CONFERENCE CONTRIBUTION

Extended shelf life milk—advances in technology

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This paper describes trends and technological advances in the dairy industry for extended shelf life milk. Demands for longer shelf life and wider distribution of milk and milk products have resulted in the development of processes and packaging concepts to increase the shelf life of these products in cold chain distribution. Factors important for the shelf life of milk are described in detail, and changes necessary from normal pasteurized production are suggested. Various processing methods such as microfiltration, injection and infusion heat treatments are described, and advantages and disadvantages of the different methods explained. In addition, the contamination sources from process to package are discussed, and the prevention of such recontamination in the filling machine is proposed. The paper describes existing and novel methods for sterilization of packaging material in the filling machine and points to possible future developments in this important market segment in the dairy industry.

Keywords ESL milk, Infusion, Microfiltration, Recontamination, Sterilization.

INTRODUCTION

Although extended shelf life (ESL) milk is not a very well-defined milk segment, this product has been processed and marketed for years in the international dairy industry. The relatively short shelf life of pasteurized milk has resulted in development of UHT milk for ambient distribution, which has gained widespread acceptance and popularity in many countries. In other areas, however, UHT milk has not been accepted by consumers because of the perceived 'cooked' taste of the product. Consequently, the need for extending the shelf life of pasteurized milk, without the negative flavour change normally associated with UHT has resulted in development of a milk product with taste similar to pasteurized milk, but with some of the obvious benefits of the longer keeping ability of the product.

Centralization of the dairy industry, increased competition among dairy companies and less frequent shopping cycles have reinforced the requirement to increase the keeping ability of pasteurized liquid milk. Because of frequent breaks in the cold chain distribution, the milk should have a built-in quality buffer to prevent spoilage at elevated temperatures.

Extended shelf life dairy products have been available in North America since the early 1960s (Henyon 1999). Dairies in the USA and Canada started limited use of this technology at this time, mainly for slow turnover products, such as whipping cream and coffee creamers. Traditional ESL technology in North America incorporates a high heat treatment of the product, which provides normal pasteurized product sensory characteristics, combined with ultraclean packaging, which includes a controlled filling environment and container sterilization.

Generally, one could define ESL milk as a product with a shelf life longer than pasteurized milk, as there currently is no legal definition for this technology. Hence, pasteurized milk packed under hygienic conditions, which might lead to increase of shelf life of a couple of days, could according to this description be characterized as ESL milk.

As no true definition exists, ESL milk may be defined based on the particular market need and system capability for various regions around the world. In this paper, the definition below will be used for ESL milk.

ESL products are products that have been treated in a manner to reduce the microbial count beyond normal pasteurization, packaged under extreme hygienic conditions, and which have a defined prolonged shelf life under refrigerated conditions.

It also follows from this definition that the process is different from that for pasteurized milk, and that ESL milk products are always a combination of processing and packaging, which will be discussed more in detail in the next sections.

MILK LEGISLATION

Milk can be processed by various methods, resulting in a product with different microbiological status and keeping ability. Legislation for the treatment and distribution of milk and milk products varies in different parts of the world. In the USA, consumption milk is categorized in the groups: pasteurized,

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ultrapasteurized and aseptic. The European legislation, however, is covered by EU legislation. According to EU (EC Milk Hygiene Directive 92/46/EEC):

Pasteurized milk

This milk must have been obtained by means of a heat treatment involving a high temperature for a short time (at least 71.7°C for 15 s, or any equivalent combination) and must show a negative reaction to the phosphatase test and a positive reaction to the peroxidase test. However, the production of pasteurized milk that shows a negative reaction to the peroxidase test is authorized, provided that the milk is labelled 'high temperature pasteurized milk'. Immediately after pasteurization, milk must be cooled to 6°C or below.

UHT-milk must:

- have been obtained by applying to the raw milk a continuous flow of heat entailing the application of a high temperature for a short time (not less than 135°C for no less than 1 s)—the aim being to destroy all residual spoilage micro-organisms and their spores—using aseptic opaque containers, or containers made opaque by packaging, but so that chemical, physical and organoleptic changes are minimal.
- be of preservability such that no deterioration can be observed by means of random sampling checks after it has spent 15 days in a closed container at a temperature of 30°C; where necessary, provision can also be made for a period of 7 days in a closed container at a temperature of 55°C.

Note that high-temperature pasteurized milk covers a large processing window in terms of temperature and holding times. In addition, the type of heat treatment (indirect vs direct, injection vs infusion) will play an important role for the shelf life and sensory quality of the product.

The shelf life of pasteurized milk varies greatly in different countries and regions. Pasteurized milk has a shelf life from only a couple of days in some countries to over 20 days in the USA. The reason for the variation is both local legislation, and technological factors such as raw milk quality, processing methods, hygiene in filling, and last but not least, the quality of the cold chain. The very long shelf life of standard pasteurized milk in the USA can largely be attributed to a very good cold chain.

MARKET TRENDS—THE FUTURE OF ESL MILK

A key trend in the global market for dairy products during recent years has been the widening range of products available to consumers, both in developed and less-developed markets. Cheaper production and storage technology, combined with higher levels of disposable income, has resulted in the development and distribution of premium products such as probiotic yogurts, more exotic milk drinks and soy milk products.

Pasteurized vs UHT milk in Europe

Liquid milk market in Europe is normally categorized as either fresh/pasteurized distributed in a cold chain, or UHT that is distributed in ambient temperature. The split between these two milk categories differs greatly in various countries, as shown in the next figure (Figure 1).

The situation is also very dynamic, and changes between the two categories have been observed in many countries, mostly represented by growth of UHT milk. This transfer is mainly driven by the large retail chains and convenience in storage and distribution.

We think that ESL milk will play an important role in these dynamics in years to come. With ESL milk technology, the obvious drawbacks of short shelf life pasteurized milk can be compensated for by increasing shelf life from 5–10 days to several weeks, and at the same time keeping the fresh taste and quality profile similar to pasteurized milk.

ESL MILK PRODUCTS—THE NEED FOR A TOTAL SYSTEM APPROACH

The following sections of this presentation will focus on the available processing and packaging methods for ESL milks. There will be several different systems and suppliers of both processing and packaging, and selecting the total system is obviously a balance between performance, success criteria, and price and running costs. We recommend going through the following analysis when a new ESL product line is considered:

- set target for shelf life;
- analyse raw milk quality;
- focus on psychrotrophic spores;
- evaluate product range (white, flavoured, physical structure, etc.);
- verify distribution conditions;
  (i) quality of cold chain;
  (ii) distribution method (wrap-around, roll-containers, crates, etc.); and
  (iii) distribution channel.

Based on this analysis, the dairy would select processing method, filling machine and packaging material.

The shelf life of pasteurized milk can in some areas be extended by introducing more hygienic transfer from process to filling machines, and by improving the hygiene of the filling itself. However, the thermoduric bacteria surviving pasteurization will reduce the potential shelf life, especially when the temperature of distribution is increased. A general rule of thumb is that for every 2°C increase

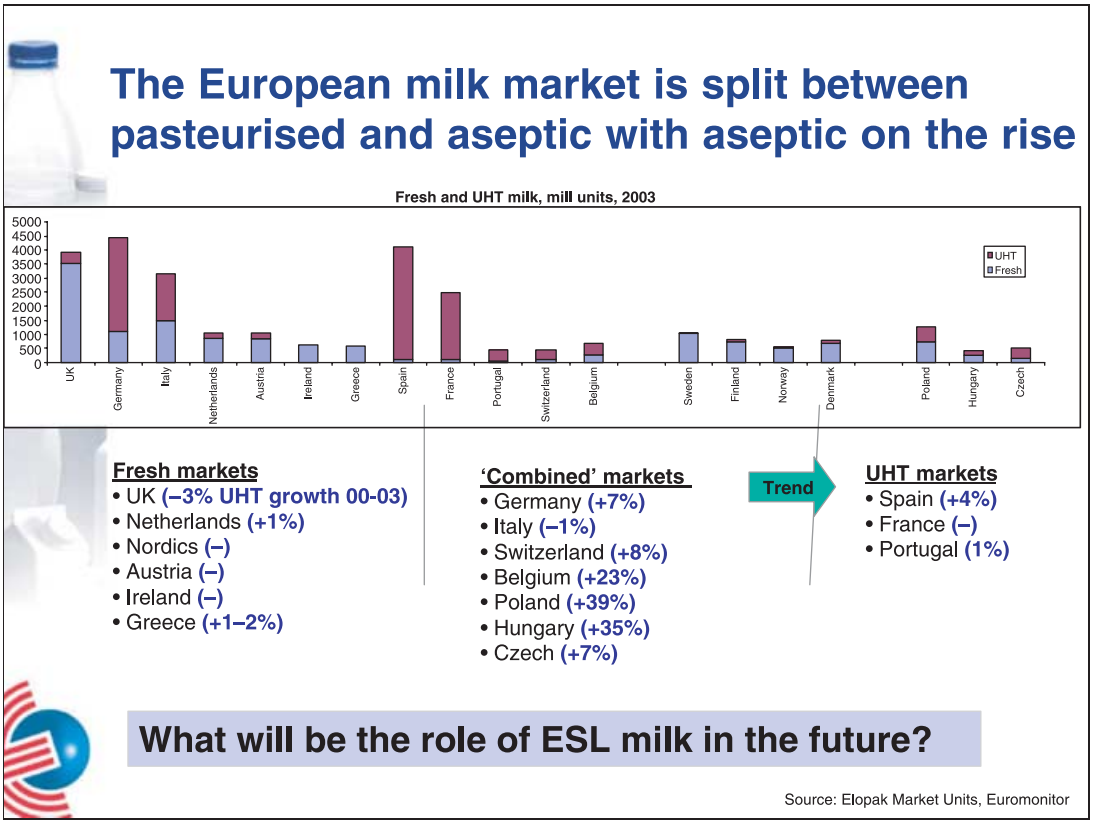


Figure 1 The market for pasteurized and UHT milk in selected European countries. The numbers in brackets represent growth in percentage of UHT milk from 2000–2003 according to Euromonitor.

of storage temperature, the shelf life of pasteurized milk is reduced by 50%.

We have performed a test filling standard pasteurized milk without recontamination (aseptic transfer and filling), and stored at different temperatures (Figure 2).

This figure shows clearly that the shelf life of pasteurized milk can be extended significantly by aseptic transfer and packaging, provided that the temperature of distribution is below 6°C. However, if the temperature is higher, the impact of the surviving flora is of greater importance, and the shelf life is reduced. The conclusion from these investigations is that in order to produce milk with significantly extended shelf life, alternative processing which reduces the number of micro-organisms surviving pasteurization has to be implemented.

THE PURE-LAC™ SYSTEM

Extended shelf life milk can only be discussed as a total system, which can be well explained by presenting the Pure-Lac™ system.

The Pure-Lac system was developed by Elopak (Spikkestad, Norway) and APV (Silkeborg, Denmark) more than 10 years ago, as a solution to the challenges already mentioned in this article. The system is thoroughly presented in earlier IDF conference papers (Fredsted *et al.* 1996; Kjærulff 2000). One important prerequisite for the system was that the taste should be similar to pasteurized milk, and significant extension of shelf life was to be achieved. As this challenge can only be solved as a total approach, involving processing and packaging, this was a joint project between APV as processing specialists and Elopak with responsibility for the packaging systems.

The objective of the Pure-Lac concept can be summarized as follows:

- give the milk (product) an extra 'quality buffer' and lower spoilage rate;
- increase shelf life;
- sensory quality after processing and after distribution similar to pasteurized milk (product); and
- cost effective and 'tailored' to the specific needs of the customer.

The Pure-Lac plant is almost identical to a direct-heated steam infusion UHT plant, but is operated at conditions designed to kill heat-resistant psychrotrophic aerobic spores without damaging milk flavour. Holding conditions are 130–145°C for < 1 s, with infusion heating and flash cooling times of < 0.2 s and < 0.3 s, respectively. Precise control is achieved by ensuring single phase flow in the holding section (by means of an imposed back pressure) and by sophisticated in-line sensing and control of holding temperature and flow rate. Holding conditions and packaging options (clean, ultraclean

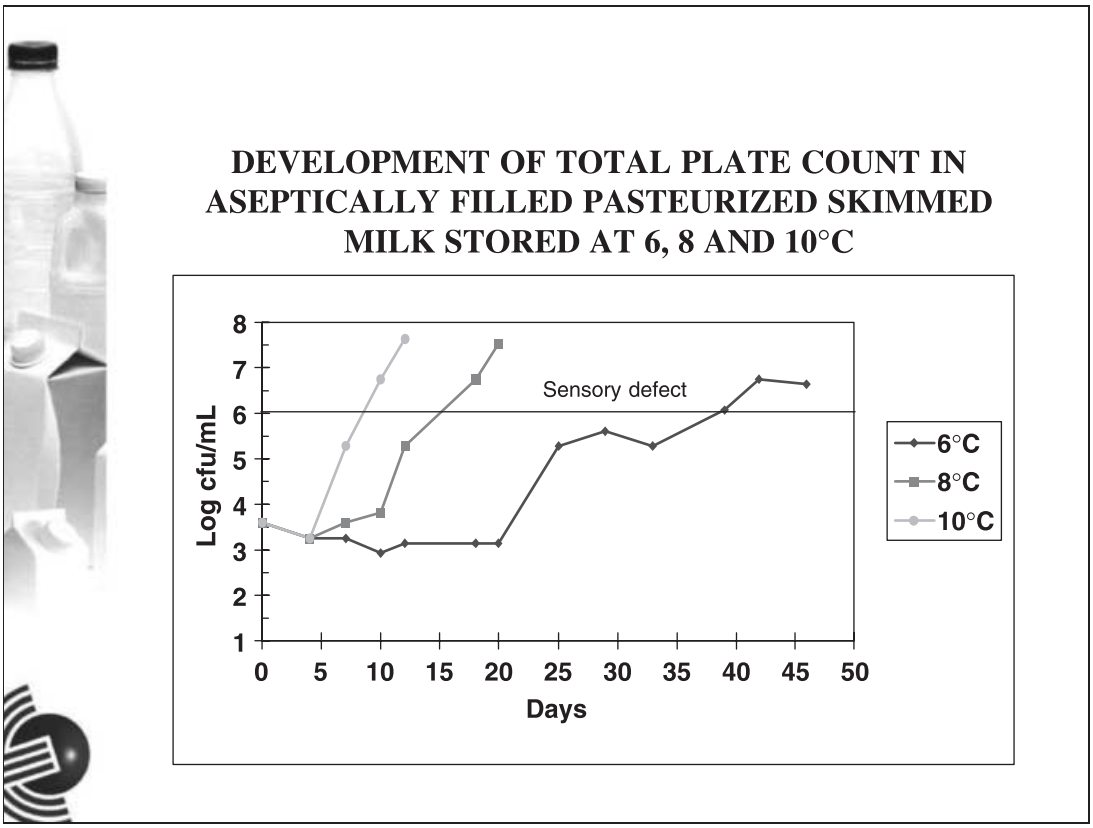


Figure 2 Development of total count bacteria and sensory quality of aseptic pasteurized filled milk and stored at different temperatures.

or aseptic filling) can be tailored to suit the flavour profile and shelf life required by the processor (Vatne and Castberg 1991). A shelf life of ≥ 45 days at the relatively abusive temperature of 10°C can be achieved.

Factors affecting the quality of pasteurized milk

It is of imperative importance to know the factors affecting the quality of the finished product. The factors that influence the keeping quality of pasteurized milk can be summarized under the following headings:

- raw milk quality;
- pasteurization conditions;
- contamination from the food contact surface;
- contamination from environment;
- distribution temperature; and
- effect of light.

For a detailed review of these factors, we would make reference to IDF Document (Fredsted *et al*. 1996).

PROCESSING METHODS FOR ESL MILK PRODUCTS

Various methods can be used to increase the shelf life of milk in addition to or as an alternative to standard pasteurization. Methods such as bactofugation and microfiltration can increase the shelf life of the milk distributed in a good cold chain (< 6°C), but if the quality of the cold chain is inferior, we have concluded that heat treatment is required. The challenge is to perform heat treatment in order to obtain better microbial kill effect while maintaining the sensory and nutritious quality of the product. The answer to this question lies in the effect of temperature on chemical (i.e. sensory and nutrition) and microbiological effects.

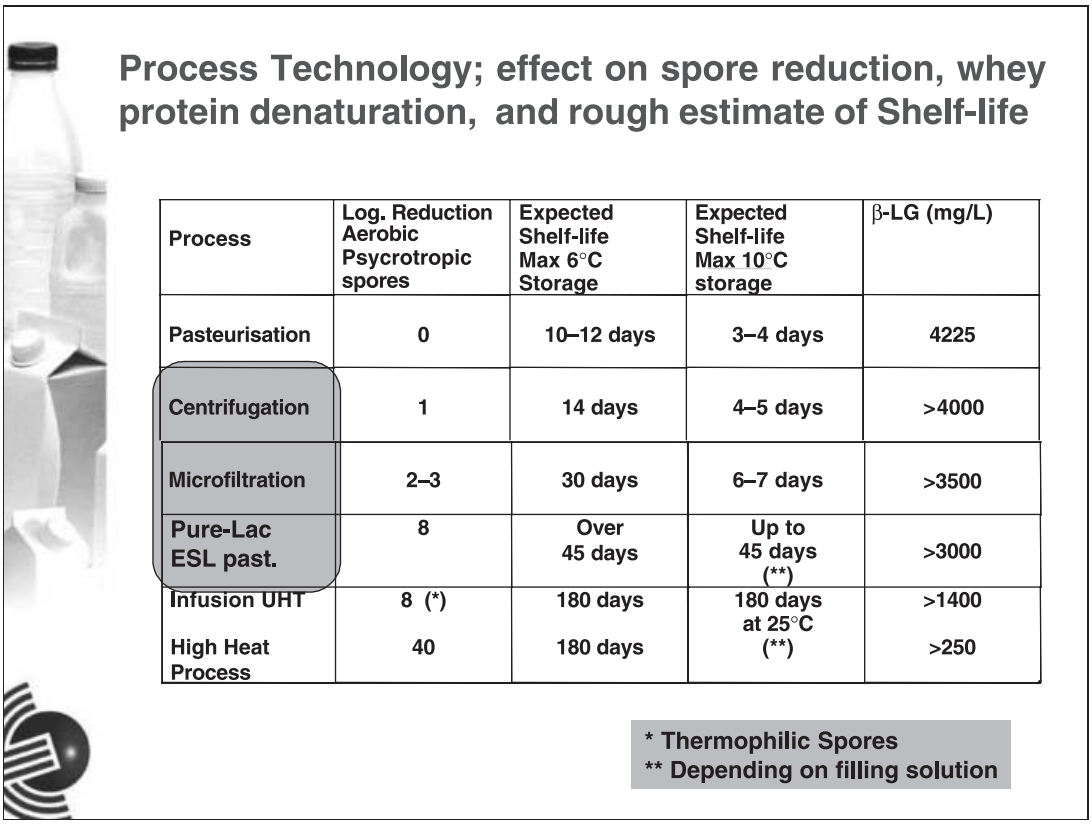
The current methods used commercially for producing ESL milk are microfiltration, direct heat treatment such as injection or infusion, or in some cases also indirect heat treatment. When comparing the different methods, it is important to consider the target shelf life of the products to be produced, the product characteristics, and the distribution conditions (temperature of cold chain). Finally, chemical degradation and its consequent effects on flavour profile is vital.

The following section is a comparison of the various methods (Figure 3).

Microfiltration

The principle of this ESL process is to remove bacterial cells and spores from the milk mechanically using membrane processing. As the pore size of the membranes used is much greater than in the cases of reverse osmosis and ultrafiltration, the process is known as microfiltration (Maubois 1997).

There are two constraints on the application of microfiltration to ESL processing (Kessler 1997).



Process	Log. Reduction Aerobic Psycrotropic spores	Expected Shelf-life Max 6°C Storage	Expected Shelf-life Max 10°C storage	β-LG (mg/L)
Pasteurisation	0	10–12 days	3–4 days	4225
Centrifugation	1	14 days	4–5 days	>4000
Microfiltration	2–3	30 days	6–7 days	>3500
Pure-Lac ESL past.	8	Over 45 days	Up to 45 days (**)	>3000
Infusion UHT	8 (*)	180 days	180 days at 25°C	>1400
High Heat Process	40	180 days	(**)	>250

Figure 3 Overview of different treatments of pasteurized and high-temperature pasteurized milk, and the effect on shelf life and chemical degradation of β-lactoglobulin.

First, as the particle size distribution of cells and spores is similar to that of milk-fat globules, it is not possible to microfilter whole milk; the milk must first be centrifugally separated and only the skim milk microfiltered. Second, the overlap of the particle size distribution of cells and spores with that of casein micelles requires a compromise in the pore size used, in order to minimize changes in milk composition; ceramic membranes with pore diameters of 0.8–1.4 mm are commonly used commercially (Kessler 1997; Russell 1998). Pores of this size allow some bacteria to pass through the membrane, and thus the final milk must be pasteurized to ensure the elimination of vegetative pathogens.

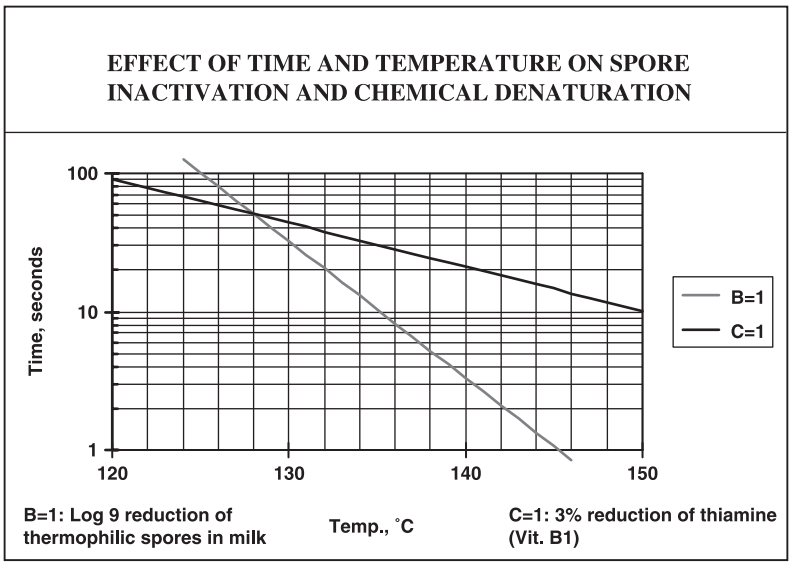


Figure 4 Curves for the biological effect (B-value) and chemical effect (C-value) as function of time and temperature (Kessler 1989).

Provided that the quality of the cold chain is good, and that a shelf life of approximately 3 weeks is sufficient, microfiltration is an excellent process for ESL milk. Although there are clear restrictions concerning viscosity and particles, new technology with inline post-process dosing can open up a wider product portfolio with this technology. Microfiltrated milk is marketed in several countries as more 'pure' and 'natural' than standard heat-treated milk, and has achieved a higher price as a branded product.

Heat treatment

Our experience is that a shelf life of 3–6 weeks in a suboptimal cold chain (> 7°C) can only be achieved by high-temperature pasteurization, and cannot be achieved with microfiltration or bactofugation.

The spore reduction is only 1–2 log for bactofugation and 3 log for microfiltration, whereas for high-temperature processed milk the critical sporeformers may be reduced by more than 8 log.

The importance of the right combination between heating temperature and holding time is shown in the next figure (Figure 4).

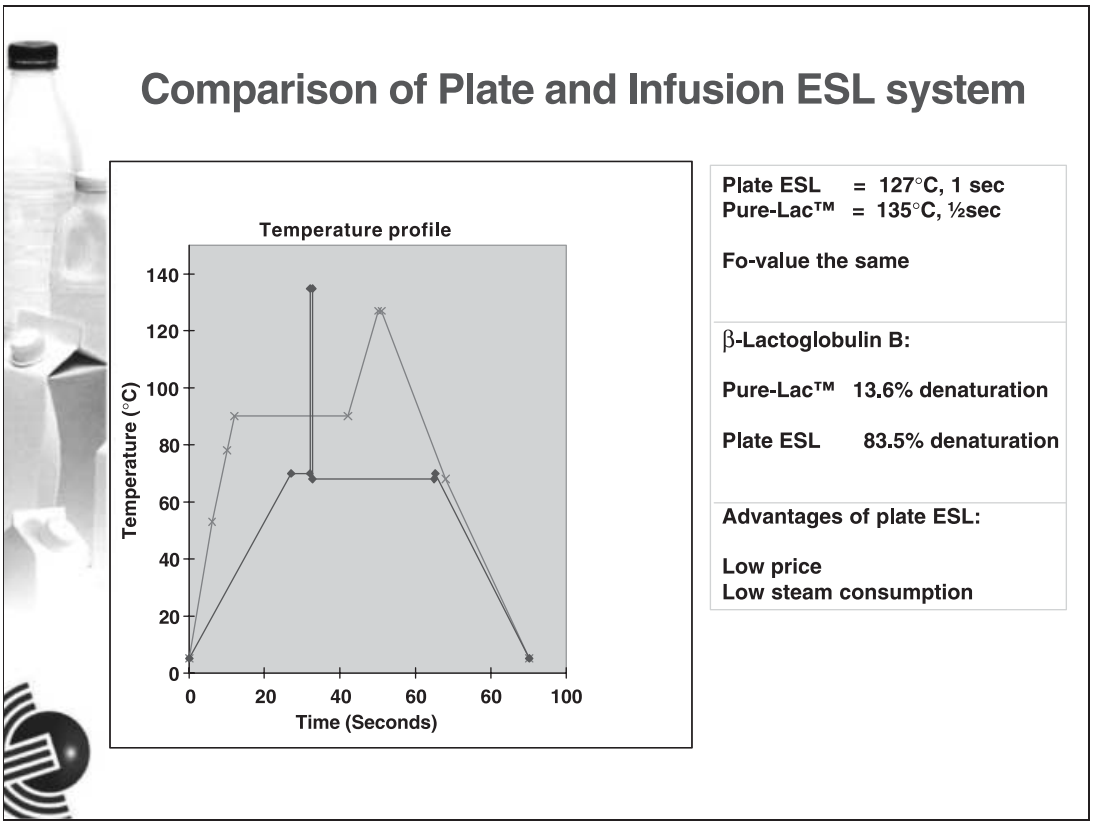


Figure 5 Temperature profile of indirect (plate) and direct heating (infusion). These two profiles show the same microbiological kill effect, but very different denaturation of β-lactoglobulin.

This figure shows the effect of time and temperature on the microbiological kill rate (B') and chemical degradation (C'). It can be concluded from this figure that the best kill rate and lowest chemical degradation are obtained by high temperature and a short holding time.

In order to minimize chemical and sensory degradation at the elevated processing temperature, an indirect heating method should not be used. Hence, direct heating by steam injection or infusion must be considered.

Figure 5 shows the temperature/time profile for milk processed with indirect heating and direct heating.

For long shelf life (> 3 weeks) or temperature of distribution above 7–8°C, we therefore recommend using direct-heating technology for processing of ESL milk. This technology enables high-temperature heating combined with a very short and controlled heating time, resulting in good kill rate and acceptable to excellent sensory properties of the product.

The following section describes in more detail the comparison between direct steam injection and infusion.

ESL technology using injection vs infusion

It is quite clear that there is a very big difference between infusion and injection, especially with regards to five critical points:

- ΔT during final heating (partial overheating of product);
- defined heating time (final heating time accuracy);
- defined holding time (holding time accuracy);
- product contact with steel surface (product fouling/reduced running time); and
- pressure drop in holding tube (influence on steam pressure (ΔT)).

It follows from these points that infusion technology is a superior direct method for producing milk with low chemical degradation because of its possible very short holding times and gentle heating. However, the choice of method will always be a combination of target flavour profile, investment and running cost of the total system. Both direct steam injection and infusion might be excellent methods to produce high-quality ESL milk.

HYGIENE IN FILLING OPERATIONS—A VITAL STEP IN ESL PRODUCTION

Public concern about food safety and quality has increased dramatically in recent years. Taking into account the large variation of products and low consumer loyalty, products spoilt by microbiological growth can have a large impact on existing established products as well as on new products introduced into the market.

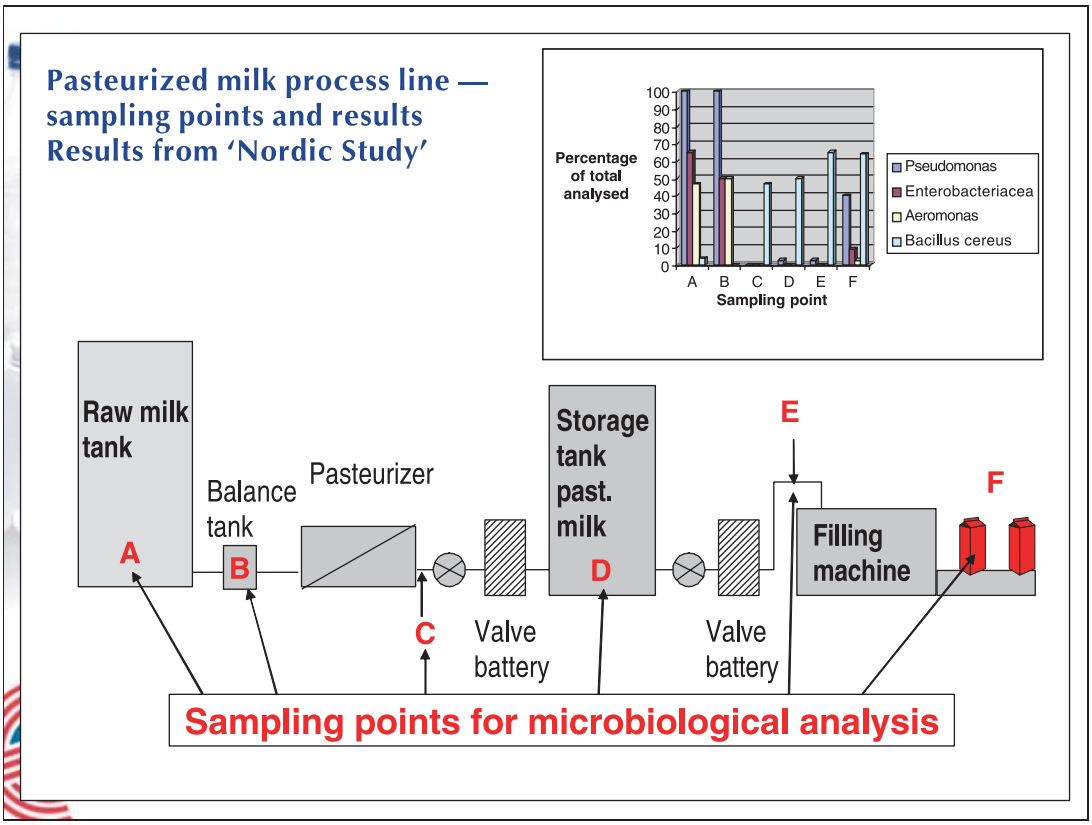


Figure 6 Result from the 'Nordic study', showing that the filling machine is the main source of recontamination in a standard pasteurized milk processing and packaging line.

In a recent study of factors important for the recontamination of milk products in Scandinavia, mapping of contaminating organisms using DNA fingerprinting (RAPD—random amplification of polymorphic DNA) showed that the filling machine was the main source of recontamination. Figure 6 represents a summary of microbial contamination routes in a pasteurized milk process line (Eneroth 1999).

In this study, it was established that even a low initial number of bacteria adapted to growth in refrigerated milk can cause spoilage. In fact, contamination at levels < 10 cfu/mL of Gram-negative psychrotrophic bacteria (GNP) spoil the milk after 7–11 days of refrigerated storage, reaching about 10^7 cfu/mL when the generation time is 4–5 h. Furthermore, it was shown that the milk-spoiling GNP bacteria were present both in the air inside the filling machine and from water samples from different surfaces inside the machine. Bacterial samples from these locations were identified from the species of *Pseudomonas*, Enterobacteriacae and *Aeromonas*, which matched in RAPD typing with incubated samples of pasteurized milk.

Bacterial aerosols may derive from sink and floor drains, water spraying and air conditioning systems. Furthermore, aerosols condensing when in contact with a cold surface may transfer the contamination within the filling machine and further into the package. As a consequence, it is regarded as best practice not to leave a water-hose on the floor or into a drain. Although the RAPD-typing did not identify bacteria from contaminated milk packages as coming from water-hoses, there was a connection between bacteria in the waste water at the bottom of the filling machine and in water from other surfaces inside the machine. Of particular concern is the filler nozzles as these also have been identified in another study (Raleya *et al*. 1998) as the main recontamination source.

The potential contribution from the packaging material is mainly restricted to Gram-positive bacteria with little potential of growth at refrigerated temperatures (6°C) (Kolstad and Junkkarinen 1997).

One major finding in the study by Eneroth (1999) is that the RAPD-typing showed that the same bacterial type could be present in the filling machine over longer periods. In particular, the water at the bottom of the machine is of concern as the stationary flora it may support may derive by aerosols from elsewhere in the plant. However, Gram-positive sporeformers may in addition follow another route of contamination due to their heat resistance. This route involves the processing line with dead ends, pockets, corners, crevices, cracks and joints; and the hydrophobic properties of the spores of *Bacillus cereus* make them attach easily to surfaces of steel, glass and rubber.

The demand for hygienic filling equipment in the dairy industry is increasing, and it is the responsibility of the supplier to ensure adequate hygienic design of their equipment. European legislation requires that handling, preparation, processing and packaging of food are done hygienically, with hygienic machinery in hygienic premises (EC Directives 98/37/EC and 93/43/EEC). It is, however, left to the industry to decide how to comply with these requirements.

The European Hygienic Equipment Design Group (EHEDG) is a consortium of equipment manufacturers, food industries, research institutes and public health authorities, with the aim of promoting hygiene during the processing and packing of food products. This organization issues documents on hygienic design that are used as guidelines for standards produced by the European Federation of Standardization Institutes (CEN). EHEDG actively promotes global harmonization of guidelines and standards. The US-based organizations NSF and 3-A have agreed to cooperate in the development of EHEDG Guidelines and in turn, EHEDG cooperates in the development of 3-A and NSF standards.

The EHEDG has recently issued the document 'Challenge tests for the hygienic characteristics of packing machines' (EHEDG 2001). This document gives proven methods for testing the performance of the various functions of packing machines, and thus provides the industry with independent criteria and challenge test methods to compare machinery from different suppliers. In order for a processor to evaluate different packaging systems, the nomenclature itself is not critical, but both hygienic challenge tests and criteria must be evaluated. The EHEDG has not defined the various filling machine classifications, and there is no common recommendation or legislation. It is therefore important that the supplier states the performance level based on a set of accepted challenge tests, and that the processor can independently compare different systems based on comparable test results.

Upon delivery, a packing machine needs to be verified by a commissioning procedure to be agreed in advance between the food processor and the supplier of the machine. Commissioning may include physical as well as microbiological tests. Additional tests are specified for commissioning of machines for aseptic packing.

Package decontamination/sterilization methods

Currently used methods

Hydrogen peroxide is the predominant agent for sterilization of packaging material in aseptic filling machines in the food industry, usually at 35% concentration in combination with heat. Another system used by some suppliers in both ultraclean and aseptic applications is the combination of low concentration peroxide and UV-C light.

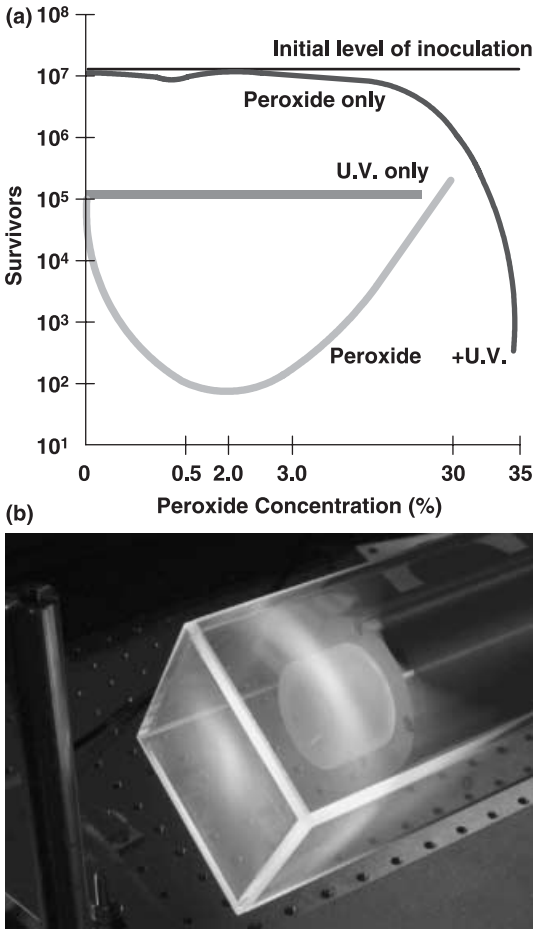


Figure 7 Bactericidal effect of hydrogen peroxide and UV light on *B. subtilis* var. *globigii* spores (a) and model system of the conical lens used to deliver UV laser light during sterilization of model carton made from plexiglass (b) (reproduced with permission from Warriner *et al.* 2004).

The synergistic bactericidal effect of hydrogen peroxide and UV light was observed by Bayliss and Waites (1979). The mode of action is considered to be primarily through the generation of antimicrobial radicals from hydrogen peroxide via exposure to UV light.

From validation studies performed by Elopak, a 5-log reduction with *Bacillus subtilis* var. *globigii* spores is typically achieved using the UV: hydrogen peroxide combination. There is also a benefit in using low concentration of hydrogen peroxide in cost and handling of the chemical, and low residues values in the packages are obtained by efficient drying by hot air. FDA legislation sets this limit to less than 0.5 p.p.m. The bactericidal effect of hydrogen peroxide on *B. subtilis* var. *globigii* spores is shown in Figure 7(a).

Other systems based on the same decontamination principle are also available with each applying different concentrations of hydrogen peroxide in combination with shorter UV-light exposure.

Another commercial method used mainly for plastic bottles (PET) is the use of peracetic acid in combination with hydrogen peroxide followed by rinsing with sterile water. This system is used when hydrogen peroxide and heat cannot be used because of the heat sensitivity of PET.

New methods

There are a number of methods for the decontamination of packaging material that are chemical free. The traditional methods of using γ-treatment or electron beam treatment are well known. However, these methods were never found to be applicable to filling machines due to cost and to safety of the operators.

Inhibition by pulsed light. The principle is based on electrical energy accumulating in a capacitor over fractions of seconds and the accumulated energy is transmitted to the lamp. The lamp releases the energy in 10^{-6}–10^{-3} s as light. The spectrum of pulsed xenon light is:

- UV-A 400 nm–315 nm: the largest portion of natural UV light.
- UV-B 315 nm–280 nm: the most aggressive component of natural UV light.
- UV-C 280 nm–100 nm: generally from artificial light.

The mode of action is believed to be physical disintegration of bacteria/spores due to instantaneous overheating after absorbing pulsed UV light. The lethal effects may be due to the high peak power and the broad-spectrum of radiation leading to a combination of DNA and enzyme damage (Warriner *et al.* 2004).

Inhibition by plasma. The principle is based on particle bombardment created by the synergy of chemical radicals and by UV-radiation. The plasma in itself is a gas containing an appropriate amount of charged particles composed of UV photons and short-lived antimicrobial free radicals (Warriner *et al*. 2004). The decontamination method is very promising at the laboratory scale, but further investigations are needed under practical conditions (Muranyi 2004). Of primary concern is the requirement to work under vacuum and the high temperatures generated within plasmas that would damage heat-sensitive materials. Atmospheric gas plasmas have been demonstrated but only on a laboratory scale.

Inhibition by UV excimer laser. The inactivation of *B. subtilis* spores deposited on planar aluminium and polyethylene-coated packaging surfaces by laser irradiation was studied by Warriner *et al*. (2000). The kill kinetics were found to give a rapid initial inactivation followed by tailing, which is possibly because of spores in crevices and pores. The mode of action is through cumulative DNA damage and through the disruption of spore germination systems (Warriner *et al.* 2004). Laser light is coherent so the beam has to be directed to each part of the pack to obtain the necessary spore inactivation, and this may result in over-exposure in some parts of the pack. A model system of the conical lens used to deliver laser light is shown in Figure 7(b).

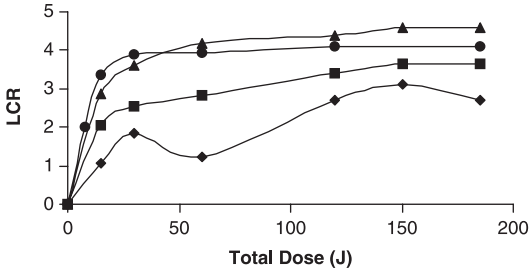


Figure 8 Inactivation of *B. subtilis* spores on aluminium-coated packaging boards exposed to UV-laser irradiation. Cards (4 cm^2) carrying 10^4 (◆), 10^5 (■), 10^6 (●) or 10^7(▲) cfu were irradiated with the appropriate UV dose and survivors subsequently enumerated. The frequency of the laser beam was 10 Hz for dose levels of 15 J, 20 Hz for 30 and 60 J, 40 Hz for 120–185 J dose levels. The fluence of the laser beam was 12 J m^{-2} as measured at the work piece. Reproduced with permission from Warriner *et al*. (2004).

An example of an inactivation curve is shown in Figure 10, and a relatively high level of spore kill can be achieved with 10J dose. However, the higher dose is required to inactivate residual spores located in pores and crevices (Figure 8).

With the conical lens showed in Figure 7(b) the experiments of Warriner *et al*. (2004) demonstrated a Log Count Reduction of 4 for *B. subtilis* spores within 5 s of treatment time. The surviving spores were randomly distributed on the carton surface so no 'cold spots' were present. Therefore, the conical lens demonstrated an optical head delivery system with enhanced dispersion of UV-photons that also eliminated the spores in the pores. Further studies should be made for the development of more rapid systems to move either the pack or laser optics during treatment.

STORAGE AND DISTRIBUTION

Distribution temperature

The temperature of storage and distribution is of paramount importance for the keeping ability of the milk. A rule of thumb for pasteurized milk is that for every 2°C increase in storage temperature, the keeping ability is reduced by 50%.

The actual cold chain varies considerably between various countries and regions, but also within different distribution routes and shops. Measurements of the cold chain temperature are an important task for any food producer in order to determine the keeping ability of the products.

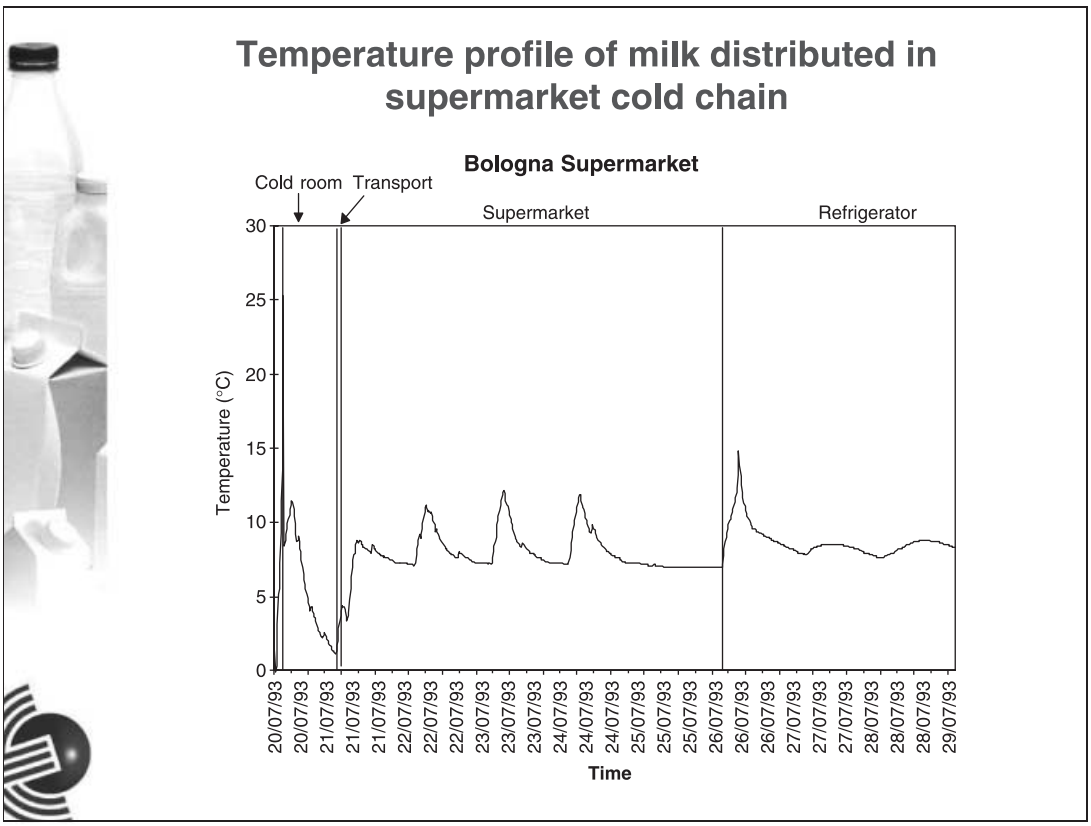


Figure 9 Temperature profile of milk distributed in cold chain in a European supermarket.

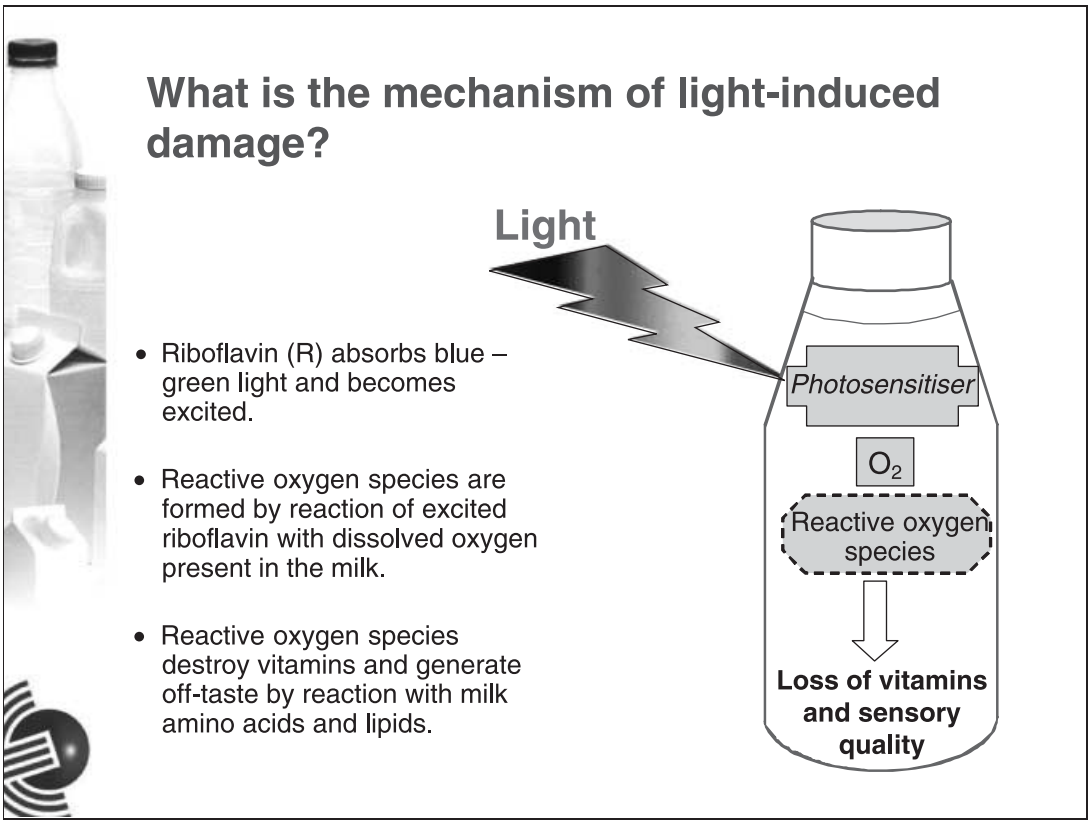


Figure 10 Mechanism for light-induced off-taste and vitamin destruction in milk.

Traditionally, the temperature in the cold chain has been checked by spot tests of the temperature in various places in the cold chain. This test has its obvious limitations. It will not give the true temperature of the product, and fluctuations in temperature in distribution and cold store temperature is not reflected.

We have been using a Datatrace (Mesa Laboratories Inc., Lakewood, CO, USA) unit for measuring the actual temperature in the product during storage and transport. The sensor can be placed within the product in the package, and a temperature profile during the entire distribution chain will be recorded.

The sensor was put into the product after filling and before top-sealing of a Pure-Pak carton, and programmed to read the temperature in the product every 15 min during the entire distribution chain. The graph (Figure 9) showed that as soon as the product left the plant, the temperature increased during transport to the shop. The temperature profile during storage in the shop showed a very typical pattern for a supermarket. During the day, when doors to the chiller cabinets were frequently opened, the temperature exceeded 10°C. Average temperature for the cold chain in this case was 8°C, which is important to use in keeping ability tests in the plant.

Effects of light on milk

Both sunlight and artificial light will have negative effects on milk quality, and it will create an off-flavour and reduce vital vitamins in the product. The nutrients in milk are most sensitive to light in the blue-violet area of the visible spectrum. This is in the range of 400 to 500 nm in wavelength, whereas ultraviolet light and visible light above 500 nm have relative little effect on the vitamins and other nutrients. The amount of photo-oxidation occurs as a function of the amount of radiant energy reaching the milk and the length of exposure to the light.

Milk is one of the best sources of vitamin B2 and a good source of vitamin A. Both these vitamins are sensitive to light. The light will, in addition to reduction of the vitamins, also create off-flavours. The main reason for light-induced off-flavour is photo-oxidation of the amino acid methionine to the strong off-flavour compound methional.

The International Dairy Federation (Fredsted *et al*. 1996) states that the quality of milk and milk products is liable to be reduced by light transmission. Consequently, all means should be applied to minimize or prevent the harmful light effect. In order to reduce the light effects, it is recommended that packaging material offering at least partial protection is used. In this respect it is recommended that the maximum permissible light transmission of a packaging material should be 8% at 500 nm and 2% at 400 nm.

Transparent packaging materials like glass or plastic offer only minimal protection against harmful light, whereas paperboard material gives a very good light protection. The best protection is provided by ALU-foil paperboard that has a 0% transmission of light.

FUTURE TRENDS

What will be the future development in ESL milk products? We will see development within marketing and product development as well as in technology.

Branded white ESL milk has been successfully marketed in various countries. Cravendale microfiltered milk in the UK is one good example, and more branded white milks with special origin or process will be launched as ESL milks. It is also obvious that new high-quality and great-tasting flavoured milks will be launched as ESL milks. These types of products require longer shelf life than traditional pasteurized milk, but may be segmented in the high end of the chilled product group through carefully selected ESL technology. The trend of new distribution channels and packaging format will also require longer shelf life than traditional pasteurized milk, without necessarily going all the way to UHT processing and packaging.

The technology of ESL processing and packaging will also develop. More gentle heat treatments, better-designed equipment and controls system will take this product category further. The developments of alternative heat treatments such as ohmic heating, radiofrequency or others have not been commercialized to a large extent. The same is the situation for nonthermal methods such as high-pressure processing or electroporation. Although these methods have not been a commercial success up to now for ESL milk products, we can expect elements and combination of such methods in the future to produce new products with different sensory or physical properties.

There will also be a further development of the filling systems. Improved and novel sterilization methods for all machine surfaces and packaging material, improved hygienic design and gentle treatment of sensitive products in the filling operation. The development of active and intelligent packaging may also play a role in the future of ESL milk products.

As consumers are looking for products with increased freshness and higher quality, the retail requires products with extended shelf life. In order to solve these two conflicting demands, the industry has to formulate and process products with these characteristics, and the packaging systems must ensure that the initial quality is largely preserved through extended storage. This is the current and future challenge for ESL products.

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