is therefore left to responsible companies to set and achieve their own temperature standards for this category of product. The maximum recommended temperature for storage and distribution of all dairy desserts is below 5°C.

In order to achieve the desired temperature standards within the distribution chain the following is recommended.

1. Products should be stacked in such a way that the cold air can circulate freely.
2. Product should be pre-cooled before entering the cold store.
3. Opening of the store or vehicle doors should be minimised.
4. Efficient temperature monitoring and alarm systems should be installed and maintained.
5. A high air flow/velocity within the store should be employed.
6. Products should be loaded on to vehicles via an air lock system wherever possible and under no circumstances should be left out on a loading bank.
7. Vehicles should be pre-cooled prior to loading the products.

The other major factor that can influence shelf life during the storage and distribution operation is light. This is most likely to be a critical factor in the display cabinet. However, it can be suitably restricted by the choice of packaging as discussed in the previous section.

7.3.5 Consumer storage

When determining the shelf life of a product, which in the main depends upon the integrity of the 'chill-chain' to maintain its desirable properties, full account must be given for the potential abuse of product by the retailer and consumer. During recent years surveys have been commissioned by industry, research bodies and government agencies to provide accurate data on the way the general public handle and store chilled products after purchase. The most recent of these is *Consumer Handling of Chilled Foods*, published in the UK by the Ministry of Agriculture, Fisheries and Food (MAFF, 1991), which investigated many factors associated with shopping, consumer handling and attitudes to chilled products.

The temperature regime used for establishing product shelf life must therefore be designed to take into account:

1. The time that the product may be out of refrigeration, between being removed from the retailer's chill cabinet and being placed in the consumer's refrigerator.
2. The number of days it will be stored in the consumer's refrigerator.
3. The likely position in which it will be stored within the consumer's

refrigerator (dairy products are often placed near the top or in the door, both of which are relatively warm positions).
4. The temperature range at which domestic refrigerators operate.

Education of the consumer about the product is important. Clear instructions of storage conditions should be given on the pack, and advertising information can be used to emphasise the importance of temperature control.

At the end of the day, however, it must be accepted that the last link in the 'chill chain' for any product is probably the weakest and all the efforts of a manufacturer can be confounded, if the product is handled badly by the consumer.

7.4 Evaluation methods

There are no absolute tests to evaluate shelf life. The methodology used and the process for evaluation will depend on the product, the quality criteria and the expertise within the company.

Before attempting to evaluate the shelf life it is important to have an understanding of the product composition, and the changes that may be induced by various processing conditions.

Different testing regimes will be required for:

1. low pH products;
2. neutral pH products;
3. those with high risk ingredients;
4. low water activity products.

In terms of microbiological spoilage it is important to establish which organisms are likely to be present in the final product, which are likely to affect safety or cause spoilage during shelf life, and the possible sources of contamination.

Microbiological, chemical and physical changes which affect final product quality can in many instances be detected by sensory analysis. These changes should be either evaluated or considered during the development process.

Sensory analysis, although subjective can play a major role in evaluating shelf life (caution must be exercised to ensure that no microbiological safety risk is present if the technique is employed).

It is essential that sufficient shelf life data are collected during the pilot and scale-up trials to identify the CCPs and the factors that will affect the stability of the product. It is recommended that a minimum of three full evaluation tests is carried out on product from factory scale pre-production trials to confirm the shelf life prior to launch of the product

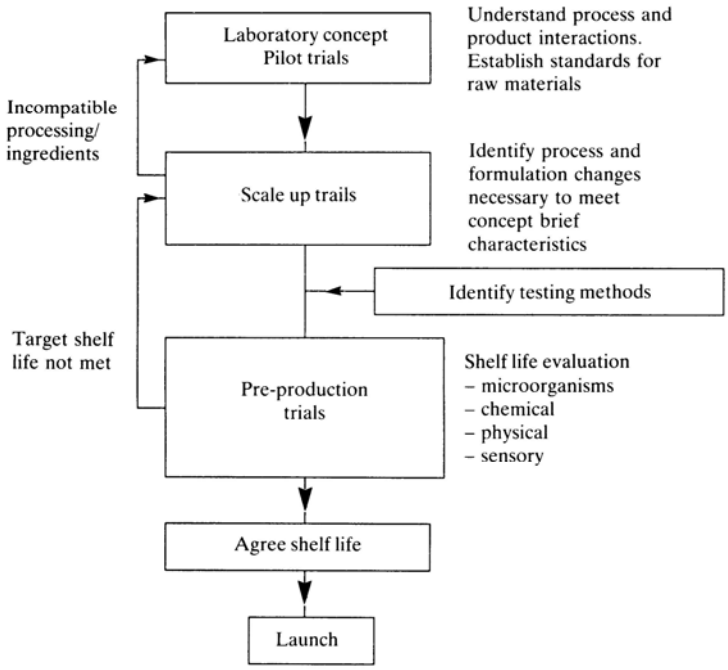


Figure 7.10 The main sequence of operations in the development of a new product.

Figure 7.10 shows the main sequence of operations in the development of a new product.

Many complicated cycling regimes to imitate the temperature patterns to which products may be subjected have been suggested and indeed are used for shelf life determinations. However, for simplicity it is often better to use a two-step system ensuring that the temperatures chosen allow sufficient room for abuse and are not idealistic.

A typical regime for dairy desserts would be storage for 2 days at 4°C followed by storage at 8°C for a period exceeding the target shelf life.

7.4.1 Shelf life determination – yogurt

The critical factors to consider are:

1. target life;
2. temperature of storage and distribution;
3. yeast and mould contamination;

Table 7.2 Testing schedule – shelf life determination

No. of days		0	1	2	3	4	7	14	21	28
Coliforms		*								
Y & M Colony count		*					*	*		
Incubated samples	7°C				*	*	*	*	*	*
checked for gas	21°C		*	*	*	*	*	*	*	*
production	30°C		*	*	*	*	*	*	*	*
Texture and Viscosity			*				*	*	*	
pH/acidity		*	*				*	*	*	*
Flavour profile			*				*	*	*	*

Storage temperature: 7°C unless indicated.
Target shelf life: 21 days.
Day of production: day 0.
* = Sampling occasion.

4. syneresis and texture;
5. degradation of flavour and colour.

The methods described can be used for shelf life evaluation of existing products as well as new products. In the case of new products however, it is recommended that a hazard analysis based on the Hazard Analysis Critical Control Point (HACCP) concept is carried out at the development and pre-production stages.

Sufficient samples must be taken to cover all the planned tests. Samples are stored in temperature-controlled rooms operating at 7°C, 21°C and 30°C. These are checked at regular intervals through to the target shelf life and beyond as illustrated in Table 7.2.

Microbiologically all samples are checked for coliforms, yeasts and moulds. Although coliforms do not survive for much longer than 24 hours due to the low pH, their initial presence in the product gives an indication of poor plant hygiene and the possibility of other contamination. The testing for coliforms using Violet Red Bile Agar is regarded as a useful check in establishing the shelf life of the product.

The number of yeasts and moulds present in the product can be detected by plating on Rose-Bengal Chloramphenicol Agar where individual colonies can be counted.

Due to the small quantity of product needed to carry out these tests (1 ml or 0.1 ml) the results tend to be unreliable especially when only low levels of yeasts are present. The tests are however a useful step in the identification of yeasts and moulds, and hence in establishing the possible cause of contamination.

Storage of yogurt at 21°C and 30°C for shelf life evaluation evolved as a result of the difficulties experienced with the plate count method. The presence of yeasts can be detected by gas formation when the product is

stored at these temperatures. Gas formation in a pot of yogurt is evident by doming of the lid, or if the product is heavily contaminated or incubated for a longer period, by the gas forcing the lid clear of the rim of the pot. Storage at 21°C and 30°C also enables the factory to react quickly to any potential problems.

The 21°C and 30°C tests were developed following trials where samples of 'clean' uncontaminated product were inoculated with yeasts from several pots of yogurt known to be contaminated.

From these trials it was concluded that the time taken for the yeasts to produce sufficient gas to dome the lid was an indication of the severity of the contamination. The shorter the time to 'gas' the more contaminated the product. The results are summarised in Table 7.3. It was also established that different species of yeasts had different rates of gas production as indicated by the hours before doming in the three trials. These differences should be taken into account in the shelf life evaluation process.

The differences in the time taken to blow (gas formation between samples incubated at 21°C and 30°C) have also been investigated. Some discrepancies between the results were found, nevertheless, storage of samples at 21°C and 30°C forms an essential part of the shelf life evaluation of yogurt and indeed of factory control measures.

The investigation was carried out at a yogurt production site covering a period of three months and involving 5760 samples (samples were taken every 30 minutes from each filling machine during the production cycle). The results of the investigation are shown in Figures 7.11 and 7.12. The

Table 7.3 Yogurt inoculated with spoilage yeasts and samples incubated at 30°C

	No. of yeasts/pot	Hours before doming
Trial 1	60 000	40
	6000	48
	600	63
	6	76
	Control (Nil)	>168
Trial 2	360 000	15
	36000	24
	360	46
	4	96
	Control (Nil)	>144
Trial 3	260 000	24
	26000	46
	260	96
	26	120
	Control (Nil)	>144

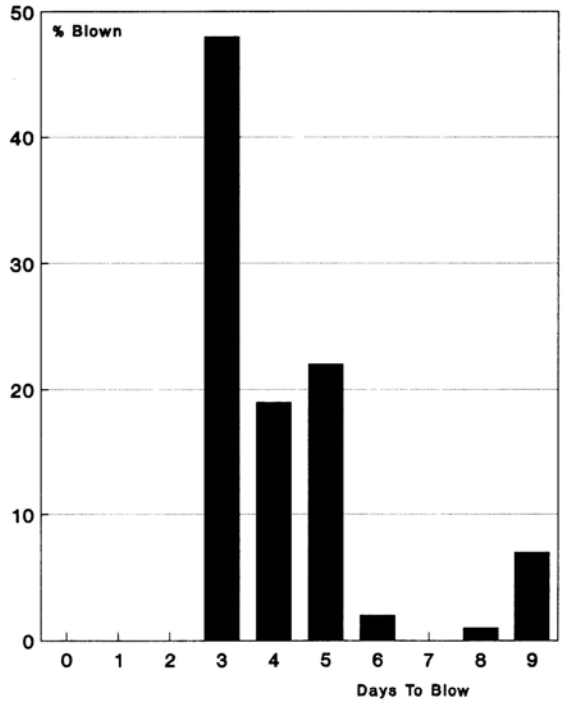


Figure 7.11 Storage of yogurt samples – comparison of gas formation at 30°C and 21°C (223 samples blown in 2 days at 30°C).

charts show, based on the total number of samples that were found to blow in 2 days at 30°C (Figure 7.11) and in 3 days at 30°C (Figure 7.12), the percentage breakdown of samples kept at 21°C, that were found to blow during storage. For example (Figure 7.11) 233 samples were found to blow after 2 days at 30°C. Among the duplicate samples stored at 21°C 46% was found to blow after 3 days, 19% after 4 days and so on.

A comparison of 'blowing' times at 21°C and 7°C demonstrates a clear correlation between the two. The shelf life of the refrigerated product can therefore be predicted by the time taken for samples stored at the elevated temperature to 'blow'. Results are shown in Figure 7.13.

The majority of short shelf life yogurts are 'live', i.e. the culture organisms are still viable. Although their metabolic rate at 7°C is relatively low there is nonetheless some activity. This can be determined during shelf life by pH measurement (see Figure 7.14), by titratable acidity determination and by taste.

The increase in acidity can alter the flavour profile and if combined

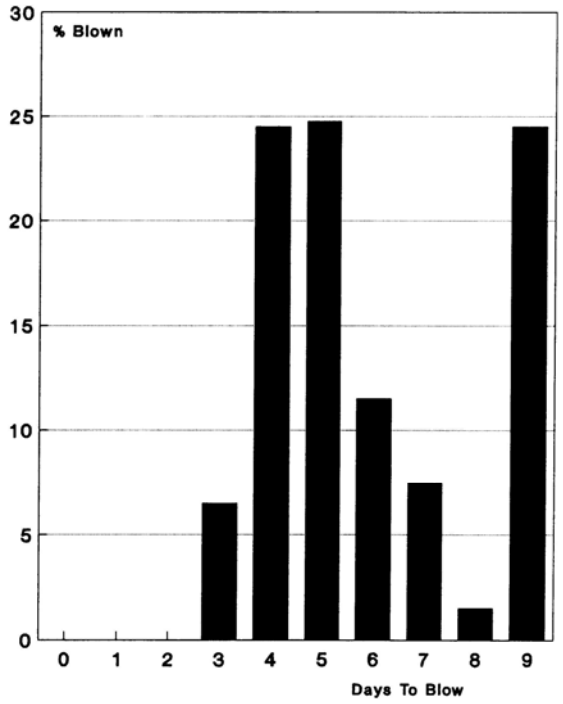


Figure 7.12 Storage of yogurt samples – comparison of gas formation at 30°C and 21°C (341 samples blown in 3 days at 30°C).

with degradation of fruit flavours, it can often become manifested as off and stale taints. To establish the extent of flavour degradation, trained assessors are used.

The deterioration can be noted and the assessors are able to rank the product according to age fairly consistently. The chemical and biochemical changes that occur over time show that the product does decline with age. From a sensory point of view the shelf life is set at least one day prior to the product changes becoming so evident that they are judged to be unacceptable to the consumer. Spider plots (Figure 7.15) can be used to highlight differences between fresh and stored samples.

7.5 Current developments and the future

During the last two decades many developments have been made by both industry and research organisations to extend the shelf life of many types of foods. These have included techniques and aids such as:

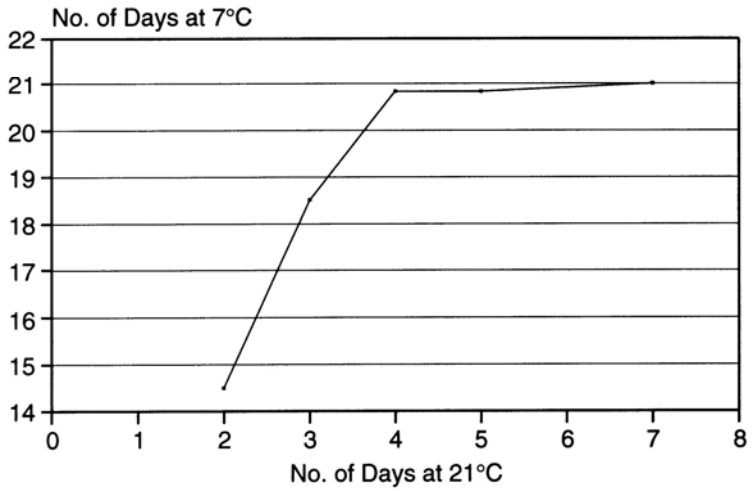


Figure 7.13 Storage of yogurt samples – comparison of blowing times at 21°C and 7°C.

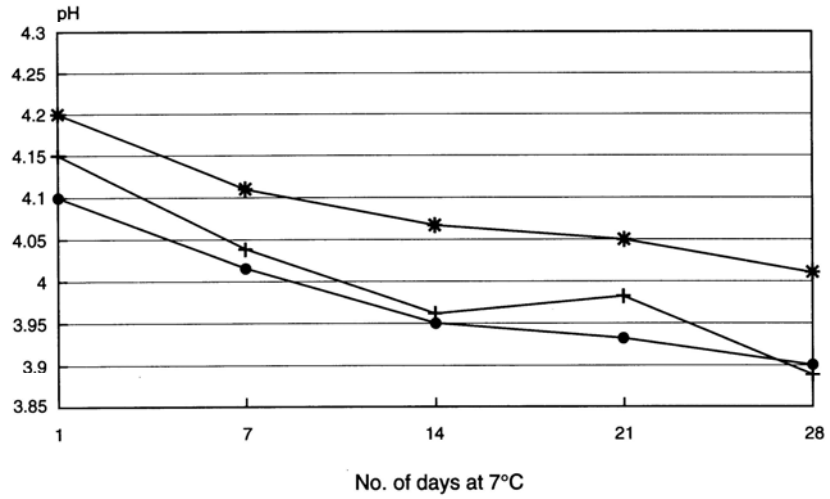


Figure 7.14 Storage of yogurt samples – pH change with time. Series 1, •; series 2, +; series 3, *.

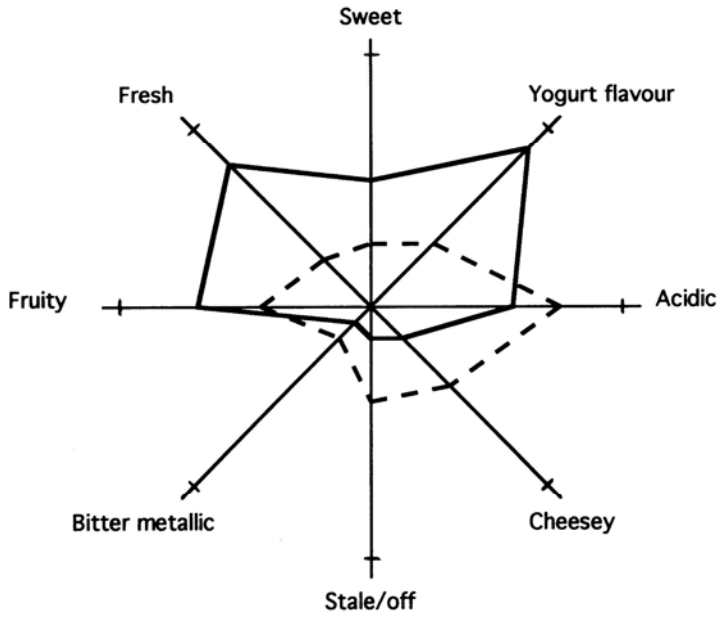


Figure 7.15 Spider plots – differences between fresh and stored samples. —, day 1; – –, day 28.

- irradiation;
- modified and controlled atmosphere packaging;
- oxygen absorbers;
- aseptic processing and packaging developments.

Few of these developments have, however, been of use in the extension of shelf life of fresh dairy desserts due to cost, adverse effects on the food or consumer attitudes.

Most progress in this product sector has been achieved by better practices and attention to detail. The key areas have been:

- improved selection and quality of raw materials;
- greater knowledge and utilisation of functional ingredients;
- improved process plant design and hygiene;
- the use of techniques such as HACCP and challenge testing to establish safe and quality related shelf life;
- greater use of rapid method techniques for analysis and hygiene monitoring;

- improved cooling and refrigeration;
- the selection of technologically advanced packaging materials.

One area which has been the subject of much recent work and debate is the use of time–temperature indicators (TTIs). These are markers which may be applied to the outer packaging, which will indicate to the reader the 'temperature history' of the product. Clearly they have the potential to indicate the residual safe shelf life of desserts, either to the retailer or the consumer. However, current costs are relatively high and some reliability problems exist.

The changes within the desserts market have been so great within the last twenty years that no one in the 1960s could have foreseen or predicted the size and scope of this market in the 1990s. Equally it is difficult to envisage what further changes will occur during the next twenty years. Certainly for the short term, growth both in terms of volume and variety, and the drive for improved quality and safety will inevitably continue. However, it can be predicted confidently that consumers will also demand:

1. Less wastage in packaging. Tertiary and possibly even secondary packaging will be gradually reduced unless they are biodegradable or can be recycled.
2. Improved safety and freshness. These are likely to become more important than a long shelf life.
3. Better value for money than in the affluent 1980s.
4. Greater attention to nutritional and health aspects. Low cholesterol, low fat, high in unsaturates, low sugars, high fibre, added vitamins and health promoting minerals.

All of these requirements will place further demand on the food technologists as they attempt to meet industry's needs and the consumer's wants.

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8 Modified-atmosphere-packed ready-to-cook and ready-to-eat meat products

R.C EBURNE and G. PRENTICE

8.1 Introduction

There have been tremendous changes in all aspects of the meat and meat products group in the last few years. These changes encompass the development, production, distribution and storage of product, legislation and, last but not least, changes of attitude by the consumers. The consumers of today want convenience; convenience in preparation, packaging, portion control and convenience in serving whether cooking is required or not. They also want, and take for granted, product safety. The 'use by' or 'best before' date on any product is regarded as a guaranteed date of safe quality, and if any other attitude is taken, it is more likely to be one of regarding it as a minimum date with one or two extra days to be taken without any decline in quality or safety.

Changes in food legislation have been fast and furious in the last ten years. The Food Safety Act 1990, the Food Hygiene Regulations and all their associated codes of practice and amendments have set the scene for improvement of good manufacturing practice. EC legislation on food safety has been reflected and often anticipated in UK legislation. In the meat products group there now exists comprehensive legislation on fresh meats and meat products, which governs all aspects of the hygienic manufacture of these products. The Food Hygiene Regulations have stipulated lower temperatures for refrigerated food distribution, and now most chilled meat products are distributed at temperatures of less than 5°C in the UK.

These changes in legislation have been paralleled by an even greater activity within the legislative and technical committees of the various food trade associations who have published an enormous number of authoritative standards and codes of practice to help their members stay at the forefront of hygienic and safe manufacture. Two associations in particular are of importance to the meat manufacturers, namely the British Meat Manufacturers' Associations (BMMA) and the Chilled Food Association (CFA). Both of these associations have published standards in 1993 on the production of 'high risk' foods. A high risk food is a cooked food which is sold ready to be eaten by the ultimate consumer without any

further cooking and, as such, requires great care to ensure that no contamination occurs after cooking, during the final processing and packing stages.

Complementing the activity of the manufacturers' trade associations an equal input of authoritative codes of practice from the major retailers for the guidance of their 'own label' suppliers, from the Food Research Associations (particularly Campden Food & Drink Research Association) and also from the food scientists and technologists' professional body, the Institute of Food Science and Technology (UK), has also been seen.

These efforts have contributed in their various ways to safer products with reliable and accurate shelf lives. However, at the same time, there have been many changes which have made the shelf life evaluation of meat products a more difficult and hazardous process.

It has already been mentioned that customers regard 'use by' dates as a guaranteed date of safety. The food technologist has to be absolutely sure his shelf life recommendation is correct. He has to make sure his experimental methodology is sound and reliable and resist the commercial and customer pressures for longer shelf lives which he cannot guarantee. He has to bear in mind there are many changes occurring in the marketplace, which are not positive factors in the maintenance of good shelf life. An example of this is the increasing use of microwave ovens for reheating foods. The uneven heating by many of the early models coupled with incorrect use by some customers can result in an unacceptable end product. Another example is the variations in temperature of household refrigerators. Only the very latest models have automatic defrost and a thermometer permanently installed, and many food manufacturers do not help themselves by just stating 'keep refrigerated', on their pack labels.

Meat products have also suffered, perhaps more than other foods, from the attack on additives, whose addition prevents the development of an unsafe product but are now being limited both in range and in quantity. Chief amongst these are common salt, nitrites and sulphites. The desire to reduce sodium in the diet, the cation common to all three additives, again contributes to a reduction in shelf life because there is a concomitant reduction in the levels of the preservative. Many bacon and sausage packs are now marketed with low salt where salt is less than 1%. This contrasts with a salt level in mild cured bacon of 2%, a level of 4% plus in Wiltshire bacon and a minimum of 1.5% salt in pork sausage.

Finally, the newly identified microbiological hazards should be mentioned, which continue to surface and require a rethink on shelf life evaluation. *Listeria monocytogenes*, first discovered in 1924, took nearly sixty years to make its effect, but what an effect that has been! Shelf life evaluation of every cooked, ready-to-eat product must now take account of this ubiquitous organism. More recently, the verotoxigenic *E. coli* type 0157:H7 has been identified as the culprit in a case of food poisoning and

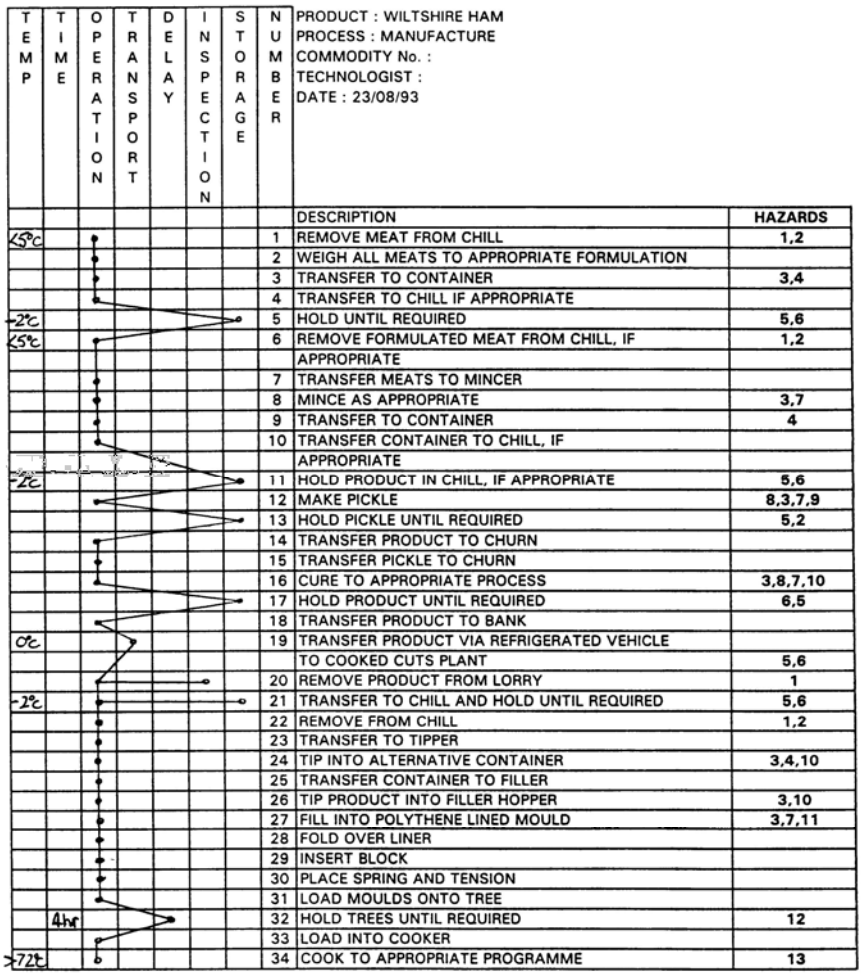


Figure 8.1 A HACCP process flow chart.

must be added to the list of pathogens which meat product manufacturers now monitor.

The scientific factors, however, that have to be considered in evaluating shelf life are still basically the same, namely microbiological, sensory and chemical. Any one factor may terminate a shelf life, but more often than not, it will be a combination of the first two. Every food product made and marketed must have a known and safe shelf life.

The design of the procedure to establish this must not only take into account all these factors but must be carefully designed to suit the

product, the process and the distribution and final storage conditions. It must be carried out on samples which are known to be representative of actual production. It is essential that a hazard analysis (based on the Hazard Analysis Critical Control Point (HACCP) principles) is carried out on the product and process, so that the evaluator is well aware of the intrinsic hazards and, therefore, is able to look specifically for those spoilage organisms which are likely to develop.

The first stage of such an analysis is to construct a process flow chart. The first page from a three page flow chart is shown in Figure 8.1. It follows the flow of the meat and other materials from intake right through to final product despatch.

It is a graphic presentation of the sequence of events in the meat product manufacture being analysed. Some charts use symbols, i.e. a circle for 'operation', a square for 'inspection' and an arrow for 'transport'. Others prefer to describe in full the various parameters, e.g. temperature, time, operation, inspection. Each item of the process is described and the hazards linked with that item denoted by a number.

In a second spreadsheet (an example of which is given in Table 8.1 which is page 1 from a 7 page analysis), the hazards are described together with the actions required, the frequency of checking and the person responsible. There is a final column in which the demerit points are listed. These are determined according to the seriousness of the hazards and are rated 1000 for critical, 100 for serious, 10 for major and 1 for minor. They are allocated by the Hazard Analysis team which in NewMarket Foods is made up of the Product Development Manager, the Food Safety Officer, and a Production Manager and the team is chaired by the Quality Services Manager. All these personnel have attended recognised training courses on HACCP and its implementation. The demerit points remain unchanged unless the process is altered, and are used as reference by the HACCP auditor when auditing the process.

8.2 Meat product groups and their basic characteristics

The group of meat and meat products is very diverse, and when coupled with the variety of preservation and packaging methods, becomes extremely diverse indeed. In this chapter, the basic product groups and their packaging formats together with the preservation methods as they apply within these groups will be briefly considered. These basic groups are fresh/frozen meats, cured meats (e.g. bacon), cooked meats (e.g. ham, pork luncheon meat) and prepared meat products. The last group is probably the most variable in that it encompasses sausages, burgers, hot and cold pies, pizzas and 'ready meals'; in fact anything containing more than 10% meat.

Tables 8.1 A table of identified hazards and their associated control

Item No.	Item description	Hazard No.	Hazard nature	Action required	Frequency	Responsible person	Demerit points
1	Remove product from chill	1	Product out of temperature specification	Target temperature less than 5°C. If temperature between 5° and 10° return to chill. If temperature >10°C reject	Each batch	Production	
		2	Product not within life	Maximum 4 days. Reject product not coded or outside life	Each batch	Production	
3	Transfer to container	3	Poor cleaning of containers	Clean as per hygiene operating instructions	As per hygiene schedule	Production services	
				Monitor ATP level (soiling and microbial loading). If high levels regularly found, review cleaning procedures/schedules (continue to monitor)	As per micro. schedule	Micro. lab	
		4	Use of soiled containers	Visual inspection before use. If soiled reject for washing	Each batch	Production	
5	Hold until required	5	Chill not running within specified limits	Target −2°C +/− 2°C		Refrigeration engineers	
		6	Foreign body contamination	Cover all product. If uncovered, inspect, reject/cover	Each batch	Production	
6	Remove product from chill	1	Product out of temperature specification	Target temperature less than 5°C. If temperature between 5° and 10°C, return to chill. If temperature >10°C reject	Each batch	Production	

		2	Product not within life	Maximum 4 days. Reject product not coded or outside life	Each batch	Production
8	Mince as appropriate	3	Poor cleaning	Clean as per hygiene operating instructions	As per hygiene schedule	Hygiene dept.
				Monitor ATP level (soiling and microbial loading). If high levels regularly found, review cleaning procedures/schedules (continue to monitor)	As per micro. schedule	Micro. lab
		7	Foreign body contamination from equipment	Check all equipment on assembly	Each piece of equipment	Engineers
9	Transfer to container	4	Use of soiled containers	Visual inspection before use. If soiled remove for washing	Each batch	Production
11	Hold until required	5	Chill not running within specified limits	Target –2°C +/– 2°C		Refrigeration engineers
		6	Foreign body contamination	Cover all product. If uncovered, inspect, reject/cover	Each batch	Production
12	Make pickle	3	Poor cleaning	Clean as per hygiene operating instructions	As per hygiene schedule	Hygiene dept.
				Monitor ATP level (soiling and microbial loading). If high levels regularly found, review cleaning procedures/schedules (continue to monitor)	As per micro. schedule	Micro. lab

Table 8.2 Typical gas mixtures used for meat and meat products

Product	Gas types and percentages		
	Oxygen	Carbon dioxide	Nitrogen
Bacon	<0.1	35–45	55–65
Cooked cured meats	<0.1	35–45	55–65
Cooked cured meats	<0.1	0	100
Fresh meats*	–	100	–
Fresh meats*	–	40	60
Fresh meats	80	20	–
Fresh sausage	<1	100	–
Fresh offal	60–80	0–20	0–20
Fresh poultry	–	35	65

*Bulk master packs

The packaging gas mixtures used for preservation are basically nitrogen and carbon dioxide mixtures (see Table 8.2), although there are some variations in use for 'master packs' or when colour development/preservation is a priority. 'Master packs' is a term used to describe the transport of several retail meat packs, usually air packed in PVC films, or several fresh meat primal joints in one large bulk pack. The gas is usually 100% carbon dioxide which gives a maximum antimicrobial effect. Colour of the meat is restored on removal from the master pack by atmospheric oxygen.

In other cases e.g. bacon, ham and cooked meats, a mixture of 60% nitrogen and 40% carbon dioxide has been shown to be an optimum combination. Higher levels of carbon dioxide have not been proved to extend the shelf life further.

However, the critical gas level, as always in cured meats, raw or cooked, is that of oxygen where the lowest possible level is used. Modern thermoforming packaging equipment, with the correct film and settings, can consistently achieve levels of less than 0.1% residual oxygen in the pack.

The basic product group characteristics can be best described as in taste panel assessments, i.e. appearance, texture and flavour.

8.2.1 Appearance

One of the most important attributes of meats and meat products is colour. If the colour is not protected during shelf life, the well-known brown colour in fresh meat and greying in cured meat will ensue as a result of oxidation. The basic pigment of raw meat is myoglobin. This, for example, in the case of vacuum-packed raw beef would be a purple/red colour (reduced myoglobin). The pigment deteriorates to the brown oxidised form of myoglobin (metmyoglobin) when the meat is exposed to

low levels of oxygen and enzymic activity, and the meat is said to have lost its 'bloom'. The bright red colour so desirable of fresh red meats is due to the oxygenation of myoglobin to oxymyoglobin at high levels of oxygen (e.g. >20%). Cured meats owe their colour to the action of nitrite on the myoglobin pigment to produce nitrosylmyoglobin. Those cured meats which are partially or fully cooked develop nitrosylhaemochromogen, the characteristic pink colour of ham. This colour can be achieved with very low levels of nitrite, and is a hazard to be aware of when producing non-nitrited products like roast turkey and roast pork in the same processing area.

8.2.2 Flavour

The most important off-flavour from a shelf life standpoint is that of rancidity due to the oxidation of fat. The high fat contents, the presence of unsaturated fats and salt, comminution and frozen storage, all tend to increase the likelihood of rancidity development.

8.2.3 Texture

Tenderness is probably the most significant characteristic in fresh meat followed closely by succulence. The former is influenced by the initial age of the slaughtered animal but is greatly affected by the handling, slaughtering, chilling and maturation treatments as well as the control of temperature during processing to the final cut of meat. Fat levels are the obvious contributor to succulence but water retention in the meat is also significant. In trying to retain this textural quality through the shelf life, it is important to prevent the gain or loss of moisture or water vapour, and avoid unacceptable levels of 'drip' in the final pack.

8.3 Factors affecting shelf life

The factors which affect shelf life can be divided according to whether they are causes or effects. The latter may be determined by laboratory tests when the shelf life is evaluated and can themselves be split into three sub-categories, i.e. microbiological, chemical and sensory. In the case of meat and meat products the following are some of the elements which would be included depending on the product and pack type:

1. Microbiological: total viable count (TVC), *Lactobacillus* spp., *Enterobacteriaceae*, *E. coli*, *Pseudomonas*, *Brochothrix thermosphacta* and yeasts.
2. Chemical: acidity, peroxide value (PV), water loss.
3. Sensory: odour, flavour, texture and appearance.

Table 8.3 Factors affecting shelf life – a list of intrinsic and extrinsic factors

Intrinsic factors
Type of animal, e.g. porcine, bovine
Breed and feed regime
Age of animal at time of slaughter
Initial microflora
Chemical condition, e.g. peroxide value, pH value
Water activity (a_w)
Basic meat product make-up, e.g. recipe, preservatives, antioxidants
Availability of oxygen
Extrinsic factors
Processing, heat treatments, time control
Hygiene, standard of personnel and equipment cleaning
Quality Management System, HACCP procedures
Temperature control
Packaging system, materials, equipment, gases
Storage

However, a more useful approach in evaluating the factors is to consider the causes, and, in this approach, to further separate them into intrinsic and extrinsic factors. A general list of these factors is shown in Table 8.3.

8.3.1 Intrinsic factors

Whilst all these factors are important and must be taken into account when evaluating shelf life, arguably the most important is the initial microflora and its level. Every attempt should always be made to keep this to an absolute minimum. Modern abattoirs are designed principally to achieve this, and if proper care is taken to avoid contamination from the gut and its natural high levels of bacteria, there is no reason why the carcass should not be nearly sterile. Thus counts of less than 1000 cfu/g can be expected. If counts are maintained at this level, rather than, say, 10^5 on fresh meats under aerobic conditions, a doubling of the shelf life is possible, before a cut off of 10^7 is reached.

Of the microflora on fresh meat, the Gram-negative aerobic rod-shaped bacteria, e.g. *Pseudomonas* spp., predominate. In anaerobic conditions, the slower-growing lactic acid bacteria, *Lactobacilli* spp., come to the fore.

The type of animal is only relevant in respect of its relative proneness to harbour pathogenic bacteria. The presence of *Salmonella* is more likely in poultry, but less so in pork and beef. The breed may also be a factor. For example, in pigs some breeds are more stress-susceptible and give rise to pale, soft and exudative (PSE) meat. This, if used in a cured product, would result in disintegration of the texture of the product.

The age of the animal at time of slaughter is a very important factor.

Tenderness of the meat improves with maturation but bacterial counts also increase and drying out occurs.

Water activity (a_w) is a measure of the amount of water available that will support microbial growth. In meat and meat products a normal level is 0.97. Unfortunately most pathogens find this a very acceptable level for growth. It can be reduced by the addition of salt and, of course, drying through heat treatment. A good example of a cured meat product is salami, where a very low water activity is achieved, although the true version of this product would not be a suitable candidate for modified atmosphere packaging (MAP) as it usually has moulds on the surface, which would be degraded by such a packaging method.

The final intrinsic factor worthy of mention in meat products is the presence or otherwise of preservatives, namely sodium nitrite and sulphur dioxide. Both are essential. Nitrite is used in cured meats and cured meat products, e.g. bacon, ham; and sulphur dioxide in prepared meat products, e.g. sausages, burgers, where a reasonable length of shelf life is required (see Figure 8.2). A minimum nitrite level of 30 ppm must be achieved at the end of the manufacturing process, with a desirable level of 100 ppm residual for both raw and cooked cured meats.

Sulphur dioxide levels have a legal maximum of 450 ppm in meat products and formulations are usually developed to achieve this. During a typical nine-day life of a fresh pork sausage this will drop by approximately 50%. The incorporation of antioxidants such as ascorbic acid and its salts, alpha-tocopherol and ascorbyl palmitate will have the effect of

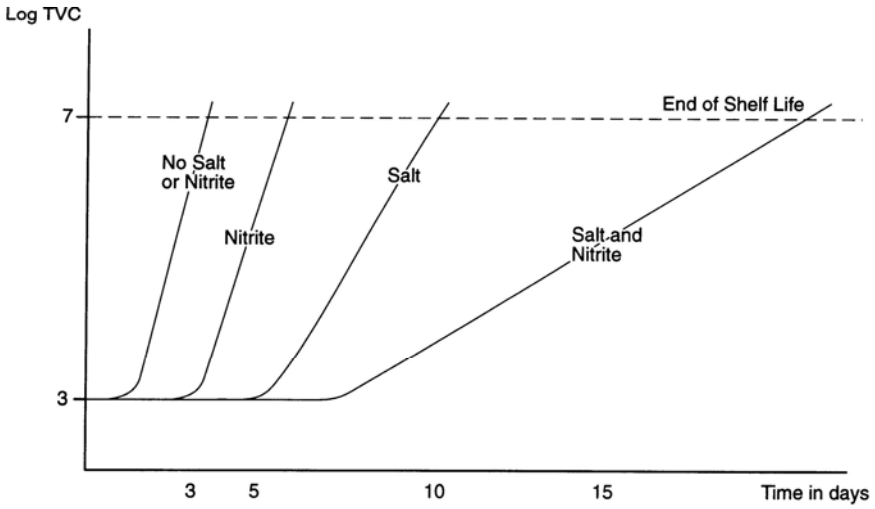


Figure 8.2 Effects of salt and nitrite on gas packed pork meat.

mopping up the oxygen and is very effective in increasing shelf life by preventing rancidity development and maintaining the colour of cooked cured products.

8.3.2 Extrinsic factors

All the extrinsic factors are the basic requirements of good manufacturing practice. Their degree of importance depends on whether the meat product is a raw meat or a partially prepared meat product which has to be cooked by the consumer; or a fully cooked ready-to-eat product. It is essential that a meat manufacturer can ensure that his products are made to a recognised standard such as the BMMA standard for the Hygienic and Safe Manufacture of Meat and other Food Products before he considers an evaluation of shelf life. It is also a prerequisite that the manufacturer operates a Quality Management System. This could be to British Standard 5750 Part II (ISO 9002) but if not, any other quality system would still need to have a clear company quality policy, and procedures covering document control, product traceability, process control, hygiene procedures, calibration of measuring instruments and staff training.

It is important to know all the factors that have to be taken into account, and therefore a detailed product specification which would include its process flow and hazard analysis must be available.

8.3.2.1 Processing. Processing can take many forms, from simple butchery into joints or minced meat to full curing and smoking and smoking treatments in ham production.

In fresh meat the size reduction of the meat is an important factor, as is the time taken to process the meat. Mincing or dicing, with the consequent increase in surface area plus the opportunity for microbiological contamination, will decrease the potential shelf life. In cooked or smoked meats the time and temperature settings of the cooking programme must be designed to reduce the microbiological load so that the product is safe to eat without further cooking. A typical TVC for a cooked meat product at the ex-factory stage would be $<10\,000$ cfu/gram.

8.3.2.2 Hygiene. The basic requirements of hygiene are set out in the EC and UK legislation on meat and meat products, e.g. design, layout, interior finishes, and the movement of materials and operators through the plant.

Procedures must be in operation specifying cleaning methods, schedules and frequency for the structure and the equipment in the factory. There must be adequate laboratory facilities for monitoring the efficiency of cleaning, e.g. by swabbing and plating or by such methods as ATP bioluminescence.

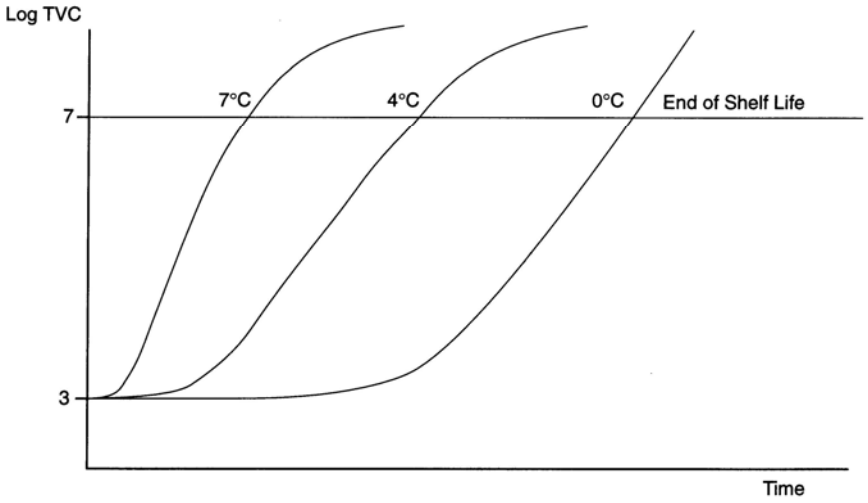


Figure 8.3 Effect of temperature on storage of raw meat.

The important specific aspects of hygiene in raw meat shelf life are the cleanliness of cutting boards and the sterilisation of boning knives in hot water pots (set at +82°C). Cutting boards should not be used for more than 4 hours without cleaning or turning.

Ready-to-eat chilled meat products must be processed after factory cooking in a 'high risk' area. This concept is now well established and a detailed specification can be found, for example, in the BMMA Standard for High Risk Operations (No. P005, dated 1.10.93). The cookers should form a barrier between the low and high risk areas. No personnel can enter or leave the area without passing through a sanitisation area which has cloakrooms, washroom and boot wash. Protective clothing must be distinctive and restricted for use in the area only. When carrying out a shelf life evaluation on cooked meat products all of the hygiene data on the high risk area, e.g. environmental swabbing, deep cleaning of equipment, organisation of raw materials and packaging and staff movement must demonstrate compliance with the specification; the objective of which is to minimise post-cooking microbiological contamination.

8.3.2.3 Temperature. The temperature of chilled meat products is legally specified. Packing rooms have to operate at room temperatures of 12°C. Product temperatures vary from offal 3°C, poultry 4°C and fresh meat 7°C. Distribution temperatures are 5°C but many major retailers specify temperatures of <3°C for cooked meats and for fresh meats. These temperatures have to be regularly measured and recorded, and also,

Table 8.4 Effect of different packaging formats on the shelf life of various meat products

(a) *Air pack*

	Days from manufacture to arrival in shop (maximum)	Days from arrival in shop to 'Use By'
Pork sausage	5	8
Skinless sausage	5	7
Sausagemeat	5	8
Stuffing	5	8
Pork chops	2	5

(b) *Modified atmosphere pack or vacuum pack – uncooked*

	Days from cure to pack (maximum)	Days from pack to 'Use By'
Mild cure back bacon	7	21
Wiltshire back bacon	7	28
Mild cure shoulder steaks	7	24

(c) *Modified atmosphere pack or vacuum pack – cooked*

	Days from cook to pack (maximum)	Days from pack to 'Use By'
Roast ham	7	21
Cooked ham	7	21
Pork luncheon meat	7	21
Hot dogs	4	24

(d) *Fresh meat – primals/cuts – bulk pack*

	Type	Days in pack (maximum)	Days from retail packing to 'Use By'
Bone-in pork (primal)	MAP	10	4
Boneless pork	MAP	9	4
Offal	VP	7	3
Dusted products	VP	7	4
Poultry	MAP	11	3

(e) *Other packaging types*

	Packaging type	Days from manufacture to 'Use By'
Paté	Chub	24
Black pudding	Chub	21
Pork pie	Bunchwrap	9
Pizzas	Overwrap	9

MAP = modified-atmosphere-packed.
VP = vacuum-packed.

equally important, the thermometers have to be calibrated. The temperature history of any product to be evaluated for shelf life obviously must be known and be within specification. Figure 8.3 shows the effect of temperature on the storage of raw meat.

8.3.2.4 Packaging. The effects of various packaging formats on meat product shelf life can best be seen in Table 8.4a–e.

8.4 Determination of shelf life

8.4.1 Procedures

The usefulness of any shelf life determination is entirely dependent on the conditions under which the determination is carried out. Ideally, any such trial would give information as to (1) the shelf life under ideal storage, (2) the shelf life under poor storage conditions and (3) the shelf life under the conditions likely to be met during normal distribution and storage and use in the consumer's home.

It would seem that (3) would be the most informative as this time, with a little extra as a safety margin, and would give an adequate shelf life. This however is not as straightforward as it may appear because 'normal' distribution and storage temperatures do not exist. Thus it is better to decide on a set of conditions for determination and keep them constant. Additionally, although in practice temperatures experienced during distribution, retail and storage by the consumer may all be different, if the temperature profile of storage in a laboratory determination is too complex, it may be impossible to gain an adequate understanding as to the microbial changes that are taking place. Also it would be most unlikely that the results obtained could be compared with those obtained in other laboratories.

8.4.2 Temperature

For the determination of the shelf life of new products, NewMarket Foods has chosen systems which are as straightforward as possible while closely reproducing the conditions likely to be met in practice. Every sample tested throughout the study is subjected to the appropriate temperature/time regime as shown in Table 8.5.

8.4.3 Test frequency

Microbiological examination and sensory analysis are carried out throughout the expected life of the product and beyond. For short life

Table 8.5 Microbiology laboratory – shelf life storage conditions

Product type	Storage temperatures		
	Bulk storage	Retail storage	Customer storage
Fresh pork	0°C	5°C	8°C (1)
Sausage	NA	5°C	8°C (1)
Cooked/uncooked retail pack	NA	5°C	8°C (4)
Cooked bulk pack	5°C Sealed	5°C (3) Opened	8°C (1) Opened

Where appropriate, figures in brackets refer to the number of days the samples are held at the stated temperature. NA = not applicable

products, e.g. fresh meats, these tests can be as often as daily with the time beyond the expected life being a day; but for fresh meats containing preservatives, tests are usually at intervals of 2 to 3 days, up to a maximum of 12 days.

Products should be tested on day of production and on at least three further occasions during the projected shelf life. Ideally these should be followed by tests at the end of the projected shelf life and two days immediately before and after that.

It is important that tests are frequent enough so as not to miss any turning points in the determination, but with most products, testing every day throughout the determination would be unnecessary and excessive. It must be remembered when setting test dates that the purpose of the exercise is to set a shelf life for the product, which is both safe and realistic. Careful preparation in setting test days will be necessary if the laboratory working week is only Monday to Friday.

8.4.4 Storage atmosphere

During shelf life determination products are stored in the sealed finished packs in which they are to be sold. To mimic usage in the retail delicatessen counter, after storage in the original packaging, bulk cooked meats are stored open for the last 4 days of their shelf life.

8.4.5 Sample numbers

In general, the more samples are examined on a sampling occasion, the more accurate the results obtained. However, the number of samples tends to be governed by practical considerations. In the case of a bulk food destined for sale from a delicatessen counter, for example, it may be appropriate to return to the same pack for sampling throughout the entire

evaluation. However, it is usually necessary to store the product being studied in its final retail packaging.

A separate set of samples must therefore be used on each sampling occasion. On each such occasion there must be enough replicates taken to give a good representation of the general state of the product under test. A high level of replicate samples could however put considerable demands on both the resources and incubation space. Testing five replicate samples on each occasion is a good compromise as the means obtained from the samples give a sound basis for comparison. Additionally, the results from five samples can easily be applied to a number of sampling plans which may be used to generate useful information about the batch from which the samples have been taken.

From time to time however, either because of scarcity of the product or other restrictions, it is not always possible to test five samples on each occasion and lower numbers of samples must suffice. The results obtained under such circumstances must be treated with caution and are only meaningful if the batch being examined is uniform. For products with a wide variation in quality within the batch the information obtained could be of limited value. Basing shelf life estimations on tests carried out on a single sample on each sampling occasion could therefore be grossly misleading.

8.4.6 Sensory analysis

As described above, a shelf life determination should give information as to the length of time a product will remain wholesome, i.e. acceptable both from a safety and an organoleptic point of view. The most effective way of determining the sensory end point of a product under storage is for a panel of trained assessors to examine the product at regular intervals.

It is not always possible for formal taste panels to be used in shelf life determinations and frequently it is left to the experience of a few individuals to determine whether a product is 'acceptable' or not. This is only possible if the individuals carrying out the assessment are highly skilled with considerable experience of sensory analysis techniques.

8.4.7 Laboratory analysis

In addition to sensory analysis during the shelf life study, it is almost always necessary to carry out microbiological analysis of the product. This provides greater understanding of the changes taking place during storage. It is also possible to carry out chemical analyses during storage – examples of these are peroxide values (assessing the development of oxidative rancidity), reduction in nitrite levels, and volatile nitrogen levels

(giving some indications of proteolysis of meat). In general however, chemical analysis is not sensitive enough to demonstrate the changes taking place during storage and the product has usually deteriorated to such an extent that it is organoleptically and/or microbiologically unacceptable before chemical analyses can detect any changes.

8.4.8 Microbiological examination

The microbiological examination of products during a shelf life study can give some information on both the time taken for the spoilage organisms to reach a level where they affect the sensory properties of the product, and, though less usefully, the likelihood of any pathogenic microorganisms present (immediately after production/packing) attaining levels during storage which would create a health risk to the consumers.

8.4.8.1 Microorganisms affecting product keeping quality. The main spoilage organisms during aerobic, low temperature storage are *Pseudomonas* spp. whereas under vacuum storage, the major spoilage organisms are *Lactobacillus* spp. and yeasts. MAP may involve spoilage by a combination of the above, i.e. *Lactobacillus* spp., *Pseudomonas* spp. and yeasts and in addition may support the growth of *Brochothrix thermosphacta*. These organisms tend to affect the sensory properties of product at levels in the region of 10^7 cfu/g. Therefore the end point of the shelf life is generally considered to be reached when microbial counts reach this level. Useful information regarding the end point can of course be obtained from sensory analysis carried out in parallel with microbiological examination.

Since the initial shelf life determination is an opportunity to gain as much information as possible about the microbial flora of the product, a wide range of organisms are frequently examined throughout the storage. Not all of these play an important role in spoilage at chill temperatures, however they may give some idea of the hygienic conditions under which the product has been prepared or the microbiological risks associated with the product (e.g. the presence of coliforms could indicate the presence of pathogenic organisms). Figures 8.4, 8.5 and 8.6 show changes that were observed in the spoilage flora of sausage, cooked meat and fresh pork respectively, under various storage conditions.

8.4.8.2 Pathogens. A shelf life determination should give information as to the likelihood of any pathogen, which survives the manufacturing process or gains access to the product after processing, to develop in the product to such a level that it would become a health risk to the consumer. This is most desirable, however, in practice there are many hurdles in the way of achieving this. These include the following:

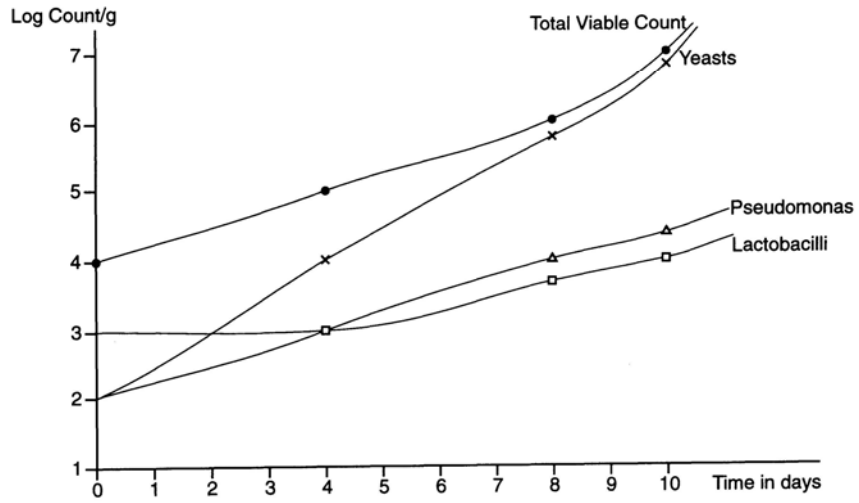


Figure 8.4 Spoilage flora of sausage – aerobic storage at 5°C.

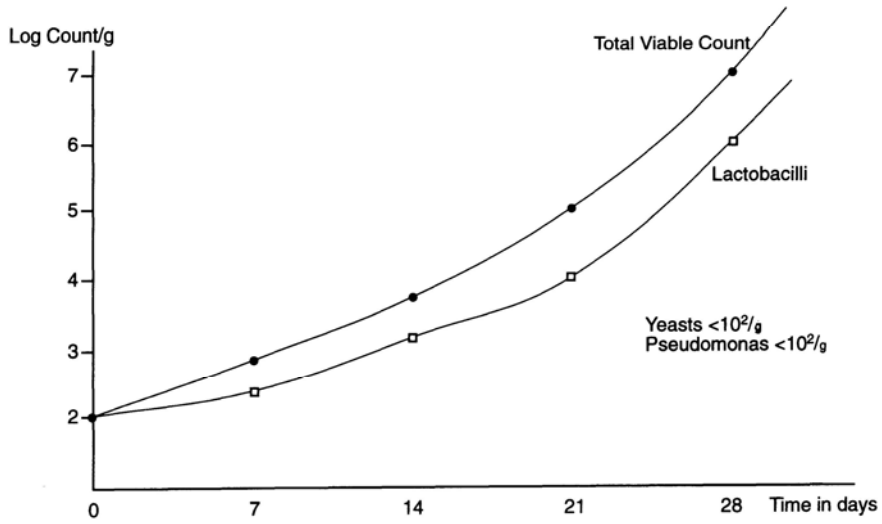


Figure 8.5 Spoilage flora of cooked meat – MAP storage at 5°C.

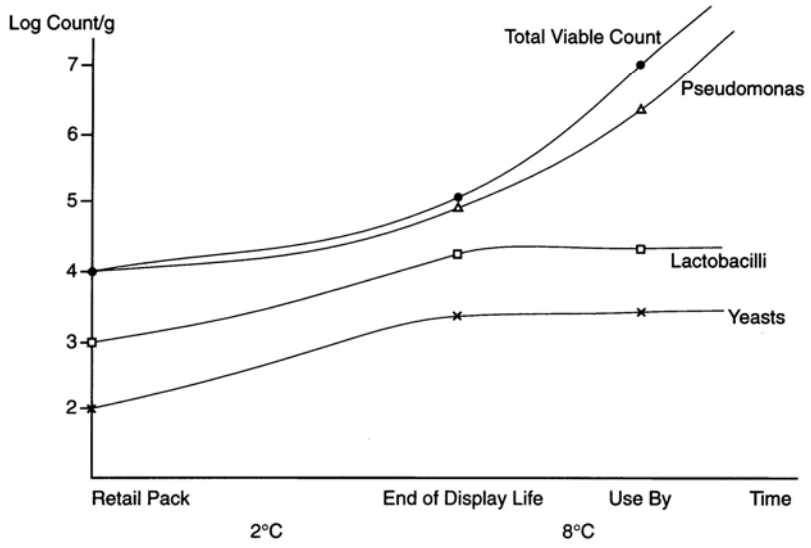


Figure 8.6 Spoilage flora of fresh pork – aerobic storage at 2°C, followed by storage at 8°C.

1. It is not possible in practice to investigate all of the organisms of concern.
2. From experience, the presence of pathogens in the product should be very infrequent. However, their absence from the shelf life results is no absolute guarantee that they will not be present in the product.
3. Inoculating the product with pathogens at the beginning of its shelf life and following their development is never straightforward. The inoculum is unlikely to bear any relationship to the microorganisms that might gain access from the environment. It would not be possible either to investigate all the strains or to reproduce exactly the growth conditions found in practice.

Shelf life determinations nevertheless do frequently include a search for pathogens of concern, e.g. *Salmonella* spp., *Listeria* spp. This does provide some information at the time but gives very little assurance that the pathogens in question are absent or that if present, will fail to multiply. Thus although shelf life determinations can give some ideas as to how long a product takes to spoil in a given storage condition, they give little assurance of safety.

8.4.8.3 Standards. There are very few authoritative statements on what is an acceptable microbiological quality for foods. A most useful docu-

Table 8.6 Microbiological quality of ready-to-eat foods sampled at point of sale

	Microbiological Count (cfu/g unless otherwise stated)			
	Satisfactory	Fairly Satisfactory	Unsatisfactory	Unacceptable (potentially hazardous)
Aerobic plate count				
Cooked pies, pasties	$<10^4$	10^3–10^5	$>10^5$	
Cooked meats	$<10^4$	10^4–10^6	$>10^6$	
Salmonella spp.	not detected in 25 g			present in 25 g
L. monocytogenes	not detected in 25 g	present in 25 g $<10^2$	10^2–10^3	$>10^3$
E. coli	<20	20–10^2	10^2–10^4	$>10^4$
S. aureus	<20	20–10^2	10^2–10^4	10^4
C. perfringens	<200	200–10^3	10^3–10^4	$>10^4$
B. cereus and other *Bacillus* spp.	<200	200–10^4	10^4–10^5	$>10^5$

ment on this topic has been produced by the UK Public Health Laboratory Service: *Provisional microbiological guidelines for some ready-to-eat foods sampled at point of sale* (PHLS, 1992). These criteria are given in Table 8.6. The figures are given with the understanding that they may be altered as more information is obtained. No recommendations have been made concerning faecal streptococci, *E. coli* 0157 or *Yersinia enterocolitica* as insufficient information was available to deduce satisfactory levels.

8.5 Current trends

Some of the current trends in the manufacture, marketing and consumption of meat and meat products have been highlighted in the introduction to this chapter. With regard to the evaluation of shelf life, the trends can be classified into three categories:

1. microbiological safety and quality;
2. packaging and packaging techniques;
3. quality and safety management.

8.5.1 Microbiological safety and quality

New and significant relevance has had to be given to certain pathogenic bacteria for which tests were not carried out routinely a few years ago.

Examination for *Listeria monocytogenes* is now routine in any meat factory microbiological laboratory. New, faster and more reliable methods are becoming available. *E. coli* 0157:H7 is another which will require greater attention by the meat microbiologist to ensure it will not become a threat to otherwise safe meat products.

Laboratory accreditation to a recognised national standard such as that of the National Measurement Accreditation Service (NAMAS), or other similar accreditation schemes, e.g. those run by Campden Food and Drink Research Association (CLAS) and LawLabs (LABCRED), will become a prerequisite of a factory laboratory. This will entail substantial changes in laboratory design, methodology and personal and environmental hygiene.

A recent development in determining the shelf life of products with special reference to safety is mathematical modelling. Here, a large bank of information is built up about the growth and survival of specific microorganisms under a variety of conditions. A computer program is then developed which will allow the growth or otherwise of these microorganisms in any given environment to be predicted. To use the program, the physical and chemical characteristics of the food under investigation are defined, e.g. pH, a_w, nutritional composition. The program then calculates the growth characteristics under any particular storage condition. Modern models are extremely sophisticated and can give a good estimate of the growth of a particular microorganism in a given food under defined conditions. The data on which they base their predictions, however, are of necessity incomplete and the results must, therefore, be interpreted with care.

No laboratory test or mathematical modelling can be comprehensive enough to reproduce the storage of a product under every circumstance. The information which can be obtained from them *vis-a-vis* the safety of the product after storage is, therefore, limited. A comprehensive knowledge of the shelf life of any product can only be obtained after the product has been in production for some time and its storage characteristics monitored regularly.

8.5.2 Packaging and packaging techniques

Probably the most important factor in maintaining the assigned shelf life using modified atmosphere packaging is the integrity of the seal. The seal area immediately prior to sealing must be free from contaminants such as fats/grease to prevent the subsequent formation of leakers. It is now recognised that a good seal should be at least 5 mm wide.

Packaging film manufacturers are researching the so-called 'smart' films which can change their permeability properties under adverse conditions, e.g. misuse of the pack resulting in microbiological spoilage. An example

is the aluminium oxide coated polyester film which has good clarity and oxygen barrier characteristics that are not influenced by the thickness of the coating. The latter can be as thin as 20–30 nm (200–300 Å). This layer is not sensitive to humidity changes (as is EVOH) and although, like other barrier layers, it tends to crack under extreme conditions during packing, the rupture will 'heal' itself by absorbing moisture from the atmosphere causing the oxide crystals to swell. This effect restores the film's oxygen barrier to almost its original value.

Other factors which affect the overall residual O_2 content of MA packs and therefore shelf life are:

1. machine cycles that alternately evacuate/back gas flush the pack several times prior to sealing;
2. optimisation of the headspace to product ratio to allow a sufficient amount of the modified gas mixture to reduce the percentage of residual O_2.
3. temperature of the product at point of packing. Since the solubility of air increases significantly at low temperatures, and the percentage of O_2, compared with N_2, is much higher in solution (33–35%), packing of product that is too cold can result in a higher than expected residual O_2 level as the gases in the final pack eventually reach an internal equilibrium.

There will obviously be further developments to reduce fogging, to increase barrier and to improve sealability whilst still allowing easy opening for the consumer and to satisfy the environmentalists with respect to environmental friendliness.

New systems for extended MAP storage of raw meats are on offer and being actively developed by Captech and Chill-tec. Both systems, initially developed in New Zealand, claim to markedly extend the shelf lives of products, particularly meat, by similar means. Hygienically prepared products are sealed in very high barrier, multilayer pouches in combination with Snorkel and Chamber machines. Very powerful vacuum pumps effectively remove all the air, including oxygen, which is then replaced with oxygen-free CO_2. This in combination with a high degree of temperature control throughout subsequent storage and distribution (typically $-1 \pm ½°C$) can, it is claimed, extend the life of pork up to 10 weeks, with additional benefits of product tenderness and colour in the ultimate retail pack.

Gas exchange preservation (GEP) involves pumping air out and replacing it by a series of gases in quick succession, each with a different role to play, e.g.

- CO – to inhibit enzymes;
- SO_2 or ethylene oxide – to kill bacteria;
- N_2 – to flush out the system.

Such a technique is unlikely to have a future because of the toxicity of carbon monoxide and the banning of ethylene oxide in food.

Gas mixtures must strike a balance between the bacteriostatic effects of increased CO_2 level and the exudation problems associated with the resultant drop in pH of the meat.

Oxygen scavengers have been around for some time. New developments are expected to use them as an integral part of the pack so that they cannot be inadvertently eaten by the consumer.

8.5.3 Quality and safety management

The trend in the meat industry of companies seeking certification to ISO 9002, the international standard for Quality Management System (or its British equivalent BS 5750), will continue. With its emphasis on process control, calibration of all measuring instruments (temperature measurement being a critical factor), document control and training, such a system will ensure, in the future, more accurate setting of product shelf life.

Similarly the use of HACCP will also continue to identify the hazards and assess the degree of risks inherent in any process. A shelf life determination will not be carried out unless a detailed hazard analysis of the product and process has been made and the critical control points understood and established.

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9 Ambient packaged cakes

H.P. JONES

9.1 Introduction

The market of 'ambient packaged cakes' covers the range of cakes sold through the supermarket rather than the baker's shop. The major distinction between the two categories is the difference in shelf life requirements. The small baker makes most goods daily and more complex confectionery products with a shelf life of several days, once or twice a week. The packaged cakes sold in the supermarket today normally have a minimum shelf life of three weeks. The need for longer life is necessary because of the time required to distribute to stores with a subsequent requirement for a reasonable period of display on the shelves. Additionally, supermarket products have to be properly packaged to protect them through distribution and in-store handling.

The ambient packaged cake market is served by a few manufacturers who can produce large quantities of cakes to consistent standards. These companies must have the technical resources to design products with the required attributes. The term 'ambient' is necessary to distinguish this market sector from the 'frozen' and 'chill' sectors which operate with very different shelf life requirements. Chilled cakes, in particular fresh cream filled ones, normally have one or two days' life and are merchandised in refrigerated display cabinets. Frozen cakes usually have a shelf life of many months whilst in the freezer but only one to two days at ambient once thawed.

A wide range of ingredients and manufacturing techniques are used in the production of cakes. Besides the many ingredients and different processes employed to make cakes such as sponges, fruit cakes and pastries, flour confectionery overlaps with other product sectors of the food industry, namely, chocolate and sugar confectionery. The latter have very different composition and product characteristics; and as such can complicate shelf life considerations when combined with flour based products.

One of the key tasks of the cake/food technologist, therefore, is to design cakes in which the characteristics of individual components are not adversely affected during distribution and subsequent storage.

Table 9.1 Classification of ambient cakes

Type	Main feature
Sponge cake	Low fat level
Fruit cake	Medium fat level and fruit
Plain cake, e.g. Madeira	High fat level
Chocolate-coated cake	Moisture barrier present
Fruit pies	High and low moisture components
Pastries	Multi-component products

9.2 Product classification

Ambient cakes may be classified in several ways such as by formulation or process type, but for the purpose of shelf life evaluation, the classes listed in Table 9.1 will be used.

One of the challenges of the ambient cake technologist is to formulate products which will retain their moistness, texture and appearance for as long as possible. To do this, an in-depth and up-to-date knowledge of ingredients, packaging materials, production processes and the technology of moisture control is necessary.

Ambient cakes belong to the category of intermediate moisture food products, i.e. with about 20% moisture, and water activities (a_w) within the range 0.65–0.90. With these water activities cakes can be preserved for many weeks in a variety of ways, i.e. canning, vacuum packaging, gas flushing and alcohol injection. Canning is sometimes used and will preserve cake for many months but there are drawbacks which limit its use. The high product temperature reached in the canning process excludes all but the simplest of oven finished cakes, as it can result in pudding-like eating quality. Vacuum packaging can damage the fragile structure of most cakes and so only the very robust type can be packed this way. The preservation of cakes therefore relies mainly on formulation and control of the inside-pack atmosphere by the use of suitable packaging, and in certain 'long life' applications, modified atmosphere packaging. The modern cake factory and the systems employed in it are designed in such a way that only raw materials of the right and specified quality are used and that production processes are carried out correctly and hygienically, so that finished products have the specified moisture content and a_w, ensuring the assigned shelf lives are achieved consistently.

9.3 Equilibrium relative humidity and mould-free shelf life

The growth of microorganisms in foods is, in part, determined by the availability of water that will support microbial growth. This is measured

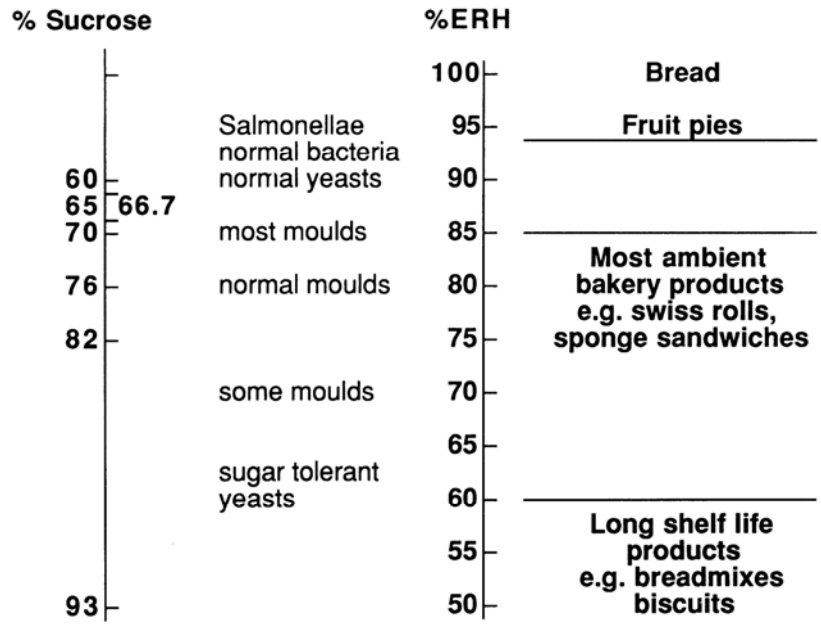


Figure 9.1 Minimum ERHs (and their approximate corresponding sucrose concentrations), permitting growth of microorganisms.

by the 'water activity' (a_w) of the food. The 'equilibrium relative humidity' (ERH) of a cake is the humidity at which rates of evaporation and condensation of water are equal. It is the relative humidity which is eventually reached in the atmosphere surrounding the cake when it is closely enclosed by a perfect water barrier. At this equilibrium, the terms ERH and a_w are interchangeable. In the bakery trade, the term ERH is more appropriate and preferred to a_w since microbial growth tends to develop on the exposed surface of the product. The minimum ERHs (and their approximate corresponding sucrose concentrations) permitting growth of microorganisms are shown in Figure 9.1. As can be seen, most moulds are only able to grow at an ERH above 80%. Table 9.2 shows a range of bakery products and their approximate ERHs (Cauvain and Seiler, 1992).

Using experimental data, the Flour Milling and Baking Research Association (FMBRA) in the UK was able to demonstrate the relationship between ERH and the mould-free shelf life (MFSL) of cake at various storage temperatures (Figure 9.2). It is apparent that there is a linear relationship between ERH and the logarithm of the MFSL within the range 74–90% ERH. This relationship is given by the following expressions for the storage temperatures of 27°C and 21°C respectively (Seiler, 1976).

Table 9.2 A range of bakery products and their approximate ERHs

Product	ERH%
Biscuits	5–15
Bread crumb	96–98
Bread crust	30–50
Plain cakes, e.g. Madeira	80–90
Fruited cakes	73–75
Christmas puddings	70–77
Jam	70–80
Marzipan	70–80
Dried fruit	65–70
Glacé cherries	75

Source: Cauvain and Seiler, 1992.

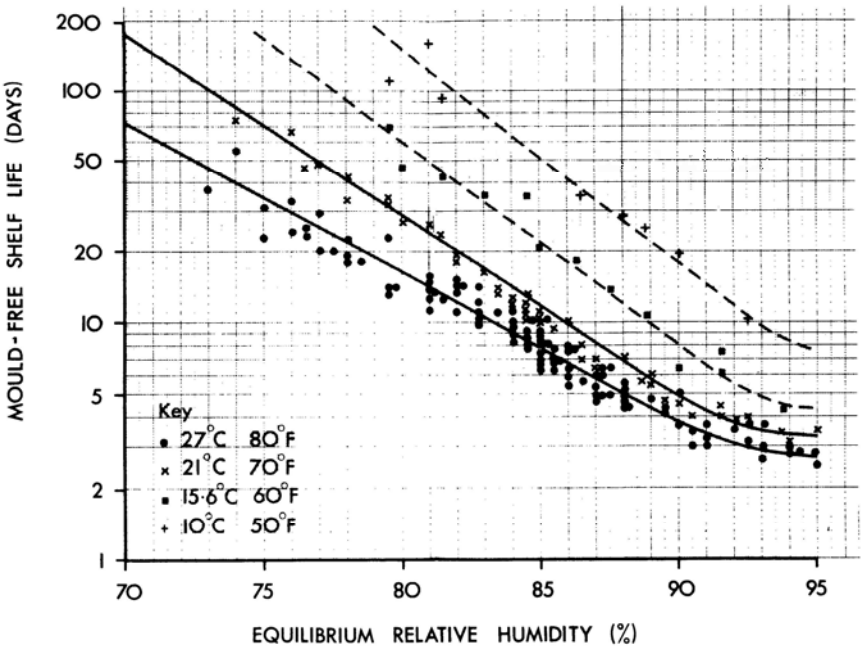


Figure 9.2 MFSL, in days, at various storage temperatures in relation to the ERH of the product. (Source: Cauvain and Seiler, 1992).

$$\text{Log}_{10}\ \text{MFSL (days at 27°C)} = 6.42 - (0.065 \times \text{ERH\%})$$
$$\text{Log}_{10}\ \text{MFSL (days at 21°C)} = 7.91 - (0.081 \times \text{ERH\%})$$

From this work it has been possible to estimate the MFSL of cakes based on their formulations, using the above relationship and since 1990, with the help of FMBRA's recently developed ERH CALC (see section 9.6).

9.4 Product characteristics

9.4.1 Sponge cakes

This product group is made up of lines such as Swiss rolls, sponge sandwiches, and the foundations for a variety of gateaux. The formulations are usually very low in fat, often containing no added fat. This is necessary to enable the sponge to be rolled, cut and assembled into a variety of shapes without cracking or breaking. Though the fat content of the sponge is low the final product may be enriched with buttercream or synthetic cream, with fat contents of around 45%. The characteristics of a sponge are light texture, delicate flavour and good cutting properties.

As well as the total product ERH that needs to be controlled, it is important to ensure that the ERHs of individual components in a multi-component product are also balanced as far as possible to minimise moisture migration from one component to another, unless this is desired. Sponge products lose moisture very rapidly when exposed to the atmosphere because of the large surface area to weight ratio and low fat contents. To prevent moisture loss, they are usually wrapped in films that can provide a good moisture vapour barrier, as soon as they are sufficiently cooled. This ensures that the correct moisture level is retained in the product. A shelf life of three weeks can usually be obtained by optimising the formulation and choosing the correct wrapping material.

9.4.2 Fruit cakes

The rich fruit cake eaten at Christmas and the more humble slab cake are British specialities noted for their moistness and good keeping qualities. Fruit contents can range from 30% to 100% of the batter weight and consequently a strong cake structure is required to support the fruit and prevent it from sinking during baking. High protein flour, egg and the judicious use of fat provide the crumb strength to maintain an even distribution of fruit and to hold the cake together when cut. Both defatted soya flour and egg albumen can be used to supplement the protein levels.

The addition of dried fruit helps to increase the shelf life by reducing the ERH of the cake. Dried fruit contains only 16% moisture but in

combination with the reducing sugars in it produces very moist eating quality, characteristics of a cake with a much higher moisture content. A shelf life of many weeks can be obtained because of this and it can be significantly extended by adding alcohol to the product before or after baking. Alcohol has been shown to act as a mould inhibitor and retard crumb staling (Guy *et al.*, 1983; Ooraikul, 1991).

Fruit cakes lose moisture slowly even when unwrapped and it is normal practice to leave slab cakes to stand overnight to allow moisture to equilibrate and fats to set before cutting and wrapping. Heavily fruited cakes soaked in alcohol will remain in good condition for one year or more if stored in an airtight container.

9.4.3 Plain cakes

This group comprises many typically British cakes such as Madeira, Battenburg and Victoria sandwich. There are also many American formulations which are popular today such as 'Death by Chocolate' and 'Fudge Cake'.

The inclusion of chocolate in a formulation increases the fat content further. High fat levels result in lower volume cake than sponge cake but produce a richer, moister eating cake which can be eaten without the addition of buttercream or other fillings. It is common for cake foundations of this type to have ingredients added such as nuts, cherries, chocolate chips and so on. They are often used as a base for converting into Battenburg, fondant fancies and iced celebration cakes. Special account needs to be taken of the ERH of post-bake finishes as moisture migration can spoil the appearance and eating characteristics of decorations.

9.4.4 Chocolate coated cakes

Chocolate coated cakes have become a significant sub-sector within the ambient cake market and they do have particular technical properties in respect of shelf life. Any of the cake formulations so far discussed can be used as a foundation over which chocolate can be enrobed. Chocolate not only adds a unique flavour and texture but also encloses the product in a fatty barrier which reduces the rate of moisture loss from the cake and thereby assists in shelf life extension. There are a number of special considerations to be taken account of when developing cakes for chocolate coating. Firstly, there is the need to avoid 'crumbing' as it will contaminate chocolate circulating in the enrober. Secondly the foundation must not shrink excessively during life as this will leave a fragile chocolate shell which is likely to disintegrate in the pack or when the product is cut or eaten. It is necessary to use a chocolate coverture which will cut cleanly without shattering and yet not be too soft to handle in warm weather.

9.4.5 Fruit pies

Fruit pies form the largest single product sector within the ambient cake market and are mainly produced in the mini pie format. The product make-up is approximately 50% pastry and 50% fruit filling and products are formulated to keep the pastry dry and crisp eating, and the filling moist.

Fruit pies are normally oven finished and packed directly after cooling. They are not film wrapped but packed into cartons thereby allowing a gradual loss of moisture to the atmosphere through life.

9.4.6 Pastries

This product group encompasses a wide variety of products which include:

- jam tarts
- puff pastries
- Danish pastries
- Viennese tarts
- cherry Bakewell tarts

Pastries come in many shapes and sizes and their make-up is often complex, as they can have up to six different components. The following fillings and decorations are commonly applied:

- synthetic creams
- jams and jellies
- cake fillings, e.g. Bakewell
- icings
- chocolate
- nuts
- glacé cherries

The complex nature of their composition poses particular problems in preserving the texture and appearance of components throughout the life of the product. Most of the products mentioned in this group are usually wrapped in impermeable films.

9.4.7 Product characteristics – a summary

From the previous outlines of product characteristics and past experience, a few generalisations can be made concerning product factors that are conducive to longer shelf life. While these are probably not new, it is useful to put them together so that they may help future product design.

1. complete enrobing in chocolate or chocolate coverture helps to retain quality inside (e.g. chocolate covered Swiss rolls vs. ordinary Swiss rolls).

2. High fruit content: the low ERH and the presence of hydroxymethyl furfural (HMF) in dark fruit cakes contribute to a longer shelf life.
3. Low moisture content (e.g. Jaffa cakes)
4. Jam and cream fillings are better than jam alone or cream alone (e.g. in sponge sandwiches).
5. High sugars content (e.g. Jamaica ginger cake).

9.5 Factors affecting shelf life

The most common causes of quality deterioration of ambient cakes are:

- microbiological spoilage (visual growth or fermentation);
- crumb staling (dryness and the development of off-flavours);
- rancidity (off-flavour development);
- crystallisation of sugars (e.g. grittiness in cream fillings);
- syneresis of jams and jellies;
- off-flavours and odours other than rancidity;
- chocolate bloom (or loss of gloss in baker's coatings);
- structural weakness;
- colour fade, change and transfer;
- moisture migration and loss.

9.5.1 Microbiological spoilage

The microorganisms most commonly found in ambient packaged cakes are moulds and yeasts. The ability of these microorganisms to grow and spoil the food is determined by a number of factors such as the availability of water, the environmental temperature and the pH of the system. In general, the risk of microbial spoilage can be significantly reduced by (a) developing formulations to an appropriate ERH, (b) using a suitable mould inhibitor and (c) optimising the pH where possible (Cauvain and Young, 1990).

There are few ingredients used in the manufacture of ambient cakes, which are generally recognised as actual or potential sources of harmful organisms; the most common potentially 'sensitive' ingredients are eggs, cocoa powder and desiccated coconut. However, these are usually pasteurised, dehydrated and subsequently baked in the products which render them microbiologically safe. Also, they are carefully controlled by the suppliers and manufacturers who ensure they remain uncontaminated. When coconut products and cocoa powder are used in 'cold' processes to make coatings and fillings for instance, the cake manufacturer is well advised to have them checked for pathogens by a competent laboratory.

9.5.2 Crumb staling

Staling is a phenomenon related to changes in the state of cooked starch and recognised in baked products as a dry crumbly texture, often accompanied by an unpleasant flavour and odour (Guy *et al.*, 1983).

9.5.3 Rancidity

The oxidation of fats can lead to off-flavours and odours but this has not been a major problem for the ambient cake manufacturer whose products have in the main three weeks' shelf life, provided the fats used are fresh and have been stored correctly. However, increase in the use of butter/butter oil over the years has resulted in a higher incidence of hydrolytic rancidity (Bennion, 1972). Furthermore, some cakes (also from Continental Europe) are now sold with shelf lives of 3 to 6 months, which tends to increase the potential for oxidative rancidity.

9.5.4 Crystallisation of sugars

This fault may occur in jams, icings, caramel, various cake decorations and fillings. The causes are frequently related to incorrect formulation and poor processing. Basically, if moisture is free to migrate from a layer of caramel, for example, into an adjoining component, it can result in graining in the caramel (Lees, 1973). Likewise, the loss of moisture from jams and icings can lead to coarse crystal growth in them (Paul, 1972). Indeed, even in the absence of any free moisture transfer, water vapour will migrate as long as there is a sufficient gradient. Of course, moisture migration can generally be minimised by judicious formulation, reducing as far as practicable the difference between the ERHs of the various components.

9.5.5 Syneresis of jams and jellies

This phenomenon can often be seen in jam-filled cakes and manifests itself as a dark, moist syrupy area above or below the jam layer. It is caused by the liquid phase in the jam separating from the gel structure and migrating into the cake crumb. The appearance is unsightly and the eat, cloying and unpleasant. The main causes are normally due to the wrong choice of gelling agents or incorrect processing during jam boiling (Anon, 1984). Excessive pumping of bulk jam after it has set damages the gel structure and encourages syneresis.

9.5.6 Colour fade, change and transfer

The widespread rejection of artificial colours in foods in the late 1980s has increased the use of natural colours in the baking industry. Many of the food colours now used are derived from plants, e.g. anthocyanins, which are unstable under certain processing and/or environmental conditions. Ultraviolet barrier films or cartons can be used, for example, to overcome instability to light. Some natural colours are unstable in acid environments and the original colours can be significantly changed as shelf life progresses (Newstubb and Henry, 1988).

9.5.7 Off-flavours and odours other than rancidity

Off-flavours and odours in cakes can be caused for a variety of reasons, some of the most common ones being:

1. The use of old or badly stored ingredients (e.g. dried fruit) can introduce stale/unpleasant flavours which will accentuate as the product ages.
2. Packaging odours can be transmitted to products from printing inks, recycled board and so on (Anon, 1960).
3. Jam fermentation due to microbial contamination produces alcohol notes which are unacceptable.
4. Taints can come from cleaning chemicals if hygiene procedures are incorrectly carried out.

9.5.8 Chocolate bloom

This is a common fault in chocolate confectionery products and may also be found in chocolate-covered cakes. It is recognised by the dull greyish appearance of the chocolate coating. The four most frequent causes are: poor chocolate tempering, incorrect cooling causing condensation and subsequent sugar crystallisation, incompatibility between fats in the chocolate and the product enrobed, and temperature abuse during storage of the finished product (Minifie, 1988).

9.5.9 Structural weakness

Many cake formulations are designed to produce light, tender cakes, e.g. Swiss rolls, Madeiras and Victoria sandwiches. These products are often described as 'whole cakes' because they are sold as single products for portioning by the end user. If the structure of the cake is too weak so that it crumbles when cut it will be unacceptable to the consumer. Such a fault may not be apparent when the cake is first produced but develops as

moisture redistributes within the product. There are several causes for this but the most common ones are protein deficiency in the flour, insufficient egg and/or excessive fat in the formulation and incorrect processing.

9.5.10 Moisture migration

Moisture in ambient cakes will migrate, if permitted to do so, whenever a moisture gradient exists, until equilibrium is eventually reached. This can be demonstrated by examining a freshly baked Madeira cake where the moisture contents of the top crust and the core are typically 10% and 25% respectively. After cooling and wrapping in a barrier film, moisture will migrate from the core to the top crust and into the air space inside the pack until equilibrium is attained. Similarly, migration will also occur between adjacent components. This is most commonly seen in fruit pies where the pastry is softened by moisture coming from the filling. Excessive moisture transfer can spoil the desired characteristics of a product by making, for example, the pastry in a fruit pie soft and soggy, and the filling dry and stale. Moisture migration can be minimised by careful formulation with a view to balancing the ERHs of the various components but this may not be feasible technically or acceptable organoleptically. An alternative solution would be to introduce a moisture barrier which inevitably incurs additional cost and may not always be practicable.

9.6 ERH CALC

ERH CALC (Cauvain and Young, 1990) is the first part of a computer-based 'Cake Expert System' for the baking industry produced by the UK Flour Milling and Baking Research Association (FMBRA), which enables the technologist to run formulation simulations and rapidly calculate theoretical ERH of the products and hence estimate their MFSL. The benefits of this computer tool are threefold. Firstly, it saves considerable time and effort in determining MFSL compared to trial and error methods. Secondly, it enables many more theoretical formulation options to be tried in a limited amount of time. Thirdly, it is an excellent training aid for new development staff who are unfamiliar with cake technology.

The main features of ERH CALC are (Figure 9.3):

1. It has a customised ingredient database which is tailored to the user's requirements thereby avoiding the need to occupy computer memory with irrelevant data.
2. It permits ingredient details to be input manually which is essential for trying out new ingredients.

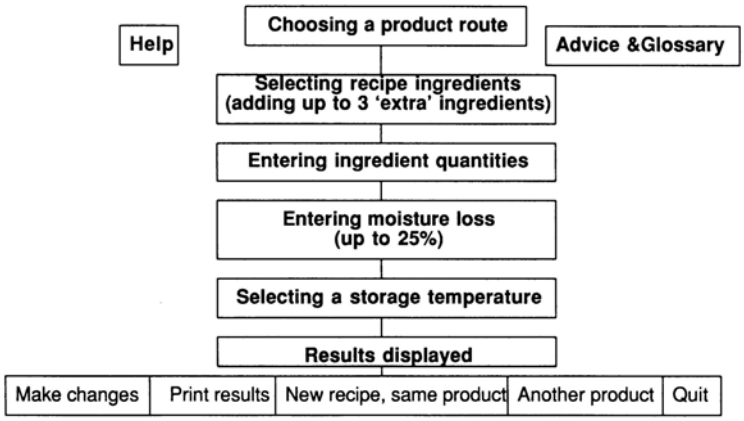


Figure 9.3 Main features of ERH CALC. (Source: Cauvain and Young, 1990).

3. It permits a range of process moisture losses to be input, e.g. baking, cooling and storage, which is essential for accurate ERH calculation.
4. ERH and MFSL can be calculated at either of two storage temperatures, 21°C and 27°C, which cover adequately the temperature range normally found in retail and domestic situations in the UK.
5. Component and product formulations are classified according to whether they are baked or unbaked, because of the effects of this on sugar solubility and the final ERH.
6. At the end, the system produces an overall ERH and MFSL prediction for the composite product, with the overall ERH being a weighted average of its components.
7. Also included are an 'advice' and a 'glossary' section. The 'advice' section contains information on possible changes to the formulation or production conditions and their effects on MFSL. For example, there are tables to help evaluate the effect of using the mould inhibitor, potassium sorbate and tables to show how shelf life can be increased further by lowering the product pH.

To get the most out of ERH CALC it is necessary to understand the design assumptions and to compare predictions with actual measured results. By reconciling differences, the user will develop skills in interpreting the information produced. ERH and MFSL predictions are made on the assumption that the product is wrapped in an impermeable film and that moisture will equilibrate within the pack. In practice, this is not always the case. For example, fruit pies are not usually film-wrapped and are free to lose moisture to the atmosphere. Also, assumptions are made about solubility levels of sugars whereas in practice, process conditions can greatly affect the amount of sugar which finally goes into solution.

The effects that mould inhibitors, e.g. sorbic acid, and others have on extending shelf life are not computed within the system but reference tables previously mentioned enable manual adjustments to be made. It is therefore possible for the user to formulate for specific shelf life requirements. By using ERH CALC the newcomer to cake technology quickly understands the role and significance of humectants in increasing cake shelf life as well as the importance of accurate control of moisture loss in baking and cooling.

The FMBRA team who developed the software is currently preparing the second edition incorporating cake formulation balance and fault diagnosis. Considerable experience gained in the use of ERH CALC since it was first launched has confirmed that it is an extremely useful tool, one that can be highly recommended to anyone involved in industrial cake development and manufacture.

9.7 The determination of product shelf life

The theoretical estimation of shelf life through ERH CALC is a very valuable tool in formulation design but there are many other factors that have to be considered. The quantitative and qualitative data collected during concept life tests relate to a development product manufactured under tightly controlled conditions. It is necessary however to take a broader view and consider external factors which may put the product at risk.

Hazard Analysis Critical Control Point (HACCP) is a system designed to identify potential hazards and their associated risks, allowing appropriate controls to be introduced and monitored (CFDRA, 1992).

9.7.1 Product data

The product data required for making shelf life decisions are derived from:

- sensory analysis
- laboratory analysis (chemical analyses and physical tests)
- microbiological examination
- travel test

9.7.1.1 Sensory analysis. The following are some of the most common quality attributes assessed in the sensory analysis of cakes:

- moistness
- crumb firmness
- colour
- flavour

- texture
- mouthfeel
- odour

Products should be assessed by trained assessors who have been selected for flavour sensitivity, colour identification and their ability to recognise consistently a range of quality attributes and assess their intensity reliably. The analyses are usually carried out at weekly intervals until the product has achieved its desired shelf life or until it becomes unacceptable. Each attribute is judged on a qualitative or numerical scale so that results can be tabulated or plotted as they become available. The information obtained can be used to make comparisons, identify trends and set product standards.

The sensory analysis environment should ensure that assessors are not distracted or influenced by one another, or affected by any external factors, and that the correct lighting is used for colour evaluation. The importance of correct experimental design and proper data analysis cannot be overemphasised. Further information on sensory analysis of foods can be found in BS 5929 Parts I–VI (BSI, 1982, 1984, 1986, 1989).

9.7.1.2 Laboratory analysis. Analyses and tests (other than microbiological examination) commonly used include:

- moisture content;
- peroxide value/free fatty acid;
- titratable acidity;
- pH value;
- refractometric solids % (RS %);
- ERH %;
- specific volume of cake (to identify possible shrinkage);
- product weight loss;
- moisture/fat migration into packaging;
- travel test and package performance.

It is necessary to carry out ERH measurement on individual components as well as on the complete product for it is possible to have an apparently safe ERH for the comminuted product but an unacceptably high ERH for one of the components. The MFSL of a cake is usually governed by the component which has the highest ERH and hence the need to determine the ERH of individual components. Big differences between the ERHs of various components also tend to suggest that moisture/water vapour migration (and other related deterioration) is likely to be a problem.

Additional chemical analysis may be carried out for nutritional labelling purposes. If a customer has specific nutritional requirements it would

be sensible to ensure that they are met at an early stage of the development programme as changes that have to be made later may affect the shelf life of the product.

9.7.1.3 Microbiological examination. Moulds and yeasts are the most common organisms that are likely to grow in packaged cakes although total viable counts and presumptive coliform counts are monitored routinely. In certain intermediate products whose manufacture involves only the mixing of ingredients (e.g. synthetic filling creams), it is necessary to check for the presence of pathogenic organisms. Although the ERH of most packaged cakes is too low to support the growth of pathogens (Parry and Pawsey, 1984), this procedure is useful to confirm that the formulations have been correctly weighed and processed.

9.7.2 External factors

The following external factors are usually considered during shelf life determination of cakes:

- plant hygiene;
- process control;
- storage of intermediate products;
- environmental and human factors;
- historical data from similar products;
- information from external sources;
- consumer use.

9.7.2.1 Plant hygiene. It is necessary to ensure that plant and machines are capable of being cleaned to a satisfactory standard and if there are potential problems they must be identified and resolved as early as possible. Some of the more common problems encountered are:

- poor access to machines;
- inefficient use of cleaning chemicals, e.g. poor control of detergent and disinfectant concentrations;
- inadequate supply of water at the desired temperature and pressure;
- inadequate hygiene specifications;
- poorly trained staff.

Regular environmental monitoring (e.g. using air sampling, swabbing of machine parts and surfaces and so on) during factory trials can provide early warnings of such problems.

9.7.2.2 Process control. It is necessary to establish at an early stage the actual process capabilities during plant trials as over-scaling of liquids,

under-scaling of powders, inaccuracy in depositing and inconsistency in baking and so on are problems which can result in unacceptable variations in product moisture content and ERH.

9.7.2.3 Storage of intermediate products. Many cakes use intermediate products that are not heat-treated (e.g. filling creams for Swiss rolls), and control of such intermediate products can be crucial to the maintenance of the assigned product shelf life. Control should include a maximum holding period, the conditions of storage, handling procedures and if appropriate positive release based on a practical and meaningful sampling plan.

9.7.2.4 Environmental and human factors. Past experience has indicated that MFSL of cakes can be extended by 10–15% simply as a result of better hygiene, improved housekeeping and more effective pest control in the bakery. It has been shown that MFSLs of certain cakes increased significantly, the main reason being the production of these cakes had been transferred from an old and poorly maintained factory to one which was purpose-built and had a superior environment in respect of general hygiene.

Poor personal hygiene can cause high levels of microbiological contamination at start of life, which can result in reduced product shelf life. The importance of personal hygiene cannot be overemphasised, this being especially critical in labour-intensive bakery operations.

9.7.2.5 Historical data from similar products. Information from similar products and processes can be very useful in shelf life evaluation. It is not uncommon for similar products that are manufactured on the same plant to be grouped together because they are similar and have the same shelf life, for production/distribution planning and scheduling purposes. Historical data and information are particularly useful to newcomers in product development as well as the more experienced product developers who are working on shelf life extension.

9.7.2.6 Information from external sources. Ingredient and packaging suppliers are good sources of technical data and often have relevant application experience which can assist in the setting of product shelf life. They may also have specialist instrumentation and product testing 'know-how' and be prepared to help in certain aspects of shelf life evaluation.

Research Associations (e.g. FMBRA) are an invaluable source of scientific and technological expertise. this is particularly true for medium to small sized companies who do not have a central research and development function. They can provide information/legislation services, private consultancy as well as a wide range of analytical services. It is reassuring to know when one is venturing into a new product or process area, one

can turn to the RAs for informal advice or consultancy on a confidential basis.

9.7.2.7 Consumer use. It is important to give some thought to the product end-use environment (i.e. the climate and the way the product may be stored and consumed), particularly if the product is destined for export. Temperature has a significant effect on the shelf life of ambient packaged cakes and any shelf life determination must take this into account. It is also important to consider at a very early stage the legal status of any additives such as preservatives (e.g. mould inhibitors) that may have to be used to achieve the target shelf life, especially when the product is being developed for the export market.

9.8 Shelf life determination

A possible decision process for determining product shelf life is outlined in Figure 9.4. The process not only utilises product data but also requires relevant information from the process and the environment in which the product is to be manufactured, distributed, stored, merchandised and consumed. There may also be a need for information from specialist/external sources (e.g. Research Associations and suppliers) when new materials (edible and/or packaging), new product types or new processes are involved. The decision requires judgements to be made about the robustness of the formulation, the microbiological profile, the process and end-use conditions. The setting of a product shelf life is usually a joint effort from among Product Development, Laboratory Service and Quality Assurance management.

9.8.1 Product development activities

The following represents the sequence of activities for the determination of product shelf life of ambient packaged cakes.

(a) Concept stage (development bakery):
1. Formulation development.
2. Estimation of baking and cooling losses.
3. Calculation of theoretical ERH and prediction of MFSL using ERH CALC.
4. Further formulation development if necessary.
5. Production of samples for shelf life and other evaluations.
6. Analysis of samples at start of life.
7. Sampling for analysis at pre-determined intervals.
8. Comparison of preliminary shelf life with prediction.

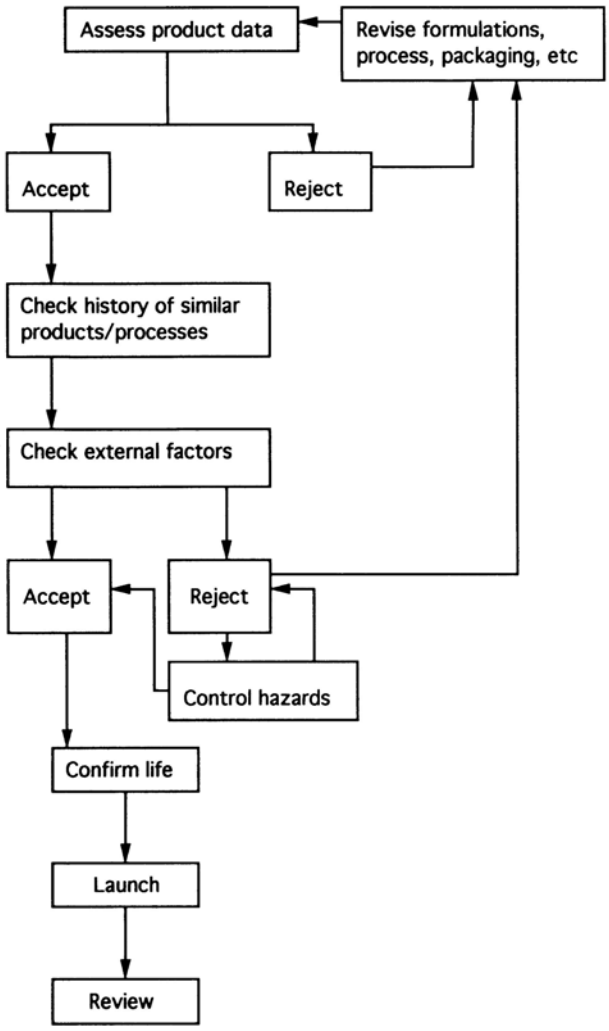


Figure 9.4 Shelf life determination – a possible decision process.

9. If necessary, further formulation adjustments and life tests.
10. Setting of provisional product shelf life.

(b) Factory stage (plant bakery):

1. Identification of food safety hazards (HACCP).
2. Scale-up of formulations and processes, with modifications where appropriate.
3. Shelf life determination using samples made from pilot or full scale plant.

4. Comparison of shelf life results with those obtained using concept samples.
5. More full scale factory runs (and shelf life determinations) especially if pilot plant only was used in (3) above.
6. Confirmation of product shelf life (issuing of finalised and approved complete 'product–process–packaging' specifications).
7. Product launch and shelf life validation and monitoring using samples from production runs.
8. Follow-up actions and investigations if necessary.

9.8.2 An example – a white chocolate mini sponge roll

The following information was obtained during the development of a new packaged cake which was a chocolate buttercream-filled mini roll completely covered in white chocolate. This was the first white chocolate cake from an industrial cake manufacturer in the UK. Little was known of the performance and potential problems associated with the handling of white chocolate although the latter is more widely used in the biscuit and chocolate confectionery industry. The sponge and buttercream on the other hand were components in everyday use. White chocolate is more prone to rancidity development than normal chocolate and therefore PV and FFA determinations were carried out on both the stored chocolate and the finished product. Sensory profiles of the white chocolate and of the whole product were obtained and recorded using 'star' diagrams or 'spider' plots. The product was produced using a well established process and standard plant and equipment with the exception of the chocolate enrober and its associated storage tanks. A standard pack format was used and as anticipated the 'travel test' gave satisfactory results and revealed no major potential problems in distribution.

9.8.2.1 Sensory data. Nine quality attributes were evaluated and the data presented (Table 9.3) were the ratings of the final product. The attributes assessed were: chocolate colour and opacity, chocolate melt and mouthfeel, chocolate flavour, sponge texture, sponge crumbliness, sponge toughness, product moistness, buttercream flavour and overall product flavour (see Table 9.3). 'Spider plots' of the white chocolate and the total product were produced based on the data obtained, using a sensory panel of six assessors (Figure 9.5 a and b).

9.8.2.2 Other data. Other relevant product data obtained are summarised in Table 9.4. The dedicated white chocolate enrober and storage tanks required special control and monitoring to minimise the risk of ran-

Table 9.3 White chocolate mini sponge roll – sensory analysis results

Quality attribute	Rating		Total score	Mean score
Chocolate opacity	Translucent	(1)		
	Opaque	(10)	31	5.2
Chocolate melt	Slow	(1)		
	Fast	(10)	43	7.2
Chocolate flavour	Weak	(1)		
	Strong	(10)	50	8.3
Sponge texture	Compact	(1)		
	Open	(10)	46	7.6
Sponge crumbliness	Crumbly	(1)		
	Firm	(10)	36	6.0
Sponge toughness	Tough	(1)		
	Soft	(10)	32	5.3
Overall moistness	Very dry	(1)		
	Very moist	(10)	32	5.3
Buttercream flavour	Weak	(1)		
	Strong	(10)	45	7.5
Overall chocolate flavour	Weak	(1)		
	Strong	(10)	30	5.0

The panel consisted of six assessors.

cidity development and colour contamination. The rest of the process was well established and controlled in the normal way. The product was eventually assigned a shelf life of 3 weeks.

9.9 Current developments

Two important issues in the packaged cake industry today are:

1. shelf life extension
2. shorter lead time to market

both of which have implications for shelf life evaluation.

9.9.1 Shelf life extension

The demand for packaged cakes with a longer life is driven by the need to export as well as to remain competitive in the home market. Extending shelf life requires new technologies (e.g. new processes and techniques) which must be evaluated by the methods described, but if shelf life is to be extended to months then the process of shelf life evaluation will

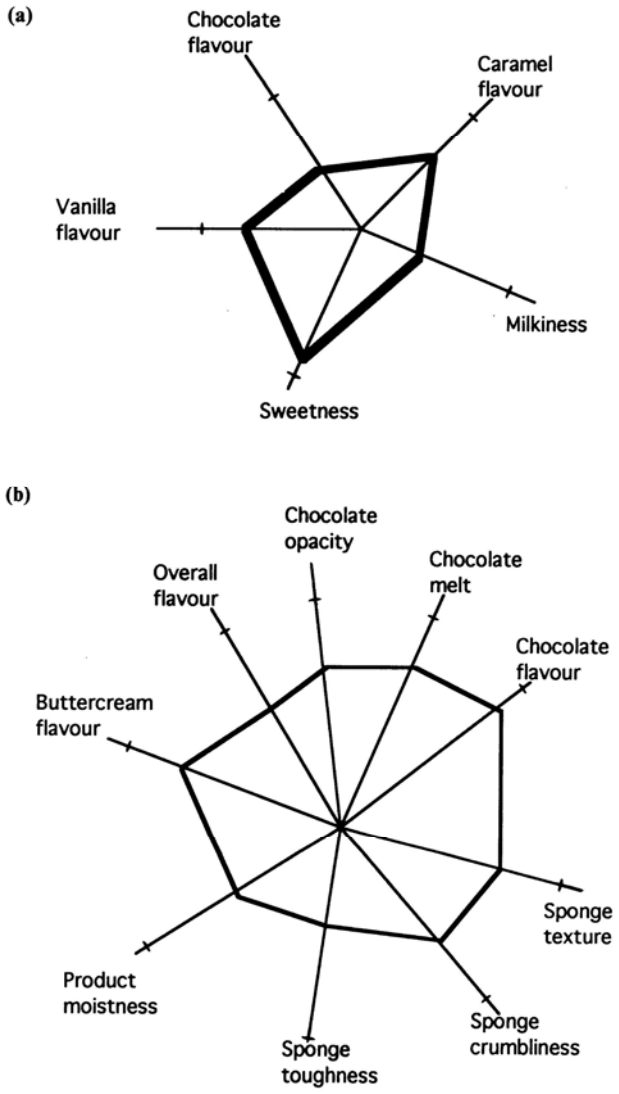


Figure 9.5 Spider plots of the white chocolate (a) and the enrobed mini sponge roll (b).

need to be speeded up. Accelerated shelf life determinations are being successfully used in certain applications and there is now a wide variety of instruments available, which will carry out chemical and microbiological analyses faster than conventional methods.

Table 9.4 Shelf life determination of white chocolate mini sponge roll – a summary of some relevant product data

Component	Moisture content%	ERH%	TVC[a] (cfu/g)	Yeasts/g[a]	Moulds/g[a]
Total product	17.3	78.5	280	10	<10
Golden sponge	20.3	79.2	–	–	–
Buttercream	15.4	77.4	150	20	10
White chocolate	1.6	70.1	–	–	–

[a]Results after 5 weeks' storage.

9.9.2 Shorter lead time to market

International competition and competition within the Single European Market in foods are demanding faster entry into the marketplace with new products. Capital investment must begin to pay back earlier to improve profitability which in turn can be used to finance business expansion. All this has meant that the development process must be shortened without compromising product safety and quality. In addition food legislation demands that food must be safe and wholesome and, should a 'due diligence' defence be used, evidence must exist to prove that 'all reasonable precautions' have actually been taken. In this context, the process of shelf life determination must not only be quicker but also more rigorous, comprehensive and well documented. The route to achieving greater speed and reliability can be facilitated through the use of predictive computer models such as the ERH CALC and where appropriate the 'Food Micromodel' (MAFF, 1992) which is the UK Ministry of Agriculture, Fisheries and Food's microbiological predictive program. Much benefit can also be gained by the implementation of techniques like HACCP as well as judicious introduction of modern sophisticated analytical instruments and data handling and analysis capabilities.

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10 Potato crisps and savoury snacks

A. REILLY and C.M.D. MAN

10.1 Introduction

Potato crisps and related savoury snacks such as extruded products, belong to a highly competitive, innovative and growing sector of the food market. In the UK, they are categorised as snack products which are generally understood as ready-to-eat ambient, 'shelf stable' (6–12 weeks) savoury products, prepacked and offered through a variety of outlets including supermarkets and other food retailers as well as catering establishments (Blenford, 1990). This then is the definition of snack products for the purpose of this chapter although it is understood that the term 'snack products' can mean very different products in different countries within the European Community, and indeed in North America. In 1991, the UK consumed some 234 k tonnes of snacks which equated to just over 4 kg per head per annum. In financial terms, the UK snack market is worth more than £3 billion a year and is still growing (Euromonitor, 1992).

10.2 The product group

Broadly speaking, snack food products may be divided into the following categories based on the process technology associated with their manufacture (Burdon, 1989):

1. *Deep fat fried.* This includes potato crisps and potato strips/sticks/rings, and represents by far the major portion of the snack food business.
2. *Quick fried.* Pre-formed partly cooked pellets derived from potato, potato starch and/or other cereal materials are fried at high temperature (i.e. of the order of 200°C) for a short time (10–15 seconds) giving expanded, light-textured products.
3. *Extrusion-cooked.* Cereal/potato powder mixes are extruded through dies at high pressure and temperature to give an expanded base which, after further drying, is enrobed with oil and flavour. A large number of products are available in this category and they display varying sizes, shapes, textures and flavours.

4. *Roasted.* This is primarily represented by nuts, particularly in the form of dry roasted peanuts.

The primary raw materials for snacks are therefore potato, either fresh or dehydrated, cereals (maize, rice, wheat, etc.) and nuts. Notwithstanding the important influence these raw materials have on the quality of the final products, by far the most important ingredient that can affect shelf life is the oil used, either in frying or as a carrier for seasoning. Snack products as a group can be said to be consumed principally for pleasure, because of their unique texture and the enormous variety of flavours available. As such, well planned and conducted consumer acceptability tests in the form of appropriate sensory analysis, are an important part of the shelf life evaluation of any snack product.

10.3 Factors affecting shelf life of potato crisps and savoury snacks

In general, the factors that can influence the shelf life of foods are (IFST, 1993):

Intrinsic

- raw materials
- product formulation and composition
- product make-up
- water activity value
- pH value and acidity
- availability of oxygen and redox potential

Extrinsic

- processing
- hygiene
- packaging materials and system
- storage, distribution and retail display

Whilst all the relevant factors undoubtedly have their influence on the shelf life of a snack product, some do have greater effects and deserve more attention.

10.3.1 The oil

Although the oil is primarily used as a heat transfer medium during the frying process, it does get absorbed and becomes a major part of the finished product. Ordinary potato crisps contain as much as 35–40% edible oil and even in reduced fat crisps, the level of oil can still be significant (typically less than 25%). It is imperative therefore that care must be taken in the selection, transport, storage, handling and use of frying oils since any abuse would most certainly result in reduced product shelf life (e.g. as a result of rancidity and off-flavour development) and in customer complaints.

Thus, a heavy duty frying oil, probably the most demanding use of any edible oil product should have the following properties (Hunt, 1989):

1. Resistance of chemical breakdown such as oxidation, polymerisation, or hydrolysis at temperatures up to 180°C.
2. Colour stability so as not to discolour food.
3. Pourability, pumpability at ambient temperature.
4. Nutritional characteristics.
5. Oil stability not only at the high temperature of the frying process, but also during the prolonged life of the fried food when this oil may be exposed to air, for example, on the large surface area of the crisps.

10.3.2 The process

Frying, be it deep fat frying or quick frying, is probably one of the most severe tests to which one can subject an oil in the manufacture of snack products. Since the quality of the frying oil is of paramount importance in determining the shelf life of fried foods, it is important to control the quality of the oil during use. In practice, the quality limits for a frying oil during use will depend on the food being fried, as different components can leach out of the food and lead to different characteristics in the oil. Although most snack product manufacturers now use fairly sophisticated continuous fryers with indirect heating systems, automatic filtration, balanced steam stacks, controlled oil flow and efficient controls and instrumentation, all of which are aimed at keeping the oil in good condition, a few basic rules based on the principles of 'Good Manufacturing Practice' (GMP), can help to maintain the quality of the oil during use (McGill, 1986; Burdon, 1989; Neilsen, 1993).

1. Turnover period (the time taken for the food to absorb the oil capacity of the fryer): Generally, as long as the recommended frying conditions are closely adhered to, the lower the turnover period, the less the oil will be degraded.
2. Specified frying temperatures: Temperatures higher than those specified promote oil degradation, and lower ones result in excessive oil uptake by the product.
3. Planned production: It is important to ensure by careful planning, a good, steady product throughput to avoid dramatic temperature changes as well as to reduce the risk of holding the oil idle in the fryer at frying temperature.
4. Cleaning: Appropriate and efficient cleaning regimes should be employed to minimise the risk of contamination by cleaning materials or as a result of poor cleaning techniques, either of which can cause deterioration in the quality of the oil.
5. Plant maintenance: A preventive maintenance programme should be

operated, that can greatly reduce the risk of contamination of the oil by metals, in particular copper (e.g. from pumps, pipes, valves, fittings or paddle shaft wear), which may act as powerful catalysts of oil oxidation.

As an indication of oil degradation, one can measure the free fatty acid (FFA) level in the oil in the fryer on a regular basis (Burdon, 1989). Determination of the FFA level is a useful check, as it is an objective measurement that can be carried out easily during production runs, and can be automated. Experience has shown, however, that there can be big differences in the levels of FFA accepted in different production processes without indicating any difference in quality of the finished products. These differences more or less reflect the differences in the type of frying oil as well as fryer used, and the product being processed. Leatherhead Food Research Association in the UK has developed a rapid method based on measurement of the viscosity of the frying oil. A good correlation has been achieved between the rheological properties measured and the quality of the oil expressed by the content of the polymers, which are being formed as the oil decomposes (Gillat *et al.*, 1991).

10.3.3 Packaging materials

One of the most important functions of food packaging is the protection of the product from environmental factors (see section 10.3.4 for further discussion) such as light, water vapour, gases and odours during its shelf life. The exact protection required, however, depends on the nature of the product. In respect of the shelf life of snacks, the following are the main properties of flexible packaging materials (e.g. coextruded OPP), which can affect the storage quality of a product.

1. Water vapour transmission rate (WVTR): For a given material such as coextruded OPP, this is primarily a function of film thickness (Figure 10.1). The lower the WVTR of a film, the better is the moisture barrier. Moisture barrier of a packaging film, of course, may be further enhanced by various processes such as coating with an additional barrier material, lamination and metallisation (Table 10.1).
2. Oxygen transmission rate (OTR): Similar to WVTR, OTR of clear OPP decreases as the thickness of the film increases (Figure 10.2). Permeability to oxygen is substantially reduced by coating with a suitable barrier material (e.g. acrylic) and by metallisation (Table 10.1).
3. Optical density (OD): This is defined as OD = Log_{10} (incident light/transmitted light). Determined using a suitable densitometer (at $23 \pm 2°C$, $50 \pm 5\%$ RH), it is a measure of the light barrier property of a film (Figure 10.3). The greater the OD of a film, the better is the

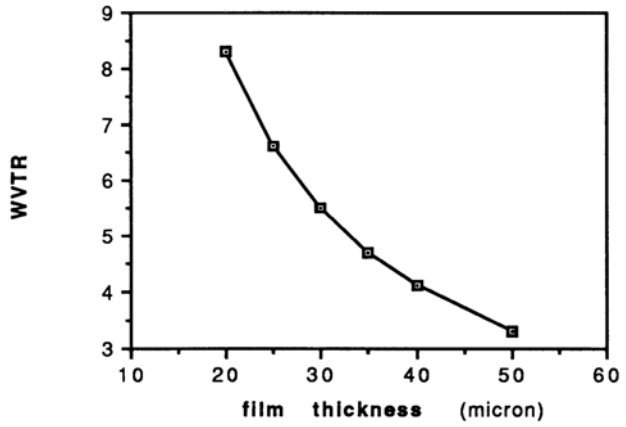


Figure 10.1 Permeability of coextruded OPP films to water vapour. (Source: CFP, UK.)

Table 10.1 Typical water vapour transmission rates and oxygen transmission rates of some biaxially oriented polypropylene films used for snacks

Material type	OTR ($cm^3/m^2/24h/atm$ at $23\pm2°C$ and 90% RH)	WVTR ($g/m^2/24h$ at 38°C and 90% RH)
Clear (CFP), 30 μm	<1500	<5.5
Opaque voided (CFP), 35 μm	1550	5.2
White pigmented (CFP), 30 μm	<1500	<5.5
Metallised (CFP), 30 μm	<120	<0.8
PVdC coated 2 sides (ICI), 28 μm	16	5.0
PVdC coated 2 sides (ICI), 39 μm	5	2.3
PVdC/acrylic coated (Mobil), 26 μm	23	4.2
Acrylic coated 2 sides (Mobil), 30 μm	650	4.0
Metallised/acrylic coated (Mobil), 21 μm	1–2	1.0–1.5

Sources: various technical data sheets, Courtaulds Films Polypropylene (CFP), ICI 'Propafilm' and Mobil Plastics Europe.

light barrier and hence protection against light-induced changes (e.g. oxidation and bleaching).

4. Flavour/odour barrier property: The significance of flavour/odour barrier performance of a packaging film lies in its practical importance in relation to the flavour retention of packaged foods such as snacks, and also with respect to protection against tainting by extraneous sources. Snack products are usually highly flavoured and contain an appreciable amount of oil, making them susceptible to contamination by taints; flavour retention and taint protection over relatively long shelf lives are therefore an important consideration. However, it has been shown by British Cellophane Limited (1982) that the odour

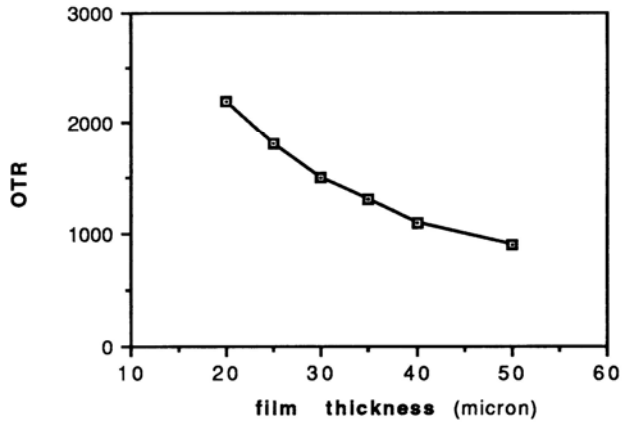


Figure 10.2 Permeability of coextruded OPP films to oxygen. (Source: CFP, UK.)

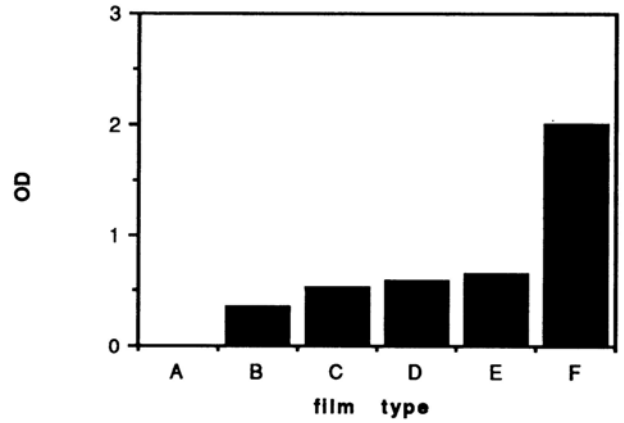


Figure 10.3 Optical densities of some coextruded OPP films. A: clear; B: opaque voided (35 micron); C: white pigmented (30 micron); D: white pigmented (35 micron); E; white pigmented (40 micron); F: metallised (20 and 30 micron). (Source: CFP, UK.)

barrier performance of coextruded OPP films should not be assessed on the basis of oxygen permeability. Indeed because of the very many flavours that can be used and odours that may be encountered potentially, there is no general measure of the odour barrier property of a packaging film. Specific storage tests and/or calculations (Zobel, 1988) have to be carried out to assess this barrier property with respect to the flavour/odour in question (see Appendix for more information on flavour loss calculations).

During the shelf life of a snack, two main deterioration processes take place together, one being texture loss due to moisture pick-up, the other being rancidity development which requires oxygen and may be light-induced. Although both need to be controlled, relatively speaking, the former is more important to potato crisps and related snacks and the latter to nuts, because of their compositional differences. Thus, currently biaxially oriented polypropylene (OPP) films are the most commonly used packaging materials for crisps and snacks within Europe, while nuts are usually packaged in, for example, PVdC coated OPP/LDPE laminate or metallised polyester/LDPE laminate, depending on the value of the product. OPP has qualities of toughness (against puncture and abrasion) and clarity and is rendered heat sealable by coextrusion with polyolefin copolymers (polypropylene co-ethylene) or by off-line coating (e.g. with PVdC).

Table 10.1 lists typical WVTRs and OTRs of some OPP films used for crisps and snacks packaging within Europe. It must be stressed that these values are flat sheet permeability values; the protection of the product depends on the total barrier provided by the film pack. The sheet barrier properties may be altered by bad conversion techniques, or by mishandling such as scratching by poorly maintained packaging machines. Moreover, the seal integrity of the pack must be good enough to prevent leakage during the shelf life of the product. Pack barrier for snacks is thus a combination of:

- film barrier
- maintenance of film barrier
- seal integrity.

In practice, to achieve the required level of protection of a snack, it does not necessarily follow that the highest barrier material is the best choice of packaging. The packaging material that is chosen will be a compromise between protective requirements, shelf life, aesthetics and cost. In the crisps sector, at present, a 30 micron clear OPP film is the most cost effective form of packaging for commodity products with short shelf life (12 weeks or less) while metallised OPP laminates are used for larger family packs, sensitive products and high added value products. In the nuts sector, commodity products with short shelf life requirements are packed in nitrogen gas flushed PVdC coated OPP/LDPE laminates while higher value added products and those with longer shelf life requirements are packed in nitrogen gas flushed metallised polyester/LDPE laminates.

10.3.4 Environmental factors

Fatty food products such as crisps can become unacceptable through the formation of rancid off-flavours due to oxidation of the oil content of the

product through the process of oxidative rancidity. It is known that this reaction may be catalysed by light and heat. Two previous investigations carried out by BCL in the 1980s looked at crisp rancidity in relation to the light barrier properties of various packaging films. The first study (1983) employed very severe test conditions where the test packs were exposed to fluorescent lighting continuously, i.e. 24 hours a day, giving a light intensity of 1000 lux on the packs which were stored flat. The second study (1985) was designed to simulate more closely the storage and display conditions to which commercial packs of crisps were usually subjected. It also used a different type of fluorescent tube giving an intensity of 1700 lux, on a 12 hours 'on'/12 hours 'off' basis. Overall, useful conclusions have been drawn from these two studies and are summarised below:

1. Improved light barrier properties of packaging films give extended shelf life of crisps in respect of rancid off-flavours. Thus, printed metallised OPP films give longer shelf life than printed OPP films which in turn give longer life than unprinted OPP films.
2. Prolonged storage under fluorescent lights (24 hour continuous exposure) at ambient humidity can cause crisps to become rancid before any texture changes due to moisture uptake are detected.
3. The incorporation of a clear window in a metallised pack significantly reduces the acceptable shelf life of the crisps in respect of rancid off-flavours.
4. Shingle storage of packs offers a longer shelf life than packs stored flat (Figure 10.4).
5. Metallised films also prolong the shelf life of crisps in respect of moisture uptake.

10.3.5 Legal standards

Within the European Community, the need to achieve harmonisation of legislation in member states in respect of materials and articles destined for use in contact with foods and the need to protect the consumer from risks associated with the migration of harmful substances from packaging materials, have meant that food packaging migration is now under the control of the relevant legislation (Ashby *et al.*, 1992). The EC 'plastics' directive 90/128/EEC as amended by directive 92/39/EEC, sets an overall migration limit for all plastics food contact materials and articles of 10 mg/dm^2 (or 60 mg/kg of food), and lists monomers and other starting substances approved for use in the manufacture of plastics, with restrictions where necessary. In the UK, the implementation of this directive and two other directives, i.e. 82/711/EEC on test conditions and 85/572/EEC on use of simulants, has now been achieved by the Plastics Materials

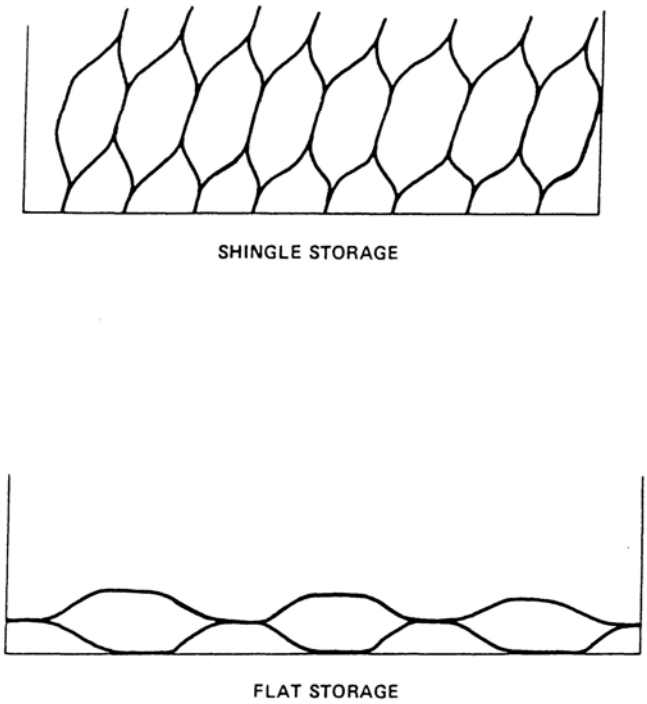


Figure 10.4 Shelf life of crisps: type of pack storage. (Source: BCL, 1985; CFP, UK.)

and Articles in Contact with Food Regulations 1992. This piece of legislation applies to all in the chain from the plastics manufacturer, through the plastics converter, the food packer/manufacturer, to the food retailer. All have a definite role to play in the compliance of the overall migration and where appropriate, specific migration limits, though each may have a slightly different responsibility to bear. Regarding overall (global) migration values from coextruded OPP films, the following are typical results (Surman, 1993):

1. <1 mg/dm^2 using distilled water or water of equivalent quality;
2. <1 mg/dm^2 using 3% acetic acid (w/v) in aqueous solution;
3. <1 mg/dm^2 using rectified olive oil.

The snack manufacturer obviously has a responsibility to ensure that all the information supplied to him by the packaging film supplier in respect of migration into food simulants is appropriate to his actual snack product, and this does not take into consideration any sensory analysis required additionally. Furthermore, since the snack manufacturer may

also be expected to supply the retailer with compliance statements, it seems therefore some migration testing by the former cannot be avoided. This is particularly relevant in the case of a new/novel product and film combination, where migration testing can well be an important part of the shelf life evaluation programme.

10.4 Shelf life determination

The nature and characteristics of snack products are such that the most common tests employed in the determination of their shelf life are:

- chemical tests
- physical tests
- sensory tests

One method for ready salted potato crisps (BCL, 1985) involves storing sufficient packs of the products under controlled conditions of temperature (e.g. 25°C) and relative humidity (e.g. 75%) for a period of 12 weeks. Packs of the same products are also stored in a deep freeze to act as controls in subsequent sensory analysis. Stored products are tested at the start of the storage period and evaluated at weekly intervals until the products are regarded as no longer acceptable by a trained taste panel of 8–10 assessors. Panel assessors are asked to give their opinion of the grading of the crisps for flavour and texture directly against a control on a scale of 1–10 where:

10 = equal to control;
9 = slight difference to control;
8 = more distinct difference but still acceptable;
7 = beginning to lose acceptability;
6 = more distinct loss of acceptability;
5 = very distinct loss of acceptability;
4 or less = unacceptability.

In addition to sensory tests, crisps are used for chemical tests at every sampling occasion. To do these, the oil is extracted from the crisps and the peroxide value and free fatty acid value of the extracted oil are determined. Moisture uptake of the packs is monitored by weighing the packs immediately before submission to the taste panel. Figures 10.5, 10.6 and 10.7 show changes in flavour, peroxide value and moisture uptake of crisps packed in printed metallised OPP, during a shelf life study in which the packs were stored flat and subjected to a 12 hour cycling exposure to fluorescent lights (BCL, 1985). It was found that the crisps began to lose acceptability after about 8 weeks of storage. Since peroxide value gives a

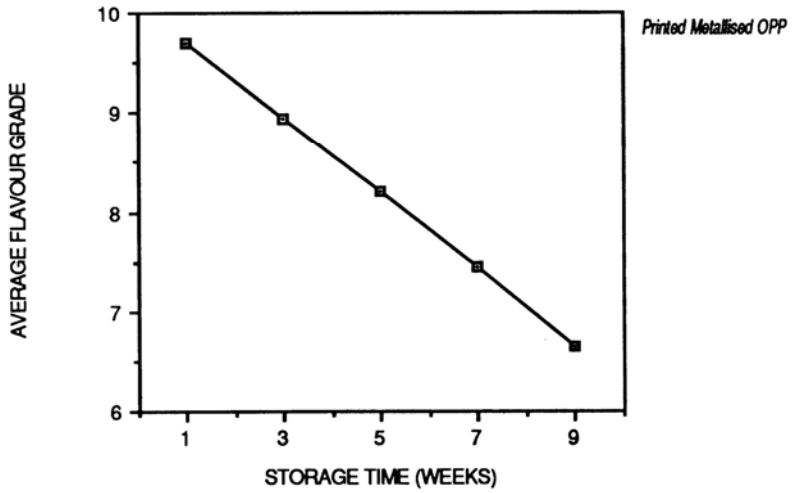


Figure 10.5 Flavour assessment of crisps (stored flat) exposed to fluorescent lighting (1700 lux). (Source: BCL, 1985; CFP, UK.)

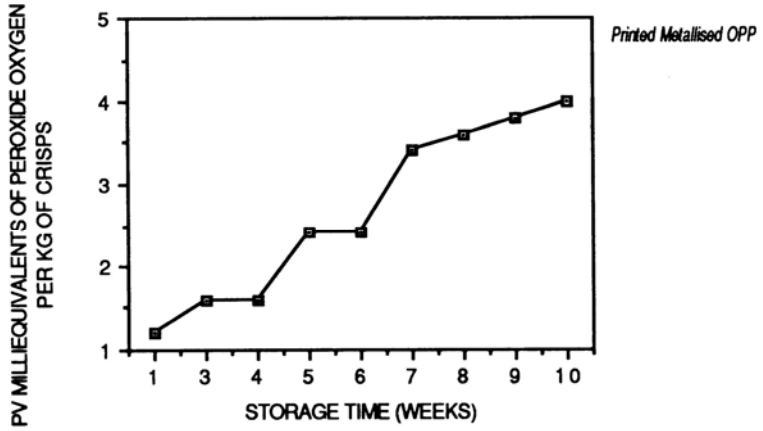


Figure 10.6 Peroxide value of crisps (stored flat) exposed to fluorescent lighting (1700 lux). (Source: BCL, 1985; CFP, UK.)

measure of the primary oxidation products which normally decompose quickly to secondary and tertiary oxidation products, it is apparent that changes in PV did not correlate as closely as changes in moisture uptake, with the gradual loss in product acceptability.

Besides laboratory tests, packs taken from production trials should be examined for seal integrity which can be a major factor limiting shelf life. Careful visual examination of returned packs from a 'travel test' through

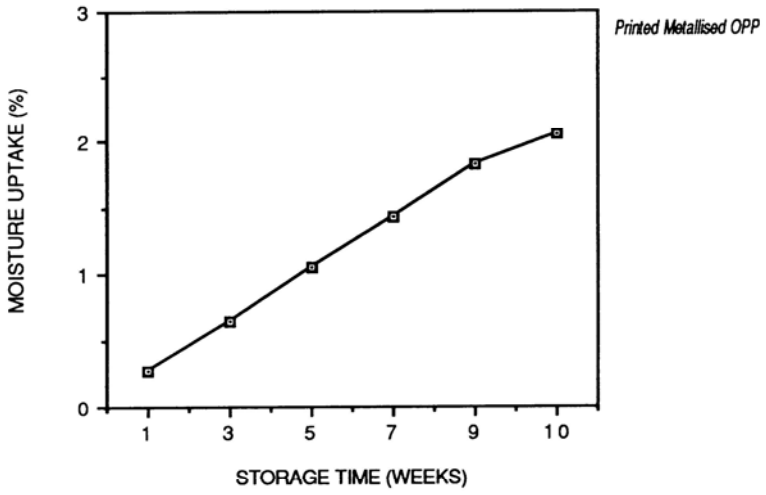


Figure 10.7 Moisture uptake of crisps (stored flat) exposed to fluorescent lighting (1700 lux). (Source: BCL, 1985; CFP, UK.)

the distribution and storage chain, is also important to reveal transit hazards due to various mechanical stresses and pressure, which can cause premature termination of product shelf life. Experience has shown that the level of sophistication of a distribution system (including handling, transport and storage) can have considerable influence on the shelf life of snack products.

It is also possible to predict ambient shelf life of snacks from accelerated shelf life tests, i.e. storage at elevated temperature and humidity. Despite obvious benefits, such tests tend to be very product-specific and require experience and care in the interpretation of results. An alternative approach to accelerated tests would be to model shelf life and pack performance, using appropriate computer programs (Oswin, 1983; Hayes, 1992). For snack products, and potato crisps in particular, there exist, as discussed previously, two competing deterioration mechanisms, i.e. oxidative rancidity and moisture uptake. Regarding moisture uptake, the information required for modelling is well known (Labuza, 1982; Hayes, 1992):

1. the moisture-sorption isotherm data for the temperature in question;
2. the packaging film properties such as WVTR;
3. the storage conditions anticipated.

Armed with other film properties, e.g. OTR and permeation data, it is conceivable that chemical changes can also be modelled using similar computer techniques. This perhaps will be one of the many technical challenges facing the industry for the immediate future.

Acknowledgements

Grateful thanks are expressed to Mr E.D. Surman, Development Manager of Courtaulds Films Polypropylene UK, for various shelf life reports and information on polypropylene films provided in this chapter.

Appendix – Flavour loss calculations

Work carried out by BCL (1984) resulted in the derivation of a simple equation which can be used to estimate the likely permeation coefficients of a wide range of chemical substances through coextruded OPP as well as polyethylene, at low odourant concentrations. In the SI system, permeation coefficients have the unit g mm^{-2} Pa^{-1} s^{-1}, which represents the weight of flavourant/odourant permeating a polymer specimen one metre thick, one square metre in area, per second, with a vapour pressure difference across the specimen of one Pascal (= 10 ppm vol/vol). The permeation data, together with information relating to the pack contents and storage/display environment, provide a convenient method for estimating the transfer rates of flavours or contaminants through commercial flexible packs. Zobel (1988) has shown that the rate of transmission (R in g s^{-1}) of flavourant (e.g. vinegar flavour measured as acetic acid) through a packaging film is given by the following formula:

$$R = (PC \times VP \times A)/L$$

where PC = permeation coefficient (g mm^{-2} Pa^{-1} s^{-1})
VP = vapour pressure of flavourant (Pa)
A = area of film (m^2)
L = thickness of film (m)

Strictly speaking, VP should be the difference in vapour pressure of flavourant between the inside and the outside of the pack; but for practical purposes, the inside pack vapour pressure, as measured by headspace gas chromatography, will suffice. Using this formula, it is possible, in the event that highly flavoured snacks are being packaged, to conduct flavour loss calculations, thereby providing the reassurance that the chosen OPP film, for example, will give an adequate barrier.

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11 Chocolate confectionery

A.V. MARTIN

11.1 Introduction

The shelf life of chocolate is the period of time during which it will retain acceptable appearance, aroma, flavour and texture.

Chocolate is a high energy foodstuff with a complex nutritional profile, containing 28–40% lipids (cocoa butter, possibly other vegetable fats and milk fat), 50–70% carbohydrates, and 4–8% proteins. It is also an important source of mineral salts (Ca, Mg, Fe, Na, K) coming from cocoa liquor, and vitamins (riboflavin, vitamin A, vitamin E).

Despite this complexity, chocolate is very shelf stable due principally to the unique properties of cocoa. Cocoa solids contain a natural anti-oxidant in the form of tocopherol and cocoa butter breaks down to inoffensive short chain fatty acids.

As a result, most chocolate products can be classified as 'medium' or 'long life' products which, when packaged, should have a storage life under normal conditions of temperature and humidity of nine months or longer. In the UK 'normal' conditions are probably represented by a temperature of 20°C and 60–65% relative humidity.

Nevertheless, degradation of the product can occur at earlier stages whereby its physical and/or organoleptic characteristics no longer correspond to the parameters set by the manufacturer's quality standard and so are unacceptable.

It is the purpose of this chapter to examine the attributes of chocolate which provide this stability and how product degradation can occur. The various forms which chocolate confectionery can take will be considered and factors influencing their shelf lives. Methods of determining shelf lives will also be examined.

11.2 Composition of chocolate

The precise composition of chocolate varies throughout the world due to differing national tastes and varying legislation which is mainly concerned with the percentages of cocoa and added milk solids, and amounts and types of permitted vegetable fats.

In many countries chocolate production is strictly controlled by law, in

most cases restricting ingredients to sugar, cocoa butter, cocoa solids and milk solids. Some countries such as the UK allow a percentage of cocoa butter to be replaced by vegetable fat, and others permit the use of nutmeat, whey and so on.

11.2.1 Cocoa liquor

Cocoa beans comprise approximately 88% nibs, 11% shell and 1% germ. Once harvested the beans are fermented, cleaned, roasted and the nibs separated from the beans. The nib is a cellular mass containing about 55% cocoa butter locked within the cell structure. Grinding breaks down the cell walls releasing the fat which, as it is liquefied by frictional heat, becomes a continuous phase in which the disintegrated cell particles are suspended. This fluid paste is called 'cocoa liquor' or 'cocoa mass'.

11.2.2 Fats

The fats found in chocolate include cocoa butter, milk fat and, in the UK, non cocoa butter vegetable fat. This last group is commonly known as 'cocoa butter equivalents' or 'CBEs'.

11.2.2.1 Cocoa butter. To meet legal requirements most chocolates contain at least 20% cocoa butter which has properties unmatched by any other fat. It is the cocoa butter which gives chocolate its unique flavour and exceptional shelf life through its oxidative stability. The characteristic physical properties of cocoa butter which give chocolate its special texture lie in its unique melting properties, i.e. it remains solid at room temperature up to 28°C yet melts fully and completely at 36°C (below mouth temperature). Cocoa butter is expressed from cocoa liquor leaving cocoa powder. From certain sources it must be deodorised to remove potentially harsh flavour tones and this process may reduce its antioxidant properties.

11.2.2.2 Milk fat. This is used for four reasons:

- for taste;
- as a texture modifier – to soften chocolate;
- as a fat bloom inhibitor;
- to reduce cost.

Two main processes exist for the incorporation of milk into chocolate, which confer quite different tastes on the resultant products:

- the continental process using milk powder added to cocoa liquor;
- the crumb process used in the UK and frequently in the US and certain European countries whereby milk, sugar and cocoa liquor are con-

densed under vacuum and the resultant solid ground to a powder which is then added to the cocoa mass.

11.2.2.3 CBEs (Cocoa Butter Equivalents). These are prepared from illipe, shea and palm oils. They have a fatty acid composition almost identical to that of cocoa butter so that the physical properties of a mixture with cocoa butter in any proportion are practically the same as those of cocoa butter itself.

11.2.3 Sugar

Sugar is used to offset the bitterness of cocoa solids in plain chocolate. In milk chocolate, sugar, particularly in crumb form, has a great influence on the ultimate flavour – the combination of milk proteins and sugar through Maillard, or browning, reaction leads to the caramelised flavour characteristic of most UK milk chocolate.

11.3 Manufacture of chocolate

11.3.1 Mixing

Sugar (and crumb or milk powder for milk chocolate) is added to the cocoa liquor (or cocoa mass) and the preparation is thoroughly mixed.

11.3.2 Refining

This enables the smooth texture of the chocolate to be achieved initially by reducing the particle size. The cocoa liquor/sugar paste is passed through a series of roller refiners with extra cocoa butter being added to maintain its flow properties as the surface area of the solid particles increases.

11.3.3 Conching

Conching is the working of chocolate, milk crumb and added fats in the form of cocoa butter, CBEs (if required), lecithin (emulsifier) and any flavours such as vanilla, into a fluid paste.

This operation further refines the texture of the mixture through continuous agitation in a large tank and coats all the particles produced in the earlier processes with fat to give the smooth mouthfeel characteristic of good chocolate. Conching also has the effect of modifying the flavour of the chocolate mass by reducing astringency and allowing the more muted and subtle pleasant flavour notes to develop.

11.3.4 Tempering

Before chocolate can be used for moulding or enrobing (coating) it must be tempered so that it can set rapidly and uniformly with good permanent colour, texture and gloss. Chocolate can set in six states, only the more stable of which gives the desired gloss and snap. To achieve this stability it is necessary to cool down the chocolate with continuous mixing to produce a multitude of 'seed' fat crystals and distribute them uniformly throughout the mass of liquid chocolate thus providing nuclei for subsequent crystallisation. During this operation changes in viscosity can be used to obtain a measure of the condition of the chocolate.

11.3.5 Uses of chocolate

There are two principal ways in which chocolate is used:

11.3.5.1 Moulding. This is the process in which tempered chocolate is deposited in warmed polished metal or plastics moulds, then cooled by passing through a cooling tunnel to give rapid setting and good appearance. Good tempering will ensure that the cocoa butter will shrink in the mould and demould cleanly. In general metal moulds may be more effective in that cooling can be transmitted readily through the mould whereas with plastics, cooling takes place primarily through the chocolate surface. Good mould design and moulding procedure, however, should minimise this potential problem and enable the full benefits to be derived from plastics, i.e. lightness, quietness in operation and flexibility which assists in demoulding. Combination moulds are now available in stainless steel with polycarbonate carriers which give the best of all worlds, but at extra cost.

11.3.5.2 Enrobing. This is the process in which centres are passed through a curtain of tempered chocolate and over a chocolate bottoming device to coat the bases. Sometimes the product is 'double' enrobed to ensure extra coating if the centre is especially vulnerable to external influences, or to complete covering of awkward surfaces. In these instances the first coating may not require to be well tempered provided it is set before the second coating is applied. The property of shrinking on cooling of cocoa butter, essential for moulding, must be taken into account in enrobing. If enrobed centres cool too rapidly the chocolate could crack but on the other hand if it cools too slowly it could end up discoloured and soft – in either case the problem might not be apparent at the packaging stage and only emerge when the pack is opened.

11.4 Types of chocolate confectionery

11.4.1 Moulded blocks

11.4.1.1 Milk or plain chocolate. This may contain:

- roasted nuts, e.g. hazelnuts, almonds, peanuts
- unroasted nuts/fruit, e.g. raisins
- fondant cream/praline
- layered wafer/biscuit
- cereal, e.g. crispies

11.4.1.2 Moulded aerated blocks. Aerated chocolate has been a very popular product for many years. The principal manufacturing processes are:

- 'vacuum aeration' in which the tempered chocolate is subjected to a vacuum under which microbubbles of entrapped air expand leading to a cellular texture. Cooling then takes place, still under vacuum to avoid collapse of the aeration.
- 'gas injection' where inert gas, generally CO_2, is injected into the chocolate under pressure. The product is then moulded under atmospheric pressure.

11.4.2 Filled blocks

Moulding of filled chocolate blocks can be done in two ways, each of which has its adherents. In straight moulding the product is deposited into the mould in its entirety in one operation or a centre is pushed into a mould full of chocolate. In 'shell' moulding the inside of the mould is in effect lined with a solid coating of chocolate to form a shell into which the centre, be it a cream or a solid such as a biscuit, is filled or inserted, with additional chocolate to provide backing cover. This operation can be described as 'fill-cool-tip-cool'.

11.4.3 Count lines

While moulded blocks or bars are generally segmented so that they can be eaten over several occasions or shared, count lines are intended to be eaten in one go and by one person. They are usually, but not exclusively, enrobed and can contain:

- wafer – layered with fondant cream or praline
- cereal, e.g. rice crispies
- biscuit

- fruit and/or nuts
- caramel (toffee)
- butterscotch
- cracknel
- nougat
- peanut butter

The above list is not exclusive and it can be seen that most, if not all, of the ingredients can also be found in one form or another in moulded products. It is, perhaps, worth mentioning that in moulded lines caramel is a centre in its own right whereas in a count line, it performs the secondary function of holding nuts, cereal and other components together.

11.4.4 Assortments

These comprise a number of different sweets which can be enrobed or moulded and may be miniature versions of the products already described. They frequently also include fondant cream centres which have been deposited in liquid form into shapes formed in starch, allowed to solidify and then brushed out and enrobed. Often the centres are formulated so that after covering they revert to a semi-liquid form. This method of producing centres has been superseded in many cases by 'starchless moulding' in which the fondant, for example, is deposited into plastics moulds. This involves the use of release oil in the moulds which must be carefully specified and controlled to avoid possible contamination of the enrobing chocolate and consequent loss of shelf life.

11.4.5 Straight lines

These comprise small sweets similar to those in an assortment but all one type in a pack. Sometimes this is done when sweets are unsuitable for mixing in an assortment where they could transfer flavour to others. This was originally the case with chocolate peppermints, but specialised 'After Dinner' mints are now branded lines in their own right.

11.4.6 White chocolate

This consists mainly of deodorised cocoa butter, sugar and milk powder and is produced in a modified version of standard milk chocolate manufacture. It can be moulded or enrobed and used wherever normal chocolate would be found but as it lacks the antioxidant properties of cocoa liquor, and as the deodorising process can reduce those of cocoa butter, it is much more susceptible to oxidative rancidity.

11.5 Attributes of milk chocolate

11.5.1 Texture

1. Hardness: This characterises the hardness of the chocolate. It is assessed by its resistance to a point and can be scored on a scale from 'soft' to 'hard'.
2. Snap: This represents the sound intensity produced when breaking the piece of chocolate and can be scaled from 'low' to 'high'.
3. Melting: Melting is the assessment of a solid product which quickly changes into a liquid or semi-liquid state under the action of saliva in the mouth. It can be scored from 'slow' to 'quick'.
4. Sticky or Claggy: This describes the texture of chocolate that remains soft, sticks to the teeth and persists in the mouth. Scoring scale is from 'very sticky' to 'non-sticky'.
5. Smoothness: Smoothness describes chocolate particle size and texture by the impression of more or less coarseness in the mouth when eating the product. Scoring is from 'very gritty' to 'very smooth'.

11.5.2 Flavour

1. Sweet is a basic taste whose reference is saccharosis. It is scored from 'not sweet' to 'very sweet'.
2. Cocoa flavour is a specific complex flavour which refers to the basic note of the product. It is scored from 'no cocoa flavour' to 'very strong cocoa flavour'.
3. Milky flavour is a general term designating the presence of a pure flavour or odour of milk. It is scored from 'no milky flavour' to 'very strong milky flavour'.
4. Toffee flavour describes the flavour associated with specific sweets. It is scored from 'no toffee flavour' to 'very strong toffee flavour'.
5. Cream/butter flavour designates the presence of pure flavour of cream or butter in a chocolate. It is scored from 'no cream or butter flavour' to 'very strong cream or butter flavour'.
6. Acid represents the elementary taste caused by diluted aqueous solution of acids such as citric or lactic. It is scored from 'no acid taste' to 'strong acid taste'.
7. Astringent refers to the ability of certain substances to cause contraction of tissues in the mouth and especially at the back of the throat. Scoring is from 'no astringent sensation' to 'very strong astringent sensation'.
8. Rancid applies to fatty substances degraded by oxidation or hydrolysis releasing short-chain fatty acids, aldehydes and ketones.
9. Butyric describes a piquant cheese odour deriving from fat lipolysis.

10. Cardboardy is a generic, ill defined taste developed by oxidation of old cocoa and chocolate.

11.6 Causes of deterioration in quality

Chocolate, when stored under the correct conditions of temperature and humidity, is a very stable product due to its low moisture content (1.0%–1.9%) and its high fat content (28%–35% including 1.4%–1.6% of poly-unsaturated fatty acids). The presence of tocopherols (vitamin E) in cocoa liquor and cocoa powder provides a high degree of protection against oxidative rancidity. Nevertheless, severe degradation may occur – fat bloom, sugar bloom, rancidity and loss of texture can result if proper manufacturing and storage procedures are not followed.

The factors causing deterioration of chocolate products can be divided into two main classes: those which are inherent in the product itself and cannot be prevented by packaging alone and those which are dependent on the environment and may be controlled to a greater or less degree by choice and effective use of packaging.

11.6.1 Product factors

11.6.1.1 Quality of raw material. It goes without saying that the quality of the raw materials has a major bearing on the quality of the finished product and strict quality control must be exercised.

11.6.1.2 Quality of chocolate. Improperly tempered chocolate will continue to stabilise after the product is wrapped and has left the factory, leading to soft texture and the appearance of fat crystals, particularly on the surface of the product, causing the greyish, mouldy appearance known as 'fat bloom'. This unsightly blemish can also be caused by incompatible oil or fat used as a lubricant in the manufacture of centres migrating through the chocolate or by the release of oil from high fat centres such as roasted nuts, coconut, truffle, and so on. Injudicious use of 'rework' in a product can also affect the quality of temper of the chocolate.

11.6.1.3 Oxidative deterioration. In the short term oxidative rancidity is unlikely to occur in appreciable concentration with plain or milk chocolate but it can relatively rapidly affect other ingredients such as high fat centres or roasted nuts which do not have a full covering of chocolate. This can be the result of inadequate coating on enrobed centres or poor backing off on moulded products. With milk or plain chocolate, after the lapse of a considerable period of time, staling or a 'cardboardy' flavour

can become apparent. White chocolate does not have the antioxidant protection of cocoa liquor and so is prone to oxidative rancidity, particularly light induced. Even with light barrier packaging its shelf life is shorter than that of milk or plain chocolate. The cost of eliminating oxygen from the packaging of chocolate would be prohibitive and not generally worthwhile in view of the relatively limited increase in shelf life which would result. It could only be justified if particularly sophisticated ingredients used in the product recipe were especially susceptible to oxygen and where the product could stand the oncost of oxygen scavengers and barrier packaging.

11.6.2 Environmental factors

11.6.2.1 Temperature. Temperature, especially high and fluctuating conditions, has a marked effect on the quality and shelf life of chocolate products with the potential to cause loss of temper, fat bloom and accelerated staling. Although low temperatures will preserve flavours and the textural quality of the chocolate, bars containing wafers, and expanded centres, can crack under low temperature storage. If the packaging of the bar is not moisture vapour proof the cracks will permit the entry of moisture to the centre with consequent rapid deterioration.

11.6.2.2 Humidity. Storage in damp conditions, condensation due to packaging in damp conditions, or condensation of moisture in coolers or fondant centres with high relative humidity (RH) giving off moisture which is then trapped in the package can all cause 'sugar bloom'. This is similar in appearance to fat bloom but with a rough rather than greasy feel and is the result of the moisture extracting soluble sugar from the chocolate and then depositing it in the form of large granules on the chocolate after re-evaporation. Certain centres, such as cracknel or 'honeycomb' are particularly hygroscopic and require extra protection against moisture pick up compared with conventional chocolate products. This could involve the use of double chocolate coating to minimise the possibility of cracks through which the moisture could be drawn into the centre. Other centres can lose moisture and dry out under some, not necessarily particularly extreme, conditions. In both these instances packaging plays a vital role in affording a reasonable shelf life to the product.

11.6.2.3 Off-odour/loss of flavour. This can be caused by external influences permeating the packaging material or, indeed, emanating from it. Storage of inadequately wrapped chocolate near strong smelling chemicals or display in shops close to strongly flavoured sweets such as poorly wrapped mints can all cause unacceptable flavour pick up. Some plastics packaging materials can cause flavour loss or 'scalping' by absorbing the

'high notes' but this is not likely with the materials most commonly used for packaging chocolate products.

Odour transfer from the inks used on packaging can cause taint but modern water or alcohol based formulations, properly applied, should minimise this risk. The increasing use of reclaimed board, for environmental reasons, on intermediate and outer packaging leads to a greater risk of taint which must be countered by enhanced barrier primary packaging.

11.6.2.4 Insect infestation. Chocolate products are very attractive to several varieties of insect and if storage or transit conditions are likely to be such as to result in infestation very careful consideration must be given to the packaging employed. It must be effectively sealed and resistant to creeping insects penetrating through folds and boring species which can drill through aluminium foil but fortunately appear to be frustrated by the flexible plastics in common use.

11.6.2.5 Light. As mentioned earlier, light-induced rancidity can be a problem with certain products such as white chocolate and chocolate containing poorly coated roast nuts. Although outer packaging should protect a product for most of its life, even short exposure on a shop counter or shelf can be sufficient to cause unacceptable deterioration.

11.7 Control of shelf life by packaging

11.7.1 Heat

Normal chocolate confectionery packaging is not designed to withstand high temperatures which are best avoided by storage and transit in controlled conditions. High temperature, approaching the melting point of cocoa butter (36°C), causes the chocolate to soften, drastically reducing its shelf life and no amount of subsequent cooling can reverse the process of deterioration.

A certain amount of insulation can be built into outer packaging by using foil lined or metallised board or expanded polystyrene, but experience shows that at best this is a short-term remedy. It is more likely that insulation only delays the effect of heat and in fact it may retain it after the pack is put into cool conditions.

11.7.2 Moisture

It is possible, by careful use of packaging material, to protect a product from external moisture almost indefinitely. The traditional foil and paper

wrap used for blocks of chocolate is adequate for most products of this type, stored, transported and sold under temperate, well regulated conditions; but if moisture protection is likely to be required and traditional appearance retained, the foil must be heat sealed. This requires the use of special machinery and the foil to be coated with either a heatseal varnish or low density polyethylene film. The latter is to be preferred as it gives a better seal and provides the foil with added protection against tearing, piercing by the corners of the product, projecting nuts and similar kinds of physical damage, and insect penetration.

By contrast, the irregular shape of most count lines does not lend itself to the foil and paper band format while the nature of the product is generally such that more protection is required against moisture, even in temperate conditions, than is the case with block lines. For this type of product the horizontal form-fill-seal (HFFS) wrap, also known as 'pillow pack', 'fin seal' and 'flow wrap', has been devised. This method takes a continuous web of flexible material, supplied on reel, and forms it into a tube around the product, sealing its edges together by heat and/or pressure as it progresses through the machine. This tube, containing the product, is then cut to a predetermined length and the open ends sealed, again by heat and/or pressure. This continuous flow wrap, by careful choice of the materials used, can give a very wide range of properties to the package. In particular it can provide a complete barrier to moisture vapour – indeed most materials which are capable of being heat sealed will also give an adequate barrier against moisture.

Where an unusually high degree of protection against moisture is required, either to keep it out of or to retain it within the product, it may well be necessary to use a laminate, e.g. of polyester and aluminium foil with polyethylene, as a heat sealant. The foil could be replaced by metallisation of the two plastics films.

11.7.3 Oxygen

The flow wrap which provides an excellent barrier to moisture can also protect its contents against oxygen, provided the appropriate material is chosen. This would generally incorporate a PVdC (polyvinylidene chloride) coating which could also be used for heat sealing. The addition of a layer of aluminium either as foil or as a coating applied by a metallisation process, will also enhance the oxygen barrier properties of a wrap.

Oxygen barrier materials are constantly being developed and PVdC can be replaced, if its chlorine content is considered to be environmentally undesirable, e.g. by silicon oxide or EVOH (ethylene vinyl alcohol), although these do not have the wide range of properties available from PVdC and are considerably more expensive.

Oxygen scavengers are available which can eliminate the oxygen contained within an oxygen barrier package. These have not been considered necessary for ordinary chocolate confectionery but have been used on occasion in Japan. Flow wrap equipment can be modified to gas flush a package, replacing air with nitrogen or carbon dioxide. This operation slows down the machine and necessitates the use of a heat seal medium, generally polyethylene, to obtain a sufficiently gas tight closure.

11.7.4 Taint/loss of flavour

The film most used to flow wrap confectionery, coextruded, cavitated or pearlised biaxially oriented polypropylene (OPP) is a good barrier to external taint or product flavour loss. This property can be enhanced by coating the film with PVdC or acrylic instead of coextruding it with polyolefin copolymer. The latter is more common and cheaper but rather less efficient as a barrier, particularly to oxygen.

It should be noted that although materials which are good oxygen barriers are also good odour barriers it is possible to have good barrier to odour without necessarily having a corresponding oxygen barrier. Some OPP films are coated with acrylic on one side and PVdC on the other, thus giving heat sealability with a wide temperature range and protection against moisture, oxygen and taint. Any film can have its barrier properties further improved by metallisation and/or lamination, both of which, incidentally, can be said to give the wrap an extra 'quality' appeal.

There is always the possibility that ink from the upper surface of the wrapping material can transfer to the inside in the reel and thence to the product. Correct procedures at the packaging converter should eliminate this but it is a potential source of taint which must be considered. The choice of inks and varnish must also be carefully made in order to eliminate the possibility of taint.

Residual solvents resulting from incomplete drying or oxidation of printing inks, varnishes and sealants are the most likely offenders in this respect. Their presence can generally be detected by simple smell and taste testing but GLC procedures should be used to identify the source of the taint.

Over the years some plastics materials have caused tainting through the incomplete conversion of monomers or the use of softeners or plasticisers and others have absorbed volatile flavours from the product. These problems should have been overcome by the plastics processors and certainly have been in the case of OPP but nevertheless it is essential that packaging materials, especially those coming into contact with the chocolate, are thoroughly checked for potential taint and flavour loss before they are used.

11.7.5 Light

Pearlised OPP has been given a degree of opacity through a process of cavitation which is adequate to eliminate the 'show through' or 'optical staining' which was a feature of chocolate wraps made from clear film, albeit heavily printed. It is not, however, sufficiently opaque to provide much protection against light for particularly susceptible products such as white chocolate. For these products a lamination of film and aluminium foil, or at least a lamination of two metallised films plus a solid background print, is required to give sufficient protection for a reasonable shelf life to be achieved.

11.8 Determination of shelf life

As the basic forms of chocolate confectionery have been on the market for many years it has been possible to assign reasonably accurate shelf lives for most products under varying climatic conditions. The most generally specified conditions are 'Temperate' and 'Tropical' although it is difficult to classify individual countries rigidly into these categories because of seasonal and regional variations. In addition, the quality of the conditions under which products are distributed and sold should be taken into account when determining shelf life.

Table 11.1 lists what may be regarded as representative shelf lives, characteristic of products adequately wrapped to withstand the effects of high relative humidities and to exclude light. These shelf lives must be regarded as the longest that can be assigned for the purpose of 'Best Before' date on packaging materials. If there is any likelihood of the product being exposed to adverse conditions for an appreciable length of time, e.g. in the unrefrigerated hold of a ship in tropical waters, the shorter life appropriate to 'Tropical' climate should be chosen.

Table 11.1 Representative shelf life (in months) of some chocolate confectionery

Category of product	Temperate conditions	Tropical conditions
Milk chocolate	16	12
Plain chocolate	24	24
White chocolate	16	12
Fondant cream filled chocolate	18	12
Chocolate with nuts	12	9
Count lines and wafer/cereal centred products	12	9
Fat filled chocolate	12	9