AN SPX BRAND

White Paper

Long Life Dairy, Food and Beverage Products

Contents

Executive Summary

There are a number of important microbiological factors that need to be addressed in the production of long life dairy, food and beverage products. The presence of microorganisms in the milk must be reduced to a safe number in order to ensure sufficient shelf life under appropriate storage conditions.

This can be achieved by a variety of thermal processes. The efficiency of these processes is a factor of temperature and holding time and can, if not properly controlled, lead to adverse effects on flavour and appearance.

A number of systems of relevance to the dairy, food and beverage industries are discussed and advice is offered on how to achieve the best quality product at a reasonable cost, taking into account safe and trouble-free operation.

Efficient aseptic processing is an important factor in development of new products. The SPX Innovation Centre in Denmark offers Pilot Plant Testing and application solution guidance services to help customers maximise the performance of their plant. Pilot Testing can also be conducted on customers' own premises based on rental equipment and, if required, with support from SPX experts.

Introduction to SPX Flow Technology

Vision and commitment

SPX's Flow Technology segment designs, manufactures and markets process engineering and automation solutions to the dairy, food, beverage, marine, pharmaceutical and personal care industries through its global operations.

We are committed to helping our customers all over the world to improve the performance and profitability of their manufacturing plant and processes. We achieve this by offering a wide range of products and solutions from engineered components to design of complete process plants supported by world-leading applications and development expertise.

We continue to help our customers optimise the performance and profitability of their plant throughout its service life with support services tailored to their individual needs through a coordinated customer service and spare parts network.

Customer focus

Founded in 1910, APV, an SPX Brand, has pioneered groundbreaking technologies over more than a century, setting the standards of the modern processing industry.

Continuous research and development based on customer needs and an ability to visualise future process requirements drives continued mutual growth.

Introduction to long life dairy, food and beverage products

As one of the most complete food products of all, dairy products are very important in human nutrition. However, dairy products are also highly perishable and would easily lose their nutritional value, flavour and appearance if protective measures were not taken.

Consequently, the dairy industry is one of the most advanced industries in the food processing area, taking care of the milk from when it leaves the udder of the cow - through transportation to the dairy, processing, packaging, and distribution - until it reaches the consumer.

The technology of producing long-life products is today applied throughout the food and beverage industries and in many cases the processing plants are designed for multipurpose operation.

When aseptic technology was introduced more than 50 years ago, it revolutionised the food industry by making it possible to distribute high quality food products over long distances in a cost-effective way.

The heart of aseptic technology for production of long-life dairy products is aseptic processing, and since its introduction this concept has been developed and refined to a point where any need in respect of capacity, product viscosity, particulate content, acidity or sensitivity to heat treatment can be met while securing high quality, long-life products.

SPX Flow Technology was one of the pioneers in aseptic processing and over the years we have developed a wide range of processing concepts to satisfy all the needs of the industry.

In this publication, we will first discuss some of the micro-biological factors, which must be considered in all aseptic processing, together with the heating processes most commonly used for reducing micro-organisms in dairy products: pasteurisation, sterilisation and ultra high temperature (UHT) treatment.

So-called commercial sterility is the aim of all UHT processes, and the extent to which this is achieved in a particular process can be measured, notably by reference to the bacteriological effect (B*) and the chemical effect (C*) of such processes. These factors are explained in the section “Process Evaluation”.

The main part of the publication is devoted to an analysis of the processing systems of most interest to the dairy, food and beverage industry: Indirect Plate Steriliser, Indirect Tubular Steriliser, Steam Infusion Steriliser, High Heat Infusion Steriliser, Instant Infusion Pasteuriser, Steam Injection Steriliser and Indirect Scraped Surface Heat Exchanger (SSHE) Steriliser.

In each case we describe the system, discuss its advantages and limitations, and list a number of products for which the system in question is particularly suitable (See Tables 1 and 4).

The Pilot UHT Plant is able to combine most of the aseptic processes in one unit, which provides an efficient tool for pilot trials and product development.

In aseptic processing, special consideration must be given to some of the auxiliary equipment required. Aseptic tanks are not a necessary requirement but often serve as a useful buffer for sterilised products.

The area of extended shelf life products is becoming increasingly important, and the development of the Pure-Lac™ concept is offering the industry and the consumers new solutions and exciting opportunities.

With the large number of options available it becomes important to be able to choose the solution, which provides the best quality product at a reasonable cost, giving safe and trouble-free operation. A separate section has been made to cover this subject.

The process control system is not only necessary, it must incorporate up-to-date technology - not least on the software side.

Special attention must be given to the subsequent filling and packaging of aseptically processed products.

Finally, we address the area of product development. SPX Flow Technology’s world wide capabilities in respect of product testing makes it possible to work closely with customers in their efforts to upgrade production and launch new products.

This publication is purely dealing with the indirect and direct heat transfer processes.

SPX Flow Technology is also manufacturing various types of electrical - or “electroheat” thermal processing equipment. This is dealt with in a separate publication.

DAIRY, FOOD & BEVERAGE PROD-UCTS	PLATE STERILISER	TUBULAR STERILISER	STEAM INFUSION STERILISER	HIGH HEAT INFUSION STERILISER	INSTANT INFUSION PASTEURISER	STEAM INJECTION STERILISER	SCRAPED SURFACE HEAT EXCHANGER SYSTEMS
Milk	x	x	x	x		x	
Milk (flavoured)	x	x	x	x		x	
Milk (evaporated)		x	x	x	x		
Milk (concentrated)		x	x		x	x	x
Milk (shake mix)	x	x	x	x			x
Cream	x	x	x	x		x	
Cream (whipping)		x	x	x		x	
Cream (synthetic)	x	x	x	x		x	
Yoghurt		x	x			x	x
Yoghurt (drinking)	x	x					
Yoghurt (fruit)		x					x
Quark products							x
Soya milk	x	x	x	x		x	
Baby food			x		x	x	x
Ice cream mix		x	x	x	x		x
Cheese dips			x	x		x	x
Processed cheese			x		x		x
Deserts / puddings		x	x	x			x
Whey protein con-centrate					x		x
Coffee whitener	x	x	x	x	x	x	x
Egg-based prod-ucts					x		
Sauce		x	x				x
Soups		x					x
Coffee/Ice tea	x	x					
Fruit juice	x	x					

Table 1: A variety of dairy, food and beverage products and their suitability for treatment in thermal heat processing systems.

Microbiology

The key to production of long-life products with aseptic technology is a detailed understanding of the microbiology of food. Using the example of the dairy industry, the milk in the udder of a healthy cow is free from bacteria, but as soon as the milk comes into contact with the air it becomes contaminated with micro-organisms.

If the temperature is favourable, the micro-organisms multiply and very soon the milk will turn sour (or putrefy), developing an unpleasant flavour. To prevent this from happening, the raw milk is subjected to heat treatment.

The term aseptic is usually defined as "free from or keeping away" disease producing or putrefying microorganisms. In the food industry the terms aseptic, sterile and commercially sterile are often used interchangeably. This is not strictly correct. Sterilisation means 100% destruction of all living organisms, including their spores, and this is very difficult to achieve.

Commercial sterility means that the product is free from microorganisms, which grow and consequently contribute to the deterioration of the product. Microorganisms are extremely small and can only be seen under a microscope. However, hundreds or thousands of individual cells or groups of cells can form colonies, which are visible to the naked eye, and some colonies have colours, shapes, textures or odours, which make the organism identifiable.

Bacteria

The term bacteria strictly means rod-shaped microorganisms only, but is also used in a loose sense to include all micro-organisms except yeast and moulds. The individual bacterium varies in size from 0.5 to 3 micron.

The groups of bacteria, which are most important in the dairy industry are the lactic acid, coliform, butyric acid, and putrefaction bacteria. The bacterial count in milk coming from the farm varies from a few thousands bacteria/ml for high quality milk to several millions if the standard of cleaning, disinfection and chilling is poor.

For milk to be classified as top quality, the CFU (Colony Forming Units) should be less than 100,000/ml.

Bacteria are single-celled organisms, which normally multiply by binary fission, i.e. splitting in two. The simplest and most common way to classify bacteria is according to their appearance and shape. However, in order to be able to see bacteria, they must first be stained and then studied under a microscope at a magnification of approximately 1,000 X.

Based on a method of staining, developed by the Danish bacteriologist Gram, bacteria are divided into Gram negative (red) and Gram positive (blue). The three characteristic shapes of bacteria are spherical, rod-shaped and spiral. Diplococci arrange themselves in pairs, staphylococci form clusters, while streptococci form chains.

Another way of classification is according to temperature preference:

- Psychrotrophic bacteria (cold-tolerant) reproduce at temperatures of 7°C or below.
- Psychrophilic bacteria (cold-loving) have an optimum growth temperature below 20°C.
- Mesophilic bacteria (loving the middle range) have optimum growth temperatures between 20°C and 44°C.
- Thermophilic bacteria (heat-loving) have their optimum growth temperatures between 45°C and 60°C.
- Thermoduric bacteria (heat-enduring) can tolerate high temperatures - above 70°C. They do not grow and reproduce at high temperatures, but can resist them without being killed.

Bacteria can only develop within certain temperature limits, which vary from one species to another. Temperatures below the minimum cause growth to stop, but do not kill the bacteria. They are, however, damaged by repeated freezing and thawing. If the temperature is raised above the maximum, the bacteria are soon killed by heat. Most cells die within a few seconds of being exposed to 70°C, but some bacteria can survive heating to 85°C for 15 minutes, even though they do not form spores.

A third way of classifying micro-organisms is by their oxygen requirement. The availability of oxygen is vital to the metabolism of all organisms. Some bacteria consume oxygen from the atmosphere; they are called aerobic bacteria. However, to some bacteria free oxygen is a poison; they are called anaerobic bacteria and obtain the oxygen they need from chemical compounds in their food supply. Some bacteria consume free oxygen if it is present, but they can also grow in the absence of oxygen; they are called facultatively anaerobic.

The acidity of the nutrient substrate for bacteria is also important. Sensitivity to pH changes varies from one species to another, but most bacteria prefer a growth environment with a pH around 7. Furthermore the salt and/or sugar concentration of a substrate has an important influence on the growth of bacteria. The higher the concentration, the more growth is inhibited. This is caused by the high osmotic pressure, which will draw water out from the cell, thereby dehydrating it. Osmotic pressure is used as a means of food preservation in sweetened condensed milk, salted fish and fruit preserves like jam and marmalade.

Spores

The spore is a form of protection against adverse conditions, e.g. heat and cold, lack of moisture, lack of nutrients, or presence of disinfectants. Only a few bacteria are spore forming e.g. Bacillus and Clostridium. The spores germinate back into a vegetative cell and start reproduction when conditions become favourable again. The spores have no metabolism and can survive for years in dry air and are much more resistant to adverse conditions than bacteria. This includes heat treatment and it takes typically 20 minutes at 120°C to kill them with 100 percent certainty. The UHT time/temperature combination reduces the number of bacteria spores by a minimum of log 9, leaving very few bacteria spores in UHT treated products.

Enzymes

When the milk leaves the udder it contains enzymes, the so-called original enzymes. Enzymes are also produced by the bacteria in the milk, the so-called bacterial enzymes. Enzymes are not micro-organisms but are formed as a result of the metabolism of micro-organisms. The ability of enzymes to trigger chemical reactions can be important when UHT products are produced.

Some of the bacterial enzymes are able to cause sweet coagulation of milk products, which destroys the product. The majority of these enzymes are produced by Gram negative Pseudomonas bacteria developing mainly in cold raw milk stored for excessive time in milk cooling tanks, road tankers or milk silos. This problem will be aggravated if the milk has been contaminated because of unhygienic conditions or lack of cleaning-in-place (CIP). The vast majority of enzymes will be destroyed by UHT treatment, but a few may still be active in the final product.

Moulds

Moulds belong to the fungi group of micro-organisms, which are very widely distributed in nature among plants, animals and human beings. Moulds normally grow anaerobically, and their optimum growth temperature is between 20 and 30°C. Moulds can grow in substrates with pH 2 to 8.5, but many species prefer an acid environment. The most common species in milk do not survive pasteurisation conditions, and the presence of mould in pasteurised products is therefore a sign of reinfection. The penicillium family is one of the most common types of moulds. Their powerful protein splitting properties make them the chief agent in ripening of, for instance, Blue Cheese.

Yeast

Yeast also belong to the fungi group of micro-organisms. They vary greatly in size. Saccharomyces cerevisiae, used for brewing of beer, has a diameter of 2 to 8 micron, but other species may be as large as 100 micron.

Yeast has the ability to grow both in the presence and absence of oxygen. The optimum temperature is between 20 and 30°C. Optimum pH values are 4.5 to 5.0, but yeast will grow in the pH range of 3 to 7.5.

From a dairy point of view, yeast are generally undesirable organisms. They ferment milk and cream and cause defects in cheese and butter. In the brewing, baking and distillation industries, on the other hand, they are very valuable organisms.

Bacteriophages

Bacteriophages belong to the group of micro-organisms called viruses. Viruses have no metabolism of their own and therefore cannot grow on a nutrient substrate. Viruses infect living cells in plants and animals. Bacteriophages (also known as phages) infect bacteria and are consequently a problem in all dairy processes where bacteria cultures are used. They are very small in size - in the order of 0.02 to 0.06 micron and can only be seen in an electron microscope.

Bacteriophages grow at temperatures between 10 and 45°C. They are killed by exposure to 63 to 88°C for 30 minutes and tolerate pH values in the range of 3 to 11.

Toxicity

Micro-organisms, which are harmful to man or animals are called pathogens. They can cause death or severe illness by the secretion of toxins either directly into contaminated foodstuffs, which are subsequently eaten, or by transfer to an animal host offering ideal conditions for reproduction and further generation of toxins. Some toxins are inactivated by heat treatment at 60°C for one hour.

Process classification

A number of different expressions are commonly used in the food industry in relation to food preservation. This section will briefly describe the most common terms used.

Pasteurisation

Most commercial liquid food products undergo some form of heat treatment, and pasteurisation is the most common. As it is usually bacterial growth that causes food to deteriorate, pasteurisation preserves the freshness of the food product. There are basically two ranges of pasteurisation:

- Low-temperature pasteurisation. For milk, this is based on heating the product to 72 to 76°C and holding at that temperature for at least 15 to 20 seconds (or equivalent) (Fig. 1).
  The pasteurisation may vary from country to country according to national legislation. A common requirement in all countries, however, is that the heat treatment must guarantee the destruction of unwanted micro-organisms and all pathogenic bacteria.
  The shelf life of pasteurised milk is limited (typically 5 to 7 days) and primarily depends on raw milk quality and storage temperature.
  During the low-temperature pasteurisation the phosphatase enzyme is destroyed, while the peroxidase enzyme is preserved. This serves as a measure to control the process and distinguish it from high-temperature pasteurisation.

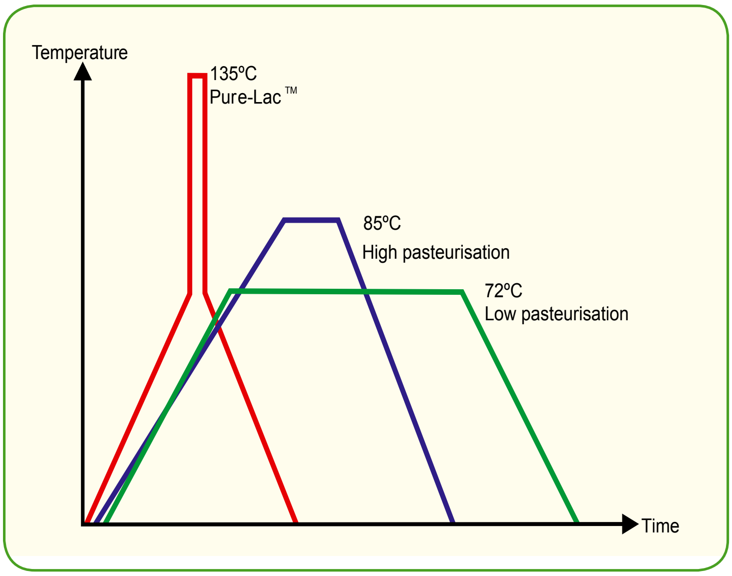

Fig. 1: Low-temperature pasteurisation

- High-temperature pasteurisation. This is based on heating the product to 85°C or higher for a few seconds (or equivalent) (Fig. 1). The aim is to kill the entire population of bacteria, which are pathogenic for both man and animals and almost all other bacteria as well. By careful monitoring of the process parameters a product with excellent quality can be obtained with minimum heat damage. The shelf life can be extended to several weeks in the cooling chain. The so-called Pure-Lac™ process is based on high-temperature pasteurisation.
  During the high-temperature pasteurisation both the phosphatase and the peroxidase enzymes are destroyed, and this serves as a measure to control that the process has actually taken place as specified.

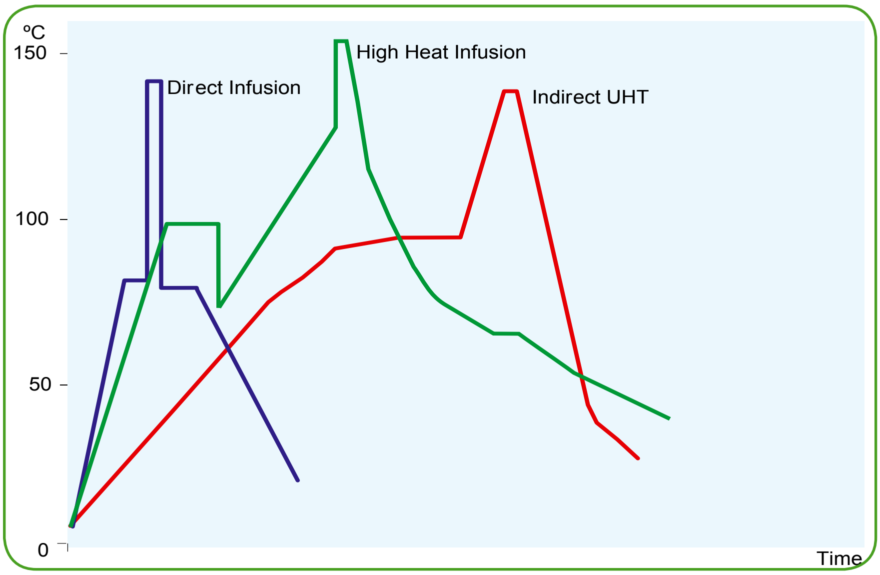

Fig. 2: Temperature profiles for direct infusion, high heat infusion and indirect UHT processes.

Extended shelf life

The term extended shelf life or ESL is being applied more and more frequently.

There is no single general definition of ESL. Basically what it means is the capability to extend the shelf life of a product beyond its traditional well-known and generally accepted shelf life without causing any significant degradation in product quality. A typical temperature/time combination for high-temperature pasteurisation of ESL milk is 125 to 130°C for 2 to 4 seconds. This is also known in the USA as ultra-pasteurisation.

SPX Flow Technology has in recent years developed a patented process where the temperature may be raised to as high as 135°C but only for fractions of a second. This is the basis for the Pure-Lac™ process described in a separate chapter, see table of contents.

UHT treatment

UHT - or Ultra High Temperature - treatment is based on the fact that higher temperatures permit a much shorter processing time. By proper time and temperature combination it is possible to achieve commercial sterility with only limited undesirable chemical changes in the product. In terms of nutritive value, flavour and appearance, the quality of the product is more vulnerable to the duration of the treatment than to the temperature applied.

In the UHT process, the milk is typically heated to 137 to 150°C and held at that temperature for just a few seconds before it is cooled rapidly down to room temperature (Fig. 2). After the product has been cooled it is led to an aseptic filling machine in a closed piping system - either directly or by way of an aseptic storage tank. The product obtained in this way has a shelf life at room temperature of several months.

The quality of the final product depends on the raw material quality but also to a large extent on the type of heat treatment system applied. This is the case for UHT milk and for a wide range of long life food products like sauces, salad dressings, mayonnaise and soups, as well as for juices and soft drinks.

In order to combat the Heat Resistant Spores (HRS) SPX Flow Technology has developed the patented so-called High Heat Infusion system enabling heat treatment temperatures as high as 150°C without adversely affecting the product quality and still maintaining acceptable running times in the order of 24 hours between cleaning.

Products with very high viscosity are more difficult to handle in a UHT system, and SPX Flow Technology has developed a special patented version of the infusion system to handle high viscosity products. This so-called Instant Infusion system is based on very short but controllable and well defined retention time in the infusion chamber.

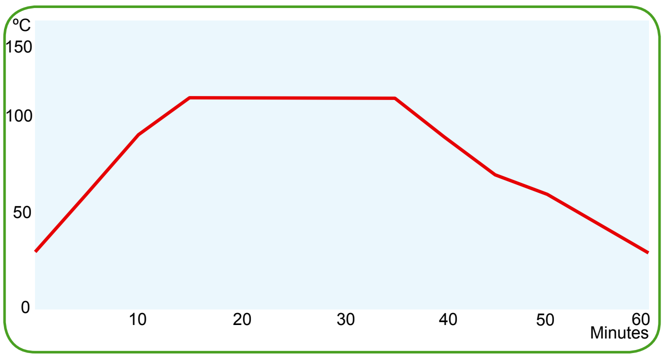

Fig. 3: Temperature profiles for conventional in-container sterilisation

MILK HYGIENE DIRECTIVE 92/46/EU				
Thermised	**Pasteurised**	**High temperature Pasteurised HTP**	**UHT**	**Sterilised**
63 - 65°C/15 sec.	71.7°C/15 sec. or equivalent		>135°C and >1 sec.	>135°C and > 1 sec.
PHOSPHATASE+	PHOSPHATASE- PEROXIDASE+	PHOSPHATASE- PEROXIDASE-	15 days at 30°C or 7 days at 55°C 0 ⇒ <10 cfu/0.1 ml	15 days at 30°C or 7 days at 55°C 0 ⇒ <10 cfu/0.1 ml
	**	**	**	**
	ß-LACTOGLOBULIN > 2600 (alt. 3000) mg/l &	ß-LACTOGLOBULIN > 2000 mg/l &	> 50 mg/l &	ß-LACTOGLOBULIN < 50 mg/l or
	LACTULOSE NOT DETECTABLE	LACTULOSE < 40 mg/kg	LACTULOSE < 600 mg/kg	LACTULOSE > 600 mg/kg

Table 2: Present legislation according to EU directive 92/46
** IDF & EU suggestions for Dual Chemical Criteria

Sterilisation

Sterilisation is another type of heating process used for products to increase keeping quality without refrigeration. The heat treatment takes place after the product is packed. The package with its content is heated to approx. 120°C and held at that temperature for 10 to 20 minutes after which it is cooled to room temperature (Fig 3). Because of the lengthy heat treatment at a relatively high temperature this process reduces the nutritive value of the product, and it is also liable to change its colour and flavour considerably.

EU classification

In the EU Milk Hygiene Directive (92/46) it is suggested that "limits and methods to enable a distinction to be made between different types of heat treated milk" may be established (Article 20).

The proposed parameters, limits and methods may be summarised as shown in Table 2.

By this method the hygienic requirements concerning food safety can be satisfied taking into consideration the keeping qualities over varying length of time. This method also makes it possible to establish a new definition of different types of fluid milk products in a way that is independent of the technology of the heat treatment and the filling such as for instance, Pure-Lac™.

It should be noted that the chemical criteria in Table 2 are the recommendation given by IDF and EU to the legislators, but the general perception is that this proposal will be followed.

Process evaluation

All UHT processes are designed to achieve commercial sterility. This calls for application of heat to the product and a chemical sterilant or other treatment that render the equipment, final packaging containers and product free of viable micro-organisms able to reproduce in food under normal conditions of storage and distribution. In addition it is necessary to inactivate toxins and enzymes present and to limit chemical and physical changes in the product. In very general terms it is useful to have in mind that an increase in temperature of 10°C increases the sterilising effect 10-fold whereas the chemical effect only increases approximately 3-fold. In this section we will define some of the more commonly used terms and how they can be used for process evaluation.

The logarithmic reduction of spores and sterilising efficiency

When micro-organisms and/or spores are exposed to heat treatment not all of them are killed at once.

However, in a given period of time a certain number is killed while the remainder survives. If the surviving micro-organisms are once more exposed to the temperature treatment for the same period of time an equal proportion of them will be killed. On this basis the lethal effect of sterilisation can be expressed mathematically as a logarithmic function:

$K \cdot t = \log N/N_t$,

where N = number of micro-organisms/spores originally present

N_t = number of micro-organisms/spores present after a given time of treatment (t)

K = constant

t = time of treatment

A logarithmic function can never reach zero, which means that sterility defined as the absence of living bacterial spores in an unlimited volume of product is impossible to achieve. Therefore the more workable concept of “sterilising effect” or “sterilising efficiency” is commonly used.

The sterilising effect is expressed as the number of decimal reductions achieved in a process. A sterilising effect of 9 indicates that out of 10^9 bacterial spores fed into the process only 1 (10^0) will survive.

Spores of Bacillus subtilis or Bacillus stearothermophilus are normally used as test organisms to determine the efficiency of UHT systems because they form fairly heat resistant spores.

Terms and expressions to characterise heat treatment processes

Q_{10} value. The sterilising effect of heat sterilisation increases rapidly with the increase in temperature as described above. This also applies to chemical reactions, which take place as a consequence of an increase in temperature. The Q_{10} value has been introduced as an expression of this increase in speed of reactions and specifies how many times the speed of a reaction increases when the temperature is raised by 10°C. Q_{10} for flavour changes is in the order of 2 to 3, which means that a temperature increase of 10°C doubles or triples the speed of the chemical reactions.

A Q_{10} value calculated for killing bacterial spores would range from 8 to 30 depending on the sensitivity of a particular strain to the heat treatment.

D-Value. This is also called the decimal reduction time and is defined as the time required to reduce the number of micro-organisms to one-tenth of the original value corresponding to a reduction of 90%.

Z-Value. This is defined as the temperature change which gives a 10-fold change in the D-value.

F_0 value. This is defined as the total integrated lethal effect and is expressed in terms of minutes at a selected reference temperature of 121.1°C. F_0 can be calculated as follows:

$F_0 = 10^{(T - 121.1)/z} \cdot t / 60$, where

T = processing temperature (°C)

z = Z-value (°C)

t = processing time (seconds)

$F_0 = 1$ after the product has been heated to 121.1°C for one minute. To obtain commercially sterile milk from good quality raw milk, for example, an F_0 value of minimum 5 to 6 is required.

B and C* Values*. In the case of milk treatment some countries are using the following terms:

- Bacteriological effect:
  B* (known as B star)

- Chemical effect
  C* (known as C star)

B* is based on the assumption that commercial sterility is achieved at 135°C for 10.1 seconds with a corresponding Z-value of 10.5°C; this reference process is giving a B* value of 1.0, representing a reduction of thermophilic spore count of 10^9 per unit (log 9 reduction).

The B* value for a process is calculated similarly to the F_0 value:

$B^* = 10^{(T - 135)/10.5} \cdot t / 10.1$,

where:

T = processing temperature (°C)

t = processing time (seconds)

The C* value is based on the conditions for a 3 percent destruction of thiamine (vitamin B_1); this is equivalent to 135°C for 30.5 seconds with a Z-value of 31.4°C. Consequently the C* value can be calculated as follows:

$C^* = 10^{(T - 135)/31.4} \cdot t / 30.5$

Fig. 4 shows that a UHT process is deemed to be satisfactory with regard to keeping quality and organoleptic quality of the product when B* is > 1 and C* is < 1.

The B* and C* calculations may be used for designing UHT plants for milk and other heat sensitive products. The B* and C* values also include the bacteriological and chemical effects of the heating up and cooling down times and are therefore important in designing a plant with minimum chemical change and maximum sterilising effect. The more severe the heat treatment is, the higher the C* value will be. For different UHT plants the C* value corresponding to a sterilising effect of B* = 1 will vary greatly. A C* value of below 1 is generally accepted for an average design UHT plant. Improved designs will have C* values significantly lower than 1.

The APV Steam Infusion Steriliser has a C* value of 0.15.

Residence time

Particular attention must be paid to the residence time in a holding cell or tube and the actual dimensioning will depend on several factors such as turbulent versus laminar flow, foaming, air content and steam bubbles. Since there is a tendency to operate at reduced residence time in order to minimise the chemical degradation (C* value < 1) it becomes increasingly important to know the exact residence time.

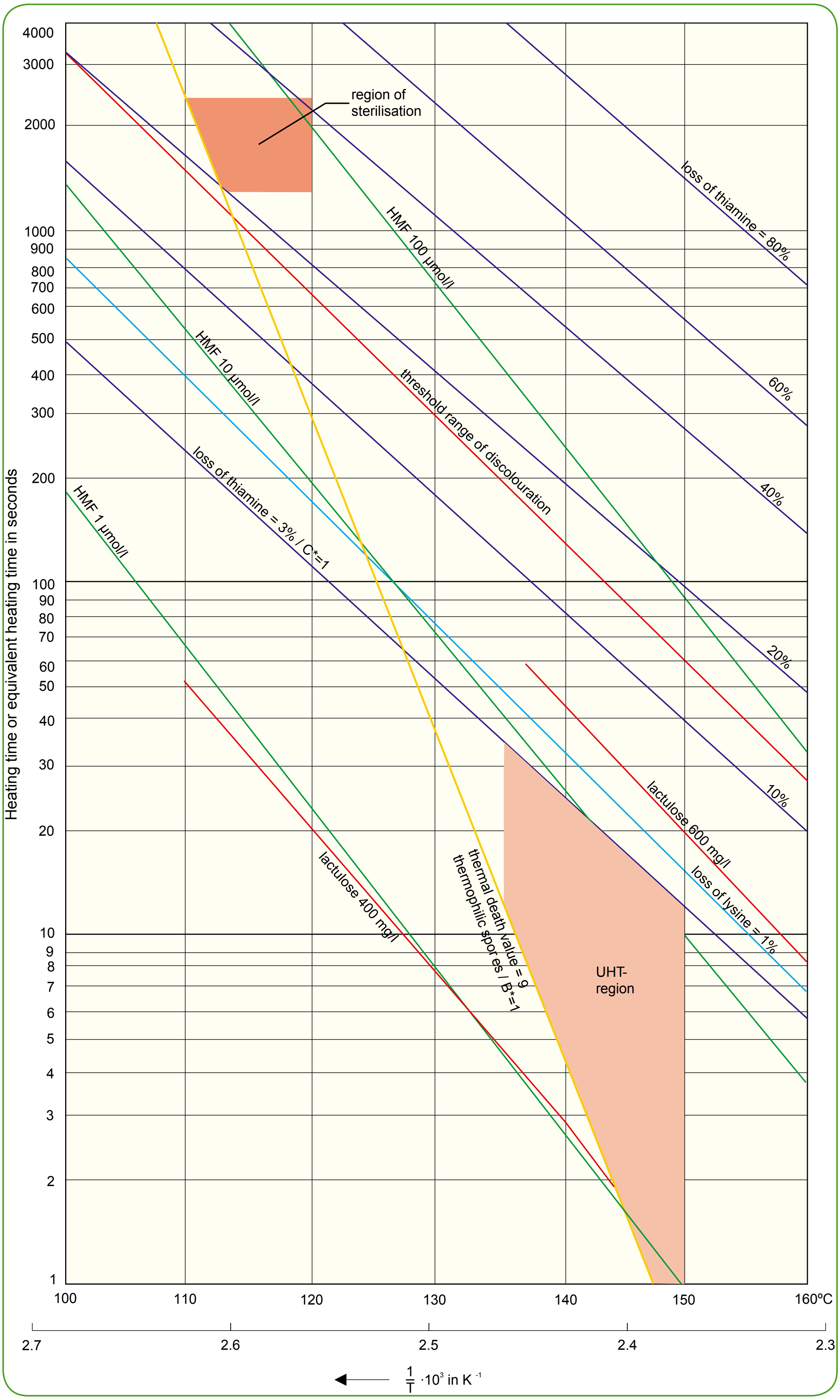

Fig. 4: Bacteriological and chemical changes of heated milk (H.G. Kessler)

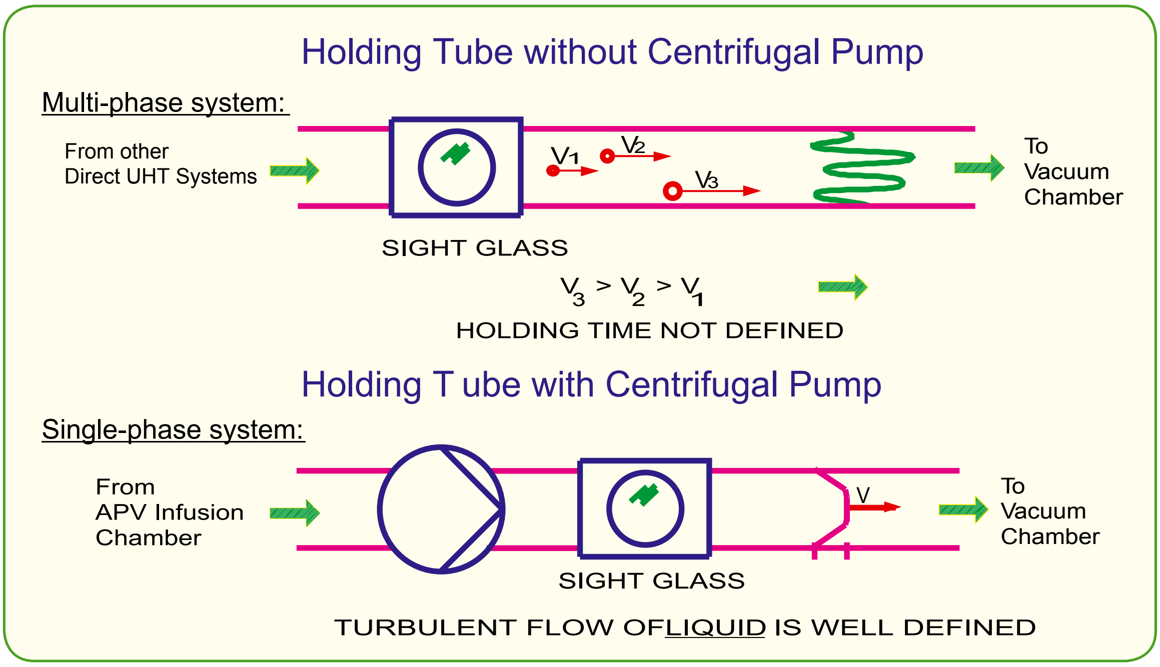

Fig. 5: Holding Tube

In SPX Flow Technology the infusion system has been designed with a special pump mounted directly below the infusion chamber, which ensures a sufficient over-pressure in the holding tube in order to have a single phase flow free from air and steam bubbles.

This principle enables SPX Flow Technology to define and monitor the holding time and temperature precisely and makes it the only direct steam heating system, which allows true validation of flow and temperature at the point of heat transfer.

The concept is illustrated in Fig. 5.

Commercial sterility

The expression of commercial sterility has been mentioned previously and it has been pointed out that complete sterility in its strictest sense is not possible. In working with UHT products commercial sterility is used as a more practical term, and a commercially sterile product is defined as one which is free from micro-organisms which grow under the prevailing conditions.

Chemical and bacteriological changes at high temperatures

Heating milk and other food products to high temperatures results in a range of complex chemical reactions causing changes in colour (browning), development of off-flavours and formation of sediments. These unwanted reactions are largely avoided through heat treatment at a higher temperature for a very short time, and it is important to seek the optimum time/temperature combination, which provides sufficient kill effect on spores but, at the same time, limits the heat damage, in order to comply with market requirements for the final product.

Even though the time/temperature combination is decisive for the final quality of the product attention also has to be paid to the actual heating profile since various reactions take place at different temperatures. This is illustrated in Fig. 6 in which type A deposit is a voluminous protein-rich deposit, whereas type B deposit is a mineral rich deposit developing primarily at high temperatures. In particular type A deposit, which originates from protein denaturation, must be minimised since it is harmful to the product quality.

Raw material quality

It is important that all raw materials are of very high quality as the quality of the final product will be directly affected. Raw materials must be free from dirt and have a very low bacteria spore count, and any powders must be easy to dissolve.

All powder products must be dissolved prior to UHT treatment because bacteria spores can survive in dry powder particles even at UHT temperatures. Undissolved powder particles will also damage homogenising valves causing sterility problems.

Heat stability. The question of heat stability is an important parameter in UHT processing.

Different products have different heat stabilities and although the UHT plant will be chosen on this basis it is desirable to be able to measure the heat stability of the products to be UHT treated.

For most products this is possible by applying the alcohol test. When samples of milk are mixed with equal volumes of an ethyl alcohol solution the proteins become unstable and the milk flocculates.

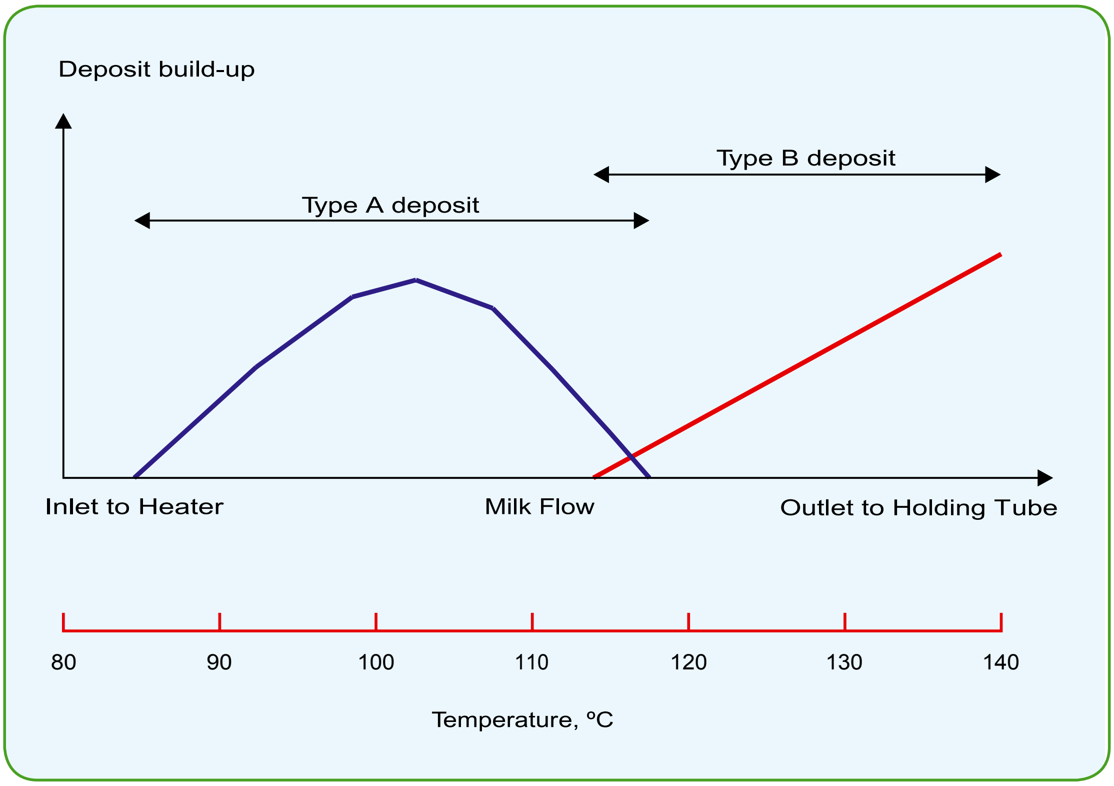

Fig. 6: Deposits in UHT plants.

The higher the concentration of ethyl alcohol is without flocculation the better the heat stability of the milk. Production and shelf life problems are usually avoided provided the milk remains stable at an alcohol concentration of 75%.

High heat stability is important because of the need to produce stable homogeneous products, but also to prevent operational problems like fouling in the UHT plant. This will decrease running hours between CIP cleanings and thereby increase product waste, water, chemical and energy consumption.

Generally it will also disrupt smooth operation and increase the risk of insterility.

Shelf life

The shelf life of a product is generally defined as the time for which the product can be stored without the quality falling below a certain minimum acceptable level. This is not a very sharp and exact definition and it depends to a large extent on the perception of "minimum acceptable quality". Having defined this it will be raw material quality, processing and packaging conditions and conditions during distribution and storage, which will determine the shelf life of the product.

Milk is a good example of how wide a span the concept of shelf life covers:

Product	**Shelf life**	**Storage**
Pasteurised milk	5 to 10 days	refrigerated
ESL/Pure-Lac™	20 to 45 days	refrigerated
UHT milk	3 to 6 months	ambient temp.

The usual organoleptic factors limiting shelf life are deteriorated taste, smell and colour, while the physical and chemical limiting factors are incipient gelling, increase in viscosity, sedimentation and cream lining.

Choosing the right process

In order to be able to produce a product with specific product qualities in the most cost-effective way it is essential to make the correct choice with respect to processing system and technology.

In many cases the choice is straightforward, but in other cases there may be more options to choose between. Some of the more important questions to ask when choosing a system are:

- What is the specification of the product to be processed?
- Which are the quality requirements to the final product?
- Viscosity specifications of products and raw materials?
- Specification of particulate and fibre content/size and shape and variation in content?

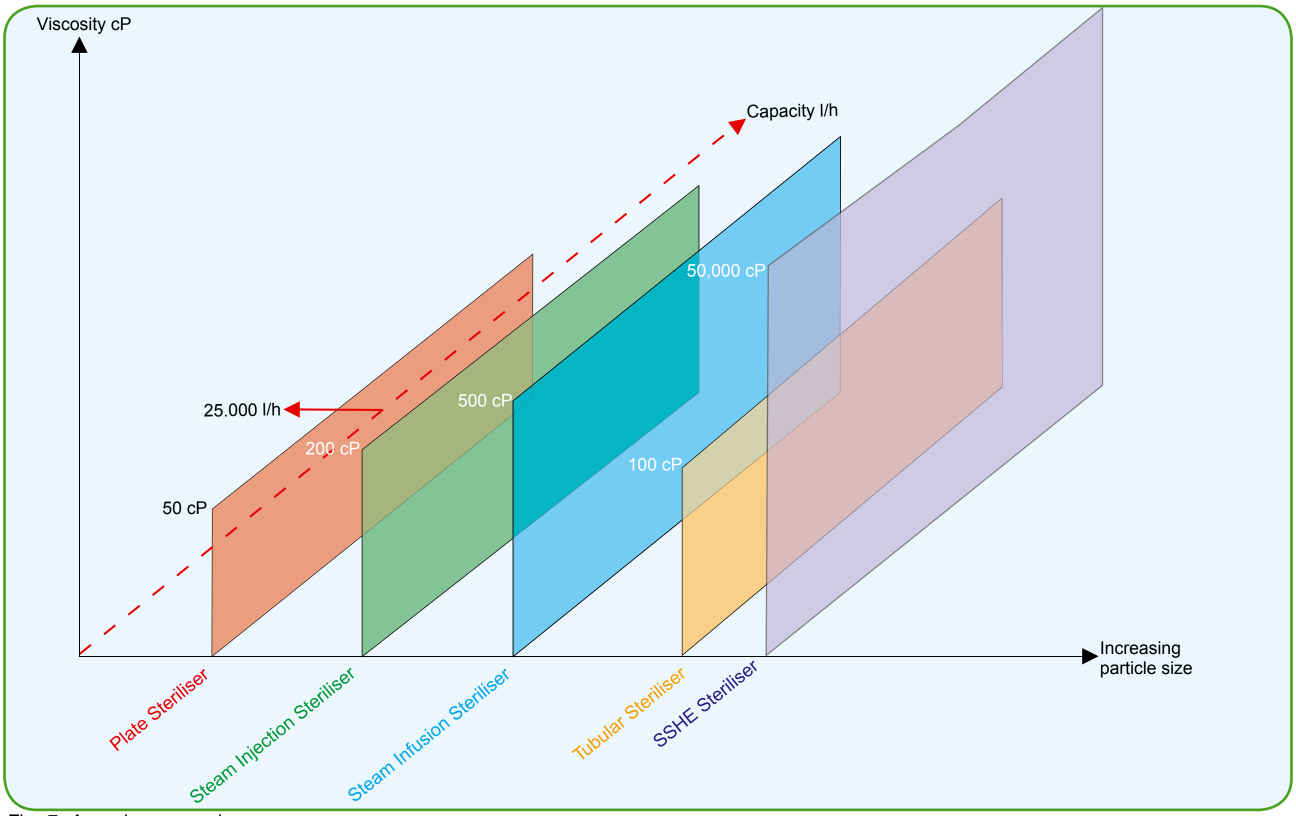

Fig. 7: Aseptic processing systems

- Acidity of product/high or low acid?
- Sensitivity to high temperatures/heat stability?
- Requirement for flexibility/multi-purpose systems?
- Requirement for variable capacity?
- Requirement for direct or indirect systems?
- Skills of technical personnel/operators?

Fig. 7 illustrates three of the selection criteria - viscosity, capacity and content of particulates - for the most common processing systems.

The systems are often flexibly designed to allow for processing a range of products in the same plant.

It is quite common to process both low-acid (pH>4.5) and high-acid (pH<4.5) products in the same UHT plant.

However, only low-acid products require UHT treatment to make them commercially sterile.

Spores cannot develop in high-acid products such as juice, and the heat treatment is therefore only intended to kill yeast and moulds.

Consequently high temperature pasteurisation at 90 - 95°C for 15 to 30 seconds is sufficient to make most high-acid products commercially sterile.

In some cases where new products have to be processed it may be necessary to carry out trials in small scale to observe the performance of specific products in different types of systems. SPX Flow Technology has designed a pilot unit for this purpose.

The trend for processors to focus increasingly on flexibility to process a range of products and the importance of being able to produce high quality products has driven the choice of systems towards indirect tubular systems and direct steam infusion systems.

The following sections will deal with the various heating principles and UHT systems followed by a more detailed comparison of the individual systems.

The heat treatment processes

SPX Flow Technology invented the plate heat exchanger in 1923 and has ever since pioneered new heat treatment principles. Scraped surface heat exchangers were developed in the USA while the direct steam infusion system was developed in Denmark. The tubular systems were developed partly in Denmark and partly in Germany and later supplemented by the corrugated tubular heat exchangers in Spain. In addition SPX Flow Technology is known for electroheat thermal processing equipment, which is dealt with in a separate publication.