SUMMARY

Long-life milk

Heat treatment in the production of long-life products is often called “sterilisation”. This means that the product is exposed to such powerful heat treatment that all relevant micro-organisms and most of the heat resistant enzymes are inactivated. Such products have excellent keeping qualities and can be stored for long periods of time at ambient temperatures. Many dairies can therefore distribute these products over long distances and thereby find new markets.
There are many advantages for the producer, retailer and consumer if a product does not require refrigeration and can be stored for long periods without spoiling. The producer can, for example, reach geographically wider markets, simplify production planning by reducing product changes and losses, make deliveries easier by using fewer and cheaper distribution vehicles, and eliminate return of unsold products. Handling becomes easier for the retailer, as expensive refrigerated display space is not necessary and stock planning is simplified.
Finally, the consumer gains in convenience as he can make fewer trips to the shops, there will be less congestion in the home refrigerator and he will have emergency reserves available. This includes expensive products such as cream, desserts and sauces, but also pet milks.

Raw material quality

Milk exposed to high heat treatment must be of *very good quality*. It is particularly important that the proteins in the raw milk do not cause thermal instability. The heat stability of the proteins can be quickly determined by an *alcohol test*. When samples of the milk are mixed with equal volumes of an ethyl alcohol solution, the proteins may become unstable and the milk flocculates. The higher the concentration of ethyl alcohol solution that can be added without getting flocculation, the better the heat stability of the milk. Production and shelf life problems can usually be avoided if the milk remains stable (does not precipitate) even after addition of alcohol solutions with a 75 % alcohol concentration.
The alcohol test is typically used to reject all milk that is unsuitable for UHT treatment because it:

- Is sour, due to a high bacterial count of acid-producing micro-organisms
- Has the wrong salt balance
- Contains a high level of serum proteins – typical of colostrum

Raw milk of bad quality has an adverse effect on both processability and final product quality. Sour milk has poor thermal stability and causes not only processing problems, *e.g.* burning-on on the heating surfaces resulting in short running times, but also difficulties with cleaning, as well as sedimentation of proteins at the bottom of the packages during storage.

Milk stored for a long time at low temperature may contain high numbers of *psychrotrophic bacteria*, which can produce *heat-resistant enzymes* that are difficult to completely inactivate by heat treatment. During storage they can cause organoleptic changes such as rancidity, bitterness or even gelation (age-thickening or sweet curdling).

The bacteriological quality of the milk must be high. This applies not only to the total bacterial count, but also, and more importantly, to the count of spore-forming bacteria that influence the rate of insterility.

Nutritional aspects

When studying any type of food process, it is important to consider the nutritional aspects. Extensive research has been carried out on the effect of heat treatment on milk.

The heat effect of UHT treatment on the constituents of milk can be summarised as follows:
Certain conclusions regarding changes in nutritional value can be drawn from these chemical changes. There are no changes in the nutritional value of fat, lactose and mineral salts, but there are marginal changes in the nutritional value of proteins and vitamins.
The major protein in milk, casein, is not affected by heat treatment.
Denaturation of whey proteins does not mean that the nutritional value (in terms of biological value, digestibility and availability of lysine) is lower in UHT milk than in raw milk. Although sterilised milk has a lower biological value (0,85), the nutritional value reported for UHT milk (0,90) does not differ significantly from that of raw milk (0,91).

Constituents	heat effects
Fat	No changes
Lactose	Marginal changes
Proteins	Partial denaturation of whey proteins
Mineral salts	Partial precipitation
Vitamins	Marginal losses

The small loss of the essential amino-acid lysine causes the marginal changes. However, it has been shown that about 0.4 – 0.8 % of the lysine is lost, and this figure is the same for pasteurised milk. The corresponding value for in-container sterilised milk is 6–10 %. Some of the vitamins in milk are considered to be more or less thermostable in regard to pasteurisation or UHT treatment. Among these are the fat-soluble vitamins A, D and E and some of the water-soluble group B vitamins. However, degradation of vitamin A can be much higher if the product is fortified. Other vitamins are less stable in response to heat, *e.g.* B9 (folic acid) and B12 (cobulamin). Thiamine losses are less than 3 % in UHT-treated milk, but considerably higher in in-container sterilised milk (approximately 20 – 50 %).

The same relationship regarding destruction of vitamins can be found in all other heat-sensitive vitamins in UHT and in-container sterilised milk, for example B6, B12, folic acid and vitamin C. Losses of vitamin B2 and vitamin C in in-container sterilised milk may be as high as 100 %.

Some of the vitamins, *e.g.* folic acid and vitamin C, are oxidation-sensitive, and their losses occur mainly during storage due to a high oxygen content in the milk or in the package. However, milk is not a good source of vitamin C and folic acid, as the content is far below the recommended daily intake. Generally speaking, losses of vitamins are considerably higher when food is prepared in the home than in UHT treatment and pasteurisation of milk. The general conclusion should therefore be that UHT milk and pasteurised milk are of about the same quality, while in-container sterilised milk is of inferior quality in terms of nutritional value.

MilkOpet® small animal nutritionist has developed our formula of added vitamin, mineral protein and “good oils” to provide a well balanced nutritional supplement for your dog. Ingredient levels consider any natural reduction, influenced by the UHT process.

Production of long-life milk

Two methods are used for the production of long-life milk for ambient storage:
A In-container sterilisation
B Ultra High Temperature (UHT) treatment followed by aseptic packaging in packages protecting the product against light and atmospheric oxygen which is the method used for MilkOpet® milk.

UHT treatment

In a modern UHT plant, the milk is pumped through a closed system. On the way it is pre-heated, high-heat treated, homogenised, cooled and packed aseptically. Low-acid liquid products (pH above 4.5 – for milk more than pH 6.5) are usually treated at 135 – 150 °C (275°F-302°F) for a few seconds, by either indirect heating, direct steam injection or infusion. High-acid products (pH below 4.5) such as juice are normally heated at 90 – 95 °C (194°F-203°F) for 15 – 30 seconds. All parts of the system downstream of the actual high temperature heating section are of aseptic design to eliminate the risk of reinfection.

Compared to traditional sterilisation in hydrostatic towers, UHT treatment of milk saves time, labour, energy and space. UHT is a high-speed process and has much less effect on the colour and flavour of the milk. However, regular consumers of autoclave-sterilised milk are accustomed to its “cooked” or caramel flavour and may find the UHT-treated product “tasteless”.

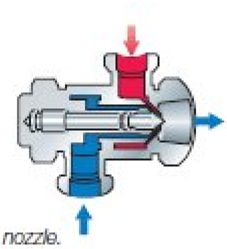

Fig. 9.10
Steam injection nozzle.

The UHT processes

UHT is a technique for preserving liquid food products by exposing them to brief, intensive heating. This treatment destroys the micro-organisms in the product. This applies only as long as the product remains under aseptic conditions, so it is necessary to prevent re-infection by packaging the product in previously sterilised packaging materials under aseptic conditions after heat treatment. Any intermediate storage between treatment and packaging must take place under aseptic conditions. This is why UHT processing is also called *aseptic processing*.

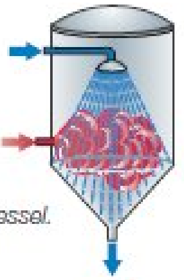

Fig. 9.11 Steam infusion vessel.

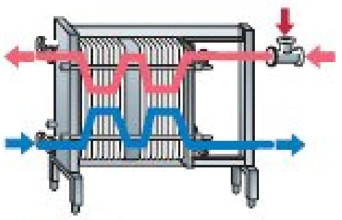

Fig. 9.12 Plate heat exchanger for heating and cooling.

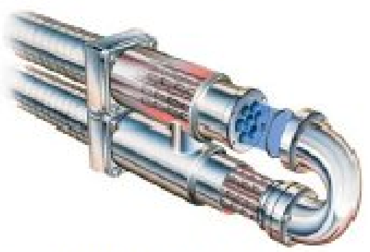

Fig. 9.13 Tubular heat exchanger for heating and cooling.

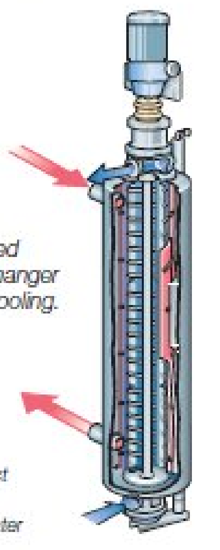

Fig. 9.14 Scraped surface heat exchanger for heating and cooling.

Development of UHT

Experiments on sterilisation of milk in bottles had been carried out by Louis Pasteur, but it was not until around 1960, when both aseptic processing and aseptic filling technologies became commercially available, as the modern development of UHT processing started. UHT-treated milk and other UHT-treated liquid food products are now accepted worldwide, but it has not always been like that.

The first UHT plants operated on the principle of *direct steam injection*. Compared with the in-container sterilisation plants, the new UHT plants soon gained a reputation for producing an excellent flavour. The first *indirect plants* were introduced on the market some ten years later.

Research and development have been intense since UHT was first introduced. Modern plants deliver a superior product with the colour and nutritional values practically unchanged.

UHT plants

UHT treatment is a continuous process, and its application is therefore
limited to products that can be pumped. UHT treatment can be applied to a wide range of dairy and food products. The list shown is not exhaustive. Many other liquid food products are likely to be of great interest to dairies in the future.

UHT plants are often flexibly designed to enable processing of a wide range of products in the same plant. Both low-acid products (pH > 4.5) and high-acid products (pH < 4.5) can be treated in a 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 heat treatment is therefore intended only to kill yeast and moulds. Normal high temperature pasteurisation (90 – 95°C for 15 – 30 seconds))194°F -203°F) is sufficient to make high-acid products commercially sterile.

UHT plants are fully automatic and have four operating modes: *plant presterilisation, production, AIC* (Aseptic Intermediate Cleaning) and *CIP* (Cleaning In Place).

Safety aspects must be a prime consideration in the design of a UHT plant. The risk of supplying an unsterilised product to the aseptic filling machine must be eliminated. Interlocks in the control programming must provide security against operator errors and tampering with the process. It should, for example, be impossible to start production if the plant is not properly pre-sterilised.

All sequences involved in starting, running and cleaning the plant are initiated from a control panel, which contains all the necessary equipment for control, monitoring and recording of the process.

Various UHT Systems

There are two main types of UHT systems on the market.

In the direct systems the product comes in direct contact with the heating medium, followed by flash cooling in a vacuum vessel and eventually further indirect cooling to packaging temperature.

The direct systems are divided into:

- Steam injection systems (steam injected into product), Figure 9.10
- Steam infusion systems (product introduced into a steam-filled vessel), Figure 9.11

It is also possible to combine direct heating and indirect cooling without subsequent flash cooling.

In the indirect systems the heat is transferred from the heating media to the product through a partition (plate or tubular wall). The indirect systems can be based on:

• Plate heat exchangers, Figure 9.12
• Tubular heat exchangers, Figure 9.13
• Scraped surface heat exchangers, Figure 9.14

Furthermore, it is possible to combine the heat exchangers in the indirect systems according to product and process requirements.

General UHT operating phases

These operating phases are common to all UHT systems and are therefore not described under each system.

Pre-sterilisation

Before start of production the plant must be pre-sterilised in order to avoid re-infection of the treated product. The pre-sterilisation involves:

• Hot water sterilisation at the same temperature as the product shall undergo. Minimum time for the hot water sterilisation is 30 minutes from the moment the relevant temperature has been reached in the whole aseptic part of the plant.

• Cooling the plant to conditions required for production.

Production

The production phases vary according to the different processes and are described below.

Aseptic intermediate cleaning

The full CIP cycle takes 70 to 90 minutes and is normally carried out immediately after production. Aseptic Intermediate Cleaning (AIC) is a useful tool in cases where a plant is used for very long production runs. A 30 minute AIC can be carried out whenever it is necessary to remove fouling in the production line without losing aseptic conditions. The plant does not have to be resterilised after AIC. This method saves downtime and permits longer production runs.

CIP

The CIP cycle for direct or indirect UHT plants may comprise sequences for pre-rinsing, caustic cleaning, hot-water rinsing, acid cleaning and final rinsing, all automatically controlled according to a pre-set time/temperature program. The CIP program must be optimised for different operating conditions in different plants.

Indirect UHT plants

In many cases, products must not only be attractive and healthy to eat and drink, but also economical to manufacture, store and distribute. The most cost-effective method of UHT processing is indirect heating – a heating method in which the processed product never comes into direct contact with the heating medium. There is always a wall in between. This technique applies to all types of heat exchangers.

Indirect UHT plants, like that used to produce MilkOpet®, are a suitable choice for processing of milk, flavoured milk products, cream, dairy desserts, yogurt drinks and other non-dairy applications, such as juices, nectars and tea.

Indirect UHT plant based on plate heat exchangers

UHT plants of the indirect heating type are built for capacities up to 30 000 l/h (7,925 gallons). A typical flowchart is shown in Figure 9.18.

The product at about 4 °C (37°F) is pumped from the storage tank to the balance tank (1) of the UHT plant and from there by the feed pump (2) to the regenerative section of the plate heat exchanger (3). In this section the product is heated to about 75 °C (167°F) by UHT-treated product, which is cooled at the same time. The pre-heated product is then homogenised (4) at a pressure of 18 – 25 MPa (180 – 250 bar). Homogenisation before UHT treatment is possible in indirect UHT plants, which means that non-aseptic homogenisers can be used. However, an aseptic downstream homogeniser might improve the texture and physical stability of certain products that have a high content of protein, dry matter or fat.

Double homogenisation, using one homogeniser upstream and one downstream, can be used to obtain premium quality and long shelf life stability for some products. This process solution is appropriate for products such as coffee cream and evaporated concentrated milk.

The pre-heated, homogenised product continues to the heating section of the plate heat exchanger, where it is heated to about 137 °C. Heating is performed by hot water in a closed water circuit. After heating, the product passes through the holding tube (5), dimensioned for about 4

seconds.
Finally, cooling is performed regeneratively in two sequences: first against the cold end of the hot water circuit, and then against the cold incoming product. The product that leaves the regenerative cooler continues directly to aseptic packaging or to an aseptic tank for intermediate storage.
If the temperature drops during production, the product is diverted into a reject tank and the plant is flushed by water. The plant must be cleaned and sterilised before restart.

Split heating

In many cases, indirect UHT plants are designed for a variable capacity between 50 and 100 % of the nominal and are directly connected to a line one of the packaging machines stops, the heating section can be divided and split into subsections.
The split heating system is illustrated in Figure 9.19. In the event of a sudden 50 % reduction of the flow compared with nominal, a valve (C) is activated so that the heating medium by-passes outside the first heating section (A). The temperature of the product will thus be kept at the preheating temperature (75 °C) (167°F) until the product reaches the second (final) heating section (B) where heating to the relevant UHT temperature takes place.
The time/temperature curves in Figure 9.20 show the difference in the heat load on the product at nominal and half capacity. The dotted line on the graph represents the temperature development in a system without split heating facilities running at 50% of nominal capacity.

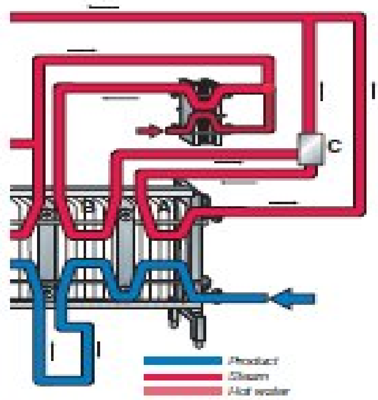

Fig 9.19 Split Heating system in a plate heat exchanger.

A First heating section
B Final heating section
C Change-over valve

1 Balance tank
2 Feed pump
3 Plate heat exchanger
4 Non-aseptic homogeniser
5 Holding tube
6 Aseptic tank
7 Aseptic filling
8 CIP

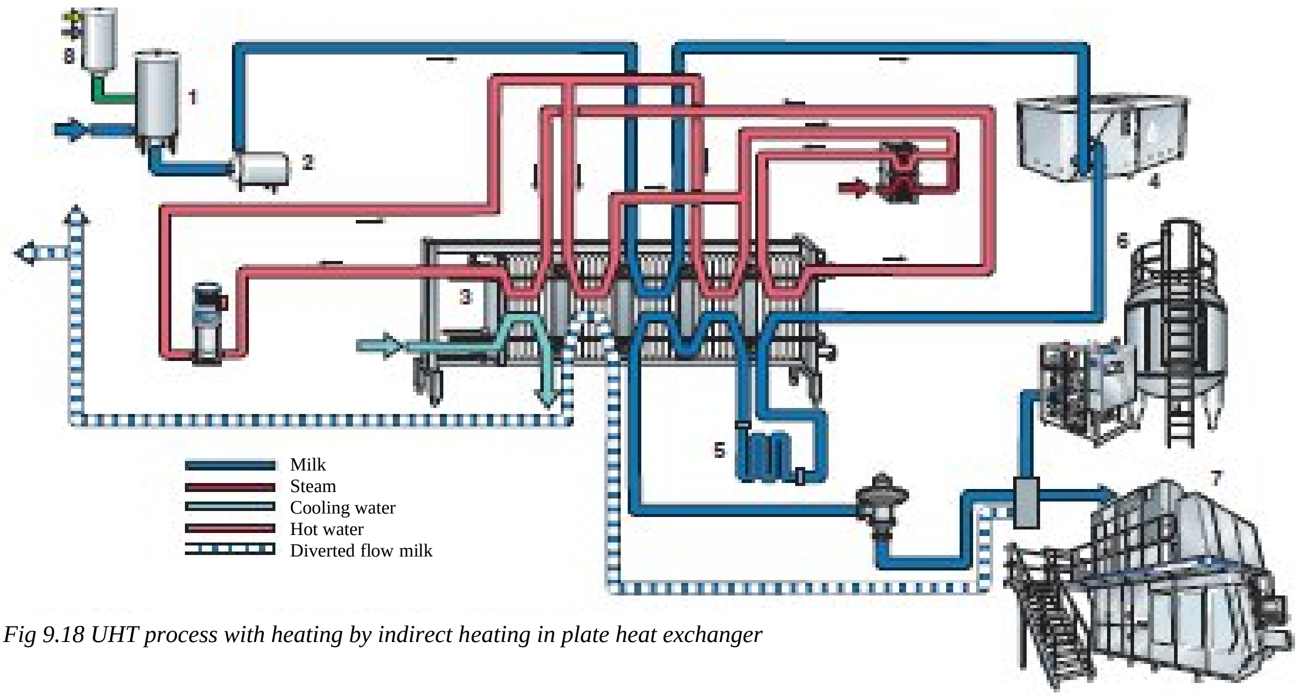

Fig 9.18 UHT process with heating by indirect heating in plate heat exchanger

Indirect UHT plant based on tubular heat exchangers

A tubular system is chosen for UHT treatment of products with low or medium viscosity that may or may not contain particles or fibres. The term medium viscosity is a diffuse concept, as the viscosity of a product can vary depending on raw material, additives and mechanical treatment.
Soups, tomato products, fruit and vegetable products, certain puddings and desserts are examples of medium -viscosity products well suited to treatment in a tubular concept. Tubular systems are also frequently utilised when longer processing times are required for ordinary market milk products.
The running time of indirect systems can be prolonged even further by installation of a stabilising holding tube, which stabilises milk proteins and thus minimises fouling in the heat exchangers and the ordinary holding tube.

The processing principle, does not differ very much from the UHT plant with plate heat exchanger described above.
Plants with capacities from 1 000 up to 30 000 l/h (7,925 gallons) can be built.
The tubular heat exchanger comprises of a number of tubes assembled into modules that can be connected in series and/or in parallel to offer a complete optimised system for any heating or cooling duty. This system can also be provided with a split heating arrangement.
If the temperature drops during production, the product is diverted into a reject tank and the plant is flushed by water. The plant must be cleaned and sterilised before restart.

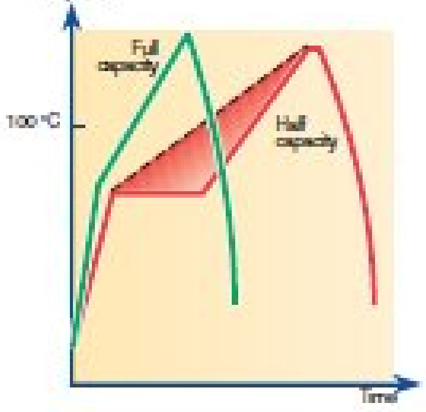

Fig. 9.20 Effect on heat load with split heater. The broken line represents the temperature development in a system without split heating facilities.
Note: Operating at 50% of the nominal capacity, the holding time will be doubled in order to compensate that the UHT temperature is lowered.

Aseptic storage

The aseptic tank, in Figure 9.23, is used for intermediate storage of UHT treated dairy products. Product flow and service media connections are placed in its valve and control module. An aseptic tank can be used in many ways in UHT lines, depending on plant design and the capacities of the various units in the process and packaging lines. Two examples are shown in Figures 9.24 and 9.25.
• If one of the packaging machines unexpectedly stops, the aseptic tank takes care of the surplus product during the stoppage.
• Simultaneous packaging of two products. The aseptic tank is first filled with one product, sufficient to last for a full shift of packaging. Then the UHT plant is switched over to another product, which is packed directly in the line of packaging machines.
One or more aseptic tanks included in the production line thus offer flexibility in production planning.
Direct packaging from a UHT plant requires recirculation of a minimum extra volume of 300 litres per hour to maintain a constant pressure to the filling machines. Products that are sensitive to reprocessing cannot tolerate this and the required overcapacity must then be fed from an aseptic tank. One of the major advantages of an aseptic tank is that the product is only processed once, and in optimal conditions. This will always secure consistent, and best, product quality.
The optimum arrangement of UHT plants, aseptic tanks and aseptic packaging machines must thus be decided for each individual process.

Aseptic packaging

Aseptic packaging has been defined as a procedure consisting of sterilisation of the packaging material or container, filling with a commercially sterile product in an aseptic environment, and producing containers that are tight enough to prevent recontamination, *i.e.* that are hermetically sealed.
For products with a long non-refrigerated shelf life, the package must also give almost complete protection against light and atmospheric oxygen.
A milk carton for long-life milk must therefore be of high-quality carton board sandwiched between layers of polyethylene plastic.
The term “aseptic” implies the absence or exclusion of any unwanted organisms from the product, package or other specific areas. “Hermetic” is a term used to

indicate suitable mechanical properties to exclude the entry of bacteria into the package or, more strictly, to prevent the passage of micro-organisms and gas or vapour into or from the container.

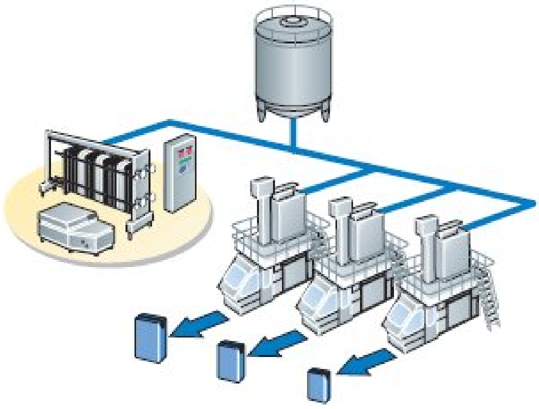

Fig 9.24 *Aseptic tank used as a buffer for packaging of one product.*

Fig. 9.23 Aseptic tank with valve and control module.

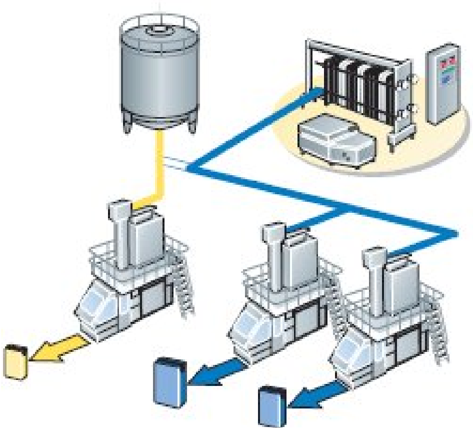

Fig 9.25 *Aseptic tank used as an intermediate storage tank for one product while a second is processed and packed*

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