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History and Scope of the Book

1.1 Setting the Scene

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Bovine milk is the main source of milk in the world today. Table 1.1 illustrates some production data for the leading bovine milk producing countries in the world. The first column shows total milk production, whereas the second shows milk production expressed as per head of population. Thus countries like New Zealand and Ireland (see footnote) produce large quantities per capita, whereas countries such as China, although positioned in the top five milk producers in the world, are most probably not producing sufficient milk for their increasing populations who are developing a taste for milk and milk products. USA and Brazil are also large producers of bovine milk. Much of the milk in Brazil is consumed as liquid milk with a fair proportion being UHT processed.

It is very exciting time to be writing a book on high-temperature processing, particularly ultra-high temperature (UHT) processing. UHT is a continuous process and as such is applicable to any product that can be pumped through a heat exchanger and then aseptically packaged, although the vast majority of products are either milk or milk-based. UHT milk and milk products are now global commodities and are being transported large distances to all parts of the world. In a number of traditional milk-drinking countries, for example, UK, Greece and Australia, pasteurised milk is still the milk of preference and the cooked flavour that is associated with UHT and sterilised milk is given as a major reason for maintaining this status quo (Perkins & Deeth, 2011). In contrast, in some other countries much more UHT milk is consumed than pasteurised milk. For example, in France, Belgium and Portugal, more than 90% of all liquid milk purchased is UHT-treated, whereas in the UK, Norway, Sweden, Australia and New Zealand, it is less than 10%. Similar variations are also found in other parts of the world, with less than 5% of UHT milk being consumed in India and USA but over 60% in Vietnam and China. In other words, availability and also preferences for pasteurised or sterilised milk vary from country to country. Some examples for Europe and other parts of the world are given in Table 1.2.

Recently, there has been a substantial increase in UHT capacity in all parts of the world. In part, this is to supply the increased demand for UHT milk from China. It is also predicted that there will be an increased demand from Africa and other parts of South East Asia. Since UHT milk does not require refrigeration and has a long shelf-life, it provides a very convenient way of providing good quality milk to large populations in remote areas, without the need for the expensive cold chain infrastructure. UHT milk is

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Table 1.1 Leading producers of bovine milk in 2012, with populations and production per head of population.

	Milk production, 2012 (billion L)	Population (billion)	Per capita consumption (L/person)
United States of America	90.9	0.318	286
India	54.0	1.244	43.4
China	37.8	1.364	27.7
Brazil	32.3	0.204	158
Russian Federation	31.6	0.146	216
Germany	30.5	0.081	377
France	24.0	0.066	364
New Zealand	20.0	0.0046	4350
Turkey	16.0	0.078	205
United Kingdom	13.9	0.065	214
World	**620.3**	**7.25**	**85.6**

from: http://dairy.ahdb.org.uk/market-information/supply-production/milk-production/world-milk-production/#.VzxQVHn2aUk and world population figures

Table 1.2 Percentage of drinking milk which is UHT processed in various European countries and worldwide.

Europe	
Greece	0.9
Norway	5.3
UK	8.4
Austria	20.3
Germany	66.1
France	95.5
Spain	95.7
Belgium	96.7
Worldwide	
US	2
India	3
Australia	11
Japan	11
Malaysia	28
China	32
Thailand	46
Vietnam	62

Information from Wikipedia and Datamonitor (China has the largest forecast growth increase in UHT milk consumption over the period 2012 to 2020. India also has a high projected growth rate but is starting from a much lower base level).

now transported to China and other parts of South East Asia from countries such as Australia, New Zealand and even longer distances from USA and several countries in Europe. Both large multinational conglomerates and much smaller companies are engaged in these activities.

The demand for UHT milk is increasing worldwide. It has been estimated that the compound annual growth rate for UHT milk in the world between 2013 and 2019 will be 12.5%, with the global market reaching USD 137.6 billion in 2019 (Persistance Market Research, 2014). In locations where fresh milk is not available, UHT milk can be produced from milk powder. Also milk demand is increasing in locations where there has previously been no strong culture of drinking milk; there is a continuing investment in UHT capability in various parts of the world to meet this demand.

Demand for UHT milk is not the only factor that is changing in relation to the market for milk and milk products. The variety of milk-based beverages is constantly expanding. In the early days of UHT processing, only white milk and some cream products were processed. The variety in milk drinks has since mushroomed and now includes flavoured milk and products containing additives offering health benefits, derived either from naturally occurring components in the milk or non-milk components, such as plant extracts, fruit juices and other substances such as melatonin and dietary fibre (see Tables 1.3 and 1.4). There are also many products of non-dairy origin; these are covered in more detail in Chapter 9.

Whatever type of UHT product is being produced, a key consideration is to ensure that the formulation has good heat stability. The first consideration is a knowledge of the chemical composition of raw milk which is complex and subject to day-to-day and seasonal variation, as illustrated by data on a bulk milk supply collected in the UK over 15 months (Chen *et al.*, 2014) (see Table 1.5). Secondly, it is crucial to understand how different additives, for example, fruit essences, flavours, mineral salts, stabilizers and emulsifiers will influence heat stability in order to ensure that fouling of the UHT plant and sediment formation in the treated product are minimized. This has been one of the authors' main areas of research and an aim of this book is to share our experiences dealing with these topics. Similar issues arise with some non-bovine milk products, such as goat's and camel's milk, which have poorer heat stability than cow's milk and need to be stabilized to be suitable for UHT processing. Historically, pH was considered to be a very important determinant of heat stability of milk, but now the role of both pH and ionic calcium and their interrelationship is better understood, as is how they change when milk is heated to 140 °C and then cooled; these issues are discussed in Chapter 6.

The first and overriding objective is to make UHT products safe to drink by ensuring that they are adequately sterilised and that they will not cause outbreaks of food poisoning. The most heat resistant pathogen is *Clostridium botulinum.* It is noteworthy that raw milk is not considered to be a source of this pathogen and incidents of botulinum have not been attributed to liquid milk and only very rarely to milk products. However, raw milk may contain some bacterial spores that are more heat resistant than *Cl. botulinum* and ensuring that these are inactivated during the UHT process will ensure the UHT milk is free of *Cl. botulinum*, even if the bacterium may have inadvertently found its way into a formulated milk product from other sources. In fact, some recent work using a probabilistic assessment model predicted that contamination of a UHT product with *Cl. botulinum* might arise only once in 367 years (Pujol *et al.*, 2015). The release of product containing the thermophilic spore-former *Geobacillus stearothermophilus* was

Table 1.3 Some drinking milk products available commercially or being developed.

Milk types
Full-cream, skim, semi-skim – HTST, ESL, UHT, sterilised
Flavoured
Lactose-reduced
Carbonated
Goat's, sheep, buffalo's, horse and camel's milk
Microfiltered
Breakfast milks
A2 milk
Yogurt drink
Pet milk
Soy, almond, oat and other plant "milks"
Additives/fortifiers
Calcium and other minerals
Vitamins
Plant sterols and stannols
Omega-3, conjugated linoleic acid (CLA)
Microparticulated whey protein
Milk bioactive peptides
Dietary fibre (e.g., β-glucan, inulin)
Melatonin
Polyphenols
Oligosaccharides

calculated to be much higher than this, but this is not a food pathogen and will only be problematic where the temperature of the products during storage is allowed to reach >50 °C, such as in hot climates.

The ideal UHT milk product should be free of environmental contaminants and also be commercially sterile. This is the combined responsibility of the milk producer, the milk processor and the packaging technologist. However, this is by no means the end of the process because UHT milk will then be expected to be acceptable to the consumer and have a "best before date" of at least six months (Rysstad & Kolstad, 2006). There are sound scientific explanations why six months is a reasonable period and problems may be encountered if this is extended. Although it is possible to eliminate microbial activity, it is not possible to prevent chemical and physical reactions taking place; in some circumstances, enzymatic reactions such as proteolysis and lipolysis may also be encountered. Thus, there is in place a dynamic situation in UHT milk during storage, where its active components are reacting or interacting and, as a result, some of its important quality attributes are also changing. The rate at which these changes take place is

Table 1.4 Some high-temperature-processed milk products from different countries.

Product	Country	Brand Name	Format	Other comments
On-the-go snack	USA	Dynamoo	UHT, 8 fl oz, boxes	
Red-bean flavoured milk	Taiwan	Acacia Lover	UHT, 250 mL bottle	
Fruit and milk drink	France	Danoo Mon fruit prefere	1 L re-sealable carton	Acidic product
Milk shake	USA	Cold Stone Milk Shake	UHT, 12 fl oz plastic bottle	
Nutritious weight loss shake	UK	USlim	UHT, 250 mL plastic bottle	
Dairy based functional drink	Latvia	Lakto	100 g plastic pots	P24, digest, acidic product
Coffee milk	Finland	Kahvi Maito, Valio	1 L cartons	Claimed to foam well
Milk with real fruit pieces	China	Meng niu	UHT cartons	Available since 2007
Milk with cereal grain	China	Yi Li	UHT cartons	Thai rice and Euro wheat
Milk with oat cereals	China	Meng niu	UHT cartons, "Miao Dian"	
Black cereal milk	China	Guanxi Huangshi Dairy Co ltd	UHT cartons	Black sesame, rice and beans
Milk and peanut protein			UHT cartons	
Breakfast milks	Australia UK UK	Up and Go (sanitarium) Weetabix The Fuel Station	UHT cartons and plastic bottles Tetra Prisma	Many flavoured varieties 2014 Caffe Latte
High protein drinks (whey based) Milk based recovery and build drink	UK	Upbeat (Good Whey Company) Maxi-Nutrition	ESL, plastic bottles UHT, plastic bottles	Microparticulated whey protein (8%) 9% protein, fruit flavoured products
Infant and follow-on formulations	UK UK UK	SMA, first infant milk Aptamil, first milk Aptamil, toddler milk	Sterilised, glass bottle UHT, 100 mL bottle UHT, 200 mL bottle	Protein, 1.3%;fat 3.6%, C/H 7.3% Contains GOS, FOS Contains GOS, FOS

influenced by storage temperature. Within the life-span of a carton of UHT milk, it may be stored at temperatures from -10 °C to over 50 °C. For example, during transportation from UK to China it may go through fluctuating temperatures as it passes from the UK through the Gulf states and across the equator. Furthermore, large countries such as China, Australia and USA have several climatic zones, and ambient temperature may

Table 1.5 Composition of bulk raw milk from one farm collected over 15 months.

Composition/properties	Mean (n = 25)	Range	Seasonal variation
pH	6.79	6.73–6.87	SP > SM and A;W > A
Ca^{2+} (mM)	2.05	1.68–2.55	NS
Total solids (%)	12.78	12.31–13.31	A > SM
Protein (%)	3.29	2.89–3.56	SP > SM and A
Total casein (%)	2.36	2.08–2.52	SP > SM and A
Fat (%)	4.08	3.62–4.77	A > SP, SM and W
Lactose (%)	4.59	4.52–4.69	NS
Ash (%)	0.71	0.53–1.03	NS
Total Ca (mM)	29.29	24.53–31.53	NS
Total Mg (mM)	5.11	4.21–5.81	NS
Total citrate (mM)	9.04	8.22–10.09	NS
Total P (mM)	27.52	22.58–33.57	NS
Urea (%)	0.0237	0.016–0.033	NS
SCC ('000)	155	65–357	W > SP, SM and A

Source: Chen *et al.,* 2014. Reproduced with permission of Elsevier.
(SP=Spring; SM=Summer; A=Autumn; W=Winter; NS=Non-significant difference (p > 0.05) (from Chen *et al.,* 2014)

extend over a wide range, from below 0 °C to above 50 °C. Also, individual milk cartons from the same specific production batch may have had totally different temperature storage histories by the end of six months. The expectations are that each one of these individual cartons will be still acceptable to the consumer. In our opinion, this is a lot to expect from the product and there is no doubt that the number of complaints will increase from stored products where the best-before period exceeds six months. In fact, the expected best-before time period is now creeping up to nine months or even one year, which is posing some new challenges for the UHT milk producer.

Also, the consumer is becoming more discerning. For example, it is reported that the Chinese consumer spends more time than any other reading food labels. There are a number of things any consumer might notice which could result in their making a complaint. On pouring the product, any physical defects such as fat separation, gelation or sediment will be obvious. The more inquisitive consumer will also notice what is left in the carton after the contents have been removed. Sediment and fat may be left in the carton and, if observed, may be a source of complaint, although this is unlikely to be a safety issue. The colour of the milk may also give cause for concern, especially if it is browner that expected. On tasting, any physical defects which change the mouthfeel might be noticed, for example, increased viscosity or presence of sediment giving rise to a powdery or gritty mouthfeel. Finally, its flavour must be acceptable and not be too cooked, oxidized or lipolytically rancid, as well as free of any other off-flavours and taints. Overall, expecting UHT milk to have a best-before period of longer than six months under all possible conditions is taking it out of its comfort zones. Consumers do allow some leeway for product imperfections such as a small fat layer on the milk but this cannot be pushed too far. One anecdote is that some consumers are prepared to accept a degree of fat separation, as this indicates that fat is actually present in the product.

1.2 Scope of the Book

This book aims to integrate the scientific information arising from several disciplines that needs to be considered in order to ensure that UHT and other highly heat-treated products are both safe and acceptable to the consumer. UHT processing requires an understanding of aspects of fluid flow and heat transfer, and a detailed knowledge of the properties of the food being processed and of the mechanisms of the various changes that occur during processing and storage. This includes knowledge of its chemical composition, the enzymes that are present and its microbial flora as well as an awareness of possible environmental contaminants.

When any food is subjected to UHT treatment, a large number of heat-induced reactions take place, which, if properly understood and controlled, ensure that the food is safe and that it will have a good appearance and taste for up to six months and probably for considerably longer. The material in this book is derived from the scientific literature related to UHT processing and the personal insights from two practitioners who have spent much of their working lives involved with UHT products and processes.

In order to put UHT processing and products in perspective in dairy processing, an overview of the heat treatments of milk is initially given (see Chapters 2 and 3). Furthermore, the microbiological aspects of these heat treatments and their associated products are provided (Chapter 4) as it has to be remembered that the basic reason why heat treatments are carried out is to destroy micro-organisms. A good understanding of the microbiological aspects is therefore fundamental to ensuring the safety and quality of the products. In these chapters, extended shelf-life (ESL) processing, a sub-UHT heat treatment, is covered in some detail because of the growing demand for ESL products.

1.3 Reasons for Heating Foods

In addition to inactivating micro-organisms, both pathogenic and spoilage, foods are heated to inactivate enzymes, as foods may change and become unacceptable due to reactions catalysed by enzymes. Milk contains about 60 indigenous enzymes (Fox, 2003), some of which, such as lipases and proteases, may cause flavour changes, whereas in fruit, browning may occur as a result of polyphenol oxidase activity. The process of heating a food may also induce physical changes and chemical reactions, such as starch gelatinisation, protein denaturation and Maillard browning, which in turn affect the sensory characteristics, such as colour, flavour and texture, either beneficially or adversely. For example, during the manufacture of canned evaporated milk, forewarming of milk prior to evaporation is essential for preventing gelation and thickening during the subsequent evaporation and canning steps. Heat treatment is also crucial in yogurt manufacture to achieve the required final texture in the product. However, such heating processes may result in loss of important nutrients, although these losses can be reduced by controlling the heating conditions.

Thermal processes vary considerably in their severity, ranging from mild processes such as thermisation and pasteurisation, intermediate processes such as used for ESL milk, through to more severe processes such as UHT and in-container sterilisation processes (see Chapters 2 and 3). The severity of the process affects both the shelf-life and quality characteristics of the product.

A UHT process contains heating, holding and cooling stages. After the product has been heated to the desired temperature, it is held for a short period of time to inactivate the microorganisms before being finally cooled and packaged under aseptic conditions. Continuous processes provide scope for energy savings, whereby the hot fluid is used to heat the incoming fluid; this is known as heat regeneration and saves both heating and cooling costs (see Chapter 5)

A wide range of products are heat-treated, ranging from low-viscosity fluids such as milk and fruit juices, through to highly viscous fluids. The process is more complicated when particles are present, as it becomes necessary to ensure that both the liquid and solid phases are adequately and, if possible, equally heated. A secondary issue is keeping the particulates suspended during storage, especially in transparent containers. The presence of dissolved air in either of the phases becomes a problem as air becomes less soluble as temperature increases and will come out of solution. Air is a poor heat-transfer fluid in comparison to steam and hence its presence affects the rate of heating of the food. For this reason, deaeration is sometimes used.

1.4 Brief History of Sterilisation Processes

Food sterilisation in sealed containers is often attributed to the pioneering work of Nicholas Appert. However, Cowell (1994, 1995) reported that investigations on heating foods in sealed containers were documented and took place earlier than this. He describes the commercialisation of the canning process in East London at the turn of the nineteenth century, which included the contributions not only of Nicholas Appert, but Peter Durand, Bryan Donkin, John Gamble and Phillipe de Girard. It is both noteworthy and worrying that bacteria which are the causative agents of food poisoning and spoilage were not understood until considerably later in the nineteenth century, through the work of Pasteur. He confirmed that the many food fermentations which were spoiling foods were not spontaneous but caused by microbial metabolism. He also discovered that both yeasts and *Acetobacter* could be destroyed by relatively mild heat treatments at about 55 °C. According to Wilbey (1993), Pasteur's work on producing beer, wine and vinegar laid the foundations for hygienic processing and the recognition of the public health implications of hygiene and heat treatment.

Early sterilisation processes were essentially of a batch nature and the food was heated in the container. Batch processing still has an important role in food processing operations and provides the small-scale food producer with a cheap and flexible means of heat-treating foods. The steps involved in a batch sterilisation process are shown in Figure 1.1. Continuous sterilisers had been patented and constructed and were able to heat milk to temperatures of 130-140 °C before the end of the nineteenth century, again well before the benefits of the process were understood. Hostettler (1972) recalls that in 1893, a continuous-flow heating apparatus with an output of up to 5000 L/h had been constructed which could heat milk to 125 °C, with a holding time of up to 6 min.

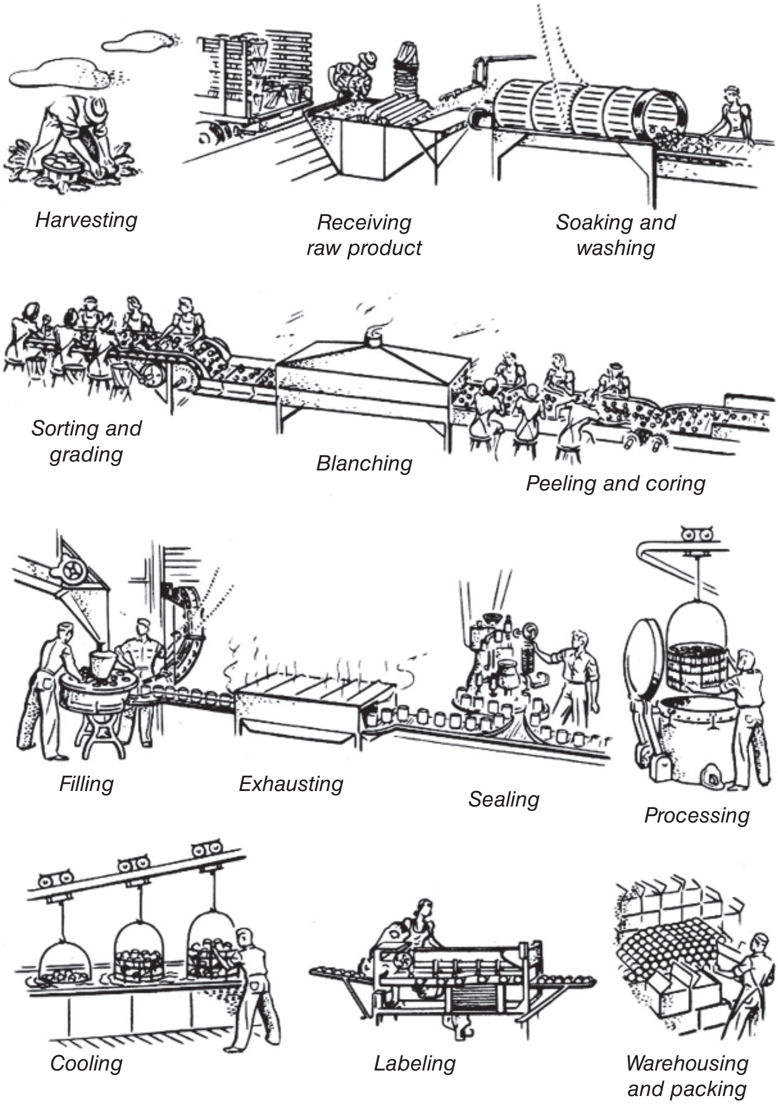

Figure 1.1 The batch canning process (from Jackson & Shinn, 1979).

Around 1909, a number of patents were registered which involved contacting milk with jets of hot air, gases and steam. Aseptically canned milk was produced in 1921 and a steam injection system was developed in 1927 by Grindrod in USA. However, the major initiatives leading to commercialisation of the UHT process began in the late 1940s, through the development of concentric-tube sterilisers and the uperisation steam-into-milk UHT system, which was developed in conjunction with the Dole aseptic canning system. UHT milk was not commercially available in the 1940s and early 1950s, as evidenced by the absence of information in both Cronshaw (1947) and Davis (1955). During the first half of the twentieth century, investigations took place side-by-side into in-container sterilisation and UHT processing, but the unsolved difficulty of filling the sterilised milk, without recontamination, into containers caused the interest in continuous processes to wane, so sterilisation of milk in sealed containers retained its dominance at this time. It is also noteworthy that many of these early investigations involved direct heating and the only mention of UHT-type processing in Davis (1955) was to uperisation, a steam injection process. In fact the marketing of uperised UHT milk in cans was first practised in Switzerland in 1953, with milk heated by steam injection at 150 °C for 2.4 s and flash cooled. The dominance of sterilised milk around that time is also illustrated in Davis (1955).

As mentioned, early commercial aseptic filling machines filled milk into metal cans, which were usually sterilised by superheated steam, which could be used at atmospheric pressure and avoided condensation and wet cans. A shelf-life of 4 to 6 months was claimed for the product.

The main developments in getting UHT milk to the market place occurred between the early 1960s and 1972 and were rapid. A major development was the use of hydrogen peroxide to sterilise the packaging material. Typical conditions then were 17% w/v solution, with a wetting agent. Hydrogen peroxide was evaporated off with hot air at about 180 °C. Equipment using this procedure was first commercialised in 1961 and from this point availability of UHT products started to accelerate.

Regulations permitting UHT milk in the UK were introduced in 1965. In 1968 UHT milk was introduced in Germany and in 1969 it commanded less than 2% of the liquid milk market. Its success there is illustrated by the fact that now over 90% of milk consumed is UHT treated. In Australia, the first successful UHT operation commenced in 1968 although an earlier installation ceased operation after a few years due in part to technical difficulties such as age gelation (Zadow, 1998).

In 1970, Hsu published the first book on UHT processing of dairy products and this was followed in 1972 by the first International Dairy Federation (IDF) monograph on UHT milk and a revised version in 1981. These publications catalogued most of the technical challenges that had been recognized and investigated in order to produce sterile milk of long shelf-life by means of a continuous-flow process involving heating at a high temperature for a short time, followed by aseptic packaging. By that time it had become well accepted as a method for heat treatment of milk for consumption.

A more detailed account of the early development of UHT processing, before it was properly commercialized is given by IDF (1972). The history of the continuous sterilisation process has also been reviewed by Burton (1988).

It is interesting that in the early 1970s there was no clear statement about how long UHT milk should keep. However, it was probably quite short because of the numerous challenges in UHT processing and the lack of a good understanding of the technology and its effects on product quality. An indication of this was given by Singh and Patel (1988) who reported that the shelf-life of UHT milk in India was only 15 days although the expected shelf-life was three months. They identified numerous aspects of the UHT process which required attention to improve the shelf-life including the initial bacterial content of raw milk, selection of suitable time – temperature conditions, problems related to heat-resistant proteases, sedimentation and deposit formation, and problems with the packaging system; these would have been similar to those encountered by the early UHT processors. With the developments in technology and a better understanding of the key determinants of shelf-life, together with market demands, it is not uncommon for the "best-before" period to be now set at nine months, and more recently 12 months, as discussed above.

At this point it is instructive to state two descriptions of a UHT treatment from the latest EU regulations (Hickey, 2009): "Continuous flow at a high temperature for a short time with not less than 135 °C for a suitable holding time such that there are no viable spores capable of growing in the treated product when kept in an aseptic container at ambient temperature" and "Sufficient to ensure that the products remain microbiologically stable after incubating at 15 days at 30 °C in closed containers, or 7 days at 55 °C in closed containers, or after any other method that demonstrates that appropriate heat treatment has been applied." The EU regulations no longer state what level of microbial activity would constitute microbial sterility after these incubation periods, whereas previous regulations stipulated it to be less than 100 cfu/mL, which seems to be a reasonable standard. This was illustrated by Quratulain and Saeed (2004) who found two brands of commercial UHT milk had mesophile counts of 75 and 96 cfu/mL after storage for 40 days; they commented that the milk met the "requirements of the standard". The current Australia and New Zealand Food Standards match the EU regulation and state that UHT milk and cream "should comply with a test for commercial sterility" (FSANZ, 2011).

In conclusion, it is worthwhile considering what factors have changed over the past 15 years since the publication of the Lewis and Heppell (2000) book. The basic processing technology and heat exchanger configurations have changed little although improvements continue to be made. There is now more recognition of the roles of the heating and cooling profiles. This has led to a wider use of the concept of bacterial and chemical indices (see Chapter 3) for characterising the process and understanding the effects of different processing conditions on the quality of the products.

The processing run times that can be achieved have increased considerably. It is now claimed that it is possible to obtain runs of 40 h. The main way of achieving this has been to include a protein stabilisation tube. One explanation is that this does not eliminate fouling but it causes the fouled deposit to accumulate in the protein stabilisation tube, which is away from areas where its build-up may be more critical.

The control and instrumentation has improved and information on when the plant needs to be cleaned and also when cleaning has been completed is more readily available. One possible consequence of longer run times is that the cleaning times may be longer, although this has not been reported to be the case. Also, a lot more information is now available to UHT process operators to provide them with a better understanding of the performance of the heat exchanger.

There have been other more subtle changes, such as improvements in homogeniser valve design, which should lead to an improvement in emulsion stability. This is crucially important as the "best-before" date for many products is now nine months or twelve months.

The product range continues to expand and there is now more emphasis on environmental considerations; for example, how much water and energy is used and how much waste is generated. One of the advantages that UHT processing offers is that the product does not need to be refrigerated during transportation or storage, although refrigeration or some form of temperature control may be beneficial in hot climatic conditions.

It has been difficult selecting a concise title for this book to reflect its entire content. However, we have chosen high temperature processing of milk and milk products. One reason for this is the dominance of white milk and other milk-based products in the

Table 1.6 Volumes of liquid dairy and dairy-like products sold worldwide in 2015 (Source: Reproduced with permission of Tetra Pak Compass).

Product	Volume (billion litres)
White milk	216.8
Baby and toddler milk	19.6
Flavoured milk	18.4
Soy milk	17.8
Drinking yogurt	9.4
*RNGS milk	8.3
Dairy cream	4.0
Sweetened condensed milk	2.5
Buttermilk	2.3
Evaporated milk	1.6

* RNGS is rice, nuts, grains and seeds products

global dairy products market, as shown in Table 1.6. Almost all of the beverages listed are subjected to thermal processing of some kind and many of them to UHT processing. Non-dairy products such as the rice, nuts, grains and seeds (RNGS) products are making inroads into the nutritive beverage market. These and most of the other products listed in Table 1.6 are discussed in Chapter 9 while some emerging technologies which have potential for processing these products are covered in Chapter 10.

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