Heat Treatment of Milk - Overview

Heat treatment is the most widely used processing technology in the dairy industry. Its main purpose is to destroy microorganisms, both pathogenic and spoilage, to ensure the milk is safe and has a reasonable shelf-life. Despite the developments of alternative technologies such as high-pressure processing and pulsed electric field technology for destroying microorganisms, thermal treatment remains the method of choice for most bactericidal treatments in the dairy industry, and in the processing of other foods. This choice is largely attributed to the tremendous success of heating processes since the introduction of pasteurisation of milk in the 1890s following Pasteur's earlier discovery that heat treatment of wine and beer could prevent spoilage. In addition, and most importantly, export certificates requested for milk products often refer to the OIE Animal Health Code, which does not leave room for alternatives to thermal treatment.

Since the introduction of pasteurisation, heat treatment of milk has attracted a huge amount of research attention. Consequently, there is large body of literature on many aspects of the technology. Several books, book chapters and reviews have been published on the topic, many of these under the auspices of the International Dairy Federation (IDF).

Any intentional heating above 50 ° C for a sufficient time such that there is a reduction in the concentration of one or more microorganisms is considered heat treatment. Thus, the heat treatment concept covers an infinite number of combinations of time and temperature. The intensity of the treatment is determined by the treatment temperature and duration at which the product is kept at this temperature.

The dairy industry uses a wide range of heat treatments and it is useful to put these in perspective in terms of their effects on milk. Table 1 lists the major treatments, their applications, and their bacteriological, chemical and other effects. The treatments can be categorised into those used for milk for direct consumption, such as pasteurisation, Extended Shelf-Life (ESL) processing, Ultra-High Temperature (UHT) and in-container sterilisation, and those used for specific dairy products such as yogurt and milk powders. In addition, thermisation used to treat raw milk, allows it to be stored for a longer time before further processing, or for cheese making. Further details are given for thermisation, pasteurisation, ESL and UHT processing, and in-container sterilisation in IDF Fact Sheets providing more specific and detailed overviews of these processes. In particular, the reader is referred to the following Fact Sheets:

1. Heat treatment of milk – Thermisation, pasteurisation and extended shelf-life processing; and
2. Heat treatment of milk – UHT and in-container sterilisation.

Prepared by Emeritus Prof. H. Deeth and Dr. G. Smithers with the assistance of the members of the IDF Standing Committee on Dairy science and technology

Table 1. Major heat treatments used in the dairy industry

Heat treatments (Temperature–time conditions)	Applications	Bacteria destroyed	Significant chemical effects	Comments
Thermisation (57-68°C/5 s-30 min)	Extending shelf-life of raw milk prior to further processing Manufacture of some cheeses	Some non-spore-forming pathogens and psychrotrophic spoilage bacteria	Little effect	Product may not be phosphatase-negative; not suitable for drinking milk as some pathogens may remain viable
Pasteurisation (72-80°C/15-30 s)1	Drinking milk Cheese manufacture	Non-spore-forming pathogens and psychrotrophic spoilage bacteria; not spores or thermoduric vegetative bacteria	Small effect on vitamins, ~5% whey protein denaturation, inactivation lipase	Product must be phosphatase-negative; standard minimum conditions in most countries are usually 72°C/15 s An alternative process is batch pasteurization at 63-65°C/15-30 min
Pasteurised with ESL (Extended Shelf Life) processing (125-140°C/1-10 s	Drinking milk with ESL at refrigeration temperature	All non-spore-forming bacteria and most psychrotrophic and mesophilic spores	Depends on actual heat treatment conditions. Significant but variable denaturation of whey proteins (25 – 85% of β-lactoglobulin)	No standard heat processing conditions. Inactivates lactoperoxidase (sometimes used as a test for adequacy of ESL heat treatment). Slight alteration of flavor but minimal at higher temperatures for shorter times. ESL milk is also produced using microfiltration, usually combined with a final (thermal) pasteurisation step

Heat treatments (Temperature–time conditions)	Applications	Bacteria destroyed	Significant chemical effects	Comments
UHT (Ultra High Temperature) processing (135-150°C/1-10 s)	Drinking milk with long shelf-life at ambient temperature	All non-spore-forming bacteria and all spores except highly heat-resistant spores; produces "commercially sterile" product	Smaller effects with direct than with indirect heating systems; high level of whey protein denaturation (70 – 95% of β-lactoglobulin); epimerization of lactose to lactulose, lactosylation of lysine residues; formation of sulfhydryl compounds	Produces mild heated/ cooked/ sulfurous flavour; further chemical changes occur during storage; market share varies between countries from < 10% to >90% of drinking milk consumption.
In-container sterilisation (110-120°C/10-20 min or 125°C/5 min)	Evaporated /condensed milk, drinking milk with long shelf-life at ambient temperature	Destroys all non-spore-forming bacteria and all spores except highly heat-resistant ones	Complete denaturation of whey proteins, extensive Maillard reaction ; production of heated-flavour compounds	Causes strong cooked flavour and light brown discolouration; now used for some flavoured mik products
90-95°C/5-10 min	Yogurt manufacture	Most non-spore-forming bacteria	Almost total denaturation of whey proteins (WP)	Causes increased viscosity of yogurt through formation of WP–κ-casein complexes and enhanced water binding capacity
72-80°C/15-30 s)	Low-heat skim milk powder (SMP)	Non-spore-forming pathogens and psychrotrophic spoilage bacteria	As for pasteurization; little whey protein denaturation - WPNI1 > 6.0 g/L	Product used for recombined milk, milk, standardisation, cheese manufacture
85°C/1 min; 90°C/30 s; 105°C/30 s	Medium-heat SMP. Pre-heating in UHT processing Whole milk powder.	Non-spore-forming pathogens and psychrotrophic spoilage bacteria	Moderate to substantial whey protein denaturation - WPNI 1.5- 6.0 g/L; inactivation of plasmin; Exposure of some sulfhydryl groups and formation of some sulfhydryl compounds which act as antioxidants in whole milk powder	Product used for ice-cream, chocolate, confectionery Decreases fouling of UHT plants and reduces plasmin-catalysed proteolysis during storage Improves storage stability of whole milk powder

Heat treatments (Temperature–time conditions)	Applications	Bacteria destroyed	Significant chemical effects	Comments
90°C/ 5 min; 120°C/1 min; 135°C/30 s	High-heat SMP	Non-spore-forming pathogens, psychrotrophic spoilage bacteria and most spores at the most severe conditions	Extensive whey protein denaturation - WPNI < 1.5/L;	Product used for recombined evaporated milk
>120°C/>40 s	High-high-heat or high-heat-high-stable SMP	Non-spore-forming pathogens, psychrotrophic spoilage bacteria and most spores	Almost complete denaturation of whey proteins - WPNI << 1.5 g/L	Product used for bakery products and recombined evaporated milk

[1] WPNI = whey proteins denaturation index; indicates level of undenatured whey protein and used to categorise skim milk powders

Further reading

Deeth, H.C. and Lewis, M.J. (2017) High Temperature Processing of Milk and Milk Products. Wiley Blackwell, Oxford.

IDF (1993) Protein & Fat Globule Modifications by Heat Treatment, Homogenisation and other Technological Means for High Quality Dairy Products. Doc. 9303. International Dairy Federation, Brussels.

IDF (1995) Heat-induced Changes in Milk. Doc. 9501. International Dairy Federation, Brussels.

IDF (1996) Heat Treatments and Alternative Methods. Doc. 9602. International Dairy Federation, Brussels.

Kelly, A., Datta, N & Deeth, H.C. (2012) Thermal processing of dairy products. In: Thermal Food Processing: New Technologies and Quality Issues 2nd edn (ed. D.-W. Sun) pp. 273-307. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Kessler H G (1989) Effect of thermal processing on milk. In: Developments in Food Preservation 5. (ed. S. Thorne), pp. 91–130. Elsevier Applied Science, London.

Lewis, M.J. & Deeth, H.C. (2009) Heat treatment of milk. In: Market Milks – Processing and Quality Management (ed. AY. Tamime), pp. 168-204. Blackwell Publishing Ltd, Oxford.

Lewis. M.J. & Heppell, N.J. (2000) Continuous Thermal Processing of Foods: Pasteurization and UHT Sterilization. Aspen Publishers, Gaithersburg, MD.

Tetra Pak (2015) Dairy Processing Handbook. Tetra Pak Processing Systems, Lund, Sweden

International Dairy Federation
www.fil-idf.org