Innovative Steam Injection for Milk Processing

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Ultra High Temperature (UHT) treatment uses high temperature for a short time to kill micro-organisms in a food or beverage product. It is widely used in the dairy industry where products can easily lose their nutritional value, flavour and appearance as microorganisms multiply. These organisms thrive at certain temperatures but if they are not present in a product, it can be stored for many months without the need for refrigeration. This state is known as 'commercial sterility'. UHT processes are designed to achieve commercial sterility. They use heat to treat the product, killing viable micro-organisms. This aseptic processing also requires equipment and packaging to be sterile, achieved with chemical or other sterilisation treatments (de Jong, 2008).

There are two well known technologies depending on the medium used for heating to the UHT, direct and indirect systems. Direct heating systems include steam injection (steam into milk) and steam infusion (milk into steam). Generally, steam, hot water, and electricity are used heating methods for UHT processing. Direct heating methods, such as steam injection or steam infusion, mix the heating steam with the product. The culinary steam must be of high quality and must not impart any off-flavours to the milk product. The product temperature increases almost instantly due to the latent heat of vaporization. The condensed steam that dilutes the milk is removed later as the heated milk is cooled in a vacuum chamber. Indirect heating methods, such as plate or tubular heat exchangers, keep the product and heating medium separate with a stainless steel barrier between them. The choice of direct or indirect heating and the system utilised depends on many factors including product specification, viscosity and sensitivity to high temperatures. Along with the quality of the raw materials used, the system chosen has a big impact on the characteristics of the final product.

Studies reported on UHT processing have been concerned mostly with indirect heating systems. This method of processing has been in commercial use since 1949 (Burton, 1969). Use of indirect heating system results in 75% to 90 % denaturation of whey proteins. In 1972, the United States Public Health Service approved the use of UHT steam injection for pasteurization of milk (Stroup *et al*., 1972). Lembke and Wegener (1968) indicated that UHT direct steam injection is less destructive to the aqueous and lipid portions than indirect UHT heating techniques. This is mainly due to rapid heating (steam injection) and cooling (vacuum) of the product. However, direct steam injection also results in 65-85% denaturation of whey proteins. Milk proteins change more than any other milk constituent due to UHT processing that contributes to loss of colour, flavour, and nutrition, as well as gelation and sedimentation. Denatured whey proteins form complexes with other whey proteins, caseins, and fat globules (Dunkley and Stevenson 1987).

Gelation is a major defect encountered in UHT milks. Among the hydrolases from psychotropic bacteria in milk, those from *Pseudomonas* spp. have been the most frequently studied and are secreted mainly at the end of the stationary phase of growth. Most of the research workers have reported that proteinases from psychrotrophs are readily able to degrade κ-, αs1- and β-casein, and have low activity on non-denaturated whey proteins. As a result of denaturation of whey proteins in appreciable amounts (>60%) using these methods, a wide range of problems are encountered in UHT milks. The major defects encountered in UHT milk include adverse effect on taste, colour, odour; gelation, sedimentation, separation, and viscosity. These attributes can be affected by raw product quality, pre-treatment process, process type, homogenization pressure, deaeration, post process contamination and package barriers. Spoilage of raw milk prior to processing can occur from poor sanitation and inadequate storage temperatures.

To overcome such problems which are inherently present in UHT milk and to reduce the appreciable amount of denaturation of whey proteins occurring using conventional methods, the Innovative Steam Injection (ISI) heater which is a novel type of steam injection that enables fast heating and high temperatures has been developed. This new preservation method is based on an ISI approach. The patented ISI technology is based on existing UHT treatment, but very short heating is combined with very high temperatures: less than 0.1 s at 150–200°C (Huijs *et al.*, 2004). The heating is directly followed by flash cooling in a vacuum vessel. The process costs of the ISI technology are some 10% higher than the prevailing UHT process, however the ISI technology is substantially less expensive than alternative technologies such as microfiltration, normally used for Extended Shelf Life products. The schematic overview of a typical ISI heater is depicted in Figure 1.

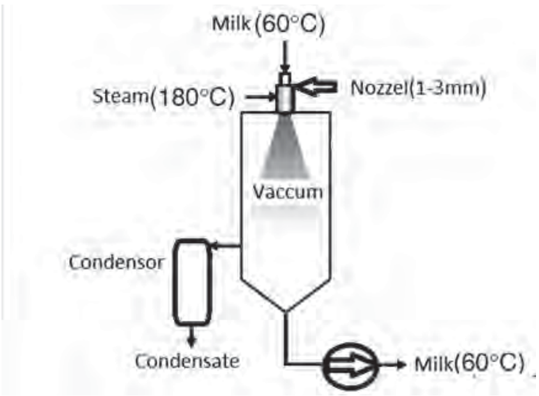

Fig. 1 Schematic overview of ISI heater

In the ISI, the product is pumped through a pipe with a narrow end (nozzle, 1 to 3 mm). The wall of this pipe contains several small openings through which high pressure steam is injected, enabling very fast heating of the product. The milk can be heated at 80°C (during different residence times) before (preheated) or after heating, the product can be instantaneously cooled using flash cooling (van Asselt *et al.*, 2008). The heat treatment in industrial applications is much shorter, but a higher temperature is applied. For example, Tetra Pak's Tetra Therm Aseptic Plus 2 (Datta and Deeth, 2003) includes a preheating of approximately 45 s at 90° C. with respect to plasmin inactivation, this heat load is equivalent to a heat load of a treatment of 80°C during 300 s. In order to optimize the process, the effect of partly (30%) denatured β-lactoglobulin was included. The level of 30% denatured β-lactoglobulin was chosen on the basis of previous experiments with the ISI denaturation (Huijs *et al.*, 2004). The results showed that a post heat treatment is sufficient to reduce the amount of plasmin below 1% of its initial level. By applying these new kinetics, the heat load for currently applied UHT treatments of milk can be reduced while obtaining a sufficient inactivation of plasmin (that is less than 1%) and to achieve a 6 decimal reduction of *B. sporothermodurans*. This opens the way for the production of extended shelf life milk with even less product degradation (that is less than 50% denaturation of β-lactoglobulin) compared with currently available UHT products (that is greater than 50% denaturation of β-lactoglobulin) and improved taste characteristics. The effect of different heating technologies on whey proteins and bacterial spores in milk is presented in Table 1.

Technical Articles

Table 1 - Effect of different heating technologies on whey proteins and bacterial spores in milk

Technology	Time(s)	Temperature (°C)	Denaturation of whey proteins (%)	Log reduction *B. stearothermophilus* spores	Log reduction *B. thermodurans* spores
Pasteurization	15-1	72-80	4-8	0	0
Indirect UHT	20-5	130-145	75-90	6	0-3
Direct UHT	6-2	142-150	60-85	6	0-4
ISI	0.1	160-180	25	6	3-4

Source : Tamime (2009)

Using the ISI, a significant inactivation of heat-resistant spores can be achieved while preserving the functionality of important ingredients. Table 1 shows the typical time–temperature combinations used in the dairy industry, and the effect of these processes on denaturation of whey proteins, *Bacillus stearothermophilus* and *Bacillus sporothermodurans* spores in milk. The denaturation of whey proteins is a measure of product damage caused by the stress of heating. For sustained stability at room temperature, the enzymes that cause spoilage must also be inactivated. The extremely heat-resistant enzyme plasmin, instigator of a bitter taste, plays the leading role here in milk products. Plasmin does not become inactivated in the pasteurization process, but that is unimportant to pasteurized milk. This is because firstly pasteurized milk is stored under refrigeration, and the enzymatic activity of plasmin is minimal at low temperature. Also, the germination of *B. cereus* spores in pasteurized milk is limiting factor for the shelf-life, long before the effects of plasmin become observable. To obtain ISI milk, that is stable for months at room temperature, an additional preheating step is necessary for inactivation of plasmin.

Conclusion

Use of conventional UHT processing results in appreciable denaturation of whey proteins resulting in adverse effects on taste, colour and odour of the product and certain defects like gelation, sedimentation, separation, and increased viscosity. Therefore, use of ISI processing which is a recent novel technology will help in overcoming such problems.

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