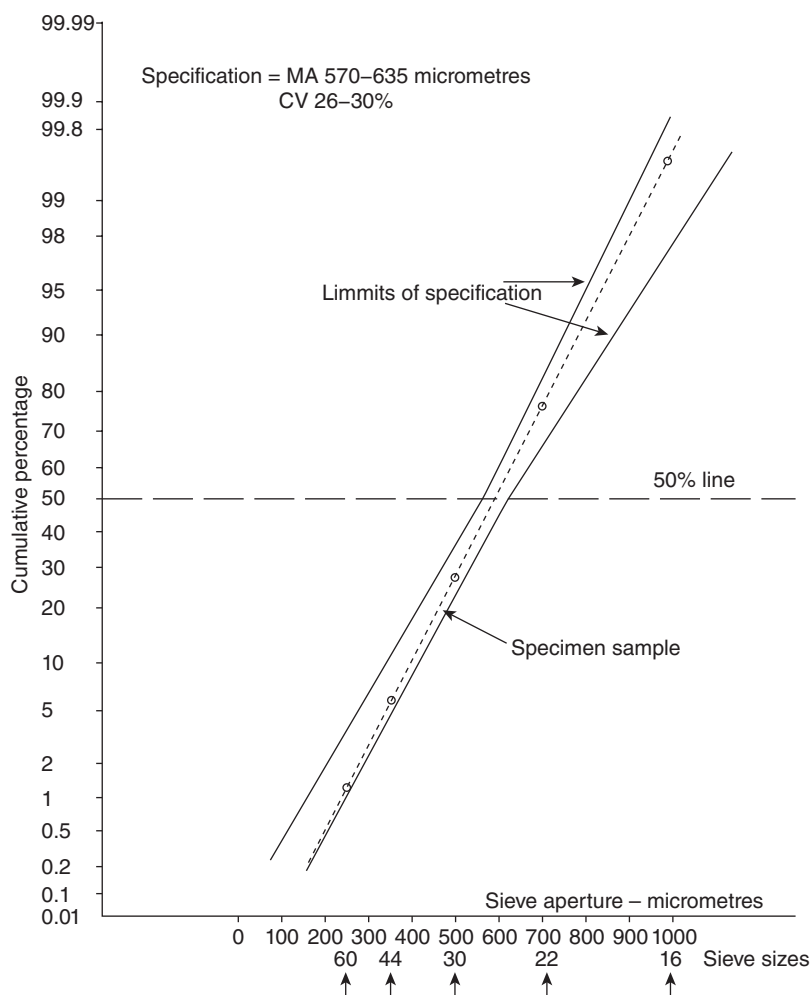


Fig. 11.2 Typical specification for granulated sugar. MA = 570–635 μm ; CV = 26–30% with a plot of a sample.

although the mean aperture size is close to the specification for caster sugar, there will be considerably more fines and coarse particles than would be found in the specified caster sugar. The sieving analysis of the milled sugar sample was:

Tails of	500 μm = 13.3%	Cumulatively, throughs of	500 μm = 86.7%
	350 μm = 15.0%		350 μm = 71.7%
	250 μm = 15.8%		250 μm = 55.9%
	150 μm = 19.6%		150 μm = 36.3%
	100 μm = 7.3%		100 μm = 29.0%
	75 μm = 8.2%		75 μm = 20.8%
Throughs	75 μm = 20.8%		

11.2.1.2 Handling and storage of crystal sugar

The moisture content of crystalline sucrose is very low at about 0.4% but every crystal has a minute film of moisture, a syrup, over it. If this moisture is reduced, for

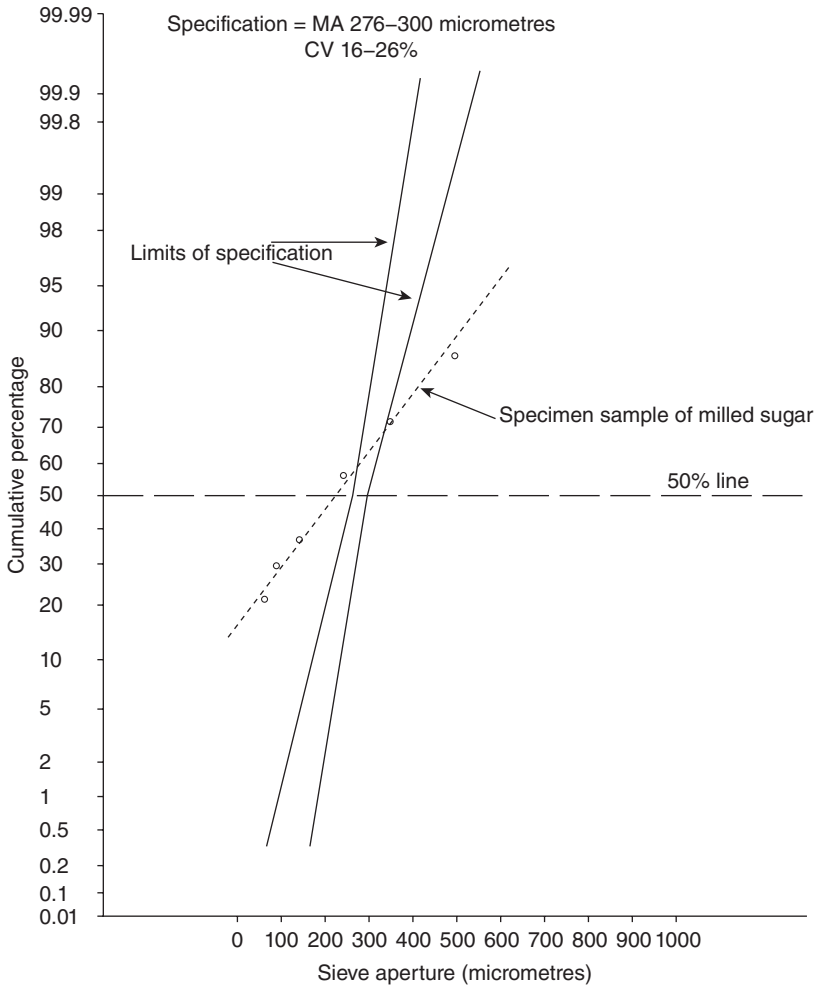


Fig. 11.3 Typical specification for caster sugar. MA = 276–300 μm ; CV = 16–26% with a plot of a milled sugar sample.

example by heating, sugar crystallises out and will cause adjacent grains to fuse together. This will form lumps or cause the sugar to stick to a silo wall. Thus it is most important to store sugar in a place of even temperature and low humidity. This temperature should be close to the temperature of the sugar when it is delivered.

Another factor which might contribute to caking of sugar, especially in silos, is local concentration of dust (sugar fines). This is created during handling whether it be mechanical or pneumatic, and generally it reduces the flow characteristic of the sugar. Being relatively dry, when sugar is moved, it tends to pick up static electrical charges. These are particularly severe during pneumatic conveying, and much care should be taken to earth (ground) pipes and containers. Sugar-air mixtures are highly inflammable, and an electrical spark could cause an explosion.

During pneumatic conveying the sugar crystals become broken to a greater or lesser extent. In view of the relationship between short dough spread during baking

and the particle size of the sugar, anything that causes variation in the particle size of sugar at the mixer should be viewed with concern. This matter is discussed again in the section on bulk handling of ingredients, see Chapter 33.

There is always a hazard during the milling of sugar due to the production of sugar dust in air, and it is wise to provide good magnet protection, before the mill, to ensure that small metal particles do not enter the mill and cause sparks.

During the milling of sugar to produce icing sugar a great deal of mechanical work is involved. This means that the icing sugar leaving the mill is quite warm. There are two problems associated with this. Firstly, as stated above, on cooling, moisture becomes redistributed, and caking may occur. Secondly, there is a gradual decrease in the volume of the icing sugar with time as the entrapped air cools and static electrical charges are dispersed. For both these reasons it is best to use icing sugar as fresh as possible from the mill. If it is necessary to store it, cooling under gentle agitation in a dehumidified atmosphere is desirable. As mentioned earlier, inclusion of up to 1.5% tricalcium phosphate powder helps to reduce caking of icing sugar in store.

11.2.1.3 Brown sugars

Refined sucrose is separated from a syrup or juice obtained from cane or beet. The impurities are in the form of a dark syrup. In the case of cane sugar, but not beet sugar, the syrup has strong and pleasant flavours. Sugar crystals are extracted from the syrup but some of the syrup adheres to the crystals and that which remains is very dark in colour. This syrup at the end of the refining process is known as molasses. The sugar crystals which have a coating of syrup are known as raw sugar or brown sugar. The colour of the syrup varies so the brown sugar may be golden brown or quite dark. The darker the colour the stronger is the flavour. Brown sugars have a moisture content of between 2 and 4% so are sticky and tend to cake and lump in store. Commonly used names of off-white to very dark brown sugars are Barbados, Muscovado, Demerara, Brown, Fourths, Thirds, Pieces and Soft.

Brown sugars are extensively used in baking for the distinctive flavour they give. They range in colour and particle size. The syrup is rich in invert (reducing sugars). With a view to standardising crystal size and brown sugar flavours, 'quality' brown sugars are frequently made now by combining white sugar of the desired size with syrup in a blender. To impart flavour in a baked product, or to darken the colour of the crumb, it is probably more economical to use a white sugar and a suitably flavoured syrup rather than cope with the problems of handling a 'brown' sugar.

11.2.1.4 Density of sugar

Single crystals have a specific gravity of 1.58. Crystal sugar has bulk density of 0.7–0.9 g/cc. The bulk density of fresh icing sugar is considerably less than this.

11.2.2 Liquid sugar

Very often sucrose can conveniently be used in biscuit manufacture as a solution, and the supply of sugar solution as opposed to crystals has become more popular as the handling and metering are easier. Liquid sugar may be available from the supplier but it is also possible to make a liquid sugar solution at the biscuit factory.

The advantages of liquid sugar are that

- it can be metered more accurately and cheaply than crystals and the first stage of a production process, namely dissolution of the sugar, has been completed before the mixing stage
- the capital cost of the installation is much lower.

Figure 11.4 shows the saturated solution curve for sucrose in water at different temperatures. Liquid sugar, as purchased, is usually 67% solids and may contain a low (never more than 5%) content of invert sugar to prevent crystallisation. It is a handleable syrup at ambient temperatures, and is concentrated enough to prevent microbial spoilage. However, the use of sterile filters is to be recommended in liquid sugar installations where condensation may occur giving lower concentrations which will allow fermentation by air-borne yeasts. It is best to store liquid sugar at not less

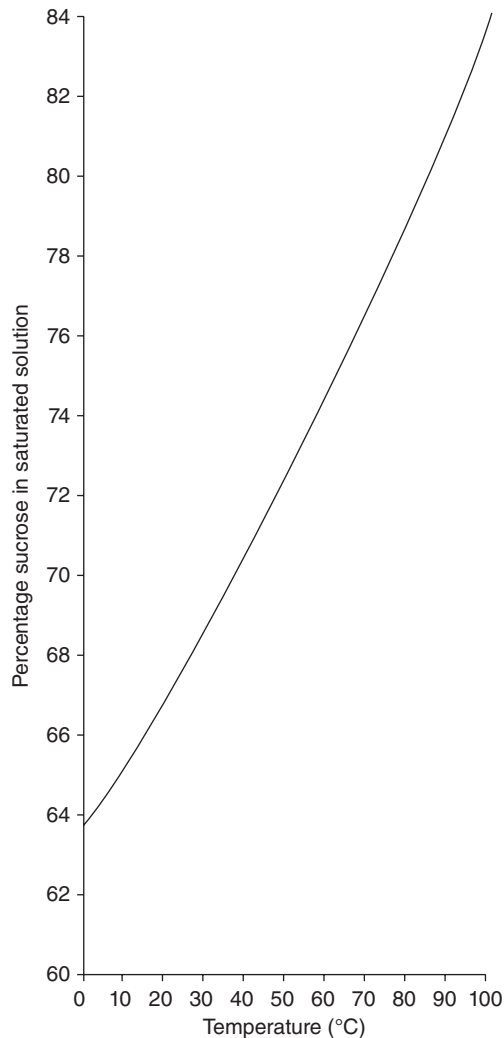


Fig. 11.4 Saturated solution curve for sucrose in water at different temperatures.

than 20°C to prevent crystallisation. Table 11.2 gives a typical specification for liquid sugar.

11.2.2.1 Measurement of sugar concentration in solution

In general, the concentration of sugars in solution are determined by indirect physical methods. The refractometer which measures the refractive index of a solution is commonly used for factory control. The refractive index of a syrup is a function of the composition of the solids, their concentrations and the temperature. Reference tables are available which relate the refractive index of a given syrup to its solids contents. Refractometers may be obtained calibrated directly in percentage sugar in the solution (see Fig. 11.5).

The concentration of sugar in a syrup is also indicated by the specific gravity. For sucrose solutions a specially designed sugar hydrometer (Brix scale) will, at 20°C, give a reading that is nearly equal to the weight of sucrose in the solution. Thus °Brix is essentially the concentration of sugar in a solution.

11.2.2.2 Inversion of sugar

Sugar solutions are optically active, that is, they possess the property of rotating the plane of polarised light. The extent of the rotation varies according to the particular sugar, its concentration, temperature and the distance that the light travels through

Table 11.2 Typical chemical specification for liquid sugar

Sucrose	66.5%	±1.0
Invert	0.5%	±1.0
Ash	0.3%	±0.2
Iron (ppm)	6	±0.5
Copper (ppm)	2	±0.5
Moisture	32.9%	±0.5
pH	6.0	±0.2
Specific gravity (at 20°C)	1.33	
Solids (per litre)	890 g	

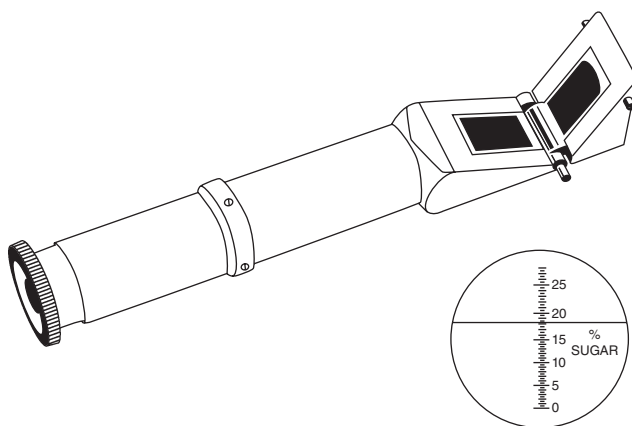


Fig. 11.5 A hand-held refractometer (after CABATEC module C1 [2]).

the solution. The direction of rotation also depends on the type of sugar. A sucrose solution rotates the light to the right (a positive direction) and as the sucrose is hydrolysed by acid or enzymes into reducing sugars the rotation changes to the left (negative direction). This is because the mixture of the two sugars produced, dextrose and laevulose (fructose) has a mean rotation to the left. This is the reason for the hydrolysis of sucrose being known as 'inversion' and the resulting mixture of lower sugars is called invert sugar.

11.3 Syrups

These fall into two classes: those derived from sucrose from sugar refining or by complete or partial inversion, and those derived from starchy materials, in particular cornstarch, by hydrolysis. In all cases the quantity and quality of the shorter chain sugar molecules are important. As may be supposed from this remark, the range of syrups of both types is very considerable.

11.3.1 Sucrose/invert syrups

These are mixtures of sucrose and invert sugar with varying proportions of other matter derived from the cane sugar liquor during refining. The latter give rise to golden or darker colours and distinctive flavours. Generally the flavour increases with the colour. Common types of syrup are golden syrup, amber syrup through to treacles and molasses (which is almost black in colour). They are strongly recommended for biscuit manufacture on account of their pleasant flavours and the stability of the flavour during baking. Molasses, however, tend to have a bitter taste.

By combining sucrose and invert sugars it is possible to obtain more concentrated syrups that are more stable in terms of crystallisation than with sucrose alone. Normally the syrups have about 80% solids. A common dark syrup used for biscuit manufacture contains about 60% of the solids as invert, 40% as sucrose and 1% or 2% as other materials. The pH of most syrups containing invert is around 5.5. These syrups are considerably more viscous than sucrose syrup and, consequently, are normally handled warm, at about 40°C, to render them more easily pumpable.

Some of the darker syrups, treacles and molasses, contain small amounts of insoluble matter that sediments on standing. It is thus necessary to empty storage silos regularly and wash them with hot water so that these sediments do not accumulate excessively.

All syrups are very attractive to insects, particularly wasps. Care should be taken to clean up spillages, and to make silo vent pipes insect proof. As an additional precaution sterile filters may be used to reduce the chance of fermentation in the silo head spaces, as described for liquid sugar.

11.3.2 Invert syrup

It is relatively simple to make invert syrup. A solution of sucrose is acidified and heated. Normally dilute hydrochloric acid (pH 2, about 1% solution of HCl) is used and after 1 hour at 75°C inversion is 95% complete. Sodium bicarbonate is added to neutralise the acid. This is invert syrup. Thus invert syrup contains a little sodium chloride, salt, as a result of the neutralisation. The sucrose is hydrolysed into

Table 11.3 Limits within which components of honey should fall

Water	17.7%	±2.8
Invert sugar	74.7%	±4.4
Sucrose	1.85%	±2.5
Ash	0.16%	±1.0
Undetermined material	4.18%	±2.8

dextrose and laevulose (fructose). Because of water uptake during hydrolysis the percentage of sugars in the invert syrup rises to about 5% above the initial percentage of sucrose. The hydrolysis can also be achieved with the enzyme invertase. The syrup is a clear liquid and has no particular flavour other than sweetness. It is usually purchased as an 80% solids syrup and should be stored at not less than 30°C to prevent crystallisation.

11.3.3 Honey

This is a very special (and expensive) syrup used in baking particularly for its flavour. The composition and flavour varies with the species of flowers visited by the bees but the components should fall within the limits shown in Table 11.3.

It can be seen that honey can chemically be described as an invert syrup and, in fact, can be matched very closely with a suitably flavoured mixture. Legislation, of course, prevents a synthetic honey being described as honey and analytical procedures can be used to detect adulterations to honey.

The problems of honey are mainly associated with flavour variation, and susceptibility to crystallisation on standing. The flavour can be controlled if many samples of honey are blended, but the crystallisation problem is more difficult to overcome. Crystals form on 'seed' particles or crystals, and efforts should be made to ensure that all sugar crystals are dissolved and natural yeasts and spores are destroyed before the honey is stored. A pasteurisation technique is usually used, but overheating can impair flavour. Storage in a cold place also promotes crystallisation. Honey is supplied in drums usually of modest size. It is never handled in bulk due both to its high value and the tendency to crystallise and, hence, block valves and pipes. The use of crystallised honey may cause specks in short dough biscuits. If honey has crystallised the crystals can be redissolved by heating.

11.3.4 Maple syrup

Maple syrup is obtained from the sap of certain maple trees. The sap contains about 3% sucrose and has a distinctive flavour. This sap is concentrated to about 70–75% sucrose. Maple syrup is used primarily as a flavouring ingredient and is relatively expensive.

11.4 Sugars and syrups from starches – glucose

The starch base is usually from maize, but wheat, potatoes or tapioca, etc., may also be the basic raw material. The starch is broken down by either acid hydrolysis or

Table 11.4 Relative sweetness of starch hydrolysis products compared with sucrose and other sweeteners [1]

Fructose	173
Invert syrup	105
Sucrose	100
Dextrose	74
62DE Glucose syrup	60
Honey	60
Maltose	32
42DE Glucose syrup	30
Lactose	16
Sodium cyclamate	10,000*
Saccharin	c40,000*

* Chapter 18 has more information on artificial sweeteners.

special enzymatic processes, or a combination of both. The ultimate breakdown product of the very long chain starch molecules is glucose (dextrose), but it is possible to stop the reaction at various stages, and the spectrum of carbohydrates present is very important in the physical and sweetness properties. The syrups produced are known generally as glucose syrups (corn syrups in the USA).

As the starch becomes hydrolysed it changes to a soluble and progressively sweeter product. Table 11.4 gives the relative sweetness of some starch hydrolysis products compared with sucrose. It should be stressed that these values are the result of taste panels. Sweetness cannot be measured in absolute terms.

11.4.1 Dextrose equivalence (DE)

The importance of reducing sugars in the Maillard reaction during baking has been mentioned above. Dextrose is a monosaccharide and a reducing sugar. Starch is a polysaccharide; it is made up of about 10000 dextrose units. The way in which the units are linked leaves only one at the end of the chain with a reducing capability, so starch is not regarded as a reducing compound. As the starch molecule is broken up in glucose processing, progressively shorter molecules are formed and each has a reducing element. Ultimately only dextrose molecules would remain, but normally the reaction does not go this far.

In an attempt to indicate how far the conversion from the starch has gone, the concept of dextrose equivalence is used. This is a measure of the reducing power of the syrup. Thus if 100 g of dry solid from a glucose syrup has a dextrose equivalent (DE) of 42 it means that the solids act in reducing terms as if they were 42 g of dextrose. The carbohydrate molecules present other than dextrose may be maltose, dextrans, oligosaccharides, polysaccharides, etc. The larger the molecule the lower the solubility and the lower the sweetness.

Using the enzyme isomerase, it is possible to make the conversion from starch produce some fructose in addition to dextrose. The result is a 'glucose' which is significantly sweeter than normal glucose syrups. These syrups are more nearly like invert syrup and are used extensively in soft drink manufacture but have little value in biscuit making. They are called high-fructose syrups but the level of fructose is not higher than in invert syrup.

Table 11.5 Typical specifications of two commonly used glucose syrups

		42 DE syrup	65 DE syrup
1. Solids		79.5–81.1%	79–81%
2. pH (20% soln. at 20°C)		5.0–5.5	4.7–5.3
3. Refractive index solids when measured on the sugar scale of a refractometer at 20°C		82–84%	78–80%
4. Typical spectrum on 100% dry substance basis	Dextrose	19%	55%
	Maltose	14%	22%
	Maltotriose	11%	7%
	Maltotetraose	10%	5%
	Higher sugars	15%	5%
	Dextrin	31%	6%
5. Appearance		Clean bright viscous liquid	Clean bright viscous liquid
6. Iron		5 ppm max.	5 ppm max.
7. Copper		1 ppm max.	1 ppm max.
8. Sulphur dioxide		250–400 ppm	20–40 ppm
9. Baume (°)		42/43	42/43

The function of glucose syrups in biscuits is limited. They provide reducing sugars to enhance surface colouration by the Maillard reaction and they give a crisp texture without significant sweetness in savoury biscuits. In soft eating biscuits glucose syrup will contribute favourably to the texture. Glucose syrups are convenient and economical products for controlling the equilibrium relative humidities, the relative sweetness, and in sugar confectionery and jams, the crystallisation of sucrose.

There are two commonly used glucose syrup grades, which have medium (42 DE) and high (65 DE) dextrose equivalents. Typical specifications for these are given in Table 11.5. The sulphur dioxide shown is derived from the process whereby the starch is obtained from maize, but it is also present to prevent discolouration, particularly if the syrup is stored at high temperature. Product that is free of sulphur dioxide can also be purchased.

°Baume is a measure of the specific gravity of a glucose syrup. Determination of °Baume (°Be) is still most widely made with a spindle hydrometer, and it is the most convenient method for determining the dry substance of a glucose syrup. Because of viscosity the °Baume are usually determined at 140°F (60°C). Reference tables are available to relate the °Be with dry solids content at various DE values. The subject is somewhat complicated but syrups with values of 42/43°Be, that is, about 81% dry solids, are commonly available and have viscosities at 40°C that are suitable for use in most applications.

11.4.2 Dry glucose, dextrins, dextrose and fructose

By a technique of spray drying, most of the syrups described above can be purchased as free-flowing fine white powders. Those with DE values up to 65 have moisture contents of 7% maximum. Maltodextrin is a commonly used product in biscuit

making. It has a DE value of 17–20% and is hardly sweet in taste. It is available as syrups or dried powders. Dextrose monohydrate (DE 99.5) is produced by a crystallisation process and typically has the following specification:

Form	White fine crystalline solid
Moisture	9.5% max.
Specific rotation (dry basis)	+ 53°
Sulphur dioxide	10 ppm

Dextrose is normally used as a very fine powder and as the crystalline monohydrate. It is possible to buy it in the anhydrous form. Dextrose gives a cool sensation on the tongue when it dissolves. For this reason and also because it is less sweet than sucrose it is used in limited quantities in fat-based biscuit creams. The moisture content limits its use as there is a tendency for the shells of the creamed sandwich to separate when moisture migrates into these shells and causes them to expand a little (and become less crisp). The solubility of dextrose monohydrate in water at varying temperatures is shown in Fig. 11.6.

Dry crystalline fructose is 73% sweeter than sucrose. It is relatively expensive but it has the property of being a safe and suitable sweetener for those suffering from diabetes. It is useful in biscuit creams but it does not give the same structures and textures as sucrose in baked biscuits.

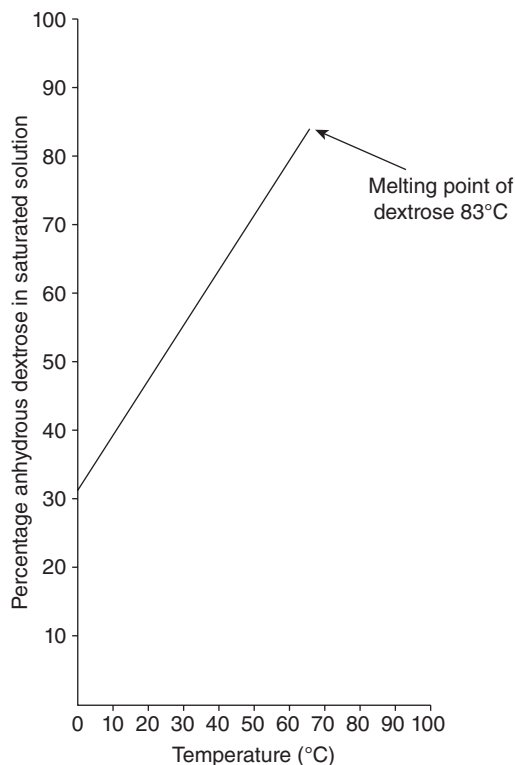


Fig. 11.6 Saturated solution curve for anhydrous dextrose at different temperatures.

Table 11.6 Typical composition of non-diastatic malt extract syrups

Solids	80%	±3
Total reducing sugars	55%	±5
Protein	5%	±1
Ash	2%	±0.5
pH	6	±1

11.5 Non-diastatic malt extract

This is made by concentrating the aqueous extract of malted barley or wheat. It is a viscous syrup of dark brown colour with a strong distinctive flavour. The principal sugar is maltose which is a reducing sugar. The composition, and flavour, vary depending on the source but a typical composition is shown in Table 11.6.

11.6 Maillard reaction

The Maillard reaction occurs between reducing sugars and principally free amino acids and peptides (usually from proteins) when heated. Actually the term 'Maillard reaction' is a misnomer. It is not a single reaction but a whole complex of reactions whose pathway and outcomes depend critically on factors such as pH and temperature. However, for our purposes here, it is the mechanism that allows products to brown at much lower temperatures than needed for caramelisation of sugars. The reaction is also known as the browning reaction, non-enzymatic browning and melanoidin formation. Browning by the Maillard reaction occurs more quickly in alkaline than in acid conditions and also at intermediate water activities. The reaction peaks at a_w 0.6–0.7. The reaction is also time/temperature related. Thus baking at low temperatures slowly gives the same colour results as baking at high temperatures quickly provided that the atmosphere around the product does not become too dry.

The Maillard reaction is most important for the production of brown hues on the surface of baked biscuits. The inclusion in biscuit dough of glucose or invert syrups is to ensure that the Maillard reaction occurs as required. If there is excessive Maillard reaction it may be difficult to dry the biscuit without too much colour formation. Sometimes proteins are added as milk powders. Milk contributes lactose which is a reducing sugar. The Maillard reaction contributes flavours to baked products.

It is worth noting that the Maillard reaction results in the production of attractive baked flavours and forms antioxidant compounds (possibly significant for extending shelf life). However, it reduces the nutritional value of food and it has been found that dogs do not like the flavours resulting from the Maillard reaction, so dog biscuits should not be baked to look like those for humans.

11.7 Polyols

Treatment of a reducing sugar with hydrogen gas in the presence of a catalyst results in a substance known as an alditol. Alditols and polyols, from other sugars, are sweet

Table 11.7 Relative degree of sweetness of different sugar alcohols

Sucrose	100
Xylitol	100
Maltitol	80
Sorbitol	60
Mannitol	60
Isomalt	45
Lactitol	35

Source: Xyrofin.

materials and sorbitol, xylitol, mannitol, maltitol, lactitol and isomalt are used commercially in food. These substances are also known as sugar alcohols, they are not reducing sugars and do not contribute to the Maillard reaction. Glycerol is a three-carbon polyol which is the basis of all edible oils and fats.

The sweetening power is always less than sucrose and all polyols have lower caloric values than sucrose. They are therefore often found in calorie-reduced products including chocolate. Sorbitol and xylitol occur naturally in fruits and berries. They and other polyols are sweeteners suitable for those suffering from diabetes who have difficulty in metabolising sucrose and other sugars due to elevation of blood glucose (see Section 31.4.4). Polydextrose is used as a non-sweet bulking agent suitable for diabetics.

Polyols exert a laxative and flatulence effect if 20–50 g are consumed per day. Xylitol is the sweetest of the polyols and is claimed to prevent dental decay. The use of polyols is subject to food legislation and some are not yet permitted for use in baked products in Europe. Table 11.7 gives an idea of the relative sweetness that may be expected from polyols compared with sucrose.

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Fats and oils as biscuit ingredients

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Abstract: This chapter looks at the role of fats and oils in the manufacture of biscuits, considering the quality, composition, specification and testing requirements for different types of fats used as dough fats, filling or cream fats, coating and chocolate fats, laminating fats, release agents and spray oils. A detailed description of the basic chemical and physical properties of fats and oils is also included along with a description of the various stages of the oil refining process, including how the physical properties of the oils can be modified to match the requirements of the products. Finally, the challenges associated with oils and fats such as sustainability and health issues for biscuit manufacturers are touched upon.

Key words: oils and fats, biscuits, oil refining and modification, properties of oils and fats, saturated fats.

12.1 Introduction

Fat is one of the most important ingredients in biscuits. It adds structure, eating quality and flavour to the product. Without fat, biscuits would be unrecognisable from the ones available today. Fat in a biscuit can be denoted in several ways: it can be seen on the label as butter, animal fat (although this is less common now), vegetable fat or vegetable oil (including the named types such as palm oil, sunflower oil, etc). It may also be presented in a generic form such as 'shortening' which is a term used to describe one of the key functions of fat in biscuits which is to 'shorten' the dough that is, to give it that typical 'melt in the mouth', crumbly texture which is characteristic of biscuits.

As indicated earlier, fat in biscuits can originate from many sources, although in the native form many of these have typically been unsuitable for direct use in biscuit making. For many years refined animal fats were an important source of fat for the biscuit industry as they had melting characteristics which gave them excellent performance in biscuits and also provided flavour. However, because of the origin of these materials they were inherently variable in quality and so could cause some issues during processing. Also as biscuit makers wanted to widen the appeal of their product to all consumers, animal fats in the main gave way to vegetable fat alternatives.

Apart from countries in the Far East such as Indonesia and Malaysia where palm oil is prevalent, the most common oils available at the time were those such as rapeseed oil, soyabean oil and sunflower oil. These oils are liquid at normal ambient

temperatures and for reasons that will be discussed in Section 12.5 unsuitable for use in their native form. To overcome this the oils were modified through a process known as hydrogenation (more of which in Section 12.3) to increase the melting point and give the oils the characteristics they need. This worked well until around 2006 when health issues relating to the level of *trans* fats (see Section 12.3) in partially hydrogenated oils came to the fore [1]. Because of the misunderstanding and confusion about the differences between *trans* fats and the process of hydrogenation, which does not always produce *trans* fats [2], there was a drive for biscuit manufacturers to look at non-hydrogenated alternatives as biscuit fats. Because biscuit fats typically need to be solid at ambient temperatures, the only real commercial alternative was palm oil which has a melting point of around 36°C and for many years now palm oil has been the non-hydrogenated oil of choice for making biscuits. However, this is now being challenged for reasons of both health and sustainability, more of which in Section 12.8.

12.2 The role of fat in biscuits

Although it may only appear once on a product ingredient list or nutritional panel, it is possible for fat to be present in biscuits from several sources during the manufacturing process. In this section I will consider a number of these sources and the function of the fat from each.

12.2.1 Dough fat

This is the most common use of fat in a biscuit and makes up by far the largest volume in use. The term dough fat is self explanatory in that it is added directly to the biscuit dough during the mixing phase to provide the ‘shortening’ effect describe in Section 12.1 and will be used in the vast majority of biscuit types from short dough biscuits such as digestives, cookies and Viennese, hard sweet biscuits such as Marie or Rich Tea and crackers.

Whether it is a premium product that uses butter or a standard product using a vegetable fat, the primary function in the dough is the same. During the mixing of the dough the fat will form a coating around the flour to limit the water in the mix from coming into contact with the flour. This is vitally important in a biscuit because when water comes into contact with flour along with the action of mixing which adds energy, the gluten (protein) in the flour is allowed to ‘develop’, i.e. become more extensible and strengthen the dough. Although this property is desirable in a product such as bread, in a biscuit after baking it gives rise to a product which is hard, brittle and very unpalatable. A secondary function of adding fat to the dough is its ability to coat any small air bubbles which may be present which in turn makes the bubble structure more stable preventing the bubbles rupturing and coalescing into larger bubbles. Although this is not as important in biscuits as it is in something like cake manufacture, it can be a factor in maintaining a good structure in the dough.

Research from Brooker [3] suggests that in this function of coating air bubbles, a fat with a developed crystalline structure is more effective than a liquid oil and to achieve this in highly automated biscuit plants, dough fats are typically crystallised on site to form a fluid shortening which is essentially crystallised fat suspended

in a liquid oil carrier. To obtain this as a stable structure it is necessary to crystallise the fat rapidly and then hold it for a period of time to allow the crystal structure of the fat to fully form and stabilise into the most functional crystalline state, known as the β' (beta prime) form.

Most fats are what are known as polymorphic, which means that they can exist in several crystalline forms as can be seen in Fig. 12.1. Initially on cooling, the fat will crystallise in the α form but this is unstable and will quickly transform into either the β' or β forms depending on the processing and storage conditions.

If the fat is cooled rapidly in what can be termed a static system, i.e. where it is simply chilled and packed, the crystals will cool to form a tight, close-knit matrix making a hard, brittle product which is unsuitable for biscuit making. To make the 'plastic' pumpable fat that is required, the fat will be typically crystallised in a continuous process through a specialist piece of equipment known as a chiller/plasticiser or more commonly by the trade names of particular manufacturers such as 'Votator' (Waukesha Cherry-Burrell, www.gowcb.com) or 'Perfector' (Gerstenberg-Schröder A/S, www.gs-as.com). An outline of such a system is shown in Fig. 12.2.

Under ideal conditions the system will operate as follows. The oil (F) is firstly pumped through chiller unit at temperature T_1 which is ideally 5–10°C above the slip melting point of the fat (see Section 12.6.2 for a description of slip melting point) and pressure P_1 which is dependent on the setup of the system but will be positive pressure as the oil meets resistance in the chiller tube. As the oil passes through the chiller unit it comes into contact with the cold inner surface of the tube which is cooled to around -20°C typically by liquid ammonia passing through a jacket surrounding the tube. As the oil contacts the cold surface it cools and crystallises quickly and is constantly scraped off the surface by a rotating barrel carrying scraper blades to initially form α crystals. However these crystals are unstable and will readily transform into the desired β' crystals under the correct conditions. These conditions will be different for each oil blend but can be identified here as T_2 . The proportion of solid fat at this point will still be low, but P_2 will have increased as the viscosity of the fat has increased. This transformation takes time and so the second stage of the process is to pass the fat at its optimum temperature through a worker unit where a series of rotating pins mix the partially crystallised fat to

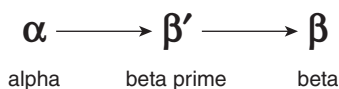


Fig. 12.1 The crystalline forms of fats.

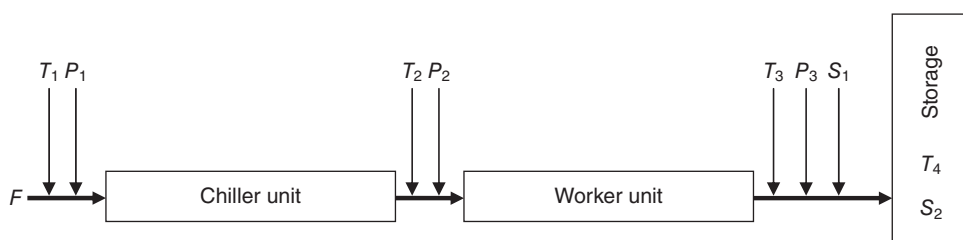


Fig. 12.2 Outline layout for a chiller/plasticiser system (after [4]).

encourage further crystallisation and provide the residence time for the $\alpha \rightarrow \beta$ crystallisation to occur. The temperature on exiting the worker unit (T_3) will be higher than T_2 because the mechanical action of the worker unit adds energy but also the crystal transformation releases energy in the form of heat. P_2 will be higher than P_1 as the solid fat content and the viscosity of the fat increases. After exiting the worker unit, most of the high energy transformations should have taken place and so the final storage temperature (T_4) should be broadly in line with T_3 . There may be a slight increase in temperature due to transformations from $\beta' \rightarrow \beta$ but these are small in comparison to the initial transformations. At this point the solid fat content should be virtually fully formed and so the values measured at S_1 and S_2 should be almost the same. Further discussion in relation to key parameters of dough fats follows in Section 12.5.1.

12.2.2 Laminating fat

In products such as savoury crackers and puff biscuits, alongside the dough fat a secondary fat is used which gives the products the 'flaky' characteristics which distinguish these products. This fat is known as a laminating fat because it is used to build up layers or laminations in the dough during the manufacturing process in much the same way that is used to make puff pastry. The dough is sheeted and then the laminating fat is deposited on top of the sheet. The more technical requirements of this group of fats is discussed further in Section 12.5.2.

The dough is then folded onto itself trapping the laminating fat to form the layers and then the folded dough is sheeted again. This new sheet, which now contains several discrete layers, is folded in the same way as described earlier to form new layers and this process is repeated as many times as necessary to give the effect required. Generally the more layers that are formed the more of the 'puff' effect will be seen in the end product.

In the same way as described in relation to dough fat in Section 12.2.1, the key requirement of a laminating fat is for it to be plastic in nature and it is even more critical in this application because of the requirement for the fat to form a continuous layer within the dough structure. If the layers of fat are discontinuous then the lift will be uneven because steam from the water in the dough will not be trapped by the fat which is what gives rise to the lift. Interestingly it is this discontinuity which is purposefully introduced into the lamination layers in products such as cream crackers that gives them their characteristic blistered appearance. The discontinuity is typically brought about through the use of a powder type laminating fat rather than a continuous extruded fat.

12.2.3 Filling fats

The requirements for a filling fat can be much more critical than those of a dough fat or even a laminating fat. These fats are typically blended with sugars such as icing sugar or glucose and possibly an emulsifier such as lecithin to be used as cream type products in sandwich biscuits. The creams are typically aerated mechanically and the structure of the fat must support this aeration to achieve specific gravities in the fillings in the range of 0.6–0.8 g/ml. As with both dough fats and laminating fats, plasticity is a key factor in the performance of filling fats and this will be achieved through correct formulation and processing during manufacture in order

to ensure that most of the fat is in the β' crystal form. The composition of these fats is also very different from any of the other fats discussed previously as the melting characteristics of the fat are critical to the flavour and mouthfeel of the end product. The fat must be designed to melt readily at body temperature (37°C), be soft enough to process and deposit but must also be firm enough at ambient temperatures to form a cream which is going to hold its shape and structure in the finished biscuit. More on composition and characteristics of these types of fats in Section 12.5.3.

12.2.4 Chocolate fats

The composition of chocolate products is well defined and is limited through legislation in most parts of the world. In Europe this is covered in EC Directive 2000/36/EC [5] and this legislation describes requirements for cocoa butter and vegetable fats which can be used in materials which can legally be labelled as chocolate. Cocoa butter is extracted from the cocoa bean and its characteristics are very well defined and understood, being the basis for all chocolate products with minimum percentages being necessary under the legislation.

The use of vegetable fats in chocolate had been a matter of some controversy in Europe [6] but the above legislation then allowed the use of six specific types of vegetable fat to be incorporated, to a maximum of 5% by weight whilst still being able to call the product chocolate. These fats were illepe, palm oil, sal, shea, kokum gurgi, mango kernels and copra (coconut) oil and the derivatives of these fats form a special class of fats known as CBEs (cocoa butter equivalents). They are special in that they have a high proportion of what are known as symmetrical triglycerides and have similar physical properties to cocoa butter which means that they can be blended with cocoa butter without affecting the overall characteristics of the product, e.g. the chocolate will still require tempering before use.

In products such as flavoured coating fats where the designation 'chocolate' is not used then a much wider choice of fats is available to be used and in many cases these do not require the tempering stage. These fats are generally referred to as CBS (cocoa butter substitutes) or CBR (cocoa butter replacer). CBS are generally based on lauric fats such as coconut oil or palm kernel oil whereas CBR are usually based on oils such as soyabean oil, rapeseed/canola oil or palm oil but go through sophisticated manufacturing processes to give them similar melting characteristics to cocoa butter. More detail about CBE, CBS and CBR is covered in Section 12.5.4.

12.3 The chemistry and physical properties of fats

Before progressing into more detailed explanations about the composition, nature and properties of each type of fat described in Section 12.2, it is necessary to understand a little more about the structure, physical properties and processes that all contribute to give each fat its own characteristics. Fats and oils are also commonly referred to as either lipids or triglycerides. The latter describes them well as they are composed of three fatty acid chains attached to a glycerol molecule backbone as illustrated in Fig. 12.3

Fatty acids are an essential building block of human life and come in many shapes and sizes. There are two key features of fatty acids which characterise them: their

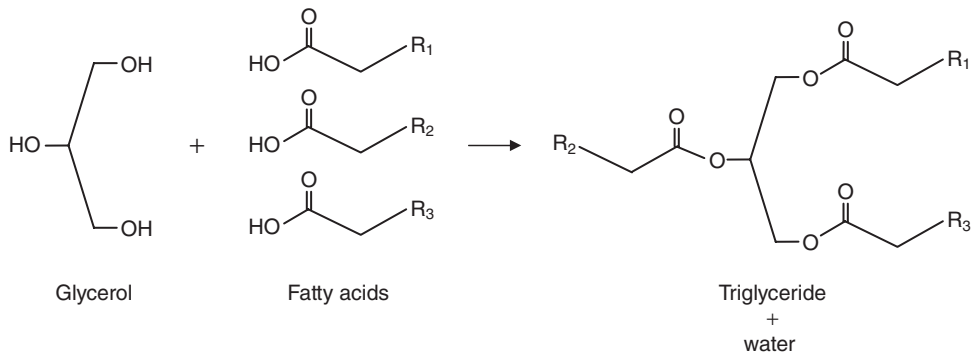


Fig. 12.3 Triglyceride structure.

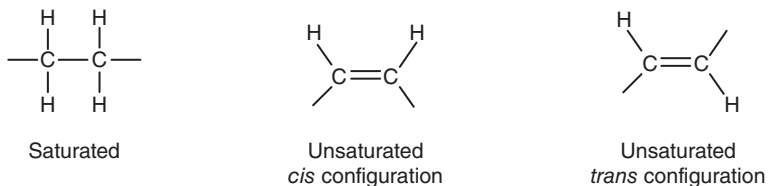


Fig. 12.4 Saturated and unsaturated fatty acids.

length, i.e. the number of carbon atoms which form the long chain; and whether they are saturated or unsaturated. In vegetable fats the fatty acids are most commonly in the range of 12–18 carbon atoms long and can be classed as either saturated or unsaturated. Saturated fats are fairly simple in structure containing only carbon–carbon single bonds. Unsaturated fats are more complex as they contain not only carbon–carbon single bonds but also carbon–carbon double bonds. These double bonds add complexity to the system in that there can be multiple double bonds in a fatty acid molecule and also that each of the double bonds can align in two different ways, one being the ‘*cis*’ form, where the two hydrogen (H) atoms are on the same side of the bond, the other being the ‘*trans*’, form where the hydrogen atoms are on the opposite sides of the double bond. These structures can be compared in Fig. 12.4.

As mentioned in Section 12.1, much has been made in recent years over health concerns relating to the presence of *trans* fats in food because of the way they metabolise in the body and can lead to an increase in so-called ‘bad cholesterol’. Most food manufacturers have now formulated *trans* fats out of their products even though this has in many instances led to increases in levels of saturated fats to compensate for the loss of functionality that *trans* fats supplied.

When referring to fatty acids there are various nomenclature systems, but the most common systems are either the scientific name such as lauric acid, palmitic acid, etc., or the shorthand version which shows the number of carbon atoms and the number of double bonds. For example, palmitic acid (a saturated fat, i.e. no double bonds and with 16 carbon atoms) could be shown as C₁₆:0 and linoleic acid (an unsaturated fatty acid with 18 carbon atoms and 2 double bonds) could be shown as C₁₈:2. In relation to the physical properties of the fatty acid, the length of

the carbon chain is an indicator as to whether the fat is going to be high or low melting with shorter chain acids melting at lower temperatures. For fatty acids with the same number of carbon atoms, the melting point will decrease as the degree of unsaturation (the number of double bonds) increases. This trend is illustrated in Table 12.1.

It is this combination of long and short chain, saturated and unsaturated fatty acids that give each of the common oils and fats its own particular characteristics and any particular oil can generally be identified by its characteristic 'fingerprint' of fatty acids commonly known as its fatty acid profile. The profile of a number of common oils and fats are shown in Table 12.2.

Referring back to Fig. 12.3, naturally occurring oils and fats have three fatty acids attached to the glycerol backbone. If all of these were the same fatty acid then the fat would melt at a single clear, sharp point related to the melting point of the fatty acid. Unfortunately in nature this is not the case so a fat is a mixture of different triglycerides which individually have a variety of fatty acids. Thus rather than a clear melting point the fat would melt over a temperature range which reflects the range of melting points of the fatty acids. This means that characterising fats can be very difficult as fats with nominally the same melting point can have very different melting characteristics and ranges. To try and characterise the way that fats melt numerous techniques have been developed, but perhaps the most common measures the relationship between the temperature and the amount of solid fat present at that temperature. Twenty years or more ago a technique known as dilatometry was used for this and measured the change in volume of a fat as it changed from a solid to a liquid as temperature increased. This is the same principle as a liquid-in-glass thermometer where the volume of liquid in the thermometer bulb expands as the temperature increases forcing the liquid up the stem of the thermometer. The test was complex and time consuming taking up to five hours to complete as samples were held in water baths at various temperatures and the change in volumes measured. To overcome this a technique known as pulsed nuclear magnetic resonance spectroscopy (pNMR) was developed which again measured the amount of solid fat but used a magnetic field to measure the ratio of solid to liquid fat in a sample at a given temperature. This test was simple and quick and soon became the *de facto* standard for testing the melting profile of fats. The technique is described in more detail in Section 12.6.1 and typical melting curves of a number of fats can be seen in Fig. 12.5.

Table 12.1 Characteristics of fatty acids

Carbon chain	Common name	Type	Melting point (°C)
C ₁₂ :0	Lauric acid	Saturated	44
C ₁₄ :0	Myristic acid	Saturated	54
C ₁₆ :0	Palmitic acid	Saturated	63
C ₁₈ :0	Stearic acid	Saturated	70
C ₁₈ :1	Oleic acid	Unsaturated	16
C ₁₈ :2	Linoleic acid	Unsaturated	-5
C ₁₈ :3	Linolenic acid	Unsaturated	-11
C ₂₂ :0	Behenic acid	Saturated	80
C ₂₂ :1	Erucic acid	Unsaturated	34

Table 12.2 Fatty acid distribution of common oils and fats

Oil/Fat	Unsaturated/ saturated ratio	Capric acid	Lauric acid	Myristic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
		C ₁₀ :0	C ₁₂ :0	C ₁₄ :0	C ₁₆ :0	C ₁₈ :0	C ₁₈ :1	C ₁₈ :2	C ₁₈ :3
Beef fat	0.9	—	—	3	24	19	43	3	1
Butter	0.5	3	3	11	27	12	29	2	1
Rapeseed (canola) oil	15.7	—	—	—	4	2	62	22	10
Cocoa butter	0.6	—	—	—	25	38	32	3	0
Coconut oil	0.1	6	47	18	9	3	6	2	0
High oleic sunflower oil	10.1	—	—	—	4	3	85	6	—
Olive oil	4.6	—	—	—	13	3	71	10	1
Palm oil	1.0	—	—	1	45	4	40	10	—
Palm kernel oil	0.2	4	48	16	8	3	15	2	—
Peanut (groundnut) oil	4.0	—	—	—	11	2	48	32	—
Safflower oil	10.1	—	—	—	7	2	13	78	—
Shea oil	1.1	—	1	—	4	39	44	5	—
Soyabean oil	5.7	—	—	—	11	4	24	54	7
Sunflower oil	7.3	—	—	—	7	5	19	68	1

Values are average/typical and may vary. Minor components are not listed hence figures may not total 100%.

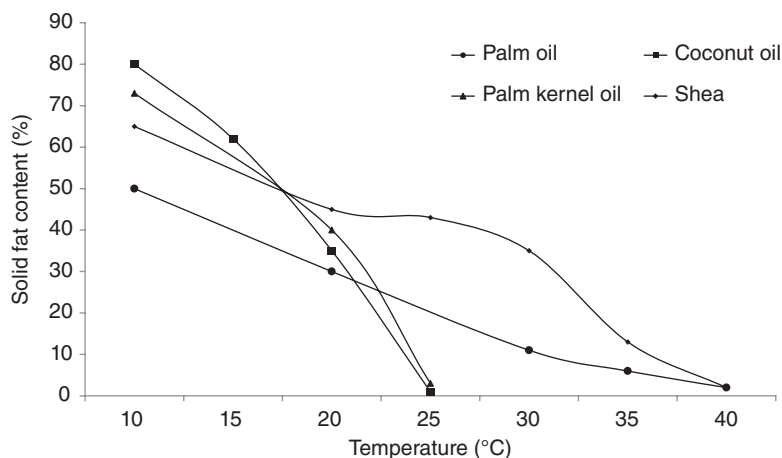


Fig. 12.5 Melting curves for common fats.

Although these simple fats are widely used and perform well in many applications, the lack of naturally occurring high melting point fat or fats with particular melting characteristics is a problem. However, a number of techniques have been developed over the years to modify the commonly occurring oils and fats to give the physical properties needed for the specialist applications such as chocolate fats, shortenings, margarines, etc.

The first of these techniques which has been in use for well over 100 years now is known as hydrogenation. This process takes a low melting point oil or fat and increases the melting point by converting some or all of the unsaturated fat into saturated fat and as illustrated in Table 12.1 as the degree of unsaturation decreases the melting point increases. The process itself involves a chemical reaction with hydrogen gas being added to hot oil in a reaction vessel in the presence of a catalyst which is there to make the reaction happen more quickly. The hydrogen then adds across the double bonds on the fatty acid, breaking one of the bonds to form a single, saturated bond. If the fat is fully hydrogenated, i.e. all of the double bonds in the fat are converted, then the fat is said to be fully saturated and contains no *trans* fat (Section 12.1). If the product is only partially hydrogenated, i.e. some double bonds remain, then this is the scenario that can give rise to the presence of *trans* fats. Given all of this, hydrogenation is still a process which has served the biscuit industry well for many years.

Since 2006, however, there has been a drive towards using non-hydrogenated fats in biscuits to remove the possibility of *trans* fats being present. Because for some applications such as filling and chocolate fats simple fats will not meet the needs in terms of melting profile, this has driven the need to use other techniques to produce these speciality fats. These techniques are known as fractionation and interesterification.

Fractionation is the process of separating an oil into different parts or fractions which are made up of different triglycerides, usually a liquid phase known as the 'olein' fraction and a solid phase known as the 'stearin' fraction. The principle of the process is relatively simple: the oil or fat is heated to a temperature just above its melting point and then cooled under controlled conditions so that the higher melting triglycerides crystallise which can then be separated via a filtration system.

This process can then be repeated if necessary on either the stearin or olein fractions to obtain so-called double fractionated stearin or double fractionated olein. This simple process is known as ‘dry fractionation’ and is suitable for most general purpose fats used in biscuit manufacture. For the more specialist fats used in chocolate coatings, etc., where a much ‘purer’ fraction is needed, a technique known as solvent fractionation is used. This involves dissolving the fat in a solvent such as hexane which improves the purity of the crystals and makes the separation more effective. The solvent is then completely removed at the end of the process. The effect on the solid fat content from the fractionation of palm oil is shown in Fig. 12.6 with the stearin fractions being especially useful in the manufacture of biscuits.

The other technique used to modify the properties of oils and fats is that of interesterification (commonly referred to as IE) which involves the rearrangement of the fatty acids on the glycerol backbone of the oils into a form where they are attached in a completely random structure as shown in simplified form in Fig. 12.7, where ‘S’ represents stearic acid and ‘O’ represents oleic acid. The catalyst is usually a chemical such as sodium methoxide which is added to the hot oil and mixed until completion. The catalyst is then completely removed at the end of the process. A newer, more specialist process which is catalysed by enzymes is also available and this gives the possibility of non-randomised interesterification with particular fatty acids being directed to certain positions on the glycerol backbone in order to tailor products to specific applications. This process can be significantly more expensive

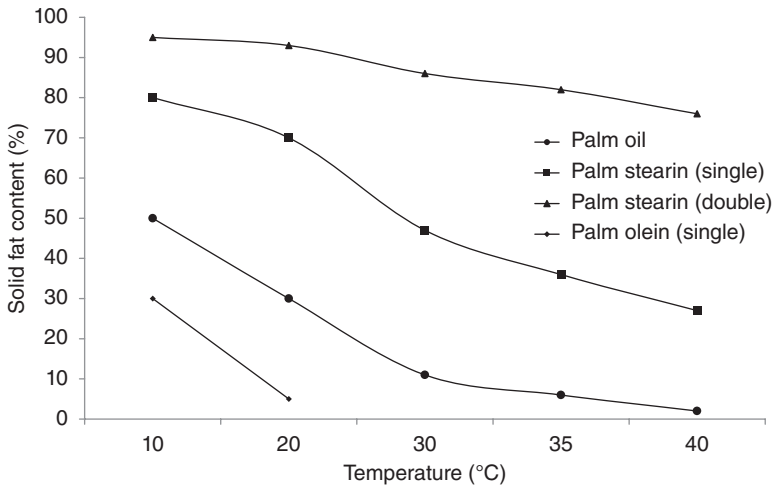


Fig. 12.6 Fractionation of palm oil.

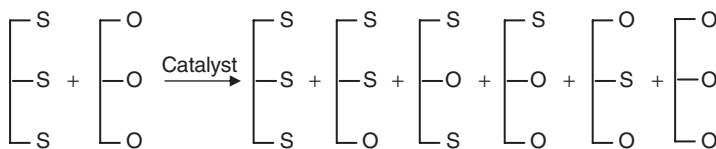


Fig. 12.7 Interesterification of fats.

than the traditional method and so is only used for very specific applications where the extra cost can be carried.

The main reason for using interesterification is to modify the crystallisation and melting behaviour of a fat, often to give a faster, sharper melting product with better mouthfeel. The effect on solid fat content through the modification of palm stearin is illustrated in Fig. 12.8.

12.3.1 Refining of oils and fats

Whether the fat is in its simplest form or modified through any of the techniques described earlier to get it into a condition which is suitable for use in biscuits, it must be refined to remove any physical and chemical impurities along with unwanted colours and flavours. The refining process involves several stages, each of which is designed to remove specific impurities.

The first stage is known as degumming. This involves the treatment of the oil with acidified water which solubilises the gums (hence degumming), allowing them to be washed out with water. These gums or phospholipids, as they are also known, are not wasted but collected and separately refined to produce the emulsifier called lecithin.

After degumming, the next stage is known as refining and this process is specifically designed to remove any free fatty acids that are present in the oil due to breakdown of the triglyceride during transportation and storage. There are two different types of refining, alkali refining or physical refining. As its name suggests, alkali refining involves treating the oil or fat with an alkali which neutralises the free fatty acids converting them into soaps. These soaps can then be water washed out leaving a neutralised fat or oil. The waste stream is known as soapstock. Physical refining does not use any chemicals but uses high temperature and high vacuum to distil out the free fatty acids which are more volatile than the triglyceride. This distillate waste stream is known as acid oil.

Bleaching is the next stage in the process of preparing the oil or fat and, as its name suggests, the main purpose of this step is to remove materials such as chlorophyll and carotene that give the oil its colour. The bleaching process does, however,

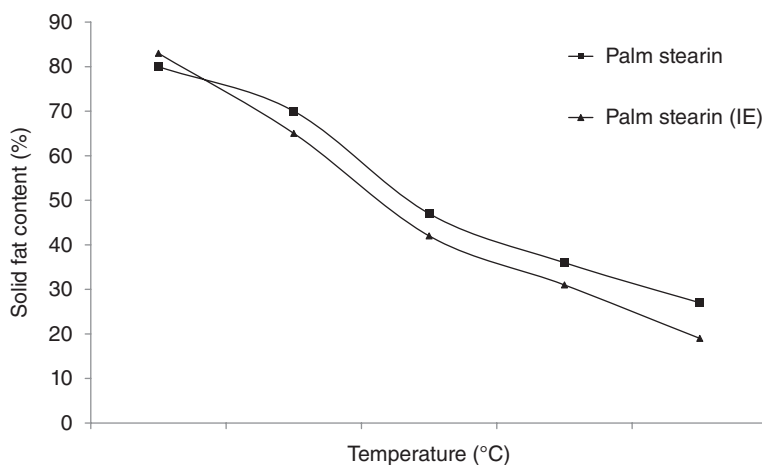


Fig. 12.8 Interesterification of palm stearin.

also remove traces of other impurities such as metals and oxidation products. The bleaching process for oils and fats is a physical one rather than a chemical one through the use of a material known as a bleaching earth which is added to the hot oil under vacuum. The earth is a very finely divided natural clay with a very large surface area, able to adsorb these impurities. The clay containing the impurities can then simply be filtered out from the oil at the end of this step.

The final step in the process is called deodorisation and is primarily designed to remove unwanted flavour and odours but it is also effective at removing the final traces of free fatty acids and pigments. Because the unwanted components are much more volatile than the triglycerides, they are effectively removed by passing high temperature steam through the oil at high temperature (typically $>250^{\circ}\text{C}$) under a high vacuum. These conditions allow the volatile impurities to distil out leaving an oil which is substantially improved in terms of flavour, stability and colour which is characteristic of a top quality refined oil.

12.4 Quality and handling issues of fats

The aim of the refining process is to deliver high quality oil of the right specification and it is important that it stays in this condition so that the end user can produce high quality biscuits through the whole period of use. Any deterioration in quality can be due to either chemical or physical problems in storage. If the quality of the oil deteriorates in quality chemically this is usually due to two possible causes.

The first is a hydrolytic reaction, where water reacts with the oil and causes fatty acids to break away from the triglyceride increasing the level of free fatty acids (FFA) in the oil. The reaction is often catalysed by enzymes called lipases which can be present in the oil through some form of contamination with organic matter such as flour, etc. Depending on the end use and the type of oil, this increase in FFA can vary in importance. For biscuit manufacturers it is especially important in oils which contain so-called lauric fats (coconut or palm kernel oils) as the shorter chain fatty acids that are present are much more easily broken from the triglyceride and can lead to the development of a soapy flavour in the oil. For this reason it is often the case that small quantities of lecithin emulsifier are added to the fats as these can act as moisture scavengers preferentially binding with the water and preventing the breakdown of the fat. One other consequence of increases in FFA in the oil is that with increasing FFA the smoke point of the oil will fall and so it is possible for excessive smoke to develop during baking if residual fat is left on an oven band, for instance over an extended period of time.

The second route for chemical breakdown is through oxidation products from where the oil comes into contact with oxygen/air. This is very difficult to avoid completely but because the reaction is catalysed by several factors including temperature, light and the presence of certain metals, various measures can be put in place to minimise the problem. As a rule of thumb the rate of oxidation will double for every 10°C rise in temperature of the oil, i.e. the shelf life of oil will decrease by half for every 10°C increase in temperature during storage. It is hence very important to carefully control the temperature of oil in storage and ideally it should never be more than $10\text{--}15^{\circ}\text{C}$ above its nominal melting point. Oils and fats should be stored away from direct sunlight, and contact with so-called yellow metals such as copper and brass should be avoided. This means that things such as pump seals, etc.,

should be checked to make sure that only stainless steel or non-reactive materials are in contact with the oil. The degree of oxidation is typically measured through the value known as peroxide value (PV), more of which in Section 12.6.

Physical issues that can affect the quality in use of fats which are of particular importance to biscuit manufacturers include viscosity and crystal structure which to a degree are related. As described in some detail in Section 12.2.1 for dough fats, cream fats and laminating fats much time and care is spent crystallising the fat in such a way as to maximise the number of β' crystals present to optimise performance. Once in storage if the crystallised fat is not held at the appropriate temperature then these β' crystals can quickly transform into β crystals which are much bigger in size and less functional. The fat will start to look grainy and dull and will become very difficult to handle as liquid oil from the fat will pump preferentially leaving a mass of β crystalline fat in the tank which becomes unusable.

Food safety is not usually a problem with oils and fats due to the absence of water in the product. It is only if there is any serious contamination in the oil that microbiological problems need to be considered when assessing risk. Transportation from the supplier to the user needs to be controlled to prevent contamination but nowadays this is very well controlled through the use of road trucks, etc., that comply with minimum standards. One such scheme is delivered in the UK by SCOPA (Seed Crushers and Oil Processors Association) and within Europe by FEDIOL (Federation de l'Industrie de l'Huilerie de la CEE) and details of these various codes of practice can be access from the individual websites [7, 8].

12.5 Key characteristics of fats for biscuits

Typical characteristics of each type of fat are described below and typical solid fat contents are shown in Fig. 12.9.

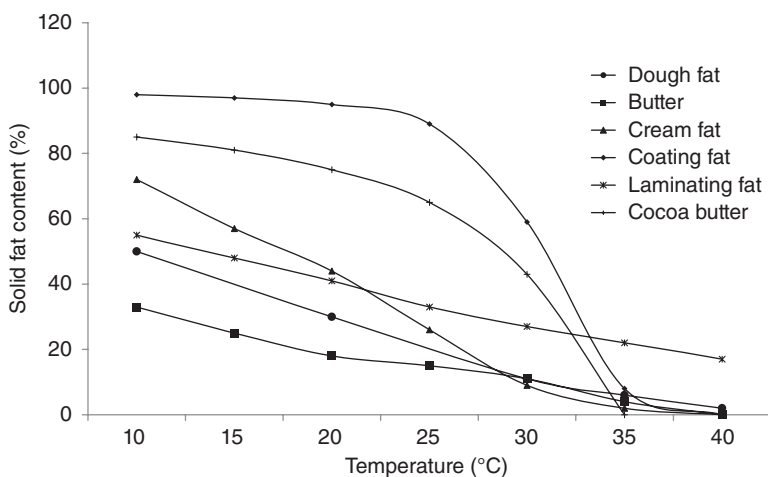


Fig. 12.9 Typical characteristics of fats for biscuits.

12.5.1 Dough fats

The melting profile and crystal form of the fat used in the dough is, as described in Section 12.1, critical to the end quality of the biscuit. For smaller scale manufacturers, who would typically use a boxed shortening in the dough, the crystallisation is done by the fat manufacturer during the packing of the fat. These boxed shortenings are generally formulated from blends of oils giving a broad melting range which can be used in a wide variety of biscuits. Margarines can be used in biscuits but typically require some rebalancing of the dough recipe because the margarines will contain around 16–18% of water. Butter is also used in premium biscuit products where it delivers excellent flavour but has the disadvantage that it can be variable in consistency and is much softer at normal dough temperatures than typical formulated shortenings which can cause problems of oiling out or very soft doughs requiring some changes to be made to the product recipe.

Since around 2006 the most common fat in use as a dough fat by large scale biscuit manufacturers has been unmodified palm oil. This is because it cost effectively provides the level of solid fat (~20%) required in the dough at the working temperatures of around 25°C and is able to crystallise in the required β' crystalline form. However, as health issues related to the level of saturated fats in baked goods including biscuits have come into the public eye and governments such as that in the UK have issued guidelines for reducing the level of saturated fats in foods [9], biscuit manufacturers have been looking to reduce levels of saturated fat in biscuit doughs. One route to this is by blending palm oil with a liquid oil such as high oleic sunflower oil (HOSO). Every 10% substitution of HOSO into the palm oil reduces the saturated fat levels by around 4%. However, as the oils become softer the chance of migration into any coating or filling can be a problem leading to other issues such as fat bloom, and this needs to be considered carefully as any changes are made.

12.5.2 Laminating fats

These fats are typically much firmer than dough fats as they need to be able to maintain a higher level of solid fat at dough processing temperatures to prevent the fat melting and simply being absorbed into the dough. If this should happen then the lamination effect will be lost. These fats are typically blends of high melting palm oil fractions with palm oil and possibly some liquid oil. The solid fat content of these types of fats will typically be around 35% at 25°C and they will be pre-crystallised by the fat supplier to ensure that they have the correct level of plasticity required for the application.

12.5.3 Filling fats

Also known as cream fats, these much more specialist fats were most usually based on hydrogenated palm kernel or coconut oils until the move to non-hydrogenated fats. These worked very well as they provided all of the necessary characteristics of a cream fat of having excellent stability, good aerating properties, a good gloss and, perhaps most importantly, a very good melting profile. The melting profile of lauric fats is particularly suited to this application because of the speed at which they melt as the temperature approaches body temperature (37°C) whilst maintaining high levels of solids at lower temperatures. This means that the fillings can be processed soft enough to be mechanically deposited on the biscuit but will be firm enough

when cooled so as not to spread when sandwiched and packed. The rapid melt in the mouth also gives the sensation of cooling in the mouth which works well with the sweetness in the biscuit base. As a replacement for hydrogenated lauric fats, manufacturers have moved to non-hydrogenated palm kernel stearin as a key component in these fats. This has similar properties to the hydrogenated fats but is much more expensive. This component is often also interesterified with other palm oil fractions to tailor the properties to individual applications.

12.5.4 Coating fats

Cocoa butter replacers (CBR) are typically non-lauric fats which again were often manufactured through the hydrogenation of liquid oils such as rapeseed/canola oil and fractionation to give the required melting profile. Because these fats crystallise naturally with the β' crystal being the stable type, they are not required to be tempered and so this makes them much easier to use than coatings based on cocoa butter/cocoa butter substitutes (CBS). Non-hydrogenated variants of these products are now based on palm oil fractions along with fractions from more exotic oils such as shea, illipe, etc. The key fatty acids are saturated palmitic and stearic along with monounsaturated oleic acid, both being C_{16} or C_{18} chain length. This is very different from the triglycerides of cocoa butter and so compatibility is limited. However, CBR do work well with milk fat which can be added for flavour but the amount is limited because more than around 20% will cause the coating to become too soft. CBR often contain small amounts of emulsifier E492, sorbitan tristearate (STS) which acts as a crystal modifier helping to prevent fat bloom developing in the coating.

12.5.5 Chocolate fats

Along with cocoa butter, up to 5% of vegetable fat can be added to chocolate in the EU whilst still retaining the term chocolate. These fats are very specialised and are known as cocoa butter equivalents (CBE). They are specifically designed to be fully compatible with and match the crystallisation properties of cocoa butter so no modification of process conditions is necessary. The basis of this behaviour is the fatty acid composition of these CBEs which is high in so-called symmetrical triglycerides where the outer fatty acids on the glycerol backbone are the same. Important triglycerides of this type are POP (palmitic:oleic:palmitic) and SOS (stearic:oleic:stearic). POP is obtained through the fractionation of palm oil and SOS is obtained from exotic fats such as shea oil. Typical compositions of CBE raw materials are shown in Table 12.3.

Table 12.3 Typical compositions of CBE raw materials

	POP	POS	SOS	Others
Palm mid fraction	65	13	2	20
Illipe butter	1	36	42	12
Shea stearin	10	8	69	22
Cocoa butter	17	39	26	18

12.5.6 Release agents

These specialist products are designed to be applied to oven bands, trays, etc., primarily to prevent the biscuits sticking to the surface after baking, but they can also be designed to control the spread of dough during baking and to influence the surface finish of the products which is especially important where the biscuit is to be enrobed and any blemishes on the surface will affect the coating.

The products are typically based on liquid oils such as rapeseed oil with higher melting point fats and waxes added to increase the viscosity and efficiency of the release performance. Emulsifiers such as lecithin or monoglycerides are added to reduce the surface tension between the dough and the baking surface and cereals such as wheat flour or starch are added to aid the control of spread and help with the surface finish. The application of the release agents is important as too much can cause the baking surface to quickly carbonise, and not enough will cause the biscuit to stick.

12.5.7 Spray oils

For savoury snack crackers a film of oil is often sprayed onto the surface after baking. This serves several functions including adding a sheen to the surface of the biscuit, acting as a binding for any flavours added to the surface, as a carrier for flavours or simply to seal the surface to prevent moisture ingress. Because the oil is exposed to air over a high surface area this type of oil needs to be very stable to oxidative rancidity. Traditionally lauric type fats such as coconut oil or palm kernel oil have been used, being highly stable because of the high level of saturates in these fats (approx. 92%). These fats are melted and sprayed onto the surface hot and the fat then sets as the product cools. More recently alternative oils such as high oleic sunflower oil or palm olein have been used either for health reasons (reduced saturates) or simply for cost.

12.6 Quality control of fats

No matter what type of fat is being considered, as discussed in Section 12.4 once the fat is refined it is important to maintain the quality and there are a number of key tests that not only the fat supplier but also the end user needs to understand so that the delivered fat meets all of the requirements of the biscuit manufacturer. These are described below.

12.6.1 Determining solid fat content by pulsed NMR (pNMR)

This technique, which measures the solid fat content (SFC) in a sample at a particular temperature, was developed to replace the old solid fat index (SFI) which was measured through a technique known as dilatometry. This measure of SFI is still in use in certain areas such as the USA to a degree, but has generally been replaced by measurement of SFC. A test method for SFI can be obtained from the American Oil Chemists' Society [10].

Using pNMR instruments such as the 'minispec' series from Bruker Optics [11] an SFC value is determined by detecting the NMR signal from both liquid and solid components in the fat sample, known as the direct method [12], or by detecting

the change in the liquid signal as it is displaced by solid, known as the indirect method [13].

The 'minispec' emits a short, intense burst of radio frequency (RF) energy into the sample which is placed in a static magnetic field. This causes excitation of the hydrogen atoms in the fat which generates a detectable signal in the 'minispec' receiver. Over time, the hydrogen atom energy drop levels back to their equilibrium state (relaxation). The 'minispec' records the time evolution of the NMR response and the resulting signal contains the analytical information from which the proportion of hydrogen atoms in solid and liquid state may be deduced. After the pulse, the signal is detectable for milliseconds to seconds. The NMR signal decays because of NMR relaxation. In solid matter, oscillations are heavily damped, and the signal decays relatively quickly. In a liquid, however, the surroundings are more mobile, thus causing less damping and a slower decay of the signal. The shape of the signal response can therefore be used to distinguish between solid and liquid components of a sample. A typical signal is shown in Fig. 12.10.

The initial rapid decline of the signal is due to energetic decay of the solid type components in the sample, which relax quickly to their equilibrium state. The remaining and slower decaying signal is from the liquid type components, which have slower relaxation. Phase A represents the combined solid + liquid signal and it is this that is used in the 'direct' method. Phase B, the pure liquid signal, is used in the 'indirect' method where the liquid phase result is checked against a fully melted sample.

The direct method is very fast, reproducible and sample preparation is minimal. Melted oil is simply poured into a glass NMR tube to a height of approximately 4–5 cm and the sample is tempered in the tube firstly at 0°C to solidify the fat and then the tube is transferred to a water bath or heating block held at the temperature at which the result is to be measured. After 30 minutes the tube is transferred into the 'minispec' unit to start the test. Only one NMR measurement is needed to obtain a SFC value by the direct method.

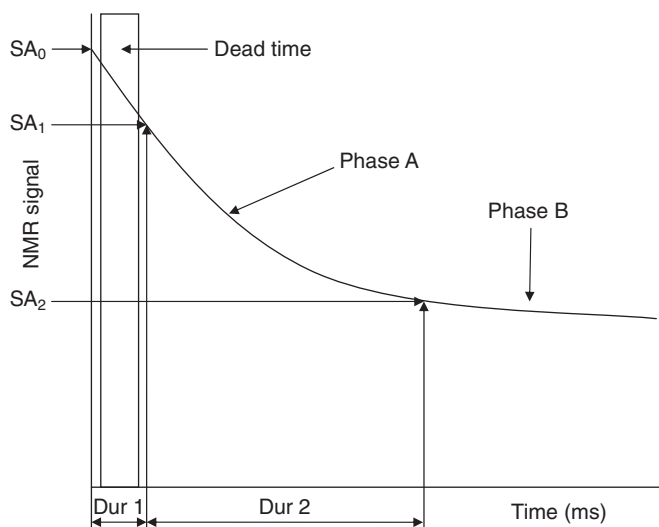


Fig. 12.10 pNMR signal for SFC determination (with thanks to Bruker Optics).

The indirect method is also reproducible and accurate, but it is not as fast. More care must be taken when preparing samples. Four measurements must be performed at two temperatures in order to calculate the percentage of solids.

12.6.2 Determination of slip melting point

As described in Section 12.3, because natural fats consist of a complex mixture of triglycerides they do not have sharp melting points, unlike pure chemical substances. The slip melting point of a fat is defined as the temperature at which a column of fat in an open capillary tube moves up the tube when it is subjected to controlled heating in a water bath. The method is described in detail in the International Standard ISO 6321 [14] but the basis of the method is that a small amount of molten fat is collected in a capillary tube and allowed to solidify. The tube is then attached to a thermometer which is in turn suspended in a water bath which is then heated under controlled conditions. The slip point of the fat is the temperature at which the column of fat in the capillary tube starts to rise as the fat melts. Because of the detailed characterisation of the fat through techniques such as SFC, nowadays the slip melting point is a somewhat outdated tool to use as the only way of characterising a fat. However, it can serve as a simple test to determine the identity of a fat on delivery, etc. As a rule of thumb the slip melting point can be estimated at the temperature when the SFC of a fat is 5%. Because of their polymorphic behaviour, the slip point of some fats is dependent on the previous treatment of the sample, i.e. whether it has been tempered or not.

12.6.3 Determination of free fatty acids (FFA)

This test measures the amount of free fatty acids in a sample and is a good indicator as to the quality of the refining process and whether the oil has been stored well before use. The test is documented by the American Oil Chemists' Society [15] and the method involves titration of the free acids with an alkali (sodium hydroxide) until neutralised. Knowing the strength and amount of alkali used, it is possible to calculate the level of FFA. The end point can be determined visually using a coloured indicator solution or more usually now through conductivity tests which also allows the tests to be automated, and there are numerous machines on the market to do this. Results are reported as %FFA, calculated as oleic acid or lauric acid for coconut or palm kernel fats.

12.6.4 Determination of peroxide value (PV)

If an oil or fat starts to degrade because it has been mishandled either through exposure to excessive air, heat, light or other contaminants, it will oxidatively degrade to form decomposition products such as a class of materials known chemically as peroxides. A high peroxide value is an indicator that this degradation is under way and this can lead to rancidity in the oil. As with the test for free fatty acids, the test is a titration but in this instance the titrant is sodium thiosulphate which reacts with the peroxides in the oil sample and the test ends when all of the peroxides (or other oxidation products) have been reduced. This can be determined visually through a colour change as starch is added to the solution or again through conductivity tests again opening the way for automation as with free fatty acid testing. The test method is documented in ISO standard ISO3960 [16].

12.7 General specification requirements for oils and fats

There are, of course, certain parameters that will be characteristic of individual fats but there are a number of core tests that will form a part of all specifications for fats either to determine the quality or to characterise the physical properties. A general specification is shown below.

Colour (Lovibond 5.25" cell	Max. 2.0 red, 20.0 yellow (can vary from oil to oil)
Free fatty acid (as oleic or lauric)	Max. 0.1%
Peroxide value	Max. 1.0 milli-equivalents O ₂ /kg
Iodine value	Depends on type of oil
Slip melting poin	Depends on type of oil
Solid fat content	
10°C	Depends on type of oil
20°C	Depends on type of oil
30°C	Depends on type of oil
35°C	Depends on type of oil
40°C	Depends on type of oil
Antioxidant or other additive levels (type and concentration in ppm)	

12.8 Challenges for the biscuit manufacturer

If making high quality biscuits consistently and cost effectively were not enough of a challenge in today's market, the use of fats and oils also poses its own challenges in a number of areas and some of these are outlined below.

12.8.1 Health issues

Obesity is an issue causing concern all over the developed world and governments, health agencies and watchdogs are all promoting strategies to improve the health of their nations. The bakery category including biscuits is one that is in focus, being relatively high in fat and especially saturated fats for reasons that have been discussed earlier in this chapter. Targets or guidelines for reducing both overall fat content and the level of saturated fats in foods are being issued by many countries, including the Food Standards Agency in the UK as mentioned in Section 12.5.1. The guidelines suggest a reduction in calories and saturated fat levels in plain biscuits of 10% and a reduction of 5% in coated/filled biscuits. These reductions are based on levels in 2008 and show there is a target for implementation by 2012. This presents quite a challenge to the biscuit maker but it is possible using the tools available now and the author has discussed the topic at some length in another book which deals specifically with fat reduction in foods [17].

12.8.2 Sustainability

The move from hydrogenated fats to non-hydrogenated fats increased the use of palm oil in biscuit making substantially because palm oil was the only naturally occurring, commercially available fat that could provide the level of solid fat required for many of the fats required in biscuit making. This increased usage raised the focus of where palm oil was being sourced and it became clear that although many sup-

pliers were acting responsibly some palm oil was being sourced from areas of high conservation value through deforestation which was having a direct impact on endangered species such as the orang-utan. To address this problem 'The Roundtable for Sustainable Palm Oil' (RSPO) was set up with the aim of setting standards for producers of palm oil to ensure that it was produced sustainably. The RSPO developed a set of 'Principles & Criteria' (P&C) to which all members must sign up and provided four possible routes for claims to be made on palm oil certification. Producers and processors are now being audited to these P&Cs to ensure compliance and the whole scheme is now gaining momentum with many large scale companies now making public statements about their position on the use of palm oil. More sources of information on this subject can be found in Section 12.10 at the end of this chapter.

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13

Emulsifiers (surfactants) and antioxidants as biscuit ingredients

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Abstract: By attention to the amounts and types of emulsifier it has been possible to reduce the fat content and still have acceptable biscuits. Emulsifiers also improve the handling properties of biscuit doughs.

Key words: lecithin, fat reduction, emulsion, shelf life.

13.1 Introduction

Emulsifiers are substances which, as the name suggests, allow emulsions to form. Emulsions are more or less stable mixtures of substances that do not normally mix, such as oil in water or water in oil. Emulsifiers, when added to a foodstuff, make it possible to form or maintain a uniform dispersion of two or more immiscible substances or to aid the wetting (film formation) of a liquid over a solid. The immiscible liquids are normally oil (fat) and water and it will be appreciated that the effect of any type of emulsifier will vary depending on the ratio of oil and water and whether other ingredients such as starches, proteins and a gas phase are involved. The materials work at the interfaces so are best called surfactants. There is a great range of surfactants from those that act to allow dispersion of water in oil (typical of food emulsifiers) to those that give good oil in water emulsions (usually called detergents). A detergent when added to water allows fat to be dispersed as, for example, when greasy dishes are washed; an emulsifier added to a fat allows water to be dispersed in it. In both cases the concentration of the surfactant is not more effective above a certain level. Excess of detergent in washing up water will not allow a greater or quicker dispersion of fat from a greasy dish. This critical level is usually quite low because the surfactants concentrate at the interfaces of the materials involved which is where they are useful. In the case of emulsifiers in biscuit formulations, it is fortunate that only low concentrations are required as these additives may give unwanted flavours and are usually limited by food legislation.

Emulsifiers are used to reduce interfacial tension to ensure a better dispersion of the dispersed phase and to achieve greater stability. Emulsifiers are polar lipids; they have two parts: the polar region which will be attracted to the water phase, the hydrophilic part, and the non-polar which is attracted to the fatty or oil phase, the

lipophilic part. Emulsifiers are mostly partial esters of fatty acids with polyvalent alcohols such as glycerol, sorbitol, propylene glycol and sucrose. Some of the compounds which perform as emulsifiers in food also exhibit starch and protein complexing properties. The term 'emulsifier' is not ideal and 'surface active agent' or 'surfactant' probably describes the functions of these compounds better. All these surfactants are effective at very low levels (less than 2% of the recipe weight) so are classed as minor ingredients or food additives.

13.2 Function of emulsifiers in biscuits

Fats in biscuits reduce the hardness by interrupting the gluten structure in the dough. By using small amounts of emulsifier the fat phase is spread more uniformly over the hydrophilic ingredients such as flour, sugar, etc., in the dough. The fat phase is thus more effective if it tends to be in films or very small droplets rather than globules.

With the interest in reducing fat in the diet for health reasons, much research has been carried out on fat-reduced biscuits which have eating qualities similar to the original products. Simply reducing the fat content of the dough necessitates more water to give consistencies suitable for dough piece forming and the extra water allows more flour protein hydration and more gluten formation. This, in turn, gives a tougher dough and a harder biscuit. By attention to the amounts and types of emulsifier, it has been possible to reduce the fat content and still have acceptable biscuits.

13.3 Types of food emulsifiers

The important character of surfactants is that they reduce the surface tension forces at the interface of two normally immiscible substances by dissolving in or complexing with both. The physical chemistry is thought to be complex but in simple terms the action, in the case of water and oil, is achieved with molecules which have polar and non-polar parts to their molecules. Depending upon the size and nature of the polar and non-polar fractions of the molecule, the function of an emulsifier in fat or water dominant situations is different, therefore it is necessary to select the most effective compound for each application. Certain emulsifiers exhibit complexing properties with the amylose fractions of starch. Compounds with a single saturated fatty acid chain seem to form helical structures with amylose which affects the reaction of gelatinisation of the starch and reduces the tendency for the amylose to diffuse out of the starch in the presence of hot water. This complexing affects the gas-retention properties of doughs, retards the staling of bread, reduces the pastiness of pasta and reconstituted instant mashed potato, etc., in the presence of hot water.

With flour proteins another type of interaction can be demonstrated such that there are changes in the viscoelastic properties of gluten which improves dough tolerance to mixing and machining. The mechanism is not fully understood, but it is probable that ionic linkages with the flour proteins are important. The crystal modifying effects of some surfactants can be used in fats to retard polymorphic changes to crystal types with less useful characters. Thus, α and β' forms show better creaming features than the most stable β forms to which both will revert in time.

Emulsifier technology is so broad and complex that it is now a specialised industry in its own right.

13.3.1 Lecithin

This is a natural food substance which occurs in all living matter but is found in significant quantities in egg yolk (8–10%) and soya beans (2.5%) which is the main source of vegetable lecithin. Being natural it is exempt from control by legislation and this sets it apart from the other substances to be described later.

Commercial lecithin is almost entirely of soya origin because of the cost. It is extracted from the beans by solvents, but varies in composition and always contains a sizable percentage of soya oil. Minifie [1] gives a detailed account of soya lecithin production and composition. He shows the average composition of the main ingredients to be:

Soya bean oil	35%
Chemical lecithin (phosphatidyl choline)	18%
Cephalin (phosphatidyl ethanolamine)	15%
Inositol phosphatides	11%
Other phospholipids and polar lipids	9%
Carbohydrates (sterol, glucoside)	12%

Lecithin in biscuit doughs allows an improved blending of the various ingredients, better dough processing and a reduction in fat needed to give a desired texture.

The potent components as emulsifiers are the phospholipids which have strong polar affinities. The amounts vary in different samples, but are normally specified as 'acetone insolubles'. Commercial lecithin is a fluid or a plastic paste which, if used in excess, imparts unpleasant flavours. The usage rates may be expressed relative to the weight of flour (normally between 0.5 and 1.0%) or the weight of fat (up to 2%). The author prefers the dosage to be relevant to the fat. Soya lecithin is not soluble in water but dissolves in warm fats and oils. It is, therefore, convenient to dissolve the lecithin in the fat before this is added to the recipe. Purified and modified lecithin is also available as a powder. Typically this is a 50% mixture with skimmed milk powder or lactose. In this form it may be dispersed in water directly.

By using lecithin at the rates suggested above a smoother dough is achieved and it is possible to reduce the fat content of a dough by up to 10% and get a biscuit with a comparable eating quality. A good account of the different types of synthetic emulsifiers has been given in a paper by Hughes [2] and the following section is based on this.

13.3.2 Mono/diglycerides

Fats and oils are esters of glycerol and fatty acids. The esterification is complete so all three —OH groups are linked to fatty acids producing triglycerides. Under conditions of partial esterification mono- and diglycerides are formed (see Fig. 13.1).

There are two forms of monoglyceride: 1- and 2-monoglycerides, and, of course, the fatty acid components can be of various chain lengths and degrees of unsaturation. The glycerol part of the molecule is hydrophilic, the fatty acid part is lipophilic.

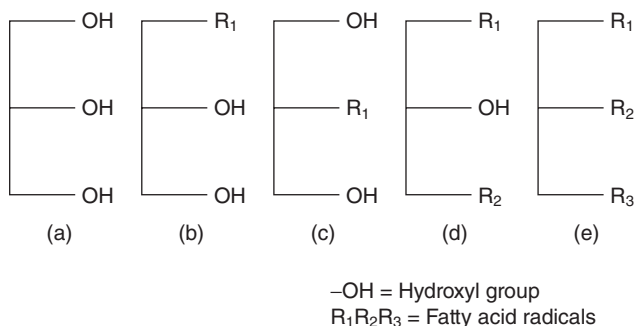


Fig. 13.1 Progressive esterification of glycerol: (a) glycerol, (b) 1-monoglyceride, (c) 2-monoglyceride, (d) diglyceride, (e) triglyceride (fat).

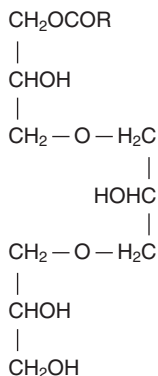


Fig. 13.2 A polyglycerol ester.

Monoglycerides are much more effective emulsifiers than diglycerides and as some diglycerides (and triglycerides) are present when monoglycerides are synthesised, molecular distillation techniques may be used to separate and concentrate the monoglycerides.

13.3.3 Polyglycerol esters

By linking together glycerol molecules (polymerisation) the polar part of the glycerides can be enlarged making it more hydrophilic (see Fig. 13.2). Although, theoretically, it is possible to produce quite large glycerol polymers, only those containing up to hexaglycerol are currently permitted in UK food legislation.

13.3.4 Acid derivatives of monoglycerides

The polar part of the monoglyceride molecule can also be enlarged and made more effective by reacting with a food acid such as lactic, citric, acetic and diacetylated tartaric acid (see Figs 13.3 and 13.4).

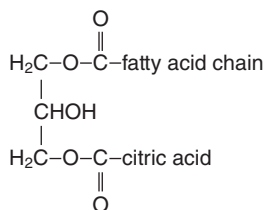


Fig. 13.3 Citric acid ester of monoglyceride.

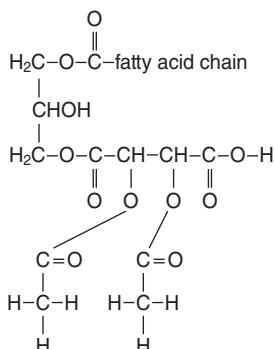


Fig. 13.4 Diacetyl tartaric acid ester of monoglyceride (DATA ester).

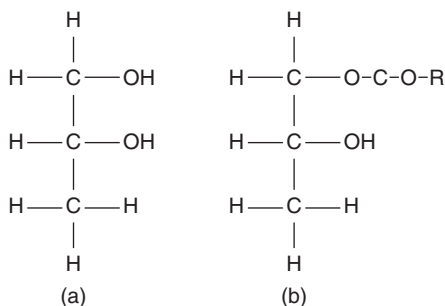


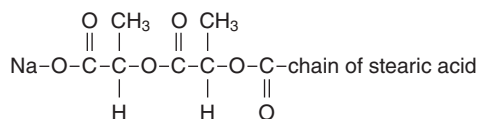
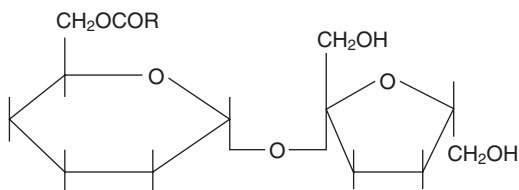
Fig. 13.5 (a) Propylene glycol and (b) a propylene glycol ester of a fatty acid.

13.3.5 Propylene glycol esters

These are esters not of glycerol but the closely related compound propylene glycol (see Fig. 13.5). In some applications this apparently small change in molecular construction has a very different effect from the glycerol counterpart.

13.3.6 Stearoyl lactylates

By esterifying a fatty acid such as stearic acid with polymerised lactic acid, one gets an acid which when made into a salt with sodium gives sodium stearoyl lactylate (SSL) (see Fig. 13.6). This and calcium stearoyl lactylate are particularly useful surfactants for starch complexing.

**Fig. 13.6** Sodium stearoyl lactylate.**Fig. 13.7** Sucrose ester.

13.3.7 Sucrose and sorbitol esters

Other compounds with —OH groups, polyvalent alcohols, may also be used to form esters with fatty acids with particular and useful properties (see Fig. 13.7). The range of compounds is augmented by using different fatty acids and other useful products continue to be found.

It will be appreciated that depending on the nature of the fatty acid and the type of compound, the melting point of the emulsifier or mixture of emulsifiers may result in either a liquid, a paste or a crystalline solid. Sometimes the compound may be added directly to the fat, water or dough; for others it may be necessary to form a dispersion in hot water before its maximum usefulness can be achieved. All these possibilities, combined with the rather formidable chemical names, do not make application assessments the easiest tasks for the biscuit technologist.

13.4 Reduced fat biscuits

The FMBRA [3] published results from trials with both semi-sweet and short dough biscuits. Hutchinson [4] reviewed the use of emulsifiers in fat-rich cookies and Burt and Thacker [5] give a detailed account of investigations with a particular short dough biscuit.

The FMBRA [3] showed that a 15–20% reduction in fat can be successfully achieved on both a hard sweet (Marie) and a short dough (Lincoln) recipe by using a DATA ester at the rate of 0.75% of the fat weight. The ester was added with the fat. In the case of the Lincoln biscuit recipe, the reduction in fat adversely affected the dough consistency which necessitated some alteration to the recipe water level.

Hutchinson [4] reported Tsen *et al.* [6] as showing how SSL and SSF (sodium stearoyl fumarate) at 0.5% based on the flour weight had a marked effect on increasing the spread of cookies during baking. He also cites investigations by himself and others [7] which showed that SSL and ETO-Mono (ethoxylated monoglycerides) seemed to be particularly effective in softening cookie textures when used at about 0.4% based on the flour weight.

Table 13.1 Equivalence of fat and emulsifier in a Lincoln recipe

Emulsifier	Equivalence in fat % for addition of emulsifier at		
	0.125%	0.25%	0.5%
DATA ester	12	19	30
SSL	4	8	17
Citric acid ester	11	13	18

This softening effect on the biscuit texture has received most attention in biscuit applications as it allows a reduction in fat levels (and cost saving) to achieve a desired eating quality. Burt and Thacker [5] concentrated on this aspect, but they also checked the flavour changes by means of tasting tests. They found that DATA esters, SSL and citric acid esters of monoglycerides were the most effective for softening texture and the preferred modes of addition were DATA esters and SSL added directly to the dough and the citric acid esters via the dough water. It was found possible to calculate equivalence of fat and emulsifier in their Lincoln recipe shown in Table 13.1. These addition rates were on a dry ingredient basis.

Tsen *et al.* [8] found that SSL, SSF and SMG (succinylated monoglycerides) improved the quality of cookies made from strong flour as an alternative to soft flour and this may be important to counteract variations in flour which occur from year to year. The starch and protein complexing features of certain compounds offer important possibilities for improving the sheetability of low fat doughs and also products made with mixtures of wheat and other cereal flours like sorghum and millet – the so-called composite flours. Distilled glycerol monostearate (GMS), DATA esters and polyglycerol esters seem the most promising for these functions.

In biscuits there is a spectrum of recipes from those with low fat and high water to those with high fat and low water both in the presence of flour and sugar. In the low-fat recipes, process problems are associated with gluten development and dough machinability and also lift during baking (problems somewhat similar to bread) but in the high-fat recipes there is more concern for the dispersion of the fat, to give maximum textural effects, dough stickiness and control of spread while baking. In both cases the dough water is a sugar solution and since certain emulsifiers can interact with sucrose in solution to form gels it will be appreciated why there is still considerable uncertainty about the types of emulsifiers that should be used in biscuit doughs.

Several brands of biscuits with substantial levels of fat reduction have been successfully made. The substitution of normal shortenings by very stable fat emulsions together with diacetylated tartaric esters of monoglycerides (DATEM) has produced some of the best results but the emulsion itself has been difficult to handle compared with pumpable shortenings.

13.5 General use of emulsifiers in biscuit doughs

Traditionally, lecithin has been used across the range of biscuit types. It is usually dissolved in the fat before addition to the recipe. It aids the dispersion of the fat in semi-sweet doughs and improves the emulsification during cream up in short doughs.

There is also a very significant fat-extending property. Soya lecithin is not an easy or pleasant ingredient to handle but it is very effective and is a natural material. The main disadvantage as a food ingredient is the flavour that it can impart when used at higher levels.

Emulsifiers may also find uses for the following developments in biscuit technology:

- Use of liquid rather than plasticised fats in biscuit dough mixing (cf. GMS).
- Control of dough and cream fat plasticity while in storage or when used directly from a chiller/emulsifier, by modifying crystal type (cf. sorbitan tristearate and unsaturated monoglycerides).
- Improving tolerance to different levels and qualities of protein in biscuit flours, in respect of dough machinability and oven lift in crackers and semi-sweet types (cf. SSL and DATA esters).
- Stabilising emulsions or suspensions required as premixes for automated mixing systems (type will depend on nature of premix components).

Emulsifiers have important applications in chocolates, chocolate-flavoured coatings, caramel toffee and margarine manufacture which indirectly affect biscuit processing, but as the subject is large, the reader is referred to more specific texts on these subjects.

Natural occurring emulsifiers are few and only lecithin, derived principally from soya bean, has been in common usage. However, for about 50 years the value of specially prepared monoglycerides of glycerol, or related compounds, has been known and much more recently there has been a rapid development of other compounds each with particular surface active and complexing characteristics in food processing.

Food emulsifiers may act in a number of different ways. These include:

- stabilising oil-in-water emulsions
- stabilising water-in-oil emulsions
- modifying fat crystallisation
- changing dough consistency, stickiness and starch gelling aspects by complexes with starch, protein and sugars
- lubricating low-fat doughs.

The development and availability of emulsifier compounds has greatly outstripped application investigations so many of the potentials for biscuit manufacturers remain to be evaluated. There is a reluctance on the part of the industry to use chemicals which are classed as additives. Emulsifiers need legal approval and should be shown on the product ingredient list by name or with an approved code number.

13.6 Application help

For ease of reference the names of the different emulsifiers are sometimes abbreviated to initials, for example: GMS = glycerol monostearate; DATEM = diacetylated tartaric esters of monoglycerides; SS = sorbitan stearamates; SSL = sodium stearyl lactate. The situation is further confused by the use of trade names.

All the major emulsifier manufacturers offer applications services and technical literature. By using these services, the type, form and combination of emulsifiers

best suited to a particular case can be narrowed down and the current permitted usage situation checked. The difficulty remains, however, that so far, biscuit applications are rather imperfectly understood and there are two principal reasons for this. First, biscuit processing involves a large number of variables and a wide range of recipes with many interactions. Trials should be made under the supervision of experts in both biscuit and emulsifier technology. Secondly, critical examinations of the effect of one or a combination of emulsifiers requires painstaking pilot plant trials where statistically designed experiments are needed to investigate the significance of results on selected properties. Few facilities exist for these pilot plant tests and the costs are high. However, the potential advantages for emulsifiers in biscuit manufacture seem good, so it is probable that there will be a growing use of various types. There is a healthy reluctance to use additives unless their technical or commercial values are assured.

13.7 Antioxidants

Antioxidants are substances which retard the onset and progression of oxidative rancidity in fats. They may be useful to extend the storage life of fats, before use in biscuits, and to extend the shelf life of biscuit products. The most commonly used antioxidants in biscuit manufacturing are BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), propyl gallate and TBHQ (tertiarybutylhydroquinone). They are thought to work by preventing the formation of free radicals that initiate and propagate autooxidation.

BHA is effective in animal fats but relatively ineffective in vegetable fats and it provides a good carrythrough from dough to baked goods. It is insoluble in water. BHT is cheaper than BHA but is similar in properties. Propyl gallate imparts good stability to vegetable oils but is heat sensitive, decomposing at about 148°C (the centre temperature of a biscuit during baking reaches only about 100°C). It has poor carrythrough characteristics to baked products and is not very soluble in either oil or water. TBHQ is the most effective antioxidant for most fats, especially vegetable fats. It has good carrythrough properties and is fat soluble.

Antioxidants are generally incorporated into food by being added to fats. They work best if added at an early stage so they should be added by the fat supplier at the end of the refining process. Adding at the stage of dough mixing generally does not give a good dispersion and the fat may already have started to be oxidised.

Antioxidants are classed as additives and therefore their use is controlled. BHA, BHT, propyl gallate and TBHQ are permitted in most countries for use individually or in combination at a level not to exceed 0.02% based on the weight of the fat. The exception is that TBHQ and propyl gallate may not be used in combination in many countries.

It is best not to rely on antioxidants to extend shelf life. Good housekeeping of the handling of fats is an important requirement. Use clean tanks, do not keep fat for too long, never agitate warm fat, use, quickly, fat from boxes that have been damaged and the fat has soaked into the cardboard outer.

Lauric fats, coconut and palm kernel oils, commonly used for biscuit creams, are very stable to oxidative rancidity so do not need additions of antioxidants. Antioxidants are ineffective in preventing hydrolytic rancidity.

There is some evidence that sucrose in the biscuit acts as a mild antioxidant. It may be that sugar masks the tastes at the onset of rancidity but if it is true, clearly additions of antioxidants to cracker formulations, where there is little or no sugar, will be more important than for other biscuit types.

13.8 References

Please note FMBRA became CCFRA, now Campden BRI.

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Milk products and egg as biscuit ingredients

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Abstract: Milk, butter and cheese have been traditional ingredients for baking due to their flavour and exceptional nutritional values. Due to microbial instability most milk and egg products used are in dry powder form.

Key words: skimmed milk powder, full cream milk powder, cheese, egg, butter, whey.

14.1 Introduction

Milk and egg products are often referred to as dairy products. This is because traditionally they were collected daily from the farm. Fresh milk and eggs have short or very limited shelf lives unless stored in refrigerated conditions. Equipment used to handle them must be cleaned very thoroughly on a daily basis to prevent the build-up of dangerous microorganisms.

Dairy products are used widely in the biscuit industry as minor ingredients but mostly they are dried or preserved in other ways to aid handling and to give longer shelf lives. Milk is produced by all mammals and is used commercially from cows, goats and sheep. Only cow's milk and its products will be considered here. The milk industry is large and complex, so the reader is referred to the book published by Tetra Pak [1] for an excellent general coverage of the technology.

All the ingredients included here are derived from milk or eggs. In biscuit manufacture their principal value is for flavour, although there are also tenderising properties associated with fats and emulsifying compounds. Milk, butter, cheese and eggs have been traditional ingredients for baking due to their exceptional nutritional values as well as their flavour. The technology of milk has now developed to such an extent that there are a very large number of distinct derivatives all with special value for the food industry. Only a few are commonly used in biscuit manufacture so it does not seem appropriate to discuss the technology in great depth even though it is most interesting and may have special points of importance where dietetic biscuits products are concerned. The reader is asked to study the papers listed in the references for specialist information but the books published by Tetra Pak [1] and by Walstra *et al.* [2] are particularly good summaries.

14.2 Milk and milk products

A large range of products are made from milk and many of these may be used in biscuit manufacture. Figure 14.1 shows the relationship of these products. This figure is taken from CABATEC [3].

14.2.1 Function and use of milk products in biscuits

Milk, butter and cheese have been traditional ingredients for baking due to their flavour and exceptional nutritional values. Butter, obtained by separating the fat from milk, was a major source of fat for baking until it was possible to refine oils extracted from various seeds and nuts. The protein and reducing sugar (lactose) contents of milk products contribute strongly to the Maillard reaction which gives golden brown surface colouration to biscuits during baking. Milk may also give slightly more tenderness to the eating quality of the biscuit but it is only used in small quantities due to the effect on the surface colouration.

It is unusual to use fresh milk in biscuits, as dried powders are easier to handle and store. However, fresh butter is still used widely due to its characteristic flavour

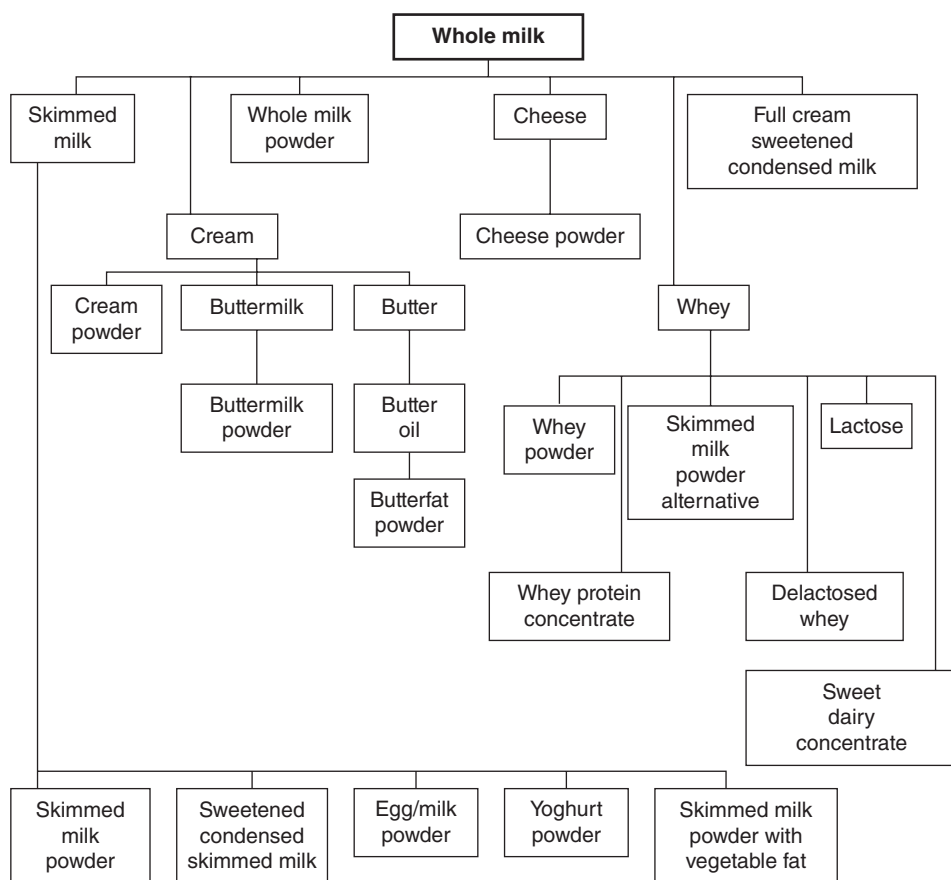


Fig. 14.1 Family tree of milk derivatives (CABATEC [3]).

contribution. Unfortunately, the flavour and colour of butter is variable due to the season of the year and the condition and feeds of the cows producing milk.

Biscuits containing butter are often described in such a way that the purchaser's attention is drawn to this fact. Labelling regulations usually demand that a certain minimum level is used in the recipe. For example, in the EU 'butter biscuits' must contain butter at least to the level of 7% of the dry matter and milk biscuits must have at least 2.4% of solid whole milk substances calculated on the weight of the dry matter.

Fresh cheese can be used in doughs but, being fairly solid, it is generally difficult to break it up well enough to get a good dispersion through the dough. Cheese powders are very useful flavouring agents in crackers as there is little loss of this flavour during baking.

Dried milk, cheese and whey powders are useful flavour components in sandwich creams. Milk powders of various types are also used in the manufacture of some chocolates. The calcium salt of casein, caseinate, is a valuable protein supplement for high protein or other dietetic biscuits. A reconstituted milk, perhaps with the addition of some egg, is often used as a surface wash on dough pieces and this produces an attractive glossy colour after baking.

Milk processing has developed many different products some of which may offer special value for inclusion in biscuits. The main advantages are flavour. These are centred on the short chain length fatty acids, butyric, caproic and caprylic acids.

14.2.2 Fresh milk

Fresh milk is now rarely used in biscuit manufacture because of its short storage life, the tendency for the cream to separate and its large bulk (it has about 87% water). It is usual to use the dried products, either full cream milk powder (FCMP) or skimmed milk powder (SMP) because of ease of handling, good storage life and low moisture content. Fresh milk is usually pasteurised. This is a heat process that destroys organisms responsible for diseases, like tuberculosis and typhus. Pasteurised milk is free from all pathogenic organisms but it is not free from all bacteria. These can grow rapidly unless the milk is kept at low temperatures.

The composition of milk and some of the products obtained from it can be seen in Table 14.1. In whole fresh milk the proteins coat the minute fat globules to form an emulsion which can be separated fairly readily and is known as the cream. The amino acid spectrum of the proteins (casein and albumins) are very valuable for

Table 14.1 Typical compositions of milk products (%)

	Water	Fat	Lactose	Protein	Ash	Sucrose
Whole milk	87.6	3.9	4.7	3.3	0.6	
Unsweetened condensed whole milk	73.9	7.9	9.9	6.9	1.5	
Sweetened condensed whole milk	27.9	8.5	12.9	8.2	1.9	40.8
Full cream milk powder	3.0	26.3	39.3	26.3	5.1	
Skimmed milk powder	4.0	1.3	52.9	36.4	5.4	
Whey powder	4.0	1.1	72.0	12.9	10.0	
Butter (salted)	15.4	82.0	–	0.4	2.2	
Cheddar cheese	37.0	33.5	–	26.0	3.5	

human nutrition and complement the proteins derived from cereals (hence the balanced value of a meal of bread and cheese). However, it is unusual to consider the basic nutritional value of biscuits except in those specially formulated for dietetic purpose (for example, high protein when milk caseinates are frequently used).

If it is decided to use fresh milk, thorough daily cleaning of containers and pipes is essential to avoid serious bacterial contamination and bad smells. The fatty nature of milk demands that detergent sterilisers are required. There are many cleaning chemicals specially prepared for use in dairies which allow CIP (cleaning in place) cleansing of pipe work and other equipment that would be tedious to dismantle.

14.2.3 Full cream milk powder (FCMP)

This material is usually derived from whole fresh milk by a process of evaporation under vacuum followed by roller or, more commonly, spray drying. It is important to control the maximum temperatures of the milk as it is processed as this affects both flavour and solubility of the resultant powder. Freeze drying techniques have the advantage of allowing less damage to the proteins but the process is much more expensive and therefore rarely used. FCMP is now rarely used in biscuit manufacture due to its high cost and the limited storage life (up to six months) which is determined by rancidity development in the fat. FCMP, however, has an exceptionally pleasant flavour and when prepared with sugar under special conditions of heating as a crumb it is valuable for giving a distinctive flavour in the manufacture of milk chocolates and coatings.

The composition of FCMP is shown in Table 14.1. Storage in moisture-proof containers at 15°C will give a satisfactory product for about six months. To reconstitute the powder it is necessary to mix with 3.5 parts of water to 1 part of FCMP. Dispersion is best if part of the water is used firstly to make a paste. The dispersion must be made with a high-shear mixer to reduce the possibility of lumps being formed.

14.2.4 Skimmed milk powder (SMP)

When the fat is separated from fresh milk for cream or butter manufacture, a white fluid, rich in lactose and proteins, remains. This is known as skimmed milk and may be concentrated and dried in a similar manner to FCMP. The flavour is strong and this powder is used in many ways during the manufacture of biscuits. The lactose is a reducing disaccharide which is only about 16% as sweet as sucrose but combines with proteins by the Maillard reaction at the biscuit surface during baking to give attractive reddish brown hues. SMP has therefore found widespread use as a minor dough ingredient both to give subtle flavour and textural improvements and to aid surface colourings. It is a rather expensive ingredient for these roles and the use of cheaper sources of reducing sugars (whey powder, glucose and invert syrups, and maltodextrin powders) have tended to replace it.

If SMP is not well dispersed in the dough the small lumps will appear as dark brown or black specks in the baked biscuits. This problem is normally overcome by dispersing the powder in some cold water before it is added to the mixer. Reconstitution requires vigorous agitation but a powder/water ratio of 1:2 is all that is needed. The dispersed 'milk' will sour rapidly like fresh milk. Thus, dispersions of milk powder should be made daily and containers and other equipment which come into contact must be cleaned thoroughly and regularly.

Overheating of milk powders during the spray drying process will lead to insolubility and dark particles. A typical skimmed milk powder should have a maximum insolubility value of 0.1%, in water, and maximum moisture of 4.0%. Storage in moisture-proof containers at the optimum temperature of 15°C should maintain the SMP in good condition for at least 12 months.

14.2.5 Evaporated or condensed milks

Some biscuit manufacturers find it more convenient to use milk in an evaporated form. Unsweetened condensed whole milk has a long shelf life if aseptically packed but it should be stored at 0–15°C. Higher temperatures cause a slight brown colour to develop. It has a slightly thick consistency but pours easily. Sweetened condensed milk with 62.5% sugar in the aqueous phase inhibits bacterial growth. It is a viscous syrup. During its manufacture attention has to be paid to the size of the lactose crystals. So long as they are less than 10 μ they are satisfactory but if larger the texture of the milk is unsatisfactory.

14.2.6 Butter and butter oil

Butter is used both for its shortening and its flavour effect. It is much more expensive than other plasticised shortenings but there is no doubt that its flavour contribution is very substantial. A typical composition is shown in Table 14.1. The normal maximum permitted moisture content is 16%. Butter varies in quality depending on its origins and whether it contains whey cream and if lactic yeast was used in its manufacture. It may be sold salted or unsalted. If salted about 1.5% of salt is normally added.

The colour and flavour of the butter and the melting curve of butter oil may be markedly affected by the time of year and what the cows were eating. When cows are fed on fresh grass the colour is more yellow and the flavour strongest, also the solids of the fat are lower at 20°C than if the cows are eating concentrated feeds. The effect of the different quality of the fat may, in extreme cases, result in fat bloom appearing on stored biscuits made from it. Butter fat with higher solids at 20°C are more likely to give fat bloom problems. From a quality control point of view the organoleptic properties of milk products are paramount in biscuit manufacture.

The flavour of butter is complemented by vanilla and sugar and in the course of biscuit baking the fresh butter flavour changes to a mild toffee or butterscotch note which has both good flavour and aroma. A baked butter flavour is enhanced with minimum baking time at high temperature.

The handling of butter has become a major obstacle to its large-scale use. Butter from creameries is nearly always packed in polythene lined boxes of about 12 kg. It is a well plasticised emulsion. It should be kept in cold store at about 4°C to preserve its freshness. The optimum temperature for use in mixings is about 17–18°C and it takes many hours for blocks at 4°C to rise uniformly in temperature. It is not practical to melt the butter and replasticise it in the bakery and it is also not possible to bulk handle the butter by means of pumps and pipelines whilst still maintaining the emulsion.

It is best to raise the butter temperature either by conditioning it in temperature-controlled rooms for perhaps 48 hours or to increase the temperature rather more

rapidly (in a warmer room or by electronic microwave energy) and then to equilibrate the temperature and plasticity by working and pressing the butter through a mincer type machine with a die plate giving about 4 mm diameter extrusions. Even so, a considerable amount of manual handling is needed and in a warm bakery it is easy for butter to become too soft before use. At ambient temperature butter will go rancid fairly rapidly.

The economics of milk and butter production are often complicated by politics and in Europe it is not unusual to find a build-up of butter held in government stores. Some of this butter may be released at favourable prices on condition that it is used in baked products or other processed foods. To inhibit its use as domestic butter it may be mixed with sugar or other additives such as vanilla. Sugared butter is very suitable for biscuits provided an adjustment is made to the rest of the sugar in the recipe.

Butter fat may also be purchased as butter oil without any appreciable moisture. Blocks of butter oil are much harder than butter and, probably because the proteins and lactose have been removed, the flavour imparted to biscuits made from this instead of butter, is not so pronounced.

14.2.7 Cheese and cheese powder

Cheese is made from milk by a series of processes involving inoculation with particular bacteria and separation of the resulting semi-solid curd from the liquid whey. There are many different types of cheese but only the strongest flavour types are used for biscuits. Mature Cheddar and Parmesan cheeses are those most commonly used in baking. They are expensive.

In the fresh form there may be some incorporation problems of cheese in dough, so the dried, powdered cheeses are preferred even though they tend to have lost some flavour. It is also possible to use freeze dried cheese which is crumbly and can be rehydrated a short time before use. This cheese is stable, if suitably wrapped, at ambient temperatures for long periods of time, unlike fresh cheese, and its flavour is far superior to spray dried cheese powder. Choice of fresh cheese should include attention to type and maturity factors as both have a strong effect on the flavour and baking performance.

Cheese is one of the most acceptable and satisfactory basic savoury flavours for biscuits. This is because the flavour loss and change during baking is relatively small. It is, however, important to obtain the maximum effect of the flavour derived from cheese by paying attention to the salt, monosodium glutamate (a flavour enhancer) and acidity levels (pH). The pH should always be slightly acid (6.5–6.7) best achieved with lactic acid additions, and the cheese can be 'extended' with whey powder. Pepper and autolysed yeast preparations complement cheese flavour and there are also many synthetic cheese flavours which work well when used with some real cheese to back them.

Cheese is rich in fat and protein which have shortening effects on doughs making it more difficult to maintain a good cracker structure. Most savoury biscuits are now oil sprayed immediately after baking. Cheese and cheese powders have limited storage life due to the fat contents. Cool storage is necessary and great care should be given to good stock rotation.

Table 14.2 gives a typical analysis of a matured cheddar cheese powder suitable for use in biscuit doughs or sandwich creams.

Table 14.2 Typical analysis of cheddar cheese powder

Solids	min.	85%
pH		6.1 ± 0.2
Protein		38–41%
Butter fat		43–46%
Salt		2.9–3.4%
Mineral matter, as ash		8–11%
Lactose	max.	0.5–1.0%
Moisture	max.	5%
Additives		
Phosphates		50 g/kg
of this P ₂ O ₅		27 g/kg
Particle size		80–110 µm

Table 14.3 Calcium caseinate – typical composition (%)

Moisture	3.5	Ash	5.0
Protein	90.4	Calcium	1.9
Lactose	0.2	Sodium	0.05
Fat	0.9		

14.2.8 Whey powder

Whey may be regarded as skimmed milk less the casein. It is the liquid fraction obtained after the curds have been separated during cheese production. The casein protein is coagulated by acids or enzymes and is separated with the fat to form the cheese and this leaves the whey. Whey is rich in lactose and minerals but also includes the serum proteins – the albumins. Depending upon the type of cheese being formed, the whey may be ‘sweet’ (from Cheddar and Swiss type cheeses) or acid (for example, from cream cheeses).

Whey is dried in a similar way to the other milk powders and because of its lower cost is now used extensively in biscuits in place of SMP. The function of whey powder in biscuits is very similar to SMP. The mineral content of normal whey powder may contribute a salty flavour which is not so pleasant as SMP. Demineralisation reduces this saltiness. Whey powder is a useful filler in savoury sandwich creams.

14.2.9 Other milk products

Separation techniques have been developed which have allowed the preparation of lactose, demineralised whey, and whey protein concentrate from whey. Lactose is used where low sweetness and savoury flavour enhancement is required. The proteins from whey are useful as an egg extender in the baking industry.

The ‘healthy’ image of yoghurt has suggested a value in biscuits but this material, made from milk by inoculation with a specific bacterium, has only a very weak and delicate flavour which has little value either in biscuits or in a coating for biscuits. Calcium caseinate is produced from skimmed milk and has a protein content of about 90% (see Table 14.3). It is a valuable protein supplement for dietary biscuits. It has a much superior flavour profile compared with soya flour which is also rich in protein.

Table 14.4 Typical composition of whole fresh eggs (%)

Water	74.8
Fat	10.9
Lecithin	1.5
Protein	12.3

14.3 Egg

The only eggs normally used for baking are hens' eggs. Due to the difficulties of cracking and subsequent handling of the egg, it is unusual to use whole eggs in biscuit manufacture. Whole egg material is, therefore, purchased either frozen or as a spray dried powder. It is very easy to denature the egg proteins with heat so reconstituted dried whole egg powder will not have the same foaming properties as fresh or carefully thawed frozen egg. Egg is an ideal medium for the growth of microorganisms so great care must be taken to clean and sterilise utensils which come into contact with it. Pathogenic organisms, like *Salmonella*, are destroyed by pasteurising and all microorganisms are killed when doughs or batters are baked. However, it is common to find *Salmonella* on the shells of egg so very careful hygiene arrangements should be observed if fresh eggs are cracked in a bakery.

Egg yolk is rich in fat and lecithin (see Table 14.4) and it is these components together with flavour that have made egg a good and traditional bakery ingredient. For most biscuits, eggs are too expensive and the fat and emulsifier can be obtained from other sources, but in batters for sponge types like Jaffa Cakes and Sponge Finger (Boudoir) biscuits, where a stable foam is required, and the only other flavoursome ingredient is sugar, the delicate taste of egg is still valued.

The baking performance of whole liquid egg shows some variation and it is known that both frozen and dried eggs deteriorate in storage. Parkinson and Wilkinson [4] reported rather inconclusive results of baking tests made to correlate the relationship between tests on samples of egg with their baking performance.

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Dried fruits and nuts as biscuit ingredients

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Abstract: Dried fruits, particularly currants and raisins are widely used in biscuits and contribute strongly to flavours and textures. Nuts are also commonly used more for their 'healthy' reputation than for the flavour they can impart. However, there are certain health problems associated with nuts that must be addressed. People who are sensitive can react when they eat even traces of nut products so manufacturers should label their products appropriately and control the handling of nuts extremely carefully.

Key words: currants, raisins, coconut, almonds, anaphylatic shock, mycotoxins.

15.1 Introduction

Considerable variety of both flavour, appearance and texture can be achieved in biscuits by the use of dried fruits and nuts. As biscuits are small and thin, the fruit and nuts usually have to be either small themselves or cut into small pieces. Generally speaking, nuts do not have enough flavour to make a distinctive contribution to the acceptability of a biscuit unless they are used at high levels. As both nuts and dried fruits are rather expensive raw materials, it is normal to use them in such a way that they are readily obvious to the consumer as, for example, by arranging that at least some of the nut pieces are applied to the surface of the dough piece so appear as decoration on the baked biscuit. There are many different ways in which nuts and fruit have been used in biscuits. It is impossible to treat the subject comprehensively here but the principal technical points will be discussed and details given for the materials used in significant amounts in biscuits.

The user of dried fruits and nuts must be concerned with:

- the flavour of the product
- the size and appearance
- the cleanliness in terms of dust, dirt, stones and other adventitious matter
- the level of infestation or deterioration which has developed after harvesting and during storage.

Attention should be given to the fact that in the countries and areas of origin, dried fruit and nuts are produced very often by unsophisticated people. This may lead to many problems with quality. Insufficient care may be taken to protect the fruit from dirt and dust, and the very nature of the product and climate mean that

insect infestation is very prevalent. Great advances have been made to improve the hygiene associated with drying and storage of dried fruit. However, it is important to realise that in order to change the practices of some of these simple farmers they must be told, shown and told again and again, for in most cases they have no idea of the stringent requirements for food in the factories and countries where their produce is used.

15.2 Dried grapes

15.2.1 Currants

Currants are small black seedless tasty and nutritious grapes grown in Greece, principally in the Peloponnese peninsula and on the Ionian islands of Zante and Cephalonia. The name is probably a corruption of 'Raisin de Corinthe' and Corinth has, for centuries, been a port of origin of this special type of dried fruit.

Currants have found particular value in biscuits because they can be obtained as very good quality small clean seedless fruit and their strong flavour gives them a particular advantage. After drying either in the sun or in the shade, the fruit is separated from the stems and stalks by a method of threshing, winnowing and sieving but the currants are damaged as little as possible. The dried fruit is either sold directly or kept in store on solid floors usually in bulk or in sacks or boxes.

Before exportation the fruit is further screened to remove stalks, stones and any other large unwanted pieces and is washed to remove dirt. The fruit is graded with sieves to give Pinheads, Smalls, Mediums and Elephants, in ascending size order. The Pinheads are of little value because it is very difficult to separate all the stones effectively. At the other extreme the Elephants tend to have very large fruit with pips (or seeds) in them which makes them less attractive to eat. Thus only the Smalls and Mediums are of much value to biscuit makers. As a rough guide there should be about 500 berries per 100 g for Mediums and 920 berries per 100 g for Smalls. This means that currants are available as much smaller fruit than any raisin types (e.g. Thompson seedless raisins). The packers claim that the currants have a moisture content at packing of around 16% but in practice values nearer to 20% are more common.

The currants are packed into 12.5 kg cardboard boxes for shipment. These boxes may or may not be polyethylene lined. The names on the boxes are extremely varied and not a little confusing. In addition to the type and grade of currant, another, less descriptive, name often appears. Each packer has his own name and often the trader or agent in the country of re-sale has his name that may be used. Thus a name may not be particular to a particular packer or conversely a packer's name may be sold through many different agents. From the point of view of the user, the packer is the important person because well cleaned and graded fruit can usually be related to a fastidious well-equipped packing factory.

There is often a problem of insect infestation in currants, especially those which have lain in store for a season. It has become standard practice to fumigate under slight vacuum, after packing and immediately before shipment.

When specifying currants it is recommended that the following quality criteria are stated:

1. Number of stones not to exceed 3/tonne.
2. Number of stalks not to exceed 25/tonne.

3. Number of stems not to exceed 25/tonne.
4. Cartons or boxes to be staple free.
5. Moisture content to be around 16%.
6. No red currants to be present – only black fruit.
7. Flavour to be free from off flavours due to packaging materials or bad storage.
8. Fruit to have been fumigated in Greece prior to shipment.

When the fruit is to be used in the biscuit factory it is advisable to re-wash a few hours beforehand. This not only removes a little more of the dust and dirt, but also breaks up the fruit which has become compacted during transportation. Finds of stones, stalks, etc., are very unpleasant in biscuits and if necessary the fruit should be checked at the time of re-washing. No machine has yet been made that can completely remove all this unwanted material from currants so picking by hand on white tables or conveyors is desirable. This work is boring and requires much concentration. It is strongly recommended that the best and cleanest fruit is purchased rather than reliance being placed on screening in the biscuit factory.

Specialist companies operate a cleaning service for dried fruit usually in conjunction with a packaging business for the domestic market. Their charges are such that it is usually more economical to buy a better grade from Greece. Also re-packaged fruit will be softer and more susceptible to damage than the dry fruit from Greece. Formerly, dressing the fruit with 0.5% of tasteless mineral oil reduced aggregation of the washed fruit. The use of mineral oil in food has now been prohibited in many countries and the mineral dressing oil has been replaced with special high-stability vegetable oils like Durkex 500. As the fruit is washed it picks up about 2% of moisture. This fact should be considered when freshly washed fruit is purchased.

15.2.2 Thompson seedless raisins and sultanas

Thompson seedless raisins, unlike currants which are peculiar to Greece, can be obtained from a number of different countries, principally the USA, Turkey, Chile, South Africa and Iran. The USA is the largest producer and there is no doubt that the quality of their fruit is very good. The Californian Raisins Marketing Board [1] has an active programme of promotion and a service of technical information. Most US raisins are 'naturals', that is, sun-dried and processed without chemical treatment, giving a dark coloured fruit. There is a small proportion of sulphur dioxide bleached grapes which are artificially dried and these produce golden raisins which are like sultanas from other countries.

Smyrna sultanas are directly related to Thompson seedless raisins and these represent a significant and very ancient trade from Turkey and Greece (principally the island of Crete). Australia and Iran are also significant producers and exporters of sultanas. Both raisins and sultanas are always larger and more fleshy than currants and therefore less suitable for biscuit making. When a fleshy fruit is dried out during baking it becomes tough and leathery, maybe even hard and bitter if on the surface of the product. Since the production of sultanas is somewhat different from currants, some description and comments are perhaps appropriate.

Firstly, the techniques and facilities on the farms in Turkey and Iran are significantly more primitive and less hygienic than in California and Australia. However, times are changing and by no means all the production from these and other developing countries is poor. Traditionally bunches of sultana grapes are dipped in a solution of potassium carbonate emulsified with a little olive oil before being laid

on a compacted earth bed to be dried in the sun. This treatment removes the bloom on the grape surface, softens the skin and hastens the drying. Since farm animals like horses, donkeys and camels are used on these farms and dogs and hens are also common, it will be appreciated that there are problems in obtaining a 'clean' earth bed for this drying. Also since little protection is afforded around the beds, it is easy for dirt and weed seeds to become mixed with the drying grapes. Certain weed seeds are very unpleasant and difficult to remove later, particularly the prickly seeds of the 'gooseberry' thorn. Sandy dust may become trapped on the sultana surfaces as they dry and become wrinkled.

The sultana is dried till it starts to darken, a pale sultana is prized so over drying is avoided. The dipping prior to drying also reduces the tendency to darken, hence the difference from Thompson seedless 'naturals'. Naturals are also produced in Turkey but they are not common. When the fruit is dry it is raked up (usually collecting a few stones in the process) and then crudely threshed and winnowed to remove the stalks and stems. The fruit is then bagged up and transported to market. Considerable progress has been made in recent years in constructing concrete drying beds with hedges or fences around them to reduce the contamination described above.

Eventually the fruit arrives at the packing factory. Here it is washed, spin dried, picked and graded. A high proportion is also bleached with sulphur dioxide gas. This has some significance for the biscuit maker as traces of this reducing agent may have an effect on the biscuit dough. Before packing, the sultanas are often dressed with oil in order to reduce the tendency to clump together and minimise contamination with moulds.

Grading of sultanas and Thompson seedless raisins is based on screen size, colour and counts of defects and foreign matter. The classifications are different in the various countries. Thus for USA the emphasis is on:

- *Size:*
 'Select' = No more than 60% by weight will pass through a sieve with holes 8.7 mm in diameter, and not more than 10% by weight will pass a sieve with holes 7.9 mm in diameter.
 'Small' or 'Midgerts' = 95% by weight will pass through 9.5 mm, and not less than 70% will pass through 8.7 mm holes.
 'Mixed' = Mixture of raisins which does not meet either the requirements for select or small size categories.
 'Select' raisins are about 380 berries per 100 g, 'Small' raisins are about 550 berries per 100 g.
- *Defects:* Grade A (US Fancy) is best. Grade C is least good. Details are published by the US Department of Agriculture [2]. The maximum moisture content is 18%.

In Greece the grading is from 00 to 5 decreasing in quality and size (see Table 15.1). There is a similar grading for non-bleached fruit, that is, naturals. Fruit should be free of foreign matter (excluding cap-stems). Cap-stems should not exceed 15 per 100 berries, and the maximum moisture content should be 16%.

In Australia grading is from 2 to 7 crowns for light-coloured fruit and from 1 to 5 crowns for darker fruit. The fruit improves in colour and quality with increasing crown number. Each crown category may be graded into two or three sizes with sieve size specified.

When purchasing sultanas the following points should be clear:

Table 15.1 Quality grades for raisins and sultanas in Greece

Grade	Colour	Permitted number of blackish or dark coloured berries	Size
00	Fair to golden	Nil	Through 11 mm sieve
0	Fair to golden	Nil	Through 9 mm sieve
1	Fair to golden	Nil	Through 8 mm sieve
2	Fair to reddish	Up to 12%	Through 8 mm sieve
4	Fair to reddish or light chestnut	Up to 20%	Through 7.5 mm sieve
5	Chestnut	Up to 50%	Through 7 mm sieve

- country of origin
- whether or not the fruit is bleached
- the size and quality with regard to foreign matter and discoloured fruit
- the packer
- the moisture content
- whether the fruit is dressed with vegetable oil and quantity used; if oil has been used, check that it is not rancid.

It is worth noting also that old sultanas tend to become 'gritty' or 'sandy' due to crystallisation of the sugars within the berries. This detracts from the eating quality. Sugar crystallisation is promoted by storage at too low a temperature. Recommended temperatures are 10–15°C at 45–55% RH.

Fruit from Turkey should not exceed 15% moisture. The fruit is graded from 6 to 12, the higher the number indicating the better quality. In fact most fruits tend to fall in Grades 9, 10 and 11. Superimposed on this is a colour grading from I to IV or from light golden brown plump berries to dark shrivelled berries. The water activity of raisins, currants and sultanas is about 0.6 at 18% moisture.

15.3 Other dried fruits used in biscuits

15.3.1 Dates

Dates are sometimes used in the form of paste, in a similar way to fig paste but also as chopped pieces of fruit. The paste is higher in sugars and lower in fibre than figs. The flavour is less distinct and mostly 'sweet'. Chopped dates may be used in wire cut doughs but it is often difficult to cut the pieces either small enough or of uniform size. Chopped pieces of date must be rolled in rice flour or the like to prevent them sticking together and forming lumps.

15.3.2 Glacé cherries

Glacé cherries are produced principally in France. They are strongly dyed and are sold in a heavy sugar syrup. It is necessary to wash away the syrup before using these cherries in a dough and this represents a large loss in weight. The cherries add only coloured pieces, not flavour, to the dough and are an expensive ingredient.

15.3.3 Crystallised or candied ginger

Crystallised or candied ginger is increasingly being used in quality biscuits. Ginger flavour has long been a popular flavour and the use of chewy pieces of ginger together with ground ginger and some paprika to increase the heat of the flavour can produce a good cookie. It is worth mentioning that clean fresh ginger root, milled to a paste, gives much superior flavour to a biscuit than dried powder of ginger.

15.3.4 Crystallised or candied peel

The peel is usually orange or lemon. It serves principally to add colourful interest and some texture to the biscuit without contributing to the flavour. There is a strong tendency for the peel to become hard, or at least tough, in the baked biscuit because the water activity situation draws water from the peel.

15.4 Fruit pastes and syrups

Various fruits like raisins, prunes, dates and figs are processed to form pastes and syrups (concentrates). The syrups are water extracts concentrated to 70% solids under vacuum and the pastes are macerated to about 75% solids. In 1979 Silge [3] described some of the more interesting uses of syrups such as a colouring agent for baked goods. Raisin juice concentrate has a pH of 2.0–3.5 and is rich in tartaric acid.

Pastes have been used for fillings of biscuits like Fig Bar (Fig Newtons) and all pastes are useful for dough flavours. Obviously the manufacture of a paste can conceal the use of sub-standard fruit so care should be taken to select the supplier well. The point of considerable importance in pastes is cleanliness of the fruit prior to processing. The presence of sandy gritty particles is particularly unpleasant as are also pieces of pip or stones (prunes and dates). Storage of pastes is more critical than for dried whole fruit since moisture pick-up will cause extreme stickiness. Drying out will cause the mass to become very hard. It is wise to store at a temperature between 15 and 21°C at a relative humidity of about 60%. The water activity of raisin paste is 0.5–0.6 so it is microbially stable.

Pastes are usually packed in polythene lined drums of 50 lb (22.7 kg) from the USA and polythene lined boxes of 12.5 kg from other countries. The pastes are dark or very dark and will darken even more during storage. There is a tendency for fig paste to develop a strong unpleasant taste on ageing, so only paste made from the current season's crop should be used. It is common for pastes, particularly prune paste, to contain preservative. This is usually sorbic acid which is permitted to a level of 1000 ppm (0.1%). Pastes are a particularly useful ingredient for flavouring and as the syrup component in soft cookies.

15.5 Tree nuts

Nuts may be used whole, kibbled to coarse pieces or sliced. An exception is coconut where, because of the size of the whole edible part within the nut, after drying (to form copra) it is shredded to a desired size. Nuts, being living seeds, will not store

well in damp or humid conditions. When they have been shelled and damaged, either by accident or by kibbling or grinding, the fat splitting enzyme, lipase, is released which will rapidly result in the development of fat rancidity. To prevent this and also to improve the flavour, it is common to roast or deep fry nuts. It is of great importance that pieces of shell are removed from shelled nuts because they are very hard and can cause damage to teeth. The shell must be removed before the nuts are kibbled or sliced. There is a growing interest in refined (fine ground) nut paste for biscuit cream fillings and as centres for dual element cookies.

15.5.1 Coconut

Coconut is the most used nut in biscuit manufacturing, in desiccated form; it is obtained principally from Sri Lanka (formerly Ceylon), Philippines and Indonesia. Ceylonese coconut is considered to have a better flavour. In the past trouble has been encountered in shredded desiccated coconut in two forms. Firstly, the presence of the pathogen, *Salmonella*, which probably originated in unclean water used to wash the white nut 'meat' prior to drying. Secondly, the presence of levels of sulphur dioxide above the permitted levels of importing countries like Britain. This sulphur dioxide almost certainly originated from impure fuel oil used to fire the driers at the mills. It is also not uncommon to find small pieces of metal in the coconut. This comes from the sieves if they are not well maintained.

Desiccated coconut is graded according to particle size and shape. For biscuit doughs it is best to use very fine coconut, known as coconut flour. As this tends to lump badly in storage it is best to buy a larger grade (medium or fine) and to mill it immediately prior to use. Roasted or toasted coconut is made, as for other nuts, by dry heating the nut particles. It produces a browned product which has a fine nutty flavour and is said to be easier to digest than the unroasted type.

Coconut should have a moisture content maximum of 3% and a fat content minimum of 55% (it is normally about 62% [4]). It is important to check that the bags are sound and dry. Dampened coconut quickly develops mould spoilage which turns it yellow or black. Damp coconut also tends to become rancid; this rancidity is mostly hydrolytic resulting from the enzymes produced by the moulds, rather than oxidative, so the fats become soapy smelling and tasting. Storage in good conditions, about 10–15°C at a relative humidity of 50%, will allow coconut to be kept for many months.

15.5.2 Hazelnuts

Hazelnuts (filberts or cobs) are commonly used in baking. They are particularly popular in European and Mediterranean countries which is where most are grown (particularly Turkey and Italy). Strangely, these nuts are not popular in the USA. The nuts may be used whole (in exceptional circumstances), roasted or as a very well refined paste in biscuit creams. The fat content of hazelnut is about 63.5% [4].

15.5.3 Walnuts and pecans

Walnuts are by far the most popular nut used for bakery products in the USA. They are available for biscuits as pieces and slices. Walnut is never roasted before use so there is a spoilage problem if the lipase is not fully destroyed during baking. Pecans

are similar to walnuts but of milder flavour. The fat content of walnut is about 68.5% and pecan about 70.1% [4].

15.5.4 Almonds

There are two species of almond, the bitter almond and the sweet variety. The bitter almond is only a very small crop and is harvested in Morocco and Israel. Californian almonds are 100% sweet variety. They are size graded by weight, thus 20/22 are 20–22 almonds per ounce (25 g). Almonds are highly prized for biscuits. They may be used as pieces or slices and are usually roasted. The brown skin of the nut is not only bitter but releases enzymes that quickly spoil the nuts if damaged. A technique of blanching is therefore common for almonds. This involves immersion in hot water which softens and loosens the skin for subsequent easy removal. After the almonds have been blanched, it is much easier to check the soundness of the kernels from their colour. Ground almonds are an essential ingredient of marzipan. A cheaper version of marzipan is made from apricot kernels. The fat content of almond is about 55.8% [4].

15.5.5 Other nuts

Amazonia (Brazil) nuts are rarely used for biscuits because of their higher price but their large size makes them very suitable for slicing and use as surface decoration. Cashew nuts are produced in India, Brazil and East Africa. Their high cost has meant that they have rarely been used in biscuits.

15.6 Peanuts, arachis or ground nut

Peanuts are extremely popular in the USA. They are usually roasted and may be used as 'halves' to decorate the biscuit surface. In certain cases peanut butter is useful. The fat content of dry roasted peanut is about 49.8% [4].

15.7 Health problems associated with nuts

15.7.1 Anaphylactic shock

There is a health problem, known as anaphylactic shock, which is an antibody-antigen reaction which may produce a state of profound collapse. It is a desperate emergency which may prove fatal. It used to be a rare condition but recently it seems that more people are sensitive in this way to nut-products which is very concerning. People who are sensitive can react when they eat even traces of nut products so manufacturers who may be worried should control the handling of nuts extremely carefully. It is advised to clearly declare any nut ingredients in biscuits and even to warn that traces of nuts may be present if other nut-containing products are produced in the same factory.

15.7.2 Mycotoxins

Microorganisms that may contaminate nuts are destroyed during baking but it is not only the microbes themselves that present dangers to health. Mycotoxins are

produced by certain moulds growing on food crops. Many are genotoxic carcinogens, i.e. they can cause cancer by damaging genetic material. Expert committees have recommended that the exposure to genotoxic mycotoxins should be reduced to levels as low as technologically achievable.

Nuts are a particular problem foodstuff because they may be stored damp enough for moulds to grow and leave toxins in the flesh of the nuts even though subsequently the nuts look and taste satisfactory. The British Food Standards Agency

provides advice to and is in constant dialogue with industry and enforcement authorities to ensure mycotoxin contamination is reduced to a minimum. It has prepared Guidance Notes intended to help food authorities, industry and any other interested parties with the interpretation of the UK regulations on aflatoxins. The Agency will continue to monitor for mycotoxins in these and other foodstuffs. [5]

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16

Yeast and enzymes as biscuit ingredients

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Abstract: Proteases are used to modify gluten quality. Their use is increasing where the gluten quality is too strong in the biscuit dough and as an alternative to sodium metabisulphite.

Key words: enzymes, yeast, fermentation, microflora.

16.1 Introduction

It is possible to bring about modifications to doughs, and thence to baked biscuit texture and flavours, with enzymes. Enzymes are natural catalysts which work on very specific substrates (fats, proteins, sugars), are sensitive to both temperature and pH and are destroyed at well below the temperatures reached by the dough during baking. The enzymes are either produced in the dough by living organisms, like yeast and the microflora always present in flour, or by added standardised preparations of enzymes which have been derived from living matter.

In biscuit making, yeast is used to produce gas and thereby mechanically to modify the gluten in the dough, other enzymes are used to change the quality of the gluten or to generate flavours such as those associated with lactic acid. The use of enzymes in biscuit making is becoming more commonly associated with the problems of increasingly less extensible gluten from flour with higher protein levels. The use of yeast is a more traditional process but the addition of other microbial preparations and more carefully controlled fermentation conditions is replacing the largely hit-and-miss conditions for long fermentations of cracker doughs.

16.2 Yeast

Yeast is a tiny plant; a single-cell fungus which is so small that there are about 1.5^{10} cells per gram. There are very many different types of yeast but the one commonly used for fermentation of dough is called *Saccharomyces cerevisiae*. Under anaerobic conditions, that is, with the exclusion of oxygen, this organism is able to produce carbon dioxide gas and alcohol from sugars. It is this gas producing ability that is of most importance in the fermentation of dough.

Yeast can be purchased either as fresh yeast in a compressed block form, with moisture content of about 70%, active dried yeast (in granular form) or as instant active dried yeast. The blocks of fresh yeast are usually 1 kg each and they should be stored at either about 4°C, when the yeast will remain in good condition for some 3–4 weeks, or deep frozen, when it will be useful for at least three months. Storage in a normal refrigerator at 4°C has the problem that there is considerable drying from the product, causing a build-up of ice on the colder parts of the refrigerator and desiccation of the yeast blocks. Active dried yeast has a moisture content of about 8% and in a sealed bag will remain viable for some three or more years losing its activity at about 1% per month. Instant active dried yeast has a moisture content of about 5% and in a sealed pack will last a long time, losing its activity at about the same rate as active dried yeast.

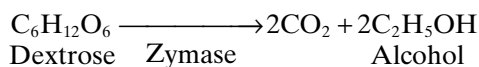
Fresh yeast in the compressed block form should be in one piece, not crumbly. It should be an even creamy beige colour, smooth and fresh smelling. (In an advanced state of decay it becomes a dark exceedingly evil-smelling liquid!). If it has crumbled and looks grey and dry, it is stale. It may still work but will not ferment well, i.e. its gassing power will be reduced. When using fresh yeast it is best to disperse it with a whisk in water, in the ratio of about 1:5 of water. To revitalise frozen yeast, use tepid water and leave it to stand for about 15 minutes.

Active dried yeast is at least twice as potent, on a weight for weight basis than fresh yeast but on a dry weight basis it is much less active. It should be reactivated by dispersing in water at about 40°C, with a little sugar, for 10–15 minutes. Active dried yeast should never be rehydrated with chilled or hot water.

Instant active dried yeast, by its mode of manufacture and the coating with an emulsifier, allows it to be rehydrated very easily. It may be added directly to the dough but like active dried yeast there is a 5 to 15 minute delay before it is as active as the fresh yeast. On a dry weight basis it is almost as active in gassing power as fresh yeast.

Fresh yeast starts to grow very tentatively for the first 45 minutes and is very susceptible at this time to adverse conditions like temperature, available water and high levels of salt and sugar. Dispersions of yeast should therefore never be made in salt water. Even a 2% salt solution can kill the cells or cause significant retardation of the gassing power. The sugar solution concentration should not exceed 5%.

Yeast metabolism is controlled principally by the external actions of two enzymes, invertase, which breaks down sucrose to dextrose and fructose, and a zymase complex that converts the lower sugars to ethyl alcohol and carbon dioxide in the absence of oxygen.



As with all other enzymes the reactions are highly temperature sensitive and Fig. 16.1 shows the effects of both temperature and quantity of yeast in a dough.

Yeast will gas at three times the rate at 30°C compared with 20°C but a maximum fermentation temperature should be considered to be 38°C (about blood heat). Yeast will die quite rapidly at 54°C. Yeast has no natural ability to ferment maltose sugar but it is this which results from the degradation of starch by the natural α and β amylase enzymes found in cereal flour. However, it would appear that flour contributes in some manner to the yeast's ability to adapt to maltose fermentation (see Syke [1]). The action of the cereal amylases may be limiting or important in the

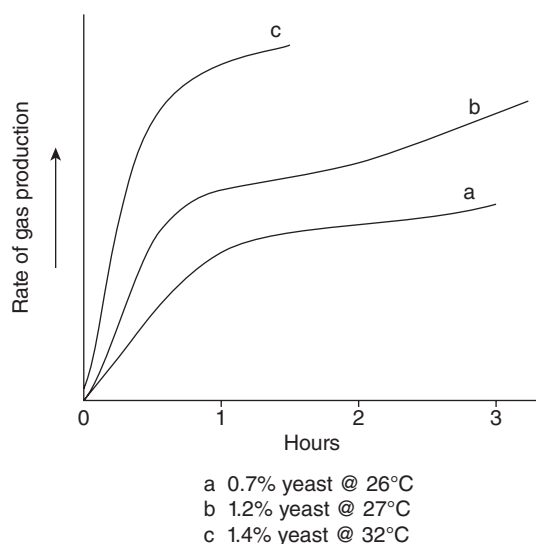


Fig. 16.1 Effects of varying yeast quantities and dough temperatures on gas production rates.

production of sugars in cracker doughs with long fermentation. Flour water doughs typically contain about 0.5% glucose and fructose derived from the flour. Fermentation starts and the yeast maltozymase system is activated. Fermentation is then sustained by the flour α and β amylase activity. However, as has been discussed elsewhere, long fermentation may be desirable not only for yeast activity but also for the growth of other microorganisms which are present in flour. A continuous fermentation procedure has been developed which allows control of other microorganisms during long fermentation of dough (see Chapters 22 and 23).

Yeast cells reproduce by budding, vegetative reproduction. It has been shown that there is little growth in the number of cells in the first 2 or 3 hours but by the end of the 4th hour the number of cells has increased significantly (by about 26%). The rate of increase depends on the number of cells at the start. A small number at the start allows a greater increase (see Hoffman *et al.* [2]). Thereafter the rate of increase declines again, presumably because a ready supply of sugars is not available.

A pH of 4 to 6 is optimum for fermentation but yeast shows a remarkable tolerance to a pH as low as 3 for about one hour at 30°C. The rate of maltose fermentation is more sensitive to a low pH than dextrose fermentation. During fermentation, some of the carbon dioxide produced will dissolve in the dough water to produce carbonic acid but as this is only weakly ionised it contributes little to a lowering of pH. The main causes of increased acidity in fermenting doughs are the lactic and acetic acid bacteria which are always present in flour. It is particularly the strongly ionised lactic acid that reduces the pH. If yeast 'foods', ammonium sulphate and chloride are present (to supply the yeast with nitrogen for growth), these will result in traces of sulphuric and hydrochloric acid which will increase the acidity. It is normal to compensate for these acids during long fermentation by additions of sodium bicarbonate.

Yeast extracts are valuable for biscuit flavouring or as flavour enhancers (see Sections 17.2.5 and 17.5).

16.3 Enzymes

Enzymes are natural catalysts. All metabolism of living organisms is controlled by enzymes and the range of reactions involved is incredibly wide. Enzyme extracts or preparations can be used to conduct chemical reactions away from living cells ranging from the well-known breakdown of starch to glucose syrups, sugars to alcohol, to the production of individual vitamins and specialist drugs. Industrial enzymes are produced by modern biochemical engineering techniques which permit a high degree of control over the production of desirable enzymes in a stable form. Well over 700 different enzymes have been isolated and can be used to control industrial processes. All enzymes are proteins and therefore are denatured, and thus inactivated, by heat.

Food materials are broken down by enzymes internally by animals and externally by microorganisms (fungi and bacteria). There are four main ranges of enzymes that are of interest to the food technologist:

1. amylases, which act on carbohydrates
2. hemicellulases, which break down pentosans
3. proteases (or proteinases), which act on proteins
4. lipases, which break down fats and oils.

Diastatic malt flour is a common source of amylase for bakers but fungal amylase and proteases are available as standardised preparations. Industrially protease enzymes are obtained from three major sources:

1. plants, for example, papain, bromelain, ficin, etc., but mostly the production of these is limited to tropical and sub-tropical areas
2. animals, for example, trypsin – chymotrypsin, pepsin, rennin, etc., but these are related to supply and demand for the products of a slaughterhouse
3. microorganisms, and in particular the fungus *Aspergillus oryzae* and the bacteria *Bacillus subtilis* and *Bacillus amyloliquefaciens*

The supply from microorganisms is the best since limitations of climate and supply of suitable sources are not involved.

For various technical reasons the protease obtained from *Bacillus subtilis* and *Bacillus amyloliquefaciens* is deemed the most suitable for use in doughs. It is sold either as a stable powder, standardised in activity by dilution with a maltodextrin or cornstarch, or as a liquid of standardised activity with added stabilisers and preservatives. In sealed containers under cool dry conditions the loss of activity is normally less than 10% in one year.

In the case of the powdered material, it is best to disperse it in 4–5 times its weight of water before addition to the dough. The enzyme is readily soluble but in cases where cornstarch is used as the diluent, this will of course not dissolve. Enzyme activity is temperature, time and pH dependent so it is very difficult to specify the exact quantities to use for a given reaction. It is best to be guided in the first instance by recommendations from the supplier.

16.3.1 Function and use of enzymes in biscuits

16.3.1.1 Protease

Proteases are used to modify gluten quality. Protease acts on the inner peptide linkages of gluten proteins. Thus while reducing agents such as sodium metabisulphite (see Section 18.4.2) cause loss of resistance and increase in extensibility by breaking the disulphide bonds, proteolytic enzymes have a similar effect in quite a different way by breaking the chains (see Fig. 16.2). Protein chemistry is complex so the above explanation is probably an over-simplification of what is occurring. The biscuit textures obtained by protease are usually more open and tender than by SMS (sodium metabisulphite, see Section 15.4.2).

Unlike SMS, protease continues to act with time and will eventually result in a very short and unmanageable dough. Care with times and temperatures is needed but most particularly in the handling of excess dough such as cutter scrap. Protease has advantages over SMS. It is denatured by heat and being a protein it does not have to be declared as an additive. Optimum temperatures for protease reactions are generally much above normal dough temperatures and the optimum pH range is 6.5–8.0 which adequately covers most doughs. As a general guide, the rate of enzyme catalysed reactions increases by between 1.5 and 3 times for each 10°C rise in temperature.

It is important to be critical and careful on temperature and time control. The dough standing time should be as long as is convenient so that the effects of using the beginning and end of a batch are not significantly different in terms of the enzyme action. As a starting point for crackers use about 20 g of proteinase 18 (ABM Chemicals Ltd [3]) for 100 kg of flour and a 3 hour reaction time at 35°C. If overdosed the dough loses its structure and becomes very short giving a plastic consistency and a very poorly developed biscuit after baking.

The efficacy of protease in dough is significantly reduced by the presence of more than 7 units of fat per 100 of flour and a similar level for sugar. Salt also inhibits protease but it seems that neither the quantity nor the type of raising agent appear to affect the action of proteases significantly. This is because in dough the buffering power of the flour proteins protects the effects that changes in pH would have. As the levels of fat and sugar increase, the inhibition effect is increased. Thus enzymatic activity in typical short doughs is very limited. However, the need for gluten modification here is low anyway.

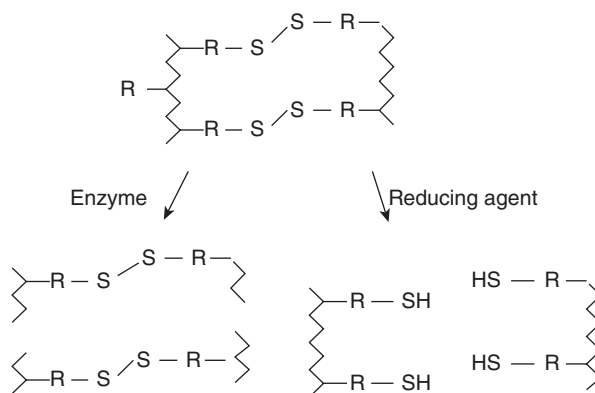


Fig. 16.2 Effect of proteolysis and reduction on dough proteins.

The following quotation is taken from van Benschop and Hille [4]:

In 1997, it was proposed by Soupe [5] that the use of an oxidation-sensitive protease, such as papain, in combination with an oxidizing enzyme (such as glucose oxidase) producing an oxidizing agent, can enable biscuit manufacturers to mimic the effect of sulphite in dough. By using a protease that may be only active at the beginning of the dough preparation, shrinking of the dough may be reduced and more regular sizes of baked products, such as biscuits, can be obtained. The action of the protease can then be substantially decreased when the concentration of the oxidizing agent has reached such a level that inactivation of the protease will take place. This will be of particular benefit when left-over dough is fed back into the system as rework.

The use of protease in dough is to effect reductions in viscosity and elasticity which are desirable for the machining of certain biscuit doughs, especially where flours with high-resistance glens are used. Two points of caution:

1. Industrial protease usually contains some amylase so it may be useful to review how much malt flour or other amylase is used when experimenting with proteinase levels. The increase in the levels of lower sugars and amino acids may give darker baked surface colours.
2. Care should be taken when handling proteinase, particularly powders, because inhalation or contact with delicate skin membranes can cause irritation or allergic reaction. The wearing of a simple dust mask is usually sufficient but advice is usually given by the protease supplier.

16.3.1.2 Hemicellulase

Hemicellulase is sometimes used in cracker doughs where, by the partial breakdown of the pentosans in the flour, the dough is softened and less water is needed to make the dough. Less water means that less has to be removed in baking. In low-fat or high-fibre biscuits more water has to be used to replace the softening action of fat. This tends to give a tough dough because more gluten is developed. By using hemicellulase, less water is needed for the dough so the toughening is reduced to the advantage of biscuit structure.

16.3.1.3 Amylase

In biscuit making not much use is made of amylase except very occasionally in connection with yeast fermentation.

16.3.1.4 Lipase

Biscuit makers do not use lipase but must be aware that these enzymes can cause product deterioration. They may be found in nut products that have not been heat treated, in non-stabilised oat flour or oat flakes and in wheat flours where the germ has not been removed or heat treated.

It is recommended that usage literature is obtained from the supplier appropriate to the dough and conditions in which the enzyme is to be used.

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Flavours, spices and flavour enhancers as biscuit ingredients

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Abstract: The flavour of a food is the combined effects of taste, smell and mouthfeel. For acceptance and daily use by a large majority of people, a food should have a mild delicate flavour. The largest group of flavours originate from plant materials. Due to their volatile nature flavours are often lost during baking. A flavour is considerably enhanced if low levels of common salt and sugar are present and, in the case of fruit flavours, the pH is correct.

Key words: flavours, spices, herbs, salt, essential oils.

17.1 Introduction

With the exception of certain crackers, which are used as bread substitutes, biscuits are luxury or snack food products. It is therefore important that the customers really like the flavours and textures otherwise they will look to other foods for their enjoyment. People eat what they like rather than what is good for them!

The human senses are incredibly sensitive to smell and taste. The flavour of a food is the combined effects of taste, smell and mouthfeel. The taste is the sensation perceived by the tongue of soluble materials and these are limited to sweet, sour, salty and bitter. The smell is the sense by which certain properties of volatile substances can be perceived on the sensitive membranes in the nose. The mouthfeel is the tactile sensation created in the mouth when a food is chewed or dissolved combined with the tasting and smelling sensations.

For acceptance and daily use by a large majority of people, a food should have a mild delicate flavour. Where a distinctive flavour is used, particularly if attention is drawn to it, most people want it strong rather than delicate. The acceptability of a flavour is complex. The human brain has an amazing memory for tastes and smells and can recall not only what but even where and when a sensation happened before. For example, there are some wine tasters that claim they can identify a wine to a particular vineyard! Thus, when someone is tasting a biscuit it is important that their identification of the flavour is a 'satisfactory' experience. There are some combinations of taste and smell that are particular to different societies, but through holidays and travel we are being 'educated' to like different eating experiences.

There is a big commercial business of flavour ingredients but it can be seen that the use of these to create a good total flavour sensation involves much more than the selection of an aromatic material.

17.2 Sources and types of flavours

The largest group of flavours originate from plant materials, usually the fruits or leaves of plants. Others come from cooking and these include the crust flavours (associated with the Maillard reaction between amino acids and reducing sugars), burnt flavours and roast flavours which include those from meats. It is important that flavour ingredients are convenient to use and of standard strength and quality. These are the tasks for the flavour ingredient industry.

17.2.1 Spices and herbs

These are a basic and valuable source of flavours. The distinction between a herb and a spice is a bit vague but it is commonly considered that a herb flavour accompanies a savoury or non-sweet food and a spice a sweet product. Some define a herb as coming from only the leafy parts of plants whereas spices may be derived from roots, rhizomes, bark, leaves, flowers, buds, fruits and seeds. Others do not accept that there is any difference between herbs and spices and regard all aromatic and fragrant vegetable products used to flavour foods as spices.

Parts of plants which have been collected, dried and ground to form a strongly aromatic powder may be used directly in or on a food. Many of the plants involved grow in tropical countries. Ground herbs and spices carry the aromatic elements in the cells of the plant tissues often as volatile oils. The finer the material is ground the more of the flavour is released from the damaged cells and this will evaporate during storage. Rosengarten [1] gives an excellent account of spices.

When selecting a spice or herb for use in a biscuit the following points should be considered:

- Is the source of supply sufficiently reliable to ensure uniformity of quality from season to season at reasonable cost? Spice markets are notoriously volatile and this must be accepted or compensated for by skilled buying under contract.
- All spices and herbs, being naturally occurring plant materials, often from hot countries, are high in microbial contamination. The possibility of product spoilage or danger to health from this contamination should be considered especially if the spice or herb is in an uncooked part of a product. The problems are worse if the water activity of the food is high enough for the microbes to grow but this is most unlikely to be the situation in biscuits.
- Is the particle size of the material suitable? The finer the grinding the more rapidly will the natural oils be lost by evaporation so the materials should be freshly milled and stored in sealed containers.

17.2.2 Essential oils

An essential oil is a volatile mixture of organic compounds. These oils may be extracted from plant materials by some physical process such as distillation,

compression or solvent extraction. A specific oil is derived from one botanical species with which it agrees both in name and odour. Chemically they are very complex and may include alcohols, aldehydes, esters, ethers, ketones, phenols and hydrocarbons, usually a mixture of several.

17.2.3 Oleo resins

These are solvent extracted compounds remaining when the solvent has been evaporated. They are very concentrated and often caustic, even more caustic than some of the essential oils.

17.2.4 Synthetic flavours – GRAS

By sophisticated chemical analysis it is possible to identify the individual compounds that make up a particular scent or flavour. It may be uneconomic to extract the flavour element from the original source but chemically synthesised ingredients can be blended in the same proportions as were found in the natural flavour. Flavours made in this way are described as 'nature identical flavours'. The inference is that natural flavours are safer than concoctions made up by a flavourist from a library of aromatic chemical compounds. The chemicals used for flavours must have an acceptability for use in food, and the term 'generally recognised as safe' (GRAS) is frequently seen in connection with synthetic flavours. There is some concern about the acceptability of synthetic flavours in food and legislation is usually in force to protect consumers. Problems come when manufacturers claim that the synthesised flavours are nature identical [2].

17.2.5 Other flavouring substances

In addition to the broad groups described above, there are many other substances commonly used to flavour biscuits. Examples include cheese powders, dried autolysed yeast, dried meats and extracts, vegetable protein hydrolysates, dried and diced nuts and fruits. Flavourings derived or based on yeast extracts are surprisingly effective. Mostly they give savoury or meaty flavours and are thus useful for enhancing savoury cracker flavours especially those based on cheese.

17.2.6 The form of the flavouring material

Ground spices and herbs are obviously powders of varying granularity. Extracted oils and most of the synthetic flavours are liquids. Oleo resins are liquids or viscous pastes. It is important that the flavouring material is at a concentration and in a form that is suitable for the application. Liquids can be diluted with a suitable solvent, such as alcohol, propylene glycol, vegetable oil or water. Liquids can also be made into powders by adsorbing them onto salt, rusk, dextrose, etc. The powders can then be weighed, dusted or pre-mixed in a more satisfactory way than small quantities of liquid.

It is also possible to micro-encapsulate liquid flavours with a vegetable fat of suitable melting point or with a carbohydrate glass. The flavour is then released when the coating melts, dissolves or is mechanically broken by chewing in the

mouth. The process of encapsulation is expensive and, at least for biscuits, this form of flavour is not commonly used.

17.3 Suitability of a flavour material

Unlike ground spice most of the other flavouring materials can be bought in a variety of forms and concentrations so when selecting a flavour attention should be given to the following questions:

- Is it of standardised quality, that is, independent of seasonal variation in the raw material from which it may have been produced?
- Is the concentration optimum for convenience of use?
- Is the flavour permitted by the legislation in all markets where the product is to be sold – many countries have strict rules about synthetic flavours and solvents? How should the flavour be declared in the product labelling?
- Does the flavour possess stability in terms of flavour profile in the conditions in which it will be used and the product packaged?
- If the flavour is a liquid does the solvent or any constituent attack plastic, metal or other materials with which it may come into contact? If it is caustic to skin or eyes can the necessary precautions be taken?
- If the flavour is a powder does it have the correct particle size range to prevent caking, allow dispersion or distribution in or on the product?

17.4 Flavouring of biscuits

The introduction of aromatic ingredients as a contribution to flavour can be made to biscuits and other cooked products in three principal ways:

1. by including the flavour in the dough or batter before baking
2. by dusting or spraying the flavour after baking
3. by flavouring a non-baked portion, such as cream filling, icing, jam or mallow, which is applied later.

17.4.1 Adding flavours to dough

The conditions experienced during baking are very severe for aromatic compounds. Not only are they easily removed by heat because, by definition, they are at least slightly volatile at mouth temperature but also during baking a process of steam distillation occurs as the product is dried and this is an extremely effective technique for releasing volatile organic compounds. In general, liquid flavours are not to be recommended in baked products especially those with doughs containing high levels of water like crackers and hard sweet types. Some means of protection is needed and the sealed cells of plant tissues are somewhat successful in this. Ground ginger is better than a liquid ginger extract.

Even allowing for the fact that there will be some loss of volatile materials during baking, there are some flavours that are satisfactory in baked products. These include vanilla (or synthetic ethyl vanillin), butter flavours, cheese, almond essence,

and flavours associated with roasting, like smoke, chocolate, coffee and caramel. Flavours that are protein based such as cheese and hydrolysates are more stable at baking temperatures but can be drastically changed if even slightly burnt. Spices generally survive baking better than flavours or extracts.

17.4.2 Flavours applied after baking

These can be of any type but more savoury types find use in this area than flavours associated with sweetness. The flavours may be dispersed on a cereal or dextrose base and dusted onto an adhesive surface, like an oil film, over the product or sprayed on as solution in edible oil. Either way the system tends to be messy and causes strong odours in the vicinity. The techniques generally are not ideal for thick products like biscuits as the flavour lies on the surface and must either be very strong, to give an acceptable overall taste, or rely much on an initial taste impression. It is also worth remembering that surface films of oil and flavour are very susceptible to oxidative rancidity so great care must be taken in the choice of packaging and of estimates of shelf life.

17.4.3 Flavours in cream and jams

Normally essential oils find their best use in these components of biscuits. Advances in the flavour industry have resulted in excellent reproductions (or nature identical mixtures) of fruit, nut and other exotic flavours and their use in non-heated parts of a product are in general extremely successful. Points to remember in the use of flavours in these situations include:

- The acidity and colour of the base is of very great importance to the acceptance of the flavour when eaten.
- The correct strength is important. Often there is a saturation level to the taste. Too great a concentration may result in lingering and unpleasant aftertastes.
- The texture of the base, especially if it is not readily soluble in water, is most important. Also the dispersion of the flavour if it is a powder is to be watched.
- Acids, flavour enhancers, sugars or salt should be of the correct particle size to allow correct solution speed in the mouth relative to the sensation given by the flavour compounds.
- Where fats form an important part of the product, as for example in biscuit creams, the dilatation, or melting, characteristics must be matched to body temperatures and ambient conditions to allow optimum flavour.

We eat with our eyes: if the food looks right we expect it to taste right. The sensation on the tongue of sweetness or acidity, etc., and the speed with which this is perceived must correspond with the volatile flavour detected in our nose.

17.5 Flavour enhancers

These fall into two main groups, simple salts and acids that on their own are relatively unacceptable, and complementary ingredients or colours that help in the suggestion of the flavour. The most important flavour enhancer is common salt. In

doughs, usually used at about 0.75–1.0% of the flour weight, this has a remarkable enlivening effect on most flavours. It may also be used to advantage in chocolate and biscuit creams, though the level is then lower than 1% and the particle size must be very fine to allow rapid solution in the mouth. Somewhat higher concentrations may be useful in savoury creams.

Monosodium glutamate (MSG) is a commonly used savoury flavour enhancer. It is the sodium salt of the amino acid glutamic acid and is usually purchased as fine white crystals. It is readily soluble in water and should be used at a concentration of about 0.5% of the product weight. MSG works in harmony with salty and sour tastes but contributes little or nothing to sweet foods.

A substance known as Ribotide is offered by Takedo Chemical Industries Limited of Japan. This is derived from the ribonucleic acids in yeast by an enzymatic process. It is claimed to have an effective strength of 50–100 times more than MSG, but probably more importantly to have an optimum effectiveness when mixed in a ratio of 6:94 with MSG.

Yeast extracts and other vegetable protein autolysates also have a flavour-enhancing characteristic for savoury foods as well as flavour in their own right. In many ways the flavour-enhancing behaviour of yeast extracts is very similar to MSG.

For fruit flavours, sugar, or some other sweetener, is an important complementary ingredient. An excellent strawberry aroma tastes very strange, for example, on a bland non-sweet base. Also, nearly all fruits are relatively sharp in taste – this is derived from the naturally occurring fruit acids, citric, tartaric or malic acid. In recipe formulation these can usually be substituted for one another, but in a dry state the particle size of the powder is of great importance as this affects solubility in the mouth.

17.6 Storage of flavours and quality control

All flavours are at least partially volatile. It is therefore important to store them in a sealed container, away from light and oxygen that may cause some degradation. Flavour may decay with age so minimum stocks should be held and stocks that have been held for more than about two months should be sampled and tasted against a control. As a matter of standard procedure a sample should be taken from a delivery and checked against a control sample. Both the new sample and the control material should be kept in a clean glass bottle, sealed and stored in a dark cold place like a refrigerator. These samples are held for reference purposes.

When comparing a sample with the standard it is important that the temperatures of both are the same and ambient is recommended. Smell is a critical test but for most fruit and 'sweet' flavours tasting at 0.1% concentration in a 2% sugar solution may be helpful. Alternatively a small batch of the medium in which the flavour is to be used should be prepared and carefully compared by a taste panel.

17.7 References

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Additives as biscuit ingredients

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Abstract: The food technologist must educate the public that most additives are neutral to health and, when used responsibly, are important processing aids that give better, more attractive, cheaper and safer products.

Key words: salt, leavening agents, acidulants, colours, processing aids, artificial sweeteners.

18.1 Introduction

A food additive may be defined as a functional chemical added to foodstuff in controlled amounts to facilitate processing, extend shelf life, ensure microbiological safety, improve nutritional value and/or modify the organoleptic and appearance qualities of the end product.

Additive categories:

Acids	Colours	Gelling agents
Acidity regulators	Emulsifiers	Glazing agents
Anti-caking agents	Emulsifying salts	Leavening agents
Anti-foaming agents	Flavourings	Preservatives
Antioxidants	Flavour enhancers	Stabilisers
Artificial sweeteners	Flour improvers	Thickeners

Other additives often controlled by statute:

Bases	Firming agents	Propellants
Bleaching agents	Humectants	Release agents
Buffers	Liquid freezants	Sequestrants
Bulking agents	Mineral hydrocarbons	Solvents
Dilutents	Packing gases	Vitamins
Excipients		

The foregoing is a more or less comprehensive list of additives used across the food industry. Not all are used during the manufacture of biscuits and many are used only very rarely and in special circumstances.

The use of additives needs to be controlled and a joint committee of the Food and Agriculture Organisation (FAO) and the World Health Organization (WHO) concluded that the use of additives was justified when they serve one or more of the following functions:

- maintenance of the nutritional quality of food
- enhancement of keeping quality or stability with a reduction of food wastage
- making food more attractive to the consumer in a manner which does not lead to deception
- providing essential aids to food processing.

The term 'additive' in connection with food is very emotive as it is thought to be synonymous with contamination, but more accurately the concern is about those minor ingredients from non-natural sources that are thought to do us 'no good'. As science and medicine advances we are introduced to discoveries of awful harm done by chemicals accidentally or deliberately eaten and much is being done to protect against harmful substances in food, drink and pharmaceutical preparations. The food technologist has a dual role of responsibility: he must ensure, by all possible means, that food is safe, but on the other hand he must also educate the public that many non-nutrient ingredients are neutral to health and are important processing aids that give better, cheaper and safer products. He must also show that some natural products, alternatives for chemical additives, derived from plants and animals may be extremely poisonous, so 'natural' does not necessarily mean 'safe'. Against this background it is the technologist's responsibility to minimise the use of additives, to keep recipes under regular review, and make appropriate adjustments to take account of changing circumstances, and clearly to declare the additives used in accordance with legislation. The declarations are needed not only to satisfy authorities but also to warn the few people who exhibit intolerances to some of the additive substances.

Not all the additives that may be used in biscuits will be included here but the use and function of the major types must be covered. Some have been described in other sections of this book because they are used in connection with other ingredients or specific types of biscuits. For example, emulsifiers and antioxidants are dealt with in Chapter 13, enzymes and yeast in Chapter 16, flavours and flavour enhancers in Chapter 17, flour additives in Chapter 9, buffers for controlling the pH in jams and jellies in Section 41.4, and vitamins in Section 31.4.2. In Chapter 31 Smith gives an account of nutrition where additives may be involved.

All inorganic chemicals used in making biscuits should be refined to food grade which demands minimal levels of heavy metals and various other compounds. For example, arsenic should not exceed 2 ppm, lead 5 ppm.

18.2 Common salt (sodium chloride, NaCl)

Salt is obtained from natural deposits and the sea and is usually purified and then vacuum dried to a desired crystal size. A typical crystal size range is given in Table 18.1, but coarser or finer material is normally readily available for special purposes. A flaky, or dendritic, type of salt which is obtained from the USA, is used to garnish certain savoury crackers. Sea salt, obtained by natural evaporation of sea water, is usually of coarse crystal size, off-white in colour and may contain many impurities.

Table 18.1 Typical sieving analysis range of pure vacuum dried salt

BS mesh no.	Aperture (μm)	Pure dried vacuum salt % cumulative overtails
12	1400	<0.1
16	1000	0.2–2.6
18	850	1.5–8.5
22	710	5.0–15.0
25	600	9.5–27.0
30	500	15.5–38.0
36	425	24.0–52.0
44	355	37.0–70.0
52	300	53.0–83.0
60	250	68.0–90.0
72	212	80.0–95.0
85	180	86.0–97.0
100	150	93.0–99.0
200	75	99.1–99.9
Pan	Pan	100.0
<i>Bulk density</i>	g/cm^3	1.22–1.32
	lb/ft^3	76.25–82.50

These results give a mean aperture of 420 μm with coefficient of variation 42%. (For the calculation of this, see Section 10.2.1.1.)

Salt is used in almost all recipes for its flavour and flavour-enhancing properties. Its most effective concentration is around 1–1.5% based on the flour weight, but at a level of more than 2.5% the taste becomes unpleasant. In doughs with significant gluten development, crackers and semi-sweet types, salt toughens the gluten and gives a less sticky dough. It may also slow down the rate of yeast fermentation and slightly inhibit the action of proteolytic enzymes on gluten. Salt is commonly used as a surface dressing and decoration of savoury biscuits.

The solubility of sodium chloride is not great and does not increase significantly with increase in temperature (see Section 34.7). The stability of a salt solution is very great. The equilibrium relative humidity of a saturated solution is 75% at 25°C so salt does not become damp, non-free flowing or lumpy except in very damp weather. Salt should be stored in plastic or stainless steel containers. Due to its relatively low usage it is unusual to handle it in bulk.

There are health concerns about the amount of salt (more particularly sodium) that is eaten. In general the amount of salt in biscuits is low and is there to improve flavour. The exception is where salt is used as a surface dressing on savoury crackers, etc. Sodium also comes from sodium bicarbonate (soda) which is included in the dough of most biscuits. Less soda is needed where an acid leavening agent is not used and as ammonium bicarbonate is particularly useful in biscuits this should be encouraged.

The United Biscuits Group reported that the share of sodium/salt in a typical diet is made up of only about 2% from eating biscuits. However, during a 10-year programme from 2005 they were aiming to reduce the salt in their biscuit products by 30%. One way in which they were doing this was to reduce the sodium/salt by a little at a time to allow consumers to get used to the slight change in taste.

Those wishing to explore a lower use of salt are referred to the edited volume by Kilcast [1].

18.3 Leavening agents

Leavening agents are a group of predominantly inorganic salts which, when added to dough either singly or in combination, react to produce gases which form the nuclei for the textural development within a biscuit during baking. Most of these chemicals leave residues in the dough which affect the final pH and maybe the flavour. A general account of the chemicals used is given here but more specific information about the mechanism of aeration in doughs is given in the accounts of the various biscuit types and in Chapter 39 on baking.

18.3.1 Sodium bicarbonate (baking soda, NaHCO_3)

This salt is relatively cheap and is readily obtainable at food-grade purity and in various particle size grades, for example, Free Running Grade, Refined Standard Grade and Fine Granular. Each of these is suitable for baking, but coarser grades may not dissolve sufficiently quickly during the preparation and baking of a dough and will result in dark brown soda specks on the biscuit surface.

In the presence of moisture, soda will react with any acidic materials to liberate carbon dioxide gas, decomposing to the appropriate sodium salt and water. In the absence of an acidulant when heated, the bicarbonate will liberate some of its carbon dioxide and remain as sodium carbonate. As many biscuit ingredients, including flour, have an acidic reaction it is often useful to use sodium bicarbonate as a means of adjusting the pH of the dough and resulting biscuit. If the carbon dioxide liberated is required as a raising agent it is best to keep the soda away from the other ingredients as long as possible by, for example in multi-stage mixes, adding at the last stage with the flour. In these circumstances the soda powder must be evenly dispersed through the mix and the soda should be screened with a fine sieve before use to remove any lumps.

An excess of sodium bicarbonate will give biscuits an alkaline reaction and a yellowish crumb and surface colouration with an accompanying unpleasant taste (this taste is known as soda bite). These high pH values, sometimes in excess of pH 8, give flavours liked by some. Normally, in all but a few special types of biscuits, the aim is for a biscuit pH of 7.0 ± 0.5 and this is achieved by the use of an appropriate amount of sodium bicarbonate. The solubility of sodium bicarbonate in water is shown in Section 34.7.

18.3.2 Acidulants and acids

Baking powder is a mixture of sodium bicarbonate and either an acid such as citric or tartaric acid or a salt that dissociates to give an acidic reaction in solution. The purpose of this combination of chemicals is to produce bubbles of carbon dioxide gas either before baking or, more particularly, as the dough piece warms up in the oven. These gas bubbles form the nucleation sites for further expansion as the gas is heated and the vapour pressure of water rises during the baking. It is therefore important that the bubbles are many and very small to produce a fine, even texture in the baked biscuit.

It is probable that production of gas from combinations of baking powders is less important in biscuit products than is commonly supposed since a single salt, ammonium bicarbonate (see Section 18.3.3) is particularly effective on its own.

Ammonium bicarbonate is not suitable for use in baked products which have appreciable moisture contents due to residual ammonia, so in cakes, sponges, scones, etc., it cannot be used successfully.

The original acidulants for baking were soured milk (lactic acid) and cream of tartar (potassium acid tartrate). The technology has developed to use other compounds which are cheaper or less readily reactive so that the carbon dioxide is liberated at stages during the baking rather than in the mixer. Most of the common acidulants are phosphate salts which have the disadvantage of leaving phosphate residues with a flavour that is not particularly desirable. Establishing the correct balance between the acidulant and soda depends on the recipe and is normally a matter of some trial and error controlled by flavour or measurement of the biscuit pH.

Table 18.2 shows a list of common acidulants with an indication of the basic quantities needed to neutralise one part of sodium bicarbonate and the relative speed of reaction in a dough as it is mixed and heated in the oven. Acid calcium phosphate (ACP) used to be the most common acid salt used for biscuits but because of the slower action of sodium acid pyrophosphate (SAPP), this has now more or less replaced ACP. Sodium acid aluminium phosphate is the salt most commonly used for domestic 'self raising' flour because it has a greater resistance to reacting with sodium bicarbonate when mixed in a flour at 14% moisture.

There is a difficulty and complication commonly encountered that acidulants are marketed under trade names. These brands are often acidulants diluted with a filler, such as dried flour or cornstarch, so that a simple 2:1 ratio to sodium bicarbonate is optimum in most recipes. These blends may be known as cream powders reflecting the original cream of tartar which also was used at about a 2:1 ratio.

Table 18.2 List of common acidulants, the basic quantities needed to neutralise one part of sodium bicarbonate and the relative speed of reaction in the dough as it is mixed and heated in the oven

Acidulant	Chemical description	Speed of reaction	Parts required to neutralise 1 of NaHCO ₃
1. Monocalcium orthophosphate monohydrate 'Acid calcium phosphate' 'Mono calcium phosphate' 'ACP'	Ca(H ₂ PO ₄) ₂ ·H ₂ O	Fast	1.25
2. Potassium bitartrate 'Potassium acid tartrate' 'Cream of tartar'	KHC ₄ H ₄ O ₆	Medium	2.25
3. Sodium acid pyrophosphate 'Puron' 'SAPP'	Na ₂ H ₂ P ₂ O ₇	Medium	1.33
4. Sodium acid aluminium phosphate hydrate	NaH ₁₄ Al ₃ (PO ₄) ₈ ·4H ₂ O	Slow	1.00
5. Gluconodeltalactone 'GDL'	C ₆ H ₁₀ O ₆	Slow	2.12
6. Adipic acid	C ₆ H ₁₀ O ₄	Slow	0.87

Therefore when purchasing an acid baking salt be clear whether it is the pure chemical or a diluted version. Ignorance could lead to the wrong soda acid mixtures in a dough. Mixtures of soda and an acidulant are available and are known as baking powder. These are used principally for domestic baking and not in biscuit manufacturing.

Gluconodeltalactone (GDL) is not an acid but when dissolved in water it slowly changes to gluconic acid which then reacts with sodium bicarbonate to liberate carbon dioxide. It has the advantage that there is no aftertaste. Adipic acid may be useful, though it is rarely used at present, since it is only slightly soluble in cold water but very soluble, and hence reactive, in hot water.

18.3.3 Ammonium bicarbonate (Vol, $(\text{NH}_4)\text{HCO}_3$)

This extremely useful leavening agent for biscuits decomposes completely when heated, breaking down into carbon dioxide gas, ammonia gas and water. The name 'Vol', by which it is commonly known, derives from 'volatile salt' because of this complete dissociation and also because in the solid state it smells strongly of ammonia. It is readily soluble in water and is very alkaline giving softer doughs which require less water for a given consistency. Despite its strong smell of ammonia, only a small proportion of the available gas is lost when it is dissolved in water and held at normal temperatures. Even in solution for 24 hours, little of its potency is lost. The dissociation is particularly rapid at about 60°C, that is, well into the oven as the dough pieces are baked. Being a carbonate it will, of course, react readily with other acidic ingredients, but the alkalinity conferred on the dough is not carried through to the baked biscuit. Sodium bicarbonate is needed if the biscuit pH is to be adjusted.

In many cases it has been found satisfactory and convenient to eliminate all acidulants in biscuit doughs and to use only Vol and soda. This has advantages where minor ingredients are to be added as solution or suspensions in premixes for continuous or automatic batch mixers. Most other acidulants, if dissolved in water react to an appreciable extent or progressively in the cold and cannot be combined in premixes which must be held for a few hours.

Vol is purchased as a white crystalline solid. It is prone to severe lumping even when stored in dry conditions. It should, therefore, be used as soon as possible after delivery and it is advisable always to dissolve or disperse the salt in water before adding to a mix. The pronounced alkalinity of doughs with Vol has a significant effect on the spread or flow of short dough products during baking. However, as it is usually more difficult to achieve enough spread rather than the reverse, other changes in the recipe can usually be made to compensate.

18.4 Processing aids

Like ammonium bicarbonate there are some other materials used in biscuit manufacture that are used to enable the process but are more or less completely lost during baking. In addition to water and reducing agents, which are considered here, there are the proteolytic enzymes that may be used to modify the gluten strength in developed doughs (see Chapter 27).

18.4.1 Water

Water is a unique ingredient in biscuit doughs. It is an additive in the sense that it is a non-food material, but it is more particularly a catalyst as it allows changes to occur in the other ingredients, both to form a dough and then a rigid and textured product after baking. All the water added to biscuit doughs is subsequently removed in the oven, but the quality of the water used may have an effect on the dough.

In most places biscuit factories draw their water from the local municipal potable water supply and responsibility for purity is left with the water authorities. However, as factories are established in developing countries and in more remote places which do not have a mains water supply, the quality requirements for water need to be considered. There are three principal aspects to be considered:

1. microbiological safety
2. concentration and nature of dissolved chemicals
3. colour and turbidity

It is not essential that water used for doughs is as free from microorganisms as is necessary for drinking water because many of the other dough ingredients are rich in bacteria and mould spores and all of these will be destroyed during baking. However, infected water will probably be polluted in other ways which may have a deleterious effect on health even when the microorganisms are destroyed. The dissolved substances in water are receiving more attention because they have a significant effect on some baking processes and there is a growing concern about trace metals in foods.

The World Health Organisation has published a recommendation for European drinking water (see Table 18.3) and there is a particular and understandable concern about the levels of heavy metals like arsenic, lead and mercury. These metals are known to be injurious to health, particularly because they accumulate in the body. However, the effect on baking of the various substances which may be dissolved in water has not received much attention in relation to biscuits. Jackel [2] reports the effects of different inorganic ions on rates of dough fermentation (see Table 18.4), but this is of relevance to bread and the volumes of baked loaves. Some biscuit doughs are fermented, but one should distinguish between the effects of dissolved substances on the vitality of yeast (and other microorganisms in the dough) and the effects on the dough itself. Doughs made with very soft water are softer and weaker than those made with hard water. It has been suggested that batter for wafers made with soft water is less inclined to form strands of gluten. Soft and hard are terms linked with the amount of soap needed to produce a lasting lather and this is due particularly to the levels of calcium and magnesium ions. Calcium, however, may be added to doughs in other ways, for example, as a leavening salt or as a nutrient supplement in flour, but the principal significance of this metal in biscuit making is that the levels in water tend to vary very considerably from season to season depending on the water source and its temperature. The pH of water can also vary quite widely in the course of a year and this may have some effect on dough quality. However, flour has a strong buffering action which will tend to reduce effects on the dough.

Traces of copper and other certain metals have a marled effect on the development of rancidity in fats and oils. Drinking water standards demand low concentrations of copper and other metals associated with the development of fat rancidity,

Table 18.3 World Health Organization's European Standards for Drinking Water

Colour (hazen) units	5–50
pH	6.5–9.2
Hardness (CaCO ₃)	Total 100–500 ppm
Nitrate (N)	50–100 ppm of nitrogen from the total nitrate (NO ₃) ⁻
Ammoniacal nitrogen	0.045 ppm of nitrogen from the total ammonia (NH ₄) ⁺
Chloride (Cl) ⁻	200–600 ppm
Sulphate (SO ₄) ⁻	200–400 ppm
Calcium (Ca) ²⁺	75–200 ppm
Magnesium (Mg) ²⁺	30–150 ppm
Dissolved solids (dried at 180°C)	500–1500 mg/l
Iron (Fe) ²⁺ or (Fe) ³⁺	0.1–1.0 ppm
<i>Other metals (ppm)</i>	
Arsenic (As) ³⁺	0.05
Lead (Pb) ²⁺	0.1
Cadmium (Cd) ²⁺	0.01
Mercury (Hg) ²⁺	0.001
Selenium (Se) ²⁺	0.01
Copper (Cu) ²⁺	0.05–1.5
Manganese (Mn) ²⁺ or (Mn) ³⁺	0.05–0.5
Zinc (Zn) ²⁺	5.0–15.0
<i>Other compounds (ppm)</i>	
Cyanide (CN) ⁻	0.05
Anionic detergents	0.2–1.0
Phenols (C ₆ H ₅ O) ⁻	0.001

Note: The first figure is the usual accepted level for each element. Where a second figure is quoted this is the maximum level permitted by the World Health Organization's European Standards.

Table 18.4 Effect of ions in slowing fermentation (at 100 ppm) (from Jackel [2])

Ion	Fermentation change (%)
Bicarbonate (with potassium)	10.3
Titanium (as chloride)	10.7
Nitrate (with potassium)	10.8
Chromate (with potassium)	11.7
Chromium (as nitrate)	12.7
Cadmium (as chloride)	15.6
Nickel (as sulphate)	15.9
Nitrite (with potassium)	17.5
Sulphide (with potassium)	31.9
Cuprous (as sulphate)	43.8
Cuprous (as chloride)	44.4
Cuprous (as acetate)	45.4
Cuprous (as nitrate)	50.8
Silver (as nitrate)	62.1
Mercuric (as chloride)	89.5

so this problem is likely to be under control if only drinking water is used in dough. If, however, it is suspected that metal ions are the cause of difficulties in dough or biscuit quality, it is possible to remove or reduce their effects with chelating agents, for example, ethylenediaminetetraacetic acid (EDTA) (see Andres [3]). Only very small quantities are needed to be effective and they are economical to use. EDTA

is also used in foods to promote stability of colour, flavour or clarity of solution. Until more detailed investigations are made it is unlikely that water treatment units designed to remove dissolved substances to lower levels than those suggested for drinking water will be of significant value for biscuit making.

As regards the colour and turbidity of water, it is unlikely that these properties will be troublesome for biscuits except that it is worth knowing the reasons for high levels as the source may have a bearing on microbiological or other properties.

The health aspects of traces of metals and certain other noxious chemicals in foods is receiving more and more attention and food processors are always expected to be above reproach. It is probable that traces of many substances are as beneficial to health as high concentrations are injurious, so the happy balance is hard to establish. Particular care must be taken when products are specifically formulated for people in the most vulnerable groups – infant children, pregnant mothers, the very old and the sick.

In conclusion it is felt to be wise and good practice to select water for biscuit making that is of constant quality and which conforms to the international standard for drinking water. Where this water is drawn from a public supply it will probably be safe to leave the responsibility for quality to the authorities, but where a well or other private source is used, regular analyses, at about three-monthly intervals, should be made to check that there is no build-up of injurious substances.

18.4.2 Sodium metabisulphite (pyrosulphite, SMS, $\text{Na}_2\text{S}_2\text{O}_5$)

This is a processing aid used to modify the quality of gluten and the rheology of dough by reducing some of the disulphide bonds (see Fig. 16.2). It is an extremely effective and useful additive for biscuit dough where gluten development is important, but it has attracted much adverse criticism because sulphites have been shown to have possible harmful side effects. The use and fate of SMS in dough is dealt with in more detail in Section 27.2.

It is also possible to use potassium metabisulphite in place of the sodium salt. The cost is higher and the usage a little higher because the potassium atom is heavier than sodium. A useful review of the use and mechanism of SMS in biscuit doughs is given by Wade [4]. The solubility of SMS in water is approximately 39 g/100 ml solution at 20°C. Because only very small quantities are used it is normal to make a 10% solution and to meter quantities by volume. A solution kept in a sealed container will be stable for at least 24 hours.

18.5 Food acids

Food acids are organic acids found in natural products but now normally manufactured by chemical synthesis. They are weak acids in chemical terms, reducing the acidity of aqueous solutions to a minimum of about pH 2. In biscuits they are used mainly to accentuate fruit flavours in sandwich creams but they also have a technical function in jams and jellies in that they control the setting of pectin. There are three commonly used food acids in biscuits. These are citric, tartaric and malic acids. Each is a white crystalline powder. They differ in their solubilities in water at room temperature as shown below (maximum concentration at 20°C):

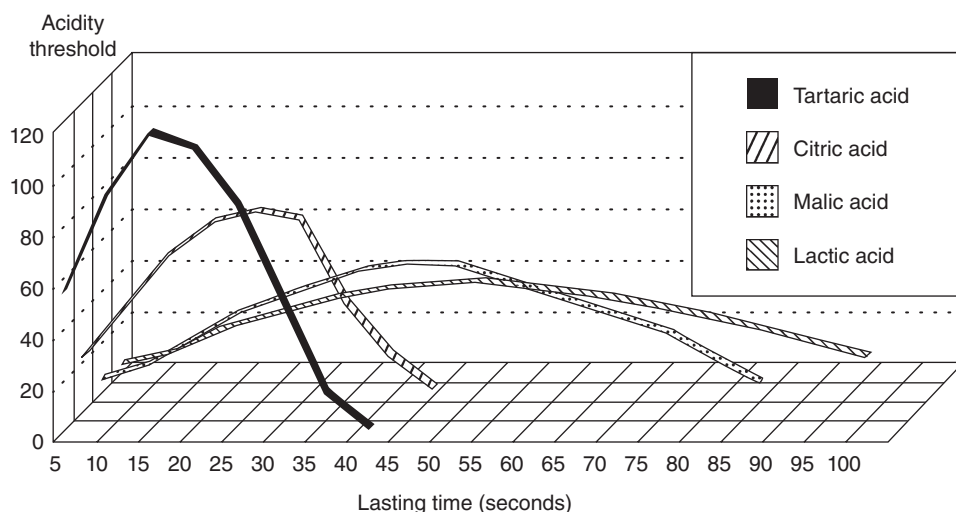


Fig. 18.1 Taste profiles of different acidulants' acidity and lasting time (Kishnakumar [5]).

Acid	g/100 water
Tartaric	19.0
Malic	58.0
Citric	64.0

Citric and tartaric acids have similar taste giving an immediate sharp sensation which is not very persistent. Malic is less strong initially but is more lasting. The selection of acid for use in biscuit creams will probably be made primarily on the basis of cost. To achieve a good spread of acidic sensation, finely ground acid powder should be used. It is difficult to assess the relative strength of acidic flavour from these acids because it probably depends on the base carrying it. However, some say that the sensation from malic acid is greatest and that this allows a 10% reduction in usage compared with citric or tartaric acid. Figure 18.1 gives a graphic idea of the relative taste profiles of food acids.

Lactic acid is a liquid at room temperatures and has a smooth, bland flavour sometimes described as slightly saline. It can also be purchased as a powder. The contribution to the flavour profile is more of a savoury than a fruity flavour so lactic acid finds occasional use in biscuits where cheese and meaty flavours are to be accentuated.

18.6 Colours

Colour plays an important part in our lives and particularly in our food. Without colour additives most biscuits would look the same pale brown. The yellow or orange colour of eggs and butter is carried through in cakes and pastry and in many cases an artificial colour is added to biscuit dough to suggest richness due to these ingredients even when neither has been used. Sandwich creams or jellies with fruit

flavours seem much more authentic and palatable when coloured appropriately than if they are white or colourless.

In the early days of the food industry a few natural colours were used to enhance products. These include cochineal (red), an extract from the bodies of certain insects, saffron (yellow) from the stigmas of a crocus flower and, of course, caramel (brown) from burnt sugar. The development of the chemistry of aniline, or coal tar, dyes presented the industry with a whole range of intense stable colours which performed very well in foods. In combination, practically any colour could be achieved from very small amounts of dye and at low cost.

Toxicological and allergy tests indicate that some of these dyes should not be used, especially where they are heated as in the baked parts of foods. Consumer reaction has been so strong that in some countries no colouring, especially artificial colouring, of foods is allowed and always there is need or a request for clear labelling of which colours have been used. Plant pigments such as carotenoids, xanthophylls, anthocyanins, and betalines which are responsible for the familiar colours of chlorophyll, fruit skins and beetroot colours have been extracted, concentrated and can be used as 'natural' food colours. Whether or not they are really less harmful to health does not seem to have been disputed but they have disadvantages because they are often less stable to heat, pH and light and the range and depth of colouration is not so good as the aniline dyes.

Variations in national legislation on food colours probably give more problems to exporters than any other factor. It is, therefore, felt likely to be misleading to give any sort of particular account of various colouring materials since checks must always be made to establish the current legislative position in each country. However, one group of colourants which is worth mentioning, even though they are not above suspicion in food, are 'caramel colours'. These brown materials are essentially end products of the controlled non-enzymatic heat degradation of edible carbohydrates. Typically the base material is a glucose syrup and the reaction takes place in the presence of heat, pressure and catalyst when ammonia or acid is used. Products produced by the ammonia reaction tend to be much darker than those by the acid methods.

Caramel colours (usually supplied as a solution in water) are used in a wide range of foods, but in biscuits they can be used to enhance baked reddish brown colours or in higher concentration the brown associated with cocoa powder, for example, in Bourbon biscuits. Brown, red and even black colouration of biscuit doughs can be achieved by using cocoa powders. Cocos which have been 'dutch' with alkali to varying degrees give dark colours, but not necessarily good flavours. The black dough of the famous Oreo biscuit shell is coloured with cocoa.

18.7 Artificial sweeteners

These are substances which are used in food to give a sweetness sensation like sucrose but which are so intense in their action that only minute amounts are needed. There are other sweet substances which are used in place of sucrose such as polyols (see Section 11.7) but these are needed in similar quantities to sucrose to provide significant bulk to the product. Although sucrose is essential for the structure and mouthfeel of most biscuits, there are times where increased sweetness is desirable but more sucrose would either make the biscuit too hard or would

interrupt the basic gluten structure in the dough. Here an artificial sweetener as a booster to sweetness may be useful. The other place where these sweeteners are used in food products is to reduce the overall calorie value. This situation is very rarely used in biscuits.

Many of the artificial sweeteners used in soft drinks, ice creams, etc., are not suitable for products that are heat treated or baked. Heat stable products include saccharin, between 200 and 700 times as sweet as sucrose is perceived by many as having a slightly bitter and metallic aftertaste. There is concern in some places about its safety as food.

Cyclamate is only about 30 times sweeter than sucrose and has no side-tastes. It has the particular advantage of being sweeter when mixed with saccharin and of reducing the overall saccharin aftertaste. The suggested optimum ratio is 10:1 cyclamate to saccharin. Cyclamate has been banned in some countries because of concerns about a toxic effect but it is still used in countries such as Switzerland and Hungary.

Sucralose is made from sucrose by Tate and Lyle. It is about 600 times sweeter than sucrose. It has taste characteristics which are very similar to sucrose and it provides no calories in the food. These sweeteners tend to have a lingering taste which some may not find acceptable.

18.8 References

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Chocolate and cocoa as biscuit ingredients

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Abstract: Flavour is a major consideration of chocolate, whether plain, milk or a substitute coating. The composition of chocolate is well legislated to protect the meaning of the name chocolate. Chocolate and cocoa are widely used for biscuit manufacture both as a source of flavour and colour. It is an expensive ingredient so buying and handling are important considerations.

Key words: chocolate, cocoa, chocolate definition, chocolate chips, chocolate drops.

19.1 Introduction

Sugar and cocoa were the first commodities to be processed by industrial methods. Early processing of cocoa beans was only good enough for use in drinks. The pioneers of chocolate manufacture, in early to mid nineteenth century, were Cadbury and Fry in England, van Houten in the Netherlands and Lindt in Switzerland. It was Nestlé in Switzerland that first overcame the difficulties of mixing the water in milk with the fats in chocolate to produce 'milk chocolate'. For those interested in reading about the industrialisation of chocolate manufacture, please see Cadbury [1].

The basis of chocolate and cocoa is the cocoa bean. These beans are from the cocoa tree *Theobroma cacao* which originated in the tropical areas of central America and the north of South America. It is a tree found in tropical rainforest habitat (within 20° north and south of the equator) and the beans are now harvested mainly in West Africa but also in South East Asia. By far the largest quantities of bean come from West Africa but supplies from other areas are valuable for the distinctive flavours and other properties that they can give. The world supply and demand for chocolate and cocoa has resulted in great variations in price from year to year. These economic pressures have prompted the development of 'chocolate' with less cocoa bean material and the inclusion of other fats. The chocolate industry worldwide is very concerned at these developments because they tend to debase the meaning of the word 'chocolate' and the particular quality that should be associated with it. The definition of chocolate has been a matter for international debate for a very long time. In Europe, where there are vested interests not to allow the inclusion of any other fats than cocoa butter, the problem was debated for a very long time but has now been resolved. It is covered in EC Directive 2000/36/EC [2]

and this legislation describes requirements for cocoa butter and vegetable fats which can be used in materials that can legally be labelled as chocolate. For more details see Section 12.2.4.

19.2 The flavour of chocolate

Flavour is a major consideration of chocolate, whether plain, milk or a substitute coating. The flavour derives very largely from the cocoa beans so, very briefly, it is worth outlining how the flavour is derived.

Firstly, beans from different growing areas have special characteristics. Often, therefore, a chocolate manufacturer will blend beans to obtain a desired flavour note. This flavour originates with the fermentation of the beans. The beans grow in big pods. After harvesting, the beans are stripped manually from the pods and, without delay, they are fermented. Traditionally this fermentation takes place in a pile on the ground, covered with banana leaves. The fermentation occurs naturally. The temperature rises and it is necessary to turn over the pile from time to time to ensure even conditions throughout the pile. After about a week the fermentation, which is a combination of aerobic and anaerobic conditions, will have produced in the beans, alcohol, acetic acid and a variety of strong flavoured aldehydes and ketones. Fermentation also changes the colour of the beans to a dark brown. The beans are then spread out to dry, bagged and taken from the plantations for sale.

In the various countries the fermentation procedures vary and this is another reason for differences in the qualities and usefulness of the beans. Variations to this somewhat uncontrolled fermentation process have been developed involving the use of boxes to hold the fermenting beans. Before the beans are suitable for grinding they must be toasted or roasted. The conditions of temperature and time are very critical to the aroma so here also variations in flavour may arise. Following toasting, the shells and germ are removed and then the beans are ground, using a series of rolls, into a dark brown fluid mass known as cocoamass or chocolate liquor. This contains about 55% fat and is intensely bitter in taste. This cocoamass is the basis of both chocolate and cocoa powder.

Cocoa powder is made from the cocoamass by removing cocoa butter (the fat), usually by pressing, and chocolate is made by adding sugar, cocoa butter and maybe milk powder to the cocoamass. Thus, because more fat is required for chocolate than is contained in the quantity of cocoamass used, it is inevitable that cocoa powder is a by-product of chocolate manufacture. It is this fact that has resulted in the very high price of cocoa butter and the desire to use fat from other sources. Cocoa butter from different varieties of beans and from different countries does vary a little in its physical and eating qualities. For example, butter from Malaysia is the hardest and that from Brazil the softest. Choice of butter can therefore affect slightly the hardness of the chocolate made.

After the chocolate recipe has been assembled and mixed it is ground (refined) to very small particle size through a series of rolls. Finally, the refined mass is conched (conged). The conch is in effect a large mixer whose function is to

- 'wet' the dry surfaces of the non-fat particles (chocolate is really a suspension of non-fat particles in a continuous fat phase)

- develop the flavour by allowing evaporation of pungent acids, aldehydes and ketones remaining from the fermentation of the beans, and promoting the oxidation of tannins which reduces the astringency of the flavour
- in the case of milk chocolate, finalise the caramelisation and Maillard reactions between proteins and reducing sugars which give particular flavour notes
- remove water so that the moisture content is less than 1%. This is achieved because the conching is at an elevated temperature; the maximum temperature for milk chocolate is 65°C, that for dark chocolate, 85°C.

Bean selection, recipe and processing conditions have a marked effect on chocolate flavour. The manufacture of chocolate is very complex and relies greatly on experience and skill.

19.3 Chocolate viscosity

The fluidity of chocolate is important to the biscuit manufacturer because it affects the handling characteristics in the enrober or moulding plant. If the chocolate is too thick it will be impossible to coat with a thin layer and air bubbles may not rise from it before setting occurs.

The viscosity is basically related to the fat level, the more fat the more fluid it is. However, the finer the particle size of the cocoa, sugar and milk solids, the less will be the fluidity because of the increased surface area for the fat phase to coat. The fat in chocolate is the most expensive component so all techniques possible are used to reduce the amount needed. There is a limit to the maximum particle size of the non-fat ingredients as coarse size gives unsatisfactory mouthfeel, but for chocolates used to coat biscuits the grinding is not so fine as for good eating (tablet, etc.) chocolate (see Table 19.1).

Wetting of the solids is important and this is achieved by both the conching process and the use of small amounts of emulsifier, such as lecithin. Typical levels of lecithin are 0.4–0.5% of the total mass of the chocolate. The effect of lecithin is impaired if the temperature is above 60°C so during making or later handling of chocolate this temperature should not be exceeded if there is lecithin in the formulation. The problem is that particularly the sugar crystals and milk powders have traces of moisture which reduce the wetting effect of the fat. The moisture level of chocolate is extremely critical to the fluidity, and attention to this both during manufacture and in subsequent storage and handling is very important (this matter will be returned to later). Normally chocolate must have a moisture content of less than 1%.

When chocolate is used for enrobing or moulding it must be in a tempered condition (see Section 41.5.1). This means that a proportion of the fat is in a crystalline

Table 19.1 Comparison of average particle sizes

	Fine eating chocolate (μm)	Average coating chocolate (μm)
Cocoa solids	30–50	75–100
Sugar	25–35	50
Milk solids	35	50

form and most of the fat is very near to its setting temperature. The number of crystals present affects the fluidity and this is a feature of the tempering not the basic composition of the chocolate. It will, however, be appreciated that the more fluid is the chocolate when all the fat is liquid, the lower will be the consistency at a given condition of temper.

The quality control of chocolate includes checks on the consistency above the melting point of the fat, and the process control of chocolate (while being used for enrobing, for example) requires attention to the degree of temper. The consistency in the latter condition is difficult to measure as the chocolate is in an unstable condition. The basic consistency of chocolate can be checked with a suitable viscometer. There are several that are used. In Europe it is usually the Casson viscometer and in the USA the MacMichael viscometer, but others are also used. Comparison of values is not straightforward as operator and temperature conditions are critical. An account of viscosity relationships in chocolate is given by Malm [3] but purchasers of chocolate wishing to check the viscosity are advised to use identical equipment and techniques to their suppliers.

19.4 Cocoa butter, cocoa butter equivalents and hard butters

The use of fats other than pure cocoa butter in chocolate has been referred to above. The triglyceride composition of cocoa butter (see Table 12.2) is unique amongst natural fats. It results not only in an exceptionally sharp melting curve (see Fig. 12.9) which is important for the mouthfeel and flavour release of chocolate as it is eaten, but also to the polymorphic crystallisation making tempering necessary to achieve a good gloss and shrinkage in moulds as the chocolate sets. The disadvantage of cocoa butter is that it softens at temperatures which make it difficult to handle in hot weather. These physical characteristics combined with its high cost have prompted the use of other fats in 'chocolate'.

If cocoamass is the basis of the 'chocolate', it is inevitable that some cocoa butter will be present; if cocoa powder is the basis, the amount will be very much less. Mixtures of cocoa butter and most other fats form eutetic mixtures which have longer and lower melting curves, and where hard fats, such as hardened palm kernel oil are used, there will be a high melting fraction that will give a tail which impairs the mouthfeel giving a greasy sensation. Thus, imitation chocolates, known as coatings or compounds, must not be mixed with real chocolate. This makes it almost impossible to alternate one with another in an enrober.

As a result of intensive and detailed research, a group of fats known as cocoa butter equivalents (CBEs) has been produced with names like coberine, choclin and veberine. These are all vegetable, non-hydrogenated products containing the same fatty acids and triglycerides as are present in typical cocoa butter. They are refined products with a bland flavour and physical properties so similar that when mixed with cocoa butter little change occurs. CBE may be used either as a total or partial substitute for cocoa butter in 'chocolate'. In the former case the product is known as a supercoating and in the latter legislation problems occur because of concern that the adulteration of 'chocolate' may lead to reduced quality.

There has been much debate on the levels of cocoa butter substitution that should be permitted while retaining the right to label the product as chocolate. Levels of up to 5% (of the total product weight), or up to 15% of the fat level, of other

Table 19.2 Compositions of chocolate to meet EU reserved descriptions. Used with permission from Yates [6]

Reserved description	Total cocoa solids (dry) (%) (min)	Non-fat cocoa solids (dry) (%) (min)	Cocoa butter (%) (min)	Total milk solids (dry) (%) (min)	Milk fat (%) (min)	Total fat (cocoa butter and milk fat) (%) (min)	Vegetable fat (%) (max)
Chocolate	35	14	18				5
Chocolate (with 'quality' description)	43	14	26				5
Milk chocolate	25	2.5		14	3.5	25	5
Milk chocolate	20	2.5		20	5	25	5
Family milk chocolate							
Milk chocolate (with 'quality' description)	30	2.5		18	4.5	25	5
White chocolate			20	14	3.5	23.5	5

vegetable fat were allowed in Britain and certain other European countries, before full international agreement was achieved. Accounts by Faulkner [4] and Caverley and Hill [5] are most descriptive of the technology and commercial situations of CBEs. In Section 19.5, EC definitions are given for some of the more commonly used terms used to label chocolate and chocolate products, together with chocolate comparisons for the USA.

19.5 Definitions of cocoa and chocolate products

- *Cocoa nib*
Cocoa beans, roasted or unroasted where they have been cleaned, shelled and have undergone germ separation and which contain, on a fat-free solids basis, not more than 5% of uneliminated shell or germ and not more than 10% of ash (more in alkalinised products).
- *Cocoamass*
Cocoa nib reduced to a paste by a mechanical process without losing any part of the natural fat content.
- *Cocoa, cocoa powder*
Solid material obtained by hydraulic pressure from cocoamass which has then been reduced to powder by a mechanical process. It contains at least 20% cocoa butter calculated on the weight of dry matter and at most 9% water.
- *Fat-reduced cocoa*
A cocoa powder with a minimum cocoa butter content of 8% calculated on the weight of dry matter.
- *Cocoa butter*
The fat obtained from cocoa beans or parts of cocoa beans.

19.5.1 EU definitions of chocolate

Table 19.2 shows the compositions of chocolate to meet EU reserve descriptions.

19.5.2 USA definitions of chocolate

Table 19.3 shows the compositions of chocolate to meet US standards.

19.6 Types of chocolate

Plain, or dark, chocolate is a blend of cocoamass, sugar and cocoa butter with traces of emulsifier and vanilla (or other flavours). It has existed since the early 1700s and is still very popular. It has a strong flavour as the cocoa solids are relatively high. In the 1870s milk chocolate was developed and today the consumption of this type greatly exceeds that of dark chocolate.

Due to the high moisture content of fresh milk, if is, of course, not possible to use this in the manufacture of milk chocolate. Some form of milk powder must be used. Normal milk powder does not have a sufficiently strong flavour for the production of good milk chocolate so techniques are used to enhance it. The flavour development is basically derived by two means: partial release of the short chain

Table 19.3 Composition of chocolate to meet USA standards. Used with permission from Yates [6]

	Total cocoa solids (dry)* (%) (min)	Cocoa butter (%) (min)	Total milk solids (dry) (%)	Milk fat (%) (min)	Vegetable fat (%)
Sweet chocolate	15		12 (max)		
Semi-sweet (bittersweet) chocolate	35		12 (max)		
Milk chocolate	10		12 (min)	3.39	
White chocolate		20	14 (min)	3.5	
Milk chocolate & vegetable fat coating	10		12 (min)	3.39	Not limited

* as chocolate liquor.

Table 19.4 Composition of a good UK milk chocolate for enrobing biscuits

Total fat	31.5%
Cocoa butter	26.0% (21% cocoa butter, 5% CBE)
Butter fat	5.5%
Emulsifier	0.5%
Sugar	47.8%
Fat-free milk solids	14.8%
Fat-free cocoa solids	5.4%
Flavouring	trace
Moisture	<1.0%
Total plate count	<5000. Pathogens absent

fatty acids, particularly butyric acid, which occur in butter fat, by enzyme action and also by development of the Maillard reaction, the chemical reactions between the milk proteins and certain sugars (principally lactose). Both of these flavour reactions require the presence of water so must take place before the milk is dried to a powder to be used in the chocolate.

Modified milk powder is commonly referred to as milk crumb and the preparation of this is a sophisticated and critical process which has been developed considerably in recent years. Milk crumb may be made with inclusion of cocoamass or not; if not, then the crumb is creamy coloured. An account of milk crumb manufacture is given by Minifie [7].

Milk chocolate contains less cocoamass than dark chocolate and is paler in colour. The presence of butter fats reduces the chocolate melting point and affects the temperatures for tempering (see Section 41.5.1). Tables 19.4 and 19.5 give typical analyses for milk and plain chocolate used to enrobe biscuits in Britain.

19.7 Supply and storage of chocolate

Most biscuit factories do not manufacture their own chocolate so it is necessary to consider supply and storage. For large users it may be convenient and more

Table 19.5 Composition of a good UK plain chocolate for enrobing biscuits

Total fat	31.3%
Cocoa butter	31.3% (26.3% cocoa butter, 5% CBE)
Fat-free cocoa solids	13.0%
Emulsifier	0.65%
Sugar	55.0%
Flavouring	trace
Moisture	<1.0%
Total plate count	<5000. Pathogens absent

economic to bulk handle chocolate in liquid form. Road tankers are used to carry and discharge the chocolate in a similar way to fats. The silos must be jacketed, kept at 49°C, and the chocolate must be constantly agitated in a gentle manner. The minimum temperature for bulk chocolate storage is 45°C. This ensures that all the fats are liquid. Great care should be taken to avoid contact with water or damp surfaces and, as for other fats, no valves or other fittings should contain copper or brass which will promote fat rancidity. Chocolate is much more resistant to oxidative rancidity than most other vegetable fats, so storage in liquid form can be several weeks.

Most users take delivery of chocolate in solid form. This may be in large blocks or in small pieces. The large blocks will have been moulded at the supplier's factory and wrapped in polyethylene or waxed paper to protect against atmospheric humidity. In the case of small pieces, these may have been moulded or cooled as strips which are subsequently broken in a random way before bulk packing in moisture-proof sacks for shipment. It should be remembered that these pieces of chocolate have an appreciable surface area so exposure to air may result in chocolate with too much moisture and hence high viscosity when melted.

Chocolate should be stored in rooms at about 15°C with a relative humidity of 50% well away from strong smelling ingredients such as spices, cheese and chemicals. The value of chocolate, combined with its appeal to most people usually requires that it is kept under lock and key! Prior to use in an enrober or moulding plant the chocolate must be melted. Melting kettles are normally heated with hot water jackets and it is important that surface temperatures are maintained below 60°C, otherwise there is a risk of flavour change (and damage to the lecithin) – a metallic flavour may be detectable if chocolate has been overheated. The advantage of small pieces of chocolate compared with larger blocks is that they are easier to handle and they melt completely more readily.

19.8 Chocolate drops and chips

Small pieces, 'drops', 'chips' or 'chunks' of chocolate are sometimes used as an ingredient in wire cut cookies. These 'drops' are typically about 5 mm in diameter and are formed either by depositing small drops of tempered chocolate or by forming with a roller moulding plant. Chocolate 'chips' may be formed by dribbling thin streams of chocolate onto a cooling band and cutting to the desired length before packing.

Chocolate chips range in number from 1750–22 000/kg, chocolate chunks 900–1300/kg. The preferred size of choc chip for cookies in Europe is 7500/kg with cocoa solid content of around 40%. For some types of biscuits 2 or 3% of the sugar in the chocolate can be replaced with dextrose to aid baking stability.

Although the chocolate melts when the cookies are being baked, there is no appreciable movement of the chocolate within the dough so it sets again when the biscuit cools. This therefore offers a means of including recognisable chocolate into cookies where the climate precludes the satisfactory use of a surface coating. Formation of a caramelised skin during baking prevents smudging and formation of bloom. If a bloom forms on the chocolate chips after 2–3 days, this may be attributed to the baking temperature being too low; increasing it by 10–30°C may reduce the problem. If the bloom appears after 6–8 weeks, the problem is probably due to fat migration from the dough. To reduce fat migration, maintain the storage temperatures below 20°C. Overbaking will allow the chips to harden and their flavour will deteriorate because a caramelised or burnt flavour will be formed.

19.9 Cocoa

Cocoa is a flavoursome powder produced from the cake formed when cocoa butter is expressed from cocoamass. There are two basic types, dutched and natural, and each is available with fat contents within a range of about 8–32%. Dutched cocoa is made from roasted and shelled beans which have been nibbed, soaked in a warm alkali solution, dried and ground to a mass prior to expressing the cocoa butter. This process results in powder with a darker and redder colour. The cocoa powder is more easily dispersible in water, has a less astringent flavour and, of course, has a higher pH. The pH of natural cocoa is about 5.2–6.0, that of ‘dutched’ powder between 6.8 and 8.8 depending on the amount of alkali absorbed. It is possible to achieve some very dark or even black cocoas by this alkali treatment. Such cocoas are valuable for colouring biscuit doughs.

The same criteria affect the flavour of cocoa powder as for chocolate except that the mellowing effects of conching are absent. The higher the fat content the more rounded is the flavour. General-purpose manufacturing cocoa as used in doughs, biscuit creams or as the basis for coatings has a fat content of between 9 and 12%, maybe rising a little higher, but cocoa for use in beverages is richer in fat, usually not less than 22%.

Since cocoa is purchased principally for its flavour contribution (but also for its colour), means of checking the flavour are worth considering. It may be tasted in a suspension with warm water and sugar with or without the addition of a standardised milk powder (for example, a baby milk powder preparation). Cocoa powder should be a fine, free-flowing powder. It is normally sold with a maximum moisture content of 5%. Higher values may lead to mould growth during storage. As the equilibrium moisture contents are about 6.5% at a relative humidity of 50% and 9.5% at a relative humidity of 70%, it will be appreciated that cocoa powder is naturally hygroscopic so should be kept in moistureproof containers. Should the powder become too warm in storage the cocoa butter will melt and lumping with uneven colour results. The apparent colour of the powder is dependent on temperature due to the condition of the fat. The storage conditions for cocoa powder should be:

- humidity, less than 50% RH
- temperature, even and between 15 and 18°C, not exceeding 20°C
- away from strong odours such as spices, cheese, ammonia.

Under these conditions cocoa will keep for very long periods (years).

Specifications for cocoa usually contain a section on microbiological contamination. As the beans originate from the tropics and are fermented under 'non-hygienic' conditions, it is not surprising to find a rich flora on unroasted beans often accompanied by some insects and other filth. The cleaning and roasting of the beans more or less ensures sterilisation so that any evidence of pathogens in the cocoa powder probably represents very poor practice in the cocoa factory. The microbiology of cocoa should be a problem only where it is to be mixed with damp ingredients which are not subsequently baked.

It is difficult to obtain good 'chocolate' flavours from cocoa powder by just mixing it with fat and sugar to form creams. The reasons may be many, not least the difference between the cream fats and cocoa butter which affects flavour release. However, the most bitter cocoas are best and these are the natural or non-alkaline types. Cocomass is superior in flavour and is sometimes used as the flavour source in 'chocolate' creams.

19.10 Handling of chocolate and chocolate chips

Please refer to Section 41.5 for recommended handling and usage procedures.

19.11 Compound chocolate

As indicated above, products that look like chocolate can be made from cocoa powder, sugar and fats other than cocoa butter. They have various names but 'chocolate flavoured compounds' usually refers to moulded or deposited products and 'chocolate flavoured coatings' to products used for enrobing. The development of compound chocolate started at the time of the Second World War when there were severe shortages of foods and imitations were demanded. Interest in these products has continued because the fat industry has developed many fats with special physical and eating qualities that make it possible to have 'chocolate' that is suitable for hot countries, special food applications where real chocolate is difficult to handle and lower prices, etc. The technical advantages of compound chocolates in relation to biscuit manufacture can be summarised as:

- easier to make; in-house manufacturing is economical for small quantities
- higher melting points useful in hot climates
- no need for tempering at the time of use with considerably cheaper machinery and less operator skill
- less critical cooling procedures required
- more flexibility on the biscuit which reduces the incidence of cracking and crazing when the biscuit changes in dimensions due to moisture equilibration (e.g. in marshmallow products)

- a great range of colours and flavours are possible, not only those based on cocoa powder.

The quality disadvantages are

- less attractive eating profile, often giving a waxy mouthfeel
- lack of a good chocolate flavour, as much of this comes from the cocoa butter in real chocolate
- more inclined to produce a fat bloom during storage
- cannot be labelled as 'chocolate'.

Basic compound chocolates are normally made with hardened palm kernel oil. As more sophisticated fats are used the price rises rapidly.

19.12 Carob powder

Carob is the dried bean pod of the evergreen tree *Ceratonia siliqua* which grows abundantly in Mediterranean areas. The beans from the pods are used to make locust bean gum. The pods are normally used as animal feed, but it has been found that if these pods are roasted and ground, the powder bears a marked similarity in colour and flavour to cocoa powder. It is claimed that it may be substituted for up to 30% of the cocoa in certain products without appreciable change in flavour. The costs are much lower than cocoa under normal circumstances and it has the additional features that it lacks the caffeine-like stimulant, theobromine, and the allergy-producing components of cocoa.

19.13 References

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Packaging materials for biscuits and their influence on shelf life

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Abstract: The properties of the most important materials used to package biscuits (plastics and paper) are presented, and key aspects of this packaging and its influence on the shelf life of biscuits, crackers and cookies is discussed. Indices of failure are discussed and calculation of the shelf lives of biscuits that deteriorate by moisture gain and oxidation are given and the importance of the surface area to volume ratio of the package is demonstrated. In addition the effect of light transmission through different packaging materials on shelf life is discussed.

Key words: packaging, shelf life, indices of failure.

20.1 Introduction

Packaging ensures delivery of goods to the ultimate consumer of those goods in the best condition appropriate for their use. In today's society, packaging is both pervasive and essential as it protects the foods we buy from the moment they are processed and manufactured through storage and retailing to the final consumer. The importance of packaging hardly needs stressing because in developed countries it is almost impossible to find more than a handful of foods that are sold in an unpackaged state.

A primary package is one which is in direct contact with the contained product. It provides the initial and usually the major protective barrier. An example of a primary package is a plastic tray to hold biscuits overwrapped with a flexible plastic film. Frequently it is only the primary package which the consumer purchases at retail outlets. A secondary package contains a number of primary packages, e.g. a corrugated case or box. It is the physical distribution carrier and is increasingly being designed so that it can be placed directly onto retail shelves for the display of primary packages (so-called shelf-ready packaging). A tertiary package is made up of a number of secondary packages, the most common example being a stretch-wrapped pallet of corrugated cases. This chapter will confine itself to a consideration of the primary package.

Packaging has a major impact on the shelf life of foods and a recent book was devoted solely to this topic [1]. This chapter will briefly review the properties of the

most important materials used to package biscuits, and discuss key aspects of packaging and its influence on the shelf life of biscuits, crackers and cookies.

20.2 Packaging materials

The protection offered by a package is determined by the nature of the packaging material and the format or type of package construction. A wide variety of materials is used in packaging, and primary packaging materials for biscuits, crackers and cookies consist of one or more of the following materials: metals, paper and plastic polymers. These are briefly described below; more detailed information is available elsewhere [2, 3].

20.2.1 Plastic packaging materials

Plastics are organic polymers with the unique characteristic that each molecule is either a long chain or a network of repeating units. The properties of plastics are determined by the chemical and physical nature of the polymers used in their manufacture; the properties of polymers are determined by their molecular structure, molecular weight, degree of crystallinity and chemical composition. These factors in turn affect the density of the polymers and the temperatures at which they undergo physical transitions.

Polymer chains can and do align themselves in ordered structures, and the thermodynamics of this ordered state determine such properties as melting point, glass transition temperature, and mechanical and electrical properties. However, it is the chemical nature of the polymer which determines its stability to temperature, light, water and solvents, and hence the degree of protection it will provide to food when used as a packaging material.

A wide range of polymers is used in food packaging and the major categories are briefly reviewed below.

20.2.1.1 Polyolefins

These form an important class of thermoplastics and include low, linear and high density polyethylenes (LDPE, LLDPE and HDPE) and polypropylene (PP). The polyethylenes have the nominal formula $-(CH_2-CH_2)_n-$ and are produced with a variable amount of branching, each branch containing a terminal ($-CH_3$) group that prevents close packing of the main polymer chains.

LDPE is a tough, flexible, slightly translucent material that provides a good barrier to water vapour but a poor barrier to gases. It is widely used to package foods and is easily heat sealed to itself. LLDPE contains numerous short side chains and has improved chemical and puncture resistance and higher strength than LDPE. HDPE has a much more linear structure than LDPE, is stiffer and harder and provides superior oil and grease resistance. It is used in both film form where it has a white, translucent appearance, and as rigid packs such as bottles.

PP is a linear polymer with lower density, higher softening point and better barrier properties than the polyethylenes. In film form it is commonly used in the biaxially-oriented state (BOPP) where it has sparkling clarity; it can also be blow and injection moulded to produce closures and thin-walled containers. The properties of PP have improved considerably over the last few decades as a result of a

wide range of technical advances ranging from new metallocene catalysts to co-monomers.

PP has a lower density (900 kg m^{-3}) and a higher softening point ($140\text{--}150^\circ\text{C}$) than the polyethylenes, low water vapour transmission, medium gas permeability, good resistance to greases and chemicals, good abrasion resistance and high temperature stability, as well as good gloss and high clarity, the latter two factors making it ideal for reverse printing.

Non-oriented PP film is often referred to as cast PP film because it is generally made by the chill-roll cast process, although other methods can be used [2]. PP film is a very versatile material, being used as a thermoformable sheet, in cast form for film and bags, and as thin, strong biaxially-oriented films for many applications. Cast and oriented PP are sufficiently different that they do not compete for the same end uses; the cost of cast PP is much lower than that of oriented PP. The cast form has polyethylene-type uses while the oriented form has regenerated cellulose film (RCF)-type uses and has largely replaced RCF in food packaging applications. Cast PP use in food packaging is limited and it is generally not recommended for use with heavy, sharp or dense products unless laminated to stronger, more puncture-resistant materials.

In recent years there has been a large increase in the use of oriented polypropylene (OPP) for food packaging. Wide variations are possible in the extent of orientation in two directions, leading to a wide range of properties. However, BOPP film has a high clarity since layering of the crystalline structures reduces the variations in refractive index across the thickness of the film and this in turn reduces the amount of light scattering. OPP can be produced by the blown tubular or high expansion bubble process, or the tenter frame process. OPP films often have a stiff feel and tend to crinkle audibly.

BOPP film has a tensile strength in each direction roughly equal to four times that of cast PP film. Although tear initiation is difficult, tear resistance after initiation is low. Biaxial orientation also improves the moisture barrier properties of PP film and its low temperature impact strength. OPP film is not considered to be a gas barrier film but this deficiency can be overcome by coating with poly(vinylidene chloride) (PVdC) copolymerised with poly(vinyl chloride) (PVC) or acrylic acid. Various coated and vacuum coated BOPP film product designs have been evaluated in terms of their moisture, O_2 and aroma barriers [4].

If heat sealing is required, the PP is normally coated with a lower melting point polymer because shrinkage tends to occur when highly stretched film is heated. LDPE, PVdC copolymer and acrylic polymers are used as fusible coatings for OPP film. LDPE is cheaper, but PVdC copolymer confers far better resistance to water vapour and oxygen permeability. Acrylic polymers do not improve the O_2 barrier properties of OPP film but do provide good protection against many odours; the use of an acrylic coating on one side and PVdC copolymer coating on the other maximises the resistance of OPP to a wide range of odours [5].

A relatively new addition to the family of OPP films is white opaque film, generally made by the tenter frame process and known as pearlescent film since the diffusion of light gives the film the visual effect of pearlescence. Homopolymer resin is evenly mixed with a small amount of foreign particulate matter such as starch. In one product, when the thick filled sheet is oriented, the PP pulls away from each particle creating an air-filled void or closed cell. After heat stabilisation the OPP film is similar to a micropore foamed product. In the second product, the material

produced is a filled film without voids, the opacity being a direct result of the amount of particulate material included in the film. The primary opacification is caused by light rays bouncing off the PP cell walls and the air within each cell [6]. White opaque OPP films find application in biscuit packaging and other applications that have traditionally used speciality paper-based packaging materials.

20.2.1.2 *Substituted olefins*

Monomers in which each ethylene group has a single substituent are called vinyl compounds. The properties of the resultant polymers depend on the nature of the substituent, molecular weight, crystallinity and degree of orientation.

The simplest is poly(vinyl chloride) (PVC) with a repeating unit of $(-(CH_2-CHCl)_n-)$. A range of PVC films with widely varying properties can be obtained from the basic polymer. The two main variables are changes in formulation (principally plasticiser content) and orientation. Unplasticised PVC rigid sheet is thermoformed into a wide range of inserts from chocolate boxes to biscuit trays, but recently they have been substituted by PET or (very recently) starch-based biopolymers.

20.2.1.3 *Polyesters*

Poly(ethylene terephthalate) (PET) is a condensation product of typically ethylene glycol (EG) and terephthalic acid and has the general formula $(-OOC-C_6H_4-COOCH_2-CH_2-)_n$. The outstanding properties of PET film as a food packaging material are its great tensile strength, excellent chemical resistance, light weight, elasticity and stability over a wide range of temperatures (-60 – 220°C). PET films are most widely used in the biaxially-oriented, heat-stabilised form.

To improve the barrier properties of PET, coatings of LDPE and PVdC copolymer have been used, but today the use of MXD6 (see next section) and nanoclays are increasingly common for bottles. PET film extrusion-coated with LDPE is very easy to seal and very tough.

20.2.1.4 *Polyamides*

Polyamides (PA) (commonly referred to as nylons) are condensation, generally linear thermoplastics made from monomers with amine and carboxylic acid functional groups resulting in amide $(-CONH-)$ linkages in the main polymer chain. They provide a barrier to gases, flavours and aromas, as well as offering good mechanical properties including toughness, puncture and impact resistance. Nylons are identified by numbers based on their manufacture. One type is made by condensing diamines and dibasic acids; they are identified by the number of carbon atoms in the diamine, followed by the number of carbon atoms in the acid (e.g. nylon 6,6). The other type is formed by condensing single, hetero-functional amino acids; they are identified by the number of carbon atoms in the amino acid (e.g. nylon 6). Nylon 6 films have higher temperature, grease and oil resistance than nylon 11 films. Orientation improves the inherent barrier and mechanical properties of nylon films.

20.2.1.5 *Regenerated cellulose*

Regenerated cellulose film (RCF) is made from cellulose and is therefore a natural and renewable polymer. It is not a plastic because it does not soften when heated but undergoes thermal decomposition. However, since it competes with synthetic

polymers in food packaging applications, it is discussed here. It is commonly referred to by the generic term cellophane which is still a registered trade name in some countries. RCF can be regarded as transparent paper and for food packaging applications it is plasticised (typically with ethylene glycol) and coated on one or both sides, the type of coating largely determining the protective properties of the film. The most common coatings are LDPE, PVC and PVdC/PVC copolymer. Although widely used for packaging biscuits, crackers and cookies for much of the twentieth century, it was largely replaced by OPP during the latter decades for reasons of both cost and performance. Because it is made from a renewable resource there has been a small revival of interest in RCF for food packaging. However, renewability is only one parameter and when all environmental impacts are taken into account, it offers no advantages over OPP.

20.2.1.6 *Heat sealing*

Heat sealable films are considered to be those films which can be bonded together by the normal application of heat and pressure, such as by conductance from a heavy heat-resistant metal bar containing a heating element. Non-heat-sealable films cannot be sealed this way, but they can often be made heat sealable by coating them with heat-sealable coatings. In this way the two facing coated surfaces become bonded to each other by application of heat and pressure for the required dwell time.

The heat sealability of a packaging film is one of the most important properties when considering its use, and the integrity of the resultant seal is of paramount importance to the ultimate integrity of the package. A number of factors are involved in determining the quality of a heat seal and they can be conveniently summarised under three headings:

- Machine factors: dwell or clamp time; temperature and pressure.
- Resin factors: density; molecular weight and additives in the resin.
- Film factors: gauge; style or form (e.g. whether gusseted or not) and treatment for printing.

All of these factors tend to interact in a complex way [7]. For example, the amount of heat available may be limited by the capacity of the heating elements, by the rate of heat transfer of the sealing bar and its coating, or the type of product being packaged. Dwell time should be able to be controlled to fractions of a second and be easily adjustable. Likewise, the pressure between the jaws should also be easily adjustable. Both these factors will need to be changed when different materials are heat sealed. Increasing the dwell time (i.e. the time during which heat is applied) will increase the heat available, but this may prove to be uneconomic since fewer units will be able to be handled per minute. Heat sealability at short dwell times is very critical and is most important on high speed wrapping machines.

Conductance (also known as resistance or bar) sealers are the most common type of heat sealers in commercial use and typically consist of two metal jaws (often patterned or embossed to give the seals extra strength), one of which is electrically heated, the temperature being controlled thermostatically. The second or backing jaw is often covered with a resilient material such as rubber to distribute pressure evenly and aid in smoothing out the film in the sealing area. Conductance sealers are used for coated regenerated cellulose films or any other materials with a heat seal coating such as foil or paper. However, they are not suitable for unsupported

materials such as LDPE film which would simply melt and stick to the jaws. Serrated jaws can be used to ensure that the two webs are stretched into intimate contact with high local pressure; they also improve appearance. For all sealing jaws a non-stick coating is desirable; PTFE (poly(tetrafluoroethylene) commonly known by the tradename Teflon®) is widely used, either as a cloth-reinforced film or, in the case of serrated jaws, as a powder bound in a heat-resistant vehicle.

In the case of form-fill-seal wrapping machines such as horizontal flow packs and vertical flow packs, acceptable fusion forming a seal may be affected by multiple thicknesses of film at the end seals. In cylindrical and rectangular packs the sealing pressure is against the contents of the pack, and very often the pressure is against biscuits with uneven surfaces or biscuits that have not correctly filled the pack. Good sealing of folded film in these circumstances is often imperfect.

Developments in very high-speed wrapping, for example of small units in flow-packs, has meant that the dwell time in the jaws of the heat sealer has become so short that normal heat sealing is almost impossible. For these applications pressure sealable (also referred to as cold seal) films or laminates are used. The film is coated with a pressure sensitive adhesive and the jaws of the wrapping machine apply only pressure. Because no heating is involved, the speed of the wrapping machine is not critical.

20.2.1.7 *Pinholing*

Pinholing can happen in biscuit packs due to surface sugar crystals or other sharp edges on biscuits. It is particularly a problem if the packaging film is drawn tightly over the biscuits or the film is too thin. Gases and water vapour can pass through pinholes much more rapidly than they can permeate through plastic films so pinholing is obviously to be avoided otherwise shelf life will be compromised.

20.2.2 **Paper**

Paper is the general term for a wide range of matted or felted webs of vegetable fibres (mostly wood) used for the production of paper, paperboard, corrugated board and similar products. When its grammage exceeds 224 g m^{-2} paper is referred to as board. Since it is obtained from plant fibre it is therefore a renewable resource. The properties of an individual paper or paperboard are extremely dependent on the properties of the pulps used (e.g. whether from hardwood or softwood species). These pulps may be used unbleached or bleached to varying degrees by various techniques.

Almost all paper is converted by undergoing further treatment after manufacture such as embossing, coating, laminating and forming into special shapes and sizes such as bags and boxes. While paper that has been laminated or coated with plastic polymers can provide a good barrier to gases and water vapour, uncoated paper packaging provides little more than protection from light and minor mechanical damage. Multiply boards are produced by the consolidation of one or more web plies into a single sheet of paperboard which is then subsequently converted into rigid boxes, folding cartons and similar products.

Fat migrates from biscuits onto many papers and all uncoated boards, moving through the fibres and forming visible grease spots. The surface area so produced combined with traces of metals in the paper encourages rancidity and the formation of off-odours that contribute to product deterioration in the pack.

20.2.2.1 *Calendering*

In many applications, the surface of the paper sheet needs improvement so that any characters imposed on it are legible. This is achieved by calendering, a process which reorients the surface fibres in the base sheet of paper (or the coating applied to the surface) by the use of pressure. This serves to smooth the surface, control surface texture and develop a glossy finish. Such papers are known as 'machine finished'.

20.2.2.2 *Surface treatments*

Surface treatments such as sizing and coating are extensively applied to improve the appearance of products. Surface-sizing agents prevent excess water penetration and improve the strength of the paper. Additional effects include improvements in the scuffing resistance of the paper surface as well as bursting, tensile and folding strengths.

The most commonly used materials for surface sizing are starches; other film-forming materials include carboxymethyl cellulose and PVC which provide oil- and grease-repellent coatings and improve paper strength. Fluorochemical emulsion sizing agents can be applied to the surface of paper or paperboard to provide good oil and grease repellency; for example they find application for cookie bags.

20.2.2.3 *Greaseproof paper*

Greaseproof paper is a translucent, machine-finished paper which has been hydrated to give oil and grease resistance following prolonged beating or mechanical refining. The satisfactory performance of greaseproof papers depends on the extent to which the pores have been closed. Provided that there are few interconnecting pores between the fibres, the passage of liquids is difficult. However, they are not strictly 'greaseproof' since oils and fats will penetrate them after a sufficient interval of time. Despite this, they are often used for packaging biscuits since they resist the penetration of fats for a reasonable period. Most greaseproof papers are expensive, hard and brittle and difficult to print well. Corrugated paper for use in contact with biscuits is usually made from greaseproof paper glued to a cheap sulphite kraft paper.

20.2.2.4 *Glassine paper*

Glassine paper derives its name from its glassy, smooth surface, high density and transparency. It is produced by further treating greaseproof paper in a supercalender where it is carefully dampened with water and run through a battery of steam-heated rollers. This results in very few pores for scattering light or allowing liquid penetration. The transparency can vary widely depending on the degree of hydration of the pulp and the basis weight of the paper. The addition of titanium dioxide makes the paper opaque, and frequently it is plasticised to increase its toughness.

20.2.2.5 *Waxed papers*

Waxed papers provide a barrier against penetration of liquids and vapours. A great many base papers are suitable for waxing, including greaseproof and glassine papers. The major types are wet-waxed, dry-waxed and wax-laminated. Wet-waxed papers have a continuous surface film on one or both sides that imparts a high degree of gloss on the coated surface. Dry-waxed papers are produced using heated rolls and do not have a continuous film on the surfaces and consequently exposed fibres act

as wicks and transport moisture into the paper. Wax-laminated papers are bonded with a continuous film of wax which acts as an adhesive. The primary purpose of the wax is to provide a moisture barrier and a heat sealable laminant. Often special resins or plastic polymers are added to the wax to improve adhesion and prevent cracking as a result of folding and bending of the paper. However, replacement of wax coatings by thermoplastics is a continuing trend.

20.2.2.6 *Folding cartons*

Folding cartons are containers made from sheets of paperboard (typically with thicknesses between 0.30 mm and 1.10 mm) which have been cut and scored for bending into desired shapes. The boards used for cartons have a ply structure and many different structures are possible, ranging from recycled fibres from a variety of sources (as in chipboards), through fibres where the outer ply is replaced with better quality pulps to give white-lined chipboards, to duplex boards without any waste pulp and solid white boards made entirely from bleached chemical pulp. Coating of the outer board greatly enhances the external appearance and printing quality, and clay and other minerals are used for such purposes. Cartons of chipboard in contact with biscuits should be lined with glassine or made from coated board to prevent grease staining.

In most cases rigid plastic trays made from unplasticised PVC or PET (or recently starch-based biopolymers) have replaced cardboard cartons within packs to overcome the greaseproof and hygiene problems. These trays are thermoformed using vacuum and heat from reels or sheets of plastic of appropriate thickness.

Sometimes the basic film wrapped biscuit pack is placed within a paperboard carton. This may be for display, to form multipacks or to give added mechanical protection. Because it is not in contact with the biscuits, the carton can be made of non-greaseproof materials, including waste paper pulp which is cheaper than new wood pulp. Paperboard for cartons should be selected with due regard to thickness and hence mechanical strength, whiteness of the surface for printing and, of course, cost.

20.2.3 **Metals**

20.2.3.1 *Aluminium foil*

Aluminium is used to manufacture thin foils that range in thickness from 0.006 to 0.150 mm. Foils thinner than 0.025 mm contain minute pinholes that are permeable to gases and water vapour. Alloying agents including silicon, iron, copper, manganese, chromium, magnesium, zinc and titanium are added to impart strength and improve formability and corrosion resistance.

Aluminium foil offers particular advantages for packaging as it is a complete barrier to light, moisture, grease and gas provided there are no pinholes. It also has excellent dead fold properties, i.e., it takes on the shape of the object over which it is wrapped unlike plastics which have the tendency to spring back. The flexibility is not very good until it is very thin and then it does not have good tensile strength either. It is possible to roll aluminium to about 0.025 mm to avoid pinholes but at this thickness it is too expensive to package biscuits. Therefore thinner gauges are used and laminated to waxed paper, polyethylene or polypropylene to give excellent barrier properties. Films and paper can also be vacuum metallised using aluminium;

recently oxides of silicon (SiO_x) and oxides of aluminium (AlO_x) have been applied using physical vapour deposition techniques. Aluminium foil can be heat sealed if coated with polyethylene, polypropylene, PVdC copolymer or a lacquer.

20.2.3.2 *Tinplate*

The term tinplate refers to low carbon mild steel sheet varying in thickness from around 0.15 to 0.5 mm with a coating of tin between 2.8 and 17 gsm (g m^{-2}) (0.4–2.5 μm thick) applied electrolytically on each surface of the material. After plating, the coating is passivated by electrolytic treatment in sodium dichromate to render the surface more stable and resistant, and then lightly oiled. The combination of tin and steel produces a material which has good strength combined with excellent fabrication qualities as well as a corrosion-resistant surface of bright appearance due to the unique properties of tin.

In the early days of biscuit manufacturing tinplate canisters were the main form of packaging and there was much ingenuity in their design. Tinplate canisters offer exceptionally good protection against moisture, light and physical damage. Today, however, they are used only for high value products and sale as presentation gifts because they are expensive, take up a lot of space when empty and are not suitable for high speed filling operations. It is usual to line canisters with greaseproof paper or to place biscuits in paper within a canister. This is because a biscuit that rubs against the tinplate surface may develop blackened spots. After filling, lids are pressed on and normally secured with adhesive tape all round.

20.2.4 **Storage of packaging materials**

If reels of regenerated cellulose film are stored in an atmosphere of 35–50% RH at 15–20°C, the moisture content will not change unduly and the film properties will be maintained. Storage in damp conditions will result in moisture pick-up at the cut edges which may cause the film to curl and give machine-handling difficulties. Reels are supplied wrapped in low density polyethylene. These should be retained until the reel is used and any part-used reels should be rewrapped to keep them in good condition. Rather less care is needed for plastics which are normally delivered in rolls wrapped in shrink film.

Paper-based packaging needs very careful storage, the main problem being moisture pick-up. If paperboard becomes damp, it loses its strength and may become loosened from the adhesives inherent in the case design. Paper-based packaging should be stored off the floor on pallets in a warm, dry, well ventilated area with minimum RH.

20.3 **Packaging and shelf life**

20.3.1 **Definitions**

The quality of most foods decreases with storage or holding time and biscuits, cookies and crackers are no exception. Therefore it follows that there will be a finite length of time before the product becomes unacceptable. This time from production to unacceptability is referred to as shelf life. In other words, shelf life is the time during which all of the primary characteristics of the food remain acceptable for

consumption. Thus the shelf life refers to the time for which a food can remain on both the retailer's and consumer's shelf before it becomes unacceptable.

Manufacturers generally attempt to provide the longest practicable shelf life consistent with costs and the pattern of handling and use by distributors, retailers and consumers. Supermarkets will generally not accept product into their distribution centres unless at least 75% of the shelf life remains. Inadequate shelf life will often lead to consumer dissatisfaction and complaints and will eventually affect the acceptance and sales of brand name products.

The shelf life of a food is controlled by product characteristics including formulation and processing parameters (intrinsic factors); the environment to which the product is exposed during distribution and storage (extrinsic factors); and the properties of the package. Intrinsic factors include pH, water activity (a_w), enzymes, microorganisms and the concentration of reactive compounds. Many of these factors can be controlled by selection of raw materials and ingredients, as well as the choice of processing parameters. Examples of extrinsic factors include temperature, RH, light, total pressure and partial pressure of different gases, and mechanical stresses including transportation and consumer handling. Many of these factors can affect the rates of deteriorative reactions which occur during the shelf life of a product. The properties of the package can have a significant effect on many of the extrinsic factors and thus indirectly on the rates of the deteriorative reactions.

Thus in theory, the shelf life of a food can be altered by changing its composition and formulation, the processing parameters, the packaging or the environment to which it is exposed. In practice there are very real limits to the extent to which a manufacturer can change the composition, formulation and processing parameters of a particular biscuit, and changing the distribution and storage environment is limited to chilled distribution and the use of air-conditioned warehouses, neither of which are viable options in many markets. In practice, therefore, the major factor influencing shelf life is the choice of packaging material and its format.

20.3.2 Package barrier properties

The transmission rate (TR) of a packaging material can be defined as:

$$TR = \frac{Q}{At} \quad 20.1$$

where Q is the amount of permeant passing through the polymer, A is the area and t is the time. The barrier properties of polymers to water, gases and organic compounds are often presented in this way, and in the case of water and oxygen, the terms WVTR (water vapour transmission rate) and GTR (gas transmission rate) or more specifically OTR (oxygen transmission rate) are in common usage. It is critical that the thickness of the film or laminate, the temperature and the partial pressure difference of the gas or water vapour is specified for a particular TR. Typical values of OTR and WVTR for a range of plastic polymers used to package biscuits are given in Table 20.1.

The data sheets from most suppliers of plastic films give the WVTRs determined at 38°C/90% RH. While this is relevant for products sold in tropical conditions, it is not particularly helpful for products sold in temperate conditions where 25°C/75% RH is more appropriate. The water vapour pressure at 38°C/90% RH (4.47 cm Hg) is 2.5 times that at 25°C/75% RH (1.78 cm Hg) and therefore shelf life calculations

Table 20.1 Oxygen transmission rate (OTR) and water vapour transmission rate (WVTR) for some plastic polymers used to package biscuits. From Mathlouthi, M. (2003) 'Packaging/packaging of solids', in B. Caballero, L.C. Trugo and P.M. Finglas, (eds) *Encyclopedia of food sciences and nutrition*, 2nd edition, Volume 7. Academic Press, London, p. 4314, with permission [8]

Polymer (0.025 mm thick)	OTR	WVTR	
	(23°C/0% RH) (mL m ⁻² day ⁻¹)	(38°C/90% RH) (g m ⁻² day ⁻¹)	(25°C/75% RH) (g m ⁻² day ⁻¹)
Low density polyethylene	7400	12.50	4.00
High density polyethylene	1600	3.70	1.45
Polypropylene (cast)	3040	8.20	3.30
Polypropylene (oriented)	1550	5.00	1.35
Polypropylene (acrylic-coated)	1200	4.60	1.80
Polypropylene (oriented and metallised)	35	1.00	
Poly(vinyl chloride) (rigid)	120	32.00	12.00
Poly(vinyl chloride) (oriented)	27	17.50	7.00
Poly(vinyl chloride) (plasticised)	190–3100	85.00	32.70
PVdC/PVC copolymer	1.25–14.5	0.6–3.20	0.25
Poly(ethylene terephthalate)	55	20.00	7.00
Poly(ethylene terephthalate) (PVdC/PVC copolymer-coated)	8.00	8.50	3.40
Poly(ethylene terephthalate) (metallised)	0.65	1.00	0.40
Polyamide (nylon) 6	40	280	80–110
Polyamide (nylon) 6 (oriented)	18	130	28
Polyamide (nylon) 6,6	35	90	15–30
Cellulose film MXXT/A (PVdC/PVC copolymer coated)	8.75	8.60	3.40

based on a WVTR determined at the higher temperature and humidity will underestimate actual shelf life under temperate conditions by approximately 2.5 times.

In order to do shelf life calculations, it is necessary to convert WVTR or OTR to the permeability coefficient P for which the standard units are mL cm cm⁻² sec⁻¹ (cm Hg)⁻¹. The conversion can be made by multiplying the TR by the thickness of the film and dividing by the partial pressure difference used to make the measurement as illustrated in the example below.

Example 20.1: Calculate the permeability coefficient of a biaxially-oriented polypropylene (BOPP) film to O₂ at 23°C given that the OTR through a 2.5×10^{-2} mm thick film with air on one side and inert gas on the other is (from Table 20.1) 1550 mL m⁻² day⁻¹?

O₂ partial pressure difference across the film is 0.21 atm = 16 cm Hg

$$\begin{aligned}
 P &= \frac{\text{OTR}}{\Delta p} \times \text{thickness} \\
 &= \frac{1550 \text{ mL m}^{-2} \text{ day}^{-1}}{16 \text{ (cm Hg)}} \times 2.5 \times 10^{-2} \text{ mm}
 \end{aligned}$$

The above units must be converted into the appropriate ones for P as follows:

$$\begin{aligned}
 P &= \frac{1550 \text{ mL} \times 2.5 \times 10^{-2} \text{ mm}}{\text{m}^2 \text{ day} \times 16 \text{ (cm Hg)}} \times \frac{\text{day}}{(24)(3600) \text{ s}} \times \frac{\text{m}^2}{(100 \text{ cm})^2} \times \frac{\text{cm}}{10 \text{ mm}} \\
 &= 2.8 \times 10^{-10} [\text{mL cm cm}^{-2} \text{ s}^{-1} (\text{cm Hg})^{-1}] \\
 &= 2.8 \times 10^{-11} [\text{mL cm cm}^{-2} \text{ s}^{-1} (\text{cm Hg})^{-1}]
 \end{aligned}$$

Therefore:

$$P \times 10^{11} = 28 [\text{mL cm cm}^{-2} \text{ s}^{-1} (\text{cm Hg})^{-1}]$$

20.3.3 Surface area:volume ratio

The main function of a pack is to contain and protect the correct weight or number of biscuits for sale. The biscuits may be packed individually, in a single column, in a series of short columns side by side, in a rectangular pack if the biscuits are rectangular in shape, in a jumble or in some other less common arrangement. The shape of the pack has a bearing on the way in which it can be displayed on the retailer's shelf. Round column packs tend to roll off, packs with fin end seals tend to interlock with adjacent packs, simple bags cannot be stacked well for display and block-bottom bags allow only one layer of packs to be put on the shelf.

The format or dimensions of the pack for a given weight of product can have a large influence on shelf life [9]. While a spherical shape will minimise the surface area of the pack (and thus the quantity of moisture or O_2 that will permeate through the package wall), it is not a practical shape for commercial use and in practice most packs tend to be rectangular or cylindrical. Given the rigid nature of biscuits, there is less opportunity to manipulate pack dimensions to minimise the surface area than is the case for food powders and liquids. Table 20.2 gives the surface areas for a range of different shapes which all have the same volume (approximately 500 mL). Compared to the surface area of a sphere, the surface area of a cube is 24% greater; a cylinder and a rectangular shape 44% greater and a thin rectangular shape 111% greater.

Extremely thin packages have a much greater surface area:volume ratio and thus require a plastic with better barrier properties to get the same shelf life than if the same quantity of product were packaged in a thicker format. For different quantities of the same product packaged in different sized packages using the same plastic film, the smallest package will have the shortest shelf life as it inevitably has a greater surface area per unit volume. Many food companies still seem unaware of this fact as they continue to launch smaller sized packs without changing the packaging material and then wonder why the shelf life is shorter for the smaller sized packs.

Table 20.2 Surface areas of different package shapes all having a volume of 500 mL

Shape	Dimensions (cm)	Surface area		Increase (%)	Surface area: volume ratio
		(cm ²)	(m ²)		
Sphere	Diameter 9.85	304	0.0304	0	0.61
Cube	Sides 7.94	378	0.0378	24	0.76
Cylinder	Diameter 5.0	440	0.0440	44	0.88
	Length 25.5				
Rectangular pack	Height 4.5	438	0.0438	44	0.88
	Length 16.5				
	Width 7.3				
Thin rectangular pack	Height 2.0	630	0.0630	111	1.26
	Length 20.0				
	Width 12.5				

Example 20.2: A biscuit having a density of 1 is to be packaged in an oriented polypropylene film (OPP) which (from Table 20.1) has a WVTR of $1.35 \text{ g m}^{-2} \text{ day}^{-1}$ at 25°C and 75% RH. The initial moisture content of the biscuit is 2% and the critical moisture content is 6%. Assuming that each pack will contain 250 g of biscuits and will be exposed to an external environment at 25°C and 75% RH, calculate the shelf life if the shapes of the packs are the same as those listed in Table 20.2. For simplicity, assume that the driving force for WVT remains constant and that there are no moisture gradients in the biscuit.

$$\begin{aligned}
 \text{Weight of dry solids} &= 98\% \text{ of } 250 = 245.0 \text{ g} \\
 \text{Initial weight of water in biscuits} &= 2\% \text{ of } 250 = 5.0 \text{ g} \\
 \text{Final weight of water in biscuits} &= 245.0/0.94 - 245.0 \\
 &= 260.6 - 245.0 \\
 &= 15.6 \text{ g}
 \end{aligned}$$

Therefore weight of water permeating into biscuits is:

$$15.6 - 5.0 = 10.6 \text{ g}$$

For a spherical-shaped package:

Quantity of water permeating into package per day is:

$$0.0304 \times 1.35 = 0.0410 \text{ g day}^{-1}$$

$$\begin{aligned}
 \text{Therefore shelf life } \theta_s &= \frac{10.6}{0.0410} \\
 &= 258 \text{ days}
 \end{aligned}$$

For the other package shapes:

$$\begin{aligned}
 \text{Cube:} & \quad \theta_s = 208 \text{ days} \\
 \text{Cylinder:} & \quad \theta_s = 178 \text{ days} \\
 \text{Rectangle:} & \quad \theta_s = 179 \text{ days} \\
 \text{Thin Rectangle:} & \quad \theta_s = 125 \text{ days}
 \end{aligned}$$

Thus the shelf life for the same quantity of biscuits packaged in the same film varies by a factor of 2.1 from 125 to 258 days depending on the shape of the package.

20.4 Indices of failure (IoFs)

In designing suitable packaging for foods, it is important to first define the indices of failure (IoFs) of the food, that is, the quality attributes that will indicate that the food is no longer acceptable to the consumer [10]. For biscuits, cookies and crackers, the IoF could be development of stale or rancid flavours due to oxidation, or the loss of crispness due to moisture ingress into the package.

Once the IoFs for a particular food have been defined, the next step is to attempt to quantify the magnitude of the particular degradation, for example, how much O₂ or moisture can react with the food before it becomes unacceptable. The final step is to ascertain which (if any) of the IoFs might be influenced by the packaging material, as packaging cannot prevent all undesirable changes in foods. If, for example, an IoF of a biscuit is loss of crispness, then the packaging material could influence this by the extent to which it permitted the ingress of moisture. Different plastic films, for example, have different water vapour transmission rates (WVTRs), and thus the shelf life obtained for a particular package format varies depending on the polymer selected. Similar considerations apply to biscuits for which an IoF is oxidation, as different packaging materials have different O₂ transmission rates (OTRs). If an IoF was fading of the colour of the icing on a biscuit, then the packaging could also influence this depending on how transparent it was, which would be affected by the level of pigmentation of the film and the amount and nature of any printing. However, if an IoF of a biscuit was non-enzymic browning, then it is unlikely that different packaging materials would influence the extent of this reaction. In most cases there will be several IoFs of a particular biscuit.

20.5 Package requirements to address indices of failure (IoFs)

20.5.1 Moisture exchange and shelf life

When a food is placed in an environment at a constant temperature and RH, it will eventually come to equilibrium with that environment. The corresponding moisture content at steady state is referred to as the equilibrium moisture content (EMC). A plot of the moisture content (expressed as mass of water per unit mass of dry matter) against the corresponding a_w at constant temperature and pressure gives a moisture sorption isotherm (MSI) which is very useful in assessing the stability of foods and selecting effective packaging.

Given the large volume of biscuits, cookies and crackers manufactured each year, there are surprisingly few published MSIs. Palou *et al.* [11] reported the MSIs for three cookies and two corn snacks at 25, 35 and 45°C; McMinn *et al.* [12] reported the MSIs for oatmeal biscuits at 5, 20, 40 and 60°C; Cervenka *et al.* [13] reported the MSIs for gingerbread over the temperature range 20–30°C.

Figure 20.1 presents the MSIs at 20°C for crackers and cookies. At any particular a_w , the cracker had a higher EMC sorbed water than the cookie, which was not surprising as the latter contained ten times the quantity of fat than was in the cracker [14].

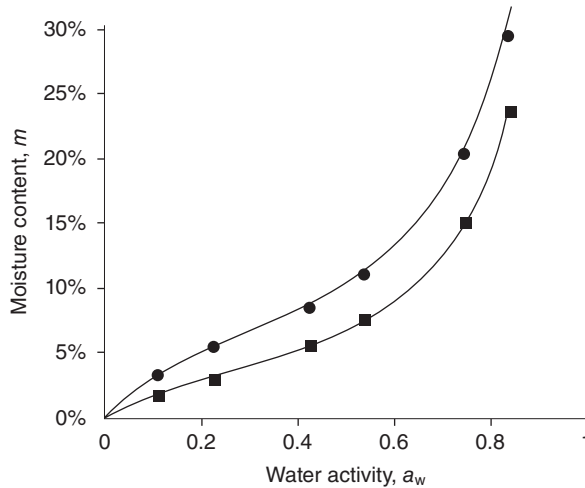


Fig. 20.1 Moisture sorption isotherm at 20°C for a cracker, ● and cookie ■. Redrawn from Kim, S. S., Kim, S. Y., Kim, D. W., Shin, S. G. and Chang, K. S. (1999) 'Moisture sorption characteristics of composite foods filled with chocolate', *Journal of Food Science*, 64, 300–302, with permission.

Although it is possible to produce cream fillings that contain no moisture, some products such as Amaretti cookies are multi-domain systems characterised by a soft internal almond paste ($a_w \approx 0.74$; moisture content ≈ 13 –14%) and a crunchy external crust ($a_w \approx 0.40$; moisture content ≈ 5 –6%). This leads to a severe hardening of the internal almond paste and a softening of the crust due to the redistribution of water, severely limiting the shelf life to only a few days [15].

As a_w is temperature dependent, it follows that moisture sorption isotherms must also exhibit temperature dependence. Thus, at constant moisture content (which is the situation existing in a biscuit packaged in an impermeable package), a_w increases with increasing temperature. As the rates of deteriorative reactions depend on both a_w and temperature, the increase in rate in such situations will typically be greater than that due solely to an increase in temperature. This has important implications for shelf life.

The expression for the steady state permeation of a gas or vapour through a thermoplastic material can be written as [2]:

$$\frac{\delta w}{\delta t} = \frac{P}{X} \cdot A \cdot (p_1 - p_2) \quad 20.2$$

where $\delta w/\delta t$ is the rate of gas or vapour transport across the film; P is the permeability coefficient of the plastic polymer; X is the thickness; A is the package surface area; p_1 the water vapour partial pressures outside of the package and p_2 the vapour pressure of the water in the food ($p_1 > p_2$). The prediction of moisture transfer into a packaged biscuit requires analysis of the above equation given certain boundary conditions. If it is assumed that P/X is constant, that the external environment is at constant temperature and humidity, and that p_2 follows some simple function of the moisture content, then a straightforward analysis can be made.

However, because external conditions will not remain constant during storage, distribution and retailing of a packaged food, P/X will not be constant. If the food is being sold in markets in temperate climates, then it is appropriate to use WVTRs determined at 25°C/75% RH or 23°C/50% RH. In tropical countries analysis should be made using WVTRs determined at 38°C/90% RH. A further assumption is that the moisture gradient inside the package is negligible, i.e. the package should be the major resistance to water vapour transport which is the case for most commercial films under high humidity conditions.

The internal vapour pressure is not constant but varies with the moisture content of the biscuit at any time. Consequently the rate of gain of moisture is not constant but falls as Δp gets smaller. Thus to be able to make accurate predictions, some function of p_2 , the internal vapour pressure, as a function of the moisture content, must be inserted into the equation. Assuming a constant rate results in the product being overprotected.

In low and intermediate moisture foods such as biscuits, the internal vapour pressure is determined solely by the moisture sorption isotherm. In the simplest case the isotherm can be treated as a linear function as shown in Figure 20.2:

$$m = b \cdot a_w + c \quad 20.3$$

where m is the moisture content in g H₂O per g solids; a_w is the water activity; b is the slope of linearised isotherm; and c is a constant.

The moisture content can be substituted for water gain and after some mathematical manipulation the following expression is obtained [2]:

$$\ln \frac{m_e - m_i}{m_e - m} = \frac{P}{X} \cdot \frac{A}{W_s} \cdot \frac{p_o}{b} \cdot t \quad 20.4$$

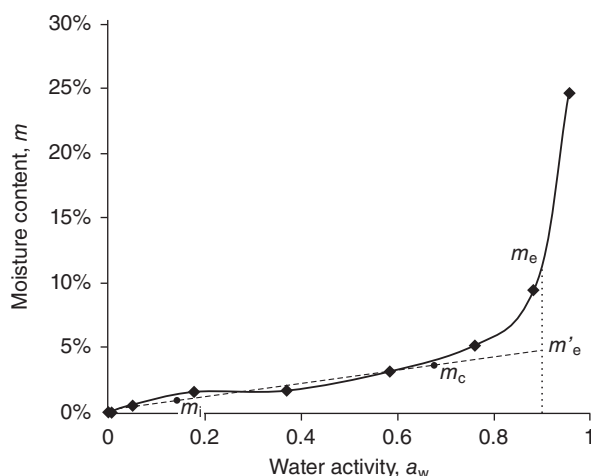


Fig. 20.2 Moisture sorption isotherm at 40°C for oatmeal biscuits with a superimposed straight line of slope b . Initial (m_i), critical (m_c) and equilibrium (m_e) moisture contents are indicated together with the pseudo-equilibrium (m'_e) moisture content used for package shelf life calculations. Plotted using data from McMinn, W. A. M., McKee, D. J., Magee, T. R. A. (2007) 'Moisture adsorption behaviour of oatmeal biscuit and oat flakes', *Journal of Food Engineering*, 79, 481–493.

where m_e is the equilibrium moisture content of the biscuit if exposed to the external package RH; m_i is the initial moisture content of the biscuit; m is the moisture content of the biscuit at time t ; p_o is the vapour pressure of pure water at the storage temperature (NOT the actual vapour pressure outside the package); P/X is the permeance of the film; and W_s is the weight of dry solids in the package.

The end of product shelf life is reached when $m = m_c$, the critical moisture content, at which time $t = \theta_s$, the shelf life. Although this equation has been extensively tested for foods and found to give reasonable predictions of actual weight gain [16], linearising the isotherm results in the use of an equilibrium moisture content m'_e that is less than what would be experienced in practice. Therefore the calculated shelf life will be longer than what would actually be achieved in practice. Despite this limitation, equations such as Eq. 20.4 can be used to calculate the effect on shelf life of different packaging films, different external conditions such as temperature and humidity, changes in the surface area:volume ratio of the package, and variations in the initial and critical moisture contents of the product. The following example will illustrate how the shelf life of biscuits varies depending on the barrier properties of the film.

Example 20.3: McMinn *et al.* [12] reported the moisture sorption data for convective-baked oatmeal biscuits and the resulting moisture sorption isotherm at 40°C is shown in Fig. 20.2. For the purposes of this example it is assumed that the biscuits had an initial moisture content m_i of 1.0% (0.010 g H₂O per g of dry solids) and a critical moisture content m_c of 3.6% due to loss of crispness. The equilibrium moisture content m_e at 40°C corresponding to 90% RH is 11.5% and the pseudo-equilibrium moisture content m'_e obtained by linearising the lower portion of the isotherm is 5.0%; the slope of the straight line (b) is 0.055 g H₂O/g solids/unit a_w .

Calculate the shelf life of the biscuits if they are packed in either a 26 µm (micron) two side acrylic coated OPP film or a 50 µm one side acrylic coated, one side PVdC copolymer coated white opaque OPP. The weight of biscuits in the rectangular package is 250 g and the dimensions of the package are 8 × 16 × 4 cm. The packed product is to be distributed under tropical conditions (38°C and 90% RH).

$$\text{Surface area of the rectangular packs} = 448 \text{ cm}^2 = 0.0448 \text{ m}^2$$

$$\text{Weight of dry solids in the package} = 250 \times 99\% = 247.5 \text{ g}$$

$$\text{Vapour pressure of pure water at } 38^\circ\text{C} = 4.969 \text{ cm Hg}$$

Using data from a plastic film supplier, the WVTR of the two films at 38°C/90% RH are:

$$26 \text{ } \mu\text{m OPP} = 5.0 \text{ g m}^{-2} \text{ day}^{-1}$$

$$50 \text{ } \mu\text{m OPP} = 3.4 \text{ g m}^{-2} \text{ day}^{-1}$$

The above WVTRs must be converted into water vapour permeances P/X by dividing by the driving force for water vapour transfer:

$$\text{Driving force at } 38^\circ\text{C}/90\% \text{ RH} = 4.969 \times 0.90 = 4.472 \text{ cm Hg}$$

For 26 µm OPP film:

$$\begin{aligned}
 P/X &= \frac{5.0 \text{ g}}{\text{m}^2 \text{ day}} \times \frac{1}{4.472 (\text{cm Hg})} \\
 &= 1.118 \text{ g m}^{-2} \text{ day}^{-1} (\text{cm Hg})^{-1}
 \end{aligned}$$

For 50 μm OPP film:

$$P/X = 0.760 \text{ g m}^{-2} \text{ day}^{-1} (\text{cm Hg})^{-1}$$

Substituting into Eq. 20.4 for biscuits packed in 26 μm OPP film:

$$\ln \frac{0.05 - 0.010}{0.05 - 0.036} = 1.118 \cdot \frac{0.0448}{247.5} \cdot \frac{4.969}{0.055} \cdot \theta_s \quad 20.5$$

Solving for shelf life θ_s :

$$\begin{aligned}
 \theta_s &= \ln [2.857] / 0.01828 \\
 &= 1.0498 / 0.01828 \\
 &= 57 \text{ days}
 \end{aligned}$$

If the biscuits were packed in the 50 μm OPP film instead:

$$\theta_s = 84 \text{ days}$$

If a longer shelf life were required (say 200 days) then Eq. 20.4 could be recalculated for another film with a lower permeance. As noted earlier, the shelf life calculated above will be longer than what would actually be achieved in practice because the pseudo-equilibrium moisture content used in the calculations is significantly less than the real equilibrium moisture content which is the driving force for water vapour transport. Because of the simplifying assumptions made in the above calculations, the calculated shelf lives should be verified by actual shelf life testing.

It is important to note that it is not just the barrier properties of the film that are important: the integrity of the package seal can also have an important influence on shelf life. Alves *et al.* [17] investigated the influence of three types of equipment (roll pack wrapping; horizontal flow pack and vertical flow pack) on the water vapour transmission (WVT) into biscuit packages. The packages sealed with roll pack and horizontal flow pack machines exhibited impaired seal integrity, particularly at the transversal seal, the WVT of the packages being from 1.1 to 3.0 times higher than the corresponding theoretical WVT values based on WVTR measurements. Vertical flow pack machines produced packages with seals of good integrity.

20.5.2 Oxygen exchange and shelf life

It is also possible to calculate the shelf life of a biscuit where the major mode of deterioration is oxidation as demonstrated in the following example.

Example 20.4: Biscuits containing 25% fat become unacceptable to 50% of consumers due to rancidity when the peroxide value (PV) reaches 15.6 milliequivalents (meq) of oxygen per kilogram [18]. Assume that the surface area of the package is 440 cm^2 (0.044 m^2) and each pack contains 250 g of biscuits.

Calculate the shelf life of the biscuits if they were packaged in (a) a laminate film consisting of two 25 μm layers of coextruded OPP with an overall OTR of $650 \text{ mL m}^{-2} \text{ day}^{-1}$, and (b) a laminate film consisting of 15 μm biaxially-oriented nylon 6 (BON6) and 80 μm LDPE with an overall OTR of $2 \text{ mL m}^{-2} \text{ day}^{-1}$, both OTR measurements being performed at 23°C and 0% RH. Assume that there is zero oxygen inside the packs immediately after sealing and that all the oxygen that enters the packs reacts with the fat in the biscuits.

Fat content of biscuits is 25%. Therefore weight of fat in each pack is:

$$25\% \times 250 \text{ g} = 62.5 \text{ g}$$

Maximum level of peroxide value (PV) for rejection by 50% of consumers is 15.6 meq O_2 per kg biscuits. Therefore maximum quantity of O_2 that can enter each pack is:

$$(15.6 \times 62.5)/1000 = 0.975 \text{ meq } \text{O}_2$$

The value expressed in millimoles of oxygen per kilogram is half that expressed in milliequivalents of oxygen per kilogram. Thus since $1 \text{ meq } \text{O}_2 = 0.5 \text{ millimoles}$, then:

$$0.975 \text{ meq } \text{O}_2 = 0.4875 \text{ millimoles} = 4.875 \times 10^{-4} \text{ mol}$$

The Ideal Gas Law can be used to convert this quantity of O_2 to mL at 23°C :

$$\begin{aligned} V &= nRT/P = (4.875 \times 10^{-4}) \times 82.06 \times 296/1 \\ &= 11.8 \text{ mL} \end{aligned}$$

where $R = 82.06 \text{ mL atm mol}^{-1} \text{ K}^{-1}$ and $P = \text{atmospheric pressure} = 1 \text{ atm}$

The OTR of laminate film (a) = $650 \text{ mL m}^{-2} \text{ day}^{-1}$ which for a pack of surface area 0.044 m^2 means that $650 \times 0.044 = 28.6 \text{ mL}$ will permeate through per day.

Therefore the predicted shelf life for the biscuits packed in laminate film (a) with an OTR of $650 \text{ mL m}^{-2} \text{ day}^{-1}$ is $11.8/28.6 = 0.412 \text{ days} = 9.9 \text{ hours}$ at 23°C .

The predicted shelf life for the biscuits packed in laminate film (b) with an OTR of $2 \text{ mL m}^{-2} \text{ day}^{-1}$ is $11.8/(0.044 \times 2) = 134 \text{ days}$ at 23°C .

Because various simplifying assumptions were made in the above calculations, the calculated shelf lives would need to be verified by actual shelf life testing.

For biscuits where the major mode of deterioration is oxidation, an alternative or supplementary approach to extend the shelf life is the use of oxygen absorbers (OAs) or scavengers. Berenzon and Saguy [19] reported on the use of commercial iron oxide-based OAs in sachet form for extending the shelf life of military ration crackers packed in hermetically sealed tin cans stored for up to 52 weeks. The metal can contained 1.5 kg crackers and the void volume was 2.5 L; oxygen depletion and lipid oxidation started immediately after baking and, unsurprisingly, proceeded at a faster rate at higher temperatures.

OAs were effective in prolonging the lag time before the PV started to build up. Once the propagation stage is reached, however, OAs are no longer effective in reducing the oxidation process. It was suggested that rapid oxidation was probably a result of using oils that do not withstand the high temperatures of baking, ineffective antioxidants capable of carrying through, presence of metals and headspace

oxygen. Under these conditions, OAs were effective in lowering oxidation rates due to a lower oxygen concentration, and thus extending shelf life for all storage periods and temperatures below 35°C.

Sensory evaluations showed that in the presence of OAs and independently of storage temperature, no stale odours were observed for up to 44 weeks. Only crackers stored without OAs developed stale odours even after 24 weeks at 25°C. This beneficial effect of OAs in reducing the stale odour was significant ($P < 0.05$).

Sensory evaluations suggested that crackers stored without oxygen absorbers developed oxidative rancid odours after 24 weeks at 25 and 35°C. Independently of storage temperatures, no oxidative rancid odours were observed after 44 weeks with oxygen absorbers.

The authors concluded that OAs required additional means to prevent oxidation and extend shelf life of crackers stored at temperatures of 25°C or above. The utilisation of OAs cannot replace certain conditions for slowing lipid oxidation rates such as: lowering the storage temperature, using high quality oil, adding an effective antioxidant and ensuring that the ingredients are free from oxidation promoters such as Fe^{2+} .

20.5.3 Light transmission and shelf life

Some of the deteriorative changes in the quality of foods are initiated or accelerated by light. The catalytic effects of light are most pronounced in the lower wavelengths of the visible spectrum and in the ultraviolet spectrum. The intensity of light and the length of exposure are significant factors in the production of discolouration and flavour defects in packaged foods. The absorbance varies not only with the nature of the packaging material but also with the wavelength and therefore the amount of light transmitted through a given package will be dependent on the incident light and the properties of the packaging material. The catalytic effect of light on the free radical reactions involved in fat oxidation is well established. Suitable packaging can offer direct protection by absorption or reflection of all or part of the incident light, depending on the light transmission characteristics of the packaging materials. Light-induced degradation of lipids in biscuits causes both formation of off-flavours and colour changes, which rapidly impair product quality and marketability.

Different packaging material categories offer varying degrees of protection against light-induced changes due to differences in reflectance, transmittance (both total and specific wavelengths), and oxygen permeability determined by the molecular composition of the material. Generally, metals offer the best protection, followed by paper/paperboard, the various plastics, and finally glass through which up to approximately 90% of the light is transmitted.

Lu and Xu [20] reported on the effect of light-barrier properties of packaging films on the photo-oxidation and shelf life of commercial cookies containing 23.5% fat. Cookies were packed in three different films: 125 μm transparent biaxially-oriented nylon/polyethylene (BON/PE), 170 μm semi-transparent polyethylene terephthalate-oriented nylon/polyethylene (PET/BON/PE) and 45 μm opaque biaxially/oriented polypropylene/metallised cast polypropylene (BOPP/metCPP). They were stored at 40°C under UV light with an intensity of 1.9 $\mu\text{W cm}^{-2}$ (the same intensity as from fluorescent lights in retail stores). The shelf life (determined as the time to reach a critical peroxide value of 19.7 meq kg^{-1}) was 37 days for BON/PE, 52 days for PET/BON/PE and 76 days for BOPP/metCPP. However, there were

large differences in the OTRs of the three films (the OTR of the best was 25 times that of the poorest) which would have had a significant influence on shelf life, in addition to the effect of the different light transmission properties of the three films which varied by a factor of 12.

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21

Classification of biscuits

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Abstract: It helps to understand ways in which biscuits can be grouped. The method of dough piece forming is limited by the enrichment of the formulation with fat and sugar. Secondary processing adds greatly to the enjoyment of biscuits.

Key words: hard dough biscuits, short dough biscuits, secondary processing, recipe construction.

21.1 Introduction

Scientists and technologists love classifications but unfortunately they find that natural products, or articles based on natural products, tend to form groups that overlap, thus confounding neat definitions. Biscuits are no exception! The problem even arises in attempts to define 'biscuits'. It is generally recognised that these products are cereal based and baked to a moisture content of less than 5%. The cereal component is variously enriched with two major ingredients, fat and sugar, but thereafter the composition is almost endless. Some problems come in defining the boundaries between biscuits and cakes, and biscuits and sugar confectionery. One may reasonably consider that the boundaries are not important and well they might be until authorities decide that different packaging declarations and weights and different taxation conditions apply to one and not the adjacent group.

The name 'cookie' can be regarded as synonymous with biscuit but the former is more comprehensive in meaning in the USA and the latter in the UK. Groupings have been made in various ways based on

- the name, e.g., biscuits, crackers and cookies, which are based on the texture and hardness
- the method of forming of the dough and dough piece, e.g., fermented, developed, laminated, cut (simple or embossing), moulded, extruded, deposited, wire cut, coextruded, etc.
- the enrichment of the recipe with fat and sugar.

A secondary classification may be used to describe the secondary processing that the baked biscuit has undergone. Examples are

- cream sandwiched
- chocolate coated

- moulded in chocolate
- iced (half coated with an icing that has been dried)
- added jam or mallow (or both).

The result is that the same English adjectives have come to be used in different contexts for different biscuits. Rather than try to untangle or describe these groupings, it is felt best to emphasise that there is overlap and to show, with the aid of figures, how various common types of biscuits fall relative to one another based on enrichment and the amount of water thereby needed to form a dough.

In the following chapters descriptions will be given of the typical characteristics and means of processing for the major groups. Then in Part IV of this book comprehensive accounts are given of the machinery used and how it is controlled.

21.2 Classification based on enrichment of the formulation

As technologists it is useful to be able to categorise biscuits from their external and internal appearance as this helps in deciding the likely recipe and means for forming and baking. In order to do this one must first look critically at the surfaces, particularly the edges and the base, to identify whether, for example, the dough piece was cut, moulded or extruded. The method of forming is limited by the enrichment of the formulation. The pattern on the base is formed during baking. Doughs rich in fat and sugar bear much stronger impressions from a baking wire than less enriched doughs where the gluten has been developed during mixing. Internal investigations will reveal a laminar structure in many biscuits with a developed gluten and a more crumbly and more irregularly open structure in doughs with higher fat and sugar.

Figure 21.1 shows the recipe areas of the major types of biscuits. Figure 21.2 shows the relationship of fat enrichment to water required to give a dough with handleable consistency. The latter term begs a question, of course, as different means of formation require slightly tighter or softer consistencies. It is necessary to define how the figures were constructed and upon what basis calculations have been made.

In all cases, recipes are of biscuits which have been commercially produced within the last 40 years. The recipes are of doughs mixed before various late additions like puff fat, cracker filling dust or garnishing sugars have been added. They are not therefore a representation of baked biscuits but of basic mixed doughs.

Each recipe has been adjusted to be relative to 100 units of flour (including other cereal products such as cornstarch, vital wheat gluten, malt flour, oatmeal, etc.). The sugar level is on a dry basis and it is assumed that liquid sugar has 67% solids, malt extract syrups and glucose syrups 80% solids and invert syrups 70% solids. The fat values are based on pure fat, so margarines and butters are only 85% fat. The fat values of fresh and dried full cream milks have been ignored because they are usually of insignificant amounts. However, the fat content of fresh cheese, although not a common ingredient, has been added to the total fat and a value of 33% fat has been used.

The water level is the total added water. This is principally as liquid water but may be as fresh milk 87.6% water, butter and margarine 15% water, fresh eggs 75%, syrups 20%, liquid sugar 33%, etc. Cereals and some other ingredients have a natural moisture content so the water values do not represent the total dough moisture level even though this is important for calculating the losses during baking.

In other biscuit texts, reference is often made to the 'percentage' of fat or sugar in a dough. Sometimes this means the amount related to 100 units of flour, as has been used here, but more correctly it should be related to the total dough weight (plus or minus added water). There are reasons for liking either system but it is felt best to use units related to 100 units of flour (cereal content) without the use of the word 'percentage', and this is used throughout this book. Basing formulations on 100 units of flour means that changes can be made to individual ingredients, such as sugar or an aerating chemical without having to recalculate all the others to get true percentage values.

The weight values used are all relative and are not confused by difficult traditional units like sacks of flour, barrels of fat, parts per million or ounces, pounds, gallons, pints or fluid ounces. There is a growing acceptance of the metric system for weighing and it is therefore easy to convert the values shown into kilograms or grams. As fats are frequently metered by volume, it is perhaps useful to remember that their specific gravities are all round 0.9. At the end of this chapter a conversion chart is given to relate ounces to decimal fractions of pounds and also to convert pounds into kilograms.

It is not surprising to see, in Fig. 21.1, that as the fat level increases, the sugar level tends to rise too. There is a fanning out so that there is less relationship at higher levels of both. In any search for a completely new type of biscuit it is best to stay within the broad limits that have been tried because there is probably a good reason for the blank areas on the chart or to the rough boundaries shown for any

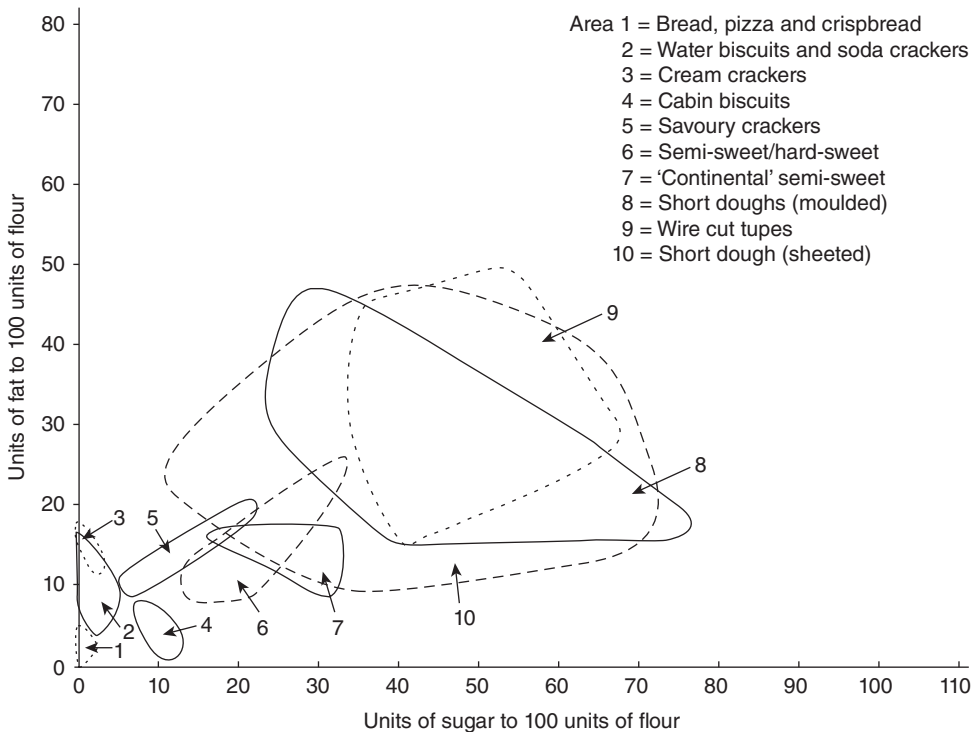


Fig. 21.1 Relationship of sugar and fat enrichment in biscuit recipes.

particular type. One of the reasons may be the concept of a balanced recipe. It is found, for example, that a certain level of fat demands a minimum level of sugar to produce an acceptable texture. There are other criteria that need to be matched, or balanced to satisfy flavour requirements (see Chapters 17 and 18). New products can easily be conceived by concentrating on the other more interesting, but minor, ingredients like nuts, fruits or flavours. It may be that including larger quantities of these 'extras', combined with the consistencies needed for particular methods of dough piece forming, give rise to the apparently poor relationship of water to the fat level as shown in Fig. 21.2.

Dough consistency (and hence dough water requirement) is also related to the type of flour or other cereal flours used, the level of alkaline leavening agents, and of course dough temperature. As has been shown, increases in the level of fat are usually accompanied by higher levels of sugar. If the sugar is added as a crystalline solid and it dissolves as the dough is mixed, that which dissolves acts as a liquid to 60% of the solid as an effect on the dough consistency. This means that if an additional 10 kg of sugar is used in a formulation it can be expected that the water level can be reduced by 6 kg (litres). This, however, will be the case only where there is enough water present to dissolve this extra sugar. In most short doughs there is not enough water to dissolve all the added sugar but in hard doughs there is always a lot of water and, as the dough is heated during mixing to as high as 40°C, all the sugar will dissolve. The solubility curve for sucrose is shown in Fig. 11.4. Sugar solutions also have a softening effect on gluten, resulting in lower water requirements

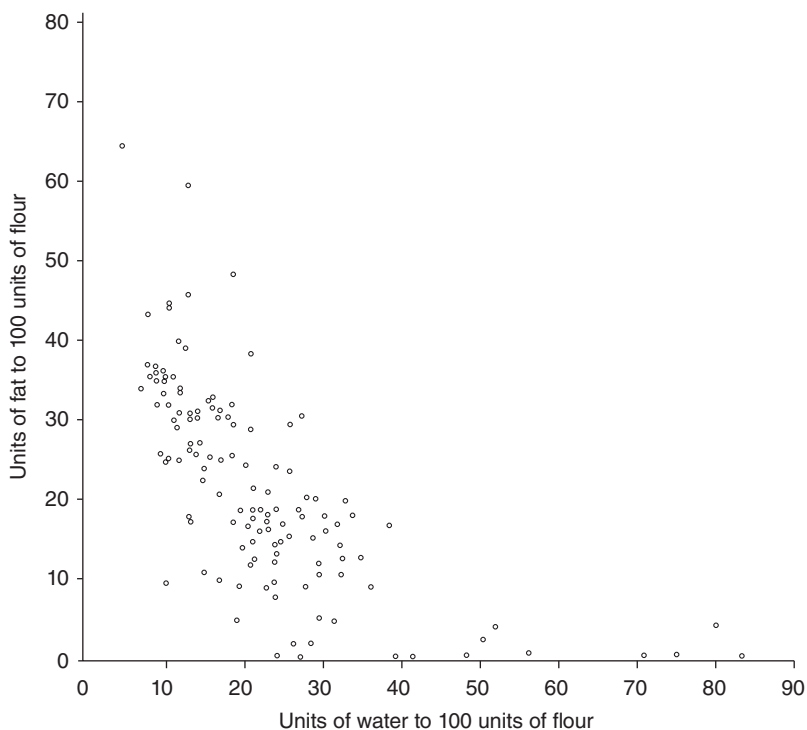


Fig. 21.2 Relationship of fat and water levels in biscuit recipes.

for a dough. This is probably only significant in cracker doughs where a small amount of sugar may be added.

Figure 21.3 is constructed very differently and so should be considered carefully if comparison is made with the relationships shown in Figs 21.1 and 21.2. Here the levels of fat, sugar and water in different recipes have been used in isolation from the flour level. In each case the total values of these three ingredients have been adjusted to 100 and the ratios of each plotted on a triangular graph. The main value of this figure is probably to show which recipes contain sugar in excess of a saturated solution of the latter. The saturated sucrose levels at two temperatures, 20°C and 40°C, have been shown so that recipes below these lines must contain some crystalline sugar at least until the temperature rises in the oven. No appreciation can unfortunately be given of the effects of lower sugars like invert or glucose which, it must be said, affect the solubility of sucrose. However, sucrose in particular has a major effect on the texture of a baked biscuit and Fig. 21.3 may be useful in any theoretical considerations of the state of this sugar before baking.

The greatest fundamental difference between all the biscuit group areas shown is in the existence or otherwise of a three-dimensional structure of gluten that imparts extensibility and cohesiveness to a dough. A point comes where, due to the

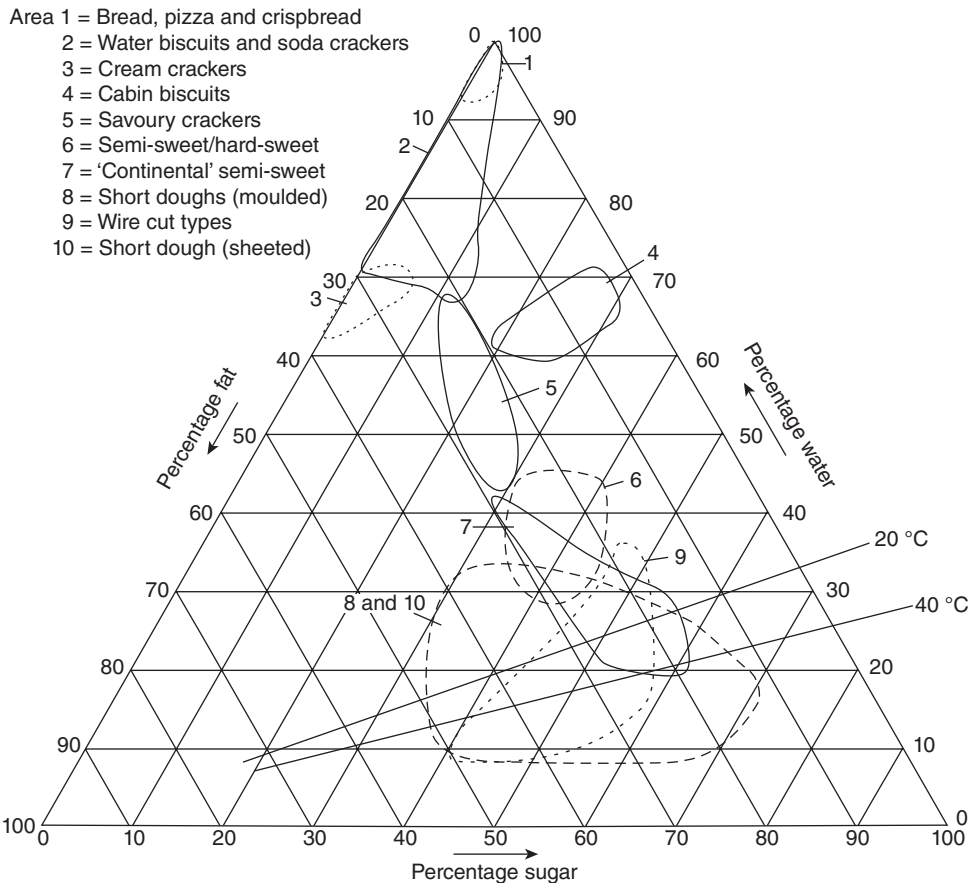


Fig. 21.3 Ratios of fat, sugar and water in biscuit doughs.

shortening action of fat, the softening action of sugars or the mechanical interference of crystalline sucrose, cohesive gluten is not developed so the dough becomes 'short'. There is a big difference in the way that short doughs can or must be handled and formed into biscuit dough pieces compared with those with extensible gluten. By and large, dough pieces formed from short doughs either do not shrink after formation and then increase in outline during baking (a phenomenon described as spread) whereas those with extensible gluten tend to shrink (mostly in their length) after cutting and during baking. By subtleties of processing, it is possible to confuse the distinctions which are recipe related described above. Thus we return to the basic problem of precise classification mentioned before.

In Fig. 21.1 areas 1 (bread, pizza bases and crispbreads), 2 (water biscuits, matzos and soda crackers), 3 (laminated crackers including cream crackers), 4 (cabin biscuits), 5 (savoury crackers) and 6 (semi-sweet types) all have a three-dimensional gluten structure. Areas 7 (continental semi-sweet types), 8 (rotary moulded short doughs), 9 (wire cut and rout pressed short doughs) and 10 (sheeted short doughs) have non-cohesive structure with very little gluten formation. It can be seen how these rough groupings overlap, defying accurate definitions. This is particularly the case with the various short doughs which, by altering their consistencies, can be formed in different ways. Doughs that are very soft and pourable, known as soft or deposited doughs, are always rich in fat, sugar or both, and lie at the extremes of the figure.

It is useful, when presented with a recipe, to get some idea of related types by consulting this figure, and comparison with Fig. 21.2 will show whether the water level is average, high or low for the given fat quantity. Water is a catalyst in biscuit making. It is added at the doughing stage then is driven off during baking. Between the time of its addition and removal it has a number of functions. The water added to make a dough

- may result in the formation of gluten from the flour protein particles
- will hydrate the flour proteins and starch
- allow dissolution of sugar, salt, various leavening chemicals
- aid in the dispersion of fat and other ingredients through the dough.

From Fig. 21.2 it will be appreciated that the amount of flour hydration, and thereafter starch gelatinisation, becomes progressively less as the fat level in a recipe increases because less water is used. This in itself has a marked effect on the eating quality of the baked biscuits. Non-gelatinised starch is softer eating, therefore biscuits in the groups 1–6 tend to be harder eating than those in the other groups, with the exception that those rich in sugar may be hard because of the effects of super-cooled sugar glass that may be formed when the baked biscuit is cooled.

Flint [1] looked at the microstructure of biscuit textures. It was shown that for crackers and hard-sweet types the matrix has relatively thin walls and is a continuous protein structure with starch embedded in it. The fat is present as small globules. During preparation of these doughs enough water and energy is applied to hydrate the protein to form gluten. In contrast, for short doughs the matrix walls are much thicker and are composed of a mixture of protein particles and starch. The fat is present as large globules or large interconnecting masses. In the preparation of these doughs care is taken to avoid development of hydrated protein and generally less water is needed because the fat is a 'moistening' agent and the sugar in solution also contributes to the liquid phase.

Superimposed on this pattern of types, which is based on enrichment of recipes with fat and sugar, come other complications which tend to make the biscuits more interesting or exotic. Thus layering of fat between the dough to make puff biscuits occurs in the low sugar types. Layering of fruit between an extensible dough gives sandwiches like Garibaldi. Moulding of short dough around a fruit paste gives fig, date, etc., rolls. Co-extruding two dissimilar doughs or co-extrusion involving a fruit, nut or chocolate centre gives biscuits with a distinct dichotomy of textures and flavours. Decoration of the dough piece surfaces with salt, sugar, nuts, egg wash, etc., improves appearance and flavour. After baking, the biscuits may be fat sprayed (mostly savoury types), sandwiched with sweet or savoury fat creams or marshmallow, or variously enrobed with chocolate, chocolate substitutes or water icings. All of these types and processes will be described in subsequent sections. Table 21.1 gives a generalised comparison of how different parameters or properties change as the recipe becomes enriched with fat and sugar.

It is interesting to note that practically all of these biscuit types have very old origins, having been made at home before factory mass-produced methods were established. This is surprising when one considers the possibilities in terms of machine facilities and the number of developments that mechanisation has allowed in other non-food fields. The baking industry is still very much craft based but the inventive skills of engineers is now growing in terms of biscuit types; co-extrusion of both doughs and creams and slicing of frozen doughs are examples. Handling of ingredients, etc., is often merely mechanisation of past manual methods and the reasons why a process is performed in a particular way is not questioned sufficiently often.

There is, however, one spectacular development which must be attributed to engineering. This is the production of expanded cereal-based foods using extrusion cookers. Originally these were confined to small snack shapes made from maize grits and when flavoured with salt and savoury flavours, formed an extension of potato-crisp-type foods. It has been found that extrusions of flat strips which are subsequently cut into medium-sized pieces are acceptable 'biscuits'. The limits or recipes that can be formed with these high-pressure screw machines is unfortunately outside the scope of this book.

Table 21.1 Comparisons of dough and biscuit properties for different groups of products

	Crackers	Semisweet	Short		Soft
			High fat	High sugar	
Added water in dough (to 100 units flour)	33%	21%	5%	15%	13%
Moisture in biscuit	3–4%	1–2%	2–3%	2–3%	3+%
Temperature of dough	30–38°C	40–42°C	18–20°C	18–20°C	c. 21°C
Critical ingredients	Flour	Flour	Fat	Fat and sugar size	Fat and sugar size
Baking time	3 min.	5–6 min.	15–25 min.	7 min.	12+ min.
Oven band type	Wire	Wire	Steel	Steel	Steel

Table 21.2 Conversion charts

Ounces into kilograms		Pounds into kilograms		Kilograms into pounds	
oz.	decimal of lb	lbs	kgs	kgs	lbs
1	0.06	1	0.454	1	2.20
2	0.13	2	0.907	2	4.41
3	0.19	3	1.361	3	6.61
4	0.25	4	1.814	4	8.82
5	0.31	5	2.268	5	11.02
6	0.38	6	2.722	6	13.22
7	0.44	7	3.175	7	15.43
8	0.50	8	3.629	8	17.64
9	0.56	9	4.082	9	19.84
10	0.63	10	4.454	10	22.05
11	0.69	20	9.072	20	44.09
12	0.75	30	13.608	30	66.14
13	0.81	40	18.144	40	88.18
14	0.88	50	22.680	50	110.23
15	0.94				
16	1.00				

Wafer biscuits represent a special type of baked product because they are formed between a pair of hot plates and not on a baking band or wire as are most other types. The recipe is simpler, low in enrichment with fat and sugar, and is mixed to a fluid pumpable batter.

Most wafers are rather uninteresting to eat on their own but they form useful, rigid, carriers for other more flavoursome mixtures like sugar cream, caramel toffee and marshmallow. Wafer batters with higher levels of sugar can be rolled after baking and before cooling. After cooling they are harder and much more palatable to eat than the other flat sheet wafer types.

21.3 Conversion of units

Charts for the conversion of ounces into kilograms, pounds into kilograms and kilograms into pounds can be found in Table 21.2.

21.4 Reference

- [1] FLINT, F. O. (1970) *A comparative study of the micro-structure of different types of biscuits and their doughs*. FMBRA Report 44. (Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.)

21.5 Useful reading

- [2] MANLEY, D. J. R. (2001) *Biscuit, cracker and cookie recipes for the food industry*. Woodhead Publishing, Cambridge.

Cream crackers

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Abstract: Cream crackers have a simple unsweetened basic recipe of flour, fat and salt but claims that the production of cream crackers is straightforward should be viewed with caution because there are several critical stages. The various techniques of dough mixing, dough sheet lamination, cutting and baking are described and compared.

Key words: crackers, lamination, dough piece formation, cracker baking.

22.1 History and introduction to cream crackers

22.1.1 Origins

Cream cracker biscuits were first introduced in about 1885 by the Irish firm of Jacobs (Fig. 22.1). Since then they have maintained a significant place in the sales of biscuits in Britain and have also become popular in many other countries. In most cases they owe their introduction to other countries to British influence and transfer of technology. In contrast to most other biscuits, cream crackers are distinguished by being made from fermented dough. They should not be confused with soda crackers which are another traditional type of cracker. The soda cracker is of American origin and as it was recorded in 1840 it probably predates the cream cracker. It is typically smaller, made by a slightly different process, but like a cream cracker is from a fermented dough.

The name cream crackers is traditional and does not indicate that cream or even milk is now to be found in the recipe. Cream crackers have a simple unsweetened basic recipe of flour, fat and salt. The dough is always fermented with yeast and is then laminated prior to cutting and baking. The combination of flour protein modification, achieved during fermentation, and lamination gives rise to characteristic flaky and variously blistered biscuits.

22.1.2 Position of cream crackers amongst other crackers

As a generic type, crackers are biscuits which are all more or less unsweetened, salty and are thin and crisp to eat. They are, in effect, bread substitutes and are usually eaten with butter, cheese or cold meat, etc., as a convenient snack. Within this group known as crackers are several different types and the chart in Fig. 22.2 gives some idea of the characteristics of these.



Fig. 22.1 Cream crackers.

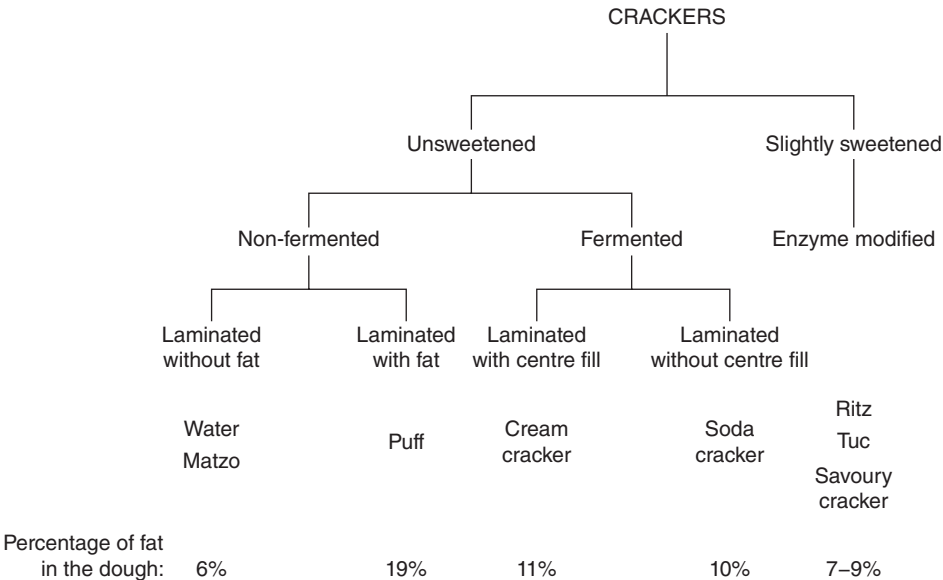


Fig. 22.2 Relationship of cream crackers to other crackers.

The definition of a product such as cream crackers which has a long history is, not surprisingly, rather imprecise. The basic expectation is for a crisp but not hard, flaky biscuit with a bland flavour. They are usually relatively large and rectangular (about 65 × 75 mm) and have a pale bake with darker coloured blisters on both top and bottom surfaces. The blisters should not be too pronounced but their presence gives a very uneven surface. Internally cream crackers have an obviously flaky structure which should be as even as possible throughout, see Fig 22.3.

Claims that the production of cream crackers is straightforward should be viewed with caution because there are several critical stages. How these are handled, and

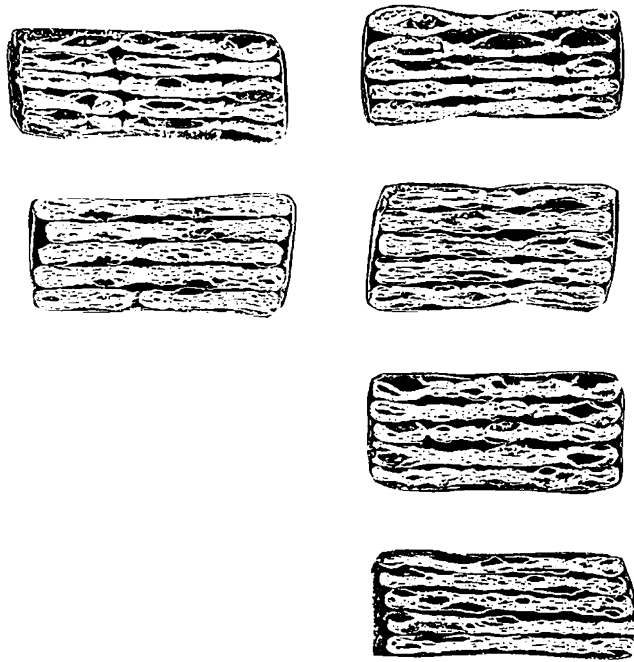


Fig. 22.3 Sections through cream crackers to show typical flaky structures.

with what type of machinery, varies as will be outlined below. However, the fundamental principles used in manufacturing are always the same.

In terms of the eating quality, the texture should be fairly soft, not hard, such that when bitten the biscuit does not shatter and crumble but ‘melts’ fairly readily in the mouth. The hardness is principally a feature of the total fat content but is also affected by the degree of separation of the flaky layers. There is no chemical leavening. The flavour is rather bland but claims of a mild ‘nutty’ flavour are made by some and is considered important.

Their open texture and unsweetened nature make cream crackers susceptible to oxidative rancidity of the fats and it is this factor which will probably be most noticeable as the product ages. When produced, the moisture content of the biscuits should be between 3 and 4% which is relatively high for biscuits.

22.2 Mixing and fermentation of cream cracker doughs

A successful cream cracker structure depends ultimately on the ability to form a pile of thin layers of dough in each dough piece which separate in the oven. The dough must be soft and extensible enough to form a good sheet which can be reduced in thickness to the laminating stage. Between the layers a fat flour mixture known as cracker dust is distributed and this dust must be soft, plastic and of more or less uniform particle size. After laminating, the extensibility of the dough must be such that further gauging prior to cutting does not rupture the gluten strands causing the laminar structure to be lost. In fact this is a very tall order and some loss of the laminar structure is probably inevitable.

Basic cream cracker recipes fall within the following range:

	(units)
Flour (about 11% protein)	100
Fat	12.5–18.0
Salt	0.9–1.5
Water	32.0–39.0
Yeast (fresh)	1.0–2.4

The formulation of the cracker centre filling dust is more constant, being approximately:

	(units)
Flour	100
Fat (hydrogenated and plasticised)	33
Salt	1

Cracker dust may be used at the rate of up to 1 part of filling dust to 5.6 of dough = 17.8%. However, 9% has been shown to be adequate to produce a good structure.

The total fat content of the baked cracker is the principal factor affecting the hardness. It is possible to achieve the typical total fat percentages which lie between 10 and 16% by adjusting the amount of fat in the dough and/or the amount of centre filling used. This technique also allows some adjustment of the effect of fermentation on the gluten modification if there is some doubt about the quality of the flour. A serious problem is that the performance of filling dust applicators at lamination leaves much to be desired in terms of consistency, and it is difficult to monitor exactly how much filling dust is being fed!

The type of flour for the centre fill is not critical but it is important that the fat is in a plastic form. A harder type of fat, with less good shortening properties than dough fat, is to be preferred. The fat is mixed into the flour until a fine uniform powdery mixture is formed. This is then kept in a cool room at about 10°C until it is required. If the temperature is too high, the fat will melt and the whole will tend to become sticky and lumpy. It is wise to sieve the dust prior to use, using a sieve of about 3 mm aperture.

Returning to the dough, fermentation times vary greatly. There is, of course, a similarity between cracker and bread dough fermentation but the final requirements are not the same and this should be clearly remembered. During fermentation the gluten is stretched and at the same time it mellows both physically and chemically. Enzymatic action breaks down some of the starch and most of the sugars present. There is some increase in acidity which may have an effect on the baked biscuit flavour. Typical cream cracker doughs are at approximately pH 6.0.

Work done at the Flour Milling and Baking Research Association, Chorleywood by Elton and Wade [1] resulted in a process patent which described the significant reduction of the fermentation time to as little as 30 minutes. They claimed that the effect on flavour difference was minimal and the physical size and texture of the crackers was unimpaired. The reduction in time was achieved by replacing the gluten modification during fermentation by a greater amount of work in the mixer.

Fermentation is the result of the growth of microorganisms in the dough. The added yeast dominates but research by Sieler [2] at Chorleywood has shown how rich the flour microflora is normally and how this varies depending upon the source of the wheat and the length of time it has been in store. The effect of this microflora during fermentation has been very imperfectly studied but it would seem obvious that it is important to the dough quality particularly during long fermentations. It may be a source of cracker flavour but it will be very important in its action on the gluten. It is suggested that this action, combined with the differences in gluten quality and quantity in different flours, is of fundamental importance in cream cracker fermentation. To eliminate the unpredictable effects of the flour microflora, the fermentation time should be short or the microflora should be dominated by bacteria which are added to the dough. Such is the case in a continuous liquid fermentation method now available, which is described in Section 22.2.4.

Excessive fermentation or excessive reaction with enzymes will give an unmanageable and short dough. It is necessary to engineer the dough modification system so that having achieved the desired level of change in a batch of dough, only a minimal further effect takes place from the commencement of using that batch until the end. Developments of continuous dough mixing can solve the problems associated with variable dough age. In fact the fermentation time is such, even under a short fermentation system, that there is a large mass of dough to handle in any continuous system and this complicates processing arrangements.

Having outlined the mechanisms of cracker dough fermentation and ways in which it may be controlled, it is perhaps important to outline the principal procedures utilised.

22.2.1 Sponge and dough method

Typical sponge dough:

Strong flour	100.0
Fresh yeast	1.5
Water	40.0
Salt	0.5
Fermentation time	12–16 hours

Addition at dough up:

Weak flour	200.0
Fat	42.0
Malt extract (non-diastatic)	2.0
Salt	2.5
Sodium bicarbonate	1.0
Water (approx.)	60.0
Fermentation time	1–3 hours

The process starts with a very soft dough, which is usually made from just flour, yeast, (salt) and water. The flour is usually of about 11% protein, that is of bread flour quality, and the dough temperature is about 26°C. This is allowed to ferment for about 12–16 hours to form a very open and bubbly ‘sponge’ dough. To the ripe

sponge are added flour, fat, water, salt, sodium bicarbonate, malt extract and maybe cutter scrap dough and some biscuit crumb waste plus other ingredients calculated to affect flavour. The sponge dough component will be up to 50% by weight of the final dough. The whole is again mixed to form a dough with moderately tight consistency at 28–30°C. This is then left to ferment further for between 1 and 3 hours. At the end of this time the dough may or may not be lightly knocked back (remixed) before taking it to the dough sheeter. There is some virtue in adding cutter scrap or other reworked dough in controlled quantities at the stage when the extra ingredients are added to the ripe sponge as any procedure which involves incorporation of cutter scrap at the laminator gives placement problems.

One major manufacturer made the sponge dough in batches and then, after fermentation, used this as a component of a continuous dough making process. It is claimed that the sponge and dough method gives the best flavoured crackers and if this is true then the adventitious flour flora must be a major reason. However, handling large quantities of fermenting dough for up to 16 hours is a logistics problem.

22.2.2 All-in dough

Typical all-in dough:

Strong flour	50.0
Weak flour	50.0
Malt flour diastatic	1.0
Sugar	1.0
Malt extract (non-diastatic)	1.5
Fat	16.0
Sodium bicarbonate	0.2
Yeast	1.7
Salt	1.2
Water (approx.)	34.0
Fermentation time	4–16 hours

This is the most popular method for preparing cream cracker doughs. As the name suggests, all the ingredients are included before a single mixing stage. The recipe is mixed to a suitable but fairly tight consistency at 30°C. The dough is fermented for 4–16 hours. No remix is made but the dough may be returned to the mixer for a knock back before being taken to the sheeter. As a guide to the desired amount of yeast needed for given conditions of time and dough temperature, it is considered a good rule of thumb to allow the dough to double its volume from completion of mixing to end of fermenting. It is also possible to include protease to modify the gluten quality.

22.2.3 Short fermentation dough

A typical recipe is similar to the all-in dough but with the yeast level increased, sodium bicarbonate reduced (as there is less acid produced during the fermentation) and 1.4 of sugars added to promote the yeast activity. This is the system patented by Elton and Wade [1] and described by Wade [3]. The principle is that of the Chorleywood Bread Process where mixing energy modifies the gluten quality

mechanically. The relatively high level of mixing results in significant heating of the dough. In order to prevent the dough becoming too hot it is usual to start with cold water in the formulation. The final dough temperature should be allowed to reach 38°C as this benefits the baked structure because the rate of carbon dioxide production by the yeast increases most rapidly at this temperature (see Wade [4], p. 32). It is reported that one notices less aroma during baking this type of dough but it is claimed that there is no significant difference in the flavour of the biscuits after 24 hours.

22.2.4 Continuous liquid fermentation

A liquid fermentation process was developed and patented in Australia by Arnotts Biscuits Ltd after 10 years of research. The system separates and optimises the two major dynamic reactions occurring in fermenting doughs.

1. Bacteria growth during the flour fermentation leading to both flavour and dough development.
2. Yeast activation producing carbon dioxide gas and flavour.

The development of this process found that after about 12 hours of fermentation the yeast causes combinations with amino acids which are flavour precursors typical of long fermentation products.

22.2.4.1 Lactobacillus fermentation

A 35% flour slurry is inoculated with a culture of bacteria. This mixture is allowed to stand for 14–18 hours at 35°C. The pH is then about 3.8. At this stage 10% of the mix is taken and pumped to a storage vessel. The original is topped up with fresh flour and water and is ready after about 10 minutes for another extraction.

The stored mixture is held in a tank at 20°C for a number of hours and here it is allowed to stabilise and mature. The pH drops to about 3.4 and in this condition the mixture is very stable and can be held for long periods of time. As with any bulk fermentation system, care must be taken to watch that stray microorganisms do not contaminate the mixture. Airborne bugs are the principal problem.

22.2.4.2 Yeast fermentation

The yeast activation is not very special. A mixture of yeast, flour and water is formed and stored for at least one hour. When needed a quantity of this mixture is passed to an activation tank where dextrose is added. The yeast ferments the dextrose producing carbon dioxide, ethanol and a range of fermentation products that contribute to taste and texture in the baked product.

22.2.4.3 Dough preparation

Liquids from the *Lactobacillus* and yeast fermentation tanks are fed to a batch mixer along with other ingredients such as flour, fat, salt, etc. The dough is mixed in the normal way and usually allowed to ferment for about 2 hours before use.

The advantage of the continuous liquid fermentation system is that there is a reduction in capital cost of large fermentation rooms and dough tubs and better control of the fermentation because the natural flour microflora which varies from time to time is dominated by the bacteria culture that has been added.

22.2.5 Dough handling

Since, with fermenting dough, we are dealing with a biological reaction, it is most important to attend carefully to temperatures and humidities around the dough. Fermentation rooms should be at, or a little above, the temperature of the dough and the humidity should be such that skinning of the dough surface does not occur. The correct humidity is dependent on the temperature but levels between 80 and 90% are needed. At no stage before it reaches the oven should the dough be chilled as this not only changes the consistency and toughens the gluten, but it also checks the gas production by the yeast. There is often a lack of attention to the humidity of the air over the dough in the sheeter hopper, but some skinning of the dough after it is sheeted is desirable to aid gauging and lamination.

If cutter scrap dough is not incorporated in the mixer, the way in which it is included with fresh dough needs careful attention. The scrap dough is drier, cooler and more dense than the fresh dough. It is also richer in fat, from the filling it has received. The aim should be to place it within the sandwich if two sheeters are used or preferably at the top or bottom side if only one sheeter is used. The problem is discussed further in the section on laminating in Chapter 36.

22.2.6 Flour strength and fat type

It has been found that flour with a protein content of about 11% forms the best crackers but with attention to fermentation times, lower or higher protein levels can be used. For the dough, either plasticised or warm liquid fats can be used and as the quantity of fat used is relatively low the type is not very critical. Normal biscuit dough fats are commonly used.

22.3 Dough piece forming

22.3.1 Sheetting of cracker dough

Having gone to much trouble to modify a dough by various biological and mixing procedures, the question is how to judge whether a suitable dough has been produced. The best place to judge this is at the sheeter. If a complete, smooth, lively looking sheet is formed, the chances are hopeful for a good dough piece and baked cracker. If the dough continues to show some shrinkage after lamination and again before cutting, these are good signs. As the dough is relatively soft, very great care is needed to ensure that it is not crushed or pulled at any of the gauging stations. Typically the dough is dropped into the sheeter hopper in large batches. As the amount of dough in the hopper varies so does the rate at which it is sheeted/extruded from the sheeter. A larger amount arriving at the next gauge roll causes an overfeed, etc. A power monitor attached to the first gauge roll pair can be used to detect an over- or under-feed situation and the signal used to modify the speed of the sheeter producing it (see Section 5.8.4.2). The quality of the dough is of great importance for the success of this stage of the production. However, the techniques for forming and baking will also affect the quality of the baked cracker.

22.3.2 Dough brake method

In the old and traditional method fermented dough was divided into handleable masses and laminated on a reversing brake by hand. Although this is a most rare

procedure now, it is worth considering as it has a bearing on the advantages and disadvantages of automatic laminators. Having made a rough sheet by pressing out by hand, the dough was floured and passed back and forth through the brake till a sheet of about 9 mm thickness was formed. (It was normal to include a quantity of cutter scrap dough with the fresh dough at this early stage. In this way not only was the scrap dough well integrated with the new dough but its inclusion helped to form a cohesive sheet that could be passed through the brake.) A weighed quantity of cracker dust (a fat/flour crumbly mixture) was spread over two-thirds of the sheet. The sheet was then folded into three to interleave the cracker dust, the whole was then turned through 90° before further passes through the brake to again reduce overall thickness. Reduction continued by repeated passes through the brake until a dough length about four times its width was obtained. This was then folded into four (ends to the middle, then in half again), giving a total now of 12 laminations. The dough was then turned through 90° again and was reduced down to about 11 mm before cutting into square sheets about 800 or 1000 mm long (the width to be fed into the first gauge roller on the cutting machine) and piled on tables.

The dough had received $3 \times 4 = 12$ laminations, been turned twice through 90° , and was then rested on the tables prior to being fed, one sheet at a time, into the cutting machine. The sheets were fed, by hand, one after another with slight overlapping into the first gauge roll of the cutting machine. The dough had been turned through 90° for a third time at this point and the overlapping joins, called splices, tended to crush into the gauge roll, as there was a double thickness of dough at these points. These splices resulted in areas of dough with damaged laminations which, after baking, could be recognised as dead, imperfectly risen, biscuits.

The important points to note about this traditional form of processing are as follows.

- A quantity of cutter scrap dough, which is richer in fat than the fresh dough because it contains some cracker dust from the lamination procedure, was intimately included with the fresh dough.
- Much flour was used throughout the laminating process in order to facilitate passage of the dough over the brake tables and through the rolls. This flour skinned the surfaces and dried the dough somewhat.
- Reduction of the dough sheet thickness at all times was fairly gradual as a rapid reduction would have been uncontrollable leading to crushing or sticking of the dough to the roller surfaces.
- Each passage of the dough through the brake rolls was fairly fast so the dough was bumped down rather than extruded.
- The process, being manual, was rather irregular though pairs of brakesmen did develop consistent procedures and rhythms.
- The dough temperature was at the mercy of the general bakery air which was usually at least 20°C .
- If the dough was firmer or softer, the brakesmen could compensate by changing the handling a little.

22.3.3 Mechanical laminators

Sheeting and laminating is nearly always carried out by machine now. Mechanical laminators are relatively large machines and there are several different types.

Basically, the fresh dough is sheeted into either one or two sheets. The stage at which the cracker dust is introduced between dough sheet layers varies. The commonest types of laminator produce a single sheet of dough that after reduction to about 4 mm is piled up with cracker dust introduced between the layers. The pile may be formed by folding the dough or placing cut sheets one over another. The operation is continuous and obviously all the dough has a similar treatment. It is important to consider carefully where the cutter scrap is introduced because this has a different character from fresh dough. It is usually richer in fat, has a higher density, and the temperature and consistency may be different. It is also older than the fresh dough. By comparison with the dough brake system we can discern the following differences in the process of lamination which might affect the structure and uniformity of the dough passing to the cutter.

- The initial sheeting of the dough is much more drastic from a pair or a group of three rolls than the hand sheeting prior to first gauging with a brake.
- Although the rolling action is very uniform both across the sheet and in time, the passage through the rolls is much slower than on the brake usually with relatively few and large reductions. It can be assumed that the elasticity of the dough is more important in this squeezing action than in the bump on the brake if the continuity of the laminations of dough is to be maintained.
- There is usually considerably less flour used on the dough before laminating, so dough skinning is different.
- There are rarely three 90° turns in the dough prior to the cutter and usually only one. The stresses in one direction in the dough are therefore probably more pronounced.
- The continuous laminating action eliminates splices in the dough so the stresses are more even, giving baked biscuits which are more uniform.
- It is unusual significantly to alter the sheeting or laminator settings to compensate for dough quality changes and these may occur between or within mixed batches of dough.
- The relaxation times are generally more uniform but very much less than for braked dough.

Typical roll configurations and sheet thicknesses for cream cracker laminations are shown in Table 22.1. A fuller consideration of automatic laminating is given in Chapter 36.

22.3.4 Final gauging and cutting

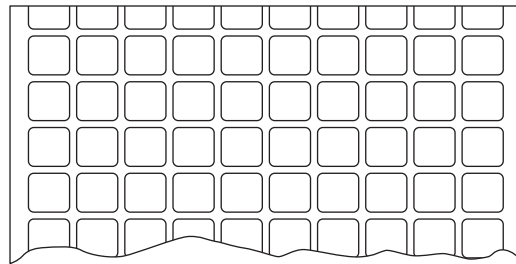
Typically the laminated dough is reduced through three (or four) pairs of rolls to a final thickness suitable for cutting. The dough is usually cut at about 2 mm thickness. The cutter may have cups separated with a scrap margin all round or only across the plant, between rows. There is always some scrap dough from each side (see Fig. 22.4).

The pieces may be entirely discrete as they pass to the oven with a lattice of scrap dough being lifted away, or they may be cut, but adjacent laterally, with a 'ladder' of scrap dough. In the latter case, the percentage of scrap may be as low as 10% but the former is rarely less than 20%.

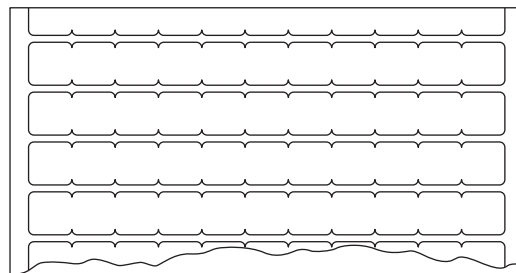
The nature of the dough and its behaviour in the oven causes considerable longitudinal shrinkage. Typically there is a shrinkage of about 18% in the length of a

Table 22.1 Typical roll configurations and sheet thicknesses for cream cracker laminations

	Sheeter		Gauge roll			No. of laminations
	1	2	1st	2nd	3rd	
1. Single sheeter vertical laminators	9 mm	–	4 mm	2 mm	–	6 or 8
2. Twin sheeter horizontal laminators	9 mm	9 mm	10 mm	4 mm	2.5 mm	8
3. Twin sheeter vertical laminators	9 mm	9 mm	10 mm	4 mm	2.5 mm	8
4. Single sheeter cut sheet laminators	9 mm	–	4 mm	2 mm	–	6



Separate-cut type of cutter with lattice scrap pattern

Scrapless configuration
(gives extra biscuit across)**Fig. 22.4** Cream cracker cutter layouts.

baked biscuit compared with the length of the cutter. The length of the baked biscuit may be controlled to a certain extent by adjusting how much the dough can shrink prior to the cutter. This is done by forming ripples in the dough sheet on an intermediate web conveyor. Shrinkage laterally during baking is very much less, in the order of 6.5% biscuit to cutter. There is no satisfactory way of controlling this.

22.4 Baking of cream crackers

As with other biscuits, baking creates the texture, dries the product and colours the surfaces. The best oven spring and texture is obtained for cream crackers with very

hot baking. Thus efforts are made to raise the temperature of the dough pieces quickly as they travel into the oven by using high temperatures followed with lower temperatures to effect the drying out. Considerable power is needed to raise the dough piece temperature and this is aided by using very light wire bands often combined with band preheating.

Cream cracker dough is one of the wettest biscuit doughs and weight losses of around 26%, dough piece to biscuit, occur in the oven. This means that provision must be made for adequate extraction during baking. The optimum 'humidity' level within the oven is still uncertain but there is evidence that high humidities impair biscuit development.

During baking, the laminations lift apart irregularly and this is how the blisters may form on the biscuit surfaces. The mechanism of this lift is imperfectly known but it is probable that the major factor is the discontinuity formed between thin sheets of dough (the laminations) by the cracker dust filling, combined with skinning caused by flour or the dough drying out during the lamination process. The lenticular cavities formed within the dough initially fill with carbon dioxide, formed by the yeast cells, but the greatest expansion results as the water vapour pressure rises when the dough piece temperature rises above 60°C and more (see Section 39.2.1).

Gradually the gas bubbles coalesce and burst but hopefully the gluten and starch structures in the dough have been coagulated and gelled by the heat to form a structure that does not collapse completely before the biscuit has dried out. Some of the carbon dioxide from the yeast will form minute bubbles which will swell the structure of the dough that forms the laminations. This mechanism contributes to a soft texture in the baked biscuit. The desired background colour of a baked cream cracker is fairly pale and relief is given because the blisters colour preferentially. If the spring of the dough is not good during baking, the colour will seem pale because of lack of this relief.

There are at least three common problems associated with the baking of cream crackers and they act together to compound each other. One problem, as has just been mentioned, is that if the blisters are too pronounced, they will tend to colour or burn very easily. These big blisters will be damaged in post-oven biscuit handling, giving the biscuits an untidy, damaged appearance. A heavily blistered biscuit will tend to have a dense general structure. This gives a hard or flinty type of texture. Bad blistering can be the result of poor lamination structure caused by insufficient filling dust, a dough quality that is unable to form thin laminations or damage to the laminated structure by crushing or pulling in the final gauging sections. Too hot an oven may cause bad blistering but this is usually subsidiary to one of the other possible causes.

A second problem of baking is the phenomenon of checking – delayed fracturing of the biscuit structure such that the biscuit falls apart as if broken. This becomes apparent only some hours after the biscuit is baked. It is caused by stresses built up in the biscuit during baking and appears as a crack as the biscuit moisture equilibrates (see also Section 33.1). Since the loss of water in baking cream crackers is amongst the highest of any biscuit, the fact that large drying stresses may be present is perhaps not surprising. If checking does cause a problem an immediate way to tackle it is to bake to lower general moisture levels. This usually means longer baking times at lower temperatures, a situation that not only affects production efficiency but also will affect the spring of the biscuits during baking. High temperatures at high speed give the best cracker structures.

It has been observed that when checking, stress cracks always develop along the length (direction of travel through the oven) of the crackers, so the weakness is accentuated along gluten elongation lines. It has also been observed that poorly developed crackers, with or without blisters, tend to check more than more open biscuits with better general lift. This could be related to rates of water removal (difficult in a dense structure) or a reflection that dough elasticity has some effect.

Efforts have been made to reduce the severity of the stresses caused during moisture migration in the biscuit by trying to encourage equilibration while the structure is still a little flexible. This is done by keeping the biscuits warm and close together in a temperature and humidity controlled environment for a while after the oven [5]. The crackers are stacked on edge immediately after the oven and passed slowly through an enclosed tunnel with minimal ventilation. Although this system has some theoretical merit, the results are not sufficiently spectacular for the idea to have received popular acclaim. Another more satisfactory solution is the use of a radio frequency post-oven unit to effect the final drying of the crackers while still hot. Electromagnetic radiation is preferentially absorbed by water so the technique is very effective for drying biscuits (see Section 39.5.2). It should be emphasised that checking is not always a problem and it is this unpredictability that is most worrying. Attention to detail in the dough preparation and laminating are important but it is probable that dough quality is a contributing factor.

A third common baking problem is in the flatness of the baked biscuit. It is extremely important that the biscuits are relatively flat for packing. Domed or dished crackers can be easily damaged at the packaging machine, or in the feeders immediately prior to it. The flatness can be controlled by the disposition of the heat above and below the band at the front of the oven. Too much top heat transfer either by radiation or air impingement will cause doming; too much bottom heat will cause dishing.

Three minutes is about the fastest that normal cream crackers can be baked. More normally the baking time is between 4.5 and 5 minutes. Typical temperature profiles are given below.

Baking time	Zone 1	Zone 2	Zone 3	Zone 4
3.0 mins	310°C	290°C	270°C	250°C
5.5 mins	250°C	250°C	240°C	210°C

The appearance of the crackers as they come from the oven will be determined by the design of the cutter used. Crackers that were cut with a cutter which had scrap all round each piece will have a uniform colouration at each edge. Those from a cutter that did not have scrap at the sides of each piece and were panned onto the band as wide strips will have darker front and back edges than at the sides. Due to lateral dough shrinkage these strips of dough pieces will have broken and will not now be complete across the band. There will typically be one or two places where the biscuits have separated laterally but unless special provision has been made on the cutter, these positions of separation will be more or less at random. Typically the breaks will be at least one-third of the way in from the edge of the band. Where the strips have separated the biscuits will have a little more colour around the edges, and this is always the case on the pieces at the ends of each row.

It will be appreciated that those crackers with three edges, as compared to only two, exposed to hot oven gases will have different edge to centre moisture distributions. Furthermore where a separation occurs the relative position of pieces to the corresponding ones before and after them on the oven band will not be in line. The biscuits in a strip are separated, cracked apart, by a system of discs used to flex the baked strips on the lines demarcated by the cutter, first one way and then the other. Significant misalignment caused by separation during baking may result in damage to some crackers by these discs. It is therefore recommended that arrangements are made on the cutter for slightly greater imprints to be made at say one-third and two-thirds across the band to encourage regular separation within the strips during baking.

22.5 Yields from fermented doughs

There is a considerable production of carbon dioxide gas and volatile alcohol during fermentation. The longer the ferment, the more gas is produced. This represents a loss in yield as sugars and breakdown products of starch are used by the yeast. It has been calculated that between 2 and 6% of flour dry matter may be lost during fermentation. In a one hour process the losses are, however, insignificant. It is claimed that the losses in the liquid continuous fermentation method are about 1.5% of the flour weight.

22.6 References

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Soda crackers

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Abstract: Soda crackers, like cream crackers, are bread substitutes which have a much longer shelf life than bread. They differ from cream crackers in their pH, which is alkaline, and their size and appearance. The dough preparation involves fermentation, and considerable craft rather than science is involved probably because the microflora in flour is variable. Baking is fast in very hot ovens.

Key words: crackers, fermentation, dough pH, surface blisters, fast baking.

23.1 Introduction

In the USA, cream crackers are almost unknown and their place in the biscuit market is taken by soda crackers, or saltines (Fig. 23.1). This situation is repeated in other areas with strong American influence, such as Central America, the Northern parts of South America, areas of South East Asia and, rather surprisingly, Italy. Soda crackers have been produced in the USA since at least 1840. It is very unusual for flavours to be added so, like cream crackers, they are a bread substitute which has a much longer shelf life than bread.

The popularity of enzyme treated and chemically raised doughs such as Ritz and TUC crackers has led to some misunderstandings of the definition of soda crackers in some markets. Savoury or snack crackers, which are typically oil sprayed after baking, are described in Chapter 24. They have no similarities to true soda crackers.

There are many similarities between soda and cream crackers but also some essential differences. The principal one is their alkaline reaction after baking (hence the name soda crackers). As may be expected, there are variations on a theme but these are mostly to do with cracker size and shape. Typically, however, the soda cracker is a square biscuit about 50 × 50 mm and 4 mm thick. Each biscuit weighs about 3–3.5 g and the moisture content is about 2.5%. The biscuits are produced with scrapless cutters so the edges are white and broken after baking. Often the cutter makes perforations between biscuits and these are clearly seen on the single or groups of pieces after they have been separated. There are usually nine docker holes in three rows of three.



Fig. 23.1 Zesta saltine crackers.

23.2 Dough preparation

Secrecy and mystique tends to surround the fermentation of soda crackers. Reports and literature suggest that this may be based on ignorance of the true mechanisms involved during long fermentation and an inability adequately to control all the variables. The fermentation typically is in two stages with a wet sponge lying for 18 hours followed by a dough stage which is left to ferment for about 4 hours. The reason for the long fermentation seems to centre principally around flavour development though protein 'mellowing' is also important.

As has been discussed under cream crackers, long fermentation has two problems. There are enzymatic regimes associated with hydrolysis of the starch in the flour by α and β amylases, the speeds of these reactions are affected by the levels of damaged starch, and also the growth of a largely random natural flour microflora of bacteria and fungi which produce proteases and particularly lactic acid. It is the latter that give rise to flavour and it would seem that in soda cracker ferments the lactic acid bacteria are particularly important. However, no attempt is normally made to control the types or levels of these bacteria. Much emphasis is given to the change in pH during fermentation and the curve shown in Fig. 23.2 is very typical of most situations.

There is a big change to alkaline conditions at the dough stage because sodium bicarbonate is added and, as stated earlier, the cracker should be alkaline after baking (pH 7.2–8.0). Very little science seems to be used to determine the level of sodium bicarbonate that should be added to the dough and it would seem that this is due to an oversight of the fact that pH is not a good guide to flavour where the sodium salts of weak acids are involved. These salts act as buffers but they do not control acidity of flavour.

The literature shows a weakness in attempts to tackle the microbiology of the soda cracker fermentation. Sugihara [1] reported that the first technical paper was by Johnson [2] in 1924 but it was not until 1955 that Micka [3] first drew attention to the bacterial aspects of fermentation. Sugihara himself saw the follies and difficul-

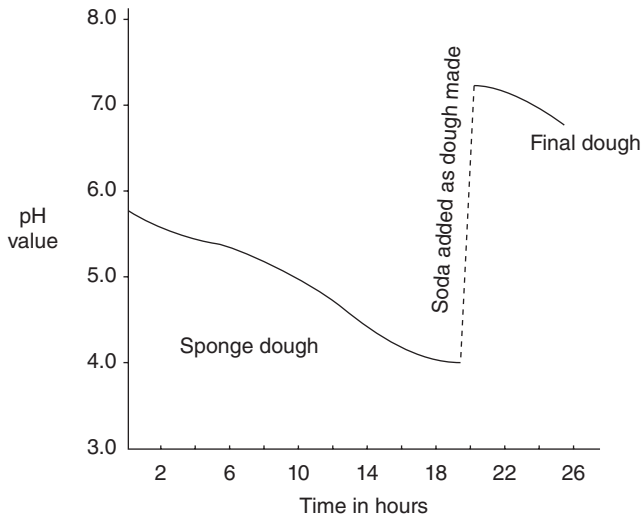


Fig. 23.2 Relationship of dough pH with time during fermentation.

ties of long fermentations to produce lactic acid, etc., and experimented with pure cultures of *Lactobacilli*, reducing the sponge fermentation down to 4 hours instead of 18. It would seem that the liquid continuous fermentation system described in Section 22.2.4 is a commercial development of Sugihara's work and would be particularly useful for controlling soda cracker dough preparation. The function of yeast and proteases is the same as that discussed for cream crackers and a wide range of flour protein levels and qualities will inevitably be used for soda cracker production. The use of standard proteases is an obvious development and has tended to confuse the distinction in the minds of many between soda and snack crackers as was mentioned above.

It is also significant that there seems to have been a singular lack of interest in the mechanical dough development success of Elton and Wade [4] for cream crackers as it could be applied to soda crackers. Perhaps this is because slow low-powered mixing machines are typically used for soda cracker doughs due to the need to do a remix at the dough stage and detachable mixer troughs are best for this.

23.3 Outline of typical soda cracker manufacturing techniques

The sponge dough has about 55–75% of the total flour to be used in the recipe. About half the shortening is added at the sponge stage but usually none of the salt. The protein content of the flour is important. A high protein flour produces a well sprung cracker but a harder texture, a low protein flour gives less spring and a softer texture. Pizzinato and Hoseney [5] found that a flour blend having a protein content of about 10% and including 30% hard wheat yielded the best soda crackers in terms of separation of the laminations during baking.

A typical sponge dough is:

Flour (9.5–10% protein but can be 8–11%)	100
Shortening	7.5
Yeast (fresh)	0.25
Water, approximately	44

Some yeast foods, old dough, malt flour or other amylases may be added as felt necessary. The dough is gently mixed till clear and a target temperature of 23–27°C is achieved by adjusting the dough water temperature. This is left in a room at 27°C $\pm$ 0.5°C and relative humidity 78% $\pm$ 2% for 18 hours. During these 18 hours the pH will fall.

At the dough stage the following ingredients are added to the sponge dough batch as detailed above:

Flour (as before or lower protein, 8.0–9.0%)	50
Shortening	7.5
Salt	2.25
Sodium bicarbonate	0.875 (variable quantity)

Some sugar, diastatic malt extract and buffer salt (diammonium phosphate) may be added as required.

Note that no further water is added and the mixing continues till a clear dough with well distributed soda is achieved. More mixing is said to reduce the spring of the cracker and makes it tough and hard instead of short, tender and flaky. This dough is fermented for a further 4 hours in the warm humid room. The ripe dough is sheeted, laminated, gauged and cut. There is no specific filling introduced between the laminations as for cream crackers but a surface dusting of flour is often used to aid passage through the rolls.

Typical dough thicknesses are:

From sheeter	16 mm
From 1st gauge roll	8 mm
From 2nd gauge roll	4 mm
Laminator to give 6 laminations (occasionally 8)	
From 1st gauge roll after laminator	12 mm
From 2nd gauge roll after laminator	6 mm
From 3rd gauge roll after laminator	3 mm

The dough is not very lively and great care should be taken to roll and reduce the sheet thickness gently to avoid crushing the dough and damaging the laminar structure. A two-to-one reduction at each gauge roll is considered maximum.

At the cutter the size is about 54 $\times$ 50 mm which gives a cracker of 50 mm square. As was mentioned above, the dough pieces are normally in strips across the plant with only scrap at the edges. Thus the shrinkage in length is only about 8% – considerably less than for cream crackers. After cutting, and before baking, fine salt is dusted onto the dough pieces at about 2.5% by weight.

Typically the baking is fast. Baking times of 2.5–3 minutes are usual. Baking is on a heavy wire or steel band and typical temperatures are around 300°C at the first

zone, declining to 250°C at the end of the oven. The oven temperatures depend on type of heat transfer and amount of turbulence but the power needed in the oven is probably higher than for any other type of cracker or biscuit.

Considerable importance is placed on the appearance of the baked cracker. There should be even spring between the dockers and the blisters should be evenly brown. A heavy gloss means that the oven is too humid and a greenish tinge means that there is too much soda in the dough. A dull greyish surface is produced if too much flour is used to dust the dough through the laminator and cutting machine. The bottom of the cracker should be nearly but not quite flat and have many small blisters.

After the oven, the strips of crackers are broken into appropriate groups with rollers known as cracker breakers and the biscuits are usually stacked at once. During cooling perhaps 1.4–1.8% of moisture is lost, bringing the biscuit to about 2.5% moisture. The size of the crackers reduces the tendency for checking in soda crackers because the moisture differential between different parts of the cracker are relatively small. It is quite feasible to use a dielectric ‘oven’ to reduce the moisture content of soda crackers after a conventional oven. Claims of up to 10% increase in throughput have been made with this type of drying. The baking loss, dough to biscuits out of the oven, is around 28% which is why there is a high oven power requirement.

In conclusion it can be seen that the changes during fermentation, many of which are imperfectly known or controlled, contribute in an important way to the handling and baking performance of the biscuit and also probably to the flavour. The quality, rather than the quantity, of the flour protein is important but adjustments to the proteolytic activity during fermentation can be made to suit most flours. The changes in the sponge and dough pH during fermentation are caused by the activities of the microorganisms. The influence of alkaline conditions during the dough stage must have a very profound action on the fungal (including yeast) activities as these organisms prefer acidic conditions. By contrast bacterial enzymes favour slightly alkaline media.

23.4 References

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Savoury or snack crackers

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Abstract: These crackers are nearly all of delicate open texture with soft eating mouthfeel. They are often cut as small pieces which makes them ideal for snacking where harder crackers may have too dry an eating quality. They feature post baking oil spraying which adds considerably to the calorific value and recipe costs.

Key words: proteinase, snacks, oil spray, cheese flavour.

24.1 General description

There is a broad group of cracker type biscuits that are variously salted, flavoured and fat sprayed after baking (Figs 24.1–24.2). Depending upon their size, because they are made in a very wide range of shapes and sizes, they can be regarded as savoury snacks, nibbles or biscuits for cheese. These biscuits are a group characterised by very open textures and soft eating mouthfeel. Usually they are simple biscuits but sometimes they may be cream sandwiched with a savoury, non-sweet, cream often based on cheese powder. (Information about savoury creams is given in Section 41.2.2.) The relationship of these crackers to other types is shown in Fig. 22.2.

24.2 Manufacturing technology

The methods of manufacture are usually based on a well developed dough modified with proteinase and/or sodium metabisulphite. Less commonly the dough is fermented with yeast followed by lamination like cream or soda crackers. These crackers are nearly all of very delicate texture, often with a great deal of aeration achieved with ammonium bicarbonate. As biscuits in this group, including well-known names such as Ritz, TUC, Cheddars, Goldfish, etc., may be rather special in formulation, only general comments about their manufacture and character can be covered here.

Those doughs that are fermented with yeast or modified with proteinase and are laminated should be handled in a similar way to methods described for cream or soda crackers. Those without lamination, with or without enzyme modification, are mixed and sheeted as for hard sweet/semi-sweet doughs (see Chapter 27). The high



Fig. 24.1 Mini Pick crackers.



Fig. 24.2 Cheddar cheese biscuits.

level of ammonium bicarbonate often makes the dough very extensible but if flavouring ingredients, such as cheese and cheese powders, are included in the formulation they tend to make the dough weak and rather short.

Flavouring of these crackers has presented much difficulty. The conditions in the oven effectively subject volatile flavouring materials to a condition of steam

distillation, resulting in their almost complete loss to the oven atmosphere. There are notable exceptions to excessive flavour loss and these are associated with cheese (due to the milk proteins and acids), yeast autolysates, vegetable protein hydrolysates and many herbs and peppers. Synthetic smoke flavour is also quite resistant to the oven conditions. It is important that flavour enhancers such as salt and monosodium glutamate are used at optimum levels to help these aromatic flavours (see Section 17.5). It is best that the biscuits have an overall acid reaction with pH around 5.5 like other savoury foods. It is common for savoury cracker recipes to include a small proportion of sugar or syrup. This reduces the dryness of the mouthfeel and flavour and the sweetness is therefore acting as a flavour enhancer.

The biscuits are nearly always cut in such a way that a relatively high percentage of the dough is recirculated as cutter scrap. This can be a problem in the dough sheeter, resulting in rather short dough. It is best to try to use dough not much above ambient temperature so that the returning cutter scrap, which is at air temperature, will not change the overall consistency much; however, these low temperatures are not ideal for enzyme activity so warmer doughs are not uncommon.

Many savoury crackers are decorated on their top surface with poppy (Maw), sesame or celery seeds, and garnished with salt (sometimes flaky crystal salt). It is usual to apply these materials after cutting and before baking. If this is so, the dough pieces must be passed over a recovery unit so that excess seeds or salt fall through and are collected for reuse. Sometimes the seeds are applied before cutting in which case no recovery unit is needed as there is a complete sheet of dough to receive them. There are advantages and disadvantages in each method. If the seeds are added after cutting it is not possible to press them into the dough surface but the cutter scrap dough does not become impregnated with the seeds. Recovery units, however, usually have fairly coarse wires and small dough pieces can become distorted on their passage over the wire. Sometimes seeds which have been applied after cutting do not adhere well to the biscuit surface and are easily rubbed off during packaging. If the dough pieces are washed with water before the seeds are applied they stick better to the surface.

Doughs rich in ammonia and salt are particularly corrosive to bronze/gunmetal dough cutters. Since most savoury crackers are cut from a very thin dough sheet it is important that the cutting edges, docker pins and print are maintained in good condition and at correct relative levels to achieve clean cuts. Metal corrosion affects the thin areas of metal first and these are the cutting edges. If there is any doubt about the corrosive character of dough it is recommended that cutters made of moulded plastic be used in preference to metal ones.

Being relatively lightweight biscuits with low densities, baking can be critical because excess heat will cause 'ringing' (browning around the biscuit edges) and bitterness in flavour. Column packed biscuits, such as Cheddars or TUC, must be handled gently to prevent damage and care is needed in baking to ensure that the product is flat and not domed or dished. Many savoury crackers are jumble packed so the thickness and weight of the individual pieces is not quite so critical. All savoury crackers are baked on some form of wire to allow maximum and quick development of structure.

Doughs flavoured with cheese or cheese powder are very difficult to bake. If the baking is too hot or too long the attractive and delicate flavour offered by the cheese is lost and bitterness develops. If the baking is too little the moisture gradients in

the biscuit are strong and checking may be a problem. (See Section 40.2 for a full account of checking.) Savoury cracker doughs without cheese flavouring are usually lively and extensible and they develop a good open texture during baking. Those with significant levels of cheese powder are much shorter and more difficult to bake to an open texture. It is well known that biscuits that do not develop well and are thus thin and dense are much more likely to exhibit checking. To reduce the chance of checking in cheese crackers it is usual to have a dough piece with many docker holes. This allows better release of moisture from the centre parts of the biscuits during baking.

24.3 Post-oven oil spraying

For most savoury cracker biscuits a dressing of oil is given while the biscuits are still hot. Immediately after the biscuits are taken from the oven band they are passed through a unit where they are sprayed with warm vegetable oil. The oil is distributed either from pressure nozzles, spinning discs or by electrostatic charge. All types except the last tend to be messy because fine droplets of oil form a fog that will drift from the spray unit unless there is positive extraction and filtering.

The oil dressing applied (either on the top surface only or on both surfaces) at around 8–18% of the biscuit weight, greatly improves the appearance of the biscuit surface, enhancing the colour, and adds a little to the eating quality. In some cases flavoured oil is applied which, for savoury or hard sweet types, is a useful technique for applying flavour that would be lost if added in the dough before baking. The main problem with flavoured oil is that it contaminates the cooling conveyors used to hold the biscuits when they leave the oil spray unit and the smell may fill the packing area of the factory.

The oil used for spraying is particularly susceptible to rancidity. It is sprayed hot and in this condition is open to oxidation. On the biscuit it is a surface film, again in an ideal situation for oxidation. It is therefore recommended that a fat or oil is used that is resistant to oxidation and the favoured choice is coconut oil because it is low in unsaturated fatty acids. This is readily available and much cheaper than specially prepared fats which are resistant to oxidation.

Attempts have been made to apply flavour after baking in the form of savoury dustings, as for potato crisps and expanded snack foods. On the whole this method is not very effective. The surface area of a biscuit relative to its weight is very much lower than for potato crisps, etc., so the flavour has to be applied very heavily to give a satisfactory overall effect. Heavy dustings of flavours can give a burning sensation as the biscuit hits the tongue. It is important that a well refined oil with low unsaturated fatty acid content be used for the fat spray. This is because the very large surface presented by the fat-coated area will be liable to oxidative rancidity during storage of the biscuits. It is usual to use coconut or palm kernel oils which exhibit relatively great resistance to this form of rancidity.

Recipe costs of savoury crackers tend to be relatively high. This is because the flavour components are expensive and the overall fat level in the biscuits is high as a result of post-oven spraying. Process control techniques should always be applied to fat spraying because higher than standard applications are not very obvious but add significantly to the cost of the biscuits.

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Matzos and water biscuits

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Abstract: These are the most basic of laminated crackers. They are made from dry crumbly doughs and baked in very hot ovens to give strongly blistered thin products. They are bread substitutes. These biscuits, which can reasonably be regarded as crackers, represent the simplest recipes in terms of enrichment. Matzos are made from flour and water only and water biscuits have only a little fat added.

Key words: water biscuits, matzos, blistered crackers, tough dough.

25.1 Matzos

Matzos are a Jewish product, being common in Israel and produced locally wherever there is a significant Jewish community (Fig. 25.1). The shape of matzos is variable, being either conventionally round or rectangular like water biscuits, or in large sheets which are broken up by the consumer.

Typically, the Matzo recipe is about 100 parts of flour to about 38 parts of water. This mixture is gently rolled together in a mixer to form a crumbly 'dough'. There is little or no dough development. The sheeter presses the mix together to form a sheet which, after reduction, is simply laminated with 2–6 layers. After further gauging, the sheet becomes clear and strong. This sheet is heavily dockered and cut. It is then baked for a very short time in a very hot oven. Baking times of around one minute at 400°C are not unusual.

The oven is often an indirect-fired brick oven to withstand the high temperatures and the oven band is very open to allow maximum heat transfer to the product. The high temperatures cause much blistering but the heavy dockering means that the blisters are small. The blisters take up colour but the rest of the biscuit remains very pale. Some moisture continues to be lost after the oven exit but a final moisture content of about 3% is typical.

25.2 Water biscuits

Water biscuits (Fig. 25.2) are a slightly more variable group than matzos. There are some that are very similar to matzos with a simple recipe of flour, fat, salt and water in the ratio 100:6.5:1:29. The dough is undeveloped and crumbly or in balls after



Fig. 25.1 Matzos blistered thin crackers.



Fig. 25.2 Table water biscuits.

mixing. There may then be a conditioning period before sheeting when some form of proteolytic activity mellows the gluten to make it a little more extensible. A very strong sheeter is required to form a tough sheet from the crumbly dough. The sheet is then laminated (without any inclusions between the layers), gauged and cut before being baked in a very hot oven. Water biscuits are usually round and may be as large as 70 mm in diameter. As longitudinal shrinkage occurs in the oven, the cutters must be oval and the shape is controlled by the relaxation of the dough before the cutter.

The majority of water biscuits are made in this simple way. However, there are some that have a more elaborate recipe including low levels of sugar, syrup or malt extract. These may then be fermented in a similar way to cream crackers but usually

for only 3–4 hours. These biscuits are really low-fat cream crackers. Water biscuits made by the fermentation method are baked in 4–5 minutes in only moderately hot ovens.

All water biscuits (strangely they are not referred to as crackers), like matzos, have strongly blistered surfaces. Normal and ‘high bake’ varieties are made. The high baked water biscuits have darker blisters. All water biscuits are fairly hard and crisp with bland flavour. They are very suitable as a carrier for butter, cheese, or other savouries. Unlike their softer eating cracker relatives, they remain crisp rather longer when spread with butter so can be prepared as snacks well before they are to be eaten.

25.3 Typical recipes

An important feature of matzos and the unfermented water biscuit doughs is their tough and crumbly nature. This makes sheeting difficult and the power and strength of the sheeter should be carefully checked. Laminating is essential to develop the gluten and thus to create a ‘clear’ dough. The simplicity of the formulations can be seen from these typical recipes.

<i>Matzo</i>	
Flour	100
Water	38
<i>Unfermented water biscuit</i>	
Flour	100
Fat	6.5
Salt	1.0
Water	29
<i>Fermented water biscuit</i>	
Flour	100
Fat	8.9
Syrup	5.4
Malt extract	0.70
Fresh yeast	0.54
Salt	1.6
Water	26.0

25.4 Useful reading

- [1] MANLEY, D. (2001) *Biscuit, cracker and cookie recipes for the food industry*. Woodhead Publishing, Cambridge.

Puff biscuits

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Abstract: The eating quality of puff biscuits is determined very largely by the nature of the fat used for laminating. Forming the laminar structure in the dough is a delicate operation dependent on the fat composition and consistency.

Key words: lamination, fat consistency, cold doughs.

26.1 General description

The flaky structure of puff biscuits offers an attractive alternative to those with more uniform internal structure. Puff biscuits are all made from doughs in which there is a non-homogeneous distribution of fat. When this dough is laminated the fat causes discontinuities between the layers of dough and during subsequent baking these layers separate to give a very flaky structure. The laminar structure of puff biscuits bears some similarities to cream crackers but the dough differs in that the fat is concentrated between the laminations and little is used to form the basic dough. The dough is not fermented and is invariably cold and underdeveloped. The methods for distributing the fat in the dough determine the type of mixers and laminators needed. The eating quality of puff biscuits is determined very largely by the nature of the fat used for laminating. Unlike puff pastry for sausage rolls and vol-au-vents which are best eaten hot, puff biscuits are eaten cold so the fat used must not have a high melting waxy tail which does not melt in the mouth. This means that close attention must be given to the melting point of the fat and the plasticity and temperature at the time of use. Thus biscuit puff doughs are always handled cold to ensure that the fat has a relatively high solids content during processing. It is generally recognised that puff doughs are among the most difficult biscuit doughs to handle.

Puff biscuits may be used as unsweetened carriers for butter, cheese, jam, etc., or as shells for sweet or savoury cream sandwiches (Figs 26.1 and 26.2). In essence they are a type of cracker biscuit. Where used as 'sweet' biscuits, it is usual to garnish the surface prior to baking with sugar. During baking this sugar will melt and form a glossy, lightly browned surface which on cooling is hard. Puff dough made into very small biscuits may be sold as 'snacks' of various flavours, often in jumble packs. Fresh cheese is often used as the flavour material.



Fig. 26.1 Lemon Puff biscuit.



Fig. 26.2 Cornish wafer.

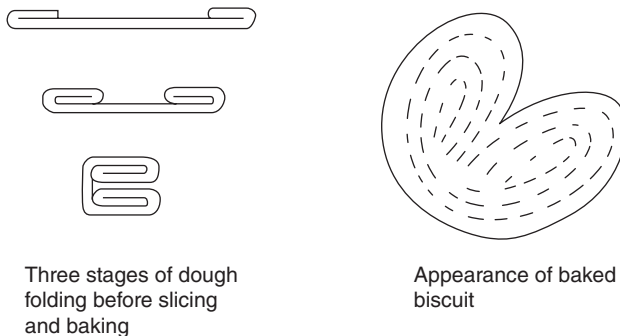


Fig. 26.3 Formation of palmier biscuits.

There are some more exotic biscuits which are on the borderline with flour confections usually produced by bread and cake bakers. Palmier is one such type made from puff dough. The dough for palmier is folded after laminating and is then sliced across the laminations to form pieces for baking. Thus, the expansion is sideways, not upwards, to produce a flaky structure during baking (see Fig. 26.3).

26.2 Puff dough preparation

The preparation of layers of dough separated by a film of fat is the basis of puff dough. It is necessary that there should be a great number of dough layers and that each is very thin and more or less discrete. Thus, an extensible dough is required and the fat must be spread as a thin film between the layers. The fat must be in a condition where it has a low liquid fraction and therefore does not become incorporated in the dough and is plastic enough to be rolled out into thin films between the dough layers.

Much attention must be given to forming a strong but extensible dough and to ensuring that fat is in the correct condition. Since the fat must have relatively high solids at processing temperatures but with little solids melting above blood heat, it is necessary to select an appropriate fat with steep dilatation and to use it well plasticised at cool or cold dough temperatures.

Extensible doughs for bread or other types of biscuits involve a significant amount of development by mixing, with or without the help of yeast, and dough temperatures are usually 30°C or above. To produce extensible doughs for puffs, which are at 18°C or less, necessitates the use of strong flours, more water and maybe some sodium metabisulphite (SMS). No fat, or very little, is used in the dough to ensure minimum shortening effects so the dough recipe is simply flour, water and salt (and perhaps SMS), there may also be a little milk powder to soften the biscuit texture and enhance surface colouring during baking. As a consequence, the dough tends to be rather sticky and this feature limits the level of water that can be used while making sheeting and gauging possible. In order to achieve a cohesive gluten structure in such a dough it is necessary to allow relation times for the dough between each gauging and laminating stage.

The fat may be introduced either as lumps in the partially mixed dough, or as a layer between two dough sheets on the forming plant. Considering firstly the introduction of the fat into the dough at the mixer, it will be appreciated that the principal requirements are to distribute the lumps uniformly while pressing as little as possible of the fat into the dough. It is necessary to use a mixer with gentle cutting and good blending action and probable that fat lumps of uniform size, say about 2.5 cm cube, will be best. Too large lumps will give sheeting and laminating problems and too small pieces will tend to merge into the dough reducing the effect of the fat and causing shortening of the dough. The fat must be plastic and of similar consistency to the dough of which it is a part. The lumps may be of pure fat, a mixture of fat and flour or fat emulsified with some water (similar to butter or margarine). Preparation of plasticised fat is of great importance and is described in Section 12.2.1.

Where the fat is spread between two sheets of dough the means of distributing the fat (or fat mixture) is the principal problem. On standard biscuit plant the sheets may be 800–1200 mm wide and it is virtually impossible to extrude fat of the desired consistency evenly over this width. The most satisfactory system involves spreading flakes of fat either by hand or by raking. The layer of fat must be as uniform as possible to allow even control of plant and product later in the process.

There are special puff dough plants available where a layer of plasticised fat is extruded between two sheets of dough but the width of this part of the plant is usually narrow. If the lamination is with a lapping type of laminator where a 90° turn is made, it is possible to increase the plant width by lapping the narrow dough sheet over a wider conveyor.

Having introduced the fat, whether discretely in a layer between two dough sheets, or randomly through the dough as lumps, it is then necessary to gauge and laminate in order to build up the structure. Considerations of dough stickiness and fat solids determine that the dough is usually of higher consistency than either cream cracker or semi-sweet biscuit dough so it is less malleable in terms of folding on a continuous lapper type laminator. A cut sheet laminator where no folding stresses are involved is thus preferable. The limitation is that on cut sheet laminators because the centre of the dough is exposed in the cut edges, fat placed between two sheets and thus exposed will form surface marking which will be unacceptable later in the process. This means that mechanical laminating must suit the type of dough preparation involved.

The number of laminations, the number of 'turns' (90° changes in direction) and the speed of processing must all be considered carefully. If the laps are too few the biscuit structure will be coarsely flaky and may be irregular in development. If there are too many laps (laminations) the rolling and stretching involved will exceed the elasticity of the dough causing breakdown and loss of laminations. This will give a poor structure also. The thickness, development of the puff structure in the biscuit, increases with the number of laminations to a certain point and then it collapses rapidly. The optimum number of layers must be found by experiment and if possible a standard established so that variations in dough quality, which affect the biscuit development and which will occur from time to time, may be compensated for by laminator settings. As a general rule, about 42 layers (7 at the first laminator followed by 6 at a second laminator involving one or two 'turns') may be near the optimum for puff biscuits. It will be necessary to dust the dough with flour through successive gauge rolls to prevent sticking and tearing of the delicate layers as they are rolled.

It is a matter for debate whether the passage through the gauge rolls should be done slowly or rapidly. There will be some spring and recovery of the dough following deformation and, traditionally, puff pastry doughs are allowed to stand and relax following each reduction. The use of SMS has reduced the need for relaxation, but it is still possible to exceed the elastic limits of the gluten in the dough if processing is too severe (either by pressure or speed). If possible the gauging reductions should be made gradually through a multiplicity of rolls. Unfortunately, a plant with two laminators is already long and complex so the introduction of extra gauging rolls is usually impracticable. Although it is not commonly used by biscuit makers at present, it is worth noting the special puff dough method offered by the Rheon company of Japan. This is built primarily for the flour confectionery trade rather than for biscuits but it offers some interesting techniques.

Dough is extruded in a tubular form and a lining tube of fat is co-extruded within it. The double tube is flattened, gauged then laminated before being gauged and laminated again. The gauging is by means of what is known as a 'stretcher' which consists of an endless chain of rollers arranged behind one another. These rollers pass over the dough sheet supported on a total of three or more conveyors. The rollers are driven over the dough faster than it is carried on the conveyors so they perform a gradual gauging action in a relatively short length. The effect is not only to reduce the thickness more gradually than one conventional biscuit gauge roller, but also to increase the dough sheet width somewhat. It is undoubtedly more gradual in action than any other method, but the change in dough width may represent some problems unless the final sheet width can be guaranteed for the

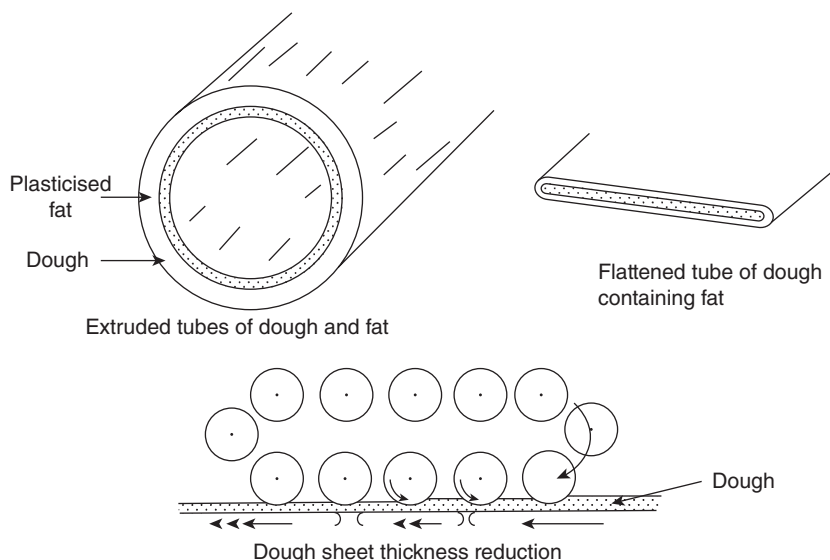


Fig. 26.4 Some stages in the Rheon method of puff dough manufacture.

purposes of cutting and weight control. Figure 26.4 shows the principle of the Rheon system (see also Cleven and Fluckiger [1]).

The technique of co-extruding the fat in the form of a lining to a tube of dough is a good idea as an alternative to two dough sheets and spreading of fat by any other means. However, unless high melting point pastry margarines are used, close attention should be given to the dough and ambient temperature because the consistencies of the fat and dough must be well related.

Puff dough pieces are cut, garnished and panned onto the oven in a similar method to other types of biscuits. The scrap dough must be returned to the head of the laminator and introduced in some form of even sheet. The scrap dough will be of significantly different quality from the fresh dough by virtue of both the fat content or the form of the fat within it.

26.3 Baking of puff biscuits

Baking presents no particular problems. Optimum development is obtained with an oven temperature profile that is very hot at the front as for cracker ovens. If the front bottom heat is too high relative to the top heat, the biscuits will tend to curl into a saucer shape with the edges high. Increasing the top heat will encourage the centres to rise more giving either flat biscuits or a doming with the centres high. Control of top and bottom heat at the front of the oven is easier if light, wire mesh bands are used.

Final moisture contents are not very critical as far as checking is concerned so in this respect puff biscuits are not like cream crackers. Moistures of around 2.5% are quite satisfactory. The molten sugar glaze frequently found on puff biscuits results from fine sugar melting during baking. Temperatures high enough to melt the sugar on the biscuit surface are easily achieved provided that there is good development

of the flaky structure. If development is poor the surface temperature is held down and the sugar will not melt and begin to caramelise. In these cases, strong radiant heat directed at the biscuit surface at the oven exit may prove useful in obtaining the desired appearance. Alternatively, a mixture of dextrose monohydrate and sugar used as the garnish will more readily melt and give a pleasing surface colour and gloss. The disadvantage of using dextrose to give a surface colour and gloss is that it is more hygroscopic than sucrose glass and this means that the biscuits rapidly become sticky either when the pack is unwrapped or before packaging on days of high humidity.

26.4 Puff biscuit production techniques

It would seem that little has been published about modern puff biscuit production methods. This is probably because techniques are closely guarded as are recipes for speciality products. However, more is disclosed about puff pastry techniques. In addition to that about the Rheon equipment [1], a useful paper was given by Thursby [2] to the British Society of Baking in 1976. This was about puff pastry production which is significantly different from biscuits being orientated to small-scale production and mostly for savoury (meat) products. Details, however, are given of the principles involved and the effects of different ingredients, particularly fats and margarines. As has been stated earlier, there is a quality problem if biscuits, which are eaten cold, have been made with high-melting-point fats typical of pastry margarines. The reader is also referred to publications by puff pastry fat manufacturers.

26.5 References

- [1] CLEVEN, F. and FLUCKIGER, W. (1977), 'A new method of continuous puff pastry and flaky pastry production', *Getreide, Mehl und Brot*, 31, 73–74 (in German).
- [2] THURSBY, R. F. (1976) 'The Modern Production of Puff Pastry', *Proceedings of British Society of Baking*, March.

26.6 Useful reading

- [3] MANLEY, D. (2001) *Biscuit, cracker and cookie recipes for the food industry*. Woodhead Publishing, Cambridge.

Hard sweet, semi-sweet and Garibaldi fruit sandwich biscuits

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Abstract: These biscuits are significant in the markets of many countries, particularly developing countries where the low cost of the formulation is attractive. They are all made from formulations low in fat and sugar which allow the hydrated flour proteins to be worked into extensible doughs. Although the doughs can be laminated, the use of a reducing chemical to modify the gluten allows most to be simply sheeted before gauging and cutting. Attention to dough mixing and thus dough consistency is a key to good process control.

Key words: extensible sweet doughs, dough temperature, dough consistency.

27.1 General description of this group of biscuits

There is no clear distinction between these biscuits and those in the plain or water biscuit groups. All are characterised by doughs which contain a well-developed gluten network but, with increasing amounts of sugar and fat, the gluten becomes less elastic and more extensible. The prime requirement is a biscuit with a smooth surface which has a slight shine or sheen and an open even texture giving a bite that ranges from hard to delicate. This is achieved by a subtle balance between the requirements of dough mixing and processing.

These biscuits can be regarded as very English in origin. They are commonly produced in many countries, particularly developing countries where the low cost of the formulation is attractive. In the USA they are of insignificant importance because products with rather more fat and sugar-rich types are preferred! As will be shown later (see Section 27.10) in continental Europe the processing of biscuits with this type of recipe is different and more akin to short doughs. Although sales of semi-sweet biscuits now account for less than 10% of total biscuit sales in Britain, they are an important group internationally. Despite the somewhat basic nature of these biscuits, processing problems are frequently encountered and as it is often difficult to define whether the troubles arise in raw materials (principally flour), mixing or forming, they do warrant some detailed consideration.

Early hard sweet types were the thick ships or thinner cabin biscuits with little or no sugar. The majority of popular types now available, such as Osborne, Marie, Rich Tea and Petit Beurre, all have very similar recipes and differ principally in their

shape and thickness (Figs 27.1–27.4). It is difficult to add very flavourful ingredients (they become lost during baking) successfully so most have a basically mild vanilla flavour or a caramel buttery flavour derived either from the use of real butter or synthetic buttery flavours. All have some syrup and/or malt extract. They are rarely eaten as a complement to other foods like butter or cheese but their mild slightly sweet flavour complements warm beverages like tea and coffee. The types known as Rich Tea or Morning Coffee reflect when they are eaten rather than that they taste of either of these beverages. (Please note that some ‘Morning Coffee’ biscuits are short dough products.)

Sometimes these biscuits are subjected to secondary processes such as cream sandwiching and chocolate coating and the low sweetness and richness makes them very suitable for these purposes. The fruit sandwich of currants (known as Garibaldi) or small sultanas is an interesting and significant variant. The processing of these is special and will be discussed later.

The processing of semi-sweet biscuits has changed significantly over the last 60 years and there is no doubt that the quality has changed as a result. Great labour saving has been achieved but the process control has become somewhat difficult or



Fig. 27.1 Marie biscuits.



Fig. 27.2 Rich Tea biscuits.



Fig. 27.3 Zoo biscuits.



Fig. 27.4 Garibaldi fruit sandwich biscuits.

critical in several areas. The lower the sugar level and the higher the flour protein content the harder is the texture of the baked biscuit. By using more sugar not only does the eating quality improve but also the texture becomes more tender and delicate. There is, however, a maximum level that the sugar can reach before the dough character is changed as the extensible characters are lost.

Flint *et al.* [1] examined the microstructure of semi-sweet biscuits and showed that it is based on a continuous protein network in which are embedded the starch grains together with fat globules. Not all of the starch is gelatinised, probably because there was insufficient water to allow hydration of all the starch. Originally the dough was braked by hand and there was a considerable amount of gluten modification as a result of this dough handling. The advent of the automatic laminator did not seem to suit this biscuit so well as crackers, probably because, unlike cracker dough, there was no opportunity for proteinase action on the gluten. In order to make a good primary sheet it was necessary to mix the dough for longer. The use of a reducing agent like sodium metabisulphite (SMS) allowed the development of extensible gluten from a wider range of flours with less mixing. This adjustment to the gluten properties significantly changed the rheology of the dough, greatly aided the sheeting of it and made the need for a laminator largely redundant.

Most semi-sweet biscuits are now produced from a warm dough with SMS used to modify the gluten chemically. The dough is sheeted, without delay after mixing, in a three-roll sheeter and is then gauged to the final dough sheet thickness for cutting. Great care is needed to balance the amount of dough kneading with temperature rise in the mixer combined with optimum machining conditions during forming of the dough sheet. If the conditions are not right a poor sheet comes from the sheeter and this will be reflected in a rough, poorly faced biscuit after baking. The condition of the dough sheet is often impaired by poor incorporation of the cutter scrap dough at the sheeter.

Old-fashioned semi-sweet dough processing with manual brakes, much flouring of the dough surface, incorporation of the scrap at the brakes and a deliberate amount of dough relaxation between braking and final sheeting was very different from today's processing. Today it is necessary to use a little more leavening agent to achieve the same degree of lift in the oven and we are more or less dependent on the use of a reducing agent such as SMS in the mixing to modify the strength of the gluten. Not all mixers, sheeters or bakery conditions are suitable for the appropriate processing and this is where quality and control problems arise. The situation is not helped by legislation in some countries restricting or banning the use of SMS in baked products.

27.2 Ingredients and recipes

The general relationship of hard sweet, semi-sweet and continental semi-sweet can be appreciated from Fig. 21.1. Cabin biscuits with low sugar and fat levels were developed for long shelf life to be used by ship crews on long journeys in the nineteenth century but are now rare in Europe. They are popular in African countries where the biscuit industry is developing and low cost and minimum effects of fat deterioration during storage are required.

Most semi-sweet types, despite varying names and shapes, have similar recipes at the upper limits of the fat and sugar levels as shown in the figure. The dough is mixed to about 40°C so the physical quality of the fat is less critical than for short doughs; there is enough dough water to dissolve the sugar completely so the crystal size is largely unimportant. Other ingredients are present in low quantities making their qualities of little significance. Flour quality is the most important aspect of

semi-sweet processing. Unfortunately, even at this stage of the science of baking, we are very ill-equipped with methods for assessing flour protein qualities which are appropriate to the production of good semi-sweet dough and this is because the latter begs definition also. Much systematic and detailed process investigation has been published by the FMBRA [2–21] and Wade [22] and the conclusion is that a baking test remains the only satisfactory means for evaluating a flour. (The FMBRA became CCFRA, now Campden BRI.) As a baking test allows the introduction of many other variables, it can be appreciated that we are still a long way from being sure of the specification for flour for semi-sweet biscuits.

Many years ago English flour with the lowest possible protein was favoured for semi-sweet biscuits. Flour from harder wheats with higher protein levels gave less extensible gluten and higher dough water requirement. This type of flour resulted in harder biscuits. Some improvement in the suitability of these flours was achieved by dilution with up to 10% of starch such as arrowroot, cornstarch or potato flour. While the inclusion of some starch is still said to be beneficial to the sheen of the baked biscuit, mostly the quality of the gluten can be tempered by the use of SMS or by the use of enzyme mixtures (see Section 16.3.1.1). In any case the very low protein English flours are no longer available as a result of wheat breeding leading to high-yielding, disease-resistant and higher protein varieties (it should be remembered that a farmer is paid principally for quantity of grain and since much wheat is used for bread or animal feed the higher the protein level the better). Protein levels of flour are increasing worldwide and this is making the preparation of good doughs for hard sweet biscuits more difficult. Doughs with poorly extensible gluten, even after treatment with SMS, do not give a good clear sheet from the sheeting and exhibit much relaxation after cutting which affects the biscuit shape. As will be discussed later there is a need for better sheeters, more relaxation before cutting and probably a review of dough-making procedures.

In 1968 carefully controlled experiments by Wade [14, 18] showed that under the test bake conditions he was using, (a) the hardness of semi-sweet biscuits is related to the protein level of the flour but protein levels less than 10% all give very similar biscuits, and (b) the relationship between biscuit stack height and weight does vary with flour properties but the differences are much reduced if SMS is used in the dough.

One comes to the somewhat general conclusion that any flour with a protein level less than 10% can probably be used to make satisfactory semi-sweet biscuits but because processing conditions may have to be altered to suit different flours, the main requirement for flour is to obtain supplies of consistent quality with respect to protein level, water absorption and colour (ash content). Typical general semi-sweet biscuit recipes are given in Table 27.1.

It can be shown that there are benefits to mixing if the sugar is used as liquid sugar (67% solids in solution). This is thought to be due to the softening action of sugar on the gluten, a reduction in surface tension hastening hydration of the flour and the absence of crystals which act as a mechanical interruption during the formation of the gluten until they dissolve. However, most manufacturers use crystal sugar in their formulations. Many semi-sweet recipes use baking powder which is a mixture of sodium bicarbonate and an acidulant like acid calcium phosphate or sodium pyrophosphate. It has long seemed curious that the acidulant is present because much of the reaction with sodium bicarbonate must take place in the mixer especially as the dough is warm. The argument that the liberation of gas from a baking

Table 27.1 Recipes for typical semi-sweet types

	Marie	Rich Tea	Cabin	Gem
Flour (9% protein)	100	100	100	100
Sugar	19	25	10	17
Fat	13	20	5.0	12
Syrup and/or malt extract	2.0	4.0	2.0	4.0
Skimmed milk powder	1.7	1.4	Nil	Nil
Salt	1.0	1.0	0.80	0.80
Sodium bicarbonate	0.40	0.60	0.80	0.80
Lecithin	0.26	0.40	0.10	0.24
SMS	0.030	0.035	0.030	0.030
Ammonium bicarbonate	1.5	0.40	0.80	0.40
Water (approx.)	24	19	20	19

powder occurs at a different stage in the baking to that liberated from ammonium bicarbonate has been shown by Hodge and Wade [16] to be insignificant in the effect on final biscuit thickness, so there would seem to be no point in using baking powder when ammonium bicarbonate, with some sodium bicarbonate to adjust the biscuit pH, will suffice. Normally the level of sodium bicarbonate is adjusted to give a baked biscuit with a pH of about 7.0 but higher (and in some cases much higher) pH levels are liked by some consumers.

The fat can be any reasonable shortening though blends described as dough shortening with a low dilatation curve are best. In hot countries a partially hydrogenated fat with greater resistance to rancidity is preferred. There has been considerable controversy about whether a plasticised semi-solid fat is better than liquid fat at about 40°C. There is probably little difference between semi-solid and liquid fat in these doughs, especially if liquid sugar is used which allows the dough to come together rapidly during mixing.

A phenomenon described as fat bloom on biscuits, which appears on biscuits that are a few days old, is attributed to fats with a steeper dilatation curve or to fats with a particular fatty acid composition. Some samples of butter give fat bloom and this can be a problem if butter is the only fat used. The condition of fat bloom, which severely detracts from the good appearance of the biscuits, shows itself as a dull mottled whitish film not unlike a fine mould on the surface. The reasons for the development of fat bloom and the particular fat properties responsible are imperfectly known but usually are found where fats with solids of more than 25% at 20°C are used in the dough. The problem is probably a combination of factors including cycling of storage temperature but can usually be avoided if the dough fat is chosen carefully.

27.3 Dough mixing

There are four basic requirements for the mixing of these doughs. The ingredients must be blended, the flour has to hydrate, the sugar must dissolve and the hydrated protein must be kneaded to produce the three-dimensional structured material known as gluten. The hydration of the flour and dissolution of the sugar are time dependent, the others are related to the design and speed of the mixer. Normally all the ingredients are placed in the mixer together before mixing begins. In some

cases the water, fat and sugar are mixed initially to allow dissolution of the sugar and plasticising of the fat.

Much investigation has been carried out on the subject of optimum mixing for semi-sweet doughs because gluten modification and dough consistency are fundamental to the production of good quality biscuits. Investigation on the amount of work applied to the dough during mixing has not given such conclusive results as was found for bread doughs which led to the Chorleywood Bread Process. A reason would appear to be associated with the design of the mixer and unfortunately, though perhaps not surprisingly, scale up from a small mixer to a large one, even of the same type, does not produce identical results when time, temperature or work are the criteria used.

The power absorbed by dough manifests itself as heat but that heat may have been derived from surface friction between the dough and the mixer bowl or the beaters. This work does not knead the dough and modify the gluten. It is very difficult to distinguish this type of work from that derived by compression or extension within the dough mass which does modify the gluten. On the whole it would seem that for a given amount of power the dough development is better in a bar-type mixer than in one where a significant amount of cutting and pushing is the case. Problems have probably arisen because of the need to use a mixer with a blade configuration suitable for mixing both short doughs, where rapid dispersion of ingredients is important, and those where kneading is a prime requirement. In small mixers these two requirements are more easily achieved than in large ones. Most of the critical investigations on mixing have, understandably, been made on small or very small mixers. Continuous mixers fall into the category of small mixers. The subject is discussed further in Chapter 34. In the author's experience, it is usually necessary to mix to higher dough temperatures in large universal type mixers than in small ones in order to ensure that sufficient kneading is given to develop the gluten.

It has been shown for British-type semi-sweet doughs, where the total sugar level is around 30 units and fat around 22 units compared with 100 of flour, that the formulation is near to the critical limits for the production of an extensible gluten structure. Higher levels produce short doughs which must be processed differently. Also, in common with normal physical principles, the higher the temperature the lower is the consistency of the dough, that is, the dough is softer. Reduction of the dough water level to compensate for consistencies that are too low at the higher temperatures (in excess of about 44°C) often results in very delayed coming together of the dough to form a cohesive mass in the early stages of mixing; the surface frictional form of heating is thereby increased at the expense of the kneading type of heat development required.

Bloksma and Nieman [23] have shown, admittedly for bread dough, that above 45°C the starch grains start to swell and rupture which not only tends to increase the dough consistency in contrast to the normal decrease expected at the higher temperature, but also may change the basic structure of the dough. It can be appreciated that at high temperatures the quality of the dough becomes unstable and this damage to the starch will also occur if water that is too hot is used to make the dough. At high dough temperatures the fat, which is of course all melted, tends to separate and an oily dough is produced.

In order to define an end point for mixing, Wade suggested that temperature was the best. By investigating the relationship between biscuit thickness (stack height)

and weight after baking he found that for both sulphited (with SMS) and unsulphited doughs, biscuits of acceptable quality were obtained from doughs only within certain temperature ranges. These ranges are: sulphited 32–46°C and unsulphited 38–49°C. It is recommended to aim for a final dough temperature of around 40–42°C where SMS is used and 44–46°C in unsulphited doughs. If the mixer does not produce a satisfactory extensible dough by the time these temperatures are reached (with not less than 4 minutes of vigorous mixing action), the starting temperature of the blended ingredients should be reduced (usually by using cooler water) to allow an extension of the mixing time before the final temperature is reached.

Wade's claims, summarised by Chamberlain [24], that mixing to constant final dough temperature is a prime control parameter, are therefore important from the consistency and certain other points of view but the starting temperature must be viewed in relation to the kneading ability of the mixer in question. The problem is not eased because of the difficulty in defining a satisfactory dough quality in terms of extensibility. The performance of the sheeter has a bearing on this and it is undoubtedly the case that not all sheeters perform as well as may be expected. This will be discussed later.

Use of SMS has a dramatic effect on the dough quality. The use of about 0.03 units of this salt per 100 of flour allows at least a 10% reduction of dough water (to give a similar consistency) and a significant reduction of mixing time compared with doughs using no SMS. A survey of recipes in commercial use shows an appreciable range in the amount of SMS used with some cases of 0.1 in 100 of flour. It is probable that levels above 0.029 units will hasten a deterioration of the dough on standing after mixing but levels below this may be sufficient to achieve desirable results with lower or weaker protein flours. The level of usage of SMS is a useful control parameter for differences in flour protein level or quality and the action is instantaneous.

The length of mixing time therefore varies with the type and size of mixer and the level of SMS used. Slow-acting vertical spindle type mixers may require as much as 50 minutes mixing, most large horizontal 'high-speed' mixers with a beater speed of around 60 rpm require about 20–25 minutes and some small mixers with a dough capacity of around 160 kg and a beater speed of 90 rpm can mix a satisfactory dough in 4.5 minutes. Under special conditions Wade *et al.* [17] demonstrated that a dough could be produced in 2–3 minutes.

Controversy surrounds the use of sodium metabisulphite, $\text{Na}_2\text{S}_2\text{O}_5$, sulphur dioxide essentially, in biscuit doughs. Fundamentally there is concern about the health effects of SO_2 in food but levels in wine and preserved fruit are often much higher than those used in biscuit doughs. Thewlis and Wade [19, 25] investigated the residual SO_2 in biscuits where SMS was added to the dough. They found that only 0.2% remained as sulphite, 30% was oxidised to sulphate, 60% enters into combination with some organic constituents of the flour and 10% is lost as volatiles. It is very difficult to detect the level that SMS was used in the dough, possibly difficult to decide whether it was used at all, due to the fact that the sulphur atom is an essential constituent of protein.

SMS acts as a reducing agent breaking some of the S–S bonds, which strongly bind the chains of protein to one another, to S–H bonds. Some investigation has been made into the use of *L. cysteine* in place of SMS. This is permitted to only about 75 ppm by weight and it would seem that 3–4 times the weight compared with SMS is required to have a similar effect to SMS. This would bring the dosage

to near or above the permitted limit. SMS is a cheap salt. *L. cysteine* is very expensive.

It would seem that any prohibition of the use of SMS is unreasonable but it also presents a technical problem for the biscuit technologist to find a suitable alternative processing aid. The benefit of SMS is that it acts immediately, in fact it can be added towards the end of dough mixing with the satisfactory result that the reaction goes to completion very quickly.

Because of the commonly experienced high levels of flour proteins in modern biscuit flours the enzyme, proteinase, is becoming more frequently used to modify the quality of the gluten in doughs. The levels of fat and sugar in typical semi-sweet doughs is rather high for a very effective action by the enzyme and the standing time required to allow the reaction to occur to a satisfactory level is often a processing limitation. At least one hour of standing is recommended so that the quality of the dough between starting and ending the use of a batch is consistent. Holding a dough at 40°C and covering it to prevent skinning requires care and attention. The enzyme is a protein that is destroyed during baking; there is therefore no concern about health risks as claimed by some for SMS.

27.4 Mixer instrumentation

The optimum mixing time for semi-sweet biscuit doughs has been shown to be somewhat elusive and the best compromise is based on final dough temperature. The mixing time depends on flour quality, ingredient temperatures and most of all, the type of mixer. A prime requirement for any series of good and uniform mixes is accurate ingredient metering but it is also wise to have some indication that the mix is proceeding in a similar way to previous batches. The mixer may be regarded as a giant Farinograph, so the power consumed by the mixer in the course of the mixing may be relevant to the development and consistency of the dough. A recording watt meter (such as the sophisticated Baker Perkins Mixer Power Monitor) can be used to obtain the curve of power usage against time during dough mixing. It has been shown that the dough consistency control principle for bread dough devised by Spillers [26] is not reliable for most large biscuit dough mixers making semi-sweet dough. The technique is based on withholding a proportion of the dough water and then calculating the exact shortfall from the early power curve. The amount required to achieve a desired end consistency is added before the end of the mix. For many biscuit doughs, addition of water to a deprived dough often increases the power requirement even though the consistency is falling because the frictional effect of the softer dough is greater in the mixer bowl. In the author's experience, the power requirement to mix a biscuit dough at optimum water content is very near to the peak power requirement related to dough moisture content (see Fig. 5.6).

It is useful to be able to follow the temperature rise in the dough during mixing, so a probe is needed, situated so that a reliable estimate of dough temperature is made while the dough is moving during mixing. Wade [27] has shown how information regarding optimum dough water level can be derived from considerations of plots of dough temperature against power input during mixing. In order to use this pair of parameters, plotted on an XY recorder, or any other parameter for dough consistency control, it is necessary to observe many experimental mixings using the

actual mixer in question before the significance of the results can be usefully used. Unfortunately, there are few biscuit dough mixers that are equipped with a dough temperature sensor that allows the mixing to stop automatically when a desired temperature is reached.

27.5 Dough piece forming

Dough sheeting is another very critical part of the process. The dough must be supplied in a suitable quality for the sheeter to produce a continuous homogeneous sheet with a smooth surface. Thus a dough of acceptable consistency and quality as judged at the end of mixing may produce inferior biscuits if the handling of that dough before sheeting is variable or careless.

Dough at about 40°C should be protected from cooling, used without delay and scrap dough should be intimately mixed with it in the sheeter or metered in some other way. This is discussed more fully in Chapter 35. It may be necessary to heat the steelwork of the pre-sheeter, sheeter, gauge rolls, etc., to avoid chilling of the dough and the bakery air should not be allowed to chill or skin the dough surface at least prior to sheeting. As has been shown, the dough consistency is very temperature dependent, chilling or cooling makes the dough much firmer and the gluten less extensible. On standing, a semi-sweet dough tends to lose its extensibility but a small amount of remixing usually revives the dough. The standing time before use of a dough should be not more than about 30 minutes.

The movement and treatment of the dough in the sheeter is a matter for some consideration. A certain amount of churning will be beneficial to the dough (in the form of a remix) but if severe rolling and tearing of the gluten occurs, it is possible that a poor sheet will result. Most three-roll sheeters cause serious rolling of the dough in the nip under the hopper because the surface of the two rolls is dissimilar. Poor incorporation of cutter scrap dough, especially if it is cold, will ruin the new sheet. Ideally, the sheeter hopper should be maintained at a low constant level but most sheeters are bulk fed from a deep hopper. Varying dough level in the hopper will tend to cause variation in the performance of the sheeter (the sheet will vary in thickness or the speed of delivery will change due to variable extrusion). Obviously dough of variable consistency will also affect the sheeter performance.

Normally, a three-roll sheeter is used to compact and to form a continuous sheet of dough. If, however, a laminator follows the sheeter, a large rolled two-roll sheeter may perform adequately. Holes or imperfections in the sheet will be lost as the dough is laminated. Following the sheeter there should be two or three pairs of gauge rolls before a sheet at the correct thickness for cutting is formed. Typical sheeter and gauge roll settings are given in Table 27.2, where it will be seen that reductions of not more than 2.5 to 1 should be set at each gauge roll. Preferably the reduction at the final gauge roll should be not more than 2:1. Too great a reduction may cause distortion and damage to the dough structure which will affect the development during baking and also the biscuit shape. The cutter scrap may either be mixed in with dough in the sheeter hopper or be sheeted separately and fed in as a continuous sheet under the feed to the first gauge roll.

Sometimes the dough will tend to adhere to one or other of the gauge rolls such that release is difficult and the dough surface is spoilt. There are some techniques to overcome this. An air blower to skin the dough before the gauge rolls is frequently

Table 27.2 Typical cutting machine settings for Rich Tea biscuits

Sheeter settings:	Forcing gap	18.0 mm
	Gauging gap	9.0 mm
1st gauge roll		5.7 mm
2nd gauge roll		2.2 mm
Final gauge roll		1.1 mm
Final dough sheet thickness at cutter		1.3 mm

sufficient but failing this a light flour dusting may be necessary. Flour dusting will tend to dull the surface of the baked biscuit. If the speed of the two rolls doing the gauging is altered so that one has a slightly higher relative speed, it is usually found that the dough adheres preferentially to the faster roll. There has been much controversy and experimentation with the nature of the roll surfaces to prevent dough sticking. Some form of low-friction coating like Teflon (polytetrafluoroethylene) helps but also tends to interfere with the grip of the rolls to give smooth and regular rolling. The best surface seems to be a lightly ground (or sand blasted) surface. An intimate contact of the dough with the roll may be reduced with this surface, resulting in better release than on a polished steel roll.

Semi-sweet doughs exhibit a certain amount of elasticity so the correct biscuit shape can be achieved by allowing a relaxation of the dough prior to cutting. This is usually achieved by rippling the dough onto an intermediate web or onto the beginning of a long web prior to cutting (see Fig. 27.5). The shrinkage of the dough sheet which is almost totally in the longitudinal, machine, direction, does not cease until the biscuit is set in the oven so the exact amount of relaxation to be provided prior to cutting cannot be judged until the biscuits leave the oven. The relaxation also results in some thickening of the dough sheet so the setting of the final gauge roller is always less than the thickness of the dough sheet at the cutter.

It will be appreciated that the relaxation of the dough before cutting offers a quickly adjustable means of controlling the biscuit shape. However, this is possible only if a condition somewhere between maximum and minimum relaxation is the norm. In the author's experience most operators run with maximum relaxation so no control is possible. The reason for this is probably twofold: the relaxation web is not long enough, especially in long and fast plants, and the dough is too elastic due to the strong gluten situation. There is a need for plant suppliers to reconsider the time for dough relaxation that is provided.

The density of the dough increases from mixer to cutter as each successive amount of compression is applied. For a given recipe and plant the density at the cutter is surprisingly uniform so the dough sheet thickness is closely related to the weight of the cut pieces. For a given set of relaxation conditions, the weight of dough pieces is controlled by the gap of the final gauge roll pair.

Unlike soda crackers and some cream crackers, semi-sweet biscuits are almost always cut with a complete surround of 'scrap' dough. This is lifted clear and returned to the sheeter (or sometimes the mixer) for reincorporation. As will have been appreciated, this dough is more dense and often cooler than the fresh or virgin dough. Satisfactory incorporation of this scrap dough therefore presents a processing problem.

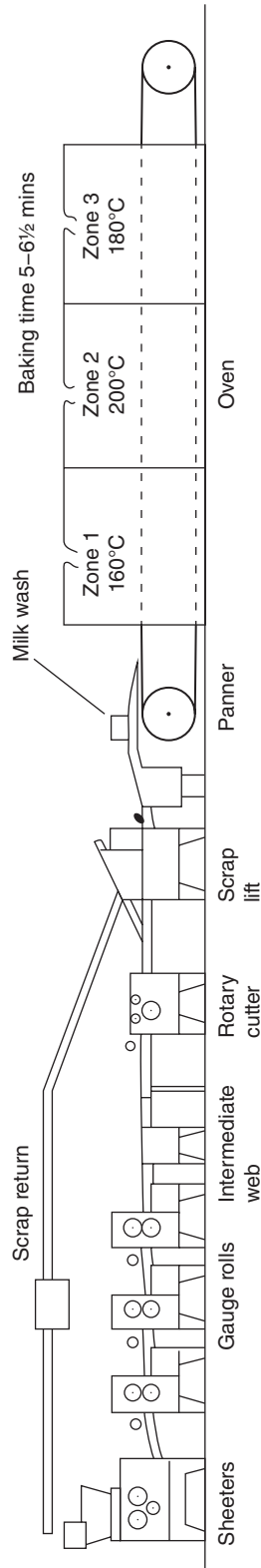


Fig. 27.5 Typical semi-sweet biscuit-forming machinery.

Semi-sweet biscuits are always dockered and usually bear a name and pattern stamped into the surface. With a reciprocating cutter this docking and printing is made at the same time as the cut of the outline. As the cutter rises, an ejector plate rests on the dough surface to effect a clean release. If the dough surface is rather sticky, the cutting web should be dressed with oil or water to encourage adherence to it rather than the cutter but an air blower over the dough surface to gently dry or skin the surface may be sufficient. Rotary cutters do not have ejector plates. In many cases a single roll will adequately perform the docking and cutting in one operation but it is better to separate the two operations with two separate rollers. The first roll pins the dough to the web by printing the pattern and piercing the docker holes, the second cuts the outline. Synchronisation of the two rolls ensures that the two operations are in correct register. The functions of the two rolls mean that when the cutting is commenced it is necessary to set the correct pressure on the docking roll before the cutting roll is lowered.

After cutting, the scrap is lifted away. Usually this web of scrap is not adhering strongly to the cutting web so with only gentle tension it comes away in a continuous lattice. However, some doughs tend to adhere rather strongly to the cutter web or the dough is too weak to apply much tension. In these cases, the operation is aided if a transfer of the dough from one web to another, over a nose piece which pulls the cutting web sharply away, is necessary. This releases all the dough and then the scrap can be lifted away cleanly.

Following the cutting operation the dough pieces may be garnished with sugar or other granular material or washed with milk or an egg/milk mixture to enhance the gloss and appearance after baking. Most semi-sweet biscuits are not garnished at all but if any sort of surface dressing is applied, care must be taken not to spill the dressing onto the panning web, otherwise either the oven band or the subsequent performance of the panning web will be impaired.

27.6 Instrumentation of the forming machine

In semi-sweet dough piece formation, weight and dough stress are the important parameters affecting the final biscuit parameters. To achieve consistent processing, not only must the dough be as uniform as possible coming from the mixer, and this implies a controlled standing time prior to sheeting, but also the performance of each forming machine must be constant.

The problem of uneven sheeter performance has been discussed. To compensate for variations in the sheet thickness coming from the sheeter combined with the difficulty of setting precisely the feed to the first gauge roll, two devices have been used to maintain control automatically. One is a dough thickness or position gauge which monitors the dough at the in-feed of the first gauge roll and alters the feed appropriately; the other is a gauge roll power monitor which detects the over- or under-feed condition to the rolls and also alters the feed to maintain a constant condition. These two systems are described in more detail in Chapter 5. With these controls near the beginning of the forming machinery, further control is less necessary. Similar devices can be used to control the feeds to subsequent gauge rolls. No satisfactory in-line dough piece weight monitor seems to be available so control of biscuit weight relies on communication following measurements after baking.

27.7 Baking

Details of changes that occur during baking are dealt with in general in the section on baking (Chapter 39). Lift, or the development of biscuit structure, is a result of gas released from the leavening chemicals and the expansion of water vapour as the temperature rises. The biscuit can be up to 4–5 times thicker than the dough piece entering the oven and the moisture content is reduced from about 21% to less than 1.5%. As moisture removal, to a relatively low level, is necessary to avoid the condition known as checking when the biscuit cools, it is normal to bake semi-sweet biscuits on wire-type oven bands. However, Marie biscuits and sometimes other thin types are traditionally baked on steel bands. The baking times are normally between 5 and 6.5 minutes and typical baking temperatures are shown in Fig. 27.5.

A prerequisite for semi-sweet biscuits is a smooth surface of even, fairly pale colour with a sheen. The smooth surface and even lift is determined by the condition of the dough surface after sheeting and gauging. The sheen can be enhanced by passing steam into the front of the oven to increase the humidity of that section so that it exceeds the dew point at the dough surface. This allows a film of moisture to be deposited which becomes a sheen when it dries out later in the oven. However, excessive steaming may cause a mottled colouration of the biscuit surface and fine blistering.

At the oven exit, checks must be made to determine whether the biscuit size, shape, colour and moisture are within the limits set for quality and packet specifications. By no means everyone has automatic measurement facilities at this point of the process so it is usually a requirement that the baker makes frequent checks of biscuits taken off the band. The weight, width, length, thickness and colour are measured and checked against statistically calculated limits. These measurements should be recorded in such a way that trends can be assessed and evidence is provided of when plant adjustments were made. This is an important point for process control checking but all too often measurements are made infrequently. Rarely are checks made more than four times per hour and if one realises that a typical batch of dough lasts for about 15–25 minutes it can be seen that the effects of beginning and end of dough batches can be missed. When continuous automatic measuring is available, the pattern of variation may permit better understanding of causes and hence the design of control loops for the oven or forming machinery as appropriate. Colour measurement (the reflectance value or darkness) of the top surface of biscuits can be made continuously; however, colour on both top and bottom surfaces is important and as yet the underside seems to be neglected.

‘Checking’ is a potential problem for semi-sweet biscuits. In order to prevent this it is necessary to bake to a low overall moisture content or to cool the biscuits carefully. In cases of persistent problems and also to decrease the baking time and thus to increase productivity, a dielectric drying unit may be used immediately after the oven. See Section 40.2 for a deeper discussion about the causes of checking.

27.8 Flavouring of biscuits

The large amount of moisture that is lost during baking of semi-sweet biscuits and their low final moisture content make it very difficult to flavour these biscuits. Volat-

tile flavouring materials added to a mix are driven off in the oven. One technique that may be considered is to oil spray with a flavoured oil soon after the oven exit. The biscuits must be hot enough to allow the oil to soak in but not so hot that the flavours included in the oil are volatilised. There is a potential problem that the cooling conveyor webs will become contaminated with oil and flavour but the use of plastic webs allows good cleaning at the end of a run.

27.9 Cooling and handling of biscuits

Semi-sweet biscuits usually strip easily from the oven band because they are rigid even when hot. If they do not strip easily after baking on a steel band, a number of causes could be responsible but the use of a drier dough often prevents the problem. It is usual to let the biscuits cool in air before collating for packaging. Cooling conveyors are typically two or three times as long as the oven and because regimentation should be maintained to facilitate stacking prior to handling, the cooling conveyors are normally the same width as the oven band. To save space these conveyors may be in two or more tiers. If it is necessary to take the biscuits around bends, special conveyors are required to maintain the regimentation as closely as possible (see also Section 40.3).

For high-capacity plants very close attention is needed to the biscuit handling up to the wrapping machines so that the transfers can be made with minimal human intervention and breakage. It is common to reduce, to a convenient and compatible number, lanes suitable for the feeds to the wrapping machines. However, these features are common to most biscuits and not especially for semi-sweet types. A number of plants have forced cooling of biscuits which have been stacked immediately after stripping from the oven band. This arrangement saves much space.

27.10 Continental semi-sweet biscuits

As mentioned earlier there is a group of biscuits within the broad category of semi-sweet types that are mixed in a two-stage process and are like over-mixed short doughs. Biscuits of this type are commonly made in France, Germany and Switzerland where the British type with warm extensible doughs is not found. It is for this reason that the author has named them 'continental' semi-sweet biscuits (Figs 27.6 and 27.7).

These recipes are similar or perhaps slightly higher in fat level but they are mixed by a two-stage process similar to short doughs. All ingredients except the flour are firstly mixed up to a homogeneous 'cream'. The flour is then added and a second mixing proceeds for only a few minutes. The dough is then rested for between 30 and 90 minutes, to reduce the stickiness, before sheeting and gauging in a similar way to that described above. The formulation sometimes includes proteinase and this requires at least 60 minutes standing time for the enzyme to react with the gluten. The dough is not normally laminated. Sometimes SMS is used instead of proteinase but the dough is always quite short and inextensible.

These doughs tend to be sticky which makes them more difficult to process through gauge rolls and a good smooth surface may be achieved prior to cutting by ensuring that at least the final gauge roll is very clean (special wiping arrangements



Fig. 27.6 Butter biscuits.



Fig. 27.7 Prince biscuits.

using damp pads are not uncommon) and the dough pieces are often brushed with a milk wash to enhance surface appearance after baking. The resultant biscuits are softer and shorter in texture than traditional British semi-sweet types and the surface is not as smooth. With the controversy or prohibition of the use of SMS in some countries and the difficulties of mixing described earlier, this version of semi-sweet biscuits provides a useful alternative method of processing for products with low sugar and fat recipes.

27.11 Garibaldi or fruit sandwich biscuits

The extensible nature of British type semi-sweet dough makes it suitable for containing, in a dough sandwich, a filling of fruit. When this fruit is currants, the product is called Garibaldi. Garibaldi biscuits were introduced by Peak Freans in London in 1861. How the name was derived is unclear. The process is quite difficult to perfect and it is important that very little fruit is allowed to break through the top and bottom dough layers, otherwise it dries too much in the oven and a tough leathery product is produced after baking.

Essentially, two dough sheets must be produced and a filling of fruit introduced before final gauging. To make the currants more free flowing and thus easier to spread as a uniform carpet, sugar may be mixed with them. The added sugar also

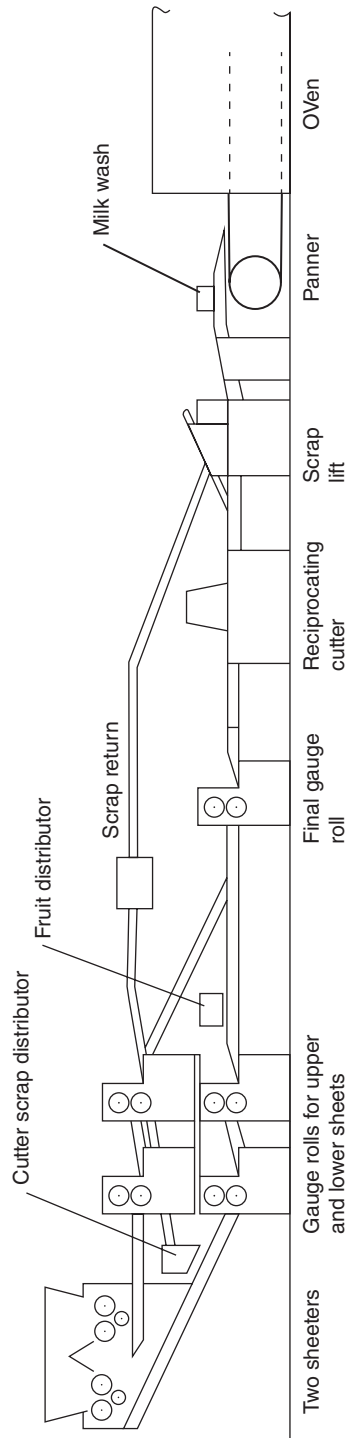


Fig. 27.8 Typical Garibaldi biscuit-forming machinery.

improves the eating quality of the baked biscuit. The dough sheet at the cutter is not much thicker than an Osborne semi-sweet type and difficulty is often encountered in obtaining an even, almost complete, fruit layer which is well enclosed in the dough.

There are at least three different forming systems for introducing the fruit between two sheets of dough, but the most successful way is to have two sheeters, each with two pairs of subsequent gauge rolls, to give dough sheets about 3 mm thick. A carpet of fruit is spread evenly over the lower sheet (this is an engineering challenge!) and the top sheet is then laid onto the fruit and reduction to the final sandwich thickness should be achieved with one further pair of gauging rolls. If more than one gauge roll is used after compressing the fruit and the dough together, there is an increased chance of the fruit breaking through the dough causing poor biscuit quality and sticking to either the gauge roll or the cutter. Obviously, the dough must be in a good extensible condition to contain the fruit, and the feed to the final gauge rolls must be controlled very carefully. It is almost essential that small currants (see Section 15.2.1) are used as larger fruit will be broken in the gauging.

Garibaldi must be cut to have minimum scrap as fruited dough is very difficult to reuse; it is either incorporated into the lower sheet of the sandwich or must be returned to the mixer to be incorporated with a new dough. Garibaldi is usually produced as slabs with only a minimal amount of edge cutter scrap. With care this can be fed back onto the lower dough sheet prior to its first gauging. Good quality Garibaldi will have about one-third of the product as fruit. Too much fruit will give a tough biscuit, too little will give a hard dry biscuit. The ratio of dough to fruit also has a very great effect on the baked biscuit thickness, therefore it is important to keep the spread of fruit even prior to making the sandwich.

Broken currants are exceedingly sticky and it is common to have trouble with sticking at the cutters. Some flouring of the dough surface prior to cutting helps but as for other semi-sweet types, excess flour spoils the baked biscuit appearance. Reciprocating cutters seem to be more reliable than rotary types with this dough. Even so it is best to have a spare cutter block so that a change can be made quickly in the event of a jam-up. The cutter produces strips which can be separated as they are panned onto the oven band but lateral separation must be carried out after the oven. Various cutting devices can be used but the stickiness of the hot slabs and the toughness of the cooled biscuits both present problems for cutting. A Garibaldi layout as described here is shown in Fig. 27.8.

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Short dough biscuits

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Abstract: Sales of biscuits included in this broad group far exceed all others in the markets of developed countries. Short dough, which lacks extensibility and elasticity, is preferably made with a two-stage mixing method. After mixing, dough pieces can be formed in several ways before they are baked. During baking, the dough pieces often spread, the extent of which depends on the recipe used, the flour, sugar and fat characteristics, the dough preparation and the applied oven conditions.

Key words: short dough biscuit making, mixing, dough piece formation, baking, cookie spread.

28.1 Description of the group

Products in this group are distinguished from others in that they are made from dough that lacks extensibility and elasticity. Wheat flour or some other farinaceous material is the major ingredient but the quantities of fat and sugar (some in solution) present in the dough create a plasticity and cohesiveness of the dough with minimal, if any, formation of gluten network, that is, it is short. The structure of the baked biscuit consists of a mixture of protein, starch and sugar glass (supercooled molten sugar). It has been stated that there is no continuous protein matrix (at least in those made from good quality soft wheat flour) and that the fat is present in the form of large globules or of larger interconnected masses between the starch protein masses. The texture is typically relatively coarse as there is much coalescence of the gas bubbles that form during the baking [1].

The features of the doughs of this group result in biscuits which tend to become larger in width and length as they bake rather than shrink as is the case for crackers and semi-sweet types (Figs 28.1–28.7). Control of this increase in size or ‘spread’ is the biggest single processing problem and will be dealt with further on (see Section 28.7). Short doughs can be seen from Fig. 21.1 to encompass the largest range of recipes of any biscuits and not surprisingly sales of biscuits included in this broad group far exceed all others in the markets of developed countries. It is possible to make rough divisions such as fat rich, sugar rich, lean, etc., but these are impossible to define sufficiently to allow descriptions as sub-groups. Boundaries with other basic groups of biscuit are also blurred. For example, continental semi-sweets (see



Fig. 28.1 Digestive biscuits.



Fig. 28.2 Shortbread biscuits.

Chapter 27), because of the way in which the doughs are prepared and handled, may be considered as short dough products. At the other extreme, fat and sugar-rich doughs, which are very soft doughs and possibly pourable, are different mostly in their consistency rather than related to the recipes. It is better to sub-divide short dough biscuits based on the method of dough piece formation (see Section 28.4).

While the use of the term 'cookies' varies in different countries, for the sake of this account all types will be referred to as biscuits. Figure 21.1 assumes that the majority of the cereal present in the recipe is wheat flour. If, however, a non-gluten producing flour or starch predominates, it is possible to form short doughs at much lower levels of fat and sugar than those shown.

In addition to the fat-rich shortbread and sugar-rich gingernut types which are included in this group, most creamed biscuit shells like custard and bourbon and many famous traditional brands such as Digestive, Granola and Lincoln, are short dough product types as well. Types low in fat are popular for chocolate coating but,



Fig. 28.3 Voultimara biscuits.



Fig. 28.4 Miranda biscuits.

as the fat content of the dough increases, there may be problems of fat migration that gradually spoils the quality of the chocolate making it softer and more sticky (see Section 41.5.8).

The nature of dough allows the impression of complex and intricate designs on the surface of leaner varieties so that their appearance can be very different from



Fig. 28.5 Hobnobs biscuits.



Fig. 28.6 Glucomalt biscuits.



Fig. 28.7 Fruit shortcake biscuits.

biscuits in other groups. Good examples are the designs on Custard Cream and Oreo shells or Lincoln biscuits. Richer recipes spread during baking and some of this definition is lost. Biscuits are rarely made at home now but those that are will almost certainly be short dough types. To a certain extent, this reflects the ease of mixing and forming but irregular shapes and sizes are valued as a virtue of 'home made' products.

28.2 Recipes and ingredients

As the sugar and fat levels are relatively high in short dough recipes, the quality of these ingredients is of utmost importance. At the dough stage, gluten is of rather low importance so, with reasonably high levels of sugar and fat present, the protein content and quality of flour is of low significance. However, the water absorption characteristics of the flour are important and, as high protein flours usually have high water absorptions, the flour type may have a bearing on dough quality. Indeed, higher (gluten) protein levels increase dough hardness and decrease its stickiness.

The method of forming dough pieces is determined very much by the consistency and stickiness of the dough. Many short doughs are formed with a rotary moulder. Generally, such machines cannot handle soft doughs. Short doughs with the highest levels of water compatible with a consistency suitable for the chosen method of dough piece forming can produce the most delicate textures after baking.

It can be seen from Fig. 21.3 that the water levels in most short doughs preclude the total solution of sucrose present, so the crystal size of the sugar is an important quality aspect for the texture of the baked biscuit. At a given ratio of water to sucrose, smaller crystals will dissolve preferentially in the dough and large crystals may give a crunchy or gritty eating texture.

As regards the quality of fat used in these recipes, the flavour will come through to the biscuit and this may or may not be a good thing. Tallow and lard are supposed by many to have desirable flavours in biscuits, but any slight rancidity or natural flavour reversion associated with fish oil, for example, must be avoided. Butter is a common fat used in short dough biscuits because of its unique flavour. However, the most commonly used fats now are blends of various vegetable fats that, in fact, are also used for other types of biscuits. These fats are very bland in taste. The use of antioxidants to retard fat rancidity may be useful if the supply of fat or the packaging of the biscuits is not first class. The solids content of the fat at mixing affects the cream-up phase and, hence, the dough density and subsequent machining. In this context, the solid fat index (SFI), which principally is related to the temperature, is an important fat specification. If rotary moulded, the doughs with lower fat solids give higher dough piece weights. Indeed, in cookie dough making, (solid) fat is essential for air incorporation [2]. It is recommended that there are at least 15–20% fat solids at the dough temperature but the D_{20} should not be more than 650 μl , (microlitres) otherwise fat bloom may occur on the biscuit surfaces during storage.

Preparation of short doughs requires good dispersion of the fat/syrup phase over the flour particles, so the physical condition of the fat is also important for this. Not only the level of solid fat, but also its crystal size at this stage is claimed to be important (see Section 12.2). It is usually best to prepare a fat/water/sugar/syrup,

etc., emulsion before adding the flour. A stable emulsion is not easy to prepare if the fat solids content is too high or very low. Preparation of the emulsion and also the effectiveness of the fat to form a soft eating biscuit are aided if certain emulsifiers are used at appropriate levels. The function and use of these is described in Chapter 13.

The baking temperatures and times are not excessive and the amount of water that has to be removed is relatively low so the conditions for steam distillation of volatile aromatics during baking are much less harsh than for semi-sweet biscuits or crackers. There is thus considerable scope for varying the flavour of short biscuits. Clearly, the choice of natural and artificial flavours is limited to those which are associated with sweetness. Common examples are vanilla, butter, caramel, spices like ginger and cinnamon, lemon oil and cocoa. Strong flavours from dark cane sugar syrups and malt extract can be blended with the mellow creaminess of milk and butter. In all cases, salt is used as a flavour enhancer. Also, the nature of the dough allows inclusions of pieces of chocolate (chips or drops), dried fruit or pieces of nuts, etc. Garnishing on the surface with sugar of different crystal size or nut pieces is a common feature.

The quality control of raw materials for short doughs is associated predominantly with dough consistency and spread during baking from the processing point of view and flavour from the eating viewpoint. Spread, being such an important subject, is dealt with separately later in this chapter (see Section 28.7) and the specifications of certain ingredients will be clear from these considerations.

28.3 Dough mixing

Although the water level in these doughs is low, it is possible to develop gluten if the kneading action of the mixing is excessive. To produce the best quality of biscuits, the amount of mixing after the flour has been added must be at a minimum. Therefore, the challenge is to achieve adequate dispersion of ingredients with minimum kneading when the flour has been added. As mentioned above, this is normally done by a two- (or more) stage mixing procedure when a 'cream-up' is made first to dissolve (part of) the sugar and to emulsify the fat, milk, eggs, etc., before the flour is introduced.

In a typical two-stage mixing all the ingredients except the flour are placed in the mixer and, at gentle speed, mixing proceeds for several minutes. The objectives are to dissolve as much of the sugar as possible in the available water, to disperse and dissolve the milk solids, chemicals and flavours and to emulsify the whole with the fat. The result should be a semi-stiff white 'cream' which supports any undissolved sugar and all the water. The flour is then added to this cream and mixing proceeds again at a gentle rate for a period calculated to be the minimum to get reasonably uniform dispersion of the 'cream' over the flour. This stage is known as the 'dough-up' and will give, at one extreme, a more or less crumbly dough which can be pressed into a sheet or moulded with a rotary moulder or, at the other extreme, a soft plastic mass suitable for extrusion on different types of machines. The second stage of mixing is desirably completed in less than one minute and it is hoped that, in this time, a homogeneous mixture will have been formed with, thus, very little opportunity for hydration of the flour protein and the formation of gluten.

In all cases, at the completion of mixing, the dough will appear softer than it is after standing. During a standing period, water (the sugar syrup) will be absorbed by the starch and protein, etc., in the flour and the dough will appear to dry out and become less sticky. In fact, the dough does not dry out, that is, it does not lose water to the atmosphere, so 'drying in' may be a better way to describe this phenomenon. The hydration of the flour is a very important stage and must not be hastened by over mixing. It is probable that the hydration continues over a very long period, but the changes are most noticeable in terms of consistency change and loss of stickiness over the first 30 minutes. After this time, it is normally satisfactory to use the dough on the forming machinery. If the dough is not stood for 30 minutes or so, it is probable that toughening will occur due to agitation (working) in the sheeter, moulder, etc., which will result in harder, and maybe distorted, biscuits.

From the process-control point of view, obtaining correct dough consistency is both important and elusive. It is difficult to be sure, from an assessment at the end of mixing, how much the dough will tighten up on standing and there are no entirely satisfactory tests for consistency due to the effects of stickiness as distinct from softness. Furthermore, if the dough is considered too soft or too dry at the end of mixing, it is usually not satisfactory to add more flour or more water at this stage as the extra mixing then required will change the dough character very markedly.

Dough consistency is of course greatly affected by temperature, as it affects the degree of dissolution of the sugar, the viscosity of the syrup so formed and the level of fat solids present. It is therefore necessary to arrange conditions so that the temperature at the end of cream-up is constant and not too high, and also so that, after the flour has been mixed, the dough is at a given temperature, $\pm 1^{\circ}\text{C}$, and preferably within the range $18\text{--}22^{\circ}\text{C}$.

During cream-up, air becomes entrained in the emulsion but it does not seem useful to strive for any particular density of this mixture. This is unlike the control required for fat/sugar mixes for biscuit creams or sponge batter production. Boxed dough fat is usually aerated, to improve the apparent colour and to reduce the consistency at a given temperature, but the density of this has not been demonstrated to have a significant effect on either the dough or the baked biscuits. However, as mentioned before, higher levels of (solid) fat significantly decrease dough piece weight due to air incorporation when a creaming stage is used. Generally, dough piece weight relates well to cookie weight.

Attention should be drawn to studies of dough consistency measurement made by Steele [3, 4] and also of factors affecting consistency (of unsweetened short doughs) by Hodge and Barnes [5]. The latter showed that the type of mixer used to incorporate the flour is significant for the consistency and the quality of the resulting baked product. Minimum work on the flour was confirmed to be desirable. A difficulty in consistency assessment is that the tightening that occurs in short doughs on standing is due both to absorption of the water by the flour particles and by a thixotropic tightening. The latter is reversed when the dough is agitated again in the sheeter or rotary moulder. The length of mixing for cream-up would not seem to be critical and is probably best achieved with a high-shear mixer. In contrast, that for the second stage is very critical and best with low-speed high-cutting, low-kneading, action. Batch mixers rarely offer both optima for both types of action.

A mixer curve of power measurement is valuable to assess the optimum point for the second mixing stage, but observation can also tell when the dough has just

become homogeneous. The dough at this stage is very short and, in some cases, is too short for satisfactory extraction from a rotary moulder. In these cases, a little over mixing can help the performance of the rotary moulder. Where ingredients with large particles like dried fruit, nuts or chocolate chips are to be included in the dough, it is best to add these at a late stage, i.e. after the flour has been partially incorporated and to mix for just long enough to give even dispersion.

All-in or single-stage mixing is not uncommon for short doughs. It will be appreciated that, although doughs can be made in this way, the potential for delayed sugar solution and toughening due to the prolonged mixing required to achieve adequate dispersion of all the ingredients, is greatly increased and thus lower quality biscuits must be expected. Under these conditions, it is essential to use a well-plasticised fat and liquid sugar. All-in mixes of short doughs normally require about 10% more water than two-stage mixes.

Scrap dough and milled biscuit scrap are commonly included in short dough mixings. Any rework material will complicate process and quality control problems, but, when scrap is to be used, it should be added at the beginning of mixing, in the cream-up, to ensure maximum dispersion. Control of spread and texture can be achieved by the length of the dough-up mixing and also by altering the stage at which sugar or syrup is added. The effect of such changes must be found by trial and error.

28.4 Dough piece forming

Short dough is formed into pieces for baking in a number of different ways. In order of importance, the main methods are:

1. rotary moulding
2. wire cutting
3. extrusion, including co-extrusion
4. sheeting, gauging and cutting.

The details of the performance of rotary moulders, wire cut and extrusion machines are described in Chapters 37 and 38. All of these machines are alike in that, when forming biscuit pieces, no scrap dough, which must be recycled, is formed. Moulders can use relatively dry and crumbly dough but much softer dough consistency is needed for the other types.

Sheeting, gauging and cutting of short dough is essentially the same as for cracker and semi-sweet doughs. Compression in a three-roll sheeter is necessary to form a complete and supportable sheet. It is usual to follow the sheeter with only one gauge roll as, each time a reduction is made, the thinner sheet is progressively more difficult to support from the roll and over web transfers. There is, of course, very little elasticity in the dough, so shrinkage before cutting is not a processing problem. Cutting with a rotary cutter may be similar to that for semi-sweet biscuit dough in that docking and imprinting of a name or simple pattern can be performed before the outline is cut. It is undesirable to attempt this with a single rotary cutter as the dough tends to be sticky. More usually, the dough piece is embossed with a deep pattern and there are no dockers. It is much less satisfactory to attempt this with a rotary cutter and an old-fashioned reciprocating cutter with embossing is usually used. Rotary moulding is far superior for this operation.

After the sheet of dough has been cut, there is a problem of separating the surrounding scrap dough. Due to the fact that dough pieces spread during baking and that the dough is short and difficult to lift away from a web, the amount of scrap is usually much greater than for cut hard doughs. This gives significant cutter scrap recycling problems. To aid the removal of cutter scrap from the cutting web, special fingers are often needed to effect the transfer onto the scrap conveyor web. Apart from the fact that small cracks in the dough often upset the stability of this operation, it is important to have a clear line of scrap which the fingers can follow. For round dough pieces, this means that a staggered configuration is not possible. This also contributes to a large percentage of scrap dough following cutting. If the dough has been over mixed, the lifting of the scrap dough may be easier because it is tougher and more cohesive.

Scrap dough is more dense and more worked than fresh dough, so incorporation of this scrap with the fresh dough can be critical. It is because of these difficulties in handling cutter scrap dough that rotary moulding is much more popular. However, there are some advantages of the sheeting and cutting method for short dough. Weight adjustment is much more flexible than with a rotary moulder and, if desired, various garnishing materials like sugar or nuts can be spread prior to the cutter and pressed into the surface. The dough pieces are of very flat profile, having been derived from a sheet, and wedging does not occur (pieces thicker at the back than at the front) as is common from a rotary moulder. It is possible to handle doughs that are coarser and more sticky than is possible with a rotary moulder. Doughs which contain dried fruit are less satisfactory in a rotary moulder as the knife cuts the fruit leaving dark and sticky areas. By sheeting and cutting the fruit is damaged much less.

On the whole, the advantages of a rotary moulder outweigh the disadvantages. Therefore, sheeting and cutting of short doughs is becoming rare. For rotary moulding, less equipment is needed but there may be problems of extraction from the moulds. A somewhat critical balance must be made between the stickiness of the dough and the adhesive nature of the moulder extraction web. If the dough fails to adhere to the web, it will not come out of the mould cleanly (if at all), if the dough is so dry that it leaves the mould easily, it may fall out underneath the moulder before the web can carry it away.

Too soft a dough will extrude past the moulder knife and, when it is pressed onto the extraction web, a tail of flattened dough will form on the web behind each piece. Much of this is removed when the piece is transferred from the extraction web to the next conveyor, but often some remains attached to the trailing edge of the dough piece to form a 'tail'. Baked-on tails, apart from looking unpleasant on the biscuit, may create biscuit handling and packaging problems. As doughs with higher water levels tend to give better baked textures, sheeting and cutting may be an advantage in these cases.

A different set of process control problems is presented if the dough is wire cut. These doughs are usually softer and the process involves continuous extrusion through specially shaped dies. At intervals, a taut wire is passed quickly across the surface of the die, cutting off the dough which has been expressed. The pieces fall onto a conveyor, usually the oven band. The rate of extrusion is affected by a number of factors including dough consistency but, typically, the main problem is uniformity of weights across the width of the machine. There are various devices built into the dies to control these weights but, at present, operation of balancing the weights is more of a skill than a science!

A rout press is an extrusion machine very similar to a wire cut except that the extrusion of dough is continuous without any cutting taking place. The extrusions usually give flattened strips. These strips may then be cut into short lengths with a reciprocating cutter before baking and panning onto the oven band separates the pieces. Sometimes, the strips are baked as continuous lengths, being cut after baking.

Other extrusion machines are designed to co-extrude two doughs or dough with a filling material within it. The simplest form is the fig bar which, like the rout press, produces a continuous rope which is cut before or after baking. Other co-extruders are much more sophisticated and produce lengths or balls that have the filling more or less sealed within the dough. These extruders require soft fat-rich doughs with very short characteristics to allow ease of cutting. Co-extrusion techniques involving two different doughs have allowed the production of products with a dichotomy of texture, referred to as crisp and chewy. The technology for these uses the crystallisation characteristics that different sugar syrups display at different concentrations.

28.5 Instrumentation of the forming machine

The most important aspect of the forming machinery is to create pieces of uniform weight both in line and across the oven band. Stresses in the dough are less important than in leaner recipes from the point of view of biscuit shape. Variations of consistency and pressure alter dough piece weight because the dough density is affected. Thus, dough mixing and dough temperature are where most control must be effected. As yet, there is no reliable method of automatic in-line weighing of dough pieces, so uniform performance of the forming machinery is the best way to control weight.

It is therefore desirable to control the height and, thereby, the static pressure of dough in the hoppers of rotary moulders, extruding machines and sheeters. This may be achieved by using level detectors coupled to dough feeders. Dough is called from pre-sheeters and it is best to kibble (break into small pieces) it, if possible, before it falls into the hoppers. Optical thickness gauges can be installed to detect variations in the thickness of the dough pieces, but there are great difficulties in measuring the very small variations that occur. There is an underlying assumption that the dough density is constant. However, it should be remembered that this, in turn, is related to consistency and pressure on the dough. Thickness gauges should constantly reference the surface of the dough piece to the position of the conveyor.

Sheeted and cut doughs are very dependent on the uniformity of scrap dough inclusion. A separate sheeteer to form and meter the scrap dough is often a good solution. As there is considerable pressure applied to the dough at the gauging rollers, attempts to finely control the feed to the rolls should be considered.

Biscuit length is sometimes not correct relative to width. Although short doughs should be considered non-elastic, it is possible that slight recovery occurs in a length direction after cutting or moulding. There is a very small facility for stretching or compression in the lengthwise direction by adjusting the transfers from one web to another or from the panning web to the oven band. In addition, there is also a very useful facility of a small adjustment of the speed of the cutter, when rotary cutting, relative to the cutting web to achieve adjustment of the length. This is of course not available with reciprocating cutting. One can thus envisage a time when

a signal from a monitor of biscuit length after baking can automatically make this adjustment.

28.6 Baking

Baking causes an expansion of the dough to a cellular product with a desirable texture. In many short doughs, the rise of the dough piece in the oven is quite spectacular so that almost hemispherical pieces may be formed. Characteristically, this rise collapses back to a very modest thickness by the time the biscuit arrives at the oven exit. The collapse is due to the fact that the warm dough piece is rich in fatty sugary liquids which are viscous enough to allow containment of the water vapour but not strong enough to remain as a structure when the moisture is lost to the oven atmosphere. Slade *et al.* [6] rather related the collapse to the presence or absence of a (three-dimensional) gluten network. For cookies made with superior quality (soft wheat) flour, a macroscopic collapse is observed due to the lack of a thermoset gluten network. For cookies made with inferior quality (hard wheat) flour, a thermoset gluten network is present and elastic shrinkage rather than macroscopic collapse is observed. Associated with this collapse, often a cracking of the dough surface occurs. However, the latter has also been related to the recrystallisation of sucrose at the baking dough's surface [7]. Pronounced surface cracking patterns are, hence, particularly evident for sugar-rich cookies such as gingernuts. The fact that the viscosity of the dough reduces so much as it warms up, and that, at the beginning of baking, there is insufficient starch gelatinisation or a continuous protein structure to retain the shape, means that the dough piece tends to flow or spread both in length and width during baking. As was mentioned above, the amount of spread depends on a number of factors and because this phenomenon is so important in determining the final size of the biscuit, a special section is devoted to it below.

It is not necessary to reduce the biscuit moisture content to levels as low as in crackers or semi-sweets because stresses due to moisture gradients which can lead to checking and breakage are most unusual. Typically moisture levels are around 2.5–3.0%. As the dough moisture levels are also lower than in other biscuits, the amount of moisture to be removed during baking is lower also. Syrups and milk powders are often present at relatively high levels, so baking temperatures must be lower to prevent excessive surface colouration due to Maillard type reactions. The baking times are across a wide range and related to the thickness of the dough piece. The minimum is probably around 5 minutes, the maximum, for the likes of short-bread fingers, as high as 20 minutes.

Recipes which exhibit much flow during baking must be baked on a smooth steel band, but less rich varieties can be baked on wires. It is, of course, possible to bake faster on a wire band because the heat transfer is better, but the tendency for the dough to sink into the wire can cause severe biscuit stripping problems at the end of the oven and may soil the wire so that, on successive passes through the oven, particles of black, charred, crumb will appear on the base of biscuits as they are removed from the oven band. As may be expected, there is frequently a tendency for the dough pieces to stick on a plain steel oven band. This results from a combination of an unsuitable band surface which allows keying of syrups and the relative proportions of sugar, fat, eggs and milk solids. In some cases, it will be necessary to clean and treat the oven band to reduce the incidence of sticking. The treatments

may be in the form of continuous cleaning of the band with wires and fabric buffs or of light dressing with flour. Oiling is very effective for giving a discontinuity to prevent sticking, but it also encourages spread. Flour dries the band surface and itself also gives an interface that helps to reduce sticking. This surface also controls excessive spread. The problem of sticking to the oven band can usually be considerably improved by adapting the baking temperature profile. If the oven band or the temperatures under the band relative to those over the band are raised slightly, the incidence of sticking is usually reduced. This also helps to prevent a condition known as 'holey' bottoms or cavitation in leaner recipes. Hollow or holey bottoms are due to entrapment of gas under the dough piece early in the baking process. It may be due to air trapped there, because the dough pieces have been placed over a particle of sugar or crumb of dough, etc., but it usually signifies too tough a dough to allow spread as it heats up. Over mixing, insufficient standing time before working the dough in the sheeter or moulder, or unsuitability of the cutter or moulder to that recipe are possible causes. Leaner, tougher doughs need docker holes to release the expanding gases in an orderly manner. It has been claimed that a dough pH of less than 7.3 encourages holey bottoms.

Stripping or removal of the dough pieces from the band may be more difficult than in most other types of biscuit. At the oven exit, the biscuit is quite soft due to the molten sugar phase. It is necessary to allow this to cool and set to a certain extent before the biscuit is lifted or peeled off the band. A long run out after the oven is necessary but forced cooling in the form of air impingement onto the band surface or even water cooling under the band may be required. Biscuits that are stripped too warm may curl or be damaged at the front edges. The soft nature of the biscuit while it is hot may be used to effect some control of the thickness by using a roller to gauge excessively thick biscuits. This can be automated by using an optical thickness gauge and a servo-operated adjustment of the gauging roller.

28.7 Factors affecting dough piece spread during baking

Since the size of short dough biscuits is so influenced by the spread during baking, it is not surprising that much investigation has been carried out and much published on this aspect of biscuit making. A selection of references has been given [2,6,8,9]. The findings are summarised in Table 28.1.

A thorough understanding of the changes occurring in the oven is crucial, and may help to overcome processing problems. First of all, one should realise that the final cookie diameter is not simply the result of a continuous spreading of the dough piece in the oven, which only ends because it is removed from the oven. Already at the beginning of baking, when the dough is heated, the solid fat melts and the remainder of the crystalline sucrose progressively dissolves. This increases dough mobility and sugar syrup volume as the dissolution of each gram of sucrose per gram water contributes ~0.6 ml syrup phase [7]. As a result, and due to gravity, the dough starts to spread. However, after several minutes, at the so-called set time, the dough viscosity increases and becomes too high so that the diameter becomes fixed. Final cookie diameter, hence, depends on both the spread rate, which itself depends on cookie dough viscosity, and the set time. Higher spread rate and postponed set time result in larger cookie diameter.

Table 28.1 Factors that increase or reduce spread during baking

Factors allowing greater spread	Factors that reduce spread
<i>Factor related to flour in the formulation</i>	
Coarse flour particles	Higher flour water absorption value, including heat treated and chlorinated flours
Minimum mixing after flour addition	Over mixing of dough
<i>Factors related to sugar in the formulation</i>	
Sugar with low mean aperture size	Sugar with high mean aperture size
Increased quantities of crystalline sugar	Lower level of sugar
<i>Factors related to fat in the formulation</i>	
Soft doughs due to higher temperature	Cold doughs
More fat	Less fat
<i>Factor related to aeration in the formulation</i>	
High dough pH (more ammonium or sodium bicarbonate)	
<i>Factors related to dough age and dough piece weight</i>	
Very fresh dough	Old dough
High dough piece weight	Low dough piece weight
<i>Factors related to oven conditions</i>	
Greasy oven band	Flouring of oven band
Cold oven band at time of deposition of dough pieces	
Low temperatures in front of oven	Higher bake temperatures, faster bake

At the same time, due to heating of the air and evaporation of water present in the dough and to the production of carbon dioxide as the leavening agents decompose, cookie height increases. This continues even after cookie dough diameter has reached its maximum and, typically, towards the end of baking, a macroscopic collapse is observed (see Section 28.6). The degree to which those phenomena occur, largely depends on the (levels of) ingredients and the processing conditions used.

It is well known that the choice of flour has a bearing on the spread of short dough biscuits of a particular recipe. There has always been a feeling that weak flours are to be preferred but there is confusion on the meaning of weak in this context as is explained in the section on flours. The water absorption of strong flours is usually higher, but this is a combination of several factors. Amongst them are higher levels of protein, damaged starch and non-starch polysaccharides.

Very little attention has been given to flour particle size, which is a function of milling, and also the whiteness of flour which is related to the bran (ash) content. Flours with coarse particles or more bran exhibit delayed hydration. The slower hydration means that more mixing can occur in the second stage of the mixing before hydration is complete. The passive hydration that occurs while the dough stands is important in this connection.

The fact that the use of redox agents, such as sodium metabisulfite, or peptidase enzymes have practically no effect on the qualities of short doughs emphasises that, particularly at the dough stage, the protein quality of flour has (very) little importance in these recipes. This seems reasonable, since, due to the high fat and sugar

levels in the dough, flour particles and, hence, gluten proteins, are not properly hydrated, so that there is no continuous network [10]. However, during cookie baking, proteins are not functionally inert. Indeed, as the starch generally does not gelatinise because of high sugar and low water levels, and as the gluten is capable of undergoing its glass transition at temperatures and moisture levels relevant to cookie baking, the viscosity increase that precludes the end of dough spreading, has been related to the gluten proteins.

Doescher *et al.* [8] claimed that because of this glass transition, the gluten proteins become mobile and can entangle so that the viscosity increased and the dough is set. Slade *et al.* [6], on the other hand, stated that cookie dough does not set, but mentioned different behaviour for doughs made with good quality (soft wheat) flour and those made with poor quality (hard wheat) flour. The former show viscous expansion followed by structural collapse, while the spread behaviour of the latter is considered to be an elastic expansion followed by elastic shrinkage. These different spread behaviours would be diagnostic for elastic recovery in a thermoset polymer system and shrinkage above a network glass transition temperature (T_g), or for expansion by film formation (without significant functional network formation) followed by collapse above the molecular T_g [6]. In this context, Pareyt *et al.* [2, 9, 11] have recently demonstrated that during cookie baking, even at high sugar and low water levels, gluten proteins cross-link and, hence, form a thermoset network. The viscosity of the obtained network would be sufficient to stop dough spreading. Several factors determine the rate by which the network is formed or, stated differently, the time at which the diameter reaches its maximum. Factors that lead to less pronounced cross-linking are:

- lower flour gluten levels
- higher levels of flour protein extractable in sodium dodecyl sulphate containing media, as smaller polymers need relatively more cross-linking to form a continuous network [12].
- lower water levels, as by decreasing the amount of plasticiser, this increases the gluten T_g and, hence, decreases the temperature difference between the reaction temperature (T_{rea}) and T_g , which determines the rate of cross-linking
- higher sucrose levels, which has the same anti-plasticising effect as lowering the water level
- lower baking temperatures, which evidently decrease the reaction rate.

Furthermore, it has been shown that the network formation through gluten cross-linking also limits structural collapse at the end of baking [10].

Chlorination of flour reduces the spread. It also increases the flour water absorption and greatly decreases the flour and dough pH. Flour chlorination is not permitted in many countries but the technique of heat treating the flour, or the grain before milling, has a similar effect but does not affect the pH.

The second most important ingredient in the cookie dough recipe is the sugar. Variation from mix to mix can occur due to the sugar particle size. Bulk-handled sugar may stratify somewhat in the silos and considerable, and variable, crystal breakdown can occur during pneumatic conveying to the mixer. This is probably the first cause of variation in doughs. The second is inadequate dough temperature control. Smaller sugar particle size leads to more rapid dissolution and, hence, to more dough spread resulting in a larger cookie diameter. Additionally, increasing

the sugar level (up to the solubility limit for a given recipe) increases dough spread rate and postpones dough set time for reasons mentioned above.

By increasing the cookie dough mobility, the fat increases spread rate and, hence, cookie diameter when added in higher levels.

The consistency of dough changes with water level. Higher water levels generally decrease dough viscosity, leading to higher spread rate, but it largely depends on the recipe whether or not this will significantly affect final cookie diameter, because dough water level also impacts set time. All other factors being equal, higher dough water levels tend to allow greater sustained rise and more delicate texture in the biscuits during baking. However, one must be aware that, when more water is held in the baked product because of higher dough water levels, moisture gradients may exist, leading to a problem referred to as checking. This is the hairline crack formation at the surface of the baked cookie due to stresses in the product.

Inclusion of variable amounts of biscuit crumb in the dough or variable amounts of cutter scrap, which is more dense, at the sheeter also give rise to variations in the degree to which the dough pieces spread during baking.

Given a certain cookie dough recipe, other factors may also impact dough spreading. The most important are the dough preparation (see Sections 28.3 and 28.4) and the oven conditions. Since baking temperatures can be lower in forced convection ovens, these ovens, for the aforementioned reasons, usually allow more spread for a given baking time.

There is controversy about the effects of humidity in the oven. This is probably related to the difficulty in measurement of this property of the oven atmosphere and also because it tends to be related to heat disposition in most ovens where air movements are greatly affected by different extraction conditions. High humidity in the front of the oven, derived either from closed extraction or by steam injection, promotes spread and cracking of the surface of sugar-rich doughs. This is because moisture condenses on the dough piece surface as the cool piece enters the oven, the surface remains soft and pliable for longer as the dough piece warms up and this allows more spread and thereafter more cracking after collapse occurs later in the bake.

Short doughs form a very large proportion of the biscuit market in the USA and, as can be seen from the references on the subject of spread, a test baking test has been established to measure the cookie spread factor. The purpose of this test is principally to evaluate flours for their suitability for short biscuit production. While this is probably the best test at present, there are unfortunately so many other factors in the baking test that can vary, that significant differences in the flour are usually impossible to demonstrate with confidence. A description of the cookie spread factor test may be found in the *Biscuit and Cracker Handbook* [13].

28.8 References

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Deposited soft dough and sponge drop biscuits

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Abstracts: Pourable fat and sugar-rich doughs are deposited to give soft eating cookies. Sponge batters based on egg are deposited to give small cake-like products that can have a jam deposit or be enrobed with chocolate.

Key words: depositing, nozzles, Danish butter cookies, Viennese whirls, Jaffa cakes.

29.1 Description of deposited biscuits

Short doughs which are soft enough to be just pourable are conveniently referred to as soft doughs. Pieces are formed by extrusion in a similar way, and often in the same machine as wire cut and rout biscuits, but nozzles rather than die holes are used to channel the dough. The dough is pressed out, either continuously or intermittently, onto the oven band which may be raised up and then dropped if discrete deposits are required. As the band drops the dough piece breaks away from the nozzle. The biscuits produced in this way are usually rich in fat or based on egg whites whipped to a stable foam, the dough must be very short to allow it to break away easily as it is pulled away from the nozzle. Types based on sponge batters are dealt with separately in Section 29.2. Typical fat-rich types are some of the Danish butter cookies, Viennese whirls, Spritz cookies and a famous sugar rich recipe is Brandy Snap. Egg white types include Macaroons and Meringues. Figures 29.1–29.3 illustrate typical examples.

The nozzles through which the dough is extruded are usually indented to give a pattern and relief to the deposits. Also by rotating the nozzles, swirls, circles and other attractive shapes can be produced. In the case of Spritz biscuits the nozzles are oscillated from side to side during continuous extrusion. This forms a broad ribbon of dough which is guillotined to length after baking. Depositing allows not only very fancy shapes to be formed, but also, by synchronising two or more depositors, different coloured or flavoured doughs can be combined. Jam or jelly can be added on top of the dough deposit.

29.1.1 Ingredients

Nearly all these biscuit types fall into the fancy or luxury types. Production rates are usually low and the ingredients expensive. Butter is widely used, also eggs,



Fig. 29.1 Sprits biscuits.



Fig. 29.2 Sponge fingers. Reproduced by kind permission of Sainsbury's Supermarkets Ltd.

ground almonds, coconut flour and cocoa. By contrast with wire cut types, coarse particle sized ingredients are avoided as they block or interfere with the smooth functioning of the depositing nozzles. The consistency of the dough is critical so the temperature of the ingredients is important, especially the butter or plasticised fat. A temperature of around 17°C is recommended for butter. The sugar should be fine or very fine as there is usually little water available to effect solution and fine crystals give a better eating texture in the baked biscuit.

Some manufacturers maintain that ground biscuit crumb (from the same type of biscuit) aids the texture and structure of these deposited products. This is a matter of opinion, but it does provide a convenient way of reusing defective biscuits made from expensive recipes. Care must be taken not to include crumb from overbaked product as this will adversely affect the flavour and crumb colour.

29.1.2 Dough mixing

As the dough is of pourable consistency it is best to use a detachable bowl type mixer. The mixing times are quite short and the actions relatively gentle. It is usually best to cream up the butter (or other fats) with the sugar, eggs, milk and water and to add the flour later with minimum mixing to achieve a homogeneous mass. Dough temperature is important to maintain consistency and correct fat dispersion. It may



Fig. 29.3 Ratafia biscuits.

be necessary to cool the flour and certainly any water or milk used should be very cold. Dough temperatures between 10 and 16°C should be aimed for.

Tough dough should be avoided, therefore minimum water and minimum mixing with the flour are required. Handling the dough to the depositor hopper can be a problem if done manually, but there is concern that pumps may damage the structure and toughen the dough. The best method of dough transfer is by gravity. If possible, a holding hopper should be filled from an upper floor and a slide valve arrangement used to release the dough from this hopper to that of the dough piece depositor as required. In this way the level in the depositor hopper can be maintained within close limits and this will help weight control as is described in Chapter 38.

29.1.3 Dough piece forming

The method was outlined above in Section 29.1. As these biscuits represent luxury products it is not unusual for them to be packed as assortments. To avoid unnecessary double handling it is common for the whole range of the assortment to be baked together. This may involve more than one type of nozzle on a single depositing machine or more commonly a series of machines located one after another and with synchronised action. Thus it will be possible to have, for example, swirls and

drops from depositors, some of which may have a deposit of jam applied from a subsequent machine, and also small rotary moulded shapes. Clearly the dough from the moulder will be of a different formulation from the depositors but, by careful attention to the dough piece weights and baking conditions, all can be satisfactorily baked together. This is commonly the situation for assortments of Danish butter cookies.

29.1.4 Baking

It is essential to use a steel band to bake products in this group. All types show some spread during baking but those rich in sugar show the most. Fat-rich products do not stick to the oven band but those with high sugar or low fat often tend to stick. Treatment of the band with oil or flour may be necessary.

Baking is normally slow at low temperatures. There is little water to remove so the baking process is principally to develop the texture and to colour the surface. The latter may be very irregular with fine peaks which will colour very easily if the oven temperatures are too high. The biscuits have a soft and 'melt in the mouth' type texture and are often very delicate and easily broken. This means that stripping from the oven band must be done carefully.

29.1.5 Biscuit handling and packaging

Where the biscuits are of thick and irregular shape they do not lend themselves to stacking and mechanical handling into wrapping machines like other biscuits. It is, therefore, usual to transfer the pieces individually into trays, boxes or tins prior to final wrapping. This may be done by hand but suction picking and transferring robots are ideal for this operation.

29.2 Description of sponge batter drops

Sponge products with jam (or jelly) such as Jaffa Cakes and Sponge Boats are on a borderline between cakes and biscuits. The 'dough' is a more or less fatless sponge mixture based on fresh egg, and jam is added to the drop either before (Sponge Boats) or after (Jaffa Cakes) baking. As is discussed in Section 41.4 on jams and jellies, etc., these sponge cakes, at about 8% moisture, offer a good partner for jam or jelly at 76% solids in terms of water activity. One particularly famous type of biscuits formed in trays is known as Champagne, Lady Finger, Cuillers, Savoird or Boudoir. Boudoir originated in France as a light biscuit intended to be dipped in wine. They developed from hand-deposited sponge batters and are manufactured without fat but using a large percentage of egg and sugar in the formulation. The batter is baked in moulds and is sugar dusted to obtain the characteristic coating. They are dried to low moisture so that they are crisp or hard.

There are variations on the sponge mix recipe, but in all cases the 'dough' is an aerated batter which is pumped to a sparge pipe depositor. Batter is released from the pipe onto the oven band or into baking trays according to a set routine and at the end of each deposit the holes are shut off to prevent drips. It is important that the batter is not too stringy otherwise 'tails' are formed at the end of each drop.

29.2.1 Sponge batter mixing and depositing

It is normal to make the mixture of batter in two distinct phases. Firstly, a 'premix' of all the ingredients (basically eggs, flour, sugar and water) is blended together to form a more or less homogeneous slurry. This is then pumped to a reservoir for the aerator and metering pump that supplies the deposit manifold. Air is metered in and the batter is converted into a fine foam. During aeration it is necessary to provide cooling to prevent overheating of the batter. The density of the batter should be about 0.88 g/cc and the temperature $19^{\circ}\text{C} \pm 1$. Depositing is with a pacing depositor, that is a sparge pipe that follows the oven band during the depositing stage then moves back while the holes in the pipe are closed. By adjusting the pacing speed, either round or elongated deposits can be formed.

29.2.2 Baking of sponge drops

Baking is usually in a moderately hot steel band oven for about 8 minutes. The fatless batter is apt to stick badly to the oven band during baking so it is always necessary to 'grease' the band in some way. Considerable difficulties can be encountered in the search for the optimum means of preparing the oven band. There are various techniques, but all involve the use of flour in addition to an oily lubricant. Spreading the oil and flour evenly and at the desired low levels, either together as a slurry or separately is a major engineering challenge! Without the flour the batter may spread to an unacceptable extent prior to setting in the oven; with insufficient oil the baked pieces adhere so firmly to the band that stripping is virtually impossible. Care and attention to the oven band surface is essential if continued good release is to be achieved for sponge drops so effective band cleaning without scratching is needed. The band dressing means that stripping of the baked sponges after baking needs attention to reduce the possibility of the dressing adhering to the pieces. Thus it is common to use fingers to release the pieces rather than a stripping blade.

29.2.3 Secondary processing

Sponge drops are soft and delicate after baking. If they are to receive a deposit of jam or be chocolate coated, it is almost impossible to do this in any other way than in line as a continuous process. Jaffa Cakes are formed in three stages. The sponge drop is baked, cooled, inverted, aligned and fed to a jam depositor. The deposit of jam is allowed to set and is cooled. The product is then inverted onto the in-feed of a chocolate enrober for half coating over the jam. The product is then inverted again off the enrober conveyor onto the conveyor of a cooler. Here the chocolate sets and cools before packaging.

The Jaffa Cake is technically sophisticated in that the sponge and jam are at similar water activities and the coating of chocolate not only adds an important third element to the product but also prevents the jam from sticking to product or packaging.

In the case of Sponge Boats, the jam is deposited onto the sponge batter before baking and is left in a hollow after baking as the sponge around the jam rises during baking. This effectively prevents the jam from sticking to other boats during handling for packaging and in the pack.

29.3 Typical recipes

29.3.1 Deposited biscuits

	Butter cookie	Spritz
Flour	100	100
Butter (salted)	54	70
Fine sugar	35	40
Fresh eggs	11	–
Sodium bicarbonate	0.2	1.0
Biscuit dust	20	–
Salt	0.7	0.5
Water	7.5	6.0
Flavours	Yes	No
Invert syrup	–	1.0
Sodium pyrophosphate	–	1.0

29.3.2 Sponge drops

Flour	100
Oil	3.2
Fine sugar	80
Fresh eggs	65
Sodium bicarbonate	0.14
Sodium pyrophosphate	0.2
Salt	0.8
Glycerine	3.0
Glucose syrup	6.2
Water	10

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Wafer biscuits

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Abstract: Wafers, unlike other biscuits, are produced from a very fluid batter which is baked between heavy hot plates to produce thin sheets. Wafer offers a unique textural eating experience. The crispness and lightness blend admirably with soft cream or chocolate. Process control demands attention to sheet weight, moisture distribution and careful adjustment of the baking plate settings.

Key words: batter mixing, oven plate setting, cream sandwiching, conditioning.

30.1 Introduction

The term ‘wafer’ usually refers to a thin crisp type of biscuit (see Figs 30.1 and 30.2). In this chapter we shall be considering only wafers which are biscuits baked from batters between heavy hot metal plates. The American products called wafers, which are baked from batters enriched with eggs and fat and sugar, like fluid cake mixes, on a hot plate and other miscellaneous biscuit products loosely called wafers, will not be included in this account.

Wafers probably had their origin from the practice of monks baking their holy bread as thin discs between iron plates engraved with the insignia of their order or other religious symbols. Wafers as we know them today were first developed in Holland in the middle of the nineteenth century using single pairs of plates (tongs) hinged at one side. The first wafer ovens were built after the First World War but automatic manufacturing lines have been available only since the 1950s.

Wafers are a very specialised type of biscuit requiring special equipment for production. The sheets formed by baking between pairs of heated metal plates, which are like large steel book leaves hinged at one side, are typically thin and usually bear intricate surface patterns with deep relief derived from the baking plates. Wafers sold in biscuit markets are usually formed as large flat sheets which are rigid as they come from the oven and these are subsequently sandwiched with cream or caramel before cutting with saws or wires. They may be chocolate enrobed or included in moulded chocolate. However, wafer variants include cone shapes, used to hold ice cream, and various rolled, folded and hollow ball forms. The recipes for some of these types are richer in terms of sugar, fat and egg allowing forming and rolling immediately after baking and before cooling.



Fig. 30.1 Pink Panther wafers.



Fig. 30.2 Ice cream wafers.

The majority of wafer biscuits are based on the large flat sheets and the techniques and technology involved in the production of these will be the basis of the account given here. Wafer sheets are baked from a simple batter containing little or no sugar. They are rather tasteless and have a regular surface and a very open cellular structure within. In Sweden cut pieces of these plain sheets are sold as a type of crispbread for eating with butter, cheese, meats, etc., and in the UK plain rectangles of wafer are sold to be eaten with ice cream but normally wafers form a carrier for some sort of cream, caramel or marshmallow by way of a sandwich. In North America these wafers are known as sugar wafers, but their composition is essentially the same as elsewhere.

Sandwiched wafers are rich in filling with the filling being around 70% by weight as compared with 30% or less in sandwiched cream biscuits. When filled wafers are chocolate enrobed or form part of a chocolate moulded bar, the wafer component becomes even more subsidiary in terms of composition. The wafer is used as a crisp, but not hard, rigid support for the more flavoursome materials.

30.2 The wafer oven or wafer baker

The oven is the heart of the process as it both forms and bakes the wafer. It is therefore convenient to consider it first and the ingredients and recipe later. Originally wafers were made one at a time in hand-held tongs heated over an open fire. The tongs consisted of a pair of strong metal plates which were latched immediately after batter was placed between them to resist the strong forces which developed as the water in the batter is flashed into steam at the beginning of the bake. This technique has been mechanised and nearly all wafer ovens still work on this principle producing sheets typically 470×290 mm (of between 50 and 56 g in weight). Mid-sized plates are occasionally used; these are 370×240 mm and 470×350 mm but there is a growing use of 'Jumbo' plates of 700×350 mm (producing sheets of about 90 g). Clearly the larger the plates the more efficient is the oven but the greater must be the engineering precision and the maintenance. Plates larger than the 'Jumbo' ones will give difficulties in removing moisture from the centres of the wafers and with lower baking speeds become less attractive in terms of efficiency.

The plate pairs are fixed to heavy carriers or are self supporting and are linked together to form a chain. The chain of plates is circulated continuously through an insulated box (oven) where the plates are heated either by direct impingement of gas flames or individually by electric heaters arranged in the backs of each plate. The heavy carriers are required not only to support the plates and to keep them rigid, but also to maintain their parallel positions against the steam pressures as the baking proceeds. In terms of heat transfer to the baking plates and the strength needed to maintain the plates parallel, there are pros and cons for the use of the plate carriers compared with self-supporting plates.

At one end of the oven the plates open to allow release of the cooked sheet and then, almost immediately, to receive a spread of batter for another wafer. As engineering techniques have developed, the length of oven chains and number of plate pairs has steadily increased so that presently up to 176 plate pairs may form a single plant. The most common oven size are between 72 and 96 plate pairs; however, on older installations 60, 45 and 30 plate pairs are commonly found. Older ovens have the plates mounted to run lengthways (the shorter edge leading) through the oven whilst now plates are almost always mounted transversely with the longer edge leading. This has the effect of reducing the oven chain length and therefore reducing the speed that the chain must move for a given baking time.

The plate surfaces carry designs that may be artistic or ornate or simply reticulate patterns of V grooves of various depths. To give the wafer sheet maximum strength the grooves in the upper plate are usually at 45° to those in the lower plate. The depth of the grooving, or reeding as it called, ranges from 0.3 to 0.8 mm with 0.5–0.8 mm being the most common. The depth of the reeding must be related both to the overall thickness of the wafer (determined by the gap set between the plates) and the end use of the wafer. For example, for wafers that are to be chocolate enrobed it is preferable to have shallow reeding as the surface will retain less chocolate.

Hollow wafers are baked with plates which have deep cavities and the corresponding plate that marries has protrusions. When placed back to back, the wafer sheets therefore form hollow balls which can be filled with cream and then punched out from the sheet pairs. The surface of the plates may be simply cut into the steel

with a micro-machined finish or may be chromium plated for a smoother surface and better release of the baked wafers.

In order that the wafers may be full rectangles and of even thickness overall, the plates are edged with strips that overlap the other plate when the pair are closed. Steam must be allowed to escape at the edges so indentations or vents are cut in the surfaces of these strips and the size and number of these vents is critical to the quality of the wafers produced. Batter is deposited, usually in lines, across the lower plate, and on closing and locking with the upper plate the very rapid production of steam not only spreads the batter evenly throughout the gap between the plates, but also to a certain extent out through the vents. A minimum extrusion through all the vents is the aim because that which emerges, and is subsequently baked in the passage through the oven, represents waste product that, incidentally, is more or less valueless even as animal feed. The extruded matter is known by various names such as 'bubble', 'bobble', 'dross' or 'doddings'. The effects on wafer quality of the size of the vent holes will be dealt with later. The waste of an ingredient as a result of bobble formation can be between 4 and 8% (but as the moisture content of the bobble is about 30% moisture, the weight of what is collected will seem to be more) on a well-adjusted oven. Clearly, if the oven is not in excellent adjustment and batter is applied to ensure that all the sheets are full, the bobble may be as high as 15% on some of the sheets.

The thickness of the wafers is proportional to the gap between the two plates. This gap is set at the supplier's factory. To change this gap setting requires engineering skill but small adjustments, to maintain the parallel location of the plates, are made with special bolts which attach the plates to the carrier frames. The forces experienced during baking (said to be up to 1.2 bar) demand that these adjustment bolts are very strong and thus the threads relatively coarse. This makes fine adjustment particularly difficult. Furthermore, strains against the locking mechanisms and wear in these bearings affect the relative locations of the carrier frames. As will be shown later, correct maintenance of these critical settings requires co-operation between process control and engineering personnel. The setting of the gaps between plates should be made by reference to the thickness of the wafers being produced and not only by measurements of the gap when the plant is cold and the chain stopped. The wafer will always be thicker (as much as 5–30% thicker, see Section 30.6.1) than the engineering measurement of the gap suggests.

The quality of wafer sheets is judged principally by their weight, surface colour and uniformity of moisture content. Texture and crispness tend to be related to one or more of these properties, but basic differences in wafer sheet thickness will affect the internal structure. Differences in recipe have little effect on the flavour but they will affect the spreadability of the batter and the colouration of the sheet during baking. Of particular importance is the tendency for the baked sheet to stick to one of the plates thus failing to release when the plates open. Sticking aspects are related to the amount of sugar in the recipe, the moisture content of the sheet and the surface condition of the plates.

A part of the wafer oven maintenance programme is the need periodically to clean the plate surfaces. Deposits of charred oils and sugars build up, blackening the surfaces and causing wafer release problems. Under steady baking conditions with low sugar recipes, cleaning may be needed after about 1000 hours of running. However, this interval will be reduced if difficulties have been encountered such that wafers have been burnt on as a result of too high temperatures or stuck wafers

that have not been removed. If more batter is added to a stuck wafer a condition known as a 'double' occurs. The production of 'doubles' and 'trebles' results in exceptional pressures on the various plate adjustment screws and bearings and may cause permanent distortions requiring engineering attention. Furthermore, a plate out of adjustment for whatever reason will be a constant source of trouble because more burnt or under-baked wafers may continually occur on it.

Trouble from under- or over-baked wafers will occur if the plate temperatures are allowed to fluctuate. Automatic control of oven temperatures is difficult because the positioning of thermometers may be unsatisfactory. The plate surface temperatures depend on conduction of heat through the thick metal of the plates. While production is steady a balance can be achieved between flame heights (gas pressures) or electric current supplied, but should production stop (that is, the deposition of batter be halted for whatever reason) it may be with some delay that the steady state can be reattained. For this reason, the oven chain should never be stopped until it has cooled down and also if the batter supply to one or two plates is halted a complete round of the chain should be treated similarly to avoid imbalance between adjacent plates. Experiments have shown that one plate allowed to proceed without batter will typically take between 4 and 5 further circuits of the oven to return to the standard condition of its neighbours after batter is reapplied. During this time the wafers from the affected plate will be different in colour and moisture content from its neighbours.

Plate-cleaning techniques are advised by the oven supplier. The basic cleaning should involve brushing off the plates at the end of each production run with a stiff fibre brush during the cooling down period (be careful with wire brushes as the skin created on the plates by an initial dressing of oil which is beneficial may become scored or removed). More aggressive and in-depth cleaning is usually done with weak caustic soda solution but other methods such as bombarding the plates with solid carbon dioxide pellets can be effective. A typical technique is to place sheets of synthetic sponge, soaked in caustic soda (8–10% solution), between each plate while still warm, but not hot, at the end of a production run. The plates are left in this condition for a few hours or overnight. The sponges are then removed and each plate carefully washed with water and brushed clean. Caustic soda is dangerous so protective clothing and goggles should be worn for this operation. Finally, the plates are cleaned by baking a round or two of wafers. These should, of course, be discarded safely. Particular care should be taken to ensure that water does not get into the bearings as deposits of caustic soda will damage the bearing surfaces and the lubricants.

The prolonged successful operation of a wafer plant is very largely due to engineering developments and in particular to the lubrication of bearings which, by necessity, become very hot due to the proximity to the heated plates.

30.3 Wafer sheet production

The technology of wafer sheet production, particularly in terms of the influence of ingredients and processing variables, has been studied in some detail and the work published by the FMBRA and the Federal Research Institute in Germany (see [1, 2, 3]). The investigations have been made from laboratory baking trials using both small and full-sized wafer plates, but they have also been related to results obtained

on normal production ovens. The following account aims to highlight those aspects that have most bearing on day-to-day wafer production and draws on both published data and practical experience by the author and his colleagues. A few typical recipes are given in Table 30.1. From these it can be seen that there is a limited range of both types and quantities of ingredients in common use.

The flour is usually of a medium protein level (9.5%) typical of most 'biscuit' flours but Pritchard *et al.* [2] considers that in terms of wafer quality practically any flour can be satisfactorily used. Flour with very low protein will give weak and fragile wafers and high protein flours, such as are used for bread, may give hard and flinty wafers. Both types may cause breakage at the sheet take-off point. The relationship between flour and batter consistency and solids content is probably more important. The higher the batter solids the heavier the wafer sheet weight and vice versa.

It is significant that few or no results have been published on wafers made from flours other than wheat flours. Provided the starch is not pre-gelatinised, it is theoretically possible to make wafer from any source of starch, although in the author's experience the wafer sheet tends to be very dense and heavy if the farinaceous material is of coarse particle size. In wafers there is a much more complete gelatinisation of the starch than in other biscuits. There is not a clear relationship between hardness of wafer and flour type given a standard density of sheet. The water absorption of flour is important because variations in this property will affect the batter consistency for any given solids content. If the α -amylase content of the flour is high, one can expect a slackening of the batter consistency with time, especially in warm conditions. However, if batters are used within 30 minutes the effect of α -amylase degradation of the starch should be negligible. Brown, high ash content flours will affect wafer texture and release of the sheets from the baking plates.

Eggs and fat are added principally as release agents. There is little or no shortening effect by fats but microphotographs by Pritchard *et al.* [2] have shown how the surface of wafers is smoother when fats are present in the recipe. Excessively high levels of fat give swirling patterns on the surface of the wafers. Without fats there

Table 30.1 Summary of typical wafer recipes

	1	2	3	4	5
Flour	100	100	100	100	100
Sugar	3.5	1.7	—	—	—
Oil or fat	2.7	5.3	—	2.4	—
Skimmed milk powder	3.1	1.7	—	—	2.5
Dried egg powder	0.33	2.9	—	—	—
Salt	0.18	0.18	—	0.23	0.75
Soda	0.29	0.29	—	0.32	0.25
Ammonium bicarbonate	0.83	—	0.89	—	—
Yeast (for 1 hr. fermentation)	—	—	0.63	—	—
Lecithin powder*	—	—	2.05	0.95	—
Lecithin (fluid)	0.05	0.05	—	—	—
Water	145	133	145	147	150

* Lecithin powder is a mixture of 50/50 lecithin/milk powder. Ideally, fluid lecithin should be added to the oil prior to mixing. The typical solids content of the batter is between 33 and 48% with most at about 35%.

would be a strong tendency for wafers to stick on the plates. Eggs are a source of both fat and emulsifier (lecithin) but some feel that they also impart a better quality to the wafer and improve shelf life. Certain fats are better than others for incorporation at the time of mixing and, for convenience, liquid vegetable oils are favoured, for example, groundnut oil, cotton seed oil or sunflower seed oil. Provided precautions are taken to ensure that setting of the fat does not occur in the mixer prior to dispersion, there is no reason why warm 'solid' fats, like palm or beef fat, should not be used. Lecithin is a useful addition, but to save expense it is better to include a fluidised soya lecithin with the fat or oil rather than use powdered lecithin. Even though the fat content of wafers is low, some precaution should be taken to retard rancidity as the surface area of a wafer surface and the internal texture is extremely large so there is a great exposure of fat films to oxygen. The inclusion of antioxidant in the oil may be useful for this purpose. It is probable that soya flour is not the best means of adding fat and lecithin.

Sugar and milk powder may be added in small quantities to improve quality. Unfortunately, both these ingredients promote wafer colouring and sticking to the plates during baking. It is believed, however, that staling is considerably retarded by the inclusion of some sugar and crispness is maintained for longer as the moisture content rises during storage of the wafers. Salt is added as a flavour enhancer and the level is usually around 0.25 per 100 units of flour.

Aeration is most important in wafer manufacture. Although bubbles of air are included during batter mixing, most of these float out of the batter before it is deposited onto the plates. If the conditions are such that insufficient time is allowed for the bubbles to leave the batter, it could be that the density of the batter changes during use and this will affect the baked sheet weights. Chemical aeration is usually achieved with sodium bicarbonate or ammonium bicarbonate or a mixture of the two. Ammonium bicarbonate is particularly effective.

Experience has shown that attention to the combination of batter consistency and ammonium bicarbonate level is the best way to control batter spread and wafer sheet weight. Sodium bicarbonate affects the final pH of the wafer and will influence the ease with which it colours during baking. The ideal pH of wafer sheets is between 6.8 and 7.4 with those for use with chocolate at the upper end of this range for best flavour compatibility. The use of yeast as a method of aeration is steeped in tradition. It is most unlikely that any flavour or textural benefits are contributed to the wafer sheet, but yeast cells probably do form the nuclei for water vapour production which is important for the formation of a good wafer texture. Batter standing times and suitable temperatures to allow multiplication of the yeast are not usually very practical in modern mixing and batter-handling systems. Yeast is now rarely used in batter recipes.

There is no reference in the literature to the reuse of broken wafer sheets in batter. As broken dry wafer sheets can represent a loss to some manufacturers, it may be worth trying to incorporate some in the batter. This technique is used in France, although the soaking process prior to incorporation in the batter can lead to hygiene problems.

Water is added to produce a convenient consistency. As the quantity of water is roughly 150% of the flour weight, it is obviously of utmost importance for the successful production of uniform batter that close attention is paid to the flour metering. Changes of flour properties which affect water absorption are normally small compared with errors in flour weighing.

Little information is available about flavouring ingredients for wafers. Most synthetic flavours and essential oils are very prone to steam distillation and are lost in biscuit and wafer production, but protein hydrolysates are fairly heat stable and, although they colour easily, may be valuable for savoury wafers.

Inclusion of small quantities of magnesium carbonate are said to reduce the tendency for wafers to stick to the plates during baking but the mechanism involved is not understood. It is the subject of an East German patent from 1981 (DD 145696) and a Ferrero patent from 1983 (DE 2929496).

With the generally increasing protein level of wheat flours worldwide, there has been increasing use of either enzymes or sodium metabisulphite to weaken the effects of the hydrated proteins in the batter. It is felt that the effects are more towards batter consistency and flowability than wafer quality.

The author has come across situations where additions of cocoa powder to the batter recipe, at the rate of about 750 g to 100 kg of flour, are claimed to reduce the tendency for wafer sheets to exhibit rancidity flavours during storage. However, the mechanisms for this are obscure and the wafers have a pale pink colouration. Colours are commonly added to wafer batter.

30.4 Batter mixing

The mixing process must achieve an homogenisation of ingredients together with allowing time for hydration of the flour. Commercial mixing times range from 2.5 to 6 minutes [4]. However, Pritchard and Stevens [1] established that 4 minutes was the minimum time necessary to achieve homogeneity even with a good high-shear mixer. However, it has to be said that modern mixers are commonly making good mixes in 3 minutes. There seems to be general agreement that a high-shear mixer is best and this is principally because slower mixers may allow gluten strand formation with the resulting strings and lumps in the mixed batter. Some uncertainty seems to exist about the reasons for strings in batter; some say it is due to over mixing, others that the flour has too high a protein content. However, gluten strands will only be formed if:

- the gluten is rather tough, as in treated bread flour and from very strong wheats
- starch is washed away from a dough
- the mixer does not shear the mix well
- the pH is low (ammonium bicarbonate is a useful means of increasing batter pH).

Some research (reported in [5]) has suggested that gluten strand formation can be prevented by including bacterial proteinase. Furthermore if protease from *Bacillus amyloliquefaciens* is used in combination with endoxylanase (from *Trichoderma longbrachiatum*), the batter viscosity is reduced meaning that less water is needed in the batter.

The mixing process should proceed as soon as possible after the assembly of all the ingredients. This reduces the possibility of a 'dough' formation between flour and water. The use of very cold water also reduces the tendency for string formation because it allows a longer time for dispersion before the protein is hydrated and can form into gluten. There has been considerable automation of the batter-mixing

processes, but in nearly all cases this has been based on traditional batch systems. As the recipe is so simple, continuous mixing would seem worth considering.

30.5 Batter handling

Immediately after mixing, the batter has much air incorporated and may be slightly lumpy due to incomplete mixing. As the air rises out of the mix the viscosity reduces. This makes it difficult to check the batter viscosity at a stage where some adjustment could easily be made. A screen is needed to remove lumps and gluten strands and constant gentle agitation is needed to prevent separation in the batter. It is normal to discharge the mixed batter into a tank and to run a ring main from this to the wafer oven(s) and back.

30.6 Batter deposition and baking

Figure 30.3 shows the qualitative processing effects of various factors on wafer sheet weight and thickness. The following sub-sections consider these factors one at a time.

30.6.1 Plate gap setting

This is a fundamental setting which is decided when the plant is set up. It is a large engineering task to make a basic change to all the plates of an oven. The thickness of a wafer sheet is determined by the body thickness, related to the gap between the plates and also the depth of the relief or reeding in the plates. The relief cut into

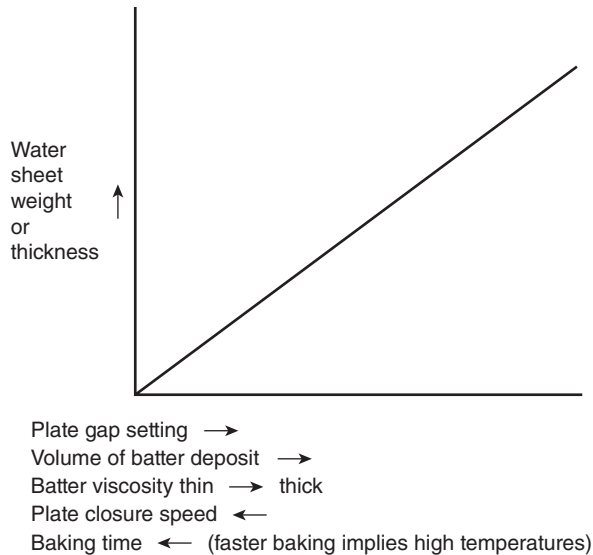


Fig. 30.3 The qualitative processing effects of various factors on wafer sheet weight and thickness.

the plates gives not only more interest to the appearance of the wafers, but also contributes to their mechanical strength. Thus, any reeding on the top surface should be at 45° to that on the bottom.

It is interesting to note that the wafer thickness is not constantly related to the mechanical gap setting between the plates. It is always thicker. The difference is between 19 and 30% from older slower plants and between 5 and 13% for newer faster plants. Thus, it is not possible to compute the exact wafer thickness from a plate setting until production conditions have been established.

30.6.2 Volume of batter

The batter is applied to plates with a sparge pipe across the plate and the batter is pumped intermittently to give exactly the same volume to each plate. The batter is deposited from many small holes in the pipe and the volume is adjusted to just fill the plates allowing a minimum of extrusion through the steam vents. Pritchard and Stevens [1] showed how excess deposit gave not only excessive waste but also increased sheet weight. Calculation from a typical production situation has shown that based on 'as is' ingredients, 95.8% is converted into wafer sheet and the remaining 4.2% is lost in the 'bobble' (see also Section 30.2). As the moisture content of the bobble is about 30%, the loss appears to be more. It is because batter is applied by volume that the wafer sheet weight will change if the density of the batter increases on standing, as was referred to in Section 30.3.

30.6.3 Batter viscosity

Changes in batter viscosity affect more than one factor. Thick batters have high solids contents and do not flow well on the plates after deposition, therefore a high volume has to be applied to achieve a full wafer sheet. This gives a heavier, more dense and harder wafer. The flow of thick batter on a plate can be increased by adding extra ammonium bicarbonate; the gas produced blows the batter to the edges of the plate.

As batter is pumped onto the open hot plate, gelatinisation occurs preferentially where the batter first touches. This can always be seen on the underside of a wafer sheet as a pattern of lines. The greater the number of deposit lines and the more free flowing the batter, the less pronounced is this effect and the more uniform the colouration after baking.

Experiments have shown that there is not a clear correlation between batter viscosity from any particular recipe and wafer sheet weight. This is a disappointment from the process control point of view and it is possible that the limitation is in the means of measuring viscosity of batter or the condition of the batter when it is measured.

30.6.4 Plate closure speed

Major differences in process performance were discovered by Pritchard and Stevens [1] by comparing modern plants, with very fast latch closure mechanisms for the plates, with older ovens where the latching operation is delayed.

Older wafer ovens were built with the short side of the plates leading on the chain. To reduce the overall length of ovens while greatly increasing the number of

plates, this arrangement has been changed so that typically the long side now leads. This has necessitated a more rapid closure of the plates both in order to keep the side-to-side effects on the sheet uniform and also because the linear speed of the plant is higher. Unexpectedly, the change in closure speed led to different wafer quality from the same batter. Faster closure gives lower weights and thinner wafers. On some ovens the final locking position of the plates and therefore the closure time can be adjusted slightly.

30.6.5 Steam venting

Experience suggests that type, disposition and the standard of steam vent engineering are of considerable importance to (a) the performance of the plant and (b) the between-plate variation of wafer sheets. Large areas for steam venting allow excessive losses of batter but aid moisture removal, small areas control losses and batter spreading better but allow development of excessive pressures. These higher pressures cause increased wear on bearings and set up strains which have bad effects on plate settings.

30.6.6 Baking speed

Baking times vary between 1.5 and 3 minutes with 2 minutes being about average. On large plants there is a mechanical consideration and it is generally felt that 55 plates per minute is the fastest reasonable speed. Most ovens, even new plants, run at approximately 60% of this speed, that is only 33 plates per minute. Fast baking speeds require high plate temperatures with increased tendency to 'shelling' (wafers with extremely fragile centre texture) and appreciable moisture gradients across the sheet when they are released. This is because there is not sufficient time for the moisture to move to the steam vents around the edges. The release of the wafers from the plates is affected because some shrinkage occurs after the wafer structure sets and is the result of drying. If the wafer is not sufficiently dried out at the time of plate opening, the shrinkage may not be sufficient to allow the sheet release. Conversely, if the drying is too much and some surface burning has occurred, sticking may be experienced for this reason also. If the heat disposition across a plate is uneven some cracks may occur in the sheet immediately the plate opens and before the sheet is released from the plate.

The sheets normally fall freely as the plates open but other devices, such as vacuum lift away using suction pads, are also used. The wafers are then transferred to some sort of conveyor and placed on lightweight plastic ropes so that cooling may occur freely on both sides. As an aid to sheet release from the plates a small blast of compressed air may be used which impinges at the edge of the sheet to lift it from the lower plate. A sweep of air is also used just prior to the deposition of fresh batter. This is because it is quite common for a piece of 'bobble' to fall from the edge of the open upper plate onto the lower plate which is to receive the batter. If this is not removed and it becomes incorporated into the new sheet, a very hard area is formed which is not only unpleasant to eat but could also break a cutting wire after the wafers have been creamed. The moisture content of wafer sheets will be in the range 1–2% and it is important that the variation of the moisture across the sheet is as low as possible (within $\pm 0.45\%$). This is discussed in Section 30.8.

30.7 Sheet handling, creaming and cutting

30.7.1 Dry sheet handling

Dry sheets prior to creaming are fragile so breakages, cracks or pieces missing at this stage can cause trouble or inefficiency later. It is therefore best to arrange that there is as little handling of dry sheets as possible.

Figure 30.4 shows how expansion of the wafer sheet is related to moisture pick-up; in certain atmospheric conditions pick-up can be rapid. Uneven pick-up across a sheet will cause bending and warping so at all times wafers should be handled to allow free circulation of air on both sides or they should be sealed in moisture-proof boxes. The common practice of stacking wafers prior to subsequent processing is to be discouraged as warping is almost inevitable.

Bending may also occur when any within-sheet moisture gradients equilibrate, therefore sheets with strongly uneven moisture distribution should not be creamed or chocolate coated until equilibration has occurred. Splitting or cracking of the chocolate may result. Barron [6, 7] has discussed this problem, and the measurement of moisture distribution as a process control technique is dealt with later. Creamed wafer sandwiches made from wafers with significantly different moisture contents will tend to bow or split as equilibration takes place. Therefore wafers of different age should be mixed with due consideration.

Wafer sheets cool very quickly and the transfer time between the oven and the creamer on modern plants is usually more related to convenience than cooling needed. The author has worked with plants where the sheets are still warm at creaming and this causes the fat in the cream to melt a little and give very good 'keying' to the wafers. Equilibration of moisture within sheets is important but most cooling systems do not give enough time for this to complete. This is why good baking and good oven maintenance are essential.

30.7.2 Conditioning of wafers

Wafers pick up moisture from the atmosphere very rapidly after baking and cooling. As the moisture is taken up the wafers expand by about 0.2% in each dimension for each 1% increase in moisture. Because wafers are unstable in their dimensions

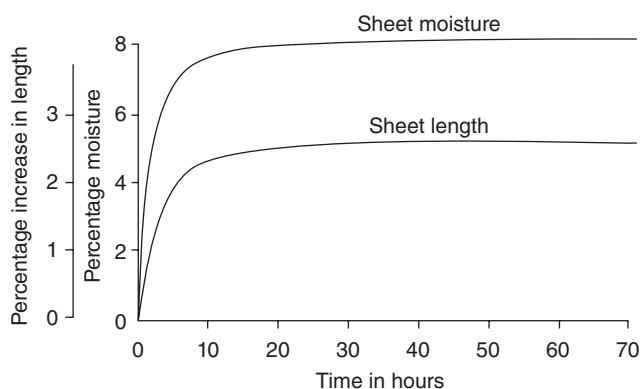


Fig. 30.4 Changes in wafer sheet exposed to an atmosphere of about 55% RH at ambient temperature.

when they are fresh from the oven, it is common for manufacturers to 'condition' the sheets before use. This is particularly the case for wafers that are to be chocolate enrobed or to be centres in moulded chocolate. Conditioning usually involves the deliberate addition of moisture to the wafer either by storage in a humid room or by passing the sheets through a high humidity chamber. In some cases water is actually sprayed onto the wafer. Conditioning usually involves increasing the wafer moisture to 4.0% by passing the wafers through a humid chamber at 35–60°C with humidity of 60–90%. The usual dwell time required is 16–20 minutes.

Consideration of Fig. 30.4 shows that the nearer the wafer is to its moisture content when in equilibrium with the atmosphere, the less will be the change in shape and this is the principle that is usually used in 'conditioning'. However, a damp wafer is significantly less enjoyable to eat! At 5–6% moisture a toughness is detectable in the eating quality. There are two major points to consider. Is the instability of the wafer after chocolate coating due to internal equilibration of moisture or is it due to migration of moisture through pin holes in the coating from the surrounding atmosphere? If it is the former, are the sheets being baked in an optimum way and could the uneven moisture distribution, both within and between sheets, be reduced by attention to wafer oven maintenance or by baking slightly more slowly? If moisture is coming through the chocolate could the problem be tackled by improving the barrier performance of the wrapping material?

Sometimes, uneven moisture conditions result from poor attention to storage before chocolate coating or excessive chilling after creaming which encourages dew formation as the cold wafers are exposed to the bakery atmosphere. If baked sheets or even creamed wafers are kept in sealed boxes for 12 or more hours, there is usually enough equilibration to avoid cracking after chocolate coating without the need for deliberate moisture addition.

30.7.3 Cream sandwiching

Creams for wafers are of similar composition to those for other biscuits except that it is usual to include a proportion of milled creamed wafer trimmings (5–10% may be acceptable) as an economy measure. Bonding between wafers and cream is improved if a warm soft cream is applied rather than a cooler stiffer one. Cream or caramel may be applied to the sheets by contact with a cream coated roller or as a film (see Figs 30.5 and 30.6). As the cream is much softer than biscuit sandwich

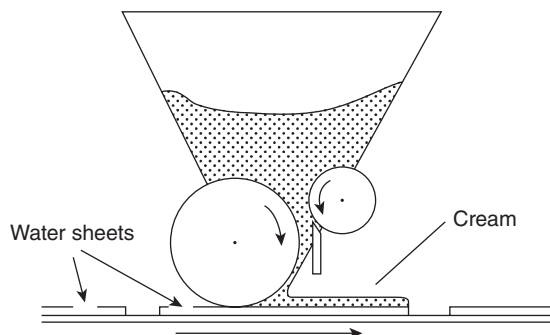


Fig. 30.5 Contact creaming of wafer sheets.

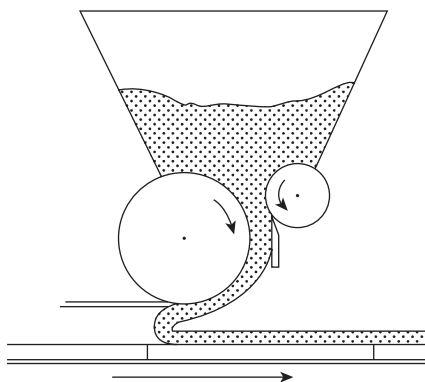


Fig. 30.6 Film creaming of wafer sheets.

cream, handling with pumps and pipes, possibly in a ring main arrangement, is possible.

30.7.4 'Book' building

Coated sheets are built up into piles as desired and a plain topping sheet is added finally. Typically there will be 3 or 4 wafers with 2 or 3 layers of cream respectively in a pile or 'book'. To save waste, precise registering of the elements of the book is essential and the operation will be impaired if conveyors or guides become heavily soiled with cream. It is normal to apply heat locally to encourage misplaced cream to melt and run away from critical areas. The assembled book must then be pressed together before cooling. Normally this can be done with a large-diameter roller, but if the gauging so required is excessive, as well as squeezing cream away, there may be superficial damage to the wafer.

The percentage of cream in the book will be around 70% and as the cream is much more expensive than the wafer sheets, regular checks on the book weights are important. It is normal to install a checkweigher to weigh each book automatically immediately after it has been assembled. Wafer book checkweighers can detect deviations of about ± 0.5 g.

30.7.5 Cooling

Cream cooling is normally done with convected cool air (at 10–12°C), but radiant cooling tunnels may have some application. The humidity of the air should be kept as low as possible because by cooling the RH rises and this promotes moisture pick-up by the exposed wafers. The cooled wafer books should not leave the cooler with surface temperatures below the local dew point otherwise moisture will be picked up on the exposed wafers and warping leading to splitting apart of wafers from cream may occur.

30.7.6 Cutting

The cooled books are cut into eating size squares, rectangles, fingers, etc., by pushing them singly or in small piles through sets of taut wires, blades or circular saws. There

are two cuts at 90° to each other and the resulting piles of wafer biscuit pieces are ready for packaging, storage or chocolate coating. The cutting operation is usually a source of significant amounts of 'waste' (unpackable product), principally as side trimmings, but these may be recycled, after milling, in subsequent batches of wafer cream.

30.8 Process control of wafer production

30.8.1 Wafer sheet weights and moistures

As has been indicated, wafer sheet weights and moistures are affected by changes in the batter composition and viscosity. Heavier weights will give harder wafers, lighter weights delicate, fragile and soft eating wafers. It is important that all wafer sheets should be complete, that is, have no shortages at the corners, and be of equal weight. So a function of plant control is to ensure that the average weights are to a standard and that sheet weights from successive plates are also within a narrow range.

Between-wafer variations in weight may be due to irregular batter deposition (usually manifest by uneven amounts of bobble or incomplete sheets) or uneven plate gap settings. Heavier wafers are paler in colour and more moist and light wafers vice versa. The higher the general moisture level the more uneven is the distribution of the moisture.

Moisture measurement in-line provides a very useful technique for watching for both average and between-sheet quality variations. Non-destructive in-line moisture determination may be achieved with an infra-red optical moisture monitor. Such an instrument performs best if a continuous stream of abutted sheets is presented to it so that there are no big differences in reading between the sheets caused by gaps. The instrument scans a track across each wafer and the readings may be displayed on a suitable recorder. The instrument may also be used as a research tool to map the moisture distribution within one particular sheet and Fig. 30.7 shows one such map. Such a moisture monitor may be used to control production and to indicate when individual plates require resetting, or when there is a heat imbalance problem in the oven.

30.8.2 Wafer plate adjustment procedure

Wafer oven manufacturers provide details of procedures for setting and adjusting wafer plates. These usually require the removal of steam strips and the use of feeler gauges or pieces of lead when the plates are cold. It has been found that these procedures are tedious and often unsatisfactory. The following schedule, which determines the nature of required engineering adjustment from observation of wafers, has proved to be the best method for keeping the wafer plant in good adjustment and thus running at high efficiency.

1. On a particular day each week collect one complete set of wafers from the wafer oven when it is running smoothly. Without delay (i.e., before there is significant moisture pick-up) weigh each sheet carefully, record in the log book and calculate the mean and standard deviation of the weights. List all those wafers whose weights are greater than (high) or less than (low) the mean by more than 1.5 times the standard deviation. These are the suspect plates that may need

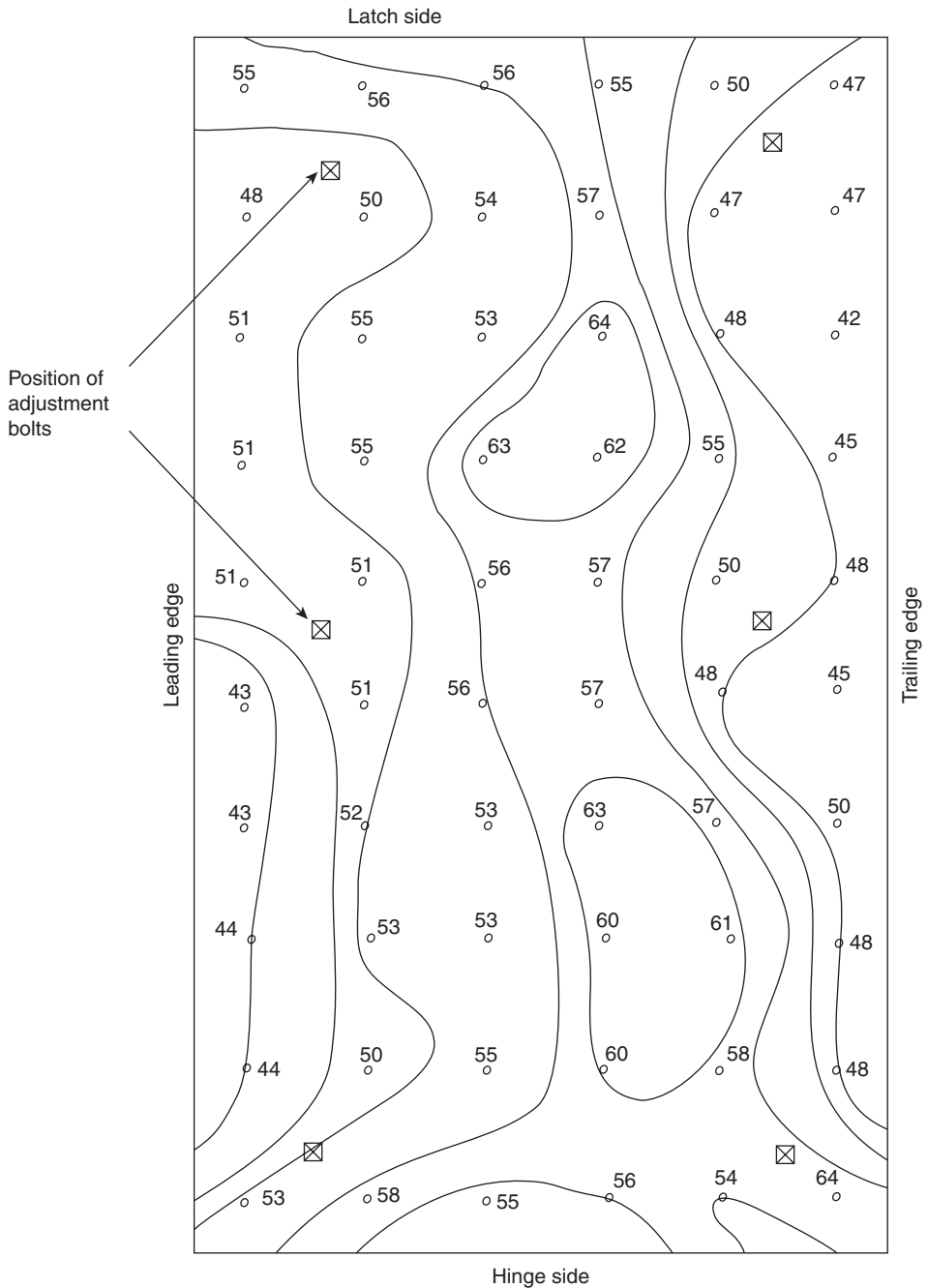


Fig. 30.7 Example of moisture map constructed from 60 spot readings with an IR moisture meter on a fresh wafer sheet.

adjustment. The plates are normally numbered by the oven supplier but if not, try to number the plates permanently.

2. Every fourth week prepare a list of those plates which have been recorded 'high' or 'low' on three occasions, or on the last two occasions in the month.
3. Ask wafer department staff whether any of these selected sheets correspond with those which they have found troublesome over the month. Also, are there any wafers that they feel are particularly under- or over-baked and that have not been included in the list.
4. List the plates considered to be most in need of adjustment in order of importance. The list should contain no more than 15% of the total number of plates for each oven.
5. Collect a sample of each of the sheets recommended for attention and measure their thickness near to the adjustment bolts positions. Use a template to get the positions. Enter these values in the log book. Using these measurements estimate the amount and direction of the bolt adjustments required for each plate and enter these values alongside the thickness measurements.
6. Give a list of these adjustments to the maintenance engineer responsible and ask that work is done within the following three days. Adjustments must be done when the plant is cool and stopped.
7. Retrieve the list signed as completed from the engineer. Should the engineer find that any adjustment was not possible (due for example to a seized or damaged bolt) this should be noted clearly.
8. Inspect the plant as soon as possible after these adjustments have been made and be assured that no position has been drastically over-adjusted. Invite comment from production staff.

Note that in 5, above, it is necessary to estimate the amount of adjustment from thickness readings. Experience plays a large part here because different makes of wafer oven have different arrangements of adjustment bolts. Adjustment of a particular bolt has a threefold effect: on the thickness of the wafer at that point, on the distribution of wafer solids within the wafer, and on the total volume of the wafer plate gap and therefore the wafer sheet final mass. Until experience has been gained, suggestions for changes in settings should be conservative. Typical physical parameters of wafer sheets baked in Britain are given in Table 30.2.

There are some very deep-reeded types of wafer sheet designed to be creamed in pairs not as a book with two or more layers of cream. These may have the

Table 30.2 Typical physical parameters of British wafer sheets

	Range
Thickness overall	2.8–3.4 mm
Thickness, body (excluding surface patterns and reeding)	1.3–2.1 mm
Reeding depth	0.5–0.8 mm
Reeding spacing	2.5–5.1 mm
Overall thickness of creamed sandwich, three wafers with two layers of cream	9.6–11.4 mm
Sheet weights	50–56 gms
Moisture content	1–2%

reeding depth at around 2.3 mm. The weight may be as low as 35 g for standard size sheets.

30.9 Hollow rolled wafer sticks

There is much interest in another type of wafer product, the hollow rolled wafer (Fig. 30.8). This type of wafer is made from a fluid batter which is relatively high in sugar (40–70% sugar relative to the flour). The batter is poured from a fishtail nozzle onto a revolving baking drum in a narrow strip. The width of the strip is determined by the size of the nozzle. The drum is typically about 2000 mm in diameter and depending upon its width more than one strip of batter can be poured and baked at once. The drum is heated and at the completion of the revolution (baking time between 45 seconds and 2 minutes) the baked wafer, which at this stage is a plastic strip due to the sugar content, is stripped off onto a revolving mandrel which winds the strip into a spiral tube which moves progressively away from the stripping point. This tube is then cut into lengths of between 45 and 300 mm as desired. Often cream is injected into the tube before cutting through the centre of the mandrel. Two different coloured batters can be baked side by side so that when rolled together a twin coloured tube is formed. Up to the time of cutting the wafer is still warm and flexible so it is then possible to press the tube and convert it into a more flattened shape if desired before packaging.



Fig. 30.8 Caprice wafers.

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Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.

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The position of biscuits in nutrition

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Abstract: Biscuits are a traditional and important food in many cultures around the world contributing to food intakes. They can be a basis for the delivery of positive nutrition whilst, in others, a potential cause for avoidance. This chapter discusses the position of biscuits in the context of nutrition.

Key words: biscuits, nutrition, manufacturing, snacking, obesity, allergy, intolerance, ageing, vegetarianism, religion, labelling.

31.1 Introduction

Biscuits products across the world are typically baked and dry edible products of varying size. The word ‘biscuit’ is derived from the Latin meaning ‘twice cooked’, as traditionally biscuits were cooked and then slow dried to harden. The early origins of biscuits can be traced back to a Roman cookbook, where they are described in the following way [1]:

a thick paste of fine wheat flour was boiled and spread out on a plate. When it had dried and hardened, it was cut up and then fried until crisp, then served with honey and pepper.

Thus the words *Biscotti* in Italian, *Zwieback* in German, *Beschuit* in Dutch and *Biscuit* in Modern French have this etymology.

The need for nutritious, long lasting, easy to carry and easy to store foods is not a modern trend that has developed in recent, modern consumer history. Rather than perishable foods, early sailors and the military needed cheap foodstuffs for sustenance that were light and easy to transport during long sea voyages and military campaigns [2]. Over the centuries with new developments in baking knowledge, technology and equipment, the array of biscuit type and quality has multiplied, whilst around the world, reliance on biscuit products for energy has changed. Manufacturers are innovative, adapting to consumers’ needs and expectations. Today there are said to be tiers of biscuit quality from entry level to the more luxury chocolate covered types, and new developments in healthier, reduced fat and sugar biscuits are emerging onto the market.

Nutrition as a science is interested in the nutrients found in foods and beverages and the interactions with the human body on health. Other than breast milk, no

single food in the diet can provide all the nutrients needed for health and so diets must be made up of a variety of foods and beverages. In 1991 the UK Department of Health published a report of Dietary Reference Values [3] for energy and nutrients, which defined the nutritional requirements of the UK population in addition to those published by the World Health Organisation [4]. We all need energy to live and this comes from fats, carbohydrates and protein (the macronutrients) found in foods. A healthy diet should contain a variety of foods from all the different food groups as the balance between macro- and micronutrients (vitamins and minerals) in addition to fluids is important to stay healthy. This means all foods, including treats, can be part of a healthy diet, but what is more important is the amount and frequency of foods that are included.

All foods belong to one of five different food groups:

- bread, rice, potatoes, pasta and other starchy foods
- fruits and vegetables
- milk and dairy foods
- meat, fish, eggs, beans and other non-dairy sources of protein
- foods and drinks high in fat and/or sugar.

Around the world there are different models used to describe the proportions these should make up in the diet. For example, the Food Pyramid is a model used by the United States Department of Agriculture (USDA), The Food Guide rainbow is used in Canada and the Food Plate or Eatwell Plate is used in the UK and Australia. Health professionals recommend a healthy diet based on potatoes, rice, pasta and other starchy foods, rich in fruits and vegetables. A variety of foods from these two groups should make up around two-thirds of the foods eaten daily. The remaining third of the diet should comprise mostly of milk and dairy foods, meat, fish, eggs, beans and other non-dairy sources of protein, with limited amounts of foods and drinks high in fat and/or sugar. Around 1.5–2.5 litres of fluids should also be consumed daily. Treats such as sweet biscuits should fall into the latter food group as they are typically rich in fats and sugars and so too can have high energy contents. It is important to remember, however, that the amount of energy we take in through our diets should balance the energy that we expend in order to balance our weight. This is commonly described as the see-saw effect; energy in = energy out. The more energy we eat in the diet, the more energy we need to burn off through activity and exercise. Humans are all individual with genetics and the environment exerting influence on individual needs. Therefore energy requirements vary from person to person and differ depending on age, gender, weight and levels of physical activity.

Global obesity statistics have been described as reaching epidemic status by numerous public health departments, with more than 1 billion adults overweight – at least 300 million of them clinically obese. Over-nutrition is a major contributor to the global burden of chronic disease and disability [5]. Often coexisting with under-nutrition in many countries around the world, obesity is a complex condition with interplay from various factors. The UK Foresight report describes this interplay as ‘the obesogenic environment’ and is defined as ‘the total sum of influences in the environment on promoting obesity in individuals and populations’ [6]. Obesity has serious social and psychological dimensions that are affecting virtually all ages and socioeconomic groups around the world. Although it is clear that the causes of overweight and obesity are complex, it is self evident that weight gain arises from

an excess of energy intake over energy expenditure [7]. It is evident from guidelines on healthy diets that foods such as sweet biscuits and cakes are seen as energy dense and the World Health Organisation (WHO) states they are conducive to obesity [4]. Adding to this, Poppitt and Prentice [8] have established that 'passive over consumption' can occur when diets are energy dense. As more people are able to enjoy a variety of foods from around the world, foods are enjoyed more for pleasure and social enjoyment than just to provide energy. They are a source of pleasure and enjoyment which is an important factor for overall well-being. This chapter will explore how biscuits can be part of a varied, balanced diet, their association with body mass index (BMI), the overall contribution of biscuits to the diet and the positive contribution biscuits can make to the diet for different people through advances in biscuit manufacturing.

31.2 Biscuits in our diets

Snacking behaviour has been around for centuries and is traditional in many societies. The English have always been famous for afternoon tea and biscuits or the occasional scone, the Germans for pretzels and the Spanish for tapas. Snacks can fit into different people's lifestyles for different needs. In recent years, modern snacking has changed both in terms of the types of foods we are reaching for and the times of day we are having these. For example in the UK, which has the longest working week in Europe, skipping breakfast is common and is often replaced by eating and drinking on the way into work. Due to the origins of biscuits, the size, shape, lightweight and characteristic hard texture make biscuits an ideal snacking food.

Sweet biscuits are typically high in fats and sugars and for this reason health professionals recommend that they can be eaten in small quantities as part of a varied diet. Scientific studies and reviews state that snacks can fit into a balanced diet [9, 10]. Some of the benefits of snacking include:

- improved concentration and mental performance
- a valuable contribution to nutrient intakes
- can help curb hunger to help prevent overeating
- can help balance energy intake throughout the day.

In the body, the brain is the most active organ and its primary source of energy is glucose. Kanarek and Swinney [11] state how responsible snacking can be beneficial in those afternoon lulls when it gets hard to concentrate. Glucose is the one of the simplest forms of sugar, and so is an important carbohydrate in our diet. Our brains only account for approximately 2% of our body weight, nevertheless accounts for a massive 20% of the energy that we need each day. As the brain does not store the glucose it needs to burn for energy, it must have a constant supply of glucose in the blood to meet its requirement of around 100 g glucose each day.

At times when we need to concentrate hard, the brain works much harder and requires a lot more energy (glucose) – this can be measured by drops in blood sugar levels as a result of the increased activity. Snacks such as biscuits, which provide large quantities of carbohydrates, have been shown to help keep the energy supply of glucose topped up for brain activity during work, school or college including concentration, focus and memory [12].

It is commonly said that many snack foods provide 'empty' calories, elevating energy intake through high fat and sugar quantities, with insignificant contributions of other nutrients. On average, biscuits, cakes, pastries and confectionery foods provide one eighth of adult energy intake and one fifth of children and young people's energy intake. Not only do these snacks provide a valuable source of energy, these types of snacks also contribute vitamins and minerals to the diet [11, 13]. Sweet or savoury biscuits will provide predominantly differing amounts of sugars and sodium respectively. In a review by Gatenby [14], snacks have been shown to contribute significantly to the nutrient quality of the diet. For example, snacks have been shown to provide greater amounts of calcium, riboflavin, iron and folate in children [14] and vitamin C, fibre and iron in adults.

In developing countries, biscuits are typically used as a positive food vector when implementing food fortification programmes cited in numerous feeding programmes. As discussed by Mannar and Sankar [15], biscuits are easy to distribute, easy to prepare and fortify and have a long shelf life for use in long-term feeding programmes.

Snacking in itself does not contribute to increased levels of obesity; it is more important to consider the type, frequency and whether foods are balanced in an individual's overall diet [16]. In fact, it can be argued that evidence shows snacking can actually be beneficial for almost everyone if balanced and responsible.

31.3 The evolution of biscuit nutrition

Foods in the diet are as much about good nutrition and healthy eating, supporting a varied and balanced diet, as about maintaining mental and emotional well-being. Biscuit snacks not only provide important nutrients to our daily intakes but are fun and tasty to eat, providing pleasure and enjoyment especially when shared with our families and friends. It has been suggested by Gatenby [14] that trends in snacking behaviour are difficult to assess as the ways snacks are defined varies greatly, and whilst there is no correlation between snacking and obesity levels, government public health departments globally are beginning to put pressure on biscuit manufacturers to reduce levels of fat, saturated fat and energy. For example, the UK Food Standards Agency (FSA) published voluntary saturated fat and energy reductions targets in 2010 [17].

Positive changes in manufactured products have begun to emerge in the market place. For example, in 2009 United Biscuits (UB) launched a number of biscuits with reductions in saturated fat, and for some products a second reduction was launched at the start of 2010. Examples in their sweet biscuit range include an 80% saturated fat reduction in McVitie's Digestives and Light Digestives, a 75% reduction in McVitie's Hobnobs, Rich Tea and Light Rich Tea and, a 65% reduction in McVitie's Light Hobnobs. In 2009 in their savoury biscuit range, UB reduced the saturated fat in Jacob's Light Cream Crackers by 55% [18]. Nestlé in the UK have re-launched some of their popular biscuits (e.g. Blue Riband and Breakaway) in a 99 Calorie range reducing their portion size, energy and saturated fat as a result [19].

In 2010, the global snack market was reported to be worth almost €197.8bn. This could be argued as part of the reason why biscuit and snack manufacturers are focusing on healthier products, according to the report published by Global Industry Analysts in March 2010 [20]:

The trend for healthy snacks or those that are perceived to be healthy by consumers shows no sign of abating as health-driven snackers are setting into motion strong demand for healthy, low fat, low-calorie snacks.

31.4 Different biscuits for different people

The nutritional needs of a global population are personal and specific to everyone one of us. There are, however, some needs which are shared by groups of people where specific dietary solutions are sought after, for example, those with adverse reactions to food, infant nutrition or high energy diets, food avoidance for religious beliefs, vegetarianism or veganism. Here we explore some of the more common special diets.

31.4.1 Adverse reactions to foods

Globally, adverse reactions to foods represent a significant public health issue. The expression 'adverse reaction' is used to describe health and digestive problems linked to foods. Food allergy and food intolerance are two of the most common adverse reactions to foods although the differences between the two are not well understood.

Genuine food allergy is rare, for example affecting around 1–2% of the UK population (and 8% of children under the age of 3). Food intolerance is becoming more common with Allergy UK estimating approximately 45% of people in the UK suffer from a food intolerance (calculated as food-related symptoms), including migraines, skin rashes and problems with the gut [21]. In 2007 approximately 3 million children in the United States under the age of 18 (3.9%) were reported to have a food or digestive allergy in the previous 12 months.

A food allergy is when the body's immune system identifies a protein in food (allergen) as a harmful substance and mounts an immune response to attack it. In this attack, the antibody immunoglobulin E (IgE) is released to fight the allergen, releasing histamine and other chemicals into the body which cause the symptoms of an allergic reaction. Symptoms can include itching, swelling, difficulty swallowing or breathing, and vomiting. Some people can be very sensitive to food allergens. In these cases, only a very small amount of the allergen need be ingested to cause a severe reaction, or anaphylactic shock, where the blood pressure drops significantly, possibly even resulting in death. There are 14 food allergens that have been identified as the most commonly responsible for producing allergic responses. These are:

- celery
- cereals containing gluten (wheat, barley, rye and oats)
- crustaceans (such as lobster and crab)
- eggs
- fish
- lupin
- milk
- molluscs (such as mussels and oysters)
- mustard
- nuts (namely, almonds, hazelnuts, walnuts, Brazil nuts, cashews, pecans, pistachios and macadamia nuts)

- peanuts
- sesame seeds
- soybeans
- sulphur dioxide and sulphites (preservatives used in some foods and drinks) at levels above 10 mg per kg or per litre.

Coeliac disease is often misunderstood as being a food allergy – it is actually an autoimmune disease. Gluten is the name for a group of proteins which are present in wheat, rye, barley and oats. In gluten-sensitive people, the gluten causes the body's immune system to attack its own tissues, mainly in the small intestine (the villi), meaning the body is unable to absorb nutrients in foods. Symptoms vary from constipation and bloating to headaches, infertility and joint pain. Some of these symptoms are often mistaken for an allergy or intolerance. There is no cure for those who suffer, and a life-long avoidance of gluten is necessary. Currently, there is thought to be a large proportion of the global population affected by coeliac disease, which includes one in a 100 people in the UK living with the disease [22].

Food intolerance does not involve a response by the immune system; rather it is the body's inability to break down and absorb certain food components during digestion. This can be caused by a lack of or insufficient amounts of digestive enzymes. Instead, the undigested food components remain in the digestive tract and in the colon, where the bacteria that naturally reside in our larger intestine ferment these foods into acids, carbon dioxide (CO₂), methane (CH₄), hydrogen (H₂) and hydrogen sulphide (H₂S), the odour associated with flatulence. This fermentation causes discomfort and pain, with typical symptoms including bloating and cramps. One of the most common food intolerances is to the sugar found in cow's milk; lactose. Lactose intolerance occurs when the milk sugar (lactose) cannot be digested and absorbed by the body due to a deficiency in the enzyme lactase. Intolerance is not generally life threatening but leaves people feeling unwell and may affect their long-term health.

Many of the common food allergens are ingredients used in biscuits, such as cereals which contain gluten, eggs, milk, nuts and peanuts. On most food packaging, ingredients lists are clearly labelled. However, since 2005, in European legislation any pre-packed foods containing an allergenic substance or derived from such must be clearly labelled. Voluntary labelling such as 'contains' or 'may contain traces of' which help to direct those people affected to foods they can consume. The UK Foods Standards Agency has developed best practice guidance on managing food allergens. This document provides detailed information for food manufacturing businesses and is titled 'Guidance on Allergen Management and Consumer Information'. It contains guidance on how businesses can best provide information to the consumer that can help them avoid allergenic ingredients in the foods they buy.

A number of years ago, adverse reactions to food were less well known and special foods catering for these needs could only be found in specialist health food shops. Nowadays, with more people becoming aware of these reactions to foods, supermarkets have begun to react to this consumer need creating their own special food ranges and stocking a greater variety of products from specialist food manufacturers. For example, the large UK supermarkets such as Sainsbury's, Tesco, Morrison's, Asda, Waitrose and The Co-Op now have 'Free From' food ranges developed specifically to provide tasty alternatives that are safe for allergy sufferers to eat.

31.4.2 Biscuits for specific needs

There are many different types of biscuits found all around the world, from sweet to savoury, and for teething to tea time; lots of different types exist with some developed for specific needs. As part of a varied and balanced diet, all foods can be enjoyed in moderation to ensure the right amounts of nutrients are delivered for good health. In some cases, however, there may be other circumstances where certain foods or groups of foods are avoided through choice and belief (vegetarianism, Judaism) or necessity (high energy diets). When this happens, supplementing the diet may be important to ensure nutrient deficiencies do not arise. Enriched biscuits can be particularly important as micronutrient deficiencies are widespread around the world and fortifying commonly eaten foods can be part of the solution to control and prevent micronutrient deficiencies in an available and affordable way [15]. Additionally, enriched biscuits may be a convenient way for people to try and get the right nutrition into their busy, hectic lifestyles when food choices and availability has never been so great. Here we explore just a few of these needs.

31.4.2.1 Biscuits for infants

The diet of infants is influenced by maternal and family characteristics, with the nature of the mother's diet being a key determining factor. This is particularly apparent at around 12 months of age as the diet becomes increasingly based upon family foods [23]. In the UK, exclusive breastfeeding is now recommended until 6 months of age [24], when the introduction of solid foods can begin. General weaning guidelines are available from the UK Department of Health on providing a varied diet, first foods, delaying allergenic foods and avoiding sugar and salt [25]. These guidelines recommend introducing healthy snacks into the diet at around 9 months and are based upon the recommendations of the COMA Working Group on the Weaning Diet.

It is common in many countries to use biscuits as a weaning food or as a way of exercising the jaw during teething and to help alleviate the pain caused by teeth breaking through the gum line. Biscuits can be a nutritious weaning food for infants as many of these are fortified with key nutrients vital for healthy development such as iron, zinc, calcium, vitamin A, iodine and fluoride. Buzalaf *et al.* [26], working in Brazil, found that biscuits can be an important contributor to daily fluoride intake when consumed once a day, supplying up to 25% of the maximum recommended daily fluoride intake ($0.07 \text{ mg F kg}^{-1} \text{ body weight}$) for a 2-year-old child. In this way, food fortification programmes can help to reduce and eliminate micronutrient deficiencies worldwide supported by adequate quality assurance, labelling and legislation and monitoring to ensure the desired effect [15].

Rusks and biscuits for infants are tightly controlled by legislation [27] to ensure high quality, both in ingredients and nutrition, and that their composition is suitable. These types of products are commonly broken into pieces and added to milk or water to soften them until an infant has teeth and is able to bite and chew.

31.4.2.2 Biscuits for an ageing population

The UK population is growing and ageing. The UK population had grown to 61.8 million in 2009 [28]. Over the last 25 years the percentage of the population aged 65 and over increased from 15% in 1984 to 16% in 2009, an increase of 1.7 million people. The fastest population increase has been in the number of those aged 85 and over, the 'oldest old' reaching 1.4 million in 2009 [29].

The human body starts ageing from about the age of 20 years, and the speed is influenced by genetics, diet and the social environment. Food and eating bring shape to a day, facilitating social interaction as well as providing essential energy and nutrients. The main dietary cause for concern in a population that is growing older is that they are not eating enough food to maintain good nutrition for health [30]. The 1998 National Diet and Nutrition Survey (NDNS) [31] for adults aged 65 years and over shows 3% of men and 6% of women living in their own home were underweight, 16% and 15% of those living in residential care, respectively.

Older people tend to lose their appetite and whilst their energy expenditure and needs reduce, their requirements for essential nutrients do not, and in some cases will increase. The UK Department of Health's report of Dietary Reference Values for energy and nutrients [3] defines nutritional requirements of the UK population and has been reviewed for older people in their report *The Nutrition of Elderly People* [32]. Thus, the quality rather than the quantity of the diet becomes more important as more nutrients are needed in smaller amounts of foods. It is in this way biscuits can play a part in the diets of all ages as a tasty enjoyable food.

Biscuits can be designed to target older people through their enrichment due to the ability to change the ingredients and modify recipes. For example, biscuit flour can be enriched with many different vitamins and minerals, whilst the choice of flour (white or wholegrain, rice or oat) or fat can also affect the amounts of fibre, saturated fat, essential omega fats and sugars in biscuits. Through these modifications, a small amount of food can be enriched to deliver higher amounts of energy and/or nutrients to a targeted population.

31.4.2.3 *Vegetarianism and religious food choices*

31.4.2.3.1 Vegetarianism

Choosing to follow a vegetarian diet is very personal. The Vegetarian Society cite the most common reasons to avoid eating meat and fish as:

- do not morally approve of killing animals
- objection to the ways in which animals are kept, treated and killed for food
- wanting to follow a healthier diet
- the environmental impact of raising animals for meat
- wasting world food resources using land to raise animals for meat instead of growing crops.

A vegetarian is someone who chooses not to eat meat, poultry or fish or any other slaughterhouse by-products such as gelatine or rennet. Some people may or may not choose to eat free range eggs, and dairy products such as milk, cheese or yogurt. As defined by the Vegetarian Society, the types of vegetarian include:

- **Lacto-ovo-vegetarian:** eats both dairy products and eggs. This is the most common type of vegetarian diet.
- **Lacto-vegetarian:** eats dairy products but not eggs.
- **Vegan:** does not eat dairy products, eggs, or any other animal product.

In 2000, approximately 3% of the UK population followed a vegetarian diet and 2% followed a vegan diet, a similar trend tracking through the 1980s [33]. Vegetarians are continually seeking specific foods which are vegetarian friendly as many foods contain ingredients derived from the slaughter of animals. For example, gelatine is made from animal ligaments, tendons and bones, etc., which have been boiled

Table 31.1 World religions, food practice and restrictions (adapted from Waibel [34])

Religion	Practice or restriction
Buddhism	• No beef, a vegetarian diet is desirable.
Eastern Orthodox Christianity	• Some restrictions on meat and fish.
Hinduism	• Beef is prohibited, vegetarian diet is desirable.
Islam	• Pork and certain birds prohibited.
Judaism (dietary law Kashrut meaning 'correct')	• Pork, rabbit and shellfish prohibited.
	• Meat and dairy at same meal is prohibited.
	• Leavened food is restricted.
Protestants	• Moderation in eating is promoted.
Rastafarianism	• Vegetarian diet followed with meat and fish restricted.
	• Salts, preservatives and condiments prohibited.
Roman Catholicism	• Moderation in eating is promoted.
Seventh-day Adventist	• Pork prohibited.
	• Meat and fish avoided.
	• Vegetarian diet is encouraged.

in water. It is often found in sweets and confectionery. Animal fats found in a multitude of products including biscuits and cakes refer to carcass fat. Suet and lard are also types of animal fats and even some unexpected sources such as food additives may be derived from animals. In knowing this, it can be relatively simple to produce suitable products for vegetarians by procuring and processing suitable ingredients. Many biscuit manufacturers and retailers now make it easy for people to choose these foods by providing clear information on the front or back of packs, using the 'Vegetarian Society Seeding Symbol' logo on packs (the only legally registered trademark for vegetarian accreditation) or other recognised logos to communicate to consumers.

31.4.2.3.2 Religious food choices

To fully understand why different religions have specific laws around diet and health would require delving into the teachings of the scholars. It is also important to note that these laws and restrictions around food were laid down before food safety, health promotion and disease were known or understood. What is important in food production is to be aware of these restrictions as it can be very easy to ensure biscuits can be suitable for a wide range of needs. Table 31.1 summarises the world religions and their food practices and restrictions.

31.5 Food labelling can help – when you understand it

European food labelling is currently regulated by Council Directive 2000/13/EC [35] which requires foods to be labelled with certain requirements, which include:

- the name of the food
- a list of ingredients (including food allergens)
- the amount of an ingredient which is named or associated with the food
- an appropriate durability indication (e.g. 'best before' or 'use by')
- any special storage conditions or instructions for use
- the name and address of the manufacturer, packer, or EU seller.

As amended by Directive 2003/89/EC [36], it has become mandatory to list all subcomponents of compound ingredients and to include a full list of food allergens to ensure allergens are very clear (for the full list of allergens, see Section 31.4.1). This legislation is due to be updated by 'The Food Information Regulation for Europe' in the near future and should be referred to once available.

31.5.1 Nutrition and health claims

Food labels can be very confusing due to the amount of information required by law as detailed above. As the prevalence of obesity grows globally, manufacturers are now adding information on nutrition and health to labels to help inform consumers to make an informed healthier choice. Across many food and drink products in the UK, retailers and manufacturers have been providing clear information on the nutritional content on labels for some time.

There are two types of claims used on labels: nutrition claims and health claims and these are governed by European Legislation [37]. For example, a *nutrition* claim stating the presence or absence of a nutrient can include statements such as low in fat, high in fibre, contains Vitamin C; only claims listed in the Annex of the legislation can be used. Currently, when these claims are made, the nutritional breakdown of the food per 100 g or 100 ml becomes mandatory of:

- energy (in kJ and kcal)
- protein (in g)
- carbohydrates (in g) and sugars (in g)
- fats (in g) and saturated fats (in g)
- sodium (in g)
- plus any nutrient for which a claim is made.

The Food Information Regulation currently in the legislation system will update the requirements of mandatory nutrition information. Lite or Light is also classed as a nutrition claim. To say that a product is 'lite' or 'light', it must explain on the label exactly what the claim means. To use this claim, the product must be at least 30% lower in at least one typical nutrient value (listed on the label on the back of the pack), such as calories or fat, than standard products. The label must explain exactly what has been reduced and by how much, for example 'light – 30% less fat' [38].

Health claims are also becoming more common on food labels. These are statements about the benefit that a product may have on the body to promote good health. For example, 'helps maintain a healthy heart', 'can help lower cholesterol', 'for healthy digestion'.

Updated European regulations on nutrition and health claims made on foods came into force in 2007 [37], meaning that any food which makes a nutrition or health claim must be based on science and for the first time, lays down harmonised rules across the European Union on the use of nutrition claims such as 'low fat', 'high fibre' or health claims such as 'reducing blood cholesterol':

There is a wide range of nutrients and other substances including, but not limited to, vitamins, minerals including trace elements, amino acids, essential fatty acids, fibre, various plants and herbal extracts with a nutritional or physiological effect that might be present in a food and be the subject of a claim. Therefore, general principles applicable to all claims made on foods should be established in order to ensure a high level

of consumer protection, give the consumer the necessary information to make choices in full knowledge of the facts, as well as creating equal conditions of competition for the food industry.

31.5.2 Front of pack labelling schemes

Today many food manufacturers and supermarkets voluntarily use nutrition information 'signposts' on the front of packs to help consumers make an informed choice quickly. There is currently not one uniform system but a series including Guideline Daily Amounts (GDAs) developed by manufacturers and retailers providing information on a serving of a food or drink; Multiple Traffic Lights (MTLs) developed by the UK Food Standards Agency based upon high, medium or low amounts of nutrients in 100 g or 100 ml of foods; and hybrid schemes which include both GDAs and MTLs.

There are currently 93 adopters (as of June 2010) of the GDA labelling scheme: five retailers, three food service organisations, two convenience store chains and 83 manufacturing companies amounting to 50% of all UK food and drinks packs, and GDAs have been voluntarily rolled out in all 27 European member states [39]. Draft legislation has been published by the European Commission which includes the provision of providing nutrition information on packs; however, this is still in the legislative system and has not yet been finalised in European law.

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Miscellaneous biscuit-like products

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Abstract: A number of products that cannot be truly described as biscuits can be made on biscuit plants. These include cracker substitutes, baked snakes like potato crisps and dog biscuits. Using cooker extruders other types of cracker substitutes can be made which do not depend on wheat flour.

Key words: crispbread, rusk, dog biscuits, cereal bars, cooker extruder.

32.1 Introduction

In Chapter 31 some account was given about biscuits developed for specific nutritional needs. Most of these involved removing or adding specific ingredients in conventional types of biscuits. In addition to these 'different' types of biscuits, many ingenious biscuit-like products have been developed, marketed and perhaps have subsequently fallen into obscurity. In most cases more or less conventional biscuit plant has been used to make these products and it is felt useful to indicate what is possible here. However, it is not practical to cover adequately all the techniques that have been used. Mention is therefore made of just a few products that have assumed importance in certain market places.

32.2 Products that are made on a type of biscuit plant

32.2.1 Crispbread

Crispbread probably had its origin in the cold countries of northern Europe where it was, and still is, traditionally made from rye flour (Fig. 32.1). It has a very long history and was popular because of an exceptionally long shelf life even without moisture-proof wrapping. The original crispbread and most other later variants are claimed to have high nutritional properties and to be aids to slimming. These claims, combined with a general increase in popularity of bread substitutes, has caused an increase in sales worldwide. Traditionally, rye flour is used for crispbread. Usually this is a fairly coarse wholemeal but it is the use of rye that limits the production of the original product. Rye can be grown in cold regions of the world and on poor



Fig. 32.1 Crispbread.

soils where most other cereals would not be productive. The acreage under rye is declining and at present about 95% of all rye is grown in Europe.

The protein in rye flour produces little gluten. However, because some gluten is formed, its effect, combined with the special water-binding characteristics of the pentosans and starch, enables rye flour to be used to make dough which retains gases during baking. If used to make bread the result is a very dense texture. This can be greatly improved by the addition of some wheat flour, even as little as 25%.

It would seem that there are no special nutritive values for rye flour, but rye crispbread may be useful in slimming because of the relatively high levels of pentosans. These gelatinise and swell in the stomach giving a feeling of satiation. Also, the hydrolysis of the polysaccharides is slow so the blood sugar level rises slowly but is maintained for 5–6 hours, thereby controlling the appetite (Kent and Evers [1]). The bran content contributes to dietary fibre.

Traditional crispbread is made with only rye flour, salt and water (sometimes also with a little milk). There are now many variants of crispbread and these may be made with rye and wheat flour mixtures or from wheat wholemeal. Often they are yeast raised and may contain small quantities of fat and raising chemicals. Traditional rye crispbread is neither fermented nor chemically raised. The dough is very cold and very soft. A typical recipe is:

Rye flour	100
Salt	1.2
Water (iced)	129

The flour, salt and water are blended to give an aerated mixture with density about 0.35 g/ml at 6°C or less. In modern plants the blending, aeration and chilling is best done continuously with a pressure beater heat exchanger like a 'Votator'. The dough is effectively a cold foam and expansion of the bubbles during baking gives the

characteristic open texture. Where non-continuous mixing is required other batter type mixers may be used.

To form a sheet from this dough requires firstly a special extruder sheeter. The dough is extremely sticky, pseudo-plastic and short so, having obtained a sheet, it must be dusted liberally on both sides to prevent adhesion to the conveyor, etc., and a skin must be formed on the surface to hold the gases during baking. Dusting of the underside may be with a mixture of ground crispbread, bran, wholemeal, etc. This dust, as well as preventing sticking, also dries the surface to make a skin. The top surface is usually dusted with a finer flour mixture so as to maintain a better appearance.

To control the lift and texture during baking the sheet is then 'docked' with two rotary docking rollers in series. The first is driven slightly slower and the second slightly faster than the sheet. The docker pins are, in fact, short fingers which stretch and push the surface of the sheet promoting a strong skin to be formed at the same time creating a suitable pattern on the surface and pinning the top skin to the bottom. The dockers merely indent the surface, they do not penetrate right through the sheet. It is necessary to brush and dust each docking roll to reduce pick-up. Excess dusting on the dough surface is sucked up and reused.

The sheet shrinks during baking so it must be cut before placing on the oven band. Cuts are, therefore, made transversely with a guillotine at about 25 cm intervals and longitudinally, with rotary knives which lift a thin strip of scrap, at about 28 cm intervals to suit the plant width. These slabs are then either panned directly onto the oven band wire or they may firstly be conditioned in a tunnel where high humidity allows the dusted surface to soften and there is some dough relaxation.

The sheets are baked for about 6 minutes in an oven with profile 280°, 270°C. The baked sheets should have a final moisture content of around 5.5% and this may be aided by using a dielectric drying unit after the oven. It is most important that the oven band is maintained flat as these baked slabs are subsequently sawn into smaller rectangles (usually about 120 × 60 mm) for collation and packing. The sawdust from this cutting operation can be used in part for sheet dusting as described earlier.

Details of manufacturing methods vary and there is a large amount of private and guarded engineering involved in different factories. Where recipes include more wheat flour and less rye, the sheeting and stickiness problems reduce, but the very open texture in a high-bran dough requires different techniques than for cracker biscuit doughs. The low- or no-fat recipe means that if the texture is too dense the product will be very hard eating.

Typically, crispbread sheets are about 6–8 mm thick. It is a major processing problem to maintain a constant thickness from such soft dough and as packs are often formed by volume from a pile of sheets, the weights tend to vary much more than normal biscuit packs. Continuous dough mixers which maintain a steady dough temperature, combined with precise control of oven conditions offer the best opportunities for pack weight control. Bressler [2] gives details of Swedish crispbread plant based on his experience while working for Wasa, the world's largest crispbread manufacturer. An interesting patent was taken out by United Biscuits (UK) Ltd [3] describing a means of making crispbread by baking between closed pairs of heated metal plates. The technique does not seem to have been developed commercially,

but it exploits the similarity of internal structure between wafers and typical crispbreads.

32.2.2 Yeastless sausage rusk

Yeastless sausage rusk is, in essence, granulated unfermented biscuit that is able to absorb twice its weight of water and still remain comparatively dry and not soggy. Production of rusk for sausages involves very similar technology and techniques to those used for dog-biscuit meal. A tight dough of flour, water and maybe aerating chemicals (sodium bicarbonate and a phosphate salt) is sheeted and cut into small rectangles (about 25×12 mm) and then baked for about 30 minutes. At the oven exit the moisture content is as high as 18% so further drying takes place very slowly over a period of about 5 hours. It is during this drying that the rusk acquires its high absorbency. The dried pieces of rusk are ground and the meal obtained is graded by sieving. The rusk is used mixed with ground meat and flavouring materials, etc., and its main function is as a bulking agent and means of holding additional moisture in the sausage. Tradition has it that sausage rusk is produced on very wide (2 m) plants. Baking with low colouration is the common aim.

32.2.3 Cereal bars

The increased interest in fibrous and oaty foods has prompted the development of both crisp and chewy types of cereal bars (Fig. 32.2). These are formed from a coarse mixture of flour and oat flakes mixed with warm syrup and various dried fruit pieces and nuts. The sticky mass is compacted into a thick sheet directly onto a steel band. The sheet is then generally divided longitudinally into strips. If crisp bars are required they are then dried in a conventional biscuit oven but if chewy bars are to be formed the drying aspect of the baking is much less. The strips are cut into the desired length before wrapping which is usually as unit bars. Cereal bars are con-



Fig. 32.2 Cereal bars.

sidered to be 'healthy' products. By using concentrated fruit juices it is possible to manufacture without the use of sucrose from entirely 'natural' ingredients.

32.2.4 Pizza bases

The development of the frozen-food market for convenience and fast foods has resulted in pizza pies becoming extremely popular. The traditional Italian pizza is a disc of fermented bread dough liberally topped with vegetables and meat pieces in a tomato sauce and garnished with grated cheese then baked in a very hot sole plate oven immediately before eating. The technique used to produce deep frozen pizzas, which are to be baked straight from the freezers when required, usually involves the production of baked bases upon which the toppings are spread before freezing. The bases, which may be in a variety of sizes depending upon whether small individual or large 'family' pizzas are required, may be prepared by hand or on biscuit-type forming and baking machinery. There are major differences between pizza bases and biscuits, but production on biscuit plant has proved successful and very efficient.

Pizza dough is traditionally yeasted bread dough which is fermented before use, therefore it is similar to cream cracker dough. The structure of cream crackers is, however, developed as a result of laminating with inclusion of a fatty dust to promote a flaky structure. When made traditionally, pizza dough is not laminated, it is merely pressed and spun by hand into the desired shape. Bread dough, whether fermented or not, does not sheet well from biscuit dough sheeters. The gluten is too tough and short so a ragged or holey dough sheet tends to form. It is also rather sticky due to the low levels of fat. By using a laminator these sheet deficiencies are improved considerably, but there is a tendency to create a laminar structure in the pizza base during baking.

As a result of these problems, compromises have been made in terms of flour type, amount of yeast and length of fermentation and also inclusion of raising agents in the dough. In some cases the cut discs are given a final proof before being baked; in others this proving is omitted or reduced to a very brief period in a warm first zone of the oven. Pizza dough is very soft and the cut pieces are large by comparison with biscuits. It is important that the baked bases are uniformly round in shape and shrinkage after cutting may be a problem. Rotary cutting is possible but a variable length cutting ring used as a reciprocating cutter has advantages for controlling baked base shape. It is difficult to prevent distortion at the dough transfer points and this problem is particularly bad if the pieces are proved in-line before baking. The dough becomes more sticky and delicate, making it almost impossible to transfer without disturbing the lift in the dough or causing distortion.

Normally, but not in all cases, the dough pieces are dockered with fine holes at about 2 cm intervals. This promotes a more even lift in the oven giving a good appearance and a level surface upon which to place the topping. (Traditional pizza bases are, of course, never baked without the toppings and these hold the centres down in the oven.) If the docker holes are too prominent it will be possible for the tomato sauce to run through, stain the underside of the base and cause sticking problems when the frozen pizza is reheated.

Baking of pizza bases is aimed at a pale surface colour and a good rise to a stable set structure within the pieces. The moisture content at the oven exit will be high as the frozen pizzas will be baked again by the consumer, so cooling is important

to prevent sweating of pieces either when placed together or while on conveyors. The oven band may be either steel, heavy weave or close mesh light weave. There is a tendency for bases to stick on a steel band so some oiling may be necessary and this type of band will require a lot more power in the first sections to allow good development before the whole structure sets.

It is possible that the pattern on the underside of the base, derived from the oven band, is not as critical as it is usual to invert the piece and to garnish the bottom before freezing so only the original top of the baked piece is seen by the customer.

A major difference between fresh and reheated frozen pizzas is in the crispness of the base. In some cases the base is unpleasantly doughy or chewy. Developments have been directed towards improving crispness which will withstand the moisture migration problems of freezing and thawing. It has been thought that fatty crusts, or harder flaky structures may be beneficial, although these are away from the truly traditional Italian product. Thus, lamination of the dough has been tried with limited success and there is also a patent on a process for deep frying dough pieces rather than baking [4]. This deep frying undoubtedly improves the flavour, but the oil pick-up also increases the costs of the base.

It is not possible to give 'typical' pizza base recipes, as variety exists related to different production methods. Successful, uniform processing depends on the sheetability of the dough and the development of an open, even, structure during baking.

32.2.5 Wafer dough drops

A group of biscuit-like products are made by baking a soft short dough between hot plates as in a wafer oven. These have various names and are particularly popular in France. The feature is principally the patterned surface on both top and bottom sides produced from the hot plates. The oven is typically formed by a pair of articulated tracks with plates about 10 cm wide fitted to a chain so that when in a flat position there is little space between adjacent plates. Dough deposits are placed on the lower plate while it is still warm. As the chain moves towards the oven a top plate locates and a fixed gap results in discs or ovals being baked at a given thickness.

32.2.6 Lebkuchen

As the name suggests, these are a group of a traditional German products but they also derive from other central European countries. Lebkuchen are typically made from a fatless, heavily syruped dough, often involving high levels of honey. The dough is usually very dark in colour derived from spices, rye or dark wheat flour and the syrups. The products which are known as 'cakes' because of their moist texture, have long shelf life due to the high sugar solids present. They are more generally popular now, but were traditionally Christmas and Easter lines. For several years Lebkuchen have been successfully manufactured on biscuit plant using a rotary moulder and conventional band oven.

Preparation of the dough is unusual as long, or very long, standing times appear to be necessary between mixing and use. Typically a tight dough of flour, very hot syrup, potassium carbonate and lactic acid is well mixed in a powerful mixer to a temperature of about 60°C. This dough is then transferred to convenient sized bins

and allowed to rest in ambient conditions for several days. Clearly it takes some time for the dough to cool while in these large masses and it may be that smaller trials should be stored at higher temperatures. The changes that occur and the periods required are somewhat vague, but it would seem that 24 hours is an absolute minimum dough storage time and at least one major manufacturer says 14 days is the minimum. The sugar concentrations preclude normal fermentations, but changes which affect the structure of the baked piece are undoubtedly involved. The fact that the dough is so hot means that starch gelatinisation and denaturing of the proteins occurs in the mixer rather than in the oven.

The stood dough is then thoroughly remixed with spices, some flour and ammonium bicarbonate before being moulded with a rotary moulder. The dough is tight, sticky and plastic. The moulder must have a specially shaped knife which smooths rather than slices the excess dough from the moulds. Techniques to facilitate release from the moulds such as oiling or moulds made as plastic insert dies are generally necessary. Typically, the moulded pieces are about 12 g in weight and are simple rounds or heart shapes. When moulded they are about 4 mm thick and after baking this has increased to about 16 mm. Baking time is between 5 and 7 minutes in a steel band oven. The baked pieces may be injected with jam while still on the oven band by means of specially synchronised depositing machinery and then after cooling they are chocolate enrobed. This effectively seals in the injected jam. Less commonly the cooled Lebkuchen may be simply dusted with icing sugar or have a water icing glaze. Lebkuchen are usually jumble packed in a bag.

When Lebkuchen pieces emerge from the oven there is a strong moisture differential between centre and crust and it may be expedient to water spray prior to cooling and enrobing to reduce the effects of natural equilibration which may cause the chocolate to crack or craze. The aim is that the Lebkuchen be eaten as a soft cake-like biscuit.

32.2.7 Pretzels

Pretzels originated in southern France or northern Italy. Small crisp pretzels which may be in the shape of knots or sticks, are made from a simple tight fermented dough that is usually extruded (as dough ropes to be cut into sticks) or sheeted and cut. Haas also offers rotary moulding as a means of forming knot-shaped pretzel dough pieces. The dough pieces, whether as straight sticks or in other shapes, are passed through a hot lye bath before being salt dusted (with coarse crystals) and baked. The lye is a 1 or 2% solution of caustic soda (more rarely a 2% solution of sodium carbonate) at more than 65°C. The lye produces a skin of starch degraded to dextrin; it is this that gives the characteristic dark brown and shiny surface during baking. In larger pretzels it may be that a secondary drying process is used after a conventional bake because checking is often a problem (see Reisman [5] and Matz [6]).

32.2.8 Baked snacks

The popularity of deep fried slices of potato (known in the UK as potato crisps) or cornflour dough pieces (tortilla chips) has promoted biscuit manufacturers to make something similar but without frying. Various products are available made from doughs using starches from potatoes, tapioca, modified cornstarch, etc. Using con-

ventional biscuit sheeting and cutting plant, very thin pieces are cut and baked in a fast oven. By using interlocking shapes scrapless cutters are possible and using corrugated final gauging rolls gives a relief to the dough pieces that remains during baking. It is normal to salt dust the pieces before baking. To flavour these snack biscuits, oil spraying and flavour dusting techniques after baking are generally used.

32.2.9 Dog biscuits

Dog biscuits (Fig. 32.3) represent a separate though not particularly distinct sector of the biscuit industry because, at least under British legislation, food for human consumption may not be prepared in the same building as that for animals. Biscuits for dogs fall into two categories, namely those with recognisable form such as bone shapes, ovals, rounds and rectangles and those which are kibbled to form a coarse crumbly meal. Ironically, rather more attention is given to the nutritional composition of pet foods than is normally given to biscuits for human consumption! Dog biscuits are very low in sugar and fat but usually high in fibrous matter. Various flavours attractive to dogs may be added, but the baking is aimed at low surface colouration because dogs do not seem to like the taste of burnt flavours. The texture and hardness is of prime importance and, as these biscuits are normally much thicker than biscuits for humans, it is not unusual to cut the dough pieces from a final sheet of up to 10 mm in thickness.



Fig. 32.3 Dog biscuits. Reproduced by kind permission of Sainsbury's Supermarkets Ltd.

The dough is usually tight and tough and contains various rather abrasive materials such as bone meal. Until very recently the dough has been formed by normal sheeting and gauging using old-fashioned reciprocating cutters to deal with the dough thickness. However, it has now been shown that it is possible to use rotary cutting techniques for these doughs also. Experiments with rotary moulding (removing the problems of cutter scrap dough) have not been so encouraging due, as mentioned, to the abrasive particles in the dough causing wear on the moulding dies.

Baking is primarily a drying operation, made more difficult due to the thickness of the product and the need to avoid surface burning. The dough is made as dry as possible, reducing the consistency by using sodium metabisulphite to modify the gluten and mixing to temperatures around 33°C. The dough has a total moisture of around 36% and after baking with a profile of around 310–250°C for 10–12 minutes, the moisture falls to about 10%. As the biscuits emerge from the oven they are significantly more damp in the centres than in the crusts reflecting the difficulties of moisture removal. For product sold as discrete biscuits this does not matter (except that checking may be a problem) as equilibration occurs before or after packaging, but where kibbling to form a meal is involved, it is necessary to store the product for about 24 hours before performing the kibbling action.

As with other sections of the baking industry, attention is being given to improved efficiency and process control. Incorporation of dielectric drying, optimum dough piece thickness for maximum production rate and different kibbling techniques are being investigated. The dog biscuit-meal trade has been affected by the introduction of extrusion cooked products (see Section 32.3.1) and it would seem that compounded and pelleted food as prepared for farm animals has become acceptable to dog owners for their pets as well as to the consumers, the dogs! Nevertheless, the sales of processed food rather than kitchen scraps for pets represents a very healthy market.

Another form of dog biscuit is co-extruded and cut into short lengths before baking. The outer dough is pale or white and the inner is dark and contains meat materials. The idea is to produce a tasty morsel for the dogs that looks like a piece of bone with marrow in its centre.

32.3 Products that are not made on conventional biscuit plant

32.3.1 Extrusion products

A cooker extruder is a machine into which are fed flours or granular ingredients. These ingredients are blended and pushed through a barrel by means of one or two screws. The configuration of the screw(s) and barrel are such that very high temperatures and pressures are experienced by the materials. These hot materials are released through small die holes at the exit of the barrel at which point they ‘explode’ giving a very open texture and release of steam. The starch is in a high state of gelatinisation. The extrusions can be cooled as continuous tubes or strips or may be cut into short lengths by a revolving knife at the die plate.

Developments in extrusion cooking have led to some biscuit-like products or pieces. Where these are broad, flat and light in texture they offer interesting alternatives to plain crackers, but the present state of knowledge in extrusion cooking allows only limited use of sugar and fat in the recipe which restricts variety com-

pared with conventional biscuits. However, extrusion cooking is attractive to the manufacturer because of the relatively low capital cost of the plant and a great reduction in space required compared with conventional biscuit-making equipment. Where the appearance of the product is not critical the technique is particularly useful because difficulties of baking and drying are tackled in a more efficient manner. Extrusion cooking has been found particularly valuable for snack foods, confectionery centres or fillers and for pet food cereal products.

32.3.2 Toasts

Bread that is sliced and then dried with a development of surface colour is known as toast, in the case of very thin slices it is known as Melba Toast. The plant required to make it is very large because both the bread baking, the cooling and the toast baking are relatively slow processes. The toast is much harder and crisper than toast made from fresh bread in a typical domestic kitchen. Even so toasts like this, which really are twice baked products (which is the origin of the word 'biscuit'), are very popular for both breakfast-time consumption and at other times when they form the carrier for cold meats and cheese.

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Bulk handling and metering of biscuit ingredients

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Abstract: Handling of ingredients from arrival at the factory to their delivery into a mixer offers many alternative options. The key points are minimal manual tasks combined with adequate precision of metering.

Key words: handling of ingredients, metering, weighing, silo cleaning.

33.1 Introduction

Whatever the size of the baking operation, sooner or later the questions of storage of ingredients and reliable metering must be addressed. Good storage and handling of ingredient materials is a key area for maintaining production efficiency. There have been great advances in mechanical-handling techniques and the use of bulk handling also improves the hygiene aspects of production. Accurate, or more correctly, adequate precision of metering for ingredients is a fundamental requirement for the preparation of good and uniformly consistent doughs. If the doughs are not right it is usually a difficult task to adjust subsequent processing to get biscuits of the desired quality. The following account aims to indicate the various techniques used for ingredient handling and to highlight the critical points for equipment design and attention.

33.2 Bulk handling

Bulk handling implies that at some stage before the metering of an ingredient into the mixer the material is moved from a large or bulk store. It may be that the material arrives at the biscuit factory in a large mass, in for example a road tanker, and is then conveyed into a storage silo. On the other hand, material may arrive in conventional bags, drums or boxes and be transferred into large storage containers in the factory prior to being conveyed to a weigher and then to a mixer.

Bulk handling has contributed greatly to improved efficiency, labour savings and hygiene in biscuit factories. Equipment and control systems are expensive and can

be very sophisticated, but it is not only economics that must be considered before the decision is made to bulk handle ingredient materials. Included in these considerations must be the supply and usage rate situations. Bulk consignments will need to be delivered in minimum economic quantities to justify the use of specially designed road or rail vehicles and it is important to know that such quantities will be consumed before deterioration occurs in the holding silos and tanks. Also the timing of subsequent deliveries must not allow the stock to run out. There needs to be good liaison with suppliers to ensure that suitable and adequate facilities are available for regular deliveries and that the fittings on vehicles are compatible with reception arrangements at the factory.

Changing to bulk handling may introduce some limitations on sources of supply with implications for the economics of purchasing. Therefore it may be necessary to provide facilities to receive consignments either in bulk tankers or in bags, sacks, barrels, etc. Non-bulk supplies can then be transferred to bulk containers in the factory. In this way maximum flexibility for purchasing is maintained. One of the main reasons for considering bulk handling is that the speed of modern plants requires frequent new batches of dough. This involves fairly rapid loading of mixers and manual methods just cannot keep up with the speeds needed.

33.2.1 Forms of bulk delivery to the factory

In addition to the well-known road tankers and railway wagons capable of carrying loads of between 5 and 100 tons, it is also possible to buy powders and liquids in Tote Bins or Big Bags. The Tote Bin is a metal tank mounted in a frame that can be carried on a road or rail vehicle. It is lifted off and left at the user factory. When the contents are to be used the Bin is placed on a special frame and a port in its base is connected to a valve of the bulk-handling system. The frame may be tilted or vibrated to ease discharge. Big Bags are similar to Tote Bins except that they are made of thick woven fabric, usually nylon for strength. They do not come with frames and when in use are suspended over the valve into the bulk-handling system and connected via a port in their base. Big Bags empty rather more easily than the rigid Tote Bins and have the advantage that they can be folded or rolled up when empty. Both Tote Bins and Big Bags are reusable. These containers normally hold up to 2 tonnes. The advantages of Tote Bins or Big Bags are that no silo installations are required and the feed from the containers is only by gravity. Cleaning of these containers is usually the responsibility of the suppliers of the materials carried.

33.2.2 Advantages of bulk handling

- Potential savings in the cost of purchasing and transportation to the factory as less packaging is required.
- Reduced labour requirements for receiving and handling of stocks within the factory.
- More uniform and hygienic storage conditions.
- The opportunity for much more rapid batch mixer cycling with automatic and more precise metering combined with data logging and stock control.

33.2.3 Disadvantages of bulk handling

- Capital costs are considerable.
- Discharge of deliveries from road tankers cannot be delayed for long so the opportunity for detailed quality control checks is limited.
- Management of stocks found to be substandard as a result of quality control checks may be more difficult than for bagged or boxed supplies.
- Machinery faults may cause severe disruption to plant running.
- Cleaning and maintenance of equipment requires special techniques and good management.

33.3 Some technical aspects of bulk handling

As will be appreciated, the possible variations in bulk handling systems are great. A more comprehensive account may be found in Almond [1] but the account here should suffice as an indication of the main principles involved. In addition some discussion on technical points has also been given in the sections on the different ingredients; reference should be made to these.

33.3.1 Flour

Bulk flour is normally delivered in road tankers or rail wagons. It is transferred from either of these via a flexible pipe to the silo installation and is pneumatically conveyed with air provided either by a unit on the tanker or a land-based blower. It normally takes about 20–30 minutes to unload 20–30 tonnes.

It is also possible to fill flour silos with flour delivered in paper bags or hessian sacks. The bags are opened manually and the contents transferred to the bulk system at a special bag tip. The bag tip has a hopper with a rotary seal and pneumatic conveying system that takes the flour to a silo. String and pieces of paper, etc., are screened out in the bag tip unit.

Ideally, a flour silo should be sized to hold one delivery of flour. Commonly they are much larger than this and therefore there is a mixing of different deliveries. Although some care is put into the design of flour silos to ensure that discharge is good, they never allow a first-in-first-out movement of the contents. Flour which remains undisturbed for long periods in a silo becomes progressively more compact and may harbour infestation. Large temperature changes around the silo may cause moisture condensation which will increase the tendency to cake and hang up on silo walls. In good conditions, flour will store well for several weeks, but rancidity and infestation will in time affect quality.

When drawn from the silo the flour should be sieved to separate lumps and remove any pieces of string, paper, etc., that may have become included. The flour then passes to the weighing equipment. It is normal to have a return circuit arrangement so that flour in excess of that required at the weighing off points is returned to the silo from where it was derived. This is in contrast to the situation for sugar (see next section).

It is normal for several flour silos to share the sifting and take-away conveying system. This means that it is generally not practical to put wholemeal or other 'brown' flours into one of the silos. The nature and particle size of the bran may

result in some undesired separation at the sieving point and bran particles may get held up in the system and contaminate subsequent white flour consignments. For this reason it is suggested that 'wholemeal flour' be formed by mixing bagged bran of the desired particle size with white flour at the mixer. The quantity of bran will be relatively small and can conveniently be handled manually. Pneumatic conveying of flour normally involves very large volumes of air. Attention should be given to the temperature and humidity of this air to ensure that only a little drying of the flour occurs.

Flour and other powdered organic materials (including sugar) can form explosive mixtures with air. When being conveyed they also generate high static electrical charges. Great care should be taken to earth (ground) all pipework, especially where non-conductive sections of glass or plastic are used as sighting sections, to ensure that no sparks may occur. It is necessary to fix earthing strips on both internal and outer sides of non-conductive parts of the non-metallic pipework. It is also necessary to earth the road or rail tanker as it is being discharged.

From time to time it will be necessary to clean the silo. To do this an operator should be clothed in a complete suit so that nothing can fall into the flour. He must enter the silo with maximum precautions for his safety and knock down the material adhering to the silo walls. No flour must be drawn from the silo while the operator is inside as the normal system is for the conveying air to be returned to that silo and it will be very dusty. It will be appreciated that in the course of the silo emptying it may be necessary for several entries to be made until the last of the flour is taken away from the bottom. There is no formal interval for doing this cleaning. It is entirely dependent on whether flour is holding up on the walls or in corners.

33.3.2 Sugar and syrups

Sugar, sucrose, may be stored as a granular or fine powder or in solution as a syrup. There are many technical practical advantages of sugar in solution, but biscuit factories also need granular sugar for many recipes and for biscuit creams and garnishing. Like flour, crystalline sugar may be delivered in tankers or bags, and transfer into a silo is similar. The crystal size of sugar is of much importance in some biscuit formulations and handling of sugar can significantly increase the proportion of fine particles. It is best not to rush the transfer from a tanker as this increases the attrition of particles and there is always the danger of stratification of sugar dust in a silo. If the particle size of sugar arriving at a mixer is affected by this stratification, problems may occur in the quality of biscuits made. In some installations, sugar is conveyed mechanically with chain- and bucket-type conveyors to avoid breakdown, but it is more usual in biscuit factories to use pneumatic conveying systems and to accept some reduction in mean particle size. The dust produced during pneumatic conveying must be collected separately and not returned to the silo otherwise caking and lumping will be aggravated.

Sugar is very prone to caking in storage and the finer the particle size the worse this is, but otherwise there is, not a deterioration in quality. The caking is caused by changes in moisture content brought about by temperature fluctuations. Although the moisture content of crystalline sucrose is very low, in effect every crystal has a thin film of syrup on its surface. If there is a temperature gradient some of the sucrose crystallises as the moisture is driven away and this bonds a crystal to its neighbour. Every effort should be made to hold the sugar at a constant tempera-

ture. What this temperature should be is determined primarily by the delivery temperature. Sugar silos must be well insulated and it is not unusual to house the sugar silo in a building and to circulate air at about 20°C to reduce the effects of day and night fluctuations. Caked sugar can be very hard, may be difficult to remove from silo walls and lumps may block feeders, etc. The problem of caking is worst with powdered or icing sugar so this is not normally held in a silo and the method of its conveying needs special attention. Icing sugar in bulk should be held for minimum periods. Purchased in bags, icing sugar normally has an anti-caking agent added. Silo cleaning offers the same problem as described for flour.

A saturated sugar solution at about 66% solids, known as liquid sugar, can be stored and handled at ambient temperature. Small additions of invert sugar increase the concentration possible without problems of crystallisation or microbial infestation, but invert sugars will affect the surface colouration of doughs when baked. Syrups of invert sugar, glucose, molasses and malt extract at about 80% solids are usually handled and stored warm at about 27°C to reduce their viscosity. These will require insulated and heated tanks and pipework. Storage of these syrups involves protection against insects, particularly wasps, and microorganisms such as yeasts which will cause fermentation or growth of moulds. Filters for displacement air must be provided as the main problems are in the head spaces where condensation results in locally weaker concentrations of solutions more suitable for microbial growth. Syrup tanks should be emptied and washed with hot water at regular intervals, paying particular attention to the tops and lids.

There is often a small sedimentation of organic and inorganic material during storage of syrups, particularly the dark types. Careful design of the tank base and the position of the outlet pipe ensures that any sludge is held in the tank and can be hygienically removed when the tank is emptied and washed.

33.3.3 Fats and oils

Most biscuit fats are semi-solid at ambient temperatures. If they are bulk delivered the temperatures should be at least 5°C above the slip melting point so are usually in the range 45–50°C. This is also the temperature at which they should be stored. Fats delivered at ambient temperature will be in boxes or barrels. In order to transfer them as liquid into bulk storage it is necessary to melt the fat at a temperature that will not cause deterioration. Normally a grid melter is used with the hot grid heated with water or steam to limit the maximum temperature. Boxed materials which can be easily removed from their container may be softened or melted by some form of electronic heating like microwaves.

Fats deteriorate by oxidation on storage so should be used as fresh as possible and in any case within two to three weeks. Rancidity can be retarded by using antioxidants but these should be blended by the fat supplier. It is important to avoid unnecessary aeration such as, for example, by splashing as the tank is filled or by vigorous agitation. For added protection the head space of the fat silo can be filled with nitrogen gas to displace oxygen. The tanks should always be completely emptied before being filled with new fat and periodically, at least every six months, the internal surface should be thoroughly cleaned with very hot water (but not with detergent). As for syrup tanks, the bases should be designed to collect sedimented materials. Water, being heavier than oil, will also collect here.

No copper or copper-containing alloys should be used in any of the pipes or valvegear used in fat installations as this metal is particularly effective in catalysing the oxidation reactions. It is unusual to use fats in dough mixings straight from the liquid bulk store. There are usually intermediate stages when blends are made or emulsifiers added and cooling, plasticising and maybe aeration takes place. For details of this see Chapter 12. It is normal to store the plasticised fat for about 24 hours before use. This is principally because the cooling operation is much quicker than the usage rate.

There is some controversy about the need to temper the cooled fat to allow a particular crystal form to develop. The evidence is slim and it is probable that cooled and plasticised dough fat can be used satisfactorily within a few minutes and the processing is principally a matter of getting the fat to the right temperature and in a state that allows it to be pumped from the holding tank. Such a condition will mean that the crystals are all small (a possibly important aspect) and so will form a matrix that reduces the chance of liquid fractions separating from the solid ones. The temperature of storage depends on the type of fat and consistency that the metering arrangement can handle. Normally the temperature for a dough fat is about 25°C. Fat is conveyed through jacketed steel pipes and is normally metered by positive displacement pumps.

In handling fats it should also be noted that the move to eliminating *trans* fatty acids (TFA) from fats has caused all sorts of process, cleaning and maintenance problems. The low TFA fats do not remain in the dough and are expressed out during forming, leach out in the oven and contaminate cooling conveyors. They are extremely difficult to clean off equipment.

33.3.4 Chocolate and chocolate coatings

Chocolate may be delivered liquid in bulk in insulated tanks but more normally it comes in solid form at ambient temperature. It is then melted and held as bulk in warmed tanks. Bulk chocolate must be continuously and gently stirred. Because moisture must be kept away, it is unusual to clean chocolate tanks. Chocolate chips or drops are conveniently handled in bulk in Big Bags. These can be stored in a cool or cold place.

33.3.5 Other materials

It is less usual to bulk store and handle other ingredients except where usage is very high. Dairy products such as milk and fresh eggs must be used fresh and much attention given to thorough cleaning of the systems to prevent build-up of micro-organisms. Dairy equipment should be designed with clean-in-place (CIP) arrangements.

Systems have been designed for storing ingredients such as milk powders, cocoa, starches, dextrose, salt and aeration chemicals in small or medium-sized bins so that quantities can be readily and frequently drawn off and weighed into portable containers for each mixing. These bins are replenished from bags or boxes so do not really constitute bulk storage or handling. As many of these solids do not flow well or are hygroscopic and become lumpy very easily, there are particular difficulties in keeping the systems in good working order.

33.3.6 Stock control in bulk silos and tanks

If load cells are incorporated in the support steelwork when silos and tanks are constructed, it is possible to obtain continuous transmittable and loggable records of the weights of materials in stock. Frequently, however, these facilities are not available and quantities of stock must be estimated visually. In dry-solids silos, such as those containing flour and sugar, the level of the contents may not be very regular and it is very difficult to guess the weight present by observation. High- and low-level probes may be present, but these are also of little help for accurate stock records. Ultrasonic level probes may be useful for measuring the position of the surface of the material in the silo, but even these cannot compensate for uneven surfaces. Floats connected to external indicators may be sufficiently accurate for bulk fat tanks, but they are not so satisfactory for the more viscous liquids like syrups and plasticised fats.

33.4 Process control in bulk storage

It is very useful to have temperature sensors in all bulk containers, as ingredient temperatures may have important effects on dough properties. It is difficult to change the temperatures of solid materials such as flour and sugar, but a record is potentially useful. Some control of the temperature of air used for pneumatic conveying, by means of water coolers after the blowers, will mean that there is a fairly constant relationship between stored ingredient temperature and that being delivered to the mixer. Temperature sensing should be of the electronic type to allow remote indication and logging. Other properties which are not normally measured but which it would be useful to monitor continuously would be

- flour moisture content as it arrives at the mixer
- sugar particle size as it arrives at the mixer
- fat peroxide values in store.

33.5 Metering of ingredients to mixers

Metering is probably the most important aspect of process control. Errors in metering may have an effect throughout the rest of the manufacturing process. In most plants insufficient is known about the precision of metering and deviations from standard are not recorded systematically so comparison with biscuit size and quality is difficult or impossible. Various metering systems with programmable logic controllers (PLCs) and electronic weighing allow a much more scientific approach to mixing control and investigation of process difficulties. To blame the flour quality for mixing faults need no longer be the standard procedure! In most factories ingredients are metered to mixers by a combination of automatic (for bulk-handled materials) and manual (for small ingredients) methods.

In general, it is possible to programme the order in which ingredients are put into the mixer and to preset the quantities required. Since supplies for a number of mixers may be drawn from common tanks or silos, queuing or priority programmes can be arranged and a mixing sequence will wait until a call for an ingredient has been satisfied. Operator assistance can be called by means of alarms set to work should a wait be excessively long or a preset weighing fall outside predetermined

limits. Ideally, data on weights or times for each mix should be logged to allow retrospective examination if necessary. Pump-metered liquids are preset on a time or revolution basis determined by periodical calibration. 'Prompt' signals may be shown to allow small and hand-metered ingredients to be added and the operator acknowledges compliance by cancelling the call. Metering may also be by a system of manual weighing, weighing-in, loss-in-weight or weighing the mixer. Each of these terms will be described.

33.5.1 Manual weighing

The mixer operator weighs the ingredient and tips it into the mixer. In most plants small ingredients such as salt, flavours, leavening chemicals, milk powders, etc., are metered in this way. It is useful to have a central department where quantities are prepared in advance for a number of mixers and the operator is responsible for using one set of materials per mix. This improves precision, speeds the task for the mixer operator and reduces mistakes of omission or duplication. It also means that materials that come in containers that are difficult to handle can be dealt with more efficiently. In some factories all ingredients are handled in this way. Many of the small ingredients are white powders or crystalline solids. To aid recognition it is suggested that coloured containers are used, for example, sodium bicarbonate is always in a yellow plastic pot.

33.5.2 Weighing-in

This automatic system illustrated in Fig. 33.1, results in pre-weighed quantities being dropped or fed to the mixer as required. The weighing hopper or metering pumps may be immediately above the mixer or remote. If the weigh hopper is immediately

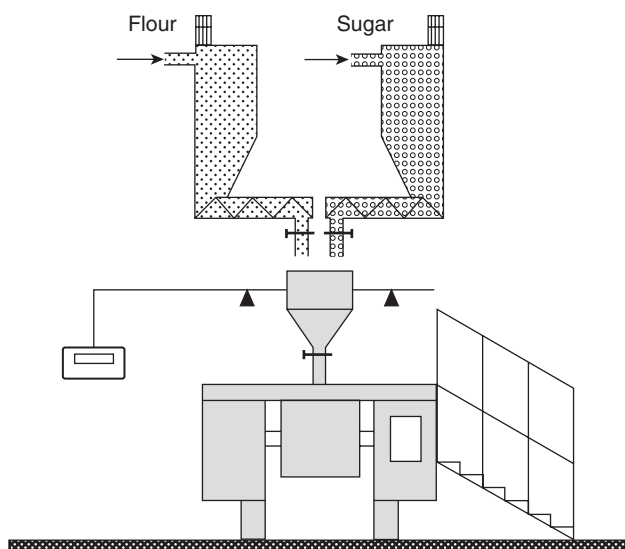


Fig. 33.1 Weighing-in system (CABATEC [2]).

over the mixer, it is dedicated to that mixer and it must receive supplies from bulk silos which are probably shared by weighers above other mixers. Whatever the means of sensing the weight, be it by a beam balance or load cell, it will be necessary to have a valve system which closes the entry to the hopper when the correct weight is made and any excess material in the conveyor from the silo must be diverted back to the silo or to another container. The precision of the measurement is dependent on the exact timing of the valve closure and this relies on a standard amount of 'in-flight' material during the period between the signal to close and the completion of closure. As feeds from bulk silos are always slightly irregular, the precision of weighing is adversely affected unless the conveying rate is slow. However, it is normal to convey as fast as possible from silos so that any weighers calling for material do not have to wait for long. Commonly, a weigher above a mixer will be used to weigh both sugar and flour so having weighed the sugar this will be dropped into a dump bin immediately under the weigher to be held ready while the flour is weighed. When a call comes from the mixer either both materials or just that held in the dump bin can be added at the desired time.

A particular version of the weighing-in system is central weighing (see Fig. 33.2). This involves one weigh hopper for receiving material from the silos and then a further system of conveyors which takes the weighment to any desired point/mixer or a dump bin above a mixer. If conveying is pneumatic, the distance between weigher and mixer is not critical. However, the further the weigh hopper is from the mixer, the greater is the potential for hold-ups of material and thus uneven delivery to the mixer.

33.5.2.1 Weighing-in advantages

If the weigh hopper is above the mixer, weights held for delivery to the mixer can be seen easily by the mixerman, errors or the size of variability can be readily

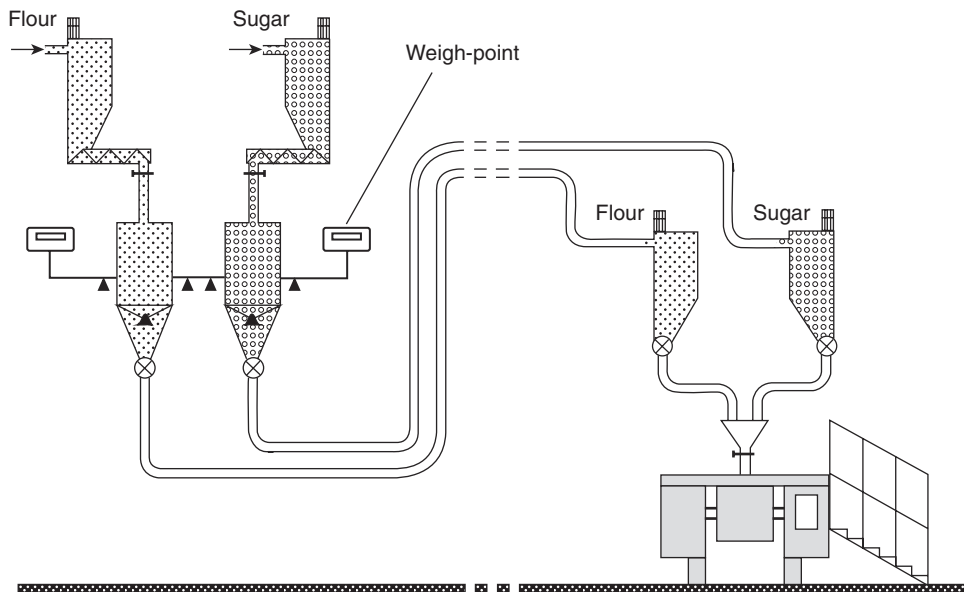


Fig. 33.2 Weighing by central weighing (CABATEC [2]).

appreciated. Also, weighing for the next batch can take place while the previous mixing cycle is in operation. This allows rapid recharging of the mixer when required as most ingredients can be dropped into the mixer at once.

33.5.2.2 Weighing-in disadvantages

High feed rates from the silo affect precision of weighing due to moment of the valve cut off. Delivery from weigh hopper, or dump bin, to the mixer may not be perfect resulting in a small but irregular amount of hang-up in the hopper. Special attention is required on the part of the operator to ensure complete discharge. Alarms may be fitted to the weighing mechanism to indicate if discharge of the hopper is not complete.

33.5.2.3 Central weighing advantage

This is a much cheaper system because only one set of weighers is required. It works best if the same weight is required for each of several mixers, but it is possible to change presets for weighments to different destinations.

33.5.2.4 Central weighing disadvantages

There is no positive knowledge of whether all of the weighment at the central point arrives in the mixer. There are various reasons why it may not. For example, there may be hang-ups in the weigh hopper, the dump bins or the conveyor. The diverter valves in the conveyor system may be leaking or malfunctioning. If the weigher system develops a fault, all mixers are affected.

33.5.3 Loss-in-weight

The term 'loss-in-weight' refers to the circumstances where a preset quantity of material is delivered from a bin or tank which contains an excess. The metering is done by loss-in-weight of the container (see Fig. 33.3). Metering controlled by the electronics of load cells and timers is far superior to volumetric metering from a screw or rotary feeder arrangement. One container for each ingredient to be metered is sited over the mixer and each is charged from a bulk silo or by hand as it is necessary to replenish it. Upon a call from the mixer, ingredient is fed or drained out directly into the mixer until the weighing system signals that enough has been delivered. All that leaves the holding bin passes into the mixer.

33.5.3.1 Loss-in-weight advantages

All ingredients may be weighed. Several ingredients can be loaded into the mixer simultaneously thus speeding the loading of the mixer. The feeders from the holding bins can be of any type so materials difficult to meter can be handled. A sufficient quantity of ingredient of each type is always available at the mixer, thus ensuring minimum reloading time. Small and large quantities of ingredients can be metered more precisely by sizing the weighing systems appropriately.

33.5.3.2 Loss-in-weight disadvantages

The system is very expensive because separate holding bins or tanks are required for each ingredient and each requires a separate weighing system. The arrangement causes congestion above the mixer. The number of bins may be reduced if a system of premixes is used. This involves the preparation of blends of selected materials,

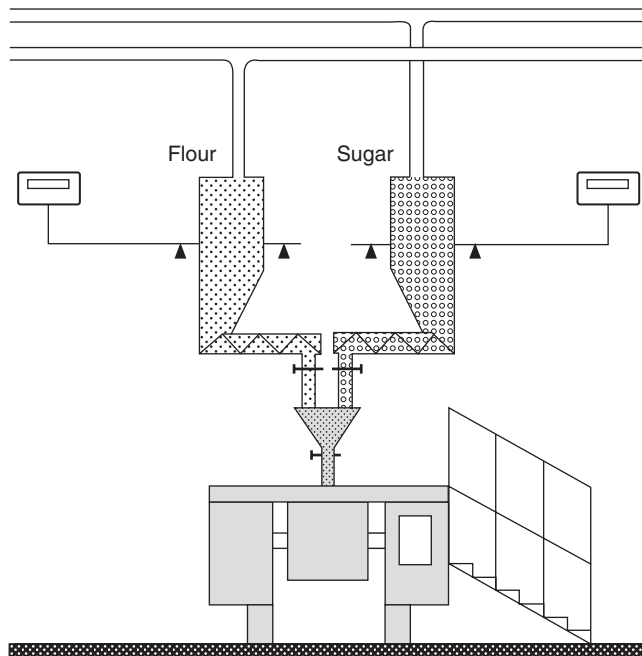


Fig. 33.3 Loss-in-weight system (CABATEC [2]).

possibly with fillers to bulk them. Containers for some ingredients may need insulation, heating or constant agitation all of which require maintenance.

33.5.4 Weighing the mixer

The whole mixer is mounted on load cells or a weigh frame. Ingredients are added from holding bins or via pumps until preset values are delivered (see Fig. 33.4).

33.5.4.1 Advantages

Weight and time records can be kept of all ingredients delivered to the mixer whether added automatically or by hand. It is also possible to know how much dough was discharged from the mixer after completion of the mix. No other metering arrangements are required.

33.5.4.2 Disadvantages

Separate holding bins and tanks are required above the mixer for each ingredient, similar to the arrangement for loss-in-weight. The weigh system must be robust to withstand the massive tare weight of the mixer and vibration when it is running yet sensitive enough to record precisely small ingredient additions. Operators must not touch the mixer while it is weighing. There is an 'in-flight' problem as described for weighing-in and only one ingredient can be metered at once. This prolongs the total time needed to charge a mixer.

It must be said that weighing the mixer arrangements are rarely used now. The account is included for those who still have this system.

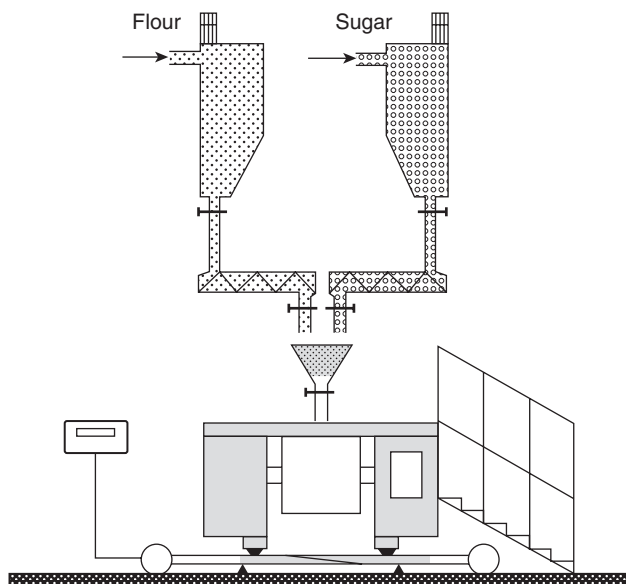


Fig. 33.4 Weighing the mixer system (CABATEC [2]).

33.5.5 Loss-in-weight metering for continuous mixers

The arrangements needed for a continuous mixer are essentially the same as the loss-in-weight system for batch mixers except that continuous weighing and adjustment are needed. The demands are very exacting especially for the minor ingredients. For the minor ingredients it is sometimes more expedient to use a system of repeated small batch weighments appropriately timed. Volumetric feeding has been tried many times but the uncertainties and variable precision make it unsatisfactory where good control is required.

33.5.6 Water metering

Metering of water presents a particular problem in that not only quantity but also temperature should be controlled. There are several programmable water meters available and these can also be set to blend warm and cold water to give the desired temperature. It is common for small adjustments to be made to the quantities of water needed and only responsible operators should make these changes. The size and timing of changes should be recorded for later reference.

Maintenance is important for water meters as small amounts of scale in the water can upset the precision of delivery. Attention should also be paid to the alignment of the pipework so that drain down after the meter stops is rapid and uniform. It is common for some ingredients to be dispersed in water immediately before being added to a mixer (see Manley [3]). Such ingredients include ammonium bicarbonate and milk powders. It is possible to use premixes but, if the dispersion procedures are manual, attention should be taken to ensure that the volume of water used each time is accurately measured.

Complete automation of metering is expensive and complex, therefore it is usual to make compromises and even to mix metering techniques. Most problems are

associated with ingredients used in small or very small quantities and with scrap dough or recycled materials. Comments are made about the handling of these in Chapter 34.

There is a general requirement to reduce the heavy labouring aspect of ingredient metering and mixing and to use mixing operators in supervisory roles. This, combined with the needs of management for automatic data recording, has emphasised the value of electronic surveillance throughout the bulk-handling and mixing departments. There is a need to understand not only the precision of weighing that is being achieved but also the precision that is needed. There is no point in wasting money on an expensive system if a simpler one would do. This is part of the process modelling task outlined in Section 4.7.1. The state of the art is changing and developments from machinery and systems designers should be compared against these descriptions and the needs of particular production plants.

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Mixing and premixes in biscuit manufacture

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Abstract: Mixing of doughs is fundamental to good process control of biscuit making. Many do not know the definition of a good dough because they do not understand what is happening during the mixing process. The type and size of the mixer should be considered critically and the preparation of premixes of certain ingredients may improve the technology of mixing.

Key words: batch and continuous mixers, dough consistency, premixes, mixing requirements.

34.1 Introduction

At the end of the eighteenth century, when ships biscuits were the only mass-produced biscuits available, there are reports that dough mixing was done initially by hand and then was finished off by the mixerman jumping into the trough and treading it with his bare feet!

The first biscuit dough mixer seems to have been a barrel with a shaft through it driven from a steam engine. The shaft had a number of blades attached and when the dough was mixed it was removed through a door underneath. There was no mechanical development of the dough and the crumbly mass was then pressed together to form a sheet.

Most of the early biscuits were low in fat so the doughs were tough and difficult to mix. Mixers for developing hard doughs need to be very powerful and strongly built. It is therefore not surprising that early biscuit dough mixers were slow and took a long time to complete the mixings. Both horizontal and vertical style mixers with one or more beaters were produced but the first 'high-speed' mixers were all of horizontal style. Supporting (and sometimes driving) the beaters at both ends gives greater strength than the vertical mixers where the beaters are in bearings only above the mixing bowl.

Forming a good dough and making many successive doughs of the same quality can be a critical operation. Many do not know the definition of a good dough because they do not understand what is happening during the mixing process. The aim of this chapter is to consider various aspects of mixing so that parameters may be established for the mixing process based on optimising mechanisms for particular types of dough.

34.1.1 Dough consistency

The term 'consistency' covers all those aspects of a dough that can be felt in a dough such as resistance to deformation and stickiness. Characters such as softness, plasticity, elasticity, stickiness and pourability can all be assessed when a lump of dough is squeezed or pulled. In common with most other materials, as the temperature of dough is increased it becomes softer. Thus, temperature is another character that can be felt and measured in a dough and which is used in an assessment of consistency.

Consistency is a function of rheology (the study of the flow and deformation of matter) and Frazier [1] has stated that 'rheologically, dough must rank as one of the most complex materials known to man'. Biscuit doughs are very complex, being made up of a liquid phase that will be of fat and water and a solid phase that includes starch, protein, sugar and often many other materials. Some of the fat may be solid and some of the solids may be dissolved in the water. Furthermore, doughs change on standing. In some cases the water is absorbed slowly by an ingredient after the end of the mixing period (oat flakes are a good example of this). This results in a tightening or hardening of the consistency. In other cases, the elasticity of the hydrated and mechanically developed flour protein, then known as gluten, becomes less extensible on standing and this results in a significant change in the feel and behaviour of the dough. In general, dough that has just been worked or moved either by the mixer or by handling has a softer consistency than one which has been standing. This property is known as thixotropy (a well-known example of thixotropy is in 'non-drip' paints which are thick as they are taken from the container and become more liquid as they are worked on a surface with a paint brush).

It is very difficult to measure dough consistency and to give it a value. This is principally because of the effect of handling the dough before the measurement is made. Just the act of putting a sample of dough into an instrument can have a significant effect unless very strict procedures are followed. Furthermore, most instruments that can be used to measure consistency are too delicate to use in the rugged environment of the biscuit-mixing department. For this reason it is almost impossible to give a specification for the consistency of any particular dough and considerable reliance is placed on the ability and experience of the mixer operator to 'know' his dough and to be able to detect differences and spot changes and faults.

The consistency of the dough is of very great importance to the smooth running of dough piece forming machines. These machines press and roll the dough continuously so changes in the consistency and stickiness have significant effects on performance. Smooth running of the forming machinery depends on a uniform quality of dough.

34.2 General conditions for mixing

In the context of biscuit doughs, biscuit sandwich creams and batters, the term 'mixing' covers a number of distinct operations. It includes

- the blending of ingredients to form a uniform mass
- the dispersion of a solid in a liquid, or liquid in a liquid
- the solution of a solid in a liquid
- the kneading of the mass to impart development of gluten from flour proteins which have been hydrated at an earlier stage of the mixing

- the build-up of temperature as a result of work imparted
- aeration of a mass to give a lower density.

One or more of these actions is required in the formation of a dough for the very many types of products that are called biscuits. In many cases the type of dough for a particular product has been formed by trial and error on equipment available and the critical factors in obtaining the dough structure are not known in scientific terms. This makes process control very difficult and hinders advancement to more efficient practice. As biscuit making becomes more automatic and new higher capacity equipment is considered, it has been necessary to question the process of mixing and to examine the critical and optimum requirements for each dough. In addition to optimum requirements, minimum requirements are also sought so that the smallest, most economical machines can be used.

Most biscuit plants produce two or more products using the same mixing machinery. This has led to the use of 'universal' type mixers capable of making many different doughs, but probably not ideal for any one. It is against this background that the biscuit manufacturer operates and demands maximum process control provisions.

The quality of a dough is determined by the recipe, the nature of the ingredients used and the degree to which these ingredients are mixed together. The result is a mass which has particular qualities of mouldability which, combined, are known as consistency. The forming machinery is sensitive to changes in consistency, and in fact may change it, so from the process-control point of view uniformity and constancy of consistency of doughs fed to these machines is very important. Despite attempts by many eminent scientists, it is still not possible to define satisfactorily and simply consistency of doughs in fundamental physical terms. Efforts have, therefore, been concentrated on understanding those factors that affect dough consistency and maintaining them as consistently as possible. The performance of mixers is of great importance here.

There are a few instruments available for measuring dough consistency. They range from simple hand-held penetrometers which can give a numerical value to the compressibility, or feel, of a dough to much more sophisticated instruments with electronic controls. Texture 'analysers' are normally motorised penetrometers which have facilities to drive probes at different rates and to record not only the resistance on a downward stroke but also the stickiness of doughs on a withdraw phase. These instruments are also useful for measuring texture-related aspects of the eating properties of biscuits [2, 3].

It is useful to consider separately the various phenomena which occur during mixing of a dough so that the efficiency of each function can be considered in relation to different mixer actions.

34.2.1 Blending and dispersion

Blending is the obvious prime requirement of any mixer. The aim is a uniform distribution of matter throughout the mix in a minimum time period. The term homogeneous is perhaps misleading because the distribution may be on a macro rather than a micro level. For example, one requires a uniform distribution of lumps of fat in a puff dough not a smooth blend of this fat. If the mixing is too vigorous in fruited doughs the currants or sultanas will be pulped and not in the form that is required.

However, one does not want clumps of fruit which will give uneven distribution. Where the mixing time is long, for other reasons, good blending is almost inevitable, but normally a mixer should give a very rapid uniform dispersion so that subsequent mixing actions will also proceed uniformly.

It is possible to test for the dispersion performance of a mixer by adding a tracer ingredient and sampling after specific times to measure the concentration of the tracer. As a research test, adding poppy (Maw) seeds is quick and easy. The method involves adding about 1% of the dough weight of poppy seeds (these are very small and black) to one extreme side of the dough in the mixer bowl. After running the mixer for short predetermined times, samples are taken from 6 or 8 areas in the bowl. The number of seeds contained in a standard weight of each sample is determined (this can be done visually if the dough sample is rolled thin) and for each set of samples the range or standard deviation of counts is calculated. The result from each set is then plotted against mixer running time (or number of revolutions of the beaters) and it can be readily seen how quickly a more or less uniform distribution is achieved (for a typical graph, see Fig. 34.1). The seed-containing dough must be discarded, of course, at the end of the experiment. If salt or ascorbic acid is used, in appropriate quantities, it is possible chemically to determine the concentrations in each sample and then the rest of the dough may be used for biscuit production without wastage.

Dispersion of liquids in liquids, solids in liquids, or air in liquids can be checked in similar but appropriate ways. In each case the mixer is required to throw materials from one side to the other and from top to bottom and, at the same time, cutting through the mass to allow dispersion at a progressively more minute level. The degree of shearing action necessary depends on the materials involved,

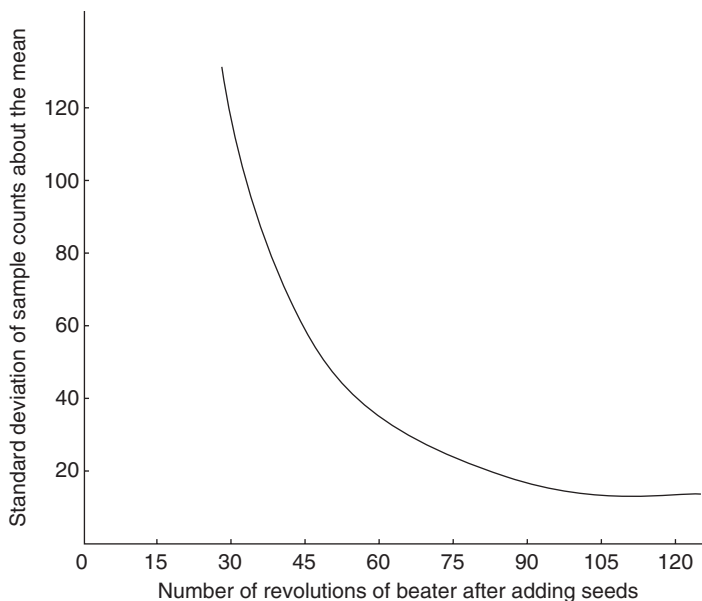


Fig. 34.1 Typical results from a test to check dispersion in a mixer using poppy seeds placed in an extreme corner of the dough in the mixer bowl.

but it will be appreciated that to form an emulsion of oil in water or air in liquid requires high speed and more cutting (shear) action than to get poppy seeds through a dough.

34.2.2 Dissolution of a solid in a liquid

There are some ingredients that dissolve in water in the course of dough mixing. The principal one is sugar (sucrose) but also chemicals such as salt, sodium bicarbonate and ammonium bicarbonate. Sometimes the mixing procedure requires maximum solution of the sugar before the flour and other dry ingredients are added so a 'cream up' or 'sugar run' stage of mixing is made. This involves the blending and agitation of the sugar with the water (and often the fat, chemicals and syrups). Solution of a solid in a liquid is time, temperature, particle size and concentration dependent. Agitation ensures that the liquid circulates freely around the undissolved solid. During this mixing action, which need not be very violent, it is essential that the mixer blades pass close to the base of the mixing bowl to lift solids lying there into the liquid. In some mixers this action is not really adequate or efficient and it is expedient for this and other reasons to effect the dissolution of solid in liquid in another vessel before adding to the dough mixer. This is dealt with later when premixes are considered.

34.2.3 Kneading

When water comes into contact with flour all the components, starch, protein and fibre absorb water; they hydrate. When hydrated flour protein is worked, kneaded, a three-dimensional visco-elastic material known as gluten is formed. Kneading is the name given to the rolling, deformation and stretching of dough rather than a cutting action, which results in the formation of gluten. The formation of gluten is known as dough development. The hydration of flour is not very fast and is slower at low temperatures. It is not particularly hastened by agitation.

It is impossible to separate the kneading action from the blending action during mixing so hopefully all areas of the dough are subjected to similar amounts of mechanical work. The kneading action requires a considerable amount of power and this power is transferred to the dough as heat, therefore doughs which are being developed always heat up.

It is very difficult to measure how much energy is being used to effect a kneading action as distinct from a lifting or pushing function in a mixer. A blade cutting through the dough or pushing it against the bowl of the mixer will cause the dough to warm up mainly as a result of friction, and there is minimal internal stress of the dough which is what is meant by kneading.

34.2.4 Blending in a developed dough

It is sometimes required to distribute some larger pieces of ingredient, such as fat lumps, chocolate drops or dried fruit through a dough at the final stage of mixing. This process ideally demands rapid blending action with minimum kneading otherwise the ingredient may be damaged. This action is therefore a particularly difficult one to achieve with a mixer that is designed to develop the dough also. Ideally, inclined knives perform this action best.

34.2.5 Temperature change

As has been described, kneading and movement of the dough results in it warming up. In most developed doughs this is a desirable situation. The warmer the dough, within limits, the softer it is for a given water content. Water is a catalyst in biscuit making, it has to be added to make the dough formable or to change the character of the ingredients, but it must be removed almost completely during baking. Biscuit making, therefore, is more efficient if minimal water is used in the making of the dough. (High water content of some short doughs improves the texture development in baking, see Section 28.6.) There is an optimum temperature for most doughs and also an optimum consistency. The mixer is important for achieving these two conditions. Obviously the final temperature of the dough is related to that of the ingredients and also the length of mixing time, but the tighter the dough (the higher its consistency) the more rapid is the temperature build-up during mixing. Also there is a minimum amount of kneading work required to change the gluten into an acceptable extensible condition, but this is difficult to define.

While mixing developed doughs there may be a requirement to adjust the dough temperature so that it does not become too high before the required amount of kneading work or time is allowed. If the mixing time is long a little control can be achieved by cooling the mixer bowl by means of cold water or refrigerant in a jacket around the bowl, but the best method is to add dough water at an appropriately low temperature. Provided that the mixing time is long enough for the flour protein to hydrate and gluten to be kneaded well, the end of the mixing is then best defined as when the dough temperature reaches a given point. The mixing time may be reduced a little if the mixer bowl is heated or one or more of the ingredients is warm before adding to the mixer; in reality this is only practical for water.

In short doughs it is the temperature of the fat that is critical for good quality and consistency. It is important here that the dough does not become too warm even though the mixing time is short, so cooling of the mixer jacket is helpful. In batch mixers, unless discharge is immediate at the end of mixing, the dough lies and will be locally affected by the temperature of the mixer bowl. In these cases it is best that the bowl temperature is maintained at the final temperature of the mixed dough.

34.2.6 Discharge of the dough

Removal of the dough from the mixer after completion of the mix should not, in itself, affect the mixing or the dough quality but if this is delayed for any reason there may be temperature difficulties due to the bowl jacket, as mentioned above, leading to non-uniform consistency in the dough mass. Also, if complete discharge is not effected, some dough will remain to be incorporated into the next mix, this may affect quality and will certainly frustrate techniques for process control. Many mixers discharge very badly and need much manual assistance to extract the dough. This is not only inefficient, but also potentially unhygienic.

34.3 Process control and instrumentation of mixers

The required and general characters of doughs for various types of biscuits have been described in other chapters. Control of mixing of these doughs involves

minimum time (as this makes maximum use of the mixing machine), optimum dough development, constant final dough temperature and consistency, both within a batch of dough and between batches. As has been stated, consistency is an ill-defined parameter, but is related to how the sheeter or other forming machinery 'feels' the dough and deals with it. For batches of dough, therefore, it is important that changes in the dough, as the batch passes through the machinery, are minimal.

The mixing process is still imperfectly understood so the control philosophy aims to keep all variables constant rather than making adjustments to compensate for observed differences. Probably the greatest variations arise from irregular metering of ingredients. Constancy in dough quality is extremely difficult, if not impossible to achieve, if metering precisions are poor or variable amounts of scrap dough are included. Attention should be given to ingredient temperatures.

The effect of dough age has been emphasised repeatedly. Attention to the time between mixing and sheeting should again be mentioned here. Developed doughs leave the mixer at temperatures between 36°C and 44°C. These are usually above ambient bakery temperatures so cooling may be variable. Also, they tend to lose extensibility on standing so there is a need to use the dough as soon as possible. Short doughs tend to 'dry out' and become firmer with standing after mixing, so either they should be used very soon after mixing, or they should be allowed to stand for at least 30 minutes to permit these changes to stabilise, thus reducing significant differences in quality as the dough is used.

Continuous mixers, which produce dough at the same speed as it is used, overcome these age problems almost perfectly, but, as will be described later, there are severe practical disadvantages. Large batch mixers producing one or two doughs per hour are at the other extreme so perhaps the best compromise is the small batch mixer producing new doughs every 5 or 10 minutes. The problem here is cycle time, that is, time to load the mixer, time to mix the dough and time to discharge the dough. Minimum time to mix the dough requires much process know-how and instrumentation to monitor it.

As it happens, there are several factors that have favoured the development of small batch mixing apart from the logic of unifying the dough age as described above.

Firstly, detailed mixing experiments have mostly been done on small or very small mixers. Results obtained have been difficult to reproduce on larger industrial equipment because of the well-known problem to engineers of 'scale up'. Small batch mixers approximate much more closely to the little mixers of the researchers.

Secondly, kneading action seems to be more efficient on small mixers than large ones because more power is added as useful work than as heat via surface friction. This means that mixing times can be shorter from economically sized motors. This reduces the cycle time of developed doughs. Also, related to the power requirement, is the speed of the beaters; in smaller mixers the beaters can be rotated faster effecting better dispersion and blending actions.

Thirdly, small mixers have a greater bowl surface area relative to the dough mass, so heat exchange at the bowl surface is more efficient than in larger types (though still relatively poor). This may aid in heating or cooling requirements. Finally, smaller mixers, although perhaps more sophisticated in design, tend to be less expensive to build, move and install than large ones.

Mixing cycle times can be reduced if loading is completely automatic and also if some of the blending, emulsification or dissolution of solids is performed separately away from the dough mixer. The use of premixes aids here. Discharge of the dough must be rapid and complete and totally automatic. A mixer design which allows inversion of the mixer bowl combined with some rotation of the beaters is essential. If the beaters and shafts have minimal area the dough should fall away reasonably cleanly.

Rapid automatic cycling of small batch mixers relies on instrumentation to minimise time loss and to guard against malfunction. The developments of electronic control and load cell weighing allows sophisticated sequencing and data logging of metered ingredient quantities. Limits can be set to alarm should unacceptable conditions occur. Mixing can be determined by time, dough temperature or consistency (as sensed by the motor torque) or any combination. By recording changes in temperature or motor torque against time, deviations from a norm which suggest that the dough may be substandard can be used to alarm or to stop the mixer and prompt operator inspection. By a combination of these techniques not only is it possible to reduce dough variations, but also to learn more about causes for variations in doughs. When these are understood more thoroughly the monitoring phase of process control can pass to corrective control via automatic loops.

The term 'dough consistency control' is frequently used in bakery process discussions. The need for it is obvious, but achieving it is still extremely difficult. Most work associated with bakery mixing has been done with bread doughs because of the importance of water in the dough and the baked bread. However, the bread recipe is simple compared with most biscuits. The use of the whole mixer as an instrument to give adequate information on all the features which affect dough quality and consistency is not very satisfactory. At least, this seems to be the case for most commercial mixers available at present. The use of off-line instruments to assess dough quality is also unsatisfactory due principally to the incomplete definition of the dough characters required.

34.4 Considerations in the selection of a mixer

As time passes it is necessary for manufacturers to replace old machines, increase capacity or to consider improving efficiencies by means of instrumentation and automation. It may also be necessary to purchase new equipment to make a new product. At this stage it is wise to consider more than just price in the choice of a mixer.

There are many different doughs requiring special mixer actions and even different mixing actions for different stages of the mix. It is felt to be useful to list the points that should be checked for when selecting a mixer. For each type of dough to be mixed consider the following questions.

- What is the maximum and minimum dough capacity per mix? What happens to the mixing action if either of these limits is exceeded?
- At what load size is the mixing action most efficient?
- What is the total minimum cycle time for loading, mixing and discharging?

- Does the mixing action look right for each stage of mixing? Are there any unswept areas and does material hang up in places preventing its correct incorporation in the blend or dough?
- Is there adequate experimental data to support blending and dispersing action?
- Does the mixer power trace (a plot of power against time) suggest that the action proceeds satisfactorily throughout the mixing cycle?
- Is there a dough temperature sensor and are the readings adversely affected by the friction of dough on it or the temperature of the bowl surface?
- Is it possible to log all the data that you need to monitor?
- Does the mixer discharge dough, at the end of mixing, in a satisfactory, speedy, complete and hygienic manner?
- Is it possible to clean and maintain the mixer in an efficient and economical way?
- Does the mix need a jacket to control temperature? Would a jacket be useful to bring the metal of the mixer bowl to operating temperature on a cold morning?
- Are the facilities for manual additions of ingredients adequate and convenient?

34.5 Types of mixer available for biscuit doughs

There is a surprisingly large number of manufacturers of dough-mixing machines. The mixers vary in size, sophistication of control, power and overall weight. However, they can all be classified into a few types and the aim here is to indicate these giving some of the major advantages and disadvantages.

34.5.1 Batch mixers

These are by far the most common type of mixers and are illustrated in Fig. 34.2.

34.5.1.1 *Detachable bowl types*

The beaters are mounted vertically and either they and their drive mechanisms are lowered into a bowl or the bowl is raised to locate with the beaters and a lid. The beater shafts may rotate on fixed positions, in which case there are usually two or three beaters which intermesh with each other, or there is a single shaft which rotates vertically and itself is driven in a circular, planetary, manner. This action allows a single beater to reach all the dough in the bowl without merely moving it in a circular motion.

It is sometimes possible to fit exchange beaters of different shape and action and to drive them at different speeds. This allows a gentle rolling and cutting action at one extreme to a vigorous whisking action at the other. The larger mixers of this type can mix up to two mixes of hard doughs and around three short doughs per hour.

34.5.1.1.1 Advantages

The bowls can be charged with ingredients at various places away from the mixer so that loading and discharge is not a critical feature of the mixing time cycle. Doughs which need to be rested, cured, fermented or remixed can be left in a tub and put in an appropriate place without additional handling of the dough. Different

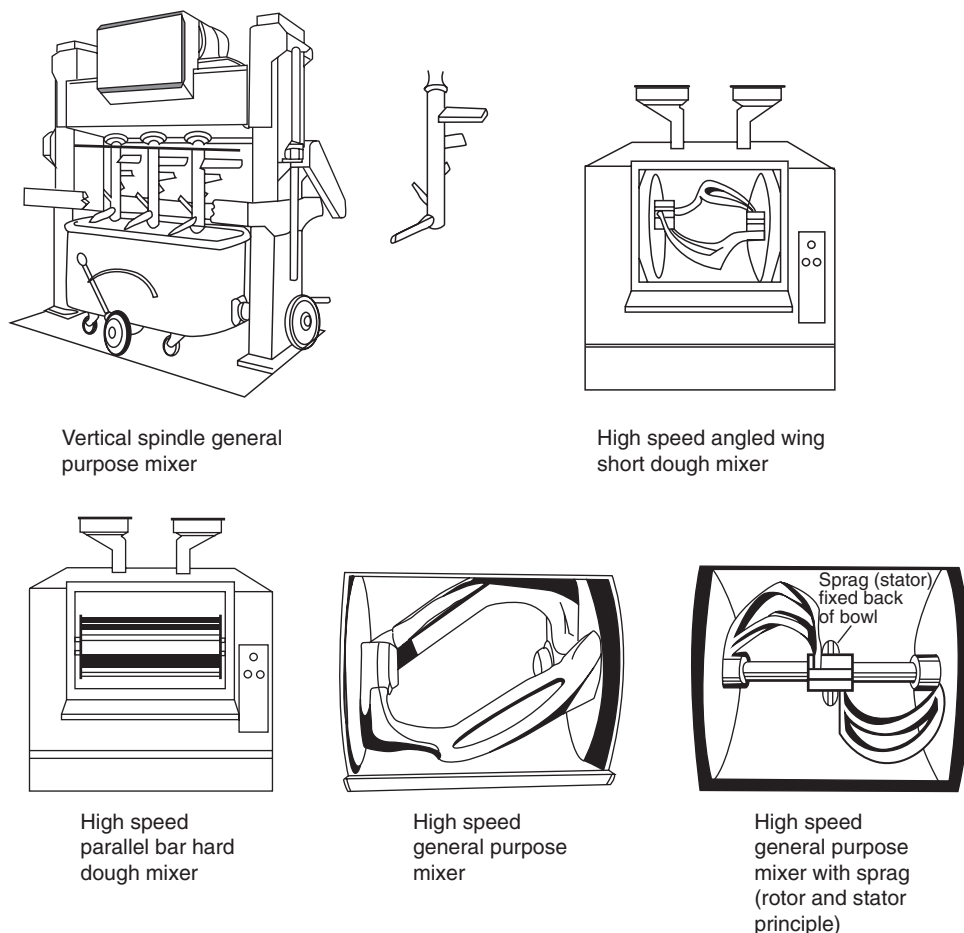


Fig. 34.2 Types of batch mixer (CABATEC [4]).

mixing actions can be achieved either by using more than one mixer or by changing the beaters on a single mixer. In many cases the mixing action and the state of the dough can be visually monitored. It is easy to charge the bowl manually with awkward ingredients such as scrap dough or biscuit dust. Bowls containing dough can be readily moved to different locations for tipping or storage.

34.5.1.1.2 Disadvantages

The mixing action is sometimes not uniform between the bottom and top of the bowl resulting in more or less activity in some parts of the dough. The water will always go to the bottom of the mixer before mixing starts. It is difficult to maintain good temperature control of the bowls because jackets containing circulated water must be connected and disconnected. Dough temperature sensors must also be connected and disconnected. The bowls are heavy and not very manoeuvrable requiring labour or mobile power units, such as forklift trucks, to move them.

34.5.1.2 *Horizontal mixers*

There are some types where the bowl is fixed and a door at the side or in the bottom opens to allow discharge of the dough, but more usually the bowl rotates on a horizontal axis around the beaters to allow discharge of the dough. The beaters are driven horizontally within the bowl and are fixed to one or two shafts. Where only one shaft is employed the beaters are usually inclined to throw the dough not only upwards but also somewhat to one side and then the other during rotation. The blades may pass close to the bowl surface or at some distance. The former type ensures that material lying in the bottom of the bowl is moved but the latter is better for kneading, rolling and stretching the dough. The action whereby the dough is cut and sheared depends on the exact shape and speed of the blades, but sometimes a stator fixed to the bowl provides an additional means for cutting the dough. Where two shafts are employed, the bottom of the bowl is 'W' shaped and the shafts rotate in opposite directions driving the dough towards the centre and downwards across the centre of the bowl or in the opposite direction. The production rates of these mixers is closely tied to the ingredient feed arrangements but most can mix about 2.5 hard doughs and up to 3.5 short doughs per hour.

34.5.1.2.1 *Advantages*

These are very powerful mixers as the shafts have bearings at each end and they are, therefore, able to develop tough doughs more rapidly than most of the vertical types of mixer. Provided that the discharge is efficient, it is possible to locate the mixer directly over a sheeting hopper and this obviates the need for handling the dough via a tub. Tubs can, of course, be used as well should it be necessary to take the dough to another location. There is good and accurate control of the temperature of the mixing bowl from a jacket with constantly circulating water or refrigerant. Ingredients can be added while the beaters are moving.

34.5.1.2.2 *Disadvantages*

Charging with ingredients is usually a significant period in the mixing cycle time and all ingredient feeds must be located over the mixer unless it is done by hand. The beaters tend to throw material up to the roof of the mixer which can result in blind spots where ingredients hang up. The lid totally encloses the mixer so that the progress of the mix cannot be readily observed. Cleaning is a major operation and because there are some unswept areas of the bowl a 'scrape down' part way through a mix may be necessary. It is very inconvenient to remix a dough as charging with dough from a tub is particularly difficult. The beater shape is usually a compromise to allow blending, dispersion and kneading so each action may not be ideal. Where a central shaft crosses the mixer there is often a severe impediment to efficient and rapid dough discharge and this shaft may prevent the free movement of the dough resulting in a barrelling, that is the dough rotates stuck to the beater assembly without much mixing action. The mixer itself is heavy and the beating action can give much vibration. This makes important structural demands on the floor upon which the mixer is located, particularly if it is not on the ground floor of the building.

As has been mentioned elsewhere, as the size of these mixers increases the efficiency in terms of kneading action tends to decline relative to the heat build-up due to friction between the dough and bowl surface.

34.5.1.3 *Size of batch mixers*

There tends to be some confusion on the capacities of various batch mixers. They may be described in terms of bowl volume or in dough weights. It is important to establish, either by experiment or by consultation with the mixer supplier, the maximum (and minimum) dough weights that may be mixed efficiently. Limitations may be related to motor power or the areas swept by the beaters. It is possible that the dough quantities will be different for different types of dough.

The capacities may be based on 'sacks' of flour (280 lb or about 125 kg) but this is not very helpful where large amounts of sugar, fat and other ingredients are included in the recipes. Alternatively, capacities may be based on volume such as 100, 200 or 500 litres (be clear whether the volume is an absolute value or the useful volume where the beaters sweep the dough). As a rough guide, volumes of 100, 200 and 500 litres relate to recipes containing 32, 64 and 192 kg of flour, that is about 60, 120 and 360 kg of dough.

Where mixers are named with a number suggesting the kilogram capacity of the mixer, e.g., HS 800, it is usual that the 800 refers to a short dough as this needs less power for the mixing than a hard dough. The capacity for hard doughs is therefore less than 800 kg even though the volume of the dough may be similar. Often the capacity for a hard dough is about 85% of that for a short dough. Notwithstanding the disadvantages that the mixing action of large batch mixers display over small ones there is a trend towards larger capacity mixers. Wider lines require larger mixes of dough and batch sizes of 1700 kg are common.

Most large batch mixers traditionally have two-speed motors ('low' and 'high' speeds) but the two speed motor is gradually being superseded by variable frequency drives. This gives more process flexibility in that the blade speed can be adjusted. What the ideal speed programmes are need to be established experimentally.

34.5.2 **Continuous mixers**

These are generally of a rotor-within-a-barrel variety. By arranging different arms and stators along the length, it is possible to alter the mixing actions within the range of blending, dispersing, aerating and kneading. Multi-section water jackets allow excellent temperature control and by adjusting the barrel length dough retention and mixing times can be suited. Also the overall capacity of the mixer is usually flexible. It is possible to feed all the ingredients at the start of the mixer or have successive ports along the barrel so that different additions can be made after appropriate intervals.

34.5.2.1 *Advantages*

Without doubt, continuous mixers provide the best and neatest facilities for making doughs or batters in optimum ways. Their outputs can be precisely matched to the rest of the production plant so that all dough is of uniform age. When they are running there is minimum supervision required.

34.5.2.2 *Disadvantages*

Starting and stopping is not easy which is a problem should the rest of the plant stop for any reason. Setting them up is difficult and presupposes knowledge of optimum mixing conditions and sequences. For this reason, use for a range of different recipes

may be difficult as each may not require the same conditions. Metering of all the ingredients must be continuous and this equipment and its maintenance can be extremely costly. It is not easy to meter scrap dough in a uniform and constant manner. To reduce the number of ingredient feeds it is best to consider the preparation of premixes both of solids and liquids and this may be a major capital and supervisory expense. Continuous mixers are best considered for single-purpose plants.

For the reasons stated continuous mixers are not popular but it is probable that the control benefits that these mixers can offer over batch mixers will result in an increase in their use in the near future.

34.6 Integrated mixing schemes in the future

As mixing is such an important stage in biscuit manufacture and as it often demands a combination of much physical effort and experience on the part of operators and their supervision, it is perhaps worth considering how the mixing department of a medium or large biscuit factory may develop in the future. Process control requires understanding the principles and applying the optimum techniques to achieve desired characteristics constantly and in the most efficient manner. Investigators have tried to distinguish the important elements of mixing and brief accounts of these have been given here. It will be seen that biscuit mixers have been developed to cope with large plant demands at the same time as remaining versatile; able to mix a wide range of different types of dough. Compromises are repeatedly exposed and reluctantly accepted. These compromises hinder effective process control so one must expect developments of systems which, by appropriate integration, will reduce the elements of compromise. A move in this direction has been made with the introduction of small batch mixers with minimum cycle times and electronic sequencing and monitoring.

As has been indicated in the previous section, the belief is that developments in continuous mixers will make them more popular but it is likely that the small batch idea will persist strongly also. Perhaps more thought is needed about the mixer involved for these batches. At present a horizontal single beater type has been used. Why not a series of specially designed vertical mixers capable of efficiently executing each aspect of the mixing? It would seem logical to separate the ingredient metering, emulsification, kneading, dough standing, remixing and dough-tipping aspects as is possible with vertical, detachable bowl types. The movement of bowls from place to place, which is at present a disadvantage, can be overcome by the use of rail tracks with self-propelled bowls whose movements are controlled centrally by electronics.

The movement of bowls, types and qualities of ingredients metered into them before and after different periods of ideal mixing action, the standing time and possible remixes can be programmed and integrated with the movements of other bowls for different doughs all at the same time by a computer which supervises the mixing department. There would be little problem, in handling large numbers of small mixings at rates to suit the plant speeds and the amount of process control surveillance could be large and the amount of manual labour minimal. Even end-of-shift bowl cleaning could be automatic. This scheme, in addition, could incorporate the advantages of minimum duplication of metering sites for ingredients and thereby allow maximum attention to precision of each type of metering.

34.7 Premixes

As more attention is given to metering of ingredients, the overall cycle time of a mixing and the labour needed, it is inevitable that the use of premixes must be considered. Some biscuit recipes include a long list of different ingredients and all recipes have some ingredients that are required in only very small amounts. The weighing operations to prepare recipes are, therefore, a problem for one or more reasons. In most factories the small ingredients are dispensed manually, and various systems have been devised to streamline the operations. There is inevitably much room for error where these small ingredient weighing operations are required to be made repeatedly every day. The errors are both in precision and in omissions. Preparation of blends of ingredients to suit a particular recipe involving thereafter the weighing of the blend for each mix obviously simplifies the operation provided that a homogeneous and stable blend can be prepared in the first place.

Many ingredients do not disperse well during dough mixing. This may be because the quantity is very small or because the material is naturally lumpy or tends to form lumps on contact with water in the mixer. Baking chemicals like sodium and ammonium bicarbonate are very inclined to lump during storage so grinding, sieving or solution (or dispersion) in water before addition to the mixer is often necessary. Milk powders are very prone to forming lumps when wetted and, in fact, they are quite difficult to disperse in water.

It was mentioned above that during mixing the dissolution of sugar may take a significant amount of mixing time. If the sugar is made into a solution before adding to the mixer, it can be shown that in many cases not only is the mix time reduced, but also the mix proceeds better and the doughs from successive mixings are more uniform in quality.

Dough fat, if delivered in barrels or boxes, is difficult to meter and handle into mixers. If it is bought liquid and in bulk, the warm oil usually needs to be cooled, plasticised and maybe mixed with an emulsifier before it is in a suitable form for both use in the recipe and for metering to the mixer. It is possible to summarise the advantages of premixes, whether liquids or powders, as

- preparation of ingredients to desired states
- reduction in number of separate weighings needed for each batch
- reduction of incidents of metering errors and ingredient omissions
- improvement in means of metering (for example, pumping rather than weighing) and more potential for automatic metering
- reduction of mix cycle time by allowing a shorter mixer loading time
- means of adjusting ingredient temperatures.

On the whole it is easier to meter liquids or suspensions than solids so there is an obvious interest in using the dough water as a carrier in premixes. If this is done the problems that may arise include the following:

- Most of the 'soluble' chemicals form saturated solutions at relatively low concentrations (see Fig. 34.3).
- Mixtures of chemicals and other ingredients may not be compatible by nature of pH or chemical reaction resulting in loss of gas, foaming or precipitation.
- As the solutions become more concentrated, especially if sugars and syrups are used in the premix, the viscosities increase causing flow, drainage, foaming and cleaning difficulties.

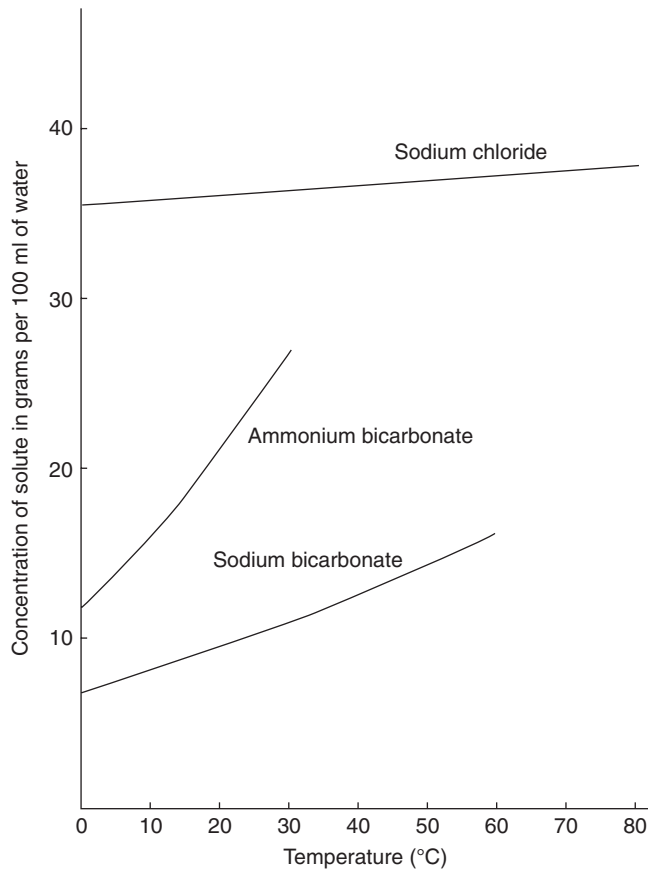


Fig. 34.3 Solubilities of salts in water at different temperatures.

- Solutions or suspensions decay or change on storage such that their potencies or characteristics become less suitable for the dough for which they are intended. Examples are loss of gases, microbial spoilage and rancidity.
- The amount of water required for the recipe may be inadequate to carry the materials to be included in the premix.

It would be good to be able to present a scheme by which one could plan the composition, number of different mixtures and methods of metering for any set of ingredients and any recipe. Unfortunately, experience is so far limited and the number of recipes and number of ingredients are extremely large. It is not at present possible to show a simple working plan. However, it is possible to suggest some principles that should be followed.

1. Firstly, examine the recipe and decide critically whether any reduction of the number of ingredients is possible. For example, could one flour type instead of two or more be accepted? Is an acid salt like cream of tartar or sodium pyrophosphate really needed? Could not the same effect be achieved with no acid, less sodium bicarbonate (to maintain the same pH in the biscuit) and more ammonium bicarbonate?

2. Next, group the ingredients which it is desired to premix into those that are acidic, alkaline and neutral and also into water-soluble, water-dispersible and others. Now, taking the water-soluble ingredients, calculate or experiment with the solubilities of each group, as mixtures, taking due note of the range of temperatures that will be required. Observe the viscosities of these mixtures as this will have an important bearing on the metering, draining or mixing facilities that will be required and on the capacity for holding fine insoluble particles in suspension.
3. Consider the quantity of each premix that it would be convenient to prepare for each batch and do chemical assays to check that there is no significant decay or loss in the time period and at the appropriate temperature that the premix should be kept. Normally the optimum batch size for a premix is that required for a shift or a production period.
4. Now decide how the premix should be prepared to ensure homogeneity and to maintain this uniformity in store. In some cases the solutions can be prepared by simple stirring in a tank, in others high shear mixers will be required to break down flocculations (for example, milk powders in water).
 - If high shear is needed, how can foaming be reduced or eliminated if a suspension is required? How can the viscosity be adjusted to retard the degree of particle fall out?
 - Should inert thickeners like substituted cellulose be used?
 - Is the shape of the mixing vessel correctly designed to eliminate solids remaining on the bottom or corners during mixing?
 - Having made the mix, is continuous mild agitation required to keep the whole uniform?

Metering of a premix will be continuous for continuous mixers and this should present little problem, but if it is intermittent, for batch mixings, there may be a drainage or sedimentation problem in pipelines or subsidiary holding vessels.

It is as well to consider at an early stage how the whole system should be cleaned and how often. How much ingredient will be wasted as a result of a cleaning operation? A premix can only be as good as the precision of metering of components at the time of its preparation. It is as well to install either in-line instrumentation which can detect critical properties of the premix such as pH, refractive index, viscosity or the presence of particular ions to check the composition of the whole, or to devise batch sampling to ensure that the premix is correct before being used.

The design of premix systems is a task for the chemical engineer because it combines ingredient technology with that of the physics of mixing and handling. The benefits to production efficiencies are potentially very attractive and the use of premixes is probably essential to the goal of total automation. If the schemes are imperfectly designed and tested, however, problems of non-uniform doughs may create process problems which are difficult to decipher.

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Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.

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Sheeting, gauging and cutting in biscuit manufacture

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Abstract: Forming dough pieces from hard doughs involves the processes of sheeting, gauging and cutting. Although plant settings can be adjusted remotely, we are not yet at the stage where dough can be fed through the plant without operator help and supervision. Attention must be given to handling the dough as carefully as possible to avoid unnecessary damage to the gluten structure and to allow adequate relaxation before cutting. There are important engineering and maintenance considerations involved.

Key words: sheeters, gauge rolls, cutters, scrap dough handling, dough relation.

35.1 Principles

Of the various means of forming pieces for baking from a mass of dough, sheeting, gauging and cutting is the most versatile and commonly used method. The integrated set of machines that form dough pieces from a mass of dough are commonly referred to as a 'cutting machine'. A cutting machine represents a straightforward mechanisation of the old manual method whereby a mass of dough was rolled out and then dough pieces were cut with a cutter of the desired shape and size. In ancient times the sheeting machine was known as a brake. The term brake is now used for a unit machine which consists of a pair of driven rolls with tables (or conveyors) on either side. With this machine a mass of dough is reduced in thickness by repeated passes through the rolls with the gap between them progressively reduced.

After mixing, dough may be rested, allowed to ferment, cured, or it may be taken immediately to the hopper of a sheeter. The function of the sheeter is to compact and gauge the mass of dough into a sheet of even thickness and at full width of the plant. It is necessary that there are no significant holes in the dough sheet and that the edges are smooth and not ragged. Often the sheeter also enables the incorporation of dough returned from the cutter, known as cutter scrap, with fresh, or virgin, dough brought from the mixer.

Within the sheeter the dough is compressed and worked to remove air and it is inevitable that some stresses are built up in the gluten structure. There is also a small increase in dough bulk density. Flanges at the ends of the rolls prevent the dough being extruded from the ends of the rolls and ensure that the emerging sheet is

always of the desired width. The new sheet of dough then passes to one or more sets of gauge roll pairs which reduce the thickness to that required for cutting. Like the sheeter, there are flanges on one of the gauging rolls to prevent the dough extruding sideways and to maintain a full width of dough sheet. Sometimes, having been reduced in thickness, the sheet is folded or cut and piled up to form many laminations before being further gauged to a final desired thickness. For simplicity of description, laminating and laminators are discussed separately in Chapter 36. Gauge rolls are sometimes referred to as 'laminators' but this is confusing because the term should be used only for the machine that creates stacks of dough which are subsequently rolled to a thickness suitable for cutting.

Each gauging station adds further stresses to the dough sheet and usually there is insufficient time for these to be relieved naturally before the next stage is reached. The way in which the dough sheet is fed into the gauge roll affects the amount of stress put into the dough so careful and precise control is needed if variable stresses, which tend to persist all the way to the cutter, are to be avoided.

The dough sheet is usually carried between gauging stations on conveyors where a little relaxation may occur but between the last, or final, gauge roll and the cutter, special provision is usually made to control the amount of relaxation of the dough before the pieces are cut out. During this relaxation the dough shrinks longitudinally and thus thickens so the thickness at which the sheet is cut, the main factor in determining the dough piece weight, is dependent on both the gap at the final gauge roll and the amount of relaxation allowed. However, the main reason for providing relaxation is to control the shape of the biscuit after baking. A dough sheet that is under considerable tension at the time of cutting will show much shrinkage in length in the oven and will tend to be thicker at the front and back of each piece as a result. When most of the tension is relieved before cutting the shrinkage will be less severe and thus the uneven thickness of the baked biscuits less noticeable also. By varying the amount of relaxation the length and shape of the biscuit can be controlled to a certain extent.

Cutting produces not only the outline of the desired shape and size, but also the surface imprint and dock holes. It is necessary to ensure that the dough piece adheres preferentially to the cutting web and not to the cutter. This adherence must not be too severe otherwise difficulty is experienced in transferring the pieces, without distortion, onto the next conveyor or the oven band. Between the cut pieces is a network of unwanted dough known as cutter scrap. This scrap is lifted away and returned either to the sheeter or, less commonly, to the mixer for reincorporation with fresh dough. As the density, toughness, and maybe the fat content and temperature of scrap dough is often different from the fresh dough, it is important that the quantity should be minimal and that its incorporation be as uniform as possible. In some cases it is best to incorporate this scrap preferentially in the top surface of the new sheet and at other times in the bottom surface. Scrap dough nearly always gives process control problems, so its reincorporation should be planned carefully.

The amount of cutter scrap produced is dependent on the design of the cutter. If the pieces are cut closely together the scrap is minimal, but the spacing depends on the change in shape of the pieces in the oven and also the strength of the dough in relation to the technique used to lift away the network of scrap.

It is possible to sheet, gauge and cut most short doughs as well as extensible cracker and semi-sweet types, but it will be appreciated that with short dough, both because the pieces tend to spread to a larger size in the oven and because the dough

is difficult to lift in thin strips, the scrap network must be significant in area relative to the cut pieces. This means that a high percentage of scrap must be returned to the sheeter for reincorporation. Short dough should be 'worked' as little as possible to achieve best-quality biscuits, so these points should be noted when the options of forming short dough biscuits by a cutting machine or a rotary moulder are being considered.

Commonly the dough sheet or pieces are garnished with sugar, salt, nut fragments, grated cheese, etc., or are given a wash of milk or egg before being baked. It will be appreciated that such applications must be made uniformly and if they are made before cutting they should not affect the performance of the cutter or have too much effect on the quality of the cutter scrap as it is reincorporated with fresh dough. It is normal to garnish or wash dough pieces after cutting and after the cutter scrap has been removed.

35.2 Sheeters

Sheeters are available with either two, three, or rarely four rolls. The two-roll varieties are usually used as pre-sheeters; that is they meter the dough from a hopper as a rough or incomplete sheet to other machinery such as a rotary moulder or a three-roll sheeter at the head of the cutting machine. The performance of pre-sheeters is usually not critical as they are not designed to produce a perfect sheet of dough.

Sheeters heading the forming machinery are nearly always of the three-roll variety because, as Figs 35.1 and 35.2 show, the configuration of the rolls is designed to compress and gauge the dough into an even full-width sheet. The two top rolls are known as forcing rolls and then one side of these rolls plus the lower third roll constitutes the gauging facility for the emerging sheet. In order to draw the dough into the sheeter, at least one of the forcing rolls has a rough surface in the form of fluting or grooving. To ensure an even pulling of the dough into the sheeter it would be best if both rolls had similar roughened surfaces, but the problem is that if both forcing rolls have grooved surfaces a pattern will be given to one surface of the

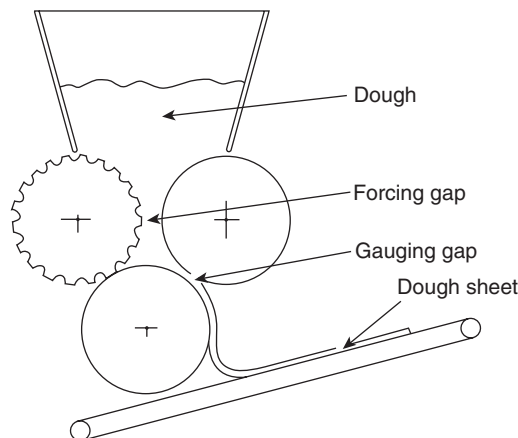


Fig. 35.1 Front discharge sheeter.

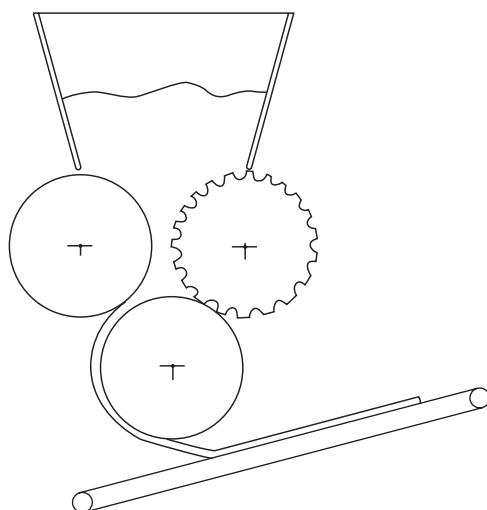


Fig. 35.2 Back discharge sheeter.

emerging dough sheet. This is undesirable as the pattern may persist on the sheet to the cutter and therefore affect the surface of the biscuit. The third, gauging roll, of the sheeter always has a smooth surface. Figures 35.1 and 35.2 also show that there are front and back discharge types of three-roll sheeters. The front discharge variety is better for extensible doughs because the dough is bent as it passes from the roller onto the take-away conveyor. The back discharge arrangement is required where the dough is weak and short so would crack or break if it is bent at the transfer.

Two-roll sheeters do not have the forcing or compression facility and consequently are apt to give sheets which are holey or have ragged edges. For both three- and more particularly two-roll sheeters, the shape of the hopper is more important than is generally recognised. Figures 35.3 and 35.4 show two basic hopper shapes.

A hopper with slopes at the base allows the dough to become 'bridged' over the nip into the forcing gap and thus not to pass down into the rolls. That with vertical sides over the top dead centre of the forcing rolls is much less likely to result in bridging particularly if the dough is dry and does not fall under its own weight. The reason why the former type of hopper is so common is that its capacity is much greater for a given height. A non-stick coating on the inner surfaces of the hopper walls also encourages a good passage of the dough down into the nip of the forcing rolls.

It should be noted that the greater the height of dough in a hopper, the greater the pressure at the sheeter and, therefore, the more extrusion of dough through the machine (that is, more dough passes through for a given number of revolutions of the rolls). For process control purposes, it is advisable to try to maintain a constant level of dough in the hopper and the best way to do this is via a pre-sheeter metering to the three-roll sheeter. However, it is quite common to drop a whole mix of at least half a tonne of dough into the hopper at intervals. In this case one must expect a change in delivery rate from the sheeter as the hopper empties.

The movement of dough through a typical three-roll sheeter is not ideal in terms of the stresses developed, particularly if the gluten is tough. A somewhat better

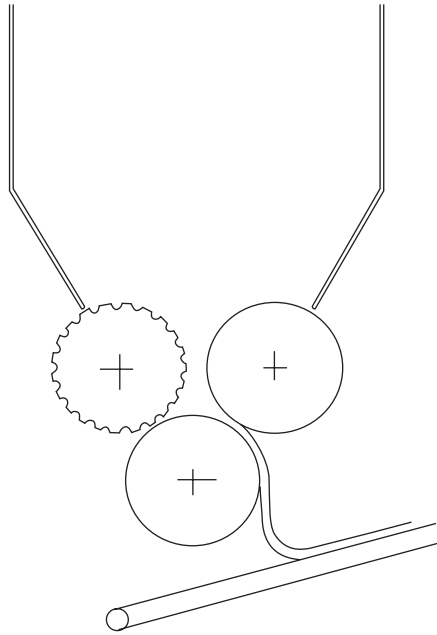


Fig. 35.3 Sheeter with typical hopper shape.

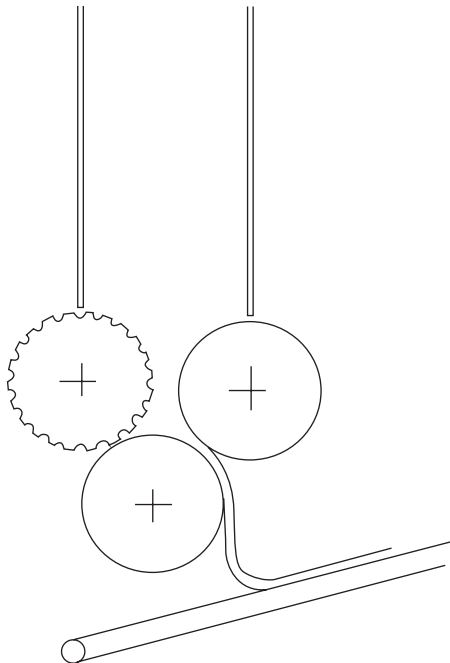


Fig. 35.4 Sheeter with vertical-sided hopper.

control of dough stresses during sheeting can be achieved with a four-roll sheeter. The configuration of a four-roll sheeter is shown in Fig. 35.5. Very thin dough sheets are claimed from a four-roll sheeter and this may allow a reduction in the number of gauge rolls subsequently required before cutting.

Where cutter scrap is fed back to the hopper of the sheeter other problems may arise. If there is a continuous feed of fresh dough to the sheeter it is quite satisfactory to run the scrap into the rear or front of the hopper for incorporation. However, where the dough is fed intermittently in large masses, provision must be made to allow a more or less regular feed of scrap along with the fresh dough into the nip of the forcing rolls. This is usually done with the aid of a gap or small feed roller as shown in Figs 35.6 and 35.7. The problem is that the amount of scrap or the way in which it is drawn in varies, so some adjustment of the gap or the height of the feed roll over the forcing roll is required – this is rarely provided and control is difficult or unsatisfactory. It will be appreciated that the placement of the cutter scrap in a four-roll sheeter is even more problematic.

It is usually possible to adjust the forcing gap and the gauging gap on a sheeter. Typically, the former gap is about twice that of the latter. The greater the forcing gap relative to the gauging, the higher the compression and, obviously, the more work that is done on the dough. The efficiency of a sheeter for compaction of the dough is related to the ability to grip the dough and pull it into the compression chamber at the centre of the sheeter. The grooved rolls are designed to improve this gripping action, but it has been found that the best surface is dough itself so if the roll surface is finely grooved and a scraper arrangement provided which allows a film of dough to remain in the grooves at all times, the gripping action is excellent.

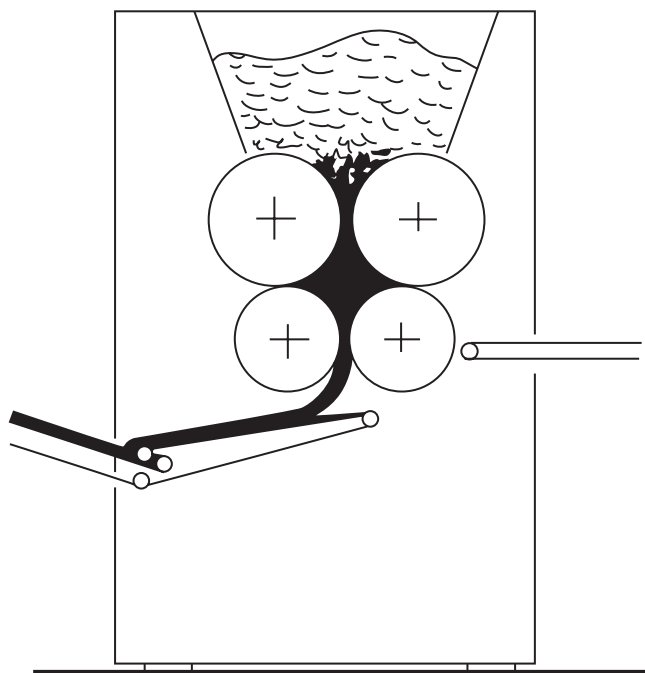


Fig. 35.5 Four-roll sheeter (Preomat machine ex Haas).

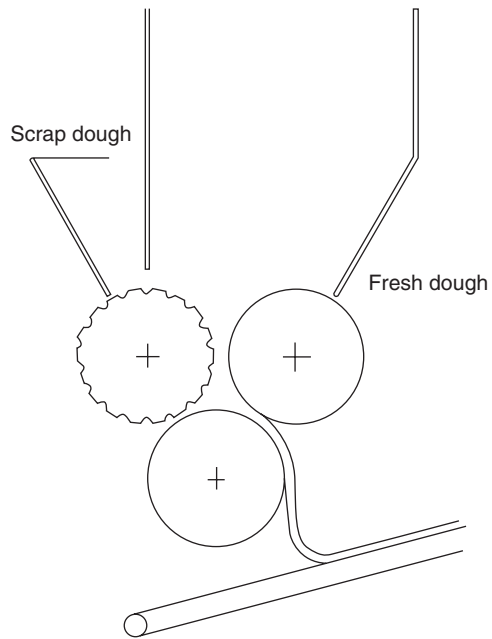


Fig. 35.6 Gap roll.

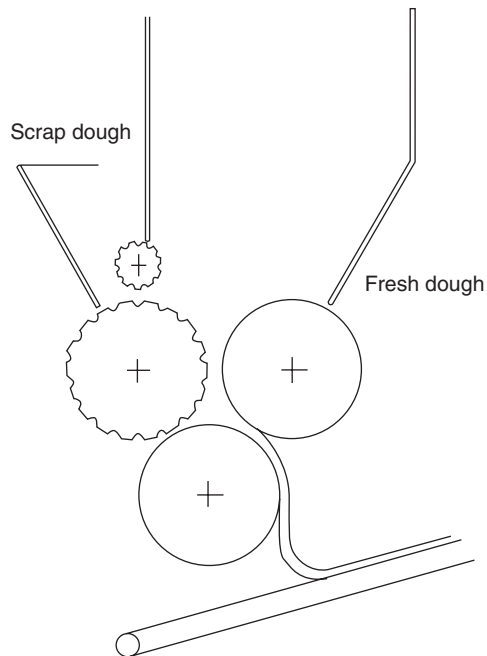


Fig. 35.7 Small feed roll.

Using this arrangement, it is possible to compact the dough and then gauge it to a sheet as thin as 3 mm which obviously requires very little subsequent gauging prior to cutting; however, most sheeters are not designed to produce such a thin sheet.

Insufficient investigation has been carried out on the effects on biscuit quality of different amounts of compression and shear experienced by the dough in sheeters, but what is clear is that the surface of the sheet as it emerges from the sheeter is of very great importance to both the baked biscuit surface appearance and often to the degree of lift obtained in the oven. It seems that a rough, rippled or holey sheet surface cannot be satisfactorily 'repaired' during subsequent gauging.

The dough sheet emerging from the sheeter is collected on a take-away conveyor which is driven by the sheeter motor and whose relative speed can be adjusted over a short range to ensure that the sheet lies well without being pulled from the sheeter. The conveyor takes the dough to the first set of gauge rolls.

35.3 Gauge rolls

Pairs of heavy steel rolls are used to gradually reduce the dough sheet thickness to that desired for cutting. Typically, there are two or three pairs though only one pair may be used for short doughs and more than three where very gentle reductions are necessary. As a rule of thumb the reduction in thickness should be about 2:1, although ratios of up to 4:1 are used. Obviously, the greater the ratio the more work and stress is put into the dough and the more potential there is for deflection of the steel rolls. In extreme cases, and with the widest gauge rolls, this deflection will result in a dough sheet that is thicker in the centre than at the edges.

Usually the pair of gauge rolls are mounted vertically one above the other, but some feel that there is an advantage to have the upper roll a little forward of the lower roll. This may allow a smoother feed of the dough to the nip. The adjustment of the gap is by moving one roll and sometimes this is the upper, sometimes the lower. The latter case is potentially better as wear in the adjustment mechanism is thereby taken up by gravity and the pressure of the dough does not change the gap so much. Wear in the bearings of the upper roll is always a problem for precise gap settings, but proximity sensors which detect the position of the roll axles and automatically adjust the gap to a predetermined value overcome this. All gauge rolls should have instruments indicating the gap setting so that the machine can be changed or the settings recorded with accuracy. The gauges should read to 0.1 mm. Often the gauges do not correspond well with the gap, but this may only be a question of engineering maintenance for calibration.

Claims are made for benefits using rolls of various diameters ranging from about 150–400 mm, and also for different surface finishes. The standard roll diameter is 300 mm. The diameter of the rolls is related to the strength of the rolls and for wide plants it is important that distortion under pressure does not result in the dough sheet being thicker at the centre compared with the edges. However, both the diameter and surface characteristics of the rolls are related to the tendency for the dough to stick to the roll as it emerges. There is also an effect on the smoothness of the surface of the dough. The roll surface can be rough as derived by sand blasting, polished (or even chromium plated) or specially treated with low-friction coatings. The latter tend to have poor wear characteristics. Detailed investigations have shown that while these different surfaces have a marked effect on the dough release

properties, they also affect the work done on the dough. This results in different 'spring' characteristics of the dough as it emerges from the gauge roll and also on the surface appearance. In general low-friction coatings are not recommended for gauge roll surfaces.

The dough sheet leaving the final gauge roll may be as thin as 0.15 mm but to achieve this the rolls must be very strong so that there is no detectable flexing at the centre of the rolls. Often the final gauge rolls are of greater diameter than the preceding rolls in order to ensure this greater precision. Dough emerging from a gauge roll is always of a slightly greater thickness than the gap it has come through. This is as a result of the elastic properties ('spring') of the dough and also because some extrusion, as compared with rolling, occurs through the nip. Measurements of the power taken by the gauge roll to make the reduction in sheet thickness have shown that much more work is done when rough-surfaced rolls are used than smooth, and this power level is very sensitive to over- and under-feed situations into the rolls. This effect is of great importance in the use of the dough feed controller device that was developed to maintain a constant feed to the rolls (described in Section 5.8.4.2). Coated rolls take less power in all situations and the spring after gauging is less because more slip has occurred on the dough surface. This surface also appears less smooth. The effects on the baked biscuit quality remain to be investigated further.

Scrapers are provided to aid in the release of the dough from the rolls and to keep the rolls clean. The aim is to cause the dough to adhere preferentially to the lower roll so that it follows it and then falls away or is eased off by a scraper before passing onto the takeaway conveyor. If the dough adheres to the top roll it is difficult to achieve a smooth transfer. It has been found that if the speeds of the rolls have a small differential the dough tends to adhere more to the faster roll. Speed differentials of up to 12.5% are tolerable. The speed differential may be achieved with geared sprockets or two drive motors. Such systems are normally required only on the final gauge rolls.

Both sheeter and gauging rolls locate together between flanges fixed on the sides of one of the rolls. The flanges allow the dough to fill the roll right to the edges, thus ensuring a full-width sheet without a ragged edge. Formerly, the flanges were part of the lower roll but as this made it difficult to bring the take-away conveyor very close to that roll, development has now meant that the flanges are on the upper roll instead. (The take-away conveyor is always a little wider than the gauge rolls to ensure that dough never hangs over an edge.) There is a difficulty in that release of the dough at the flanges can be a problem so when upper flanged rolls are used there is a greater tendency for the dough to follow this roll rather than the lower. It will be appreciated that all of these problems are greatest when the dough sheet is thin, that is, at the final gauge roll pair.

Since tensions in the dough should be minimal and as constant as possible, it is necessary to maintain a full sheet by allowing a slight loop in the dough on the feed side of the gauge rolls and to have a similar loop at the discharge side. If the dough is pulled away from the rolls, tensions are produced. The optimum conditions are shown in Fig. 35.8. Some manufacturers have used laser proximity devices to maintain a constant loop of dough through a feed-back speed control system (see Section 5.8.4.2).

Short doughs are very non-elastic so careful attention must be given to the scraper position and the proximity of the take-off conveyor to prevent strong

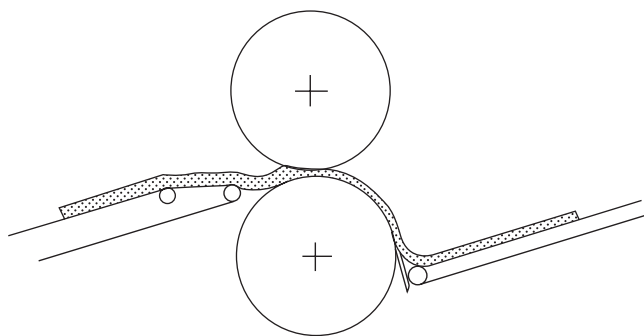


Fig. 35.8 Optimum dough path through a gauge roll.

curvature at the discharge side of the gauge rolls. It is here that the top flanged roll configuration has maximum potential advantage.

Careful engineering adjustment is necessary for good performance of a series of gauge rolls. It is sometimes found that there is a tendency for overfeed at one side of the plant compared with the other. This may be due to either an uneven gap caused by non-parallel rolls or because the gauge roll pairs are not perfectly in line on the plant. To check for uneven gap across the roll, it is best to weigh, precisely, cut discs of dough taken from the sheet at each side. Testing the gap with feeler gauges when no dough is present will not show the effects of wear in bearings that are only apparent when under load.

When machining harder or tight doughs it is frequently found that the dough is slightly thicker in the centre of the sheet than towards the edges. This is because some flexing of the rolls occurs under load. If this situation is so bad as to be significant in the weights of biscuits produced at the cutter, crowning of the rolls may be considered. However, the amount of crowning is difficult to define because it is likely that the optimum degree required will differ with doughs of different consistencies. Equipment manufacturers prefer to offer solid steel rolls rather than crowning to reduce the possibility of distortion at the centre of the plant.

The gauge rolls may be solid or constructed from a strong tube of case iron with shafts inserted at each end. The solid rolls are much stronger and less likely to be flexed under load. This is particularly the case if the rolls are made of mild steel clad with stainless steel. This construction also avoids corrosion and allows repair if the roll surface becomes damaged.

There is a trend towards larger diameter gauge rolls, typically 400 mm, especially the final gauge roll. This is partly because of wider lines and partly to obtain better transverse weight accuracy. However, a large roll subjects the dough to more work than a small roll, so there is a risk of more damage to the dough structure.

35.4 Multiple-roller gauging units

The severe reduction that tends to occur at a gauge roll, with the inevitable stresses produced in the dough, have led to the development of multiple-roller units that 'stroke' the dough to a thinner gauge. Figures 35.9 and 35.10 show two common types. The machines are particularly useful for laminated dough where it is

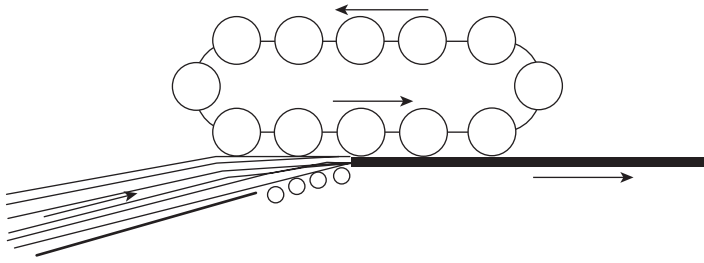


Fig. 35.9 Rheon RM stretcher.

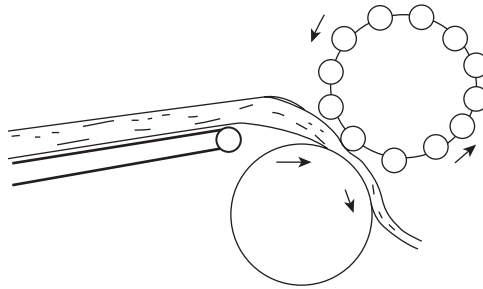


Fig. 35.10 Rijkaart Multiroller.

important not to damage the structure that has been built up. Multiple-roller units have the serious disadvantage for biscuit plants that the dough sheet does not fill the width of the rolls because the normal flange arrangements cannot be used.

35.5 Dough relaxation units

The reasons for dough relaxation have been outlined above. Usually special provision is made for this only between the final gauge roller and the cutter. It may, however, be desirable to relax the dough more often in puff or other laminated types. The dough is relaxed by allowing time and also giving facility for unlimited shrinkage. In some older cutting machines the conveyor between the final gauge roll and the cutter was very long and the dough was slightly overfed onto it so that low ripples were formed. Before the sheet reached the cutter the shrinkage had absorbed the ripples so that a smooth sheet was available for cutting. The plant length required for this was often impractical, especially on high-speed lines, so the use of an intermediate web is now the more usual method. Dough is grossly overfed onto this intermediate web to form ripples. The intermediate web feeds the cutting web whose speed is such that the ripples are just taken out by the time that the sheet is passed onto the cutting web. Thus a smooth and relaxed sheet is presented to the cutter.

This arrangement is reasonably satisfactory but it can frequently be noticed that this rippling causes local transverse lines of stress, particularly in dry doughs, that are not completely removed before cutting. Also, it is easy to neglect the plant adjustment so that the dough is pulled off the intermediate web onto the cutting

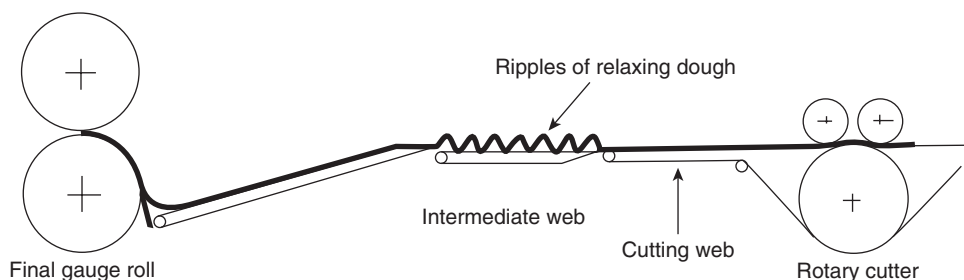


Fig. 35.11 Typical arrangement of dough feed conveyors between the final gauge roll and the cutter.

web thereby introducing some stress again. The deep rippling also allows circulation of air under the dough and this can be a disadvantage when one remembers that preferential adhesion to the cutting web rather than the cutter is required (see Fig. 35.11). With the increase in flour protein that is being experienced so often, it is becoming increasingly important to provide enough relaxation for the dough sheet before cutting. The author has also experienced problems of dough sheet transfers both onto and away from the relaxing web where plastic-coated conveyors are used. Dough tends to stick to these conveyors if the surface is very smooth and this impairs controlled transfers. A matt surfaced conveyor is better.

35.6 Cutting

Older biscuit plants always employed reciprocating cutting machines. These used heavy block cutters which stamped out one or more rows of pieces at a time. The equipment needed to be strong and incorporated a swinging mechanism so that the dough sheet travelled at constant speed and the cutter dropped, moved with the dough, then rose and swung back before dropping again.

There were two basic procedures used depending on whether merely cutting or embossing and cutting was required. Where simple cutting and docking was needed, as for most crackers and hard sweet types, the cutting edges, docker pins and any type of decorative patterns were mounted on a baseplate and a spring-loaded ejector plate was located to move vertically around the fixed parts. When the cutter dropped onto the dough the ejector plate was pushed back and as the cutter was lifted away the ejector pushed the dough to ensure it stayed on the cutting web and did not stick to the cutter. If there was a tendency for the dough to stick to the ejector it was necessary either to lightly dust the dough sheet with flour, or to effect a little drying with a blast of air before the cutter.

When cutting *and* embossing was required, as for some short dough types, the ejector plate was replaced with an embossing plate. This plate was held back as the cutter dropped, then the plate was dropped to a predetermined position to press a deep pattern into the dough pieces. The embossing plate was then lifted away followed by raising of the cutting edges. This arrangement meant that the dough pieces were firstly determined (which is important for weight purposes) then the surface relief was imprinted without loss of any dough by extrusion. It was unusual to have

docker holes right through this type of dough piece, but if they were required, they were incorporated in the pattern cut in the embossing plate.

Reciprocating cutters therefore required a much heavier mechanism with many moving parts that needed good lubrication and maintenance. They were often noisy, especially if the plant was run at high speed. Speeds of up to about 180 cuts per minute could be achieved, usually less with embossing cutters than cutting only types. It was, however, unusual to run these cutters at more than 100 cuts per minute. Two or more rows could be cut per drop of the cutter, but the more rows there were at once, the wider and heavier the cutter block became.

Reciprocating cutters are rarely used nowadays. Their high maintenance requirement has meant they have been superseded by rotary cutters. Reciprocating cutters are only used for doughs with difficult to cut inclusions like fruit shortcake.

With the development of longer ovens (higher line speeds) and wider plants, it was necessary to consider improvements in the cutting arrangements. Rotary moulders have largely replaced embossing cutting for short doughs and rotary cutters are now used almost exclusively for most other types.

Rotary cutters are of two types, those that employ two rolls, one immediately after the other, and those with only one roll. Dealing with the two-roll type firstly, the principle is that the dough sheet, on a cutting web, is pinched between engraved rolls (mounted in series) and a rubber-coated anvil roll(s) (see Figs 35.12 and 35.13).

The first roll docks the dough, prints any surface pattern or type and thereby pins the dough onto the cutting web. The second roll is engraved with only the outline of the biscuit and cuts out the piece leaving a network of scrap (which has not been pinned down) as with the reciprocating type of cutter. There is a facility

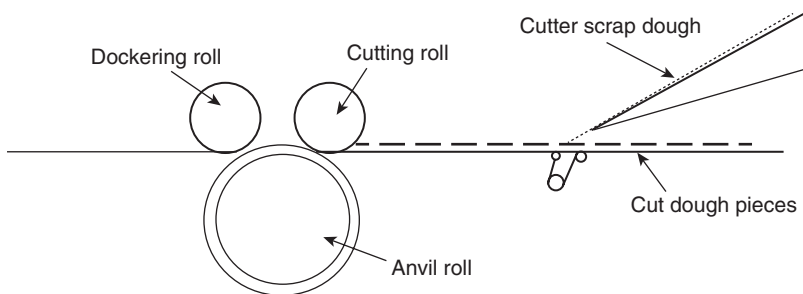


Fig. 35.12 Typical rotary cutter arrangement (single anvil roll).

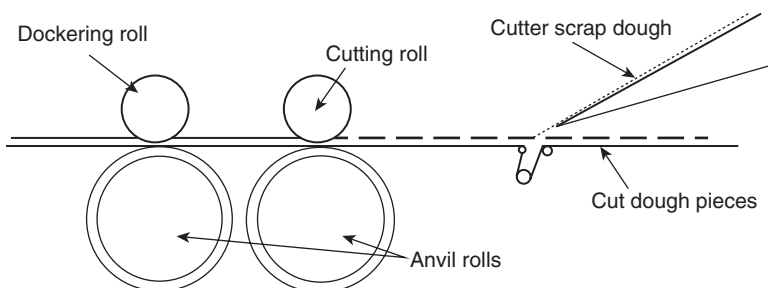


Fig. 35.13 Typical rotary cutter arrangement (double anvil roll).

to adjust the rotation of one roll relative to the other so that correct synchronisation between pattern and outline cut is possible. The pressure between each of the cutting rolls and the anvil can be adjusted independently both as a whole and from side to side. Often there is a quick release arrangement that lifts both rolls and allows their return to the original position.

It will be appreciated that there is a fine adjustment required for the height of the first roll to make sure that the dough is dockered and pinned down sufficiently, but the pressure must not be too great otherwise displacement of the dough both backwards to form a wedge and sideways affecting the thickness of the eventual dough piece may occur. The dough sheet thickness and hence the piece weight should be determined at the final gauge roll not at the cutter. Docker pins must be long enough to penetrate the dough sheet and form a join between the top and bottom surfaces. Inadequate docking can lead to blistering of the biscuit. It is also important that the docker pins are not too long otherwise the cutting web will be damaged.

The cutting rolls are driven so the speed relative to the cutting web can be adjusted slightly to affect the length of the cut piece and also to assist release of the dough from the cutter.

A single-roll rotary cutter achieves both docking, pinning and outline cutting with only one roll. In many cases this works well and there is a saving in capital equipment, but there is a strong tendency to lift the dough piece from the cutting web because the pinning down facility is not independent of the cutting pressure. Cutting rollers are expensive so one should not have two where one would do, but the frustration and disruption to production caused by malfunction leads one to advise that the chances of difficulty which may occur from using a single-roll type are significantly avoided by using the two-roll system.

There is no doubt that the performance of cutters, of either rotary or reciprocating types, is affected by the surface of the cutting web which carries the dough. The webs originally were woven cotton canvas or cotton/polyester mixture. Now plastic-coated webs are the norm. At all times one is seeking the fine balance between good, but not excessive adhesion, of the dough to this web. New canvas webs may have to be 'dressed' before use and webs which have dried out between production runs may also need some pre-treatment. This treatment usually involves the soaking of the web with a liquid oil such as groundnut or soya oil, but sometimes a flour water mixer is rubbed in to fill the pores and give a sticky surface. There is some trial and error involved. The dough itself dampens and 'conditions' the web very soon after production commences, but where a very dry dough is used or the bakery atmosphere is hot or dry, some additional dampening of the web may be needed throughout the production run. This can be achieved with a moistening (water) roller running on the return of the web under the cutter, or, alternatively, a steamer which lets steam condense on the web on its return run.

Plastic-coated webs may offer too much adhesion due to their very smooth surface. These webs must be joined by splicing and heat bonding which is an ideal system when done well but requires special equipment. Canvas cutting webs are normally sewn by hand at the joint with polyester twine. The best webs are made endless but the design of the complete cutting section must be such that an endless web can be fitted and replaced easily.

Rotary cutting rolls are usually fabricated in bronze or gunmetal and modern automated engraving techniques allow high precision of shape and thickness of the

patterns over the whole roll surface. Moulded plastic ‘cups’ which are attached to a roll surface are also a standard. The moulded cups are produced from a single die so they are all identical. The cost is not much different for the fabrication of a cutting roll with cups compared with an engraved roll but as it is possible to have an unlimited number of spare cups from the same mould, savings in the event of wear or damage are very favourable.

35.7 Cutter scrap dough handling

Ideally, the network of dough not included in the cut pieces (cutter scrap) will be adhering less firmly to the cutting web than the pieces. It can therefore be lifted and gently pulled upwards onto a scrap return conveyor (see Fig. 35.12). If the dough is very weak it may be necessary to use supports to aid the lift onto this scrap return web. These supports are called ‘fingers’. It will be appreciated that they can be used only where the pieces are in straight lanes with clear lines of scrap where the fingers can be located. Scrap fingers cannot be used where the pieces are cut in a staggered arrangement as is usual for round or oval biscuits.

A web ‘break’ arrangement may be provided just at the scrap lift position (see details in Figs 35.14 and 35.15). This involves a downward loop in the cutting web which allows peeling off of the dough at a sharp nosepiece and thus a release at the crucial moment. Pieces which are peeled and then replaced on the cutting web in this way tend to transfer to the panner or oven band better. A web break should be used only when absolutely necessary as the extra nosepiece and strong flexing of the web reduces the life of the web and its joint and also makes web tracking more difficult.

The scrap dough, having been lifted away, may be returned as a full-width network to the front of the sheeter hopper, or it may be collected and sent back on a narrow conveyor to be distributed across the back of the sheeter hopper or, less commonly, back to a bin or to a mixer. Whichever is the arrangement, it is important to ensure that this scrap dough is spread evenly in the sheeter to optimise a good distribution in the new dough. It is worth watching that edges of the new sheet are not rich in scrap as this will have an adverse effect on the quality of biscuits produced. If the quantity of scrap is high it may be worth considering using a two-roll sheeter to

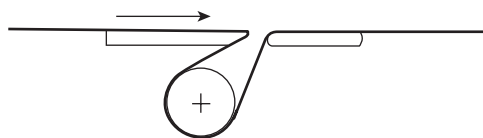


Fig. 35.14 Web break with two nosepieces.

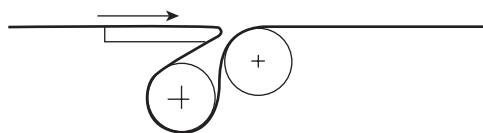


Fig. 35.15 Web break with one nosepiece and a roller.

make a continuous layer of scrap dough which is fed beneath the fresh dough from the main sheeter. The advantage of this arrangement is that the scrap can be metered and its placement is fixed.

35.8 Dough piece garnishing and panning

Having removed the scrap dough, a surface dusting of sugar, salt or nuts, etc., may be applied to the pieces before they are placed onto the oven band. Systems for this operation always include a means for recovering the excess material which falls between the pieces or rolls off. The recovered material can be reused. At this point, as an alternative to dusting, a milk or egg wash may be applied. This is done with a revolving brush or roller and care must be taken that as little as possible of the liquid spills onto the web as this will make the surface very sticky and necessitate continuous washing and drying. It is also possible to apply the wash with a spray arrangement but this involves an appreciably larger and more costly machine. It is fair to say that wash application is often unsatisfactory.

It is not usual to run the cutting web right through to the oven band. Normally there is a transfer onto a panning web. This is essential if surface dusting or washing is involved as the cutting web and its support rollers should be kept as clean as possible. If the finished dough pieces are transferred (panned) onto the oven band from a panning web, this is the part of the cutting machine known as a panner unit. The panner has several functions. It allows an acceleration of the pieces off the cutting web which may be useful if some spatial separation, etc., is required and it is usually capable of swivel so that it can follow the line of the oven band as this tracks slightly from side to side. In this way the dough pieces are always deposited away from the extreme edges of the oven band. The garnishing and washing units mentioned above are sometimes incorporated in the panner.

The transfer of pieces from the panner to the oven band must be adjusted carefully so that the spacing is optimum and they lie down smoothly. Badly panned pieces may be distorted in shape after baking. As a general rule the spaces between dough pieces on the oven band should be the same in longitudinal and transverse directions. This promotes even colouring all round during baking.

35.9 Control of biscuit cutting machines

Emphasis has been given to the need to handle the dough carefully and consistently through the forming process. As the sheet gets thinner it is necessary to carry it faster so the relative speeds of successive machines must be very precisely controlled. Early biscuit cutting machines were driven by one large motor with individual parts being controlled at appropriate speeds with a series of variable speed (PIV) gearboxes. All machines are now driven with independent motors with electronically monitored and controlled speeds that can be adjusted from a central control panel. This offers much more precise speed control in the cascade and good potential for local control loops activated by sensors monitoring the thickness of the dough or power usage of individual units.

The dough feed controller and optical sensors for dough thickness measurement are described in Chapter 5. There remains the need to develop instruments to aid

the optimum settings for rotary cutter pressures and to detect defects in the operation of scrap dough removal. Baking time (the speed of the oven band) is usually the reference speed for the cutting machine.

35.10 Operator maintenance requirements

The main requirement for non-engineering maintenance is to keep the various parts of the machine clean and free from dough that will harden as it dries out. At the end of each production run the sheeting hopper should be completely emptied and the grooves in the rolls scraped clean. Dough tends to collect at the scrapers on all rolls and can become lodged at the edges of the web rollers.

The web tensions should be relaxed and dough which has collected on the drive and support rollers should be scraped off. It is also necessary to check that there is no build-up of dough on the rubber roll(s) which act as anvils for the rotary cutters and if these need cleaning this should be done with care so that the rubber is not damaged. At the end of a run always relax the pressure between the cutting rolls and the anvil(s). All webs should have scrapers on their return runs and these should be checked and catch trays emptied.

The webs themselves should be examined and faulty joints repaired as necessary. Due to wear at the edges, the webs often become ragged and loose threads appear. Trimming with scissors or a sharp knife prevents these threads finding their way into the dough. Very badly worn webs will, of course, have to be replaced.

It is particularly necessary to remove and clean thoroughly the cutters, whether of rotary or reciprocating type. The cutters are heavy and expensive so suitable lifting equipment is needed to remove them from the plant and then specially constructed racks or trolleys should be available to take them away for cleaning and then to a store. The cutting rolls must be supported by the shaft ends not resting on the patterned parts. In the case of reciprocating cutters the cutter blocks should be inverted for transport. Cutters should never be placed on the floor. Rotary cutters can usually be cleaned adequately with stiff nylon brushes and compressed air blast, but the reciprocating cutter blocks should be soaked in warm water and then blasted clean with steam. It is important to check that all dough residues are removed from behind the ejector plates. Dough left around the machines or within them attracts vermin and insects and these, or their droppings, may later contaminate dough. Good supervision will insist that dough dropped under machines is cleared away regularly, but especially at the end of a production run.

There has been a marked raising of end user requirements for machinery that is non-soiling, easy to see when it is dirty and easy to clean. The increased awareness of genetically modified organisms, allergens and pathogens has meant that standards of GMP are being raised, especially in the USA but inevitably worldwide.

As practically all machinery controls and instruments are now electronic it is usually to link signals to a network so that monitoring and recording can be done centrally in the factory. Equipment suppliers are also finding it useful to make these records accessible anywhere in the world via Internet connections. This means that surveillance and troubleshooting can be done remotely saving time and expense. It has become less necessary to have specialist technologists and engineers at all factory sites and the implications are truly revolutionary.

35.11 Useful reading

- [1] MAKINS, A. H. (1974) 'The evolution of sheeters and laminators', *Baking Ind J*, October, pp. 28–29.
- [2] MANLEY, D. J. R. (1998) *Biscuit, cookie and cracker manufacturing manuals*, 3. *Biscuit dough piece forming*. Woodhead Publishing, Cambridge.
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Laminating in biscuit manufacture

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Abstract: Dough lamination is needed to produce a flaky structure in crackers, especially where a filling dust or fat is introduced between layers of dough. With the general increase in flour protein levels worldwide, giving stronger and less extensible doughs for biscuits, laminating may become necessary to improve the handling of these doughs. The machinery used to laminate dough can be of either a continuous lapping type or a cut sheet type. There are benefits and disadvantages in either case.

Key words: gluten modification, lamination, filling dust, dough stresses.

36.1 Principles and techniques of laminating

Before the advent of modern automatic laminators, biscuit doughs and pastries were subjected to forms of laminating by hand. This followed hand rolling of the dough with a pin or dough sheeting and reduction using a dough brake (a pair of rolls with reversing facility and a table on either side). The purpose of laminating was fourfold. Firstly, it provided a method of repairing a poor dough sheet that tends to be formed with a simple pair of rolls. Secondly, by turning the folded dough through 90°, stresses in the dough are made more uniform in two directions. Thirdly, by rolling, then folding a dough, followed by more rolling, a significant amount of work is done on the gluten making it more suitable for baking to a delicate structure. Fourthly, by introducing another material, like fat, between layers of dough, a characteristic flaky structure is produced after baking (cf. cream crackers and puff biscuits).

Automatic laminators used for semi-sweet dough are useful for the first three reasons given above, namely, sheet repair, dough stress equalisation and gluten modification by working. The development of high-speed dough mixers and the technology of chemical modification of the gluten with sodium metabisulphite (SMS) or proteolytic enzymes has largely replaced the functions of a laminator so that sheeting with a three-roll sheeter usually produces a satisfactory sheet for subsequent gauging and cutting. However, there remain some occasions where chemical modification of the gluten is undesirable, insufficient or even not permitted, so lamination is very necessary. Pizza dough is basically a bread dough and because of the gas-retention properties required, the gluten must be quite strong and inextensible. Sheeting of this dough is difficult but laminating improves it considerably prior to cutting.

Cream cracker dough is somewhat like pizza dough in that it has a bread-type recipe and is fermented. It is difficult to sheet smoothly but it is usually laminated not only to create a clearer (smoother) dough sheet but also to allow the introduction of flour and fat mixture designed to keep the dough layers separated a little during baking. The fact that some cream cracker manufacturers use very little 'filling' tends to show that it is the dough sheet/stress relieving function of the laminator that is of more importance to the biscuit structure.

By introducing a lot of fat between the dough layers a very flaky structure is produced during baking and this is the characteristic feature of puff biscuits (see Chapter 26). The fat may be introduced as lumps into the dough prior to sheeting, or as a continuous layer after a good dough sheet has been formed. In either case, gauging and laminating is needed subsequently to build up the number of dough layers which appear as very thin flakes in the baked biscuit or pastry. A critical feature of puff dough production is the plasticity of the fat or fat/flour mixture that is used. It is necessary for the consistency of the fat and dough to be very similar so that the fat does not break through the dough layer or, conversely, squeeze out. In order that the fat used does not have a long high melting point tail above body temperature but is sufficiently firm and plastic in consistency, it is normal to arrange that the dough is cold, usually not more than 18°C. The laminator is also housed in an air-conditioned room which is kept cool.

36.2 Types of automatic laminator

Having outlined the reasons for laminating, let us now consider the various types of automatic laminator. Although there are many advantages in the use of these laminators, it should be remembered that the continuous action does not allow as much dough relaxation between operations as occurs with a manual reversing brake. In some cases conveyors have been introduced in the automatic laminators to allow some relaxation of the dough at various stages in the operations. Some different types of automatic laminators are now described.

36.2.1 Vertical laminator with continuous lapper and one sheeter

This type of laminator (see Fig. 36.1) usually incorporates a three-roll sheeter with cutter scrap inclusion on one side, two or more gauge rolls, cracker dust spreader on part of the sheet and a zig-zag lapper (see Fig. 36.2) capable of building up about 10 or 12 layers. The advantage of this type of laminator is the continuous smooth action of most parts, but the disadvantages are:

- The stresses introduced in the laminated dough due to folds at the edges.
- The exposure of top and bottom of the sheet on successive Vs of the folded dough (this can mean that the scrap dough is alternately exposed if incorporated in one side of the sheeter) (see Fig. 36.2).
- The cracker duster is intermittent in action and must be synchronised with the lapper. Also the filling dust is normally between only every other lamination (see Fig. 36.3).
- The folded sides give rise to a non-uniform transverse weight distribution.

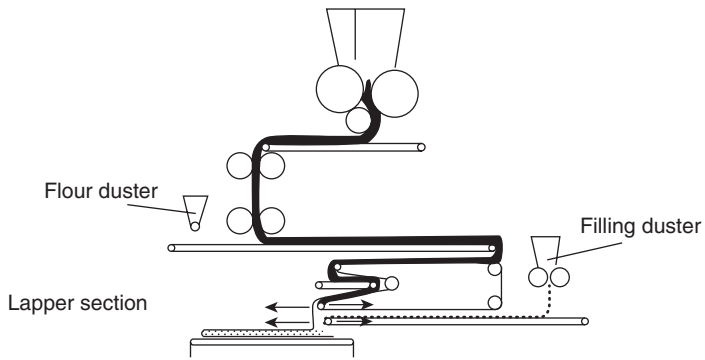


Fig. 36.1 Vertical laminator with continuous lapper.

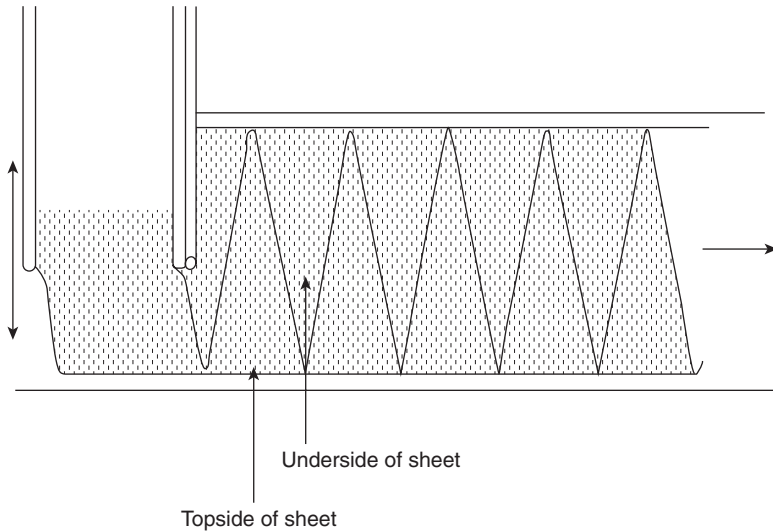


Fig. 36.2 Formation of laminations on a continuous lapper.

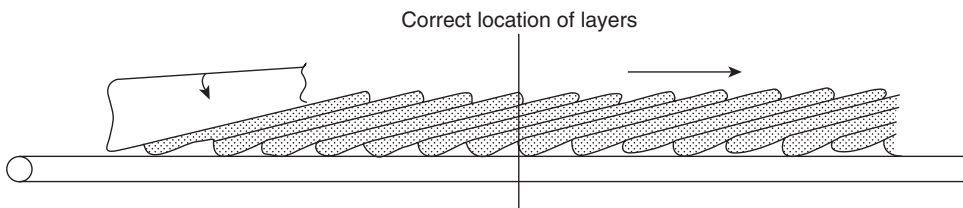


Fig. 36.3 Formation of four double laminations with a continuous lapper. The filling dust is shown between each double layer.

36.2.2 Vertical laminator with continuous lapper and two sheeters

With this type (Fig. 36.4) it is normal for two two-roll sheeters to make sheets and filling dust may be incorporated prior to subsequent gauging. The advantage of this type would appear to be that the filling can be spread continuously over the full width of the sheet, but disadvantages are the same as for the previous type of laminator combined with the fact that by using two-roll sheeters, poor sheets may be formed and it is these sheets that have to 'hold' the filling. The sheets from the sheeters need not be of similar thickness and some use one of the sheeters to control the addition of the cutter scrap.

36.2.3 Horizontal laminators

These laminators (Fig. 36.5) are similar in performance to the vertical types but the sheeting and gauging (also the cracker dust filling) occurs on units arranged horizontally before the lapper(s), more like conventional biscuit cutting machines. The disadvantage of this type is that the whole machine takes a lot of floor space because a right-angle bend in the line of plant is required where the lapper is sited. For this reason it is rare to find horizontal laminators now. The advantage is that more than one lapper can be used if required, introducing a second 'turn' to the dough. It is usual to use two three-roll sheeters in horizontal laminator systems and cracker dust or more fatty fillings can be added between the two sheets (that is, on the lower sheet of dough).

36.2.4 Cut sheet laminators

There has been a growing interest and preference for cut sheet (cut and lay) laminators for many years now. Both the vertical and horizontal laminators described above are of the continuous sheet folded type, but either can be supplied with a cut sheet lapper. However, in cut sheet laminator descriptions the term layering carriage is better than 'lapper'. The folded sheet types always involve a 90° turn in the direction of travel of the dough after lamination, but a cut sheet type need not have this feature. Sheets are cut and laid down one on top of the previous one to form a stack.

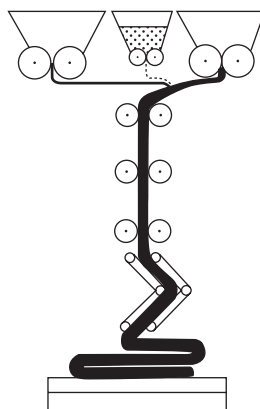


Fig. 36.4 Vertical laminator with two sheets and a continuous lapper.

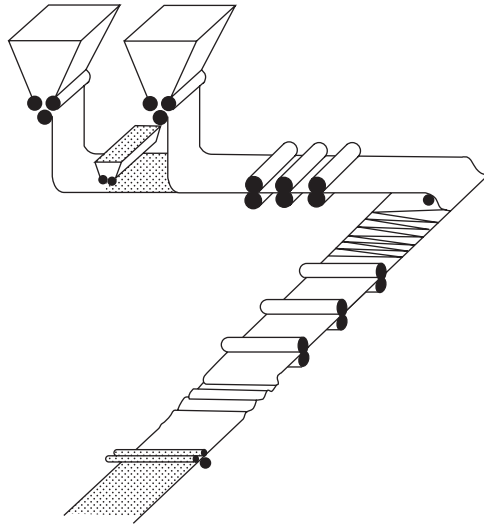


Fig. 36.5 Horizontal laminator with a continuous lapper.

To keep the plant running continuously the stack is obviously not absolutely vertical, it is slightly sloping. The advantages of cut sheets are that little or no stress is involved at the edges since no folding occurs and also that an in-line laminating arrangement is possible if a turn in the direction of dough rolling is not needed. Also the underside of the dough sheet, where the cutter scrap may be incorporated, is never exposed on the upper surface. The disadvantages are a much more complicated mechanism for the laminating action to produce cut sheets and to lay them down precisely and the possibility that the cut edges may expose the filling onto the subsequent surface of the dough. This is particularly important where a heavy fat filling is involved. A cut sheet laminator will also produce only half the number of dough layers per stroke of the laminator carriage as the lapping variety.

There are many different aspects of design ingenuity for cut sheet laminators from the various suppliers. The mechanisms are rather complex and difficult to illustrate with simple diagrams. The author therefore reluctantly must refer readers to specialist data sheets available from equipment manufacturers. Key aspects to consider when selecting a cut sheet laminator include the following.

- How is the positioning of the dough sheet controlled and adjusted? Servo motors are better than cams for adjusting stroke length and speed.
- Where and how is a cracker duster used? Can its performance be monitored easily and can it be filled easily?
- Does the stroke when the sheet is laid down act very rapidly to give a minimum angle to the front edge of the sheet relative to the new direction of travel of the dough? (See Fig. 36.6.)
- Is there a facility for using the sheeteer of the laminator as the first unit in a simple sheet and cut plant layout if a laminator is not needed?
- Is it possible to run the lapper to give continuous lapping rather than cut sheets (and hence twice as many layers per stroke) if required?

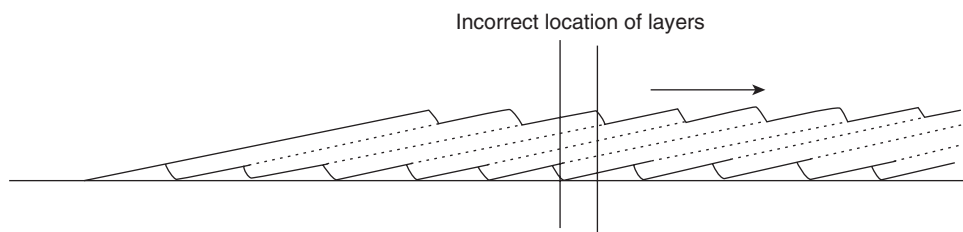


Fig. 36.6 Formation of incomplete four laminations with cut sheets showing position of filling dust between the layers.

- How large is the space needed for the laminator, that is, what is the shape of the machine's footprint compared with the rest of the plant?

The performance and reliability of laminators has been greatly improved by replacing the cams and levers with electronic servo drives. The control of the cutting and the laying down of the sheet is much more accurate. The elimination of mechanical components has resulted in a cleaner and more reliable machine.

36.3 Is laminating really necessary?

Where a flaky structure is to be built up, the answer must be 'yes'. Biscuits with a flaky structure are cream crackers, soda crackers, water biscuits and puff dough biscuits. In most cases hard doughs for savoury crackers and semi-sweet types of biscuits can be satisfactorily processed with a sheeter and subsequent gauging prior to cutting and a laminator is not necessary. Where the sheet produced from a sheeter is not smooth and further treatment of the gluten during mixing to make it more extensible is not possible, laminating the dough will probably improve the dough sheet prior to cutting and therefore the biscuit quality. There is a general increase in flour protein levels worldwide and this is giving stronger and less extensible doughs for biscuits. There is also a resistance to the use of SMS in many countries; in these cases laminating is a great advantage to the biscuit manufacturer.

If the flour protein level is less than 9.5% it will generally be possible to make a dough sheet for cutting without laminating. If the flour is stronger with higher protein level it may be useful to laminate. It is never wrong to laminate hard doughs but a laminator is an expensive piece of machinery so to buy one when it is not necessary is a waste of money.

36.4 Process control during laminating

Most laminators have a bulk rather than a metered feed of dough into the sheeter hopper(s). This means that the discharge of sheeted dough is rather irregular due to the height of dough in the hopper. This problem was discussed in the previous chapter. Thus, a dough feed controller at the first gauge roll is very desirable to reduce the need for continual surveillance of speed here.

As the lapper builds up the layers of dough it is important to make speed adjustments so that exactly the same number of laps is present at all times. If a variable

thickness occurs, as in Fig. 36.6, the feed to the next gauge roll will be uneven and irregular stresses will be set up in the dough on gauging. The best check on whether the laps are placed correctly is to observe the dough as it emerges from the next gauge roll. If it shows bands of crushed or stretched dough associated with the edges of each lap, appropriate opening or closing of the space between each lap can be made by changing the speed of the laminator relative to the laminated dough web. These changes are easier and more precisely made if the laminator carriage mechanism is powered by servo motors.

It is quite important for the quality and shape control of the baked biscuit that the amount of filling introduced between the laminations is uniform. Malfunctioning of the filling duster will result in uneven weights and lift of biscuits and may be enough to affect the colouration and eating qualities also. There should be a standard ratio of filling dust to dough and a procedure should be devised to enable checks to be made that this standard is maintained. Unfortunately, it is not always simple to collect the delivery from the duster to permit checks on weights to be made.

The number of laminations required to give an optimum quality of biscuit should be decided by experiment. Too few laminations will give a ragged flaky structured biscuit and too many will result in excessive crushing during gauging prior to cutting. The latter effect can be reduced if thinner dough is laminated. Indications on the number of laminations to use are suggested in the sections on cream cracker and puff biscuits.

Poor quality edge-lane biscuits are often observed in laminated products. Careful observations at the gauging after the laminator will usually indicate the reasons. If, for example, the width of the laminated dough is too great, crushing will be occurring at the edges; if too narrow, some pulling will be apparent. It is simple to make adjustment to the length of the stroke of the laminator carriage to correct these problems.

A particular problem may be apparent with cut sheet laminators because of the offset nature of the dough layers (see Fig. 36.7). Unlike continuous lapper laminations where the leading edges of the dough layers are diagonal in alternate directions, a cut sheet laminator gives diagonals that are all parallel. This can lead to a

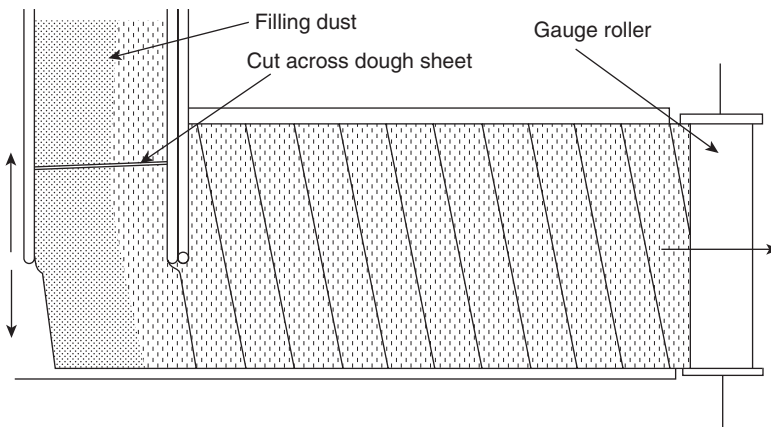


Fig. 36.7 Formation of laminations with a cut sheet laminator. Dough is deposited only on the backward stroke of the lapper.

slight lateral displacement force at the feed to the first gauge roller which results in a tendency for overfeed and crushing of the dough at one side. The problem is not always of significant proportions, but it is worth knowing about. The design of the laminator should be that it drops the dough as fast as possible on the back stroke so that the angle of the leading edge of dough is as near to 90° to the direction of travel of the laminated dough pile as possible.

36.5 Useful reading

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Rotary moulding in biscuit manufacture

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Abstract: Rotary moulding is the most efficient method of producing dough pieces but works only for short doughs. Understanding, in detail, how a rotary moulder works helps the operator to control dough piece weight and to handle problems such as extraction of the dough piece.

Key words: dough piece formation, weight control, dough consistency.

37.1 Introduction

Short dough biscuits are the most common type in the world. It is possible to form dough pieces from many short doughs by sheeting and cutting but the invention of the rotary moulder, a single machine, to produce dough pieces from a mass of short dough was a very great step forward in the history of biscuit making. The first commercial moulder is recorded from about 1928.

Until recently only short doughs could be formed with a rotary moulder. That is because, as is explained below, the scraper knife drags back a cohesive dough so the mould is not filled and the resulting dough piece is incomplete. However, it is now possible, in a few cases, to rotary mould doughs that would not be defined as short. This is possible principally where the area of the mould is small, as in pretzel knots, or the dough is undermixed.

Most biscuit rotary moulders involve the extraction of dough from filled moulds as described below. It is, however, necessary to mention that there are other, smaller unit moulding machines where the formation of the dough piece is different. In these dough is forced between two rolls one of which is the moulding roll (often ceramic) and has cups formed in its surface. As the dough leaves the nip of these rolls it sticks to the forcing roll as a thick blanket. On the surface of this blanket are the raised embosses of the dough extracted from the cups in the moulding roll. These areas of dough are cut from the underlying blanket with a vibrating knife and transferred onto a conveyor to take them to a baking tray or the oven band. The form of the machine is thus very different in design from the main mass of biscuit rotary moulders. These machines are not suitable for high speed work nor are they made in the widths common for biscuit plants. By adjusting the position of the knife it is possible to control the dough piece weights but there is often a problem in

transferring the doughs without distortion across the knife and onto the takeaway conveyor. This type of moulder is best for small-scale production where the dough pieces are baked on trays.

37.2 General description of the rotary moulding machine

A rotary moulder is a machine commonly in use for producing biscuit dough pieces from short doughs. In principle, the dough is forced into moulds which are the negative shape of the dough pieces complete with patterns, name, type and dock holes. The excess dough is scraped off with a knife bearing upon the mould and thereafter the piece is extracted from the moulds onto a web of cotton canvas or other fabric. Short doughs may be sheeted, gauged and cut with an embossing type cutter in a similar way as for extensible doughs, but the advantages of a moulder are

- it is not necessary to form and support a dough sheet
- difficulties of gauging are eliminated
- there is no cutter scrap dough which must be recycled.

The last is of great significance as short dough, in common with other types of dough, increases in density and toughens as it is worked and gauged. In a rotary moulder all the dough has a similar history, there is no cutter scrap that has to be reincorporated. The shape of the mould allows a much more intricate pattern outline than cut dough and can give hollow centres to the pieces if required. Figure 37.1 shows the diagrammatic cross-section of a typical moulder.

Roll A (Fig. 37.1) is known as the forcing roll. It is usually made of steel and has deep castellations, in various patterns, designed to hold on a blanket of dough. It is driven so that dough from the hopper (H) is drawn down into the nip against roll B. Roll A may or may not be adjustable in a horizontal direction. Roll B is the

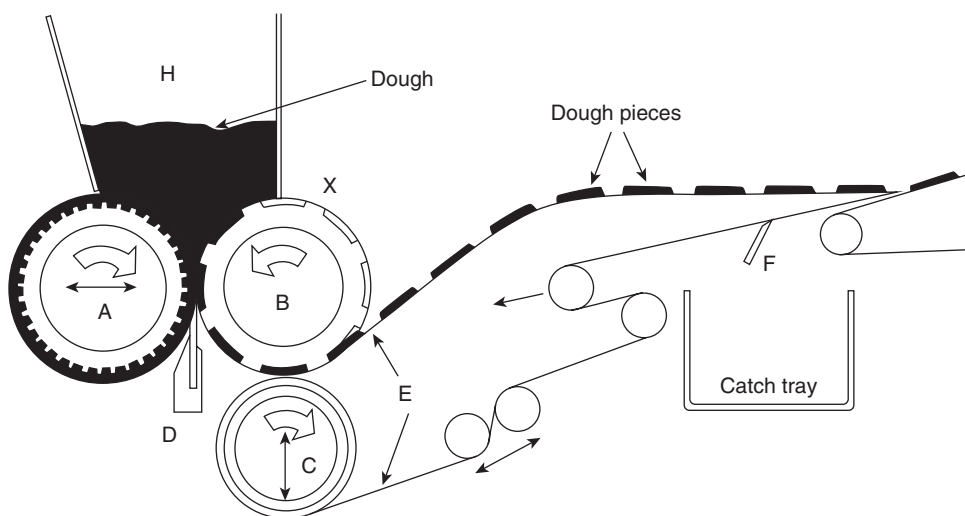


Fig. 37.1 Cross-section to show the parts and action of a rotary moulder.

moulding roller. Typically it has a similar diameter to roll A but it has a smooth surface into which are engraved, or inset, moulds to form the shape of the dough pieces. Typically the roll is made of bronze or gunmetal (a malleable alloy of copper, tin, zinc and sometimes lead) which is suitable for delicate engraving. However, if plastic insert moulds are made, the roll may be of steel. In both cases the roll, which is the same width as the biscuit plant, is usually a tube mounted on an axle. It is important that this tube and axle is rigid and does not flex under the pressure of dough created in the nip with the forcing roll. The moulding roller is driven as shown so that dough is forced into the moulds in the nip. Its position is fixed. There are side flanges on the forcing roll and the moulding roll fits into these so dough cannot be squeezed out from the sides of the two rolls.

Bearing on the moulding roll is a blade of steel known as the scraper (D). The tip of this blade is below the centre line of rolls A and B where maximum dough pressure is exerted in the nip. Dough which has been forced into the mould is sliced off and the excess runs down the scraper and is pressed into the blanket of dough which adheres to the forcing roll. The scraper knife may be adjusted in its position on the moulding roller but the ways and means of achieving this vary in different moulders.

Roll C is the extraction roll. It has a thick rubber coating over a steel centre and around it passes the extraction web (E). By adjusting the position of this roll in a vertical direction the extraction web can be pressed against the moulding roller.

As has been stated, the forcing and the moulding rolls are driven with variable speed motors. The situation with drives for the extraction roll and the extraction web have changed over time. At one stage neither of these rolls was driven and the pressure of the moulding roll against the extraction web and roll caused the drive of both. This was generally unsatisfactory so a drive was added to the extraction roll (as is shown in Fig 37.1). Thus the extraction web was driven by the extraction roll. This was also found to be less than completely satisfactory as the pressure onto the extraction web by the moulding roll tended to take over the drive of the extraction roll. Also with this arrangement the extraction web was *pushed* away from the nip so was under less tension when bearing dough pieces than before going into the nip between the extraction and moulding rolls. The situation now is normally that the extraction roll is not driven but the extraction web is. This means that the extraction web is pulled from the extraction nip and over the nose piece where the dough pieces are transferred away from the rotary moulder. The tension in the web as it leaves the extraction nip provides much better control of the extraction of the dough pieces.

The hardness of the rubber on the extraction roll is fairly critical and with time and use this changes. The rubber coating will have to be replaced at intervals to maintain optimum efficiency of the rotary moulder but replacement of the rubber is normally after years rather than more frequently.

After the dough pieces are transferred from the moulding roll onto the extraction web they are carried to the nosepiece where they are peeled off and panned onto either the oven band or an intermediate web.

On its return to the extraction roll the web passes over a web cleaning scraper (F) which removes any remaining traces of dough. The web is seamless so easy removal of the extraction roller is necessary in the design. The extraction web will need to be replaced at regular intervals. The life of this web depends on the pressures needed to run a dough and also on whether the moulds have docker pins that

tend to snag into the web surface. A normal life of an extraction web in continual use is about six months but much shorter and longer lives are common.

To form different biscuits it is merely necessary to move the scraper away from the moulding roll and thereafter to exchange the latter with a different one. This change is straightforward and quick, but as the rolls are heavy, lifting tackle is always required. Great care must be taken not to knock the moulding roll while it is being moved as it is expensive and the metal being relatively soft is easily damaged.

The position of the scraper tip is between 3 and 11 mm below the axis of rolls A and B. The scraper knife warrants some further consideration. In order to slice the dough the blade should be as sharp as possible, but as there is a great pressure of dough in the nip, the tip of the blade should not be so thin that deflection towards the moulding roller can occur, otherwise it will cut into the metal. The scraper is sprung so that the tip always runs against the roller, otherwise dough may pass behind it tending to force it away and quickly it will engage with the forcing roll and cause much damage. The position of the moulds on the roller should be such that as uniform as possible an amount of 'land' is provided for the scraper knife to bear upon during the moulder's revolution. In Fig. 37.2, (a) and (b) give fairly uniform land, but (c) does not and uneven wear of the moulding roller will occur. As some flexing of the scraper knife tip is inevitable, the docker pins in the mould must be fractionally lower than the level of the mould edge otherwise they will be damaged by the blade.

When the height of the scraper blade is to be changed it is important that it is moved as nearly as possible in a tangential direction relative to the moulding roll surface. In some machines there is a single adjustment which moves the blade tip

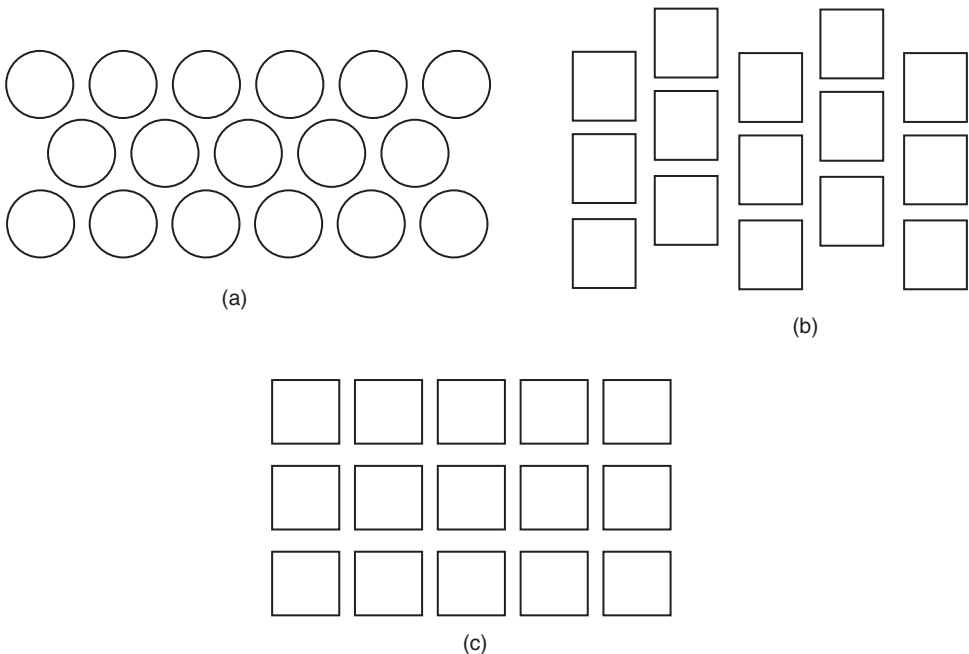


Fig. 37.2 Alternative mould patterns.

tangentially, but in others there are two controls, one for vertical movement and the other horizontal. It is more difficult to use the latter arrangement successfully.

The speed of the rotary moulder is matched to the oven band speed. Rotary moulders can run at up to 45 metres per minute.

37.3 The formation of the dough piece

Dough is placed in the hopper and the machine is started. Dough trapped at the nip is churned and worked as it is forced through the nip. This churning may toughen the dough, but the toughening effect is less if the dough from the mixer has been allowed to stand for at least 30 minutes before use. The level of dough in the hopper should be maintained at a minimum so as to reduce pressure differences at the nip, excessive working of dough and also to minimise the chance of bridging of the dough above the nip. The dough is typically of a firm and crumbly consistency. It is advisable to add dough to the hopper in a kibbled form in lumps of no more than 50 mm diameter to reduce the chance of bridging.

The dough is pressed against the forcing roll and also into the moulds on the moulder. The scraper knife slices off the dough level with the top of the moulds and presses the excess against the forcing roll to form a blanket which revolves with the forcing roll. Depending upon the position of the knife, some dough may be forced round behind the knife to effectively overfill the mould (see Figs 37.3 and 37.4). The dough piece then passes to the point where extraction is achieved. This is the place where greatest difficulties can occur. Either the piece sticks preferentially to the mould or there is a squeezing action that causes the piece to be wedged in cross-section and some dough extruded behind the piece in a 'tail' on the extraction web (see Fig. 37.5).

The surface of the extraction web must be sufficiently rough or sticky to effect good adhesion of the dough piece, but not so good that subsequent peeling at the transfer off the web is difficult. The surface and type of web is important and many have been tried. A thin web is usually not rough enough and a thick web will not go round a sharp nosepiece. A sharp nosepiece is needed to cause a peeling away

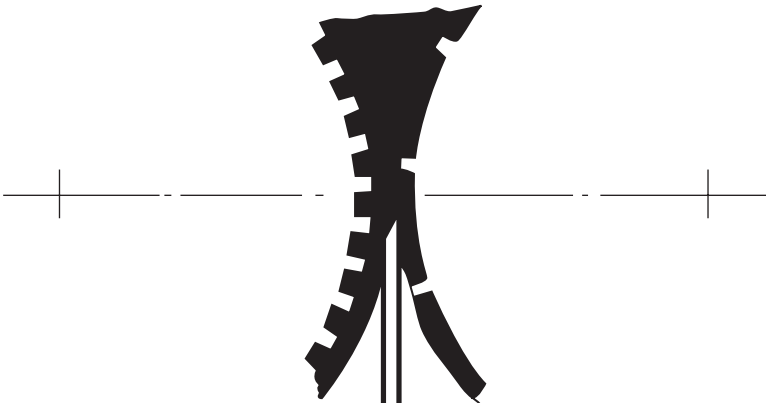


Fig. 37.3 Scraper knife in high position to show how dough becomes extruded past it.

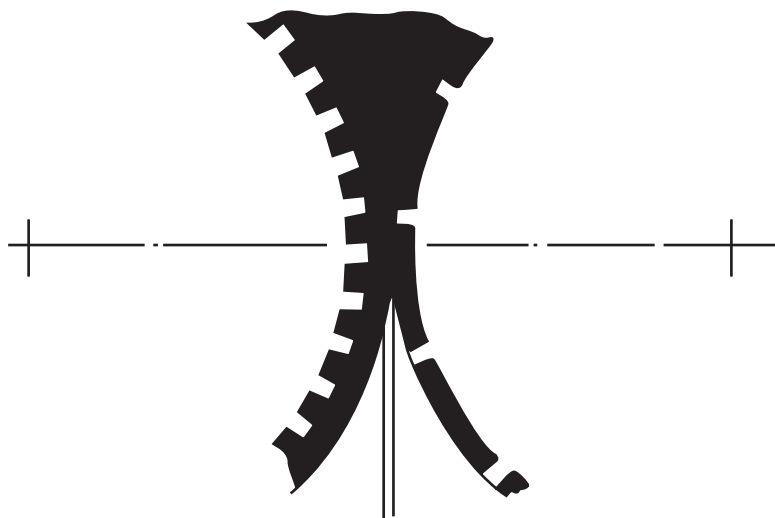


Fig. 37.4 Scraper knife in low position showing how dough does not overfill the mould.

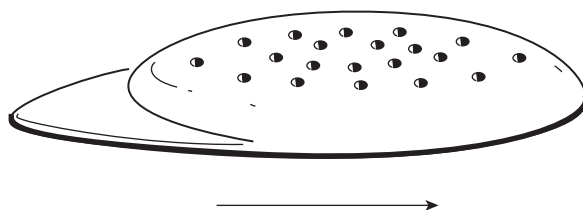


Fig. 37.5 Dough piece with a tail of dough.

of the dough pieces. The internal surface of the moulds is important in both shape and smoothness with regard to ease of removal of the dough piece. If the mould edges are too steep or the pattern too deep or intricate, extraction will be difficult. If the mould is very deep, with docker pins the physics of the change in direction from rotation to linear at the extraction point can give difficulties for removal of the dough piece. The pins will have to tear through the dough or will hold it in the mould (see Fig. 37.6).

Low-friction coatings such as PTFE are useful for lining the moulds but they may wear off. Plastic insert moulds are very effective for aiding dough piece release. In these plastic moulds docker pins, where necessary, are usually in bronze for added strength. If the release is made too easy from the moulds the pieces may fall out in the period between the scraper and the extraction point. This problem is accentuated by the fact that there is a drag from the knife that tends to pull the front of the dough piece away from the mould causing it to curl (see Fig. 37.7). This also affects the shape as the piece is pressed onto the extraction web and, incidentally, is the main reason why extensible or toughened doughs cannot be successfully rotary moulded.

Other aids to extraction include heat applied at point X (see Fig. 37.1) or a light spray or brushing with release oil at the same place. Use of either of these techniques

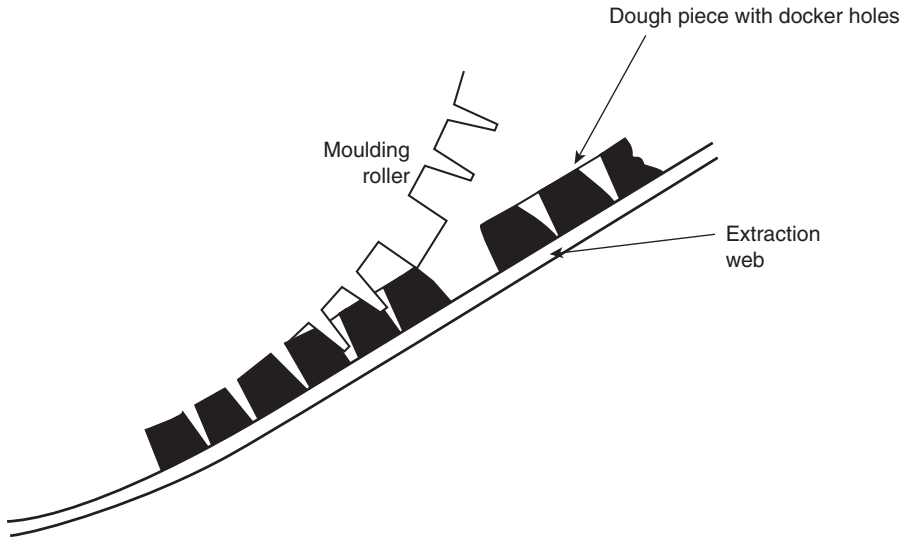


Fig. 37.6 Extraction from the moulds to show problems associated with thick dough pieces.

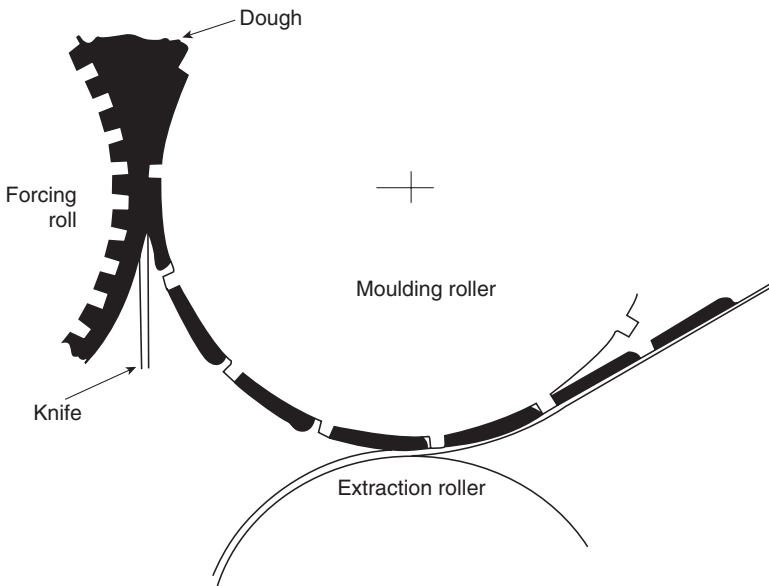


Fig. 37.7 Detail of rotary moulder action to show effect of dough drag on the scraper.

is uncommon. Extraction is effected by the web being pressed against the dough held in the mould. The slightly soft surface of the extraction roller allows the web to be pressed into the mould. This has two effects. Firstly, the dockers, if present in the mould, pass right through to the dough piece and, secondly, a slight excess of dough is extruded outside the limits of the mould. The rolling action means that the dough is extruded mostly at the rear of the piece and this forms a 'tail'. Some tail

is almost inevitable and traces of it on the biscuits can be used to identify rotary moulded dough pieces. However, the tail will be excessive if

- there is high extrusion around the scraper blade, associated with high pressure in the nip or a high blade position
- there is too much pressure at the extraction point due to the extraction roll pressure being set too high
- the rubber surface of the extraction roll is too soft allowing too much dough to escape at the back of the mould.

If the extraction roll is hard and the pressure is too great, the biscuits will be wedged with the leading edge thicker (the dough is pushed back then forward at the moment of release) and if the roller is too soft and a large tail is formed, the biscuit will also be wedged but this time with the rear edge thicker. Wedging and tailing are thus associated with scraper position and extraction roll hardness and pressure. Generally wedging of the dough pieces is worst when the scraper knife is in its highest position. Usually, large deep mould shapes need less extraction pressure than small shallow ones.

The pressure between the moulding roll and the extraction web should be adjusted to the minimum for satisfactory dough piece extraction. If pressure has to be increased to achieve lower dough piece weight, attention should be given to the dough consistency or to reducing slightly the depth of the moulds. This is done by skimming the diameter of the moulding roll.

37.4 Dough piece weight control

Compared with a cutting machine there is less range for weight control using a rotary moulder. However, there are a few techniques, which are interactive, that can be used to adjust the dough piece weight somewhat. Firstly, if the forcing gap is adjusted, the smaller the gap, the higher the pressure and the higher will be the dough piece weight due to slight changes in dough density. As described above, the position of the scraper knife affects the amount of extrusion of dough around it. The higher the knife position the greater the amount of dough in the mould; conversely, the lower the knife position the less dough there will be in the mould. (There is also the possibility that in the lowest position of the knife the moulds will be incompletely filled with dough.) At the extraction point, the higher the pressure the lower will be the weight and the tail greater. Related to this, the softer the extraction roll surface, the lower the dough piece weight and greater the tail (and wedging!). The consistency of the dough may have some effect on the dough piece weight so control of this is also important – do not forget the importance of dough standing time. The dough piece weight usually increases as the dough water is reduced.

The effects on dough piece weight of changes to the settings of a rotary moulder have been investigated in detailed experiments by the author, both in pilot plant and production conditions. Typical effects of changes to moulder settings are summarised in Fig. 37.8. There seems to be very little published literature on the functioning of rotary moulders and it is, therefore, somewhat disconcerting that results discussed by Thacker and Miller [1] from work at the FMBRA, Chorleywood, show conclusively that changes in the position of the scraper knife on their rotary moulder had precisely the opposite effect on dough piece weight to those observed by the

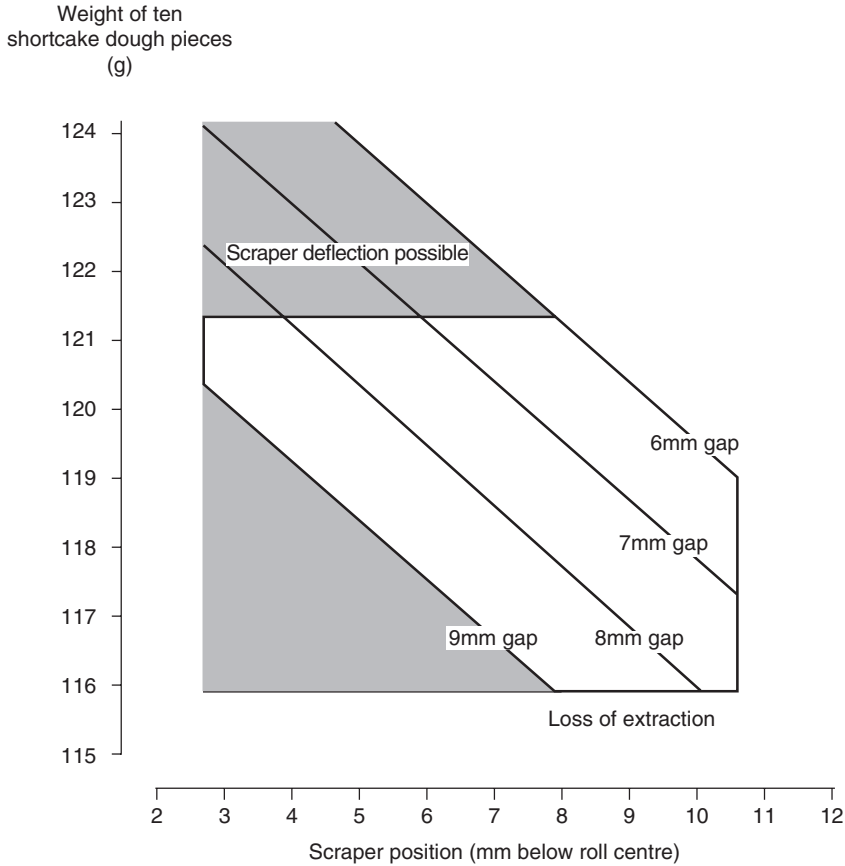


Fig. 37.8 Diagrammatic example of effects on dough piece weight of changes in rotary moulder settings.

author in his experiments. In discussing this strange situation with Dr Thacker, it was suggested that the very low speeds of operation of the moulder at the FMBRA may be a contributing cause. Users wishing to use the settings of a rotary moulder to control dough piece weights are advised to make a series of calibration tests using the appropriate moulding roller and dough.

37.5 Differential speeds of moulding roller and extraction roller

If the extraction roll is driven, usually the relative circumferential speeds of both the moulding and extraction rolls is fixed by gears linking their drives. This means that the diameters of the rolls should be matched also. If one roll diameter changes either by wear or because a new roll is a little different, the relative surface speeds will not be matched and there may be a tendency to tear the dough piece out of the mould or extraction will be impaired.

A small variable differential between the surface speed of the moulding roll and the extraction web may be useful to perfect dough piece extraction. Care must

be taken that conditions are not set up which cause excessive wear to the extraction web.

37.6 Common difficulties that may be encountered with rotary moulders

1. If dough gets behind the extraction web it will stick to and build up on the surface of the extraction roller. This will give variations in dough piece weight or problems with tails or extraction. At frequent intervals the extraction web should be slackened off and the surface of the extraction roll carefully cleaned.
2. With time the rubber on the extraction roll will become softer or harder and performance will deteriorate as described above.
3. The extraction web should follow a gentle curve away from the extraction point to the nosepiece. If it is taken over a sharp curve the dough pieces, particularly if they are thick or formed in very dry dough, will tend to crack. These cracks will impair the strength of the biscuits after baking (see Fig. 37.9).
4. When a new extraction web is fitted or the moulder has been out of use for a long time, the surface of this web will be non-adhesive. Application of water or a flour water mixture should return it to a suitable condition, thereafter the dough itself should maintain it in satisfactory condition. In some cases a very fine application of water with, for example, a steel wetting roll running on the web, may aid extraction.
5. Coarse or fibrous material in the dough affects the performance of the scraper in the moulder. Large bran particles, desiccated coconut, pieces of fruit and nuts, etc., may drag back on the knife rather than be cut. Very sticky dough will also cut badly. Various modifications to the knife tip geometry have been tried in order to reduce these effects. However, the main dilemma is the production of

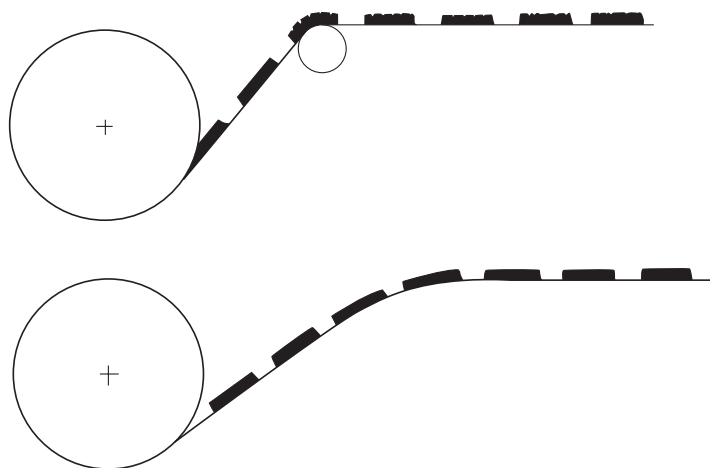


Fig. 37.9 Top: Inflection of dough pieces causes permanent cracks. Bottom: Optimum arrangement for extraction web to minimise damage to dough pieces.

a blade that will separate the moulded dough from the mass without undue pressure on it causing damage to the moulding roll. Blades with blunt tips of one sort or another have been tried and for particular doughs they seem to be superior.

6. If the dough piece weight, and particularly the tails on the dough pieces, are different from each side of the machine an adjustment can be made to the alignment of the extraction roll.

37.7 Instrumentation of a rotary moulder

Basically, as with any other machine, the adjustable parameters should be well calibrated or have only a few fixed positions. There are three basic adjustments other than the overall speed of the machine:

1. the scraper knife tip position
2. the extraction pressure
3. the forcing gap width.

From a process control point of view, it is necessary to know the dough piece weights and the degree of wedging. The difficulties of continuously monitoring dough piece weights has been dealt with elsewhere and it has been shown that optical thickness gauges have limitations. However, advances in electronics allow these instruments to survey differences in the height of dough pieces relative to their substrata and also to follow the change in height along a piece thus estimating the nature and degree of wedging.

Dough height in the hopper may be controlled with simple optical or proximity gauges which, on an 'on/off' system, can control the dough feed to the hopper. As has been indicated, dough consistency control is advantageous not only to dough piece weight but also to the general running of the rotary moulder. Standing the dough before use significantly reduces consistency variations in the rotary moulder.

37.8 Disadvantages of a rotary moulder

With care, considerable advantage can be achieved with this relatively simple, low maintenance unit machine. Its performance is not good on fruited dough or dough with many large inclusions; a depositor or wire cut or even a sheeting and cutting machine is superior for these doughs. It is also not possible to press sugar or nut garnishes into the dough surface but, in fact, these do tend to adhere well if 'dusted' onto the dough surface before baking and most especially if a milk or egg wash is given first.

Dough for a rotary moulder must normally be of higher consistency than for a sheeter and cutting machine. Improvements in rotary moulder design claim that softer doughs may be satisfactorily moulded. Higher dough consistencies are achieved by limiting the amount of water used to mix the dough. During baking better biscuit volume and a more delicate structure is usually achieved from dough with higher moisture content, therefore the biscuits obtained from a rotary moulder may be slightly inferior to those from a cutting machine.

37.9 The soft dough rotary moulder and Rotodepositor

Soft dough rotary moulders work on the principle of supporting the dough in the mould for longer and applying less pressure than in a conventional rotary moulder. A soft dough rotary moulder (see Fig. 37.10) is offered by Baker Perkins and the machine is described thus. The unit consists of three main rolls; a profiled forcing roll, an engraved moulding roll and a free-wheeling rubber roll. A scraper is positioned against the moulding roll. The forcing roll and scraper are mounted near the top of the moulding roll in order to allow the extraction web a high angle of wrap around the moulding roll. A hopper is mounted above the forcing and moulding rolls. The forcing roll draws dough from the hopper and pushes it into the pocket formed by the forcing roll, moulding roll and scraper. This generates a controlled amount of pressure which presses the dough into the engraved cavities of the moulding roll. The scraper cuts away any excess dough before the filled impressions pass over the extraction web. The rubber covered roller gently presses the web against the dough pieces and adhesion is increased during the rest of the travel. As the web and roll diverge the dough pieces are pulled gently out of the moulding roll.

A soft dough rotary moulder is said to be capable of handling most conventional moulded and wire cut doughs. Compared with wire cutting the weight control is much superior and the speed potential greater and, like wire cutting, large pieces can be handled in the dough.

The Rotodepositor, from Meinke, is another special type of rotary moulder. The design and the way that dough pieces are formed can be appreciated from Fig. 37.11. The moulds are formed by pistons drawing back to receive dough and the pieces are then expelled and cut off with a wire rather than extracted with an extraction web. In this way much thicker dough pieces may be formed and there is little pressure on the dough. Softer dough can be formed than is possible with a conventional rotary moulder. The Rotodepositor is particularly useful for use with doughs which contain large particles such as raisins, nuts and chocolate chips.

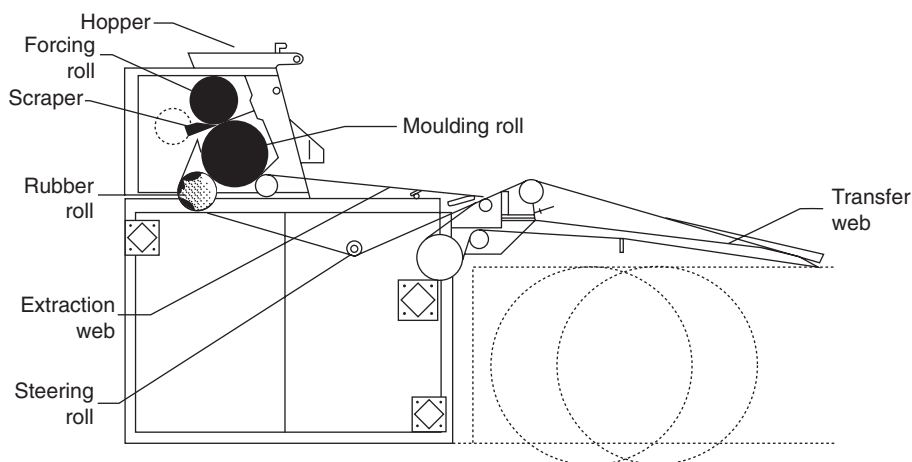


Fig. 37.10 A soft dough rotary moulder.

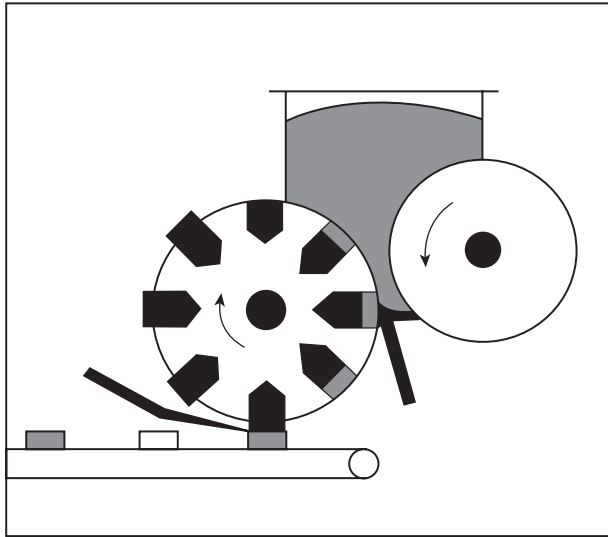


Fig. 37.11 A special type of rotary moulder.



Fig. 37.12 BUM biscuits.

Another form of rotary moulder uses air pressure to eject the dough pieces from the impressions. This is especially useful for small pieces with low tensile strength and adhesion.

37.10 Printing on dough pieces

The novelty of pictures printed on biscuits is possible (Fig. 37.12). These are usually achieved by printing a caramel solution or some other edible ink onto dough pieces (either after a cutter or a rotary moulder) before baking. There are three established techniques. The most popular method involves screen printing (the Reinke method which is produced in Japan by the Comco Corporation), another is an offset system (Baker Perkins and Imaformi) and the other is an ink-jet system (Video Jet, USA).

The latter is much more expensive but also allows application of three different colours. The offset system from Imaformi uses up to three printing rolls so also allows different colours on the same dough piece.

The screen printing and offset methods rely on a flat dough surface, which will not be the case after a rotary moulder if there is wedging, and excellent registration with dough piece position. The printing units are normally sited immediately after a moulder or cutter so that tracking of webs does not influence the position of the dough pieces relative to the printing machine. (Ink-jet printing allows printing on uneven surfaces such as baked biscuits and wafer sheets.) The consistency of the 'ink' is critical and is adjusted in the formulation. There tends to be a problem that temperature strongly affects this consistency and therefore the ink must be prepared at the temperature of the bakery.

37.11 Reference

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37.12 Useful reading

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Extruding and depositing of biscuit dough

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Abstract: Soft doughs or those containing pieces like chocolate chips or nuts must be formed into dough pieces by extrusion rather than moulding. Wire cutting gives attractive product appearance but production efficiency is not as good as with other methods of dough piece forming. Co-extrusion permits the formation of products with a dichotomy of textures, colours and flavours. Depositing is a special form of extrusion suitable for pourable mixtures like sponge batter.

Key words: wire cutting, co-extrusion, bar cookies, chocolate chip cookies.

38.1 Introduction

Depositing is a form of extrusion so the mechanism of these two means of dough piece forming are not distinct from one another. However, the machinery that handles soft short doughs for wire cutting or continuous extrusion is normally different from that which deposits a dough that is so soft that it is pourable or is a batter. The firmest doughs will be wire cut and these may have a similar consistency to rotary moulder doughs. Wire cutting makes it possible to form pieces from more sticky doughs and dough containing coarse particles, such as nuts or oat flakes, that cannot be successfully rotary moulded. Examples are shown in Figs 38.1–38.4.

In all cases of extrusion and depositing the dough is forced through orifices having been pressurised either by means of rollers (short and soft doughs) or a pump (sponge batters). The two types will be dealt with separately.

38.2 General description of extruding and depositing machines for doughs

Most machines basically consist of a hopper over a system of two or three rolls which force the dough into a pressure/balancing chamber underneath. The rolls may run continuously or intermittently and may be capable of a short period of reverse motion to relieve the pressure and cause a suck back at the dies or nozzles at the base of the pressure chamber. This means that dough can be forced



Fig. 38.1 Double chocolate chip cookies.



Fig. 38.2 Raspberry cookies.

continuously or intermittently out of the pressure chamber. Figure 38.5 shows the general arrangement of the machines for wire cutting.

The machine spans the width of the plant and is usually situated over the oven band. In the case of certain drier, wire cut doughs and rout types (continuously extruded) which are subsequently cut into lengths before baking, the machine is over a fabric conveyor and not the oven band. Dough pieces formed on a conveyor may be spaced out as they are transferred onto the oven band.



Fig. 38.3 Soft kings.



Fig. 38.4 Bastogne.

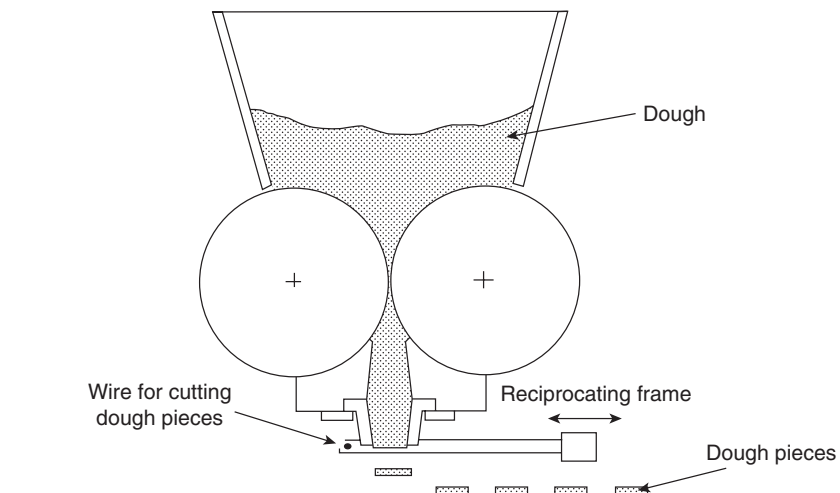


Fig. 38.5 General arrangement of wire cut machine.

For wire cutting the dies are about 70 mm above the band or conveyor, but provision is usually available to change this gap if necessary by raising or lowering the band or the whole machine. Dough is extruded through a row of dies (of any desired size or shape) and a frame bearing a taut wire or blade strikes across the base of the die holes 'cutting' off the extruded dough at intervals. The dough pieces then fall onto the band or conveyor. The wire may cut in a forward (direction of the oven band) motion or more usually in the opposite direction. In any case, the cutting stroke is close to the die and the return stroke is lower, away from the dies so that it does not touch the dough which is continuously being extruded. The pieces may fall off straight or they may turn over before they reach the band. It does not matter whether they turn or not, but all must do the same all the time! It is here that difficulties are often encountered because sticky, coarse-textured dough may not always fall as expected. Some control of the fall of the dough piece is possible by adjusting the height of the dies above the band and also by attention to the position of the wire as it passes through on the cutting stroke. When the wire is cutting against the direction of flow, a 'backstop plate' can be used. The backward motion of the dough pieces is arrested by the backstop and their alignment across the band is improved.

Every effort must be made to achieve uniform dough piece weight and uniform dough consistency if the performance of the wire cutter is to be satisfactory. The current generation of wire cut machines employ a 'filler block' in the cavity between the rolls and the dies. The filler block assists with the uniform flow of dough across the machine and improves the transverse weight accuracy.

Sometimes a blade with a sharp smooth edge or even a fine serrated edge is used in place of the wire. Also the wire or blade may be constantly vibrated in a horizontal plane to improve the 'cutting' action. The best arrangement for a particular dough is, unfortunately, found principally by trial and error. Having found the good settings, record them in terms of machine calibration.

The speed of wire cut machines is now up to 300 strokes per minute, though the number of rows can be increased either by having a double row die, if the pieces are fairly small, or by having two machines synchronised to deposit alternate rows of pieces. Dough extruding from a round die may be distorted somewhat as the wire or blade 'cuts' across it. This is particularly common if the dough contains coarse pieces of dried fruit that drag on the knife. The shape of the baked piece will be affected, but maybe not as much as expected. It is sometimes found beneficial to have a light foam plastic roller running over the dropped pieces to press them into a flatter shape before baking. Wire cut dough pieces always have a rough surface which is often not lost during baking. A 'home made' look is accentuated by the fact that the outline after baking is often a bit irregular. The nature of extrusion means that the dough pieces are thicker in the centre than at the edges.

When operating below 60 cuts/min, performance is improved by using an intermittent cutting action. The wire cuts at high speed to ensure a well formed dough piece and then pauses for the rest of the cycle.

It is, of course, possible to have different die shapes across the band and even, by dividing the hopper laterally, to use two or more different doughs at once. This allows variety production for packs of assorted biscuits, but the dough recipes and piece weights should be calculated carefully to achieve optimum baking of all types.

In order to make more use of the baking surface area, the loading density can be increased by setting the wire cut machine at 30° to the oven axis. Instead of straight lanes of product, this gives a nested (quincunx) pattern with 25% more dough pieces per unit area.

When the machine is used in a continuous mode, without wire cutting of pieces, the products are called bar or rout cookies. The die plate is now usually inclined in the direction of the extrusion so that transfer of the dough ribbons onto the conveyor are as smooth as possible (Fig. 38.6).

For rout cookies the dies are typically of asymmetric shape to give a smooth base and ribbed upper surface. The ribbons are usually guillotined into short lengths before baking, but, alternatively, some form of cutter may be used on the oven band after baking. Depending on the character of the dough in terms of coarse ingredients and consistency, the bar cookies may have smooth or rough edges and surface.

It is possible to elaborate on the bar cookie by arranging twin pressure chambers under separate hoppers so that one dough is extruded within the other. This arrangement is called co-extrusion and is used in the production of, for example, fig bars (also known as Fig Newtons in the USA) (Fig. 38.7). The fig (or other fruit) paste is fed from one hopper and dough of similar consistency from the other (see Fig. 38.8). The filled tube so produced may be cut before or after baking as described above. Co-extruders can have 2, 3 or 4 rolls according to the nature of the materials.

The disadvantage of this type of co-extruder is that it is difficult or impossible to have a cutting device that seals the filling within the dough. The Rheon company of Japan has produced some innovative machines capable of co-extrusion with cutting systems that seal, or encapsulate, the filling within the outer dough. The cutting and sealing action is achieved either with specially shaped rotating discs or with iris cutters made of a plastic material. The machines are capable of handling a wide range of materials such as jam, minced meat, or very sticky dough but the outer

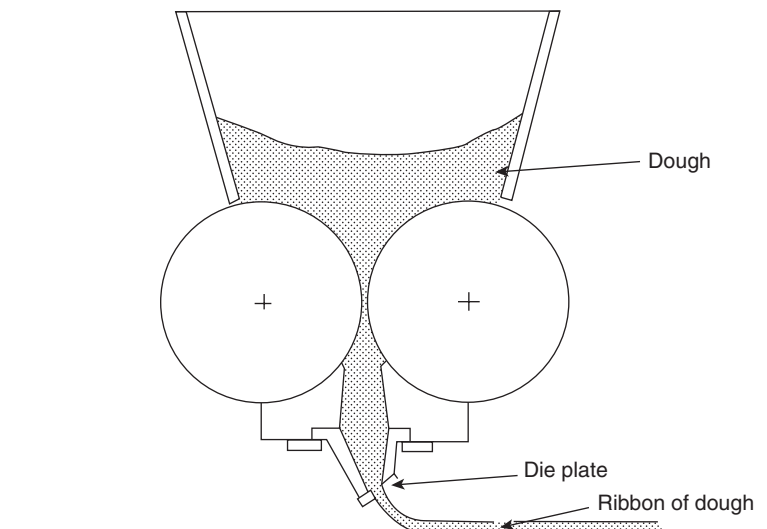


Fig. 38.6 General arrangement of rout press machine.



Fig. 38.7 Fig rolls.

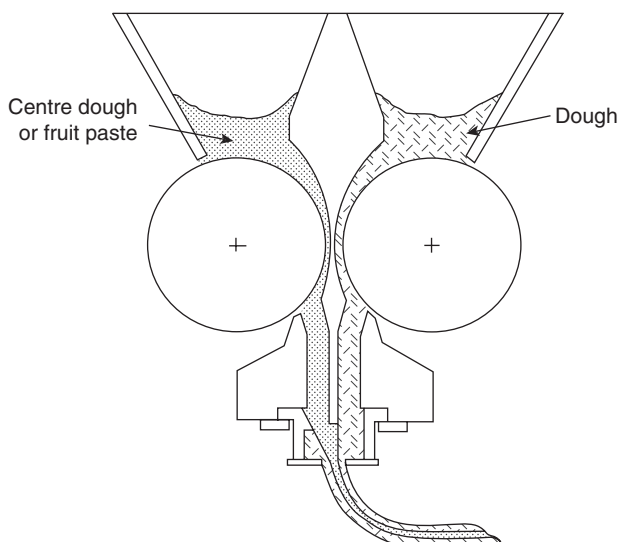


Fig. 38.8 General arrangement of filled bar forming machine.

dough must always be fairly soft and very short in texture. A typical example is shown in Fig. 38.9.

If the dough consistency is soft, smooth and almost pourable it is possible to produce deposited rather than wire cut types. The die plate is replaced with a set of piping nozzles. These nozzles are cone shaped and may have patterned ends to give strong relief to the extruded dough. Individual deposits are achieved by raising and lowering the oven band or depositing machine to coincide with intermittent extrusion. When the nozzles are close to the oven band, dough is forced out which spreads on the band and preferentially adheres to it. At the end of the extrusion the nozzles are taken away from the band and the deposit breaks away from the nozzle. The breakaway may be encouraged by a reversing action of the feed rollers which produces a suck back of the dough at the nozzles. It will be appreciated that by using variable times and mechanisms which twist the nozzles, it is possible to produce fingers, swirls, circles and other shapes of dough pieces. By synchronising a second



Fig. 38.9 Sablés Fourrés.

depositor with the first, it is possible to deposit jam (or jelly) or another dough on or within the deposit made by the first.

38.3 Process control of extruded and deposited biscuits

There are more problems of weight and shape variations with these methods of dough piece forming than most other types. Much of the weight variation is attributable to the extruding machine but differences in mixings must also contribute. The amount of dough pressed through the dies or nozzles in a given time is determined by the pressure behind the dies and this is controlled basically by the speed of the rollers in the machine which are pressurising and/or pumping the dough. Therefore the way to effect a general alteration in the weight is by the speed of the rollers. Unfortunately, the height of the dough in the hopper may also have an effect on the extruded weight. If this is the case, it is wise to arrange that the level in the hopper is maintained between fairly close limits and it will be found that low levels of dough tend to give less weight variation than high.

If the dough consistency or stickiness varies, this affects the performance of the rollers in creating a desired pressure behind the dies and for this reason, as with short doughs for rotary moulding and sheeting, it is recommended that doughs are allowed to stand for at least 30 minutes after mixing before being fed to the forming machine so that the initial rapid change in consistency has passed. Even when these precautions are observed, it is quite common to find significant variations in extrusion rates across the width of the machine. The weights at the sides tend to be lighter than at the centre.

Engineers have devised many different devices to try to overcome this problem but the requirements of different doughs vary. An adjustment of the extrusion from one die tends to affect that from its neighbours so it will be appreciated that the balancing of weights is not dissimilar to tuning a piano! Partitions may be introduced within the pressure chamber to reduce lateral movement of the dough or constricting screws or slides fitted in each die to allow some running adjustment. It must be possible to make the adjustments while the machine is running because stops tend to upset the extrusion rates for a short period after restart.

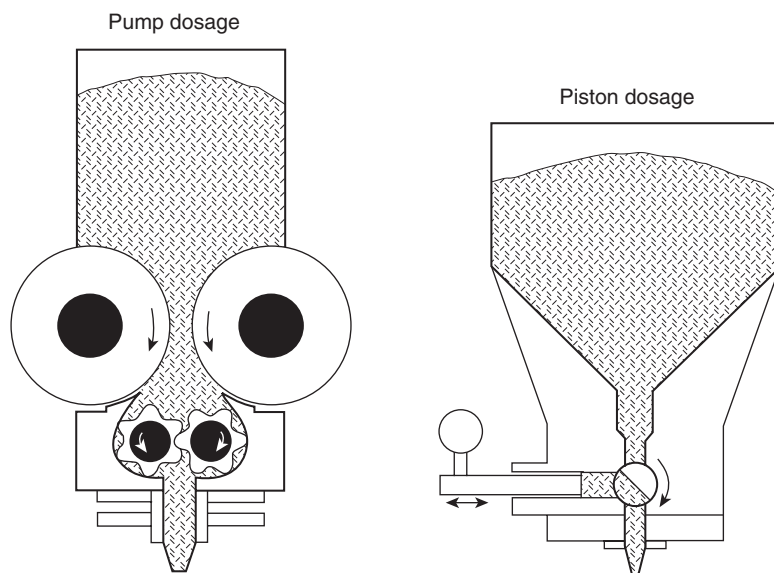


Fig. 38.10 Two improved systems used by Meinke for controlling the extrusions of dough or butter.

Various other systems have been invented to control the extrusion pressures behind each nozzle. Of particular note are the more sophisticated extruder designs from Meinke (Denmark) and Bepex Hutt (Germany). Figure 38.10 shows two systems used by Meinke where dosing pump rollers for dough or pistons for batters, one for each nozzle, create precise extrusions of dough for wire cutting or depositing.

The variations in weight of dough pieces affect the spread of the dough during baking. Other factors which affect flow (including oven conditions) are described in Chapter 28. When it is suspected that the variations in size are originating from the dough rather than the forming machine or oven, it is necessary to consider carefully how this may be checked. It is not satisfactory to introduce a sample of a new dough into the forming machine ahead of the main batch because dough age is different. A small hand-driven extruder used to produce test pieces is very difficult to standardise with sufficient precision. It is suggested that the most practical method is to pin out a small quantity of dough on or between two sheets of greaseproof paper. The precise thickness, which should be similar to that of the wire cut pieces, can be achieved by using two strips of metal as guides for the rolling pin. From the sheet so formed, discs may be cut using a simple hand cutter. These pieces should then be placed on the oven band in place of other pieces that have been removed. After baking, the weight and diameter of the pieces can be checked accurately and the general appearance noted. The results should be checked against standards obtained from previous hand trials when dough was used that had been shown to be satisfactory. It is important that the dough samples for these trials should be of given age after completion of mixing and be handled in a standard fashion during sheeting and cutting.

Wire cut and deposited biscuits tend to be of richer formulation and more irregular shape than most. They are much favoured for high-quality assortments. Danish



Fig. 38.11 Sponge fingers. Reproduced by kind permission of Sainsbury's Supermarkets Ltd.

Butter Cookies are a good example of such an assortment. In the production of these it is possible to use a rotary moulder, one or more depositors and a wire cut machine, all synchronised to produce the whole range for the assortment at once on the oven band. The pack can then be assembled directly at the end of the production line removing the need to make only one type at a time with labour-intensive boxing up and subsequent rehandling to make the assorted packs.

38.4 Sponge batter drops and sponge finger biscuits

Sponge batter (based on eggs) is aerated and deposited via nozzles which may be below a depositor as described above or in a pipe or manifold across the oven band or baking trays. In the case of the manifold system the batter has to be pumped under pressure through the pipework. In either case the depositor with nozzles or manifold swings with the band, rises and returns in a fully adjustable fashion so that the shape of the deposit can be controlled. The same machines and mechanisms can be used to deposit jam, jelly, soft cream or marshmallow onto baked bases if they have been suitably lined up firstly.

There is often a weight variation problem across the band that may be compensated for by adjusting the apertures in each of the depositing nozzles. In practice, this is quite difficult for sponge batter drops because it is difficult to catch neatly a single deposit and to weigh it. Since one must compare any given weight against the mean weight, it is really necessary to go through the tedious procedure of collecting deposits from each nozzle over a short time to decide whether any particular deposits are too heavy or too light. In practice, because the deposit flows out rapidly after depositing, it is usually possible to judge uniformity with neighbours by eye. Two depositors working in unison allow jam to be dropped on top of the batter before baking. The jam reduces the lift in the centre of the sponge in the oven and this is beneficial when it comes to packaging as the sticky jam zone is recessed so does not come into contact with the base of another piece.

Sponge batter biscuits such as Boudoir and Jaffa Cakes are described in Section 29.2. The sponge batter deposits may be placed onto a plain oven band or into formed trays (as for sponge fingers (see Fig. 38.11)).

38.5 Useful reading

- [1] MANLEY, D. J. R. (1998) *Biscuit, cookie and cracker manufacturing manuals, 3. Biscuit dough piece forming*. Woodhead Publishing, Cambridge.
- [2] MANLEY, D. (2001) *Biscuit, cracker and cookie recipes for the food industry*. Woodhead Publishing, Cambridge.
- [3] Manley's The Biscuit Doctor website. www.thebiscuitdoctor.com

Biscuit baking

D. Manley, Consultant, Duncan Manley Ltd, UK, reviewed by H. Clark, Baker Perkins Ltd, UK

Abstract: Tunnel ovens for baking biscuits are ‘black boxes’ in which there is great uncertainty about what is happening! When establishing a baking profile in a travelling oven, understanding what is needed in terms of heat transfer rather than temperatures is important. There are different heating systems and different oven band types suited to particular products. Engineering attention is being driven by the need to use fuel more economically.

Key words: heat flux, oven atmospheres, what happens during baking.

39.1 Introduction

The baking and drying of dough is the essence of biscuit making. The first biscuits were dried out slices of bread (rusks), useful as long-life food for sea journeys. Later plain, more or less flour and water, doughs were formed into flat pieces for baking and drying and were known as ‘ships biscuits’. The drying of these was of very great importance to give long life. Early cooks making confections with flour, fat and sugar would have found that if little dough pieces are baked in a typical hot oven and taken out when they have a good colour and a stable structure, they would not have been dry enough in the centres to be entirely crisp after they cooled. Putting these baked pieces back into a somewhat cooler oven to dry them out improved their eating qualities and also their shelf life. This is probably the origin of the name ‘biscuit’ meaning twice baked. Baking from the start in a cooler oven for a longer period allows drying but results in less good colouration and structure development. (The idea of separating the control of moisture from the control of development of internal structure and colour is a technique that has been returned to relatively recently with modern electronic technology as part of the baking processes; see Section 39.5.2.)

Baking involves heating the dough. The physics of heat transfer, heat flux, includes convection, conduction and radiation which are difficult concepts to appreciate and evaluate where only the temperature at selected places can be measured in an oven. Heat and temperature are not the same. Heat is energy and is measured, for example, in joules (calories). The effect of heat is to change the temperature and this is measured in degrees (°C). An analogy with climatic conditions might be

helpful to illustrate the point. Think of a person standing on a sandy beach on a hot day with the sun shining. The person feels warm because of radiant heat from the sun, his feet will feel the heat of the sand because of conducted heat and the air around him will warm him by convection as it will be moving at least a little. The temperature of the air and the sand are the same. The person will sweat and lose moisture (this is a natural process designed to cool the body as much heat is taken from the body to cause the water to evaporate). If the sun goes behind a cloud the person will not feel so hot because the transfer of heat by radiation is lower but the temperature of the surrounding air will not have changed. If the person stands on a towel or wooden board his feet will not feel so hot because the transfer of heat by conduction will not be so fast but the temperature of the surface will not have changed. If the wind starts to blow he will become warmer (but the temperature of the air will not have changed) and he will lose more moisture although the increased evaporation may cause him to feel a little cooler.

In baking we can conveniently measure only temperature in the oven and of course the amount of heat transferred is related to temperature difference between two bodies. However, a very hot surface, such as a burner, will give more radiant heat than the internal surface of the oven, a steel oven band will allow more conducted heat to a dough piece than a wire mesh band and moving air within the oven will allow considerably more heat transfer by convection than a static oven atmosphere. When considering baking temperature profiles it is therefore necessary to consider also the mechanisms and magnitudes of heat transfer that are involved.

The simplest oven is a heated box with a door. The temperature can be set and when the door is opened to put in dough pieces the temperature drops a little and then gradually rises back to the set point. Most biscuits are now baked in travelling ovens, long boxes with an entry at one end and the exit at the other. The dough pieces are carried through on a band or on trays. The big difference between a static oven and a travelling oven is that in the latter the temperatures and the heat transfer conditions can be changed through the oven, that is during the baking period. Therefore high temperatures and high radiation but with low convection can be in one part but lower temperatures with high convection in another part. How fast the heat is transferred to a dough piece makes a great difference to the development, colouration and moisture content of the baked biscuit and is the essence of the skill of baking.

During baking much water is evaporated from the dough piece. If the oven has direct gas firing much water is also generated in the oven chamber from the burnt gas. The amount of water vapour in the oven atmosphere is controlled by the extraction system. If the atmosphere in the first part of the oven is high in water vapour some water may condense on the surface of cool dough pieces as they enter the oven. The effect of this will be twofold. Firstly, the surface will become wet which may allow solution of sugars, etc., and secondly, heat released by latent heat as the water passes from vapour to liquid will heat the dough surface and some of this heat will be conducted to the centre of the dough piece. Soon this water will evaporate again but the time when the surface becomes dry and hard will be later than if the oven atmosphere was lower in water vapour. (To heat 1 g of water by 1°C requires about 2.4 joules (1 calorie) of energy. To change 1 g of water at 100°C (boiling point) to steam requires about 1296 joules (540 calories). Conversely when 1 g water vapour at 100°C condenses it liberates 1296 joules. This is the latent heat

of evaporation and reflects the very large amount of energy to dry a biscuit.) A BTU (British thermal unit) is equivalent to 1055 joules.

The temperature profile in a biscuit oven does not give anything like all the information required to know how baking is proceeding. The indicated temperatures are useful only as part of a record of the oven conditions.

Baking times for biscuits are quite short, ranging from 2.5 to 15 minutes with a mean at about 6 minutes, and as it is not normally possible to change the temperature in a static oven quickly; the results of baking in these ovens compared with that in travelling ovens are often very different. Experimentation to determine optimum conditions for baking in a travelling oven requires a constant supply of uniform dough pieces so is potentially a time-consuming and expensive business. This has resulted in a situation where the facility to change the oven conditions through the bake is not always used to maximum advantage for a particular type of biscuit. Baking often remains a black art!

The conditions needed for different types of biscuit are not the same because the way in which the structure is developed and the amount of moisture that must be removed depends on the richness of the recipe. Although the cost of fuel to heat an oven is a low proportion of the total production cost of biscuits (typically around 5%), there is a growing concern to improve oven efficiency and to use less fuel. Oven design is concerned not only with the efficiency of heat transfer and maintaining steady conditions but also with construction because they are large pieces of machinery that can be very expensive. Heat recovery systems to use 'waste' heat from the oven flues are not common as the heat recovered is low grade. However, there is increasing concern about atmospheric pollution and until now little has been done about controlling emissions from bakery ovens. If there is a demand to 'clean' the gases from an oven then such systems can be expected to incorporate heat recovery.

There are many different oven designs and progress is constantly being made. It is not possible to give an exhaustive summary of how all types of oven work or are controlled because of the engineering detail that would be required. The aim here will therefore be to outline what changes occur during the baking of biscuits and to show how the designs of various ovens achieve these when using the principal types of fuel, gas, oil and electricity.

39.2 Changes to the dough piece during baking

There are three major changes which can be seen as a piece of dough bakes:

1. a large reduction in product density associated with the development of an open porous structure
2. a reduction of moisture level, to between 1 and 4%
3. a change in surface colouration (reflectance).

Although these changes are thought of as being distinct and sequential, broadly in the above order as the product passes through the oven, it will be shown that there is considerable overlap and coincidence of these physico-chemical changes. It is, however, convenient firstly to consider them separately. Figure 39.1 summarises the changes that occur and relates them to baking time.

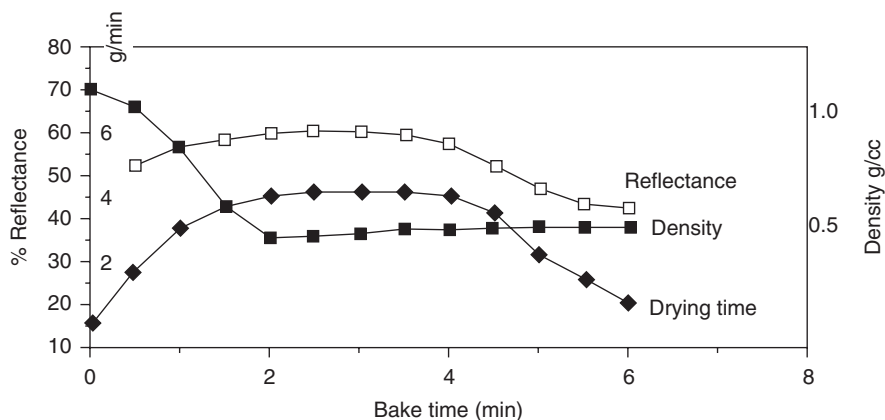


Fig. 39.1 Generalised changes to the dough piece during baking.

39.2.1 Development of structure

Development of the internal structure of a biscuit takes place mainly in the first quarter or third of the baking period (see Fig. 39.2). The changes are all temperature related and involve several aspects of the recipe and the form of the dough piece. Bubbles of gas and water vapour are formed which expand and result in a large reduction in the density of the dough. It is the open porous structure that gives a biscuit a pleasant eating texture. The development of the structure is often known as oven spring. The conditions for giving maximum spring, which are sustained through the remainder of the bake, are imperfectly understood but the changes to the dough piece that are involved include:

- heating the starch and proteins to levels where swelling, gelatinisation, denaturation and setting occur
- liberation of gases from leavening chemicals
- expansion of these bubbles of gases as a result of increasing temperature which also increases the water vapour pressure within them
- rupture and coalescence of some of these bubbles
- loss of moisture from the product surface by evaporation followed by migration of moisture to the surface and continued loss to the oven atmosphere
- increase of sugar solution concentration as the temperature rises
- reduction in consistency of sugar solutions and fat with temperature rise.

It will be appreciated that the most important changes centre around the formation of gas bubbles and their expansion in a medium that at first becomes softer and more flexible followed by tightening and hardening. It has been shown by many experimenters that the increase in volume associated with the mass of gas that is liberated from leavening agents is inadequate to explain the magnitude of the oven spring in biscuits. The gas produced from leavening chemicals can explain up to only half of the volume increase. Water vapour production contributes the balance because there is a dramatic increase in the volume of water as it changes to vapour. Although the expansion must, in fact, be due to water vapour, the term 'steam' is misleading because this word should be reserved for water vapour above 100°C. Consideration of the physics of water vapour pressure provides the answer.

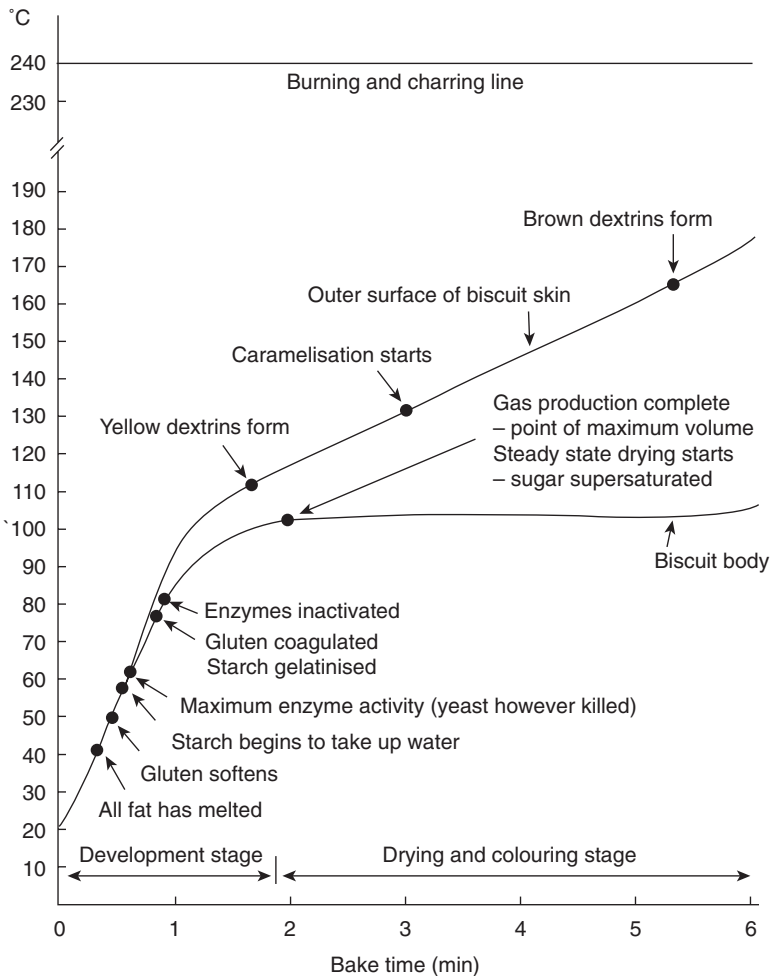


Fig. 39.2 Changes during baking (after Mowbray [8]).

Figure 39.3 shows the increase in volume of air (or other gases like carbon dioxide) if dry or saturated with water vapour. Since the biscuit structure is cast long before the dough piece has reached 100°C , it is now clear how the water vapour contributes to the expansion.

This massive increase in volume due to increase in water vapour pressure with temperature is limited within the dough because the forces of surface tension determine that the pressure within small bubbles is much higher than in large bubbles. Thus as the temperature rises, a very unstable physical situation occurs in dough because there is a delicate balance between (a) the expansion that a softening starch/protein/water/sugar complex can accept before rupture, (b) bubble coalescence and (c) increase in rigidity as the gels set.

With the inevitable loss of water vapour from the dough piece surface an inflexible crust will occur there first. Also, as the surface dries, heat will not pass so readily by conduction through the dough. The centre will heat more slowly and this will retard the development of the gas bubbles. This means that heating the centre of

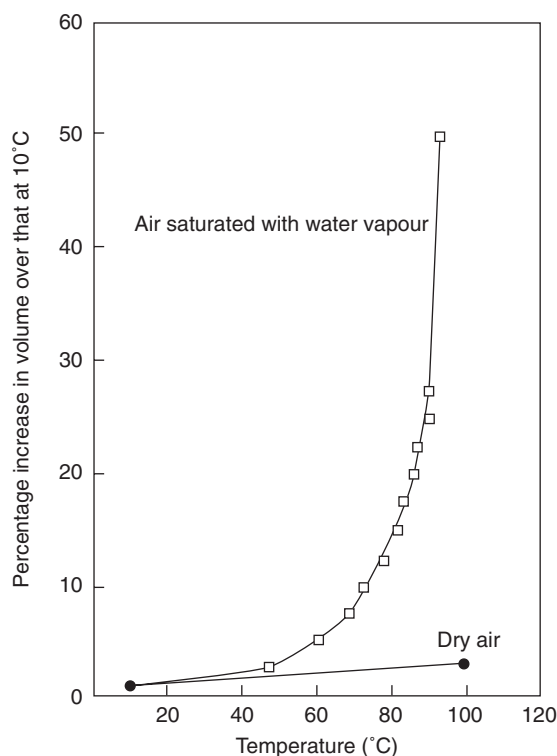


Fig. 39.3 Expansion with temperature of dry air and air saturated with water vapour.

the dough piece early in the bake before drying and setting of the surface occurs is very important. It may therefore be assumed that radiant heat and heat conducted from the baking band will be relatively important for the heating of the centre of the dough piece early in the baking process.

The bubbles that form the structure will tend to be largest in the centre of the dough and smallest where the crust forms. An extreme example of this structure can be seen in Arab pocket bread. This product is made from a thin piece of dough which is placed in an extremely hot and dry oven. A crust rapidly forms and the whole blows up to an almost spherical ball before it ruptures and collapse occurs. The product is now two layers of crust with a rupture line through its centre like the empty shells of an oyster.

To produce a more even texture the crust formation must be delayed and the minimum of bubble coalescence should occur in the centre of the dough piece. The other extreme from the Arab bread situation is displayed in sausage rusk baking where by very slow heating combined with minimum gas nucleation, because little or no chemical leavening is used, the crust forms very slowly, the gas bubbles are very small and little coalescence occurs. The structure becomes rigid and the size of the bubbles and thus the texture is very uniform throughout the baked and dried material.

There are two basic forms of biscuit structure, those where a more or less even bubble formation is required and those where some large cavities are formed. Water

biscuits, cream crackers and puff biscuits are examples of the latter. The baking conditions required for the two types of structure are very different and are determined by the formation of a different number and type of gas nuclei which are subsequently expanded by water vapour. The large nuclei in the cream cracker and puff types are derived from discontinuities in the dough produced by layers of fat or interfaces of drier dough resulting from lamination. Rapid heat input causes great expansion of these long flat nuclei (lenticels) which result in the blistered and flaky structures.

To obtain the more even round-celled structures of most other biscuits, it is necessary to achieve a considerable amount of expansion before significant setting of the structure precludes further expansion. As has been stated, setting of the structure is a combination of gelatinisation of the starch/protein matrix and hardening due to moisture loss. The loss of moisture from the biscuit surface is related to the temperature, heat flux and water vapour pressure (humidity) at the surface. The latent heat of evaporation of water is large so much heat is required. The idea of 'humidity' in the oven atmosphere can lead to a misconception in terms of baking conditions. No matter how much water vapour is present in an oven atmosphere which is at a temperature of more than 100°C, moisture will always be lost from the dough piece surface. The only conditions where moisture loss will be retarded is where the surface of the dough piece is at less than 100°C and the microclimate at the surface is saturated with water vapour. There is a requirement in the first part of an oven, where structure development is occurring, to conduct heat into the dough piece as quickly as possible with a minimum of moisture loss at the surface. This situation will be discussed later.

Starch gelatinisation occurs in the temperature range 52–99°C and the change is somewhat time dependent. Proteins are denatured and coagulated above about 70°C. Gas is liberated from chemical leavening agents at a significant rate from about 65°C. From Fig. 39.3 it can also be seen that the volume increase due to water vapour accelerates very rapidly above 70°C. Fats used in baking melt completely well below any of these temperatures. It will be seen that as the different parts of the dough piece reach about 65°C expansion and loss of flexibility are converging forces. Too much expansion and the structure ruptures, too little expansion and a dense close structure forms.

Development of the structure depends on a continuous controlled increase of gas expansion until the matrix of starch and protein gels sets. There will always be some limitation to the size of the expansion, due to gas bubbles coalescing resulting in a less strong structure. There will be collapse also if the expansion is too rapid (too much liberation of gas from the leavening chemicals) or too rapid heat transfer either of which will increase the formation of less strong large bubbles compared with small. If the dough experiences a drop in temperature, for example, if it passes from a warm zone to a cooler one before the matrix sets, the gas bubbles will shrink and are unlikely to rise again before the matrix sets.

Before leaving the subject of structure development, the importance of dough piece docking should be mentioned. By creating air passages right through the dough piece, crust formation is encouraged and this reduces the chance of big blisters such as that described for the Arab pocket bread. The greater the aeration and the faster the temperature rise in the dough piece, the more important are the docker points. If the docker holes are too far apart blisters will tend to form.

Products which are rich in fat (and sugar) have less water in the dough. This means that the protein is imperfectly hydrated and less gluten has been formed; also

when the dough is heated there is insufficient water present to gelatinise much of the starch. The structure relies more on a sugary or toffee-like matrix which becomes softer rather than sets as the temperature rises. It will only set by cooling after the biscuit has left the oven, therefore during the baking of sugar-rich doughs a very large expansion is observed followed by considerable collapse. The spread of the dough piece and collapse are responsible for the cracked surface of biscuits like ginger nuts or crunch types. The amount of this spread for a given recipe can be controlled somewhat by the temperature of the oven and by the condition of the oven band. Doughs which spread appreciably during baking cannot be baked on open wires as they would sink deeply into them. Although a flat steel band is best, some may be baked on closely woven wires.

39.2.2 Reduction of moisture

Ideally, moisture loss should occur after the structure has set but obviously this is impossible to achieve throughout the dough piece. Moisture can only be lost from the dough piece surface so migration to the surface by capillary action and diffusion must occur. Both of these phenomena are accelerated by temperature gradients so a rapid heating of the whole product to 100°C is required during this stage of baking. If the surface is heated too much, and it dries too rapidly (as will occur if there is much air movement in the oven), colour changes occur prematurely and it is thereafter difficult to dry the biscuit enough without excessive surface colouration.

As the starch and protein gels lose moisture, some contraction occurs and therefore some loss of product lift or spring is inevitable (see Fig. 39.2). In most cases this is small compared with collapse of the internal structure due to rupture and coalescence of the gas bubbles but it is worth noting that contraction will continue even until the biscuit is completely charred if heating continues.

The moisture gradient across a dough piece increases during drying and as the biscuit structure dries the starch/protein structure shrinks. While hot the biscuit is flexible enough to withstand these shrinkage stresses, but a phenomenon known as 'checking' may occur if a large moisture gradient remains after the biscuit leaves the oven. As the biscuit cools moisture equilibrates (moving from the wetter areas to drier) and the shrinkage stresses so developed may cause cracks to form. This is checking. The best way to prevent checking is to ensure that the total moisture content of the biscuit is low so that any gradients will be small.

Products with more fat or sugar have a more plastic structure and the stresses are less pronounced as the biscuit cools. Therefore it is more important to control the moisture levels in crackers, semi-sweet and other 'lean' products than other types.

The desired moisture level of biscuits is determined by two main factors. Too low a moisture level and the biscuit will have a burnt taste and maybe the colour will be too dark. Too high a moisture and the structure will not be crisp, may develop checking cracks and flavour changes associated with staling during storage will be more rapid.

39.2.3 Colour changes

Although there is a change to a yellow-brownish hue during baking, the term colour here is used to imply merely a darkening, reduction in reflectance, of the biscuit

surface. The colour changes are caused by a number of factors. The Maillard reaction (see Section 11.6), non-enzymic browning, involves the interaction of reducing sugars with proteins to produce attractive reddish-brown hues. This occurs around 150–160°C and will happen only in a moist situation. It is not possible to reheat baked biscuits to increase significantly the surface colour due to the Maillard reaction. In order to get these high surface temperatures while the dough piece is relatively moist, it can be seen that radiant heat rather than convected heat is likely to be important. Colour also develops associated with dextrinisation of starch and caramelisation of sugars. At even higher temperatures the biscuit structure chars or burns.

If the biscuit structure is very open, migration of the moisture to the surface is slower so a local increase in surface temperature and therefore colouration can more easily be achieved. Thus well-sprung puff dough will colour more easily than a dense puff structure. An excess of alkali, usually resulting from too much sodium bicarbonate in the recipe, will cause a general yellowish colour throughout the biscuit structure and this will be unattractive in products where there is no other colouration present.

As drying continues, the colouration due to the changes already described will develop in the thinner or more exposed areas of the biscuit. This change is accompanied by the development of a bitterness of flavour. A condition known as ‘perishing’ will occur if this continues throughout the biscuit structure. Perished biscuits are bitter and unpleasant to eat.

39.3 Oven conditions

An oven is a hot box or tunnel which is designed to provide the desired conditions of heat flux to the dough pieces and to allow removal of moisture. The heat is provided by burning a fuel such as gas, oil or by hot electric elements. This heat is transferred by the three modes known as radiation, conduction and convection. All three modes are always involved though engineering techniques are used to enhance the effects of each separately. Oven design is determined by the constraints to allow rapid and precise control of temperatures under varying load conditions and to provide heat in predominately one of the three modes required. All ovens fall short in one respect or another and the situation is not helped by an, as yet, imperfect understanding of the relative effects of each mode of heat transfer at each stage of baking.

Dough pieces are supported on a baking surface which is usually a band of steel or a metal wire mesh. On entering the oven, heat is applied to the dough piece by a combination of conduction (through the baking band), convection (from the hot air moving in the oven) and radiation (from hot surfaces of the structure of the oven and glowing burners). Radiant heat, at the wavelengths involved, does not penetrate the dough piece significantly and the amount of radiant heat reaching the product is inversely related to the distance from the hot surface. A high proportion of the heat absorbed by a dough piece is radiant heat but clearly this is greatest where there are some very hot surfaces like burners and where the baking chamber is small (the roof of the baking chamber is low). The most effective form of heat transfer is by convection but moving hot air also sweeps away moisture and dries the dough surface very rapidly.

As the moisture evaporates from the product and as cool air, brought into the oven with the product, expands, there is a rise in pressure in the oven. In the case of direct-fired ovens where gas is burnt in the baking chambers, the increase in pressure is even greater. This pressure must be relieved so flues are provided which exhaust to the atmosphere. If the pressure rise is exactly matched by the extraction rate through the flues, it will be seen that the oven atmosphere will soon become very rich in water vapour. This is often referred to as humidity but because the temperatures are above 100°C, the connotation of relative humidity used to measure the moisture content in meteorological terms is not applicable. The amount of moisture present has to be defined in terms of relative mass to the air present, for example, grammes of water in a given weight of air, or as dew point – the temperature to which the air must be cooled before condensation occurs.

The gases extracted through the flues are hot and represent a waste of heat, so great efforts have been made to devise means of limiting the extraction rates to a minimum. Although it would be possible to bake and dry a biscuit in an oven with a very 'damp' atmosphere, the effect at the mouth of the oven should be understood. As a cold dough piece enters the warm humid atmosphere moisture will condense on the surface. This condensed water will delay the surface drying and will release a lot of heat from the latent heat of evaporation and this heat will be conducted into the dough piece causing it to warm up quite rapidly. Later, as the dough temperature rises, this water will again evaporate and retard the rate at which the surface temperature rises. The wetting of the dough surface at the oven entrance where the oven atmosphere is high in water vapour aids the general rise in temperature of the dough piece and maintains the flexibility of the crust longer than if the oven atmosphere is dry. However, excessive condensation on the dough surface can cause uneven colouration and spotting where sugar is locally dissolved. Provided that the moisture film is not excessive, solution of surface sugars may give the biscuit an attractive 'bloom' or 'sheen' later in baking.

The humidity of the oven can be deliberately increased by injecting live steam. Drying of the dough piece surface may be retarded by spraying with water before placing in the oven. Apart from this effect of a damp oven atmosphere, it has been difficult to be sure about the benefits or otherwise to baking performance of moisture vapour content in oven atmospheres. Reducing the extraction rates of flue gases to increase oven humidities may also reduce the convection currents and the size of the radiation from the burners (because they will be on lower power settings) and thus heat transfer rates. It would seem, theoretically, that the moisture level of the oven atmosphere is irrelevant but some tests have suggested that oven spring is reduced at high moisture levels. One aspect of this that has been brought to the attention of the author is the nature of live gas flames in a very humid oven atmosphere. Although air is mixed with gas before it is burnt (carburation), for complete combustion there must also be oxygen around the flame. If the oven atmosphere is very humid it is probable that there is a shortage of oxygen and therefore the appearance of the flame is different and the amount of radiant heat transmitted from this flame is reduced. It is possibly a sub-conscious appreciation of this condition that has led to operators insisting that crackers need open dampers in the first zone of a direct-fired oven. The setting for dampers should perhaps be based on oxygen sensing in the oven chamber rather than 'humidity'.

It would be ideal if the dough piece could be heated uniformly and rapidly before much moisture is lost. This means that air movement at the dough surface should be minimal. In conventional ovens it is not possible to apply heat fast enough to the surface (and at a low enough temperature to prevent colouration) merely by conduction and radiation. Some pre-heating of the oven band before the dough pieces are placed upon it is very desirable to promote heat transfer by conduction.

After the dough has expanded and the structure has set, it is necessary to concentrate on moisture removal. Air movement will keep the temperature at the dough piece surface favourable for this to occur. However, as the biscuit dries, conduction of heat from the surface to the wetter centre becomes progressively more difficult and a large moisture gradient will develop. During this drying phase and before the surface becomes too dry the temperature may be adjusted to give a desired level of colouration to the biscuit.

It is important throughout the bake that oven atmosphere conditions are kept even across the width of the oven otherwise dough pieces which are similar at the entrance to the oven will appear as biscuits with different thickness, shape or colour after baking. In many ovens the movement of gases in the oven is not ideal. A common problem is that air to replace that pulled out through the flues enters mostly at each end of the oven. There is thus considerable cooling due to this ingress of air and the effective length of the oven is thereby reduced. Also it is usual to find inspection doors, which may or may not be glazed, down one side of the oven only. If air enters through these as a result of bad seals, for example, this side of the oven will be cooler. In addition to controlling the balance of heat across the band it will also be necessary to have provision to apply heat differentially from top or bottom. This facility permits control of top and bottom surface colouration and also the shape of the biscuit.

39.4 Typical baking profiles

As has been explained, baking involves heat transfer and temperature is only one factor in determining this.

It is possible to control both temperature and extraction from all ovens and in many turbulence, the deliberate circulation of the oven chamber air, is possible. Usually the probes that sense the oven chamber temperatures and also control the heating systems do not represent the temperatures near the dough pieces. It is therefore not possible to give a reliable set of baking temperatures suitable for specific biscuits. The indicated temperatures are useful only as part of a record of the oven conditions.

It will also be appreciated that the temperatures will need to be higher if the baking speed is increased and the baking time is related to the type of biscuit and the size (particularly the mass and thickness of the dough piece). For the purposes of this consideration it will be assumed that each oven has three independently controllable zones (commonly there will be more, very rarely less) with provision to adjust the relative amount of heat transfer from the top and bottom of the band. When looking for optimum baking profiles consider the mechanisms and adjust oven conditions gradually and systematically and record the results and the settings. It may be found that, having achieved good settings, these need to be adjusted from time to time because external climatic conditions affect flue extraction, etc. Finding

and maintaining optimum baking conditions normally requires many hours of production.

39.4.1 Crackers formed by lamination or by aeration with chemicals

There is much water to remove from these doughs. A very open structure is required which will be flaky from laminated types. The best structures are obtained with high or very high heat transfers at the front of the oven. The significant contribution of radiant heat in the first zone is probably important and a partly open extraction will ensure good air movement and the use of significant burner power for radiant heat transfer. Some oven band preheating may be useful to increase the effects of conducted heat in the first part of the oven. The oven band is usually of light mesh construction but in the USA heavy wire weaves with strong preheating are used. It is unlikely that optimum heat transfer can be achieved without a directly heated first zone. In order to increase the radiant heat in the first zone of an oven, structures that glow are added within reach of the live gas flames.

The biscuit is crisp and hard on leaving the oven and the moisture content should be not more than 1.5% to reduce the chance of checking. Much turbulence in the later zones will improve moisture removal. Dockering of the dough piece is essential to control the structure but it is doubtful whether they contribute significantly to removal of moisture from the centre of the biscuits. Baking times are fast and are typically between 2.5 and 5 minutes. The faster the bake, and hence the higher the first zone heat transfer, the more open is the structure.

The flatness of the biscuit needs to be controlled by the ratio of top to bottom heat in the first zone. The centre of the biscuit will be drawn to the higher heat source, so will be dishd if the bottom temperature is too high relative to the top and domed if the reverse.

Typical indicated temperatures (depending on the type of oven) for a cream cracker are 250, 290, 250°C with a bake time of 3.0 minutes and for a snack cracker 200, 250, 240°C with a bake time of 4.5 minutes.

39.4.2 Hard sweet types

There is much water to remove from these doughs, though not as much as for crackers, and normally only a moderately open structure is required. The best structures are obtained with a gradually increasing heat transfer to the highest near the centre of the oven. The contribution of radiant heat in the first zone is probably useful but fully indirectly heated ovens can be used for these biscuits. Oven band preheating is not needed.

High water vapour in the front of the oven gives a good surface sheen. The biscuits can be baked on steel or wire mesh but the latter is the more common as higher baking speeds can be achieved. Dockering of the dough piece is essential to control the structure and to allow adequate moisture removal from the centre of the biscuits.

Baking times are moderate, typically between 5 and 7 minutes. The biscuit is crisp and hard on leaving the oven and the moisture content should be not more than 1.5% to reduce the chance of checking. Much turbulence in the later zones will improve moisture removal.

Typical indicated temperatures (depending on the type of oven) for a Tea Finger are 140, 200, 200°C with a bake time of 6.0 minutes and for a Rich Tea 150, 210, 240°C with a bake time of 7.0 minutes.

39.4.3 Short dough types with low fat and sugar levels

There is not much water to remove from these doughs and the structure required is usually not very open. Good structures are obtained with more or less uniform heat transfer throughout the oven. The importance of the contribution of radiant heat is uncertain but all types of ovens are suitable for these biscuits.

The biscuits can be baked on steel or wire mesh but the latter is the more common as higher baking speeds can be achieved. Steel bands commonly give hollow bottoms; these do not occur on wire bands. Commonly, some spread of the dough piece occurs during baking and the use of a wire mesh band controls the size of the biscuits better than a steel band. Dockering of the dough piece allows slightly increased baking speeds.

Baking times are not fast and are typically between 6 and 13 minutes but depend greatly on the thickness of the dough piece. The biscuit is firm to soft on leaving the oven and the moisture content is typically about 2.5%. Turbulence in the later zones will improve moisture removal.

Typical indicated temperatures (depending on the type of oven) for a Shortbread are 205, 230, 230°C with a bake time of 11 minutes and for a Digestive 180, 240, 170°C with a bake time of 7.0 minutes.

39.4.4 Short doughs with high fat and sugar and most wire cut and deposited types

There is very little water to remove from these doughs and the structure required is not a significant feature. Good structures are obtained with more or less uniform heat transfer throughout the oven. All types of ovens are suitable for these biscuits. High moisture in the first zone will allow more development and spread which after collapse may give an attractive cracked surface.

The biscuits must be baked on a steel band as there is usually spread of the dough piece during baking. The dough becomes soft in the oven and would run into a wire mesh making it difficult to remove the baked biscuit and cause the band to become 'dirty'. Dockering of the dough piece is most unusual.

Baking times are not fast and are typically between 8 and 12 minutes but depend much on the thickness of the dough piece. The biscuits are usually soft and pliable on leaving the oven and require cooling (sometimes forced cooling) on the band before removal. The moisture content is not critical and is usually around 2.5%. Turbulence in the later zones will improve moisture removal.

Typical indicated temperatures (depending on the type of oven) for Ginger Nuts are 150, 180, 180°C with a bake time of 8.5 minutes and for a Choc-Chip Cookies 185, 185, 170°C with a bake time of 12 minutes.

39.5 Types of oven

Most biscuits are now baked in travelling ovens but many small manufacturers bake on trays placed in a static oven which may be one of the following types:

- peel or sole plate, where the trays are placed on the floor of the oven
- reel, where the trays are placed on platforms that rotate in a horizontal plane when the oven is closed
- rack, where trays are placed in racks that are then wheeled into the oven and rotate in a vertical plane when the oven is closed.

Most, except for the sole plate ovens, usually have forced convection to aid uniform heat distribution.

There is a report of a travelling oven built in 1810 which used a moving belt of wire mesh but this was not successful. However, travelling ovens were introduced into British biscuit factories around 1849–51 but were not generally accepted until near the end of the century.

Tunnel ovens remained relatively short until about the 1950s. In 1972 travelling ovens about 60 feet long are recorded. Initially, the bands were chains upon which baking trays were placed and then removed after they emerged from the oven. Later, as rolled steel in long lengths became available (in the early 1930s) continuous bands were introduced. Initially, these bands were 24 inches wide and were only steel bands, but soon the standard became 32 inches (about 800 mm) and wire meshes of various forms were used for certain types of products. Now the standard widths are 1000, 1200 and 1500 mm, with others even wider.

In early ovens a lining of refractory bricks permitted a considerable storage of heat which helped to reduce changes in oven air temperatures when passage of product was intermittent. However, it took some time to heat these bricks when the oven was fired, and a long time to cool them afterwards. Therefore there was considerable inertia if the product required a higher or lower heat input. In view of this, control of baking was principally by changing the bake time. The important feature, however, was that a considerable amount of heat could be transferred to the product in an oven with little turbulence (convection). Brick-lined ovens are now very rare and the change to lightweight structures insulated with rock wool or fibreglass, with much turbulence to enhance heat exchange from the gas flame, or hot ducts has allowed capital cost reduction and much better control of oven temperatures.

Engineers have debated long about the ideal baking oven design and many attempts at mathematical models of oven heat distribution have been made. However, the fact that there are so many designs claiming to be the best suggests that we still have not reached the optimum configuration. Difficulties have basically been due to the impracticability of measuring the dough piece temperatures through the oven or the microclimate around the dough piece. It is still not known for certain the practical values of radiant and convected heat as means of heat transfer to the product. Some control of the amount of product lift can be achieved by changing the oven conditions in the first part of the oven but how much and what is optimum for each type of biscuit is far from being defined. More critical measurements of oven conditions and resultant product parameters are needed. Biscuit ovens are available to suit the type of fuel to be burnt (gases, oils of varying qualities or electricity) and to dissipate this heat either directly or indirectly into the oven chamber. Only gas, light oil with low sulphur content and electricity can be used to heat the atmosphere directly. Heat from other oils must be transferred indirectly via heat exchangers. There are now a few ovens heated indirectly by firing with wood.

The use of electricity allows some other types of heat exchange. In addition to hot wire elements which may or may not glow red, electrical power can be trans-

ferred using radio frequencies (high frequency or dielectric heating), microwaves or induction heating of metal parts like the oven band. The special case of forms of electrical heating will be returned to later.

39.5.1 The main types of biscuit oven heating systems

39.5.1.1 Direct fired

In direct gas fired (DGF) ovens, many strip or ribbon burners are situated above and below the baking band. Each burner is supplied with carburetted gas and air and the pressure of this mixture determines the power delivered. There are various arrangements for adjusting the size of the flame across the width of the oven to ensure even heating across the band. DGF ovens may additionally have a turbulence system which improves the rate of heat transfer. The top of the baking chamber is usually low and the burners are as near to the baking band as is practicable. This means that there is a high radiant heat component in the heat transfer profile reaching the product. Infra-red heating has been known about for many years and modern DGF ovens employ ways of increasing the amount of radiant energy. There are now a number of radiant DGF burners available which can improve the thermal efficiency of the oven and uniformity of baking.

Electric fired ovens are similar to DGF ovens but each burner is electric.

In forced convection direct fired ovens, each zone of the oven has one large burner and the products of combustion are blown to plenum chambers above and below the band. Control of the velocity of blowing and the ratio of hot air circulated above and below the band is possible. To maintain even air flows the roof or crown of the baking chamber is usually higher than in a direct-fired oven. This means that forced convection ovens contribute a lower proportion of radiated heat to the heat transfer profile but allow more uniform temperature and heat transfer conditions across the width of the baking chamber.

In convectoradiant ovens, hot gases from the burner in a zone pass through tubes above and below the baking band and then are released from further tubes to blow over the first tubes in the direction of the band. The first tubes radiate heat to the biscuits and then the released air gives convection currents of air. The radiant tubes are located as near as is practicable to the baking band to maximise the radiant heat effect.

39.5.1.2 Indirect fired

Indirectly fired forced convection ovens are similar to the direct-fired forced convection oven but a heat exchanger near the zone burner heats the air that passes through plenum chambers in the baking chamber.

In the indirectly fired Cyclotherm oven, hot gases pass through tubes above and below the baking band and circulate back to the burner. No products of combustion pass into the baking chamber. There is a separate air circulation system that moves air in the baking chamber and over the hot tubes. Cyclotherm ovens are rarely installed nowadays. Their low thermal efficiency is seen as a significant disadvantage.

39.5.1.3 Hybrid ovens

These are a combination of two of the above types. A very common hybrid oven consists of a first zone of DGF followed by two or more zones of forced convection

type. The idea is that maximum power and much radiant heat is available early in the bake and then much convected heat is provided for the drying part of the oven.

If the products of combustion are released into the oven atmosphere, a considerable amount of water vapour is involved with the attendant need for increased extraction from the chamber. Provision is always made to vary the amount of heat supplied in each zone of the oven and also the ratio that can be supplied to the top and bottom of the product. Indirectly fired ovens usually have a few large burners with the oven divided into large zones along the length. Directly fired ovens usually have a large number of small burners grouped in similar large zones for control purposes. In these ovens it is possible to turn off individual burners either above or below the band. Dampers are provided to control and divert the passage of hot gases to various parts of the oven chamber or up the flues to atmosphere. In addition to direct and indirect firing of ovens, designs are available that promote convection or radiant transfer of heat. Successive zones may have a different emphasis on type of heat transfer and a 'hybrid' oven may employ different fuels in different zones (e.g., use of electric radiant panels and oil fired indirect convection zones).

Ovens of all types tend to have a very large number of control points offering a bewildering range of possibilities. In many cases the problem is increased because the controls are only crudely calibrated and are located along the length of the oven. For example, the damper in the extraction flue is probably a simple flap mounted within the flue pipe. The lever that turns this damper to allow more or less gas to pass up the flue may be calibrated with a linear scale of 0–10 but in this case a setting of 0–5 will probably give extractions of about 10–80% and settings of 5–10, 80–100%.

The number of independently controlled zones and the length of these zones should ideally be designed to suit the product being baked and the time that the product spends in each zone, but to simplify engineering design and manufacturing costs it is common to have all the zones of similar length but the power supplied to each different. The first zones must have the highest power because it is here that the oven band must be heated and here that the dough pieces must be raised to a temperature to start moisture removal.

The hot gases from the baking chamber will convect naturally up the flue pipes but it is normal to have fan assistance to draw the gases up. Nevertheless, the conditions of ambient temperature, wind speed and direction will affect the speed of extraction from the flue pipe. The movement of the hot gases in the oven chamber are critical for uniform heat transfer and it is interesting that nowhere, to the author's knowledge, in direct-fired ovens have both bottom and top extraction of flue gases been designed. Even with forced extraction it is always assumed that hot gases should be taken from the roof of the oven chamber. This unfortunately often affects air movement and heat transfer around the edges of the oven band.

The production rate of an oven is defined by its length and the baking time needed to bake a product to the desired structure, colour and moisture content. For most products the baking speed is determined by the time required to dry the product satisfactorily. For very rough calculation it is possible to use the following loading values for different kinds of dough provided the power of the oven is rated appropriately:

-
• Wire cut doughs	16–18 kg/hr/m ² of band
• Short doughs	18–20 kg/hr/m ² of band

- Semi-sweet doughs 16–22 kg/hr/m² of band
- Cream cracker doughs c. 22 kg/hr/m² of band
- Soda cracker doughs 22–25 kg/hr/m² of band

The efficiency of an oven may be calculated from a measurement of the amount of fuel of known calorific value burnt in a given time compared with the loss in weight which represents the amount of water evaporated and the temperature increase of the ingredients of the biscuit.

Indirect-fired ovens usually do not have enough power in the first zone to bake crackers and water biscuits satisfactorily. They can be boosted with direct gas-fired or electric elements to make them more versatile.

Oven bands are generally available in 800, 1000, 1200 and 1500 mm widths, although other sizes can also be obtained. There are various types of band which offer varying degrees of openness, weight and usage life (see Fig. 39.4). Sheet steel bands may be 1.2 or 1.3 mm in thickness and weigh about 9 kg/m². Perforated steel bands, with holes of chosen diameter, are available and these give the strength and durability of steel bands but with improved ventilation to the product base. They are expensive. There are various wire bands ranging from the light square mesh types (such as 5 × 5, etc., describing the number of weaves per inch and weighing about 3.5 kg/m²), to the looped wires which offer greater product support, improved durability and great flexibility at the terminal drums. Heavy flattened chevron-type woven wire bands offer the extremes in band weight at around 19 kg/m². These

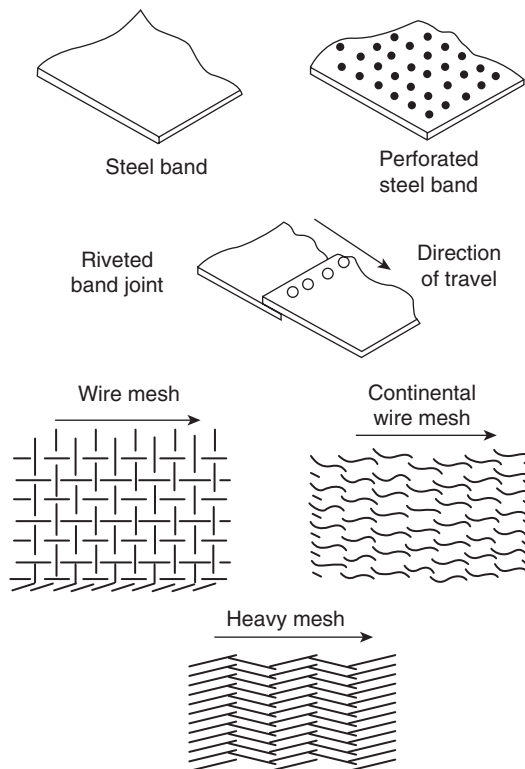


Fig. 39.4 Illustration of various types of oven bands.

bands are particularly favoured by producers in the USA but it will be appreciated that much power is needed to heat the band at the oven mouth. Preparation and care of oven bands will be dealt with in the next section.

At each end of an oven is a terminal drum. At the oven exit the drum is driven and at the feed end there is a tension device which holds the band taut but not so tight that it is damaged (especially light wire bands). As the band heats up it expands so the tensioning device must compensate for this. Conversely, as the band cools after production ends, the tensioning must allow it to contract. The drums are of sufficient diameter that the bands and their joints are not strained in flexing and their axles can be inclined to facilitate tracking. To prevent slip it is sometimes necessary to coat the drive drum with fibrous, fire-resistant material. Through the oven the bands are supported on metal or graphite skids or rollers spaced sufficiently closely to prevent appreciable sagging of the band between them.

The distance that the oven band extends beyond the oven chamber at each end is related to the way in which a product is placed upon it (at the front end) and also how much cooling is required before the baked product can be removed (at the back end). Deposited or wire cut goods require considerable lead-in space to allow room to locate the forming machinery over the band. Sugar-rich or delicate products require long run out lengths, possibly with fan-assisted air or under band water spray cooling, to allow them to set hard before stripping from the band.

Ovens have been supplied up to about 150 m in length but the average length is about 60 m, producing around 1.2 tonnes of biscuits per hour or about 100×200 g packets per minute.

The product is removed from the band by a stripping knife. This must be designed to lift the product clear and transfer it with minimum disruption to the relative positioning of the biscuits. This ensures good feeding to a wrapping machine or for subsequent processing. The stripping knife may be a thin blade of steel or hard synthetic material or a comb of wire fingers. Different types are used to lift different products. Lean recipe biscuits are usually quite rigid by the time they are stripped so the knife can be a little below the curvature of the band as it passes round the terminal drum; other more flexible types of biscuit have to be stripped perfectly flat to prevent lateral cracking. It is important that the knife does not bear so firmly onto the band that it damages or scratches the band surface. Band cleaning, to remove baked on particles or grease is a separate cleaning operation performed later as will be described in the next section.

With the growing concern of energy conservation, schemes have been devised to reclaim some of the low-grade heat which is lost in the oven flues. A major problem is that the exhaust gases are very humid and may be rich in somewhat caustic and gummy materials derived from sulphurous compounds in the fuel and products of biscuit leavening agents, like ammonium bicarbonate, and volatile fat fractions in the dough.

39.5.2 The extended use of electricity for baking

Electric ovens, although not new, deserve some special consideration because it is probable that they will assume a much more important role in the future when combustion of hydrocarbons such as oil and gas become less acceptable. At the moment, electric ovens are similar to direct gas fired ovens with multiple burners in transverse tubes in the oven chamber above and below the oven band. Power to

these burners may be controlled with thyristor switches which are very economical of power. The currents are very high and the 'burners' are expensive to replace. It is desirable to have some turbulence in the oven to enhance heat transfer to the product but the extraction can be very precisely controlled since there are no products of combustion. It is possible to have banks of incandescent heaters which will give intense radiant heating for product colouring.

Electric ovens can be expected to see a resurgence. The next generation of ovens will have multi-fuel capabilities that enable them to be converted to electric heating if required.

There is interest in the use of microwaves and radio-frequency (RF) energy to enhance baking speed and efficiency. It is clear that radiation that penetrates the dough piece or the part-baked biscuit will have a considerable advantage over heat supplied only to the surface. In theory at least, heating of a dough piece will encourage a more even structure development.

Post-oven RF driers are now quite common. It is claimed that by using post-oven dielectric drying, it is possible to increase the output of a conventional oven by up to 33%. Product that is baked in terms of structure and colour is transferred to a non-metallic band and passed through the relatively short unit. Biscuits which emerge are at the desired moisture level and the moisture gradient between centre and surface is very low which significantly reduces the occurrence of checking after the biscuits cool.

RF driers usually use 27.12 MHz which is one of the internationally stipulated frequencies for such applications. RF ovens are available in 25, 40, 50, 60, 75 and 85 kW modules. RF units have an overall efficiency of between 65 and 72% in terms of the conversion of mains electrical consumption to transfer of RF energy to the product.

The microwave frequency used is 2450 MHz. Microwave heating increases with the distance from the band as the field at the band is zero. However, there is good conduction of conventional heat from the band. The use of microwave energy in biscuit ovens has not proved sufficiently effective or economical to develop further.

39.6 Preparation and care of oven bands

39.6.1 Preparing a new band

Before a new oven band can be used for baking, it is necessary to prepare it. This involves conditioning and cleaning. The cleaning is principally a process of removing mineral oil and dirt, and in the case of wire bands this can be simply done by rubbing the band, after heating to about 150°C, with clean cloths. Steel bands (including perforated steel bands) require more attention in order to create a clean shiny surface which will not allow the product to stick while baking. It is customary to heat the band to about 150°C and to rub a fat into it, heat it through the oven, and then to rub this off again at the oven exit with clean cloths. A rough surface due to scratches, metal pitting or a build up of carbon from dough particles tends to cause product sticking.

39.6.2 Greasing of oven bands to prevent sticking

The conditions which cause a product to stick to the band during baking are not always obvious but a thin film of vegetable oil usually prevents the keying of sticky

substances such as syrup or milk products which develop on the bases of products during baking. Products low in fat and high in sugars or egg may need a deliberate coating of the band prior to depositing of the product. Various 'greasing' arrangements are available that use either vegetable fats or waxes like beeswax. The film of grease should be absolutely minimal and even. Even then an unacceptable spread of the product may occur as the sugars melt or dissolve as they are heated, this can be limited by an additional dressing with flour or starch on top of the oil film before the dough pieces are deposited. Mixtures of oil and a cereal may prove easier to apply than each separately. Proprietary blends of specially formulated release materials are available but their application is very critical.

39.6.3 Cleaning of oven bands

Whether oven band dressing is required or not, it is important to keep the band clean and equipment is usually provided as part of the oven design to do this. After the product has been stripped from the band a scraper should be used to remove the largest particles of product adhering. Thereafter the careful use of rotating wire brushes or fabric buffer brushes may also be required. Too much brushing may remove the important conditioned band surface and very greasy brushes may merely redistribute the 'dirt' rather than remove it. As the band returns underneath the oven it is supported on rollers. If these rollers become excessively dirty with a build-up of biscuit crumb and grease, the action of the brushes may be impaired by subsequent deposit of more dirt.

If greasy or syrupy products are baked on wire bands, there will be a progressive build up of carbon in the meshes of the wires. If this is loosened with brushes and not adequately cleaned off, black particles will adhere on the bases of the baked product. Therefore cleaning of wire bands is best attended to either before or after baking commences. In the event of very excessive carbon build-up on a band this can be removed, when the band is warm, with scrapers, by hand or in exceptional cases with caustic soda treatments. If the latter method is used it is important that the caustic soda is applied with great caution and subsequently thoroughly removed by washing before product is baked again. In Section 30.2 mention was made of wafer plate cleaning by bombardment with granules of dry ice (solid carbon dioxide). In exceptional cases this method is also used for cleaning baking bands. It is relatively expensive and slow but very effective.

Reconditioning of steel bands will probably be necessary after a comprehensive cleaning routine.

39.6.4 General care of bands

Oven bands expand when heated and to preserve flat surfaces and reduce tensions which may give distortions and difficulties with band tracking it is most important to maintain even across-the-band heating through the oven. When baking is finished and the heaters are turned off the band should be allowed to run until the temperature falls to about 100°C or less for steel bands and not more than 150°C for wire bands. Only then can the band drive be stopped. Thus a cooling period is most important and this should be done with the inspection doors in the side of the oven closed to prevent one side of the band cooling faster than the other. Cooling will

be hastened if the extraction dampers and doors at the ends of the oven are fully opened.

If the oven band should stop during baking due to a power failure, two problems may arise. Firstly, the product will quickly overheat and may actually ignite, and secondly the band will become excessively hot. There should therefore be provision for automatic extinguishing of the oven heating in such a case and every effort should be made to wind out the band without delay. In some cases standby power, for example, from banks of batteries, may be provided but in any case crank handles which can be attached to the drive drum and wound by hand should be used immediately. It is then important to provide a facility for collecting, safely, the burnt or burning product and the band should continue to be turned until power is returned or the band is cool enough to be left.

Rust can quickly ruin a band surface so if an oven is in a humid atmosphere and especially if it is not used regularly, it is wise to apply a film of oil or fat on its surface.

Also to prevent rusting on the inner surface of the band occasional very light greasing should be provided in the form of silicon or graphite grease. Too much may result in drive slip on the terminal drum.

39.7 Measurement and control in baking

In Section 39.4 some indication was given of typical oven temperature profiles for different types of products. We now come to the question of how a set of conditions which has been shown to give a satisfactory product can be returned to at different times and be precisely maintained.

Although biscuit ovens have several independently controlled zones, there is usually significant movement of air from one zone to the next because the ingress of air to replace that being extracted has not been specifically controlled. It is not unusual to find that there is a strong draught into the oven at both the mouth and the exit. This effectively is reducing the length of the oven because the air being drawn in is cold. The development of zone integrity is important for control. This design involves monitoring the pressures in each zone and making them identical. Fresh air drawn in to replace that being extracted in each zone enters and is also warmed before arriving in the baking chamber. The advantages for precise control are obvious, the only danger is that a sudden drop in temperature experienced by a dough piece as it passes from one zone to the next may affect the structure by causing collapse.

The means of control of ovens is usually rather crudely calibrated and often, even though their scales are linear, the effects are far from linear. This is particularly the case, for example, with extraction dampers as was mentioned in Section 39.5. Very few ovens have any indication of air flow velocities or humidities and in most cases thermometers or thermocouples used to detect oven atmosphere conditions are few in number and positioned in such a way that they give very little information about the conditions at or very near the dough pieces being baked.

As the inspection doors are normally only one per oven zone, it will be appreciated that visual checks on the effects of oven conditions are very limited for the baker and he has to use his experience, from inspection of the biscuits emerging from the oven, to decide whether the various zones in his oven are performing as he wants. The facts are that 'optimum' oven conditions are established by trial and

error and adjustments from day to day are made by experienced operators or as a result of their quirks of preference.

The conditions existing near the product can be measured by passing a probe or a series of probes through the oven and recording temperature changes. In the simplest form a thermocouple at the end of a light twin lead insulated with heat-resistant plastic can be run through the oven and then either pulled rapidly back like a fisherman's line or released from the recording instrument to pass totally through the oven. The advantage is that a temperature profile is obtained instantly and subsequent ones can be recorded with little loss of time. The disadvantage is that the wire is very long, must be very flexible, and tends to deteriorate due to the effects of heat.

Various other oven temperature recording devices based on recording electronics housed in insulated boxes have been developed. These can record temperatures at several places at once and pairs of wet and dry bulb probes can be used to estimate water vapour levels and small anemometers used to record air speeds. The major difficulty here is the hazardous environment in an oven from which the electronics must be protected and the extremely low head room, often not more than 30 mm, that the instrument must clear in its passage.

At the high temperatures involved, the difference in temperatures between wet and dry bulbs used to estimate water vapour levels are very small for relatively large and perhaps significant changes in moisture content, and precise enough probes with reliable water feed to the wet bulb are extremely difficult to engineer.

On a continuous basis, estimations of oven water vapour conditions can be made by sampling the oven atmosphere either through heated pipes (to prevent condensation) or in the flue pipe and passing the sample over suitable sensors. Calibration and maintenance of these sensors is a problem as dust, fat fumes and various corrosive gases are also present in the oven atmosphere. The moisture level in an oven atmosphere, or more particularly at various places in an oven, has important implications on extraction rates and hence oven heat efficiency. The position of extraction points and probably the quality of the bake are also related to water vapour levels so monitoring of 'humidity' would seem to be a useful requirement. When the 'humidity' monitoring is reliable, and a positive effect can be demonstrated on the quality of the biscuit baking, the obvious means of controlling the level would be to have a link to the extraction dampers. The use of variable-speed extraction fans is probably the best method.

The measurement of the temperatures and sources of heat at the product (conduction, convection and radiation) presents major problems also and as a consequence, despite many attempts at mathematical modelling and critical test baking, its importance remains uncertain. Attention is also drawn to specialist instrumentation described in Section 5.8.5. Our relative ignorance on oven control stems from two basic problems.

1. There are many variables in the form of controls along an oven which are difficult to record and the effects of which are very interactive.
2. As yet there has been very limited progress on continuous measurement of baked product parameters against which to correlate the control or oven measurement readings.

Microelectronics and centralisation of oven controls with remote drives for dampers, etc., is now allowing much better data logging. The possibility is now available for

quite complex control loops when the desired conditions and the effects of various controls are understood.

Since we know that oven spring occurs early in the bake and product colour later, it would also seem wise to explore ways of measuring these properties, and probably others like length and width of the biscuits, at the end of appropriate oven zones rather than at the oven exit where information for control purposes is already somewhat too retrospective. To allow this it would be good therefore to see a more widespread use of oven zones separated from one another by observation tunnels. The importance of oven band temperature when the product is placed upon it needs more research and probably control, for we cannot yet be certain whether heavy or light bands are better for product quality and efficiency.

Many workers have applied themselves to these problems of measurement and control but it would be most unfair not to make particular reference to the work of the FMBRA (CCFRA) in their considerable work on biscuit oven automation and computer control [1–4].

39.8 Post oven oil spraying

For many savoury cracker biscuits, and also some other types, a dressing of oil is given while the biscuits are still hot. Immediately after the biscuits are taken from the oven band they are passed through a unit where they are sprayed with warm vegetable oil. The oil is distributed either from pressure nozzles, spinning discs or by electrostatic charge. All types except the last tend to be messy because fine droplets of oil form a fog that may drift from the spray unit unless there is positive extraction and filtering.

The oil dressing, applied either on the top surface only or on both surfaces at around 8–18% of the biscuit weight, greatly improves the appearance of the biscuit surface, enhancing the colour, and adds a little to the eating quality. In some cases flavoured oil is applied which, for savoury or hard sweet types, is a useful technique for applying flavour that would be lost if added in the dough before baking. The main problem with flavoured oil is that it contaminates the cooling conveyors used to hold the biscuits when they leave the oil spray unit and the smell may fill the packing area of the factory.

The oil used for spraying is particularly susceptible to rancidity. It is sprayed hot and in this condition is open to oxidation. On the biscuit it is a surface film, again in an ideal situation for oxidation. It is therefore recommended that a fat or oil be used that is resistant to oxidation and the favoured choice is coconut oil because it is low in unsaturated fatty acids. This is readily available and much cheaper than specially prepared fats which are resistant to oxidation.

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Please note the FMBRA became CCFRA, now Campden BRI.

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Biscuit cooling and handling

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Abstract: Cooling of biscuits after they leave the oven is necessary to allow secondary processing and packing in plastic moisture-proof films. More loss of heat occurs during the biscuit cooling period. There will be some moisture equilibration within the biscuit structure and the biscuits can be moved into different alignments and to different parts of the factory.

Key words: checking, cooling time, lane reduction, stacking.

40.1 Introduction

After baking the biscuit must be packaged or passed for secondary processing such as chocolate coating. Packaging involves not only grouping into practical sizes for sale, but also protection from moisture uptake from the atmosphere, dirt and damage. It has been usual to cool the biscuits before packaging. A drop of temperature of the baked biscuits is necessary if the biscuits are to be manually handled, sandwiched with cream or chocolate coated, etc. In addition some other changes may occur. There may be a small loss in moisture, though this is normally insignificant, but moisture gradients within the product will be partially relieved and the structure will become more rigid (especially in sugar rich products).

In most factories biscuits are not packed hot and it is therefore important to consider the conditions for cooling, the cooling requirements and the consequences of not cooling and handling biscuits correctly before packaging.

40.2 Checking

Certain groups of biscuits are prone to spontaneous breakage at variable times (up to 24 hours) after cooling and packaging. A phenomenon of hairline crack formation occurs and this is known as 'checking'. Checking cracks usually extend partway across a central portion of the biscuit rendering it very prone to complete breakage on subsequent handling. These cracks are the result of stresses which develop as the biscuit cools and are due to dimensional changes associated with equilibration of moisture within the biscuit. The drying process in the last zones of the oven

inevitably result in the central and thicker parts of the biscuit retaining slightly more moisture than surrounding parts. After cooling and standing the moisture gradients are relieved as moisture equilibrates throughout the biscuit. This movement of the water causes the central areas to shrink as they dry and the outer parts to expand as they gain moisture. Stresses are set up which in certain circumstances result in cracks, checking. Why some biscuits do not check and others do is still imperfectly understood despite extensive investigations by technologists over many years. It has been shown [1–7] that factors including basic recipes, ingredient qualities, mixing and baking conditions, cutter design and other factors contribute to the tendency to checking but always it is the moisture distribution, related to the elasticity of the biscuit structure as it cools, that is the basic cause.

Checking can be reduced or eliminated if the baking results in a generally low moisture content, that is, the moisture gradients are small, and if the cooling is gradual. Post oven radio-frequency or microwave driers have been found valuable for reducing moisture gradients. These electronic driers heat the wetter areas of the product preferentially thus accomplishing the final stage of drying efficiently.

Rapid cooling will accentuate checking as the biscuit structure will harden quickly. If the biscuit can be retained flexible during the first stages of moisture equilibration, stresses will be reduced. Therefore in products prone to checking, forced cooling should be avoided and some form of stacking and delayed cooling in a warm chamber may be beneficial. Crackers and semi-sweet varieties of biscuits are the types most likely to check, but problems can sometimes occur in others. Products made with around 15 units of fat to 100 of flour and with low sugar seem to be the most susceptible. As the fat and sugar levels increase, checking becomes less of a problem, presumably due to the fact that the biscuit structure is more flexible for longer as it cools, and less water has had to be removed during the baking process. Products with a more dense, less aerated texture are also a problem and this is probably because the structure is more rigid. It is more difficult to remove the moisture from the centre of a dense biscuit. If biscuits are cooled in an atmosphere of excessively high humidity, perhaps in a refrigerated tunnel, there will be moisture pick-up on exposed edges that will cause the structure to expand relative to the centre and cause checking.

40.3 Methods and speeds of cooling

In the early days of biscuit manufacture, biscuits were left to cool on the trays upon which they had been baked. With travelling ovens the biscuits are stripped from the baking band and passed onto conveyors that take them to a place for packaging or secondary processing. These conveyors provide the opportunity for the biscuits to cool.

Little critical investigation seems to have been carried out on the ideal/minimum time required for cooling. If the exposure to the air is too long the cost and maintenance of the long conveyors is a waste and it may be that, under conditions of high atmospheric humidity, some moisture is picked up by the biscuits before they are packaged. If the cooling is too little, hot biscuits may cause shrinkage and distortion of wrapping films, melt cream in a sandwich or cause loss of temper in coated chocolate.

When biscuits are manually transferred to wrapping machines, etc., after cooling it is clearly necessary to have the products cool enough for handling. With the introduction of mechanised handling it is not necessary to worry about what is acceptable to human hands but many feel that if the biscuits are packed too hot they will sweat in the pack. In other words there is thought to be a significant loss of moisture while the biscuits are cooling. It is probable that cooling arrangements are mostly excessive. The 'rule of thumb' cooling times on open conveyors given by machinery suppliers range from 50 to 200% of the baking time. In some cases biscuits are stacked immediately after removal from the oven band and then cooled on wire conveyors with fans blowing air from below or in forced convection tunnels with or without refrigeration.

Long cooling conveyors usually involve transfers and often turnovers between the oven exit and the final destination. With increased mechanisation of biscuits it is most important that the uniform orientation of the biscuits on the oven band is maintained to the handling machines before wrapping, etc. A jumbled positioning means that the handling mechanisms are less efficient. The longer the cooling conveyors and the more the transfer points, the more disorientated becomes the biscuit positioning. There is thus a need for minimal cooling and transportation before packaging.

Because the optimum conditions for biscuit cooling seem so vague the author undertook to make some measurements which should form a better basis for determining cooling requirements. The temperature of various types of biscuits was measured at intervals after leaving the oven band and also at the stacker immediately before packaging. He also checked the weight loss during the cooling period to determine the moisture losses. His findings and conclusions are as follows.

40.3.1 Findings

1. Biscuits leaving the oven are always at about 100°C unless the final zone of the oven is set at a temperature lower than this.
2. Cooling is rapid immediately after the biscuit is removed from the oven band.
3. The speed of cooling after about one minute from the oven band is determined mostly by ambient temperatures and the thickness of the biscuit. The weight of the biscuit is not so critical because size is a factor of this. Biscuits which are blistered (like cream crackers) cool faster than their overall thickness would suggest.
4. Only thick biscuits, more than 8 mm, lose a measurable amount of moisture during cooling. Moisture loss is effectively complete by the time the biscuits reach 50°C.
5. Most plain biscuits can be packed at temperatures of 45°C.
6. Biscuits which are to be cream sandwiched should be at or below the temperature of the cream which, depending on the ambient conditions, is usually not more than 30°C. Claims that the biscuits should be warmer than the cream in order to allow some melting at the contact area and thus better keying during cooling and crystallisation of the fat should be treated with care. It is difficult to control precisely the temperature of cooled biscuits and if the biscuits are too warm the density of the cream will be increased and this will reduce the thickness of the cream sandwiches.

7. Biscuits which are to be chocolate coated must be below 29°C so that the chocolate does not lose temper. Where chocolate-flavoured coating is used, the temperature can be much higher, perhaps 45°C.
8. Biscuits cool to 45°C slightly more slowly at high ambient temperatures, so cooling times should be calculated for the warmest conditions likely to be experienced.

40.3.2 Conclusions

1. When designing cooling systems, attention should be given to the thickest biscuits that are to be produced and the highest ambient temperatures expected rather than the baking times. (The fastest expected baking time for the range of products to be made on a plant will need to be known to determine the length of the cooling conveyor in minutes of cooling time.)
2. From the curves in Fig. 40.1 and values in Table 40.1 the following can be seen.

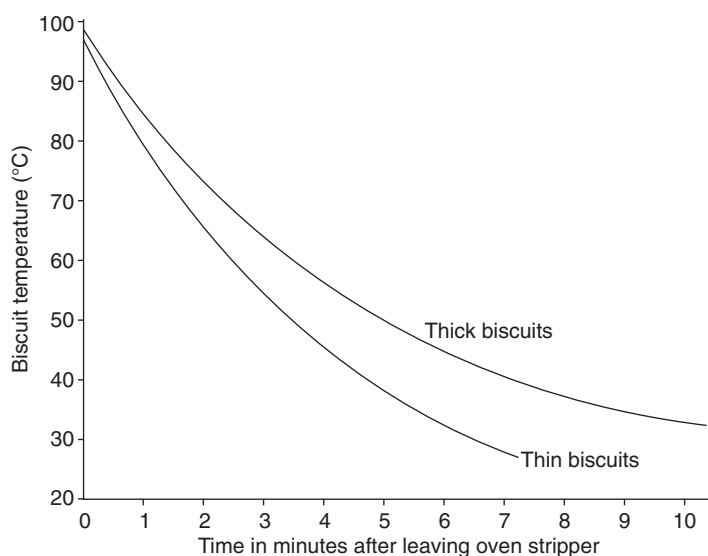


Fig. 40.1 Generalised cooling curves for biscuits in air at about 25°C.

Table 40.1 Recommended minimum cooling times for biscuits cooled on flat conveyors

	Ambient temp.	Final biscuit temperature	
		27°C	45°C
Biscuits of 9 mm thickness	30°C		6.5 mins
	20°C	7.0 mins	5.0 mins
Biscuits of 6 mm or less	30°C		4.5 mins
	20°C	6.0 mins	3.5 mins

- (a) For biscuits that are to be packed at 45°C or less, cooling times of 6.5 minutes for biscuits at 9 mm thickness and 4.5 minutes for those at 6 mm should be adequate in still ambient air at 30°C or less. The time will be longer if the biscuits are stacked very hot.
 - (b) For biscuits to be cream sandwiched or chocolate coated, the ambient air will have to be at 27°C or less and cooling times of about 9 minutes should be enough. If the ambient air is more than 27°C forced cooling with cooled air may be necessary.
3. Short dough biscuits can generally be forced cooled with ambient air and the cooling conveyors can be reduced in length by stacking the biscuits as they come off the oven band. Forced cooling on a long oven band run out (giving about 2 minutes of cooling) can give better control of cooling than forced cooling when stacked.
 4. Crackers and semi-sweet products that are prone to checking should be packed as warm as possible and cooled without draughts. In some cases covering the conveyors to delay the cooling may help to stop checking. Crackers packed at 45°C require only about 4 minutes of cooling.

40.4 Biscuit handling prior to packaging

Various conveyors and devices are used to handle and to carry baked biscuits. It is useful to define the names commonly used for the different pieces of equipment. Figure 40.2 should aid in understanding the relative positions and alternatives. For clarity in these descriptions, it is also worth redefining the meanings of 'row' and 'lane' as used for lines of biscuits. A row is a line across (at 90°) to the direction of travel of the plant, and a lane is a line in the direction of production. Thus, a row is only as wide as the plant, but a lane is of infinite length.

40.4.1 Oven stripper

A flat blade or a set of fine fingers bearing on the oven band as it curves downwards on the terminal drum lifts the biscuits and allows them to fall or be pushed onto the first cooling conveyor. This conveyor is usually quite short and may be wire mesh or cloth fabric. It is normally possible to retract the nosepiece of this conveyor immediately behind the oven stripping knife or fingers so that burnt or bad biscuits may fall down onto a cross conveyor to be collected for scrap (see Fig. 40.3). This whole unit is known as the oven stripper and is powered by the oven drive. Its speed is usually slightly faster than the oven band to allow some separation of the rows of biscuits. The stripped biscuits are pushed across the knife by the biscuit following

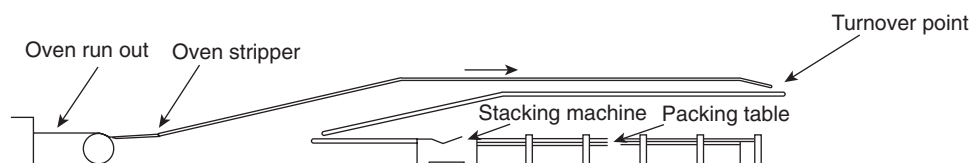


Fig. 40.2 Typical two-tier biscuit cooler.

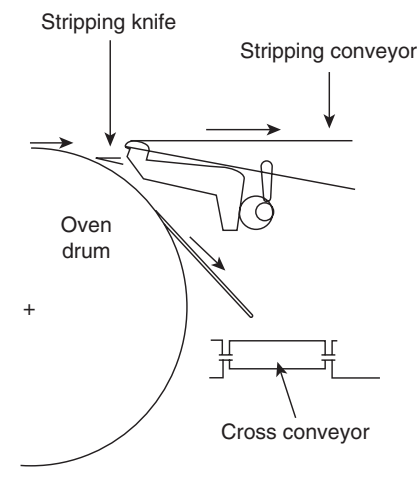


Fig. 40.3 Detail of reject system before oven stripper conveyor.

but it should be possible to keep the lanes of biscuit straight and in good regimentation as they pass for cooling.

Should the oven band stop during production, as a result for example, of a power failure, it is necessary to move the oven band either with an auxiliary power source or by means of a handle. Either way, there is usually a short delay before the oven band is moved again and then rather slowly. Under these conditions it is not unusual for product to emerge from the oven and to catch fire. It is important that this hot product does not fall onto any canvas or plastic cooling conveyors otherwise they will be damaged and may ignite and the fire spread. The oven stripper conveyor, if made of wire mesh, provides a safe buffer from which burning product can be swept onto the floor or into suitable containers.

40.4.2 Cooling conveyors

The cooling conveyors are usually of fabric construction, full width and arranged in one or two tiers. They allow the biscuits to cool flat in the ambient air or, in certain cases, under controlled environment conditions. They are usually designed to run slightly faster than the oven band to allow good separation of the rows of biscuits. By using radial bends and various turnover devices, they can be used to take the biscuits wherever needed within the factory.

40.4.3 Stacking machine

The function of a stacking machine is to collect biscuits from the cooling conveyor, confirm the lane arrangement and stack them on edge or overlapping each other for easier handling. The performance of the stacking machine may be improved if the spacing between rows is adjusted before it. To effect this a stacker feed conveyor with separate drive may be used. Before the stacker it is often useful to have a lane reduction facility (see below). In this way fewer lanes of stacked biscuits are presented for later handling.

Immediately before the biscuits are stacked they normally slide down a dribble board which has ridges to deflect the biscuits. The function of the dribble board is to confirm the orientation and alignment particularly of rectangular biscuits. The alignment of round biscuits is not a problem but oval and not-quite-square biscuits can give much trouble in later handling if they are not stacked uniformly. Stacking may be effected by different techniques, but the main types are, star-wheel stacking (see Fig. 40.4), penny stacking (Fig. 40.5) and flip stacking (Fig. 40.6).

The mechanism of the first two should be clear from the diagrams. The flip stacker relies on an acceleration by a fast rotating flipping roller which throws each biscuit forward over the one before it. It may be necessary, as shown in the diagram, to have a trailing chain or web to control the flight of the biscuits. The flip stacker can stack at very high speeds and is superior in this respect to the other types. The star-wheel stacker allows a more vertical orientation of the biscuits, but this orientation is possible from the other types if there is a transfer to a slower-moving vertical stacking band (see Fig. 40.5) or if the stacking is done onto vibrated inclined conveyors.

Vibratory conveyors have become a popular and useful means of stacking and feeding biscuits to the in-feeds of wrapping machines. These U-shaped single-lane conveyors are gently sloping and biscuits fed onto them are both transported and, as they bunch up, they are stacked. The added advantage is that they can form a buffer storage because the bunched biscuits occupy much less room than those being transported flat. Biscuits can accumulate if the wrapping machine stops for short periods and no manual removal of product is needed.

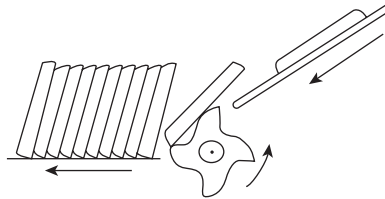


Fig. 40.4 Principle of the star-wheel stacker.

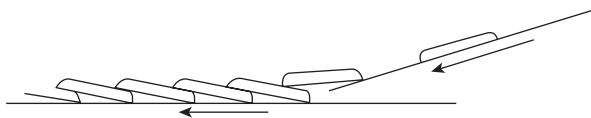


Fig. 40.5 Principle of the penny stacker.

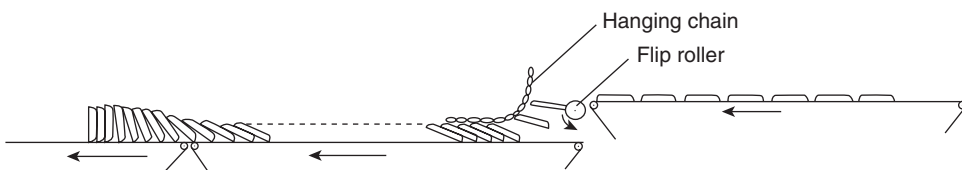


Fig. 40.6 Principle of the flip stacker and vertical stacking.

40.4.4 Packing table

The stacking machine usually stacks the biscuits directly onto the packing table. The height of this conveyor is to suit operators sitting or standing by it while they transfer the biscuits to wrapping machines, individual packets or into tins or trays. Guide strips of steel are usually fitted at appropriate spacing across the packing table to collect the lanes from the stacker and to maintain them along the packing table.

If the feeding of the wrapping machines, creaming machines, etc., is automatic, the packing table also provides a reservoir should there be breaks in the running of either the production plant or the wrapping machines. It will be appreciated that recycled biscuits can also be introduced to the system on this packing table. The recycled biscuits may result from opened defective or lightweight packs, or from trayed-up product collected at some previous time when a wrapping machine was stopped, etc.

Biscuits which for one reason or another are not packaged or trayed up will fall off the end of the packing table and should be collected in suitable containers. In an efficient operation, only unpackable product should be allowed to reach the end of the packing table.

40.4.5 Lane adjustments

It may be expedient to change the number of lanes of biscuits resulting from the cutter to suit the wrapping machine feeders, the number of operators employed or to mix the biscuits from different rows in the interest of more uniform pack weights. Many devices have been designed to lane reduce, lane distribute and lane multiply. Mostly they are simple deflector devices which aim to push the biscuits sideways without arresting their forward movement. It has been possible to introduce some electronic sensing and servo operations to compensate for lane wander as a result of band tracking, etc. By using relatively inexpensive micro-electronic devices, much more sophistication can now be used. This includes

- programming of wrapping machines
- feeders to collect biscuits from across the lanes to balance weights and vary supply in different lanes
- adjustment of lane reducers to suit groups of wrapping machines working in parallel but with any individual machines being stopped on a random basis
- arranging logical plant shut down
- deflection of product should hold-ups occur in the wrapping area.

Alarms can be arranged to call staff for manual assistance should the automatic arrangements reach a saturation point. By these means the amount of labour needed in the wrapping area can be considerably reduced effecting big improvements to the plant efficiencies.

40.4.6 Process control considerations

All aspects of biscuit handling and cooling are more efficient if the biscuit shape is constant. As we have seen before, this is achieved by attention to detail right through the process. As the handling and wrapping machine feeding arrangements become

more automatic, there is progressively less tolerance to biscuit dimensional variation. More surveillance is needed at the oven exit to ensure that bad product does not pass forward or that trends to out-of-standard dimensions are detected in time for corrective action to be taken.

Traying up and feeding back of product becomes disproportionately labour intensive and the economics of completely eliminating these procedures is discussed in Chapter 43.

The basic biscuit shape can contribute significantly to the efficient performance of biscuit-handling equipment. For example, round biscuits can be manoeuvred most easily but out-of-round, slightly oval, or even deliberately oval biscuits create problems because when stacked they are unlikely to all lie together uniformly. The same problems occur with square biscuits. Rectangular product is next best to round for handling and wherever possible the biscuits should be cut with the short edge of the rectangle leading. If the long edge leads, at each transfer, and particularly at the stacker where lanes are being redefined, there is a tendency for the biscuits to turn so that the short edge leads. It is best to arrange that this turning occurs deliberately so that the short edge then leads.

40.4.7 Special provisions for biscuit handling

Only the main features of biscuit handling techniques and possibilities have been outlined. Very many ingenious and special systems have been designed, including the use of air jets, air beds, vibrator arrangements and pick and place robotics to move the biscuits to predetermined positions. Although the cheapest in most cases, gravity is not a very reliable method. Falling biscuits can easily be deflected or retarded by air currents, and friction alters with the humidity of the day or the cleanliness of the conveyor. When biscuits are passing at very high speeds and very close together, the movement of each one must be identical if uniform performance with no jamming is to be achieved.

40.5 References

Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.

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Secondary processing of biscuits

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Abstract: Addition of cream, chocolate, jam, caramel, etc., to baked biscuits adds very considerably to their eating qualities. In production terms it is necessary to balance the savings in labour which can be obtained with in-line secondary processing against the cost of plant which may be idle for some of the time.

Key words: cream sandwiching, chocolate coating, jam, jelly, water activity, chocolate tempering.

41.1 General considerations

In many cases biscuits that have been baked and cooled are subjected to further treatment in the form of coatings or sandwiching with flavoured materials. These treatments are known as secondary processes. The additions include chocolate, fat-based creams, water icing, marshmallow, caramel toffee and jam or jelly. There may be a single addition such as chocolate or a combination of two or more materials. In the latter case each addition is usually made separately and a cooling or drying period allowed between each.

Secondary processing allows a much greater variety of flavours, textures and appearance to be achieved than by baking alone. The additions may result in a biscuit becoming a confectionery product and the materials used are more akin to the sugar confectionery industry than flour confectionery. It may be that chocolate enhances a biscuit or a biscuit fills out and enhances a chocolate product.

In-line secondary processing is not always the case and in many factories baked and cooled biscuits are collected in tins or trays to be coated or sandwiched, etc., at a later time. This is principally because there are staffing complications with in-line secondary processing unless the whole plant can be used every day. It is more usual that the baking plant is used to make a variety of biscuits and only some of these are further processed before packaging. Furthermore, as ovens become longer and wider, the production of biscuits is very fast compared with the speeds of the secondary processing equipment. An in-line arrangement may involve investment in more equipment requiring bigger cooling and drying tunnels that make the whole plant very long both physically and in process time. It is necessary to balance the savings in labour which can be obtained with an in-line operation against the cost

of plant that is idle for some of the time when other products are being baked. Also one must consider the inefficiencies that occur if one part of a long plant gives trouble necessitating complete stoppage with staff idle followed by difficulties with renewed start-up. Arrangements are sometimes made to use a secondary process plant fed from different ovens by means of alternative conveyor systems. This may allow an optimisation of plant and balance to overall labour requirements. It is unusual to have the secondary process plant mobile to be located on alternative plants.

It will be appreciated that additions to a basic biscuit will always reduce the final precision of size or weight of the product. Thus, packs of creamed biscuits will always show greater weight variation, on a count basis, at the wrapping machine than if the baked product had been packed without further processing. Secondary processes require special process control attention not only because of the inherent variations that are experienced but also because the materials added, such as chocolate or fat cream, are usually more expensive weight for weight than the base biscuits.

The physical length of production plants with in-line secondary processing, increases factory communication problems associated with process and production control. Decision-making with respect to start-up, shut down and adjustment of successive machines can be greatly aided with electronic equipment such as television cameras, data logging with visual display screens and, of course, automatic control loops. It is difficult to generalise on these devices and aids because there are so many combinations of variables, but techniques of control should be considered in great depth at the design stage of long multi-process plants.

Most manufacturers separate secondary processes in their factory at least until demand makes it economic to invest in specially integrated plant. Handling and storage of product between stages necessitates consideration of techniques and facilities that will protect against breakage and spoilage due to temperature or moisture pick-up. Baked products at low moisture contents are very hygroscopic so it is most important to preserve freshness by storing them in well-sealed containers or in specially conditioned rooms. Reusable containers are prone to damage resulting in lids not fitting well.

Moisture pick-up from the atmosphere is surprisingly rapid as Fig 41.1 shows. It will be seen that exposure for even one hour may result in a biscuit which has significantly less crisp eating characteristics.

Biscuits that are transported around in tins can become marked where they are in contact with the metal (paper linings will prevent this) and crumbs, creams, chocolate, etc., will soil the container making it necessary to do some cleaning to prevent contamination with later products.

It is very common to see casual attitudes in respect of protection of trayed-up stock. Maintenance of the containers can be a problem if insufficient attention is given to the size and design for optimum use and handling.

41.2 Sandwich creams

41.2.1 Types of creamed products

Creamed sandwich biscuits occupy a significant place in the world biscuit market. Typically, two identical biscuits (the shells) contain a layer of sweet or savoury fat cream (Figs 41.2–41.5). There are many variations on this basic type. For example,

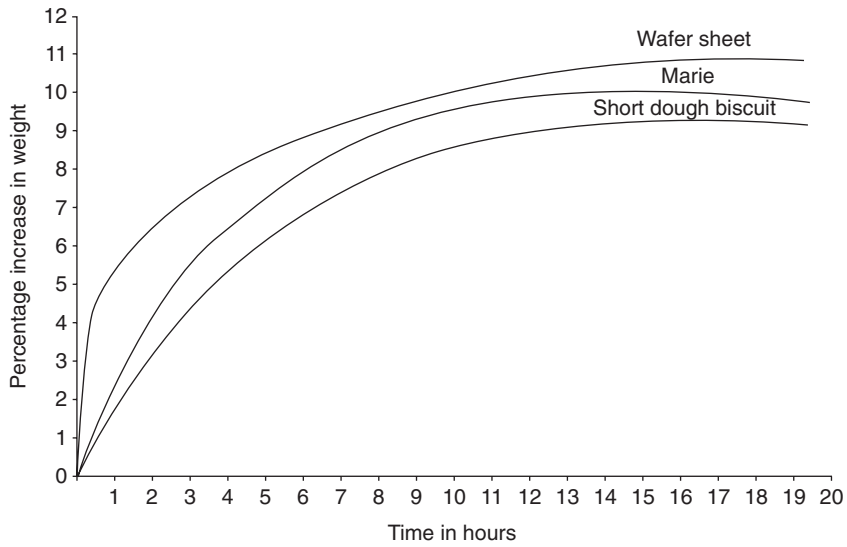


Fig. 41.1 Typical rate of moisture pick-up of biscuits in an atmosphere of about 70% RH.



Fig. 41.2 Bourbon biscuits. Reproduced by kind permission of Sainsbury's Supermarkets Ltd.



Fig. 41.3 Aymorito biscuits.



Fig. 41.4 Cheese sandwich biscuits.



Fig. 41.5 Custard cream biscuits. Reproduced by kind permission of Sainsbury's Supermarkets Ltd.

the shells may be dissimilar in shape or colour and one shell may have a hole (or holes) through which the cream can be seen or in which jam is deposited. Creamed sandwich biscuits may be enrobed with chocolate to form a count line (a product that is wrapped and sold individually) or they may form the centre of a moulded chocolate bar. The sandwich may be formed with wafer sheets in which case it may have multiple, two or more, layers of cream between wafer sheets. The same type of cream may be deposited on a biscuit base but with no topping biscuit followed by chocolate enrobing.

The cream offers extensive opportunities for variations in flavours, colours and improved acceptability of a biscuit. The weight of cream is typically around 30% of the creamed sandwich, but amounts within the range 20–36% can be found. In general, the larger the biscuit the lower the percentage of cream. Wafer biscuits with two or more layers of cream are usually much richer, about 70% of cream by weight. As will be explained later, the quantity of cream is related to its density and the hardness of the biscuit shells used to make the sandwich.

41.2.2 Composition of the cream

In sweet creams the major ingredients are sugar and fat. The nature and quantity of fat is paramount for determining the characteristics of the cream. Whether emphasis is given to having low or high percentages of fat in the cream depends on the relative costs of fat and sugar and also on the nutritional information that may be displayed on the wrapper. It is usual to use a recipe which has around 30% fat in the cream, but levels as low as 23% and as high as 45% are found. The sugar, sucrose, should be in a powdered form with few, if any, large crystals. When eaten the sugar should not be gritty in the mouth and the smaller the particle size the

more readily it will dissolve. However, there must be a balance as the finer the particle size, the more fat is required to give a desired consistency for cream sandwiching.

Flavouring materials such as skimmed milk powder, fruit acid (citric, tartaric or malic), cocoa powder and natural or synthetic flavours may be added to the base cream. Natural or permitted artificial colours also add very significantly to the attraction and often 'point' a flavour. By this is meant that if the cream is coloured appropriate to the flavour involved, there is more conviction about the taste than if the basic flavour level is increased. White, uncoloured, creams require the consumer to think more about the flavour present.

There is often a concern that the cream is very sweet. Dextrose monohydrate may be used as a partial substitute for sucrose. It has the attractive quality of giving a cooling sensation when dissolved in the mouth and it is also less sweet than sucrose. It may be less expensive than sucrose. Starches such as corn, potato and rice have been used as fillers and cream 'driers', but they do not generally improve the cream flavour, texture or sweetness. In the USA the style is for softer creams which use softer fats and some starch. The cream is more pliable, very stable in consistency as the temperature changes, not so attractive to eat and, during processing, very difficult to pump.

There are certain similarities in the consistency of biscuit creams and chocolate since they are both fat/sugar mixtures. The important features are the effects of moisture and emulsifiers. Small additions of water cause a considerable increase in consistency which may or may not be desirable. The use of lecithin as an emulsifier, at a level of around 0.2% of the fat weight, reduces the consistency. Lecithin aids the mixing of the cream and the effect of moisture is mentioned because it is often convenient or desirable to add colours as aqueous solutions. Powder colours (lakes) are much more expensive and, in the average cream mixer, more difficult to disperse uniformly.

The fat demands some detailed consideration because it affects not only the eating characteristics of the creamed biscuit, but also other important aspects of process and quality. The requirement is that the cream in the sandwich should be firm at ambient temperature. This is from the point of view of maintaining the biscuit in the shape that is desired, and so that as the biscuit is broken or bitten the cream does not squeeze out. The harder the biscuit, the harder should be the cream. As the biscuit is chewed the fat in the cream should melt rapidly to release the sugar and other ingredients giving maximum flavour sensation. There should be a minimum of unmelted fat at blood temperature otherwise an unpleasant greasy film will remain on the roof of the mouth. Between about 20°C (ambient) and 37°C (blood heat) there should be a large change in fat solids. The types of fat that best exhibit these characteristics are coconut and palm kernel oils and their hardened derivatives. These fats have very steep melting curves. The rapid melting characteristics present difficulties in cream handling and processing. They result in large changes of consistency with little temperature change so that the mixing and ambient temperatures in the factory can be important. Some manufacturers ease the problem by using winter and summer blends of fat in their creams, but there is often confusion about whether this is to suit the customer who eats the biscuit or the cream sandwiching process! Blood heat remains the same throughout the year and with centrally heated homes ambient conditions for the consumer in temperate climates do not alter very greatly. There are also the problems of knowing when hot summer

weather can be expected and how long the packets of biscuits will be in the shops before purchase.

Another factor which affects the firmness of a fat-based product is the degree of plasticity of the fat. If the fat has been allowed to solidify passively from a fairly fluid condition, it will be much harder at any given temperature than if it has been cooled under agitation. This is because crystals formed are broken by the movement. Since the handling of cream for sandwiching involves much agitation, it follows that the smaller the temperature differential between the cream at the time of handling to the ambient when the biscuit is eaten, the less firm will be the cream at a given fat content. The higher the fat content the firmer will be the cream under these conditions. It is necessary to have a certain minimum change in fat solids between the time of creaming sandwiching and when the biscuit is eaten otherwise there will not be enough keying of the cream to the biscuit surface resulting in the shells falling away from the cream. Therefore, as with so many processes involved in biscuit manufacture, it is best to make as much provision as possible to keep cream ingredients and machine temperatures constant from one season to the next.

In countries with high ambient conditions the choice of fats for cream is more restricted as a suitable hardened palm kernel oil will have a significant waxy tail which will be unpleasant when eaten. It is therefore common for biscuit manufacturers in hot countries to use the same fat for biscuit creams as is used for doughs.

Most cream sandwich biscuits have a thickness of cream that is readily seen between the shells. Economic trends have resulted in some sandwiches having less cream, to an extent that the filling appears more like a layer of adhesive than a true sandwich. In these creams it is possible to use a fat that has a much slower melting curve with inherent advantages in machinability of the cream. It is felt that moves in this direction while simplifying the technology of control are to the detriment of biscuit quality.

Cream formulations sometimes include rework material, that is, broken or misshapened biscuits which have been ground up. This tends to 'dry' the cream and give it a browner or greyer colour. The practice is not recommended, but it is economically expedient in some cases, particularly for wafer creams where the cutting of the creamed books always results in a lot of cream-rich 'waste'. An exception to this situation is in the preparation of savoury creams. Here the use of sucrose as the filler is precluded and palatable non-sweet alternatives are not many. Ground (savoury) biscuits offer a possible filler along with lactose, whey powder and maltodextrins, all of which have low sweetness values and blend well with cheese powders, etc.

Creamed biscuits are common components of packs of assorted biscuits. In these packs there may be a problem of flavour migration during storage. Flavour ingredients, whether natural or synthetic, are very volatile. It is possible to obtain flavours which have been flavour 'locked' in some way, such as microencapsulation, so that their smell is greatly reduced but when eaten the flavour is released in the mouth by mastication or dissolution in water. These special flavours are, of course, more expensive, but their use in biscuit creams is worth considering should it be necessary to improve the quality of biscuits in assorted packs.

41.2.3 Methods of cream application

The operation of biscuit cream sandwiching was originally entirely manual involving the stencilling of the cream onto a base followed by the addition of a top. The stencil

was cut in a metal sheet of thickness appropriate to the thickness of the cream required and the shape of the stencil was appropriate to the size of the base biscuit. The base biscuit was located under the stencil hole, cream was filled and smoothed into the hole either with a palette knife or from a swinging hopper and the biscuit was then taken away with the cream adhering (see Fig. 41.6). The stencil plate was maintained at a temperature slightly higher than the cream to reduce preferential sticking of the cream to it. The cream needed to be fairly fluid but rigid enough to maintain a shape as the biscuit was withdrawn from the stencil plate.

This system was mechanised and creaming machines are still sold which operate on the stencil principle. They are usually intermittent in action allowing location of the biscuit beneath the stencil, filling of the stencil hole and then removal of the biscuit to a 'topping' station where the top biscuit is pressed on to make the sandwich. Although this type of machine is relatively slow in action, the system allows a second deposit such as jam to be applied on the precisely located biscuits. Stencilling requires a fairly fat-rich cream to maintain the desired fluidity. As the stencil plate thickness is fixed, the only means of weight control is by changing the density of the cream. This is not easily achieved with most mixing equipment.

A second method of cream application is by means of multi-nozzled depositors of the cake batter type. The depositor head may lower and travel with the biscuit in a continuous motion or the head may be fixed and the biscuits moved intermittently. This system relies on the deposit breaking away from the nozzle as the latter is raised so the cream must be quite fluid and the biscuit relatively heavy if clean operation is to be achieved. Suction systems have been devised to hold the biscuits down where necessary, but this is an engineering complication. The topping arrangement is similar to that for the stencilling machine. Alternatively, rows of biscuits are presented to the depositor head in such a way that cream is placed on alternate rows and a suction mechanism picks up the other rows and places them onto the creamed bases. This is the arrangement for the Cookie Capper machines and others like them. Clearly the biscuits in the rows for receiving the cream have to be inverted and those used for the tops are not (see Fig 41.7).

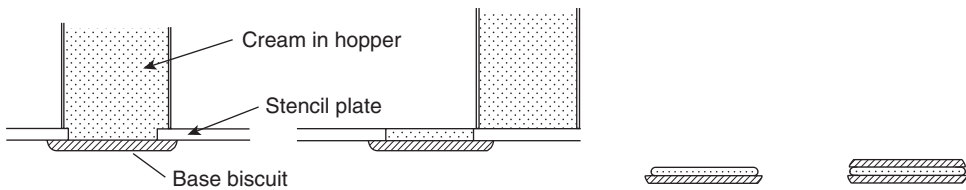


Fig. 41.6 Sequence for forming a cream sandwich by stencilling.

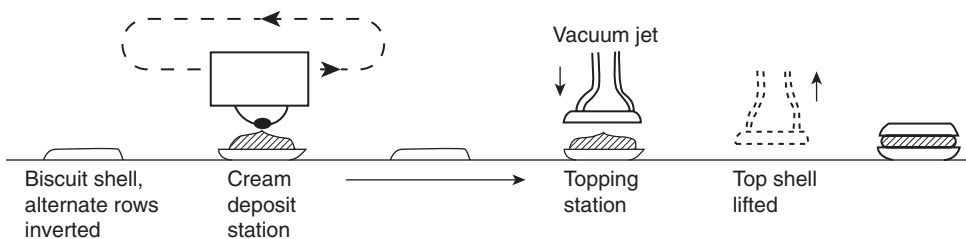


Fig. 41.7 Sequence for forming a cream sandwich by depositing and capping.

Stencilling and depositing machines usually require the presentation of biscuits in rows on a conveyor up to one metre wide. Although this arrangement is possible as an in-line system (as for the Cookie Capper machines), it is usual to feed the biscuits from magazines providing the appropriate number of lanes. These magazines are hand-filled and an exactly similar magazine is required to provide the biscuits for the tops of the sandwiches. Speeds of up to 45 and 60 rows per minute are typical for stencilling and depositing machines respectively. The wide (row type) arrangement is ideal for cooling and subsequent presentation to a chocolate enrober.

In order to handle stiffer (lower fat content creams) and to increase production speeds, there was a development of extruded and wire cutting machines to meter and deposit the cream. Although the systems are sometimes referred to as stencilling, this is not accurate and there is a clear difference from the true stencilling arrangements. Cream from a hopper is pushed out of a nozzle of appropriate shape, the cream is located onto the biscuit base and it is then severed from the nozzle with a taut wire. Machines of this type operate in continuous motion which extracts a biscuit from a magazine feed onto a pinned chain. The biscuit is transported under a rotating nozzle arrangement such that as a nozzle and biscuit coincide there is an extrusion of cream which presses onto the biscuit and is then cut off with the wire. The creamed base moves onwards to a topping station where the pin pushing the biscuit extracts a top biscuit and the two are pressed together under a wedge or roller (see Fig. 41.8).

Most machines of this type are based on the original designs by the Peters and Quality companies of the USA. They apply cream onto only one to four lanes of biscuits, but at speeds of up to 800 biscuits per minute per lane. Lane multiplication devices allow a doubling, or more, of the number of lanes after they leave the machine for the purposes of biscuit cooling. Penny stacking can be arranged onto the cooling conveyor. It will be appreciated, however, that this arrangement means that longer narrower cooling conveyors are required than those that follow the stencil type machines.

A major problem of these high-speed machines is the potential damage to the biscuit shells as they are stripped from the magazine feeders onto the chains that carry them under the cream depositing position. Normally the stripping is by pairs of pins fixed to the chain but some machines use a belt stripping unit. In this a specially profiled belt with notches passes under the biscuit magazine and both supports the column of biscuits and takes one biscuit at a time. The feeders may or may not invert the biscuit before it is deposited in front of pins on the chain of the sandwiching machine. This unit is a development of an earlier invention offered by the Tenchi Sangyo company of Japan where a notched drum rather than a belt was used to strip and deliver the biscuits.

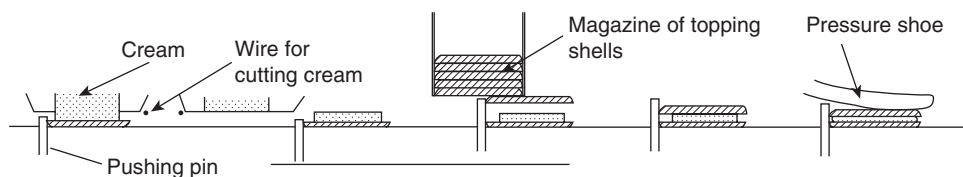


Fig. 41.8 Sequence for forming a cream sandwich by extrusion and wire cutting.

These Peters type machines can also deposit jam (provided the consistency is suitable) and some can deposit two creams, or a cream and a jam, as a co-extrusion. The interest in the co-extrusion of jam is that there is some protection to delay the migration of moisture from the jam into the biscuit and soften it. This matter is mentioned in Section 41.4.2.

Maintenance of the Peters type machines is critical as it is easy for the cream, an abrasive material because of the sugar, to get onto the conveyor chains and cause wear. As the chains wear they elongate and the precision for positioning the biscuits is lost. Haas Hecrona offer a machine where the chains do not pass near the cream depositors so are relatively well protected from soiling by cream.

The Cookie Capper family of machines work on full-width conveyors as has been mentioned above and Baker Perkins has a full-width creaming machine of the Peters type with as many tracks as there are lanes of biscuits on the oven band. Only every other biscuit is creamed, the alternate biscuits being used to provide the top biscuit of the sandwich. This machine can run at baking plant speeds producing up to 100 rows of creamed biscuits per minute and obviates the handling needed to fill feeder magazines and presents the biscuits for cooling and subsequent enrobing in an ideal arrangement. It is, however, very inflexible being limited to a given number of lanes of biscuits (this also defines the size rather precisely) and is therefore best for dedicated production plants where only one type of product is made.

The extrusion, with wire cutting, creaming machines as just described, not only handle firmer creams, but also allow some weight adjustment at the point of cream application. A disadvantage is that at the very high speeds involved with the two- or four-lane machines, there is frequently damage to the biscuits as they are taken from the feeding magazines. Very fragile or irregularly shaped biscuits, also oval shapes, are difficult or impossible to handle efficiently. The lane multiplication and stacking of sandwiches with soft cream may result in distortions that may give difficulties for packaging after the cream is set.

41.2.4 Mixing and handling of creams

Cream may be mixed on batch or continuous systems. The difficulties of handling soft, sticky, messy masses of cream have encouraged more interest in continuous mixing systems for biscuit cream than for dough, although many of the problems are similar. The batch systems usually commence with block or pumped quantities of plasticised fat. Bulk handling of plasticised fats with steep melting curves needs to be critically controlled as small changes in temperature give significant changes in consistency. When the sugar and other ingredients are added, the temperature of the whole is lower than that required in the mixed cream. By a beating and blending action the mass is slowly warmed and there is incorporation of air. At the end of mixing the cream should have a desired temperature, density and consistency. It is difficult precisely to control all these three features in relation to one another (though consistency is ill-defined) unless close attention is given to the temperatures and qualities of the ingredients. The ranges in properties that are acceptable depend on the type of creaming machine and the type of fat being used. It is advisable regularly to monitor the cream properties and to relate variations with creaming machine performance and biscuit weight control.

Cream densities vary from 0.75 to 1.15 g/cc. In general, the low density creams are used on depositor type machines and the highest densities on extrusion wire cut

machines. However, cream that has to be pumped any distance to the creaming machine will be subject to considerable pressures and when this pressure is released it is difficult to maintain a homogeneous aerated cream. The lower the cream density the greater will be the volume for a given weight per sandwich. The amount of cream will therefore appear more to the consumer.

Many creams are difficult to discharge from a batch mixer, will not flow into pumping systems and have to be man-handled. There are, therefore, labour and hygiene problems. Continuous mixing systems usually commence with warm fully melted fat and the mixer also aerates and pumps the cream to the appropriate creaming machine. This means there is a need for fat cooling (compared with warming in batch mixing) which requires a scraped surface heat exchanger as part of the system. Metering of icing sugar on a continuous basis is very difficult as big changes in density occur due to static electricity charges in the fine dry powder. This precludes volumetric metering unless much attention is given to powder preparation. The normal procedure is to form a premix of sugar and liquid oil and to pump meter this suspension to the continuous mixer. Other difficult-to-meter ingredients such as milk powder and rework can be included with the premix.

The continuous mixer is very similar to a fat chiller and plasticiser and arrangements must be made to accommodate the phenomenon of fat super-cooling. The system pressures required to convey the fat to the creaming machines and back around a ring main can give uniform aeration and density problems. This is because the air bubbles, which are very small under pressure, enlarge and coalesce as the cream is released onto the creaming machine hopper with its agitator. Thus most of these cream systems deliver only high-density creams to the sandwiching machine.

Pumping a mixture of fat and sugar presents particular wear and oil-seal problems due to the abrasive nature of sugar. It is normal to protect these bearings and seals by applying edible oil under pressure into the seals to prevent the leakage of the cream mixture.

It is usually best to keep the continuous mixer working at an even speed and to supply the prepared cream in a ring main with take-off points at each creaming machine. The ring main must return to a feed tank that contains all the cream ingredients. Here it must be completely melted prior to reprocessing. If this is not done the quality of cream will vary in its fat crystal and aeration structure.

Cleaning of such a cream system requires some thought. Cleaning will not be necessary if the same flavoured and coloured cream is always used; it will suffice to increase the pipe jacket temperature at the end of a production run and to drain out into a holding vessel. However, if significant changes are required, the system should be washed through with very hot water and allowed to dry. Alternatively, one cream can be followed by another by introducing a 'mole' to clear completely the pipework ahead of it.

41.2.5 Creamed biscuit cooling

In most cases creamed sandwiches are held in a cooling tunnel to set the cream before the biscuits are packed or further processed. Sometimes no cooling is carried out and the sandwiches are immediately and mechanically fed to wrapping machines. The latter arrangement saves space and time, but there is much risk of product spoilage due to the squeezing out of the cream. Only firm low-fat type creams, or biscuits containing very little cream, are suitable for handling without cooling. In

some cases the creamed sandwiches are not cooled and are manually fed into wrapping machines with folded end seals secured by pressure. In these cases not only is there a great likelihood of distortion of the sandwich by manual handling but the biscuits are not rigid enough to permit satisfactory end sealing pressure. The packs are therefore imperfectly sealed with inevitable short shelf life potential.

Sandwiching machinery suppliers have recognised the problems of handling non-cooled sandwiches and there are some machines which incorporate biscuit collation and mechanical handling directly into wrapping machines. Where cooling is carried out, this should be minimal to effect a desired firmness of the cream on the hottest day. Cooling air temperatures should be adjusted so that the biscuits are not taken to below the dew point otherwise condensation will spoil the biscuit shell quality. It is best that the biscuit shells should be as cool as possible before creaming, as cooling of creamed sandwiches is a slow process.

41.2.6 Splitting of creamed sandwiches

Creamed sandwiches should not fall apart (known as splitting) during storage. If they do, the reason may not be obvious. Satisfactory keying of the cream to the shell is achieved by a combination of a sufficiently rough surface into which the cream can be pressed to form a mechanical keying and a migration of melted fat from the cream into the surface of the biscuit prior to it crystallising on cooling. If these situations do not occur to a sufficiently great extent the adhesion may be weak. Thus either the cream should be warmer at depositing, or the biscuit shell should be warmer than the cream (however, see above in relation to biscuit cooling). Good pressure following topping of the sandwich helps as this presents a great area of contact between cream and biscuit.

Biscuits are hygroscopic and when they take up moisture they expand. If this expansion should be marked and the cream is hard (as compared with plastic), separation may occur at the biscuit cream interface. A well-aerated cream is more plastic and hence more tolerant to this situation, but it is best not to allow biscuits to pick up moisture.

The most elusive form of splitting is that due to fat incompatibility. In some cases, mixtures of two different fats display physical characteristics different from either of the constituents. The phenomenon is known as eutectic formation. For example, a steep melting cream fat, solid at ambient temperature when mixed with just a little dough fat is much softer than expected at that temperature. Should the eutectic which occurs at the cream/biscuit interface, combined with the physical nature of the biscuit surface, be so pronounced as to prevent satisfactory crystal growth in the fat or allow a migration of fat away from that area, the bond will be weak and splitting may result. The problem is reduced if the fats used in the biscuit and cream are as compatible as possible. Having made this point, because it was a major problem once encountered and solved by the author with creamed puff biscuits, it must be understood that it is usual for dough fat and cream fat to be dissimilar and, therefore, non-compatible. Luckily, despite this, splitting does not normally occur!

41.3 Icing

Icing is applied to the biscuit as a thick aqueous suspension. It is usually coloured and may be flavoured, although this is usually very mild. After application the

coating is dried. The result is a hard finish which greatly enhances the appearance if not also the eating qualities of the biscuit (Figs 41.9 and 41.10).

41.3.1 Methods of application of icing

The drying process is slow so it is unusual to have biscuit icing as an in-line secondary process. A drying tunnel would have to be very long to accommodate even a short biscuit oven. Thus, biscuits to be coated or 'iced' are magazine fed and the loading of the magazines is by hand. Normally a flat icing is applied as a coating on the underside of the biscuit only, like half-coated chocolate biscuits, or it is stencilled on in a more or less distinct shape. If an aerated icing mixture is used it is possible to pipe (deposit) the icing in which case deposits with high relief can be produced.

Many other techniques have been used such as contact spreading in the manner that wafer sheets are creamed, wire-cut deposits by using modified sandwich creaming machines, and spraying to produce more of a glaze than in coating and screen printing. These systems are rather specialised and have usually been developed by innovative plant engineers in individual factories.

Our principal concern here is with the icing of normal biscuits, usually of a short dough base. The most common method of coating biscuits with flat icing is with an arrangement very similar to a chocolate enrober for half coating. Biscuits are fed onto an open wire mesh conveyor or onto a system of fine ropes of nylon or cotton



Fig. 41.9 Café Noir.



Fig. 41.10 Party Ring biscuits.

which is drawn through a bed of icing mixture so that the base and edges of the biscuit are coated. The biscuits are then turned over as they leave the icing machine so that the icing may be dried without being in contact with a conveyor.

If a stencilling arrangement is used, similar to that described for biscuit creams, it is not necessary to invert the biscuits after coating and it is also possible to apply more than one colour at once in the form of stripes. These coatings then may be further decorated with fine lines of icing trickled over the surface or drawn into simple patterns with reciprocated wire fingers. All flat icings are rather fluid and sticky so care is needed to make sure that the biscuit conveyors do not become soiled resulting in patches of icing adhering in the wrong places.

A double-icing technique, where a flat coat is dried and then a further deposit is stencilled on in a fine pattern, allows the production of intricate designs of animals, flowers, letters, words or even company insignia. However, it will be appreciated that as this involves a double drying operation, the whole production process is rather long.

There are not many biscuits with piped icing deposits but Iced Gems (very small round hard sweet biscuits with a large deposit of icing in various colours) is a well-known traditional variety which is very popular with children (Fig. 41.11). Because the biscuits are small and relatively light they must be held down, usually by air suction, after they have been rowed up for presentation to the icing deposit nozzles. Several different colours are deposited at once so that the biscuits, after drying, can be collected together en masse and jumble packed as a variety.

41.3.2 Composition of the icing

The icing is simply a mixture of very fine icing sugar in water with some gelling material, such as gelatin or pectin, to give it some 'body' and increased viscosity. The



Fig. 41.11 Iced Gem biscuits.

gelatin should be used at about 1% of the sugar weight, but the quantity is related to the water needed to give the icing the correct viscosity for the machine used for coating or depositing.

The procedure is to dissolve the gelatin in 50–75% of the water in the recipe at a temperature not exceeding 60°C. The gelatin should be given plenty of time to hydrate completely, that is 15 minutes or more. The sugar is then mixed in gently, followed by any colourings, flavours and acids that may be required. The mixture may be beaten to achieve some aeration to make it thicker, but for flat icings it is best to have no deliberate aeration as the bubbles will spoil the surface of the icing on drying. The mixture should be used warm, not less than 21°C otherwise the gelatin will start to set and give increased viscosity. The viscosity should be controlled by the amount of water not the temperature.

41.3.3 Drying of the icing

Biscuits are very hygroscopic and uptake of moisture softens them (the major cause of staling) and causes them to expand. When a water-based material is added, as when they are iced, it is essential that drying proceeds without delay so that moisture penetration is minimal and dimensional changes do not cause cracking in the icing at the later stages in drying. The maximum temperatures in the drier should be 80°C as above this bubbling and cavity formation will be severe giving a poor structure to the icing and weak adherence of the icing to the biscuit. (The formation of these cavities is as a result of the large increase in vapour pressure of water at higher temperatures. The matter is discussed in Chapter 39.) The drier should have a gradually increasing temperature profile so that skinning and good gloss occurs at first followed by progressively more intense drying. A good turbulent air flow with controlled humidity is desirable as in any standard drier.

The drying time will be between 30 and 50 minutes, depending on the moisture content and thickness of the coating. After the initial setting has occurred it is possible to transfer the biscuits from one conveyor to another without much trouble. In order to reduce the floor space of plant, multi-layer driers may be used. Drying not only reduces the moisture content of the icing to a level that is acceptable for long shelf life but also results in sugar crystal growth giving a hard set. The icing is a suspension of fine sugar crystals in a saturated sugar syrup. The suspended crystals must be many and small to ensure that when further crystallisation occurs a fine interlocking structure is formed. By using small additions of glycerine the hardness of the dried coating may be reduced as required; 0.2–0.4% based on sugar weight is usually adequate. The prolonged drying will tend to remove volatile materials such as flavours in the same way as does baking. Thus, as mentioned above, the flavour of icings is not usually a significant aspect of their quality.

41.4 Jams, jellies, caramels and marshmallows

Biscuits with any of these confections are relatively insignificant in the total market. However, sugar syrup-based materials like these contribute strongly to the overall texture and flavour of products and there has been much more interest in using them and fruit pulps in recent years. The reasons for this are, on the one hand, that fruit materials are regarded as 'healthy' and, on the other, there is more

interest in soft or chewy products and particularly those with both soft and crisp elements.

For the purposes of this chapter the confections have been grouped together because they are all sugar solution-based products which present softening problems when in contact with biscuits. Careful compromises in quality must be made to ensure that the biscuits do not soften too much by migration of moisture from the confection and that the sugar in the confection does not crystallise (becoming fudge-like). The toughness of the confection should be controlled and be related to the biscuit of which it is a part. In view of the relatively low importance of these secondary process materials, details of their manufacture will be rather brief, concern being centred on the principles and problem areas, but, as in other chapters, references are given which will aid those wishing to understand the technology in more detail.

41.4.1 Water activity, a_w , and its importance for biscuits

It is necessary to discuss briefly the concept of water activity, a_w . It is a fundamental property of any substance that it will lose or pick up moisture until it is in equilibrium with the atmosphere around it. The amount of moisture in an atmosphere compared with the maximum that there could be at any given temperature is known as the relative humidity (RH). This is expressed as a percentage, e.g., 60% RH.

A substance that is in equilibrium with an atmosphere of 60% RH is said to have a water activity of 0.6. That which is in equilibrium with an atmosphere of 100% has an a_w of 1.0. If a substance that has an a_w of 0.6 is placed in an atmosphere of 100% RH it will pick up moisture until its a_w becomes 1.0. If now it is returned to an atmosphere of 60% RH it will lose moisture until the a_w returns to 0.6.

Biscuits typically have an a_w of about 0.25, and they will not be crisp if this a_w is above 0.35. It is very unusual for the atmosphere in temperate climates to be less than 40% RH so fresh biscuits will always pick up moisture if left exposed. Knowledge of just a product's moisture content does not tell one whether that product left in an atmosphere of given humidity will lose or gain water.

It is not of great interest to biscuit technologists but the a_w of a food product is important to know as it affects the potential for food spoilage by microorganisms. Moulds can grow in contact with food at a_w above 0.75 but most pathogenic microorganisms need a_w above 0.85. Such values are almost never found with biscuits.

It is almost impossible to calculate the a_w of a food product from knowledge of its composition and moisture content because it is so complex. However, the relationship of simple solutions to water activity can be calculated according to Raoult's law. This states that the water vapour pressure over a solution is related to its gram molecular concentration. The higher the gram molecular concentration the lower will be the water vapour pressure, the lower will be the water activity. In a simplified example, the molecular weight of dextrose, $C_6H_{12}O_6$, is 180; that of sucrose $C_{12}H_{22}O_{11}$, is 342; that of salt, sodium chloride (NaCl), is 58. If 50 g of each of these substances is dissolved in 100 g of water the gram molecular concentrations will be: dextrose solution = 0.28; sucrose solution = 0.15; salt solution = 0.86. It can be seen that the gram molecular concentration is highest for the salt so this will have the lowest a_w .

A knowledge of water activity is important for biscuits because it affects the crispness and it will predict the movement of moisture if two components are placed

together (not necessarily in contact but in the same atmosphere) such as biscuit and jam or marshmallow or butter and a cracker. Raoult's law prompts us to consider the gram molecular concentrations of materials like jam, marshmallow and caramel.

The change in a_w as a product increases in moisture content is known as the absorption isotherm and as it loses moisture the desorption isotherm. It is often the case that the a_w is higher at a given moisture content as the product gains water than as it loses water (see Fig. 41.12). The a_w also usually increases as the temperature rises at a given moisture content (see Fig. 41.13). Figures 41.14 and 41.15 show generalised isotherms of biscuits and sugar solutions.

It should be remembered that it may take a long time for materials with different water activities to equilibrate. Labuza [9] reports that crackers starting at 3% moisture when held in an atmosphere of 75% RH at 25°C came to complete equilibrium

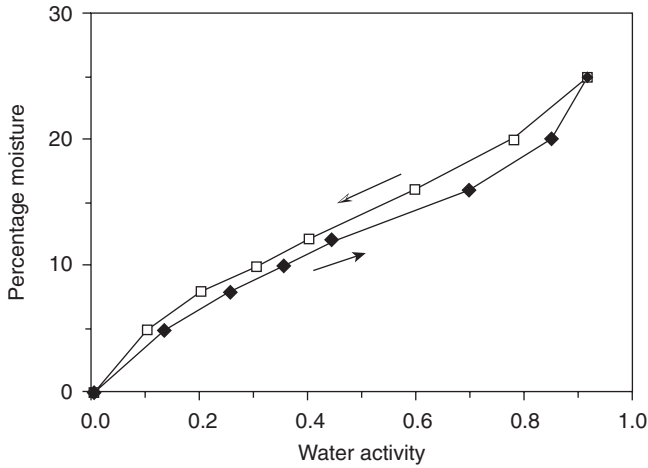


Fig. 41.12 Absorption and desorption isotherms (an example).

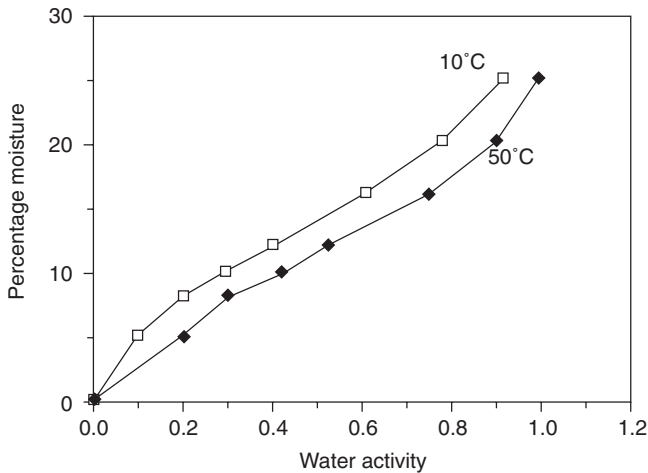


Fig. 41.13 Effect of temperature on sorption isotherms.

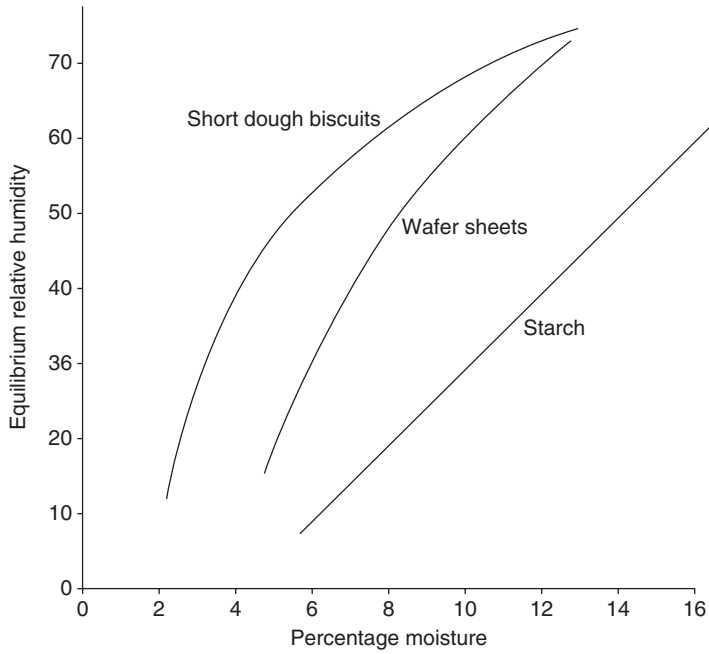


Fig. 41.14 Moisture isotherms of starch and two types of biscuits.

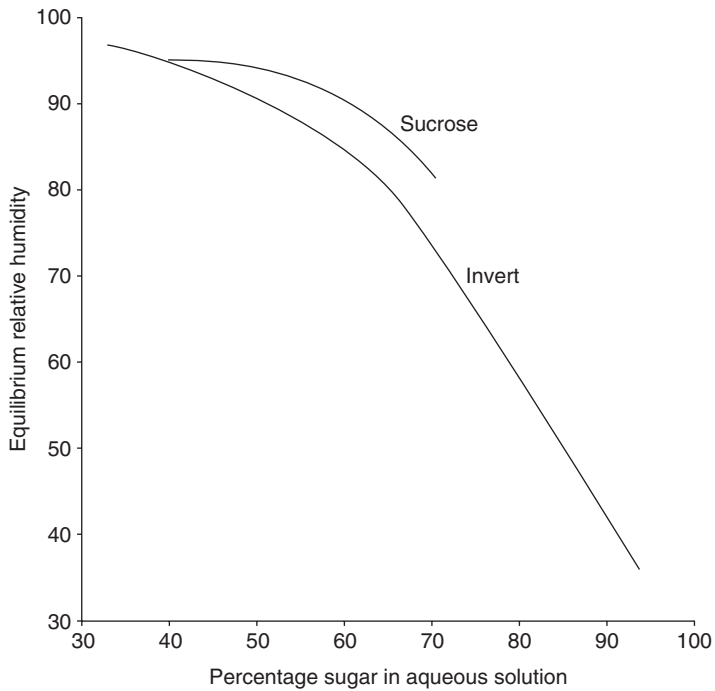


Fig. 41.15 Moisture isotherms of sucrose and invert syrups.

at 12% after 10 days. However, as is shown in Fig. 41.1 biscuits very quickly pick up enough moisture to make them lose their crispness and therefore to become much less acceptable for eating.

41.4.2 Jams and jellies

There is a range of biscuit products which include jam either deposited as a result of secondary process or added to the dough piece before baking. Included in products formed as a result of secondary processing are

- types where shells are sandwiched together with a layer of jam
- jam is deposited in the centre of a ring of cream before or after cream sandwiching
- jam is deposited on a base of sponge prior to half coating with chocolate (e.g., Jaffa Cakes; see Fig. 41.16)
- jam is injected into a soft baked dough before cooling (e.g., Jam Lebkuchen).

Products where jam is introduced before baking include

- fruit-filled extrusions (e.g., Fig Bars, Fig Newtons; see Fig. 41.17)
- sponge boats (where jam is deposited on the centre of a batter deposit)



Fig. 41.16 Jaffa cakes.



Fig. 41.17 Fig rolls.

- various jam toppings where wire cut or deposited dough pieces are garnished with a small deposit of jam
- jam pouches where dough is folded over a jam deposit (e.g., Pop Tarts which are designed for toasting before eating).

Jam can be considered as a three-dimensional network of pectin with syrup held in it. The firmness of the jam is related to the amount of pectin present and the concentration of the sugar syrup which affects its viscosity. Jam is distinguished from jelly principally because it has fibrous or recognisable fruit particles suspended in it. If these insoluble solids are removed a clear jelly is obtained. However, jelly can be made from fruit juice or from commercially prepared pectin and added flavours. In most countries there is a legal requirement to use a certain minimum amount of fruit material in the product if it is described as jam, but jellies, especially if they are called fruit-flavoured jellies or merely jellies, need not be made from any fruit base material.

The fibrous pieces in jam can present production problems if the jam is to be deposited through small nozzles in precise quantities so more and more jellies are used in biscuit manufacture. A jelly made from commercially standardised pectin, sugar, invert sugar or glucose syrup, flavour and colour can be manufactured to close tolerances with a minimum of skill and laboratory control. Recipes for fruit-based jam or jellies have to be adjusted to compensate for variations in fruit quality. This requires a considerable degree of skill and experience on the part of the production staff.

Traditionally, bakery jams and jellies have been purchased from specialist suppliers against specifications, but there has been difficulty in defining the viscosity, spreadability, setting characteristics, etc., required for a particular application. Much work has been done to investigate test methods and effects of recipe on jam quality by the British Food Manufacturing Industries Research Association (BFMIRA), [14–16]. Also, with the greater understanding of principles, more biscuit manufacturers have decided to make their own jellies (and jams sometimes) so that handling and control is improved. It is proposed, therefore, to outline the characteristics required of jams and jellies to be used with biscuits so that either they can be purchased with better understanding or, alternatively, they can be made in the biscuit factory.

By a combination of low pH (around 3.0) and high sugar concentration (67% and above) microbial growth is prevented or greatly retarded at ambient temperatures. This is the principle of fruit preservation involved in jam. However, sucrose forms a saturated solution of 67% solids at 20°C and the solution is not particularly viscous so if the solids are higher as a result of supersaturation some crystallisation can be expected. Addition of invert sugar (which occurs naturally in jam manufacture either because it is derived from the fruit juice or because the sucrose hydrolyses as the jam boils at low pH) increases the solids content at which crystallisation occurs to about 75% at 20°C. This is why domestic jams with around 69% solids do not crystallise (see Fig. 41.18).

By using glucose syrups instead of invert sugars this crystallisation can be prevented or at least retarded at an even higher solid content in the jam (up to about 83% solids), but at these levels the jam tends to be rather tough in texture. Crystallisation is also retarded by the viscosity of the material.

Jams or jellies for use in conjunction with biscuits need to have higher solids contents than domestic jams because of problems of water activity. It can be shown

that biscuits at about 9% moisture could be compatible with a sucrose/invert syrup (jam) of 76–78% solids. This is a high moisture for biscuits and a very solid type of jam. Hence the dilemma and the need for compromise. As the biscuits draw moisture from the jam some crystallisation may occur in the jam. The smaller the mass of jam relative to the biscuit the less the biscuits will soften.

Pectin is a linear polysaccharide which has the ability to form gels under suitable conditions of sugar concentration and pH. All high solids bakery jams and jellies require slow setting high methoxyl pectin which has a rather narrow setting range between about pH 3.2 and 3.6, although under certain conditions the range is extended to pH 3.8. To reduce the viscosity of the jam it is usually necessary to handle and deposit it at temperatures of between 60 and 70°C. At these temperatures and at pH 3.4 or so, inversion of the sucrose will be occurring at a rate which will soon change the character of the jam. It is possible to heat a set jam which will redissolve the pectin and make the jam fluid and suitable for depositing but breakdown of the sucrose to invert sugars will be appreciable and result in a jam that has a strong tendency to crystallise on cooling and storage. It is better to handle a 'jam' or jelly at a higher pH, about pH 4.5 (but not much higher because the pectin will be degraded) and to add acid to reduce the pH to the

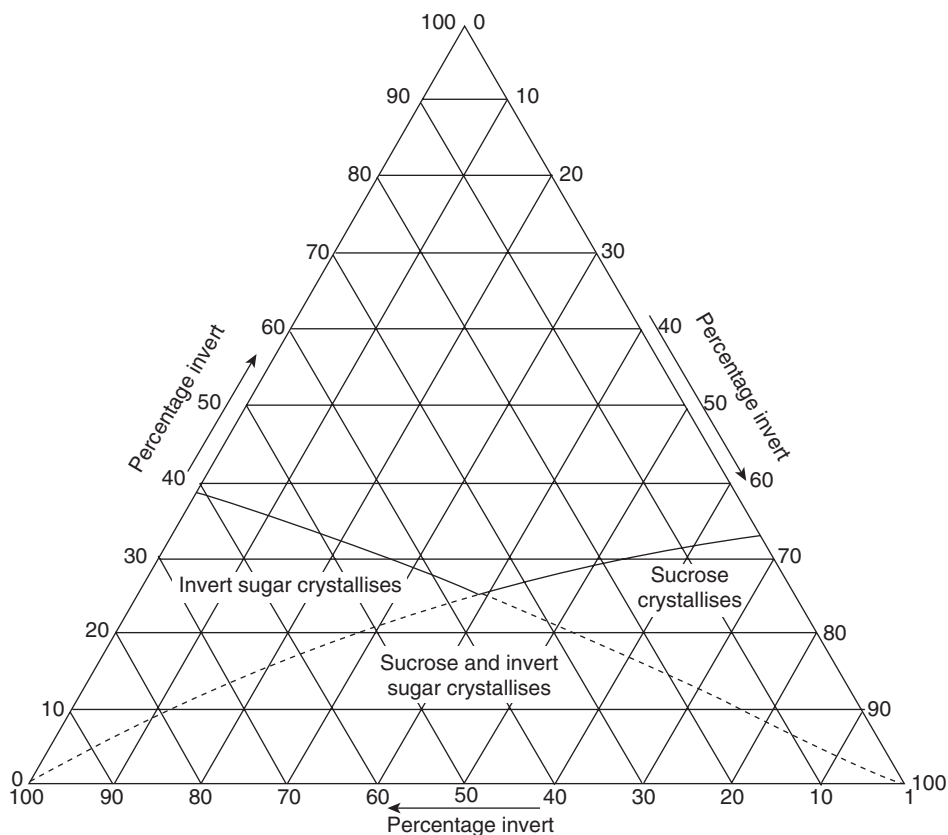


Fig. 41.18 Solubility of sucrose, invert sugar, water mixtures at 20°C.

desired level for a set immediately prior to depositing. The jam at pH 4.5 will remain in a fluid stage (at high viscosity but suitable for pumping) at ambient temperatures.

Process control of jams and jellies requires constant attention to soluble solids content, which can be checked either in-line or by sampling with a refractometer, and also acidity (pH). Refractometers are usually calibrated for sucrose solutions at 20°C (in hot countries the standard temperature is 27°C) and care should be taken that the appropriate correction is applied if other temperatures are involved. (Correction tables are usually supplied with the instrument.) pH meters are also temperature sensitive, but a temperature probe is usually incorporated to effect a correct readout. If jelly at high pH is pumped to the depositing head, acid (citric acid solution) can be mixed immediately prior to depositing and the amount that is added can be automatically controlled from an in-line pH meter. Setting is rapid as soon as the temperature falls, but even at the deposit temperature, setting will commence if the jelly contains too much pectin or there is a delay in reaching the depositor nozzles. Stringiness or a large increase in viscosity can upset the performance of the depositor.

It is possible to make jellies with gelling agents other than pectin, for example, alginates, natural gums and sodium carboxymethyl cellulose. There are special applications where these are beneficial. Also it has been shown to be possible to aerate bakery jams to stable foams, but these situations are so rarely used for biscuit applications that they do not warrant detailed consideration here.

41.4.3 Caramel

Caramel is formed as a stiff brown mass when sugar is heated to just below its melting point. The flavour is rather bitter and the colour is dark brown. However, when caramel is referred to in connection with biscuit fillings or confectionery, a toffee or butterscotch type of material is implied. These toffees and butterscotches owe their character mainly to the presence of milk, butter and certain hard fats like palm kernel oil when these have been heated together in the presence of sugar. The partial decomposition which gives the characteristic flavour is known as caramelisation.

Toffees are essentially supersaturated syrups relying on their high viscosities to prevent sucrose crystallisation. However, seeding of the cooling toffee with sugar will cause crystallisation and a fudge will be formed. The texture of a seeded toffee determines whether it is a fudge (with fine crystals) or a grained toffee (with larger crystals).

Toffees (or caramels) used for spreading on biscuit products must:

- be plastic at ambient temperatures such that they are not too short, too tough nor too hard when bitten
- have a consistency at about 45°C such that they can be spread evenly and smoothly but be short enough to allow separation from biscuit to biscuit
- have a a_w of around 0.6 such that moisture migrations will not adversely affect the eating qualities of toffee or biscuit.

Soft toffees have a moisture content of about 10% and low a_w so the moisture migration problems are not so much of a problem as with jams and jellies.

Preparation of these toffees to the desired flavours and homogeneity of the fat is a somewhat specialised procedure if between-batch uniformity is to be maintained. As with jams, most biscuit makers purchase the toffee from confectionery manufacturers, but on the other hand most toffee biscuit products also involve chocolate and this puts them into the confectionery market rather than biscuits.

Caramel wafers (Fig. 41.19) are a typical biscuit product involving toffee (with or without a layer of cream also). These are formed by spreading a film of toffee onto wafer sheets followed by topping and 'book' building as for creamed wafers. The relative humidities of the wafers and the toffee result in an appreciable loss of crispness of the wafer sheets. However, as the toffee proportion is about 70% of the product, the texture of the wafer is subsidiary to that of the toffee. For those wishing to make their own caramel toffee, recipes are given in Table 41.1 as starting points.

Process control requires a uniform composition of the toffee in terms of moisture content and consistency which results from the method of manufacture. Small variations in consistency can be compensated for at the time of spreading by alterations to the handling temperature.

41.4.4 Marshmallow

Marshmallow is a mechanically aerated foam composed of sugars in solution and including a foaming or stabilising agent. The latter may be albumen with agar-agar, but is more usually gelatin (prepared from animal sources) or Hyfoama, a proprietary product. There is now no connection with the shrubby flowering plant called Marshmallow, but the name derives from the past when powder from the root of marshmallow was prepared in a foam 'candy' for pharmaceutical purposes. The moisture contents of marshmallow foams are in the range 15–18% and the water



Fig. 41.19 Caramel wafers.

Table 41.1 Typical recipes for soft caramel toffee

Skimmed sweetened condensed milk	50	50
Glucose syrup 42 DE	20	12
Hardened palm kernel oil	21	21
Invert syrup (75% solids)	20	6
Glucose syrup 63 DE	—	24
Flavours	As required	

activities lie midway between jellies and toffees. Thus the potential for softening effects on biscuit bases can be appreciated.

The marshmallow for biscuits should be short, not rubbery or tough, in texture, so that it can be deposited discretely via nozzles in a similar manner to jelly. The shortness can be promoted by the addition of icing sugar to the foam which causes some crystallisation of the sugar in the syrup. Marshmallow biscuits may be garnished with desiccated coconut, etc., or enrobed with chocolate (Fig 41.20). The coconut should be sprinkled on as soon as possible after the marshmallow has been deposited so that it sticks well to the surface. However, it is usual to 'skin' the marshmallow a little before enrobing with chocolate. This can be done by holding the product in a low humidity atmosphere at slightly lower temperature for a few minutes before passing to the enrober. It should be noted that moisture migration from the marshmallow into the base biscuit will cause a contraction in volume that may result in pulling away from the chocolate covering or a cracking of the chocolate. If the moisture content of the biscuit can be deliberately raised before the mallow is applied by a period of conditioning, this problem will at least be reduced.

It is important, as with jams and jellies, to prevent drying out of the foam otherwise the marshmallow will become tough and unpleasant as well as contracting in volume. Good moisture-proof packaging is essential and even then the shelf life will be less than for most other biscuit types. Unlike jellies and toffee, marshmallow must be prepared immediately before use. This involves dissolving the sugar and the gelatin, blending in the invert and glucose syrups, cooling, aerating and pumping to the depositing machinery. The recipe and preparation depend on the type of machinery available, so it is difficult to generalise. Wherever possible an integrated plant for continuous manufacture should be used. This allows superior control of temperatures, pressures and aeration right up to the point of deposition. Guidance on preparation procedures and conditions should be sought from the manufacturer of the equipment, though full discussion on possible types of marshmallow is available in the references given at the end of this chapter. Unlike the preparation of jam or caramel, marshmallow has to be prepared immediately before use and there is a potential for microbial growth during the preparation. This means that attention to hygiene and cleaning are very important.



Fig. 41.20 Wagon Wheels.

41.5 Chocolate and chocolate flavoured coatings

Addition of chocolate to biscuits either as a covering or by means of moulding is probably the most important type of secondary processing. Despite the high price of chocolate, sales of chocolate biscuit products are very substantial in all but the hottest countries of the world. Legislation has been introduced to protect the name 'chocolate' by ensuring that the principal fat is cocoa butter, but as a result of recent fat technology there are many different 'hard butter' fats that are used either as cocoa butter substitutes, meaning that they have physical properties very similar to cocoa butter or that they are also compatible with cocoa butter and can be used in real chocolate. As has been explained in Chapter 19, 'chocolate' made from non-cocoa butter fats should be called 'coating'. The cost is lower and technology has developed a very good quality of flavour and texture. After cooling and setting coatings are more flexible so there are also some technical advantages on biscuit products. Much more coating is now used than real chocolate on biscuits worldwide.

41.5.1 Tempering

The quality of chocolate whatever its colour and flavour is very greatly enhanced by its appearance and snap. The surface should be glossy and the texture hard and brittle. These properties are derived by very carefully controlling the fat crystallisation as the chocolate cools. Cocoa butter, in common with other fats, crystallises in up to five different forms. The commonest types of crystal are, in descending order of stability β (beta), β' (beta prime) and α (alpha). If the fat is cooled rapidly all three types will be present, but with time both α and β' types will change to the β allotrope. The change involves liberation of latent heat of crystallisation and a physical rearrangement.

From Fig. 41.21 the melting curves of cocoa butter can be seen in relation to other fats used for chocolate or coatings. It will be appreciated that the melting curve is very sharp due principally to the low spread of glycerides naturally present. The cooling must be very carefully controlled in order that the desired gloss and hardness is achieved. This cooling must be commenced before the chocolate is applied to the biscuit and is known as tempering.

The temper of a chocolate can be defined in terms of the number and type of seed crystals it contains in the fat phase. In tempering chocolate we aim to seed it with stable β crystals so that on further cooling, crystallisation is more likely to proceed in the desired form of all β crystals. The level of seeding is important. If there are too few crystals present, the chocolate must be cooled very slowly to avoid supercooling with the associated presence of α or β' crystals. If there are too many crystals, the liquid chocolate will be very viscous and difficult to handle in the enrober and, especially if the crystals present are in groups rather than discrete, the chocolate on cooling will be set as a soft and plastic mass. When there are too few crystals the chocolate is said to be under-tempered; when too many it is over-tempered. Correctly tempered chocolate should have about 4–5% of crystals and such a level has minimal effect on the fluidity. The lower the temperature of the chocolate the more rapidly will more crystals form and cause increased viscosity.

If no crystals are present in liquid chocolate, on cooling the temperature will drop as sensible heat is lost until a very supercooled condition exists. Then crystals will suddenly be formed liberating much latent heat and causing a rise in the tempera-

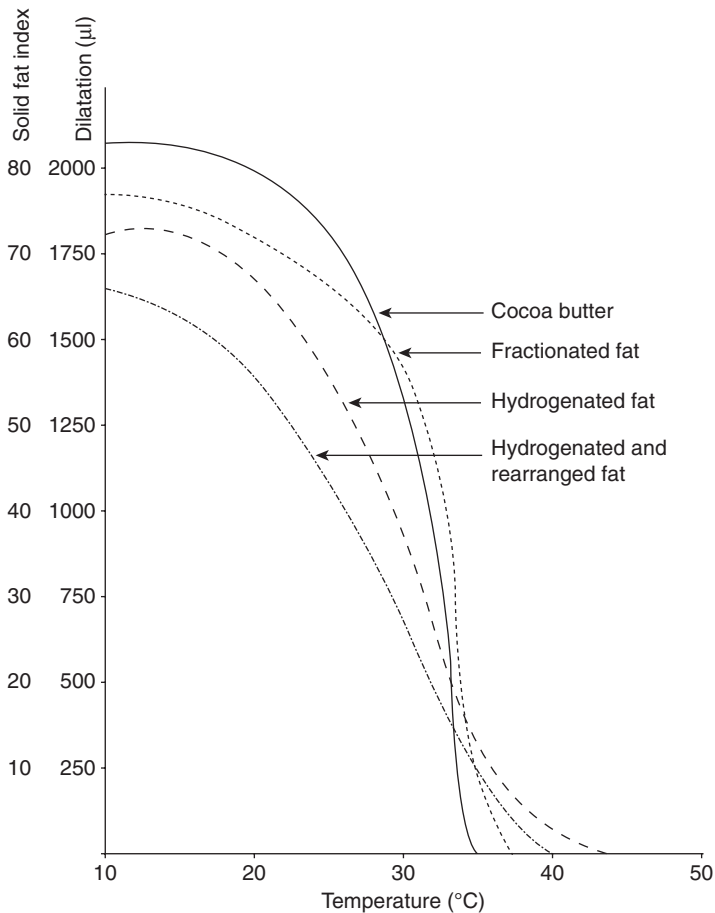


Fig. 41.21 Melting curves of cocoa butter and other types of replacement fats.

ture of the mass; α , β' and β crystals may then be formed. Sensible and latent heat will then continue to be lost until the chocolate sets. In time the α and β' crystals will rearrange and a mottled, whitish surface (known as fat bloom) will develop on the chocolate surface. By seeding the liquid chocolate (tempering), supercooling is reduced and the rate of crystallisation is controlled by the rate of heat removal. It is an important property of fats that when they crystallise rapidly from a super-cooled state, they tend to produce a rigid matrix of crystals. This structure is much more resistant to mechanical deformation than that formed when a heavily seeded mass is slowly cooled. The latter produces a plastic soft structure. Also a mass cooled to the most stable crystal form shows darkest colour and maximum shrinkage, which is an important aspect particularly for removing chocolate from moulds. The preparation of tempered chocolate must therefore be viewed in relation to conditions while the chocolate is being applied and the subsequent cooling conditions.

The β crystals of the largest glycerides melt at about 34–35°C, the β' at 27–29°C and the α at 21–24°C. Very gradually cooling chocolate to about 31°C will permit only β crystals to form. This method of tempering was used by Kreuter in their

interval pre-crystallisation system. The problem is that cooling must be very slow and if during handling the temperature drops lower there will be a progressive increase in seed crystals resulting in increasing chocolate viscosity. Also the growth of crystals at 31°C is very slow. The more normal method of chocolate tempering involves cooling in a scraped surface heat exchanger so that all types of crystals are formed at the cool surface, then by mixing with warmer chocolate all but the unwanted crystals are melted. With time in the enrober, as the number of β crystals increases to an unacceptable level the whole is reheated and re-tempered. The rate of re-melt and re-tempering is balanced so that the viscosity of the tempered mass is maintained as constant as possible. The retention time in an enrobing machine prior to re-melt is determined by the quantity of tempered chocolate held, the rate of throughput of the tempering machine and the rate that chocolate is taken away on the coated product.

It is quite difficult to set up ideal conditions in the chocolate to maintain temper and viscosity at the optimum levels and much trial and error is involved. It will be appreciated that the higher the temperature of the chocolate without losing temper, the lower will be the viscosity and the longer before too many crystals grow. The maximum working temperatures are about 33°C for dark chocolate and 31°C for milk chocolate.

An aid to understanding the degree of temper at any particular time is by means of a chocolate temper meter (there are several different types available but the temper meter from Sollich is probably the most popular). The principle is to measure the cooling curve of a sample of tempered chocolate with a sensitive thermometer under standard cooling conditions. A diagram of a typical apparatus is given in Fig. 41.22. The temperature recorded should have a range of 15–30°C and the chart should run at about 6 mm per minute. The cooling system (possibly a mixture of ice and water) and the sample tube size should be chosen so that at the centre of the sample the cooling rate is at about the same as in the production plant cooler (6–10 minutes between 29 and 15°C is a good average).

The sample tube, clean and dry and at room temperature, is filled with chocolate to be tested. As quickly as possible the sleeve containing the thermometer probe is slipped over the sample tube and the cooling section is immersed in the iced water. The recorder is switched on and the cooling curve recorded. Inspection of the shape of the cooling curve can give fine but only comparative distinctions on the degree of temper of the chocolate sample. Figure 41.23 shows the types of curves that may be obtained:

- with no seed crystallisation (a)
- when there is only light seeding (b)
- when no supercooling occurs due to very heavy seeding (c).

It is not possible to state the optimum curve shape because this, as explained above, depends on the equipment being used and also the composition of the chocolate. The reader is referred to Reade [17] for further discussion on interpretation of chocolate cooling curves. Reade makes the point that use and interpretation of cooling curves is best suited to experimental work, for setting up new machines, etc., rather than for routine plant control. However, with developments in electronic data store and computing, it may be possible to develop an automatic sampling system capable of recording and interpreting the curves produced against a datum and arranging changes in temperatures or chocolate retention times accordingly.

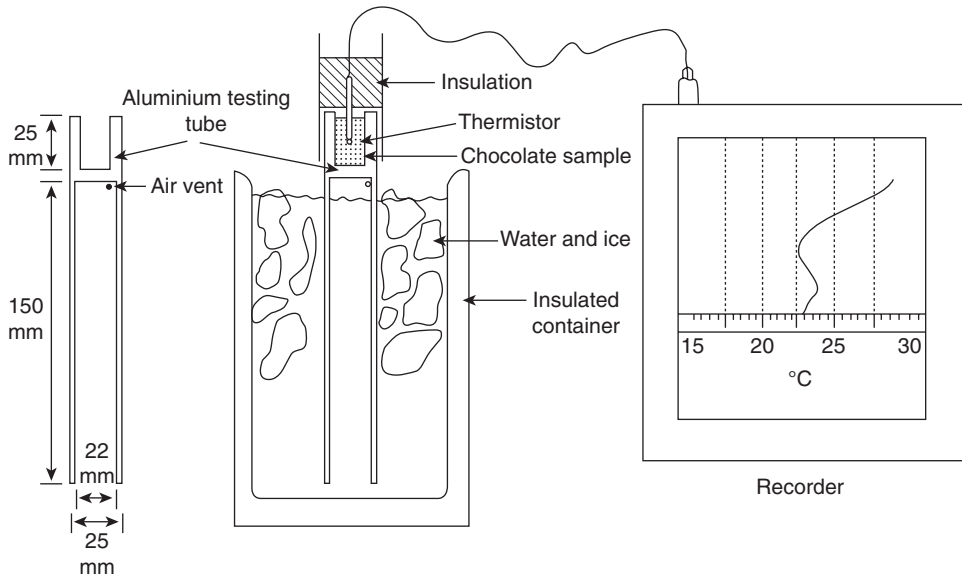


Fig. 41.22 Components of a typical chocolate temper meter.

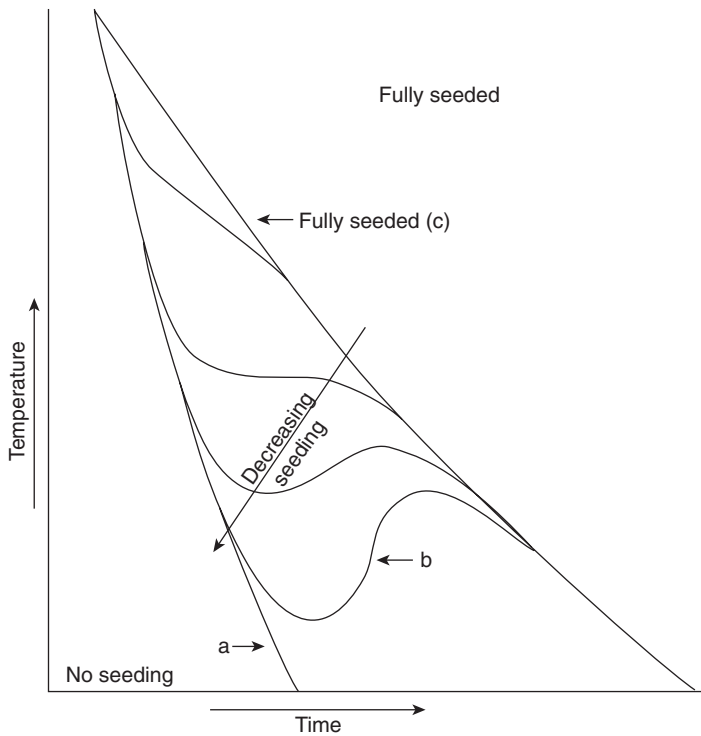


Fig. 41.23 Typical curves of chocolate with varying degrees of crystal seeding.

Chocolate-flavoured coatings, made from non-cocoa butter fats, do not need to be tempered. To know the best temperature to use for any particular coating, it is wise to obtain advice from the supplier and furnish them with details of the chocolate-handling plant available. Commonly coatings are used at up to 50°C. It is unusual to try to use coatings and real chocolate alternately in the same enrober because the two materials are not compatible. It is possible to use coating in an enrober with a little chocolate left in it but one can certainly not put chocolate into one with some remaining coating.

41.5.2 Enrobing

The coating of products with chocolate or coatings has led to the development of sophisticated machines known as enrobers. As the handling of chocolate for enrobing must be continuous with means of tempering the chocolate and maintaining it in correct condition, many enrobers have tempering devices built into them. In other cases the tempering machine is separate, but situated very nearby so that a minimum of temperature-controlled pipework is required for conveying the chocolate.

Enrobing is essentially a mechanical process but close attention must be given to temperature control of the chocolate. The circulation within the enrober must ensure that there are no dead spots where the chocolate can become heavily crystallised and affect the rest of the mass. As stated above, provision should be made to adjust the retention time in the enrober in relation to the rate that the chocolate is taken away on the product. Despite the fact that viscosity of the chocolate is so important in respect of chocolate performance and pick-up rate, it is unusual for an in-line viscometer to be used. Sampling for viscosity is complicated by the unstable nature of tempered chocolate.

The importance of temperature control has perhaps been emphasised enough but one should also point out that the enrober room should be kept between 25 and 30°C and hoods over the enrobing station, with or without heaters, should be used to keep the air around the chocolate at the same temperature as the chocolate.

Enrobers have an open wire mesh conveyor up to about 1.4 metres wide or more which carries the biscuits through a bath of chocolate circulated from below and through a curtain of chocolate poured from above. In the case of only half coating, the curtain is not used. Various devices are used to remove excess chocolate from the biscuit before it is transferred to another conveyor for cooling. The biscuits to be coated should ideally be at a temperature of about 25–29°C; too warm will affect the temper of the chocolate and too cool will cause viscosity problems which affect the evenness of coating and maybe the chocolate pick-up weight. The products should be fed into the enrober as closely together as possible without touching or overlapping to achieve the highest throughput at the lowest possible enrober speed. Any loose biscuit or wafer crumb should be removed before placing the biscuits on the enrobing wire, but provision is usually supplied to filter out crumb which falls into the chocolate. Smooth surfaces coat better than rough and a particular problem is caused by biscuits with loose bases such as those that have pulled out due to sticking on the baking band. The chocolate is quite thick and it does not flow well into these cavities. For certain difficult-to-coat biscuits like wafer pieces and also at high production speeds, it may be necessary to have two coating stations, particularly

for the bases. Such 'pre-bottoming' machines are essentially separate enrobers with short contact type coolers before the main enrober.

A roller may be provided to depress biscuits into the bath of chocolate so that coating is not only on the base but also up the sides. Care should be taken to ensure that the roller does not pick up chocolate otherwise it may soil the tops of subsequent biscuits. Having got the chocolate onto the product, the excess must be removed so that only the desired pick-up is achieved. Pick-up weight control is very important as chocolate is an expensive ingredient. Excess chocolate on the tops of biscuits is blown off with an air knife directed downwards and of even velocity across the width of the enrober. The air must be warm and is thus recirculated within the enrober under the hood.

A vibrating or shaker device encourages excess chocolate to run off the coated biscuits and also to even out any ripples over the surface produced by the air curtain. If the shaker is merely a ratchet and gravity arrangement it may vibrate at about 300 movements per minute, but if on a torsion bar up to 800 movements per minute can be obtained. There may also be one or more 'scraping' rollers either under or after the wire conveyor, which scavenge chocolate from the base.

Finally, there may be a de-tailing roller, as the biscuit passes to the cooler conveyor which licks the drips at the back of the product reducing the possibility of a tail on the cooling conveyor. The detailing roller is of small diameter and revolves at high speed snatching the chocolate away. Tails may be a problem in packaging as they can form hard, sharp protrusions which pierce the wrapping film. Fully coated biscuits are usually transferred flat onto the cooling conveyor, but half-coated products may be inverted before cooling (see Figs 41.24 and 41.25). Inversion is usually achieved by means of a roller which is a set of discs situated and driven immediately after the enrober wire. The biscuits adhere to the discs, follow them round and are knocked off to fall inverted on the cooling conveyor. Scraper fingers clean the discs and the whole may need gentle heating to prevent chocolate build up. If the discs are too hot they will spoil the temper of the chocolate and cause lines of fat bloom to appear when the chocolate is cooled.

41.5.3 Chocolate garnishing and decorating

After enrobing it is possible to decorate the top of the biscuit with thin streams of chocolate which can be oscillated to give patterns. Also, a sprinkler may be used to



Fig. 41.24 Chocolate Rich Tea biscuits.



Fig. 41.25 Penguin biscuits.

add nut pieces, rice crispies, etc., onto the surface of the chocolate. Excess pieces are collected for recirculation.

41.5.4 Chocolate pick-up weight-control procedures

Despite the importance of correct chocolate weight on biscuits, it is difficult to monitor the chocolate pick-up in a continuous way. As has been mentioned elsewhere, full width in-line weighers for biscuits or dough pieces are not yet very reliable and as chocolate pick-up is best assessed by comparing before and after weights, this is one reason for the difficulty of in-line monitoring.

Enrobers fed from a bulk store of liquid chocolate often have automatic, intermittent, topping-up arrangements activated from high- and low-level probes in the chocolate reservoir tank. The amount of chocolate used between the high- and low-level points can be determined and if this quantity is integrated with a biscuit row counter, monitoring the feed into the enrober, various calculations of chocolate pick-up can be made and displayed automatically. The display is updated each time the reservoir is topped up with chocolate.

The main reason for change in pick-up rate will probably be inconsistency in chocolate viscosity. This is related to temperature control and also retention time in the enrober as this affects the level of seeding. The author is not aware, as yet, of any automatic feedback arrangement that can alter either chocolate or enrober mechanical settings to compensate for deviations in chocolate pick-up from a desired standard. Without the need for sophistication, checks on chocolate pick-up may be made by weighing a few biscuits plus a piece of card or paper, feeding the biscuits through the enrober and catching them on the paper before they pass onto the cooling conveyor, and reweighing. Unfortunately, this method, as well as being rather difficult to carry out accurately, also results in wastage of coated product.

41.5.5 Chocolate moulding

By comparison with plant for enrobing biscuits, that required for moulding chocolate around biscuits is massive and a lot more complex. The mould sets are in the form of metal or plastic trays which are removable from a continuous chain that passes through chocolate and biscuit depositing stations, a cooler, a demoulding

point and a return circuit that allows warming of the moulds before being refilled. The chocolate must be tempered as for enrobing but the exact procedures for filling the moulds with chocolate and biscuit vary somewhat. The simplest arrangement involves partial filling of the mould with chocolate, introducing the biscuit and then filling the rest of the mould and wiping off the excess chocolate.

It will be appreciated that the size and shape of the biscuit is very important as it must fit into the mould but not too loosely otherwise an excess of chocolate is needed to fill the mould. Demoulding of the cooled product is a critical stage. If the demoulding is imperfect the automatic operation of the plant is impaired. Release from the moulds is achieved because well-tempered chocolate contracts on cooling. This contraction is a little less than 2% under ideal conditions. Points to watch in order to achieve good mould release are as follows.

- The moulds should be clean and free from oxidation, condensed moisture and scratches.
- The moulds should be at chocolate temperature or slightly lower when filled. They should not be too warm or too cold otherwise the chocolate temper will be upset and this will reduce the degree of contraction on cooling.
- Moulds that need cleaning should be dug out with a soft non-scratching implement, such as plastic, and be washed in warm soapy water. Good rinsing and drying is essential before reuse.

Figures 41.26–41.29 show examples of popular moulded biscuits.

41.5.6 Conditioning of biscuits and wafers before enrobing or moulding

Chocolate which has been set is very rigid and inflexible. It can easily be cracked by deflection and straining. As the moisture content of biscuits changes, so do their dimensions. It is, therefore, important that biscuits which are to be coated or cast in chocolate are stable in their dimensions before being coated and are protected from moisture pick-up afterwards. Biscuits which pass straight from the oven cooling conveyors to enrobers may have moisture differences between centre and outside



Fig. 41.26 Kitkat biscuits.



Fig. 41.27 Club biscuits.



Fig. 41.28 Breakaway biscuits.



Fig. 41.29 Chocolate Leibniz biscuits.

that will equilibrate with time (this may cause checking as well as chocolate cracking). This within-piece equilibration is a particular problem on wafers and was the subject of a special investigation by Barron [20].

Biscuits which are not completely enrobed either deliberately or because there are gaps or pin holes in the coating may pick up moisture and cause the chocolate to crack and fall off. Well-covered, fully enrobed biscuit will be adequately protected from outside moisture by the chocolate. These moisture problems should be considered when packaging is being designed for chocolate products.

41.5.7 Cooling

Cooling is a continuation of the crystallisation process started by tempering. It is as important that conditions here are right for the cooling as it is that the tempering is good otherwise some unwanted crystals may be formed. There are two important principles to remember. Chocolate temperature should always be changed slowly either down or up and chocolate should be protected from moisture, especially that formed by condensation. Thus, cooling should not be rushed nor should the surface temperatures be allowed to go below the dew point of the atmosphere.

The simplest coolers are convection systems where chilled air is circulated in such a way that the centre of the tunnel is at the minimum temperature. However, there is always the danger that the air at the mouth of the cooler will shock cool the chocolate and that humidities of the air within the tunnel will be high. It should be remembered that in addition to dew point condensation problems, dark chocolate will absorb moisture from atmospheres whose relative humidity is above 80% and milk chocolate from air at a relative humidity of 75% or above. Air in cooling tunnels should be dried and recirculated. Drying can be achieved by pre-cooling fresh air drawn in to much lower temperatures than that at which it will be used. Air temperatures in subsequent tunnel zones of 13–19°C, 10–13°C and 13–15°C should suit most conditions. Minimum cooling time will probably be about 3.5–4 minutes for thin coverings of dark chocolate, 6–7 minutes or longer for milk, but maybe as long as 25 minutes for heavier, thicker quantities and that in moulds. The presence of butter fat has a delaying effect on the crystallisation of cocoa butter.

Other means of heat transfer have been exploited for chocolate cooling. Radiation has proved very satisfactory and by using a thin cooling conveyor over cooled plates, some conduction or contact cooling is also possible. In radiation coolers heat radiated by the chocolate as it cools is absorbed on black cooled surfaces above and on the sides of the tunnel. There is no deliberate air movement around the chocolate, though some natural convection must occur. The black surfaces are cooled either by chilled convected air behind them or they form the surface of water-cooled radiators. Fins on the black surfaces improve the ability to transfer the absorbed radiant energy.

To summarise again, too rapid cooling will increase the chance of supercooling resulting in metastable crystallisation which will result in soft, coarse-textured chocolate, and exposure to either high humidities or conditions where atmospheric moisture will condense (dew point) will bloom the chocolate surface giving poor appearance. In strong contrast cooling arrangements for coatings require a shock cooling at the beginning of the cooling tunnel to achieve best results.

It is necessary to air condition the chocolate packing room to temperatures of around 20°C and a relative humidity below 65%. Controlling the humidity in various areas of a biscuit factory is now possible with automatically recharging desiccant units [25].

The conveyor used to take the chocolate pieces through the cooling tunnel is usually plastic coated. A high-gloss finish is essential if chocolate in contact with it is to have a good surface also. The use of patterned or embossed designs on the conveyor is not so common now as it was. The conveyor should be thin to allow as much heat dissipation as possible and also to allow it to pass over a sharp nosepiece at the point where the product is transferred off it. As it flexes on the nosepiece the chocolate easily peels off and any tails, drips or other spilled chocolate will also

become detached and fall away leaving a clean band. Scrapers should also be provided to ensure that the band stays as clean as possible.

The return run of the conveyor should be outside the cooling tunnel so that when it picks up more product for cooling the band is at room temperature and not excessively cold. It is usual to station an operator between the enrober and the mouth of the cooler to check that pieces of coated product are not touching before cooling. Separation at this stage can prevent considerable wastage later. The economics of using this operator should be balanced against lower throughput which would result if the biscuits were more separated in the enrober. Coated biscuits that touch after leaving the enrober are often the result of poor feeding alignment to the enrober.

41.5.8 Handling and storage of chocolate biscuits

After cooling, chocolate biscuits are handled and packed in a similar way to other biscuits. It is necessary that the chocolate should not be touched with bare hands as traces of moisture from the skin will develop as clear fingerprints on the chocolate. Operators should be provided with light nylon or cotton gloves which should be exchanged for clean at each shift change.

Moisture on the chocolate surface results in a whitish, even bloom known as sugar bloom. Fat bloom caused by changes in crystal structure as a result of cooling from non-tempered chocolate is also whitish but is usually more mottled in appearance. If the chocolate was not tempered before cooling it is often still 'wet' at the end of the cooling tunnel and the fat bloom develops later.

Chocolate products must be stored in cool, dry conditions for obvious reasons. If the chocolate melts in store it will cool to produce fat bloom. There is another problem with chocolate biscuits kept in store for long periods and particularly in conditions of temperature fluctuation. This is fat migration. Liquid fractions from the biscuit dough fat move into the chocolate causing it to soften and become cheesy. This problem is worse where high-fat biscuits are involved or where storage temperatures are over 16°C. Using harder dough fats reduces the problem only slightly and the development of speciality dough fats, for example, by Lodars Crocklaan and Karlshamns, is claimed to reduce fat migration into chocolate significantly. The problems and remedies for fat migration are also discussed by Talbot [28].

41.5.9 Chocolate chips

The inclusion in biscuits of small pieces of chocolate, referred to as chocolate chips or chocolate chunks, originated in the USA with Toll House Cookies. Chocolate chip cookies are now popular in many other countries and provide a useful way of offering chocolate biscuits where high ambient temperatures would mean that coated biscuits are impossible to sell. The chocolate is normally in the form of precisely formed drops ranging in size from about 3500 to 22000 drops per kg (7500/kg is the most common size used for biscuits) or broken strips of more irregular size and shape. The chocolate chips are added to short dough at a late stage of its mixing. It is important that the chocolate does not melt in the dough otherwise a brown dough will result! It is common to freeze the chips (at about -14°C) before use to reduce the chance of melting in the dough. Dough pieces are formed by wire cutting.

During baking the chocolate, of course, melts but after the biscuit has been cooled it sets again in more or less its original shape. One would expect the surface

to be badly fat bloomed as no tempering was involved and this does occur. However, if the baking temperature is high enough to caramelise the surface of the exposed chips, this bloom is not so obvious and the chocolate is less sticky to the touch.

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Please note the FMBRA and BBIRA became CCFRA, now Campden BRI.

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Biscuit packaging and storage

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Abstract: The success and profitability of biscuit manufacture is closely associated with the packaging operations. Customers choose their purchases visually and the quality of the biscuits depends on the care in handling and the effectiveness of the packaging and storage before they are unpacked and eaten. Vision systems and robotics allow very precise handling and control.

Key words: pack types, wrapping machines, handling mechanisation, foreign body detection, pack coding, robotics.

42.1 Introduction

The last part of the biscuit-making operation is the packaging. Biscuits leaving the oven or secondary processing should be of correct shape and appearance and, when cooled, in prime condition for eating. The object of packaging is to collate the biscuits in groups of suitable size for sale and to protect them so that their flavour and appearance is preserved for as long as possible.

The majority of biscuits are sold in 200 g packs, but packs range in weight from only a few grams, if a single biscuit, to 300 or 500 g in 'family' packs. Sometimes much larger units, particularly in tins, are packed and there is also a growing demand for very small packs of only a few biscuits suitable for vending machines or individual snacks. The preparation of packs usually involves much specialised machinery, more labour than all of the rest of the production line and a considerable amount of space. Attention to detail in terms of labour utilisation, presentation of the biscuits to both the packaging operators and the wrapping machine and the handling of wrapping materials and packed stock, will have important effects on the efficiency and costs of production. The packing area has received much attention for mechanisation to reduce labour. This has been through automatic feeds to wrapping machines and the use of robotics to pick and place biscuits precisely into positions for final wrapping. Customers demand a variety of biscuit shapes and types in packs of different sizes. This is a major challenge for the production manager!

In the sections on technical management it was shown that the packaging machine represents the boundary between process control and quality control as defined in this book. One can view the division as process control activity being an aid to

production staff and quality control as protection for the customer and company reputation. The quality is determined at the wrapping machine for there is little the production manager can do to control the various conditions in storage or transportation as the pack passes to the place of sale.

42.2 Functions of a pack

A pack is more than just a means of conveniently and safely conveying biscuits to the consumer. It also allows the display of information about manufacturer, type, weight, age, contents and composition, etc., which may be required by law, and other more artistic attributes associated with customer appeal aimed at tempting sale or permitting easy recognition. The marketing aspects constitute a subject in themselves, but it is perhaps worth considering some points here as they have an effect on the problems of packaging.

A very high proportion of biscuits are bought on impulse so it is important that the design and colour of the packet is attractive and sufficiently descriptive of the contents. Legislation is becoming more demanding and considerable amounts of essential information have to be displayed in a clearly readable form. This can detract from those design aspects which may be deemed attractive. Thus, the size or nature of a pack may be determined to some extent by requirements for the labelling.

The setting-up costs for wrapper printing are substantial so it is important that great care is given to the design and labelling. Mistakes after the wrapper has been printed can be very expensive and may lead to legal proceedings against the company. Display is not only a matter of print design. The stackability of packs at the point of sale to the consumer is also important. Cylindrical packs tend to roll, packs with fin seals tend to become interlocked with neighbours and stacking on a narrow side of the pack to present the top face forwards may lead to toppling from the shelf. Certain types of bags make it impossible to pile the packs on the shelves and irregular shaped packs also give the retailer shelf-stacking problems. Arrangements can, of course, be made to aid the stacking of any shape, but the facilities in shops, the height and depth of shelves, etc., should be considered before a pack shape (and hence maybe the type of wrapping machine) is decided.

Customers tend to associate firm tight wraps with biscuits, feeling perhaps that floppy film packs may contain broken product. Packages with polypropylene film used as a single wrap will not feel so firm as those with multi-ply wraps of paper or cellophane. It may be that both forms of packaging afford adequate and equal protection and hence the fears of the consumer are unfounded, but a skill of marketing is to avoid subconscious doubts in customers.

The protection that a pack must provide is in the form of moisture barrier, resistance to mechanical damage, hygiene and light. The barrier which prevents moisture pick-up by the biscuits from the atmosphere will also be adequate for hygiene aspects. Plastic (polypropylene), plastic-coated papers, or various laminates are used to form the moisture barrier (see Chapter 20). They are usually heat sealable and this is how the pack is closed on the wrapping machine. The barrier properties are a combination of the basic moisture-proofness of the materials used and the effectiveness of the seals. Tests for moisture-proofness form a significant part of shelf life testing and this is described later.

Biscuits are typically very fragile and lose much of their appeal if broken. A tight group of biscuits affords much self protection, but aids to rigidity such as specially formed trays, base cards or folds of corrugated paper reduce the chance of breakage as a result of vibration or knocks in the life of the pack.

Some biscuits have sharp edges or rough abrasive surfaces due to sugar, etc., and the packaging materials must be chosen to cope with these to prevent perforation of the film. Flavour change is mostly due to chemical reactions in the ingredients particularly the fats. Oxidation of fats results in rancidity and this is greatly promoted by light, particularly ultraviolet light. The packaging materials can retard the effects of chemical change by excluding (or reducing) the intensity of light and by excluding oxygen. Additionally, the deleterious effects of oxygen may be reduced by flushing the pack with another gas to remove the air. The gas used for biscuits is usually nitrogen but for higher-moisture products, where some microbial growth could occur, a mixture of carbon dioxide and nitrogen is used. This gas-flushing technique is known as modified atmosphere packaging (MAP). See also Section 6.4.3 on shelf life.

Biscuits are very susceptible to the pick-up of strong odours and even small traces can spoil their flavour. Plastic and paper-based wrappers are not particularly good barriers against aromatic chemicals so biscuits should not be stored near detergents, antiseptics, perfumed products, leaks of fuel oil or where paints and resins are being used. More subtle problems may arise from solvents used in inks to print the wrappers so it is as well to discuss these problems with the converters of wrapping materials to ensure that adequate removal of odours takes place before the printed matter is reeled up or boxed for delivery.

Cardboard may give a musty flavour if in contact with biscuits within a moisture-proof barrier. Always use good-quality cardboard manufactured from new fibres (not recycled paper) and check carefully for odours that may be transferred to the products. It is permissible to use cardboard made from recycled paper for outer boxes which do not come into contact with product. It should be remembered also that recycled paper cardboard may present a hygiene hazard if placed in contact with food. These are some of the aspects of a pack which should be deliberated in detail by both technologists and marketing specialists as failure in pack design may ruin the sales of an otherwise tasty and well-manufactured product.

42.3 Types of primary packages

The primary pack is the moisture-proof unit which is to be offered for sale to the consumer. Secondary packaging into groups of 10, 20 or more in boxes or cases is for ease of storage and transportation, but as this packaging may have a significant effect on the mechanical protection afforded to the primary packs, it should be designed carefully. Secondary packaging will be discussed later along with storage.

Primary packages are of only a few basic types. The wrapper may be rigid in the form of a tin or plastic box, but much more commonly it is some form of flexible material. If flexible it may be a pre-formed bag which is sealed after the biscuits have been placed in it, or it may be formed around a group of biscuits and heat sealed automatically. Some biscuits are collated and placed into pre-formed bags which are hand sealed, but by far the most common form of biscuit packaging is with sophisticated machines which carry groups of biscuits through wrapper forming

and sealing arrangements at high speeds. The group of biscuits may be a column, a set of piles, or jumbled (see Fig. 42.1). The biscuits in the pile packs are usually determined by number, those in column packs by thickness and those in jumble packs usually by weight.

The pack sealing may be by fin seals or lap seals (see Fig. 42.2). Fin seals require only one surface of the wrapper to be heat sealable, but lap seals require both surfaces to be heat sealable and pressure must be applied against the pack contents. Sometimes there is a combination of seal types to utilise the greater efficiency that fin sealing allows in respect of moisture protection combined with the neatness that lap sealing gives to pack appearance.

Printed or unprinted wrapping materials are usually fed from reels and the action of the wrapping machine may be intermittent or continuous. Fin sealing involves the formation of a tube around the product which is crimped and cut at appropriate pitch after the pack is completely formed. The tube may be formed horizontally or vertically. The horizontal type allows the introduction of a group of biscuits in a pre-formed arrangement, but the vertical type is used for pre-weighed biscuits in a jumbled arrangement. Product over wrapped and sealed with fold seals, particularly on the pack ends, permits the simultaneous feeding of more than one wrapper (for example, paper within a moisture-proof heat sealable film) and card or corrugated materials for additional protection and rigidity (for example, corrugated folds or base cards). Wrappers for packs with fold seals is cut before the pack is formed so transportation of the materials through the wrapping machine is much more critical. Within these generalised methods of pack construction there are many sophistications of engineering design which give particular advantages and characteristics to meet different requirements. Where printed wrapper is used, it is necessary to control the feed against register marks to ensure that the design remains central on each consecutive pack.

It is extremely unusual to print the wrapper at the same time as it is used for wrapping, but there is a general demand for every package coding to communicate the age of the biscuits or a 'best-before' recommendation to the consumer. This

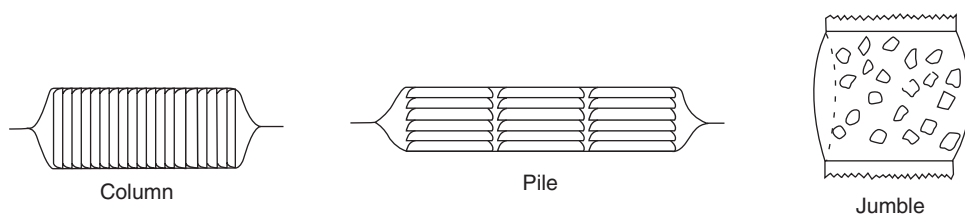


Fig. 42.1 Types of biscuit packets.

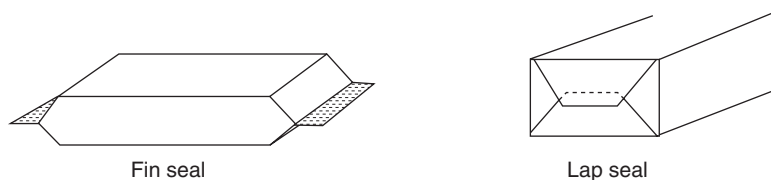


Fig. 42.2 Types of flexible wrapper seals.

necessitates in-line printing with a few characters and to overcome smudging problems as the film is drawn past folding and driving devices on the wrapping machine, special dry printing techniques must be used. Obviously the film cannot be perforated as this would spoil the moisture barrier properties and the most commonly used method is by heat/pressure transfer from a coated ribbon. The technique is known as hot foil printing and the method is similar to that used on carbon ribbon typewriters.

Another demand from customers is ease of opening for the pack. On certain machines it is possible to incorporate tear strips which hopefully initiate the splitting of the tough moisture-proof film. Unfortunately, tear tapes are not common on biscuit packs and probably the most common criticism by consumers of biscuits is of the difficulty of opening packets without damaging the biscuits. To use a knife or scissors cannot be regarded as convenient! Having opened the pack there is then the problem of continued protection against moisture until all the biscuits are eaten. Simple resealable packs are not really successful and transfer to a tin or plastic box in the home is still the best solution. As this is not universally convenient, sales of biscuits in relatively small packs, allowing all the contents to be eaten soon after opening, has increased despite the significant increase in total packaging costs that this involves.

Biscuits fully coated with chocolate do not require the same degree of moisture protection and packaging is often different. When using film with good dead fold characteristics, that is, the sheet remains in position after bending without springing back, such as aluminium foil or a laminate including aluminium foil, a seal may not be required. These packs are not only easier to open but also can be resealed somewhat.

Tins and closable plastic boxes are now rarely used for packaging small units of biscuits. Although these containers offer many advantages, they are expensive and difficult to fill. Machines have been developed which will collate and drop biscuits into the tins, but the mechanism is elaborate and the cost is justified only for expensive types of biscuits made on dedicated plants. Assortments of Danish Butter Cookies may be packed in this way, but in most cases even these are still packed into the tins by hand. Another disadvantage of tins is the enormous amount of space needed to store them while still empty! Tins and boxes, therefore, are now used only for relatively large packs or for expensive types and assortments in presentation packs.

42.4 Collation and feeding to wrapping machines

The improvements in efficiency that mechanical wrapping has achieved have been followed by the mechanisation of the feeding to these wrapping facilities. Although most wrapping machines are still fed by hand, developments have been made so that in many cases no labour is required as the transport of the cooled biscuits into packs is entirely automatic. Buffer arrangements are provided so that manual intervention is not required when there are short stops of the wrapping machine.

Automatic handling of biscuits and the relatively close tolerances required by wrapping machines in respect of biscuit size to achieve satisfactory pack seals has demanded maximum attention from process control techniques. In fact, it can be said that the success of process control functions in a biscuit factory can be judged

primarily by the performance of the wrapping machine and the average weights of the packs it produces.

Stacked biscuits on the packing table may be transferred by hand to the flights of an in-feed conveyor of a wrapping machine. This usually involves placing a column of biscuits into a chain conveyor which may be moving continuously or intermittently. Packing operators can become quite adept at manoeuvring the correct column length. However, packers who are not so good may fill the flight too loosely or too tightly which will have a detrimental effect on the structure of the final pack. A feature of this method of loading the wrapping machine is that columns from individual lanes of biscuits form packs so the weights of packs will reflect variations in biscuit weights lane to lane. A packing operator can conveniently collect columns of biscuits from several lanes across a packing table and feed them to the wrapping machine so row reduction prior to stacking is not necessary. If, however, lane reduction techniques are used to give only a few lanes of well-mixed biscuits, it may be that the speed of the packing table will be too fast for ease of pick-up by the operators.

If the lanes of stacked biscuits are channelled or hand fed into more or less vertical feeders, it is possible to pick off and transfer an exact column length mechanically (plus or minus one biscuit) to the wrapping machine in-feeders (length metering feeders, LMF). Biscuits in vertical feeders may also be pushed out one, two or three at a time in such a way that piles are built up in the wrapping machine in-feed based on number of biscuits rather than by volume. This arrangement offers somewhat better weight control because there is not the problem of packs with one biscuit extra or less as is inevitable where a column length is critical. It is also a better arrangement where large or thick biscuits are to be packed, for example, sandwich creams.

A problem of feeding biscuits from vertical magazines is that pressure on the lowest biscuits may result in damage (especially to types with delicate structure or blisters) and scuffing as the biscuits are divided or pushed out. 'Pressureless feeders' involving the gripping of the upper parts of the column while biscuits at the bottom are extracted are in common use in these situations.

The design ingenuities and potential production advantages of automatic feeders for biscuits have, not surprisingly, resulted in many patents protecting designs. Mostly these patents are held by the manufacturers of wrapping machines as the techniques and precision used for the biscuit handling must be related to and synchronised with the mechanisms of the wrapping machines. However, a wrapping machine with a linked automatic feeding arrangement represents a set of machinery which can be very expensive. The relatively close tolerances in biscuit dimensions required to make good packs usually mean that change parts must be fitted to the wrapping machine when different types of biscuits are to be wrapped. It may be a substantial engineering task to fit these change parts and in each case careful final adjustments are needed to allow good machine performance. Comprehensive calibration of the adjustable parts of a wrapping machine is essential.

It is worth drawing attention to the following points about wrapping machines.

- It is unusual to succeed in producing more than one type of biscuit with exactly the same size and range of dimensions. If one wrapping machine is to be used for different biscuits, it will be best to load the biscuits into standard sized trays or cartons for overwrapping before presentation to the machine or to fit sets of

change parts specially designed for each type of biscuit. Some wrapping machines have sufficient adjustable parts to allow different biscuits or different pack sizes to be produced. The problem of flexibility becomes all the more complex if automatic feeding systems are expected to cope with more than one size of biscuit.

- The wrapping machine parts and wrapper size should be designed and built to match the biscuits, not vice versa. (It may be necessary to make two or more adjustments to a cutter or moulding roll size to achieve biscuits which will be within the size range to fit a predetermined pack size.) Cutters and moulding rollers are expensive! Wherever possible, a good-sized sample of representative biscuits should be sent to the wrapping machine manufacturer so that the critical parts can be built accordingly. Therefore in the development programme for a new product, time must be allowed between production trials and the product launch date.

As mentioned above, calibration of positions for the adjustable parts of wrapping machines is necessary. During commissioning it is frequently necessary to make trial and error adjustments to get the mechanisms to perform well at the desired speeds. If the final positions of all adjustments can be recorded accurately, from scales provided, it is much easier to return to optimum settings should the machine be used for more than one biscuit size. The best wrapping machines are provided with fine calibration scales attached and it is worth requesting similar facilities on all wrapping machinery.

The comments made above apply principally to machines which wrap neat groups of biscuits in columns or piles and for wraps around individual biscuits. Some biscuits are wrapped in jumbled bags and in no particular arrangement. This system is suitable for small or very hard biscuits as the bag does not give much mechanical protection. The biscuits may be automatically fed to the bagging machine via a volume feeder, but usually via a weigher. The labour requirement for jumble bag packing is particularly low as there is no need to maintain a regimentation of biscuits between the oven and the packaging machine and should it be necessary to remove biscuits from the line due to a machine stop, they can be collected in bulk in trays or boxes which can be tipped back into the system later.

The organisation, mechanisation and labour requirements for biscuit collating and transfer to wrapping machines is therefore shown to be of great importance. Although packing operators do not require a high degree of intelligence, they can benefit from periods of training and an advantage of using people rather than machines is that decisions can be made and alternative tasks undertaken more easily. If, for example, burnt or mis-shaped biscuits arrive to be packed, it is easier for people to decide what should be done with them rather than sensors linked to diverting mechanisms. Also, it is inevitable that from time to time a wrapping machine must be stopped. It may be simply to change a reel of paper, or it may be for an engineering adjustment. In these cases biscuits arriving to be packed must either be absorbed automatically in a buffer store, be temporarily removed for subsequent return to the system, or be allowed to fall away and be treated as scrap. Although, at a cost, total automation is possible, it is usually found most economical to use people to cope with these disruptions. This situation puts into question just how much mechanisation should be provided as it is better for labour to be constantly employed than intermittently.

It is always necessary to programme for some wrapping machine stops and the usual rule of thumb is to arrange that the capacity of the wrapping machine(s) is 10% greater than the maximum output of the biscuit plant for any particular product. Furthermore, it is usually better to run the wrapping machine at a fixed speed and to stop for short periods if the supply of product is insufficient. The reason for this is that the temperatures of heaters for sealing usually need adjustment for the dwell times when they are in contact with the wrapping films. These times change with overall machine speeds. Also, automatic feeders often need slight adjustments to suit speed.

Pressure-sensitive, cold seal wrapping films have been developed that allow variable speed of the wrapping machine. Sensors can detect the length of the queue of biscuits coming to the machine and speed or slow the wrapping machine appropriately. The seals may not be as complete as by heat sealing but these wrappers are commonly for individually wrapped biscuits that are subsequently collated and overwrapped with another film.

There is considerable expansion in the use of robotics to transfer biscuits, particularly chocolate-coated biscuits and wafers, into vacuum-formed trays, tins or boxes. The robotic machines work at great and untiring speeds and coupled with vision systems they locate, pick up and rotate to align and place the individual biscuits into spaces as required. The investments are substantial but the labour saved is significant.

42.5 Biscuit size variations

The author has frequently been asked what size variation is likely for biscuits. The question is not simple to answer because so many factors may be involved; however, here are a few that should be considered.

42.5.1 Crackers and semi-sweet types of biscuits

These are made from extensible doughs. There is always some shrinkage in length (and normally some shrinkage in width) as the dough piece is baked. This change of size and shape is related principally to the quality of the flour and the consistency of the dough. Some adjustment to the length (which may also affect the width) is possible at the cutting machine by giving more or less relaxation before cutting. If there is great shrinkage in the length there may be a little expansion in the width. Additionally, the use of more sodium metabisulphite in the dough will give a more extensible dough which will shrink less after cutting. Where enzymes are used to modify the gluten quality, more enzyme or a longer standing period will result in less shrinkage after cutting. Drier (or colder) doughs will shrink more after cutting than soft doughs.

In all cases higher dough piece weights will show more shrinkage than lower. Weight control of biscuits is of primary importance. The thickness of the biscuits is related to the shrinkage but can be controlled to a certain extent by attention to the baking profile, a hotter front part of the oven usually gives thicker biscuits. The development in the oven, to give thicker biscuits, can also be adjusted somewhat with the amount of ammonium bicarbonate used in the recipe.

As a rough guide,

- The weight variation that can be expected is very much related to operator skill and dough handling. It can be expected that the weights will vary by at least $\pm 3\%$.
- The shrinkage in length can be expected to be up to at least 12% on the cutter size and may vary by about $\pm 3\%$.
- The shrinkage in width may be up to 6% with a variation of $\pm 1\%$.
- The thickness may vary by $\pm 5\%$ but can be adjusted significantly.

42.5.2 Rotary moulded and sheeted and cut short dough types

If these doughs are mixed correctly there should never be shrinkage in either direction. If the formulations are relatively low in fat and sugar there will be very little change in size during baking, especially if the biscuits are baked on a wire oven band. They may be slightly larger in both length and width. The higher the weight the larger will be the biscuits. Weight control of biscuits is of primary importance.

Products that are richer in sugar and fat tend to spread during baking and this is particularly the case if they are baked on steel oven bands. The increase in both length and width, or diameter, may be significant. The reader is referred to Section 28.7 where the factors that affect spread are shown. As some of these factors, such as the particle size of the sugar, may be difficult to control precisely one can expect significant variations in size for rich short dough types. The thickness is related to the spread. Additions of aerating chemicals tend to increase the spread rather than increase the thickness during baking.

For rotary moulded biscuits the weight variation should be within $\pm 2\%$ but for sheeted and cut it will be greater. It is not possible to give an indication of the amount of spread but for products which show significant spread one can expect the variation, in both width, length and thickness to be around $\pm 3\%$.

42.5.3 Extruded, deposited and wire cut short dough types

These are always made from doughs which are soft and relatively rich in fat and sugar. If they have been mixed correctly there should be little gluten development and they will show a strong tendency to spread during baking and therefore will show the same variations as have been described in Section 42.5.2. There is the added complication of weight control because these forming machines are relatively poor in this respect both across the band and with time. It is this weight variation that is the principal cause of significant size variations that are commonly seen in these types of biscuits. The weight variation is often in excess of $\pm 8\%$. More recently developed machines improve on this but they are never as good as rotary moulded dough pieces.

42.6 Post-wrapping operations

Packets passing from the wrapping machine must be collected together into units suitable for storage and distribution to the point of sale. Traditionally, strong cases of corrugated board known as fiberites containing about 20–30 individual packets

are used, but demands from grocery supermarkets have led to the development also of display cases. These reduce the handling involved to stock the shelves in the shop by allowing the packets to be seen in at least part of their secondary packaging. The mechanical protection given by the display case may be less than that from fiberites but the use of a tray or end pieces and then overall shrink wrapping is often satisfactory. Fiberites or other units are arranged on pallets for within-factory and probably further transportation. These pallets may also be shrink wrapped to form stable units for trucking to remote stores or large shops.

Where the scale or speed of production warrants, it is possible to use machines to erect, fill and seal fiberites and to print codes or dates to define the time of production. In other cases, these operations are done by hand. A robotic system may be used to build up fiberites on pallets. The arrangement of materials and packed goods around the wrapping machine requires a significant amount of space, plus access gangways. The ergonomics of supply, storage and handling of wrapping materials, cases, pallets, etc., and also finished stock, requires detailed planning if frustration is to be avoided. Major difficulties commonly arise if provision is not made for handling substandard stocks of, for example, badly sealed packs, or boxed up biscuits which have accumulated during periods of wrapping machine malfunctioning. Procedures should be well defined because trouble is usually intermittent and considerable rather than constant and at low level.

42.7 Process and quality control

Successful process control will be manifest by smooth performance of the biscuit feeding and wrapping operations combined with good average pack weight. There is little more by way of process control that can be achieved by the time the biscuits arrive for packing except to ensure that the feeders are maintained full and that excess product is diverted to appropriate back-up wrapping machines or that staff are available to ease congestion. In addition to the pre-production checks on the packaging materials, which fall within the responsibility of the quality control department, operators and quality control staff must maintain a constant check on the quality of the packs being produced. The features of the packs which are important are:

- the pack weights
- the seal qualities, as these will affect shelf life
- the appearance of packs in terms of wrapper print and location
- clear and correct display of the 'best-before' date or other pack coding.

Aspects of the packed biscuits which should be checked are:

- the number of broken or substandard biscuits (poor colour or misshapen) per pack
- the flavour and texture.

The tests involved for each of these checks will be considered.

It is obviously not possible to check every pack so sampling procedures must be designed to give as much information as is considered necessary. The cost of surveillance and checking must be weighed against the consequences of poor or substandard product falling into customers' hands. Fortunately, or maybe unfortu-

nately, very few aggrieved customers complain; they merely remember and are reluctant to purchase again. The laws on food quality are somewhat general because it is recognised that even in the best-run factories occasional unfortunate errors occur. The codes of practice which local environmental health officers apply are designed to prevent food of obnoxious or dangerous quality being produced. With the exception of foreign matter detection (which is more or less limited to metal) and pack weight checks, the main concern of quality control is to defend the company's reputation by way of consumer appeal rather than the reactions of authorities.

42.7.1 Pack weights

Most biscuits are sold by weight and this must be declared on the pack. There are two systems and they are based on minimum weight or average weight. The former is easier to understand and administer and is somewhat more satisfactory from the consumers' point of view, but the average weight system has become the standard in all EU countries and many other places in the world. The system benefits the manufacturer because it recognises that transient variations occur during production runs and, therefore, waste in productivity is reduced should a limited period of low weight packs be produced.

Briefly, the minimum weight system declares that no pack shall be offered for sale which is below the net weight stated (that is the weight of the pack less all the packaging materials). With some exceptions the overweight is without limit and, if high, is to the customers' advantage! The manufacturer can protect himself by check weighing every pack and rejecting those which are lightweight. The customer and inspectors from the authorities may also check and complain or prosecute if necessary. The manufacturer need keep no records of weights except in so far as it is useful for him to know the average weight of the production run because there is a cost (efficiency) implication. Lightweight packs must be opened and the contents fed back with subsequent production or they may be offered for private sale, for example, to production staff, provided that the packs which are substandard are clearly advertised. There is obviously a strong motive for pack weight variation to be as low as possible so that the average weight is close to the minimum weight. The difference between the two weights is referred to as the excess weight, overweight or give away. Automatic every-packet checkweighers can be used to reject lightweighters and to compute the average weights of all those not rejected.

The average weight system states that over a given period of time the average net weight of the packs must be as stated on the wrappers or above. Records must be kept to show how the weights varied throughout the run, but only samples need be checked, not every packet. There is a lower weight limit below which no pack may be sold and this is roughly 5% below the stated average weight. The exact value is stated in the legislation. The onus is on the manufacturer to keep records at the factory and inspectors can demand to see these records and can make spot checks of stock either in the factory or in shops. It is necessary for the quality control department to maintain all these records and understanding of the principles of probability associated with normal weight distributions is a distinct advantage. It is possible to arrange that the average pack weights from a production run are a lot closer to the stated weight than in the minimum weight system so 'give away' may be low or negligible.

42.7.2 Seal qualities

The moisture-proof qualities of flexible wrappers have been discussed in Chapter 20. However, as a result of printing, folding and heat sealing, it is likely that the protection offered by the wrapper is somewhat less than expected by calculation. The main reasons are imperfect seals and perforations of the film by sharp edges such as sugar crystals or the corner of a tray included within a moisture-proof film. Quick checks can be made of the seal performance by observation, blowing through the folds to see if the pack inflates, or by immersing the pack in water and then either reducing the pressure over the water to encourage air to bubble out, or increasing the pressure inside the pack by pumping through a hollow needle slipped into the pack. These tests will give an idea of the position and size of poor seals or perforations.

Moisture which passes into the pack from the atmosphere and is absorbed by the biscuits results in loss of crispness and this may be combined with deterioration of flavour and appearance. The changes are known as staling. Not all the changes which occur in store are due to moisture pick-up, but, as this is likely to be the major cause of loss of quality, a particular type of accelerated shelf life test is designed to estimate the problem. Figure 42.3 shows the percentage increase in weight of some biscuits left in air at relative humidity 70% and 20°C. The speed of moisture uptake is quite fast and emphasises the requirements of a package if this type of deterioration is to be avoided. Obviously, the speed of moisture pick-up is related to the ambient conditions. There are some very dry climates where biscuits will pick up very little moisture, but in most countries the humidities both indoors and outside are quite high for most of the year and good moisture protection is required. It is unusual for a biscuit pack to be exposed on all surfaces equally so when contained in a box next to similar packs there is an appreciable amount of self protection of the packs. Estimations of moisture pick-up rates are, therefore, only relative and it is almost impossible to define shelf life in absolute terms (see also Section 5.4.3). Accelerated shelf-life tests are designed to test the effectiveness of the package for moisture-

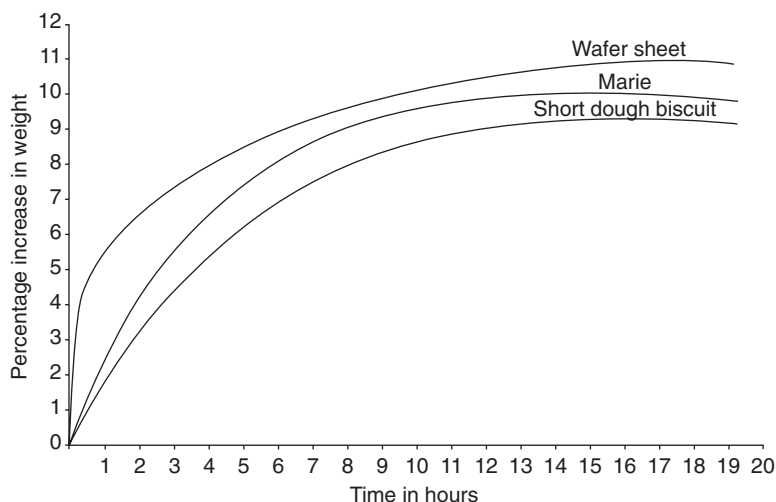


Fig. 42.3 Typical rate of moisture pick-up of biscuits in an atmosphere of 70% RH.

proofness rather than other changes which cause deterioration. For the purposes of these tests one of two conditions is commonly used.

- Temperate conditions are defined as 75% relative humidity at 25°C.
- Tropical conditions which are 90% relative humidity at 38°C.

A pack stored under temperate conditions is estimated to pick up moisture three times faster than under 'normal' British storage conditions. Whether this estimate of the degree of acceleration is correct or not is not really important because results from the tests must be viewed relatively.

There is a problem in defining how much moisture can be absorbed by a biscuit, or what its final moisture content can be, before it is deemed too soft or 'stale' to be edible. For the sake of comparison it is convenient to estimate the time taken for a pack to increase in weight by 1% under controlled storage conditions. This can be done by checking the increase in weight of packs kept for seven days in a cabinet under controlled 'temperate' or 'tropical' atmospheric conditions. The atmosphere over a saturated solution of salt (sodium chloride) provides an atmosphere of 75% RH.

This is a destructive form of testing because the contents of tested packs will not be suitable for eating. It is, therefore, necessary to consider very carefully the number of packs that should be tested and the use of the information that is obtained. The moisture-proofness of packs can be compared with the theoretical maximum based on the specified properties of the packaging film. Also, the moisture pick-up can be compared from different packs of the same type giving an idea of short-term or long-term variation from a particular wrapping machine.

42.7.3 Pack appearance

The customer is much influenced by the pack appearance and faults with wrapper printing or position on the pack should not be allowed to pass for sale as they may suggest a casual approach to the quality of the contents also. It will be the job of all operators associated with packaging to watch for these faults as spot checks by quality control staff are unlikely to be adequate.

42.7.4 Pack coding

The best before or other pack coding is important as it provides a manufacturing reference which will be needed if there is a customer complaint. If a serious manufacturing fault is discovered this coding will enable product to be traced and recalled if necessary.

42.7.5 Broken and substandard biscuits, flavour and texture

Biscuits may be broken as a result of wrapping machine action, 'checking' (see Section 40.2) or rough handling after the packs leave the wrapping machine. Quality control checks should ascertain the size and nature of the problem as broken biscuits are particularly annoying to the customer. It is obviously most unsatisfactory if broken biscuits are present in packs before they leave the factory, but some checks should also be made to see whether transportation or handling in depots or shops causes breakage.

It will be necessary to open some packs, sampled appropriately, to assess the quality of biscuits, so, as for the shelf life tests, one must decide whether a few packs each week or a lot of packs at intervals should be the pattern of sampling. Examination for broken biscuits should be combined with assessment of general quality including colour, flavour and texture. Flavour involves tasting tests and these need to be very carefully set up if useful results are to be obtained. The subject of tasting tests is dealt with fully in Section 5.4.2.

The administration and cost in sampling from shops or depots for the purpose of quality control tests may be considerable so a maximum of information should be obtained from these samples. Not only the appearance and flavour of the biscuits should be recorded. It is worth noting pack weights, wrapper condition, pack age and the exact situation of the samples at the time of sampling so that changes associated with storage, transportation and handling can be compared with fresh packs in the factory. The opportunity should be taken to compare samples of competitors' biscuits because it is under these conditions that customers will also be making comparisons. It is very easy for management to become complacent about the quality of the company's products as a result of satisfactory quality control tests on fresh packets. The effort required to follow the packs to the point of sale and to make comparisons with competitors at this stage is well worthwhile and should be handled by technologists in conjunction with sales and marketing personnel.

42.7.6 Foreign matter in biscuits

Processing of food always involves the risk of inclusion of foreign matter. A few materials such as slivers of metal, glass or toxic chemicals may be dangerous to health, but mostly the effect on consumers is one of revulsion rather than danger. Every means possible should be taken to ensure that foreign matter does not become included and that which does is detected before the product leaves the factory. Foreign matter in biscuits is more likely to lead to prosecution and bad publicity than any other shortcomings of the company or its products.

Foreign matter such as glass, stone and metal have significantly different densities than biscuit and this property has been used in the development of detection methods using, for example, X-rays. However, at present, instruments that scan the densities of every packet of biscuits are very rarely used. The problem is that pieces will probably be small and scanning, followed by recognition and rejection has to be very fast. Metal detectors capable of finding and rejecting packs containing particles of metal one millimetre or more in size are commonplace and it is recommended that each production line should be equipped to scan every pack after the wrapping machine. The quality control department should be intimately involved in the use of metal detectors, not only to ensure that their performance is checked regularly according to at least the manufacturers' recommendations, but also to see that packs rejected are reliably collected and subsequently examined for the offending metal. Since prevention is the aim, it is worth trying to identify the source of each piece of metal, by consultation with engineers if necessary, so that action aimed at preventing further cases may be taken. Attention at this stage as well as protecting the company reputation may also provide early indication of the need for machine maintenance.

Attention to operators' hand wounds and skin conditions are dealt with in Chapter 2. By using adhesive plasters with metal strips included, the crisis which

may occur as a result of a chance loss is reduced if the metal detector can reject the offending piece. Unfortunately, detectors are not yet available which will find human hairs or pieces of fibre such as cotton, nylon or polyester. Although there is no particular danger involved in eating any of these, customers are not particularly impressed with such finds!

It is most important that a manufacturer can identify and trace production from a given machine or time so that should a serious fault become apparent all product that could have been affected can be recalled. Such recall is only possible if a suitable code has been imprinted on each pack and the destination of cases of these packs has been recorded. This is the essence of traceability of product which has been increasingly important for food manufacturers.

42.8 Storage

There are many systems for store mechanisation and computer control which allow automatic placement and retrieval of pallettised stocks. Management is thus provided with constant information of stock levels and correct rotation of stock is assured. The cost of such systems may be offset by the reduction of labour required and facilities to use high buildings with purpose-built racking. High buildings require close attention to air circulation to avoid big temperature fluctuations near the roof.

Once the biscuits have left the factory site they tend to be forgotten in terms of quality control, yet care is necessary right up to the point of sale in shops. Conditions of temperature and humidity are very important in biscuit stores. High or fluctuating temperatures may cause fat migration, fat bloom, chocolate and rancidity problems. High humidities or dampness will reduce the strength of the cardboard cases and increase the rate of moisture transmission through wrapping films. Thus, all parts of biscuit stores should be dry and cool. Good insulation of walls and ceilings combined, if necessary, with air conditioning and air circulation will reduce the chance of local high or fluctuating temperatures.

Cases should not be stored on floors or touching walls. Dampness problems are considerably reduced if air circulation is good and gaps left at floor/wall junctions will help in prevention of rodent and insect infestations.

42.9 Robotics

There is an increase in the use of 'intelligent' mechanisation within biscuit factories and most of this is in the packaging and storage areas. Mention has been made in some places earlier in this chapter but it might be useful to give a generalised account of what is meant by robotics.

Robotics is an integrated system of sensors controlling mechanical lift/move/place machines (robots). Early robots were hydraulic but most now use electric motors. The common use of robots is to move relatively heavy items like boxes and place them accurately on, for example, pallets but they are also used to store and retrieve pallets of stock, etc., from large high store areas.

Pick and place robots are also used during processing and the creation of packs. Common applications are:

- transferring items from a cooling band to an in-feed conveyor of a wrapping machine
- transferring small packs to form groups on an in-feed conveyor to make multipacks
- transferring items onto other products (e.g., placing labels onto packs).

Products are scanned with a camera/vision system and the information gives exact position information on the conveyor and can be programmed to screen out items that are out of standard in terms of size, shape, colour, etc. There are usually several picking robots in series but the programme dictates which picker takes which item and the last picker normally works more slowly taking items when the quantity exceeds the capability of the earlier ones. The pickers can work at up to 160 movements per minute but are best at slower rates because the acceleration often damages or causes movement on the picker head at very high speeds.

The picking (grabbing and lifting) may be by

- venturi air so that very little contact is made with the picker head
- by mechanical grippers
- by needles which penetrate at an angle that prevents slip and allows clean withdrawal.

Robotics allow precise movement and placing of items which would not be possible if gravity (sliding or falling) is used for a transfer.

42.9.1 Justification for installing robots

A system is relatively expensive but the costs are falling rapidly as the technology advances. It is wrong to consider the justification based only on labour saving. Other points to consider are:

- the 'extra' saving that can accrue with less labour, e.g. holidays, sickness, overalls, training, recruitment, supervision
- quality control: out of standard items/packs can be reduced
- process control
- better measurement of reject items is possible giving fewer wrapping machine stops due to out of standard items being presented
- much better placement of case on pallets allowing fewer errors/damage in handling
- fewer errors resulting from tired or less vigilant staff
- flexibility in handling line speeds
- high-speed precise collation of items or packs including high-speed addition of topping items, etc

Robots allow much finer tuning of production line capacity. The exact wrapping machine requirement can be better calculated and less space is needed for post wrapping activity.

The vision system is a key to the success of the operation but this can also be used to record product trends and abnormalities allowing a more precise definition of standards and tolerances. The vision system can be networked to other production and process control data systems.

42.10 Useful reading and address

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Recycling, handling and disposal of waste biscuit materials

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Abstract: Despite good management of quality and process control, it is inevitable that there will be waste of resources during any production run. The amount of waste and its cost will vary and this makes efficient management of waste more difficult. Clearly the best way to maximise the profit from a manufacturing operation is to reduce the waste to minimum levels. Thereafter there must be well-considered and planned procedures for handling and disposing of waste materials.

Key words: broken biscuits, recycling within a factory, quantifying waste.

43.1 Management of waste

Having reached the end of this book it is hoped that the reader will have found some information useful for his/her activity in biscuit making. It should not be forgotten that the principal objective for anyone making biscuits is to make money, to make a profit! One of the best ways to maximise the profit from a manufacturing operation is to reduce the waste to minimum levels. Waste can arise from many places and can be classified as materials not used as expected and labour not performing as expected. Controlling waste is an essential management task. The results are often not recorded and presented vividly enough to encourage greater attention in this area.

Standards have to be established for each aspect of manufacturing and standards for waste are no exception. Based on these standards products can be costed. If waste standards are exceeded the product costs more than expected. By experience and attention to detail it should be possible to identify critical areas of waste and by some development, investment or training improve the efficiency.

In the author's experience people relate better to waste (inefficiency) presented as a financial cost rather than a percentage of an expectation. For example, if workers are told that a production run ran at 95% efficiency they could be expected to feel quite pleased with themselves (after all it is only necessary to gain 50% marks to pass many examinations), but if they were told that the result of the 95% efficiency cost the company £10,000 they would probably think that this was not at all satisfactory.

Most companies collect data from each production run such as the amounts of ingredients used, the number of cases of good product made, the downtime of the plant, etc. With a correctly constructed computer program it is possible to enter these values and for the efficiency to appear as a monetary penalty for the company. These results should be a major factor for prompting development activity.

Techniques for management and supervision are outside the scope of this book but the following is a look at where waste materials may arise and what may be done with them.

43.2 Sources of waste materials

43.2.1 Sources producing significant quantities of waste

- Faulty mixings giving doughs which cannot be used.
- Doughs which for reasons of plant stoppage and other reasons have gone out of condition and cannot be used.
- Cutter scrap, particularly from the end of a run or that which is in excess of the quantity normally incorporated with fresh dough at the sheeter.
- Baked biscuits which are of unsuitable quality due to over and under baking, are misshapen, etc., removed before passing for packing or secondary processing. This will include the bobble from the edges of wafer sheets.
- Cutter trimmings, particularly from wafers.
- Broken biscuits arising from a variety of causes.
- Product that has been taken for sampling and not been returned to the production line.
- Good biscuits which have been imperfectly wrapped or from underweight packs which cannot be released for sale.
- Wrapping materials from damaged packs, bad printing, poor storage, etc.

43.2.2 Sources which usually produce less significant amounts of waste

- Spillages on the floor or in inaccessible parts of machines.
- Cleanings from the plant at the end of production runs.
- Dust from dust collectors and tailings from sieves and filters.
- Substandard or contaminated ingredient stocks, doughs and deteriorated biscuits.

It will be appreciated that waste from the categories in Section 43.2.1, both by its quantity and nature, must be considered for recycling within the factory or sale. Exceptions are waste packing materials and wafer bobble. If recycling within the factory is to be involved, it is most important that the materials from each source are collected carefully in clean, appropriate containers, are protected from infestation and deterioration and are well labelled. The materials will have to be stored and possibly prepared somewhat before use. It is essential that detailed inventories be kept of the quantities collected and reused as these will have bearings on plant performance and yield calculations. As there is considerable potential for contamination by recycling within the factory there should be much resistance to even considering this.

Most of the materials included in the categories in Section 43.2.2 will leave the factory as garbage or in the drains as sewage or be sold for animal feed or as waste paper. As such they will represent a financial loss to the factory and at the same time involve a disproportionate amount of labour and administration to see them off the premises.

43.3 Estimating the size of the problem

Factories vary very considerably in the amounts of waste they produce. As a general rule new plants, those with long runs of each product and those with little manual handling give lower percentages of waste at all stages than those which are older and make many varieties of products on short runs. The following values probably are near to the averages in the industry.

- Ingredient losses: about 0.04%, less from bulk handling installations, more where bags, barrels, boxes, etc., are used. Nearly all may be disposed of as 'animal food'.
- Mixing and forming department losses: losses to 'animal food' about 0.4%, wastage which is fit for recycling about 5% (average of very irregular amounts).
- Baking losses: losses to 'animal food' will be around 0.2%. (There is an overall inevitable loss of around 8% which is the difference between the moisture content of the ingredients and that of the baked biscuits. This should not be regarded as 'waste'.)
- Packaging and secondary process losses; here there are several categories: broken and misshapen biscuits (which may be sold in special packs or recycled), 3%; good biscuits which need unwrapping and repacking due to pack defects, 3%; and various pieces and spillages fit only for 'animal food', 0.3%.

For each 100 tonnes of biscuits made there may be about 0.8 tonnes of 'animal food', about 3–5 tonnes offering potential for recycling in some way of which up to 3 tonnes could be sold as substandard product.

Put in a different way, if there was no recycling and no sales of substandard product, for each 100 tonnes of biscuits produced up to 6 (or more!) tonnes may have to be disposed of elsewhere. This is a very large figure. Luckily, there are many factories where considerably lower wastage figures are the norm. However, it is because wastage is significant that recycling has to be considered despite its inconvenience and detrimental effects on process control.

43.4 Recycling

Incorporation of scrap dough is the biggest problem in the recycling programme. This is because it is difficult to handle old dough and it can often be in a condition where it is hard and is not easily dispersed in a mixing. From the process point of view one can easily get into a vicious circle where use of scrap dough in a mixing creates a substandard mix which either means more scrap dough or substandard biscuits after baking. By every means possible the amount of scrap dough to be recycled should be kept as low as possible and be incorporated at a steady rate in mixes until it is used up. This is easier said than done because by its very nature the supply of scrap dough is irregular, arising mainly from faults in metering or mixing.

Process control techniques should concentrate on the production of uniform good doughs because prevention is better than cure, or to start right gives a better chance of staying right. There should be manual inspection of each dough after mixing as this will give early indication of metering errors. A mixer power monitor (see Section 34.3) may be an instrument useful for assessing between mix dough quality differences.

Small batch mixers, used on a rapid cycling scheme, will produce less scrap dough than larger ones, but a problem is that it is exceedingly difficult to incorporate scrap into them because of the high cycle rate which will probably be controlled automatically. Preparation of scrap dough into some sort of premix is hardly a practical operation.

Scrap dough should be used in mixes of the same recipe and it should be introduced into the mix at the beginning of the mixing cycle, that is, in the cream-up or sugar run if appropriate. This gives maximum opportunity for the mixer to break up and soften the old dough. Where it is not possible to use the scrap in the same recipe, great care should be taken in considering the effects of texture, flavour and colour that the scrap will impart on the mixing. It is not possible to be specific about what should be done and where because any scrap reuse must be regarded as unfortunate, undesirable and introduces compromises into what should be a smooth-running operation.

Clean, that is free from paper, aluminium foil and, of course, floor dirt, biscuit waste such as broken biscuits and misshapes may also be introduced into the mixer. In this case distribution is aided by grinding the biscuits into a crumb or in making a thick suspension in water immediately before adding to the mixer. Incorporation is not so difficult as with scrap dough, but the practice is always detrimental to process and quality control. It is easier to maintain a steady usage of biscuit material because storage in the dry state is not the problem that it is for dough. The flavour and colour of biscuit crumb will affect the dough and subsequently biscuits made from it. The reuse of over-baked and burnt biscuits should be avoided. Some manufacturers use biscuit crumb as an ingredient to colour the biscuits.

It is important to remember that unwrapped biscuits attract insect and other pests so they are a potential source of serious infestation. Bringing biscuit into the mixing room for recycling may result in infestation that can spread to other ingredients stored nearby. Certain biscuit creams can carry a proportion of ground biscuit so offer a means of using waste. Wafer creams are particularly suitable as small coloured particles are not very obvious in the thin layers and as the cutter trimmings from creamed wafers may amount to as much as 10% of the production, it is important to recycle this cream-rich material to make the costings viable.

Many attempts have been made to tackle recycling of biscuit waste in a positive uniform manner by developing products which require a certain proportion of waste in the formulation. For example, savoury creams (requiring unsweetened biscuit crumb as the filler), dark strongly flavoured short dough biscuits and fillers for fruit and jam pastes to make them less sticky. Some of the textures achieved are very acceptable. Biscuit crumb also finds a limited sale in its own right for various products, like cheesecake base and dessert toppings. The basic problem is the irregular quantities and non-uniform quality of biscuit waste produced in most factories. To match exactly the sales of a product based on waste with the supply of that waste is practically impossible.

Before considering recycling of waste or scrap calculate the value of this material at each stage. Is it really necessary to reuse it? There will be significant labour costs to handle and prepare material for reincorporation into a dough. The value in the dough is limited to the ingredient cost. Maybe it is better to save the labour costs, avoid the process and quality control problems and sell the waste for animal feed.

43.5 Disposal of waste materials that are not recycled

Since there is a basic value in all waste the problem is to assess who would pay the highest price and at the same time would be prepared to take varying amounts regularly. It is important to the biscuit manufacturer that wastes are removed from the site regularly otherwise space is lost or infestation and decomposition may develop. This need is exploited by all traders in waste products and is the reason why they are difficult people to bargain with.

Most edible waste, provided it is free from noxious materials (paper, metal, plastic, chemicals) can be fed to animals. Pigs were the traditional recipients of edible garbage, but even these are now fed more scientifically; therefore most edible material in recent years has been sold to animal feed compounders. By mixing the sugary, fatty wastes from biscuits with cereal, etc., dried pellets of reasonably uniform nutritional value can be made for pigs, cattle, fish and poultry. In order to obtain the best price for edible waste it is worth discussing with the feed compounder or his agent how he is likely to use the waste and, therefore, how it can be sorted or handled to mutual advantage. It is probable that any sales in this way will recover only a fraction of the ingredient cost of the materials involved.

Disposal and treatment of organic wastes has not been a problem confined to the biscuit industry. It is similar in most food factories, many chemical works and, of course, sewage. The development of processing with microorganisms and enzymes which has become known as biotechnology, offers some interesting possibilities for waste utilisation. Practically any organic substrate can be inoculated with appropriate microorganisms to produce either biomass or metabolites which are useful. Complex chemicals such as antibiotics, simple fuels like methane or useful solvents such as alcohol are well-known 'products of biotechnology'. It would seem reasonable that waste products rich in carbohydrates could be upgraded to proteinaceous feed for animals or nitrogenous fertiliser, etc., by fixation of atmospheric nitrogen at the basic end of the range or to more complex specialist chemicals at the other. A feature of biotechnology is the relatively narrow and low temperature range needed for optimum growth of the microorganisms. Natural large-scale 'fermentation' of organic waste has been hindered in the UK because of low atmospheric temperatures for much of the year and the supply of heat has been uneconomic. Heat wasted from baking plant is difficult to recover for normal usage, but it would be an admirable source of low-grade heat to aid natural or enzymatic conversions.

To have one's own bioconverter fed with factory waste (and maybe some brought in from elsewhere locally) and heated with flue gas waste heat offers an interesting diversification for a biscuit factory. The economics are worth considering, but they should perhaps be compared with the costs of having one's own poultry farm! As far as the biscuit manufacturer is concerned the investment and management of a bioconverter is a substantial and highly technical project. Few food manufacturers wish to be involved even if the returns can be shown to be favourable.

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