Subject: **Food Technology**

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Paper No. : 04 Unit Operations in Food Processing

Module : 10 Heat Transfer applications: Pasteurization, sterilization, UHT processing

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Description of Module	
Subject Name	Food Technology
Paper Name	04 Unit Operations in Food Processing
Module Name/Title	Heat Transfer applications: Pasteurization, sterilization, UHT processing
Module Id	FT/UOFP/10
Pre-requisites	Heat transfer theory
Objectives	To know the applications of heat transfer in food processing like pasteurization, sterilization and UHT processing. To know the processing methods and process equipments used in these processes.
Keywords	Pasteurization, sterilization, UHT, commercial sterility, retort processing

10.1 Introduction

Thermal processing involves heating the food materials at specified temperature for a definite period of time so as to inactivate the microbial flora which otherwise would cause deteriorative effect on food during storage. For every 10^0C rise in temperature in the range of 0 to 60^0C, the activity of microorganisms increases by two folds. Above this temperature the growth stops and many enzymes are destroyed. So, for any heating processes it is intended to heat the food materials above 60^0C to inactivate the microbial flora. Heating is carried out by packing foods in pouches or by passing the bulk food through heat exchangers. Heating is immediately followed by cooling and then packaging to check cross contamination. The extent of heat treatment depends on the intended use and storage. Mild heat treatment is done to preserve foods for a short duration of time. High heat treatment like ultra high treatment is done at very high temperature to keep the food material safe for a longer period.

The process of heating is thus divided into three categories viz. pasteurization, sterilization and ultra high temperature (UHT) processing. We will discuss the individual processes in the following sections.

10.2 Pasteurization

Pasteurization word is coined by the scientist Louis Pasteur in 1857 who established that the souring of milk could be delayed by heating milk to 50-61^0C. However, the disease causing and spoilage effect by microorganism was not established till late 20^{th} century. Pasteurization is a mild heat treatment process applied to wide range of food materials. The objectives of pasteurization are

- To kill the pathogenic bacteria so as to ensure safety against disease, and
- To remove spoilage microorganisms to improve keeping quality.

The IDF definition of pasteurization is; "pasteurization is a process applied to a product with the objective of minimizing possible health hazards arising from pathogenic microorganisms associated with the product (milk) which is consistent with minimal chemical, physical and organoleptic changes in the product". *Mycobacterium tuberculosis* is the most heat resistant pathogenic bacteria which is widely accepted as target microorganism for pasteurization. More recently *Listeria monocytogenes* has been considered as the target organism, especially for dairy products. Since the process is not severe enough to kill *Clostridium botulinum*, the pasteurized foods require refrigeration storage immediately after processing. The pasteurized products have limited shelf life during their distribution chain. The severity and duration of pasteurization depends on the nature of the product, pH, initial microbial load, type of heat processing, the nature of the resistive microorganism, etc.

10.2.1 Methods of pasteurization

10.2.1.1 Batch pasteurization is the age old process used from ancient times. Batches of food products are kept in container and allowed to heat or boil. Source of heat may be wood, petroleum oil or steam. The advanced technology in batch pasteurization is the use of steam jacketed vessel. The stainless steel container is jacketed outside through which hot water or steam is supplied followed by cold water. An agitator is mounted on the equipment to achieve uniform heat transfer in the products and to avoid localised overheating. The drawback of this system is that, the warming and cooling time required are long. Moreover, the regeneration of heat is not possible and huge amount of latent heat is lost through heated products.

Batch pasteurization of milk is carried out at 65^0C for 30 minutes followed by quick cooling to 4^0C.

10.2.1.2 ***Continuous pasteurization*** can be done to bulk fluids followed by cooling and packaging. The pumpable products such as liquids, puree, semi-liquids and suspension with small particles are generally heated in bulk. The processes are in most cases continuous and this has been possible due to the development of heat exchangers. Plate heat exchangers are common heating equipments used in food industries due to their high thermal efficiencies. Moreover, the maintenance of the equipments is very easy.

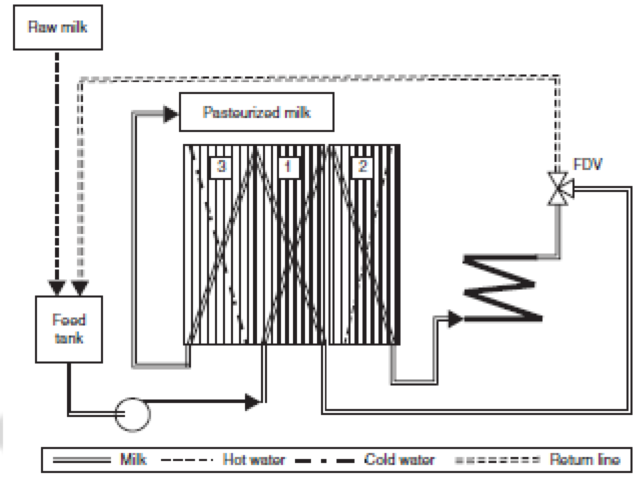

Fig.10.1 Schematic diagram of a continuous milk pasteurizer (courtesy: Elsevier Inc.).

In continuous operation, the heated food products are cooled in the exchanger itself as shown in fig.10.1. The advantage of cooling inside the exchanger is that, the latent heat of hot food products is utilized to heat the incoming cold product. This phenomenon is commonly known as 'regeneration'. Pasteurizer basically consists of three sections. Section 1 shown in fig.10.1 is preheating or regeneration section, where, fluid is heated to about 50^0C before fed to the heating section (section 2) where it is heated to specified temperature. Hot water is employed as the heating medium whose temperature is kept 5^0C above the product pasteurization temperature. The heated fluid passes through a holding tube, the flow is controlled in such a way that the residence time is just above the heating time required to achieve lethality. If the product is not heated to set temperature, it is diverted back to balance tank by a flow diversion valve (FDV) as shown above. Heated products are sent to cooling section (section 3) via regeneration section, where it gives off some heat to incoming raw products. Chilled water is allowed to pass through other side of the cooling plates which make the product cooled to around 3-4^0C. The cold pasteurised food is hermetically sealed and packed before refrigeration storage and final transport for consumption.

Some minor adjustments in the gap of plates are required to handle high viscosity food products. The flow velocity is also increased to overcome the drag force created by the food products. The pasteurization temperature is kept little high for viscous products due to difficulties in heat transfer through viscous mass.

Other heat exchangers which can be used for continuous pasteurization are tubular, shell and tube and spiral heat exchangers.

10.2.1.3 Another alternative of the process of pasteurization is that, after bulk heating, the food products are hot filled, sealed and cooled by normal water. The advantage of hot filling is that, viscous products at low temperature are difficult to fill. So, at high temperature viscous products behave as free flowing liquid. Normally, metal cans are used as packaging materials. Heat sensitive poly pouches are suitable in this case. One major disadvantage of hot sealing and cooling is that, it takes longer cooling time to attain the required temperature, thereby chances of overcooking is high and organoleptic changes in food products may occur. Tomato purees and other tomato products are still processed in this method. More recently, aseptic processing has replaced this process in delicate food products.

Scrapped surface heat exchangers are used to pasteurise high viscous products where it is very difficult to pump through plate heat exchangers.

10.3 Sterilization

Sterilization is a process of severe heat treatment given to food products with the intension to kill all form of microbial population including spore forming bacteria and keep the product safe without refrigeration. Apart from microbial destruction, it inactivates all the enzymes which would cause enzymatic changes during storage.

The heat sterilization involves exposing food products to a temperature generally exceeding 100^0C for a period sufficient to inhibit enzymes and all forms of microorganisms including bacterial spores. Nicolas Appert first understood that thorough cooking over a suitable period of time slowed the decay of foods and various liquids, preserving them safe for consumption for a longer time than typical. Canning operation has evolved from the principle of sterilization.

Complete destruction of microorganisms may be achieved through heating food at 121^0C for atleast 15 minutes. This can be considered as very harse heat treatment. As a result of sterilization many physicochemical changes take place. The target microorganism in sterilization process is *Clostridium botulinum*.

Always sterilization is an indirect heat transfer process. The foods are kept in a container, basically tin cans, or glass bottle or metallic cans. The thermal heating time is calculated based on the temperature reached to the coolest spot of individual can. Following are the various sterilization methods adopted in food processing.

Commercial sterility: The condition achieved by application of heat, irradiation, high pressure or other processes, alone or in combination with other ingredients or treatments, to render the product free of microorganisms capable of growing in the product at non refrigerated conditions at which the product will be held during storage and distribution.

In commercial sterilization product is not necessarily free of microorganism, but those that survive the sterilization process are unlikely to grow during storage and cause product spoilage.

10.3.1 In-container sterilization

Canning of packaged foods is carried out through batch or continuous processes. Small volume of foods are packed and fed to batch retort for thermal processing where as hydrostatic sterilizers are used to process high volume of food materials.

10.3.1.1 Batch process

Batch sterilizers, otherwise known as retorts, are used in small to medium size canning operations. Basically, retort is a horizontal or vertical still pressure vessel equipped with necessary doors, heating and cooling pipes and valves, and control equipments. Fig.10.2 shown here is a schematic presentation of a batch retort. The food cans are loaded in the crates of wagons and are moved into the retort. The doors are closed hermetically. The heating medium is basically saturated steam fed from the pipe fitted on the bottom line guided through a steam spreader. The retort air is vented out before start of the process. The total heating time includes the calculated thermal heating time plus 58% of the 'come-up' time (time required to reach the retort temperature to saturation temperature). Hot water can also be used as heating medium. The cans of retort are cooled to ambient temperature using normal water sprayed over the cans. Overriding air pressure prevents the cans from bulging, deformation of metallic containers and popping of lids of glass jars due to thermal expansion.

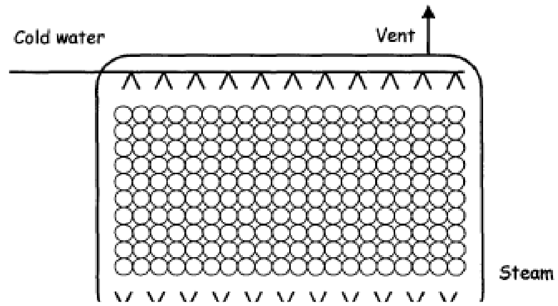

Fig.10.2: Schematic diagram of a batch retort

Rotation can be given to the can crates inside the retort with the aim to increase the rate of heat transfer and reduce the process time. Horizontal end-to-end rotation is generally practiced.

10.3.1.2 Continuous sterilization

As mentioned earlier, continuous sterilizers are advantageous for large volume operation in canning line. The sterilizers are fed with continuously with cans which are preheated, sterilised and cooled in different sections as shown in fig.10.3.

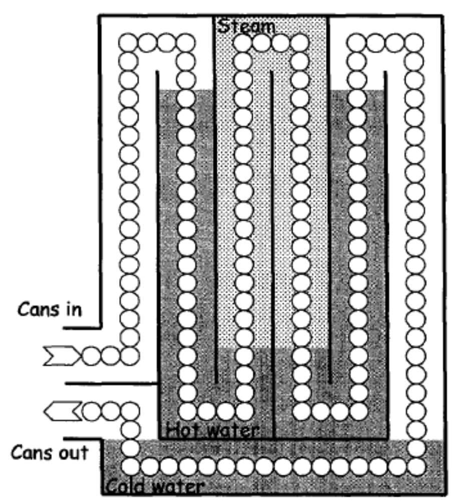

Fig. 10.3: Hydrostatic continuous sterilizer

Rotating spiral reels guide the cans through hot water section where water comes in direct contact with cans, followed by steam section and again hot water section. Finally, the cans are passed through cold water section and taken out from the sterilizer at ambient temperature. The pressure in the hydrostatic sterilizer is maintained by water columns, which is above atmospheric pressure and the temperature is more than 100^0C. The system is very tall since, to maintain 1 bar pressure 10 m of standing water is required. However, it does not require closed door system or any pressure accessories.

Hydrostatic sterilizer consists of 4 chambers viz. a) hydrostatic feed leg, b) sterilization chamber, c) hydrostatic discharge leg and d) cooling canal. Multiple chain conveyors are accommodated to feed the cans in the sterilizer. The residence time is maintained by the speed of the conveyor belt.

10.4 UHT Processing

UHT stands for *Ultra High Temperature*. The name implies, the food products are exposed to a very high temperature for a brief. It is a method of preserving liquid foods aimed to achieve a shelf life for months. The intensity of heating normally ranges between 135-150 ^{0}C and the exposure time between 2-4 seconds for liquid milk. UHT processing kills the microflora in foods which would otherwise destroy the products. UHT processed foods can be stored for upto 6 months if packed aseptically.

UHT treatment is a continuous process that is carried out in aseptic condition to avoid airborne contamination to foods. The product passes through heating and cooling section in quick succession. Aseptic filling and packing is done thereafter to avoid contamination.

There are two methods of UHT treatment generally adopted:

- Direct heating by steam injection or infusion
- Indirect heating and cooling in heat exchanger

10.4.1 Direct heating

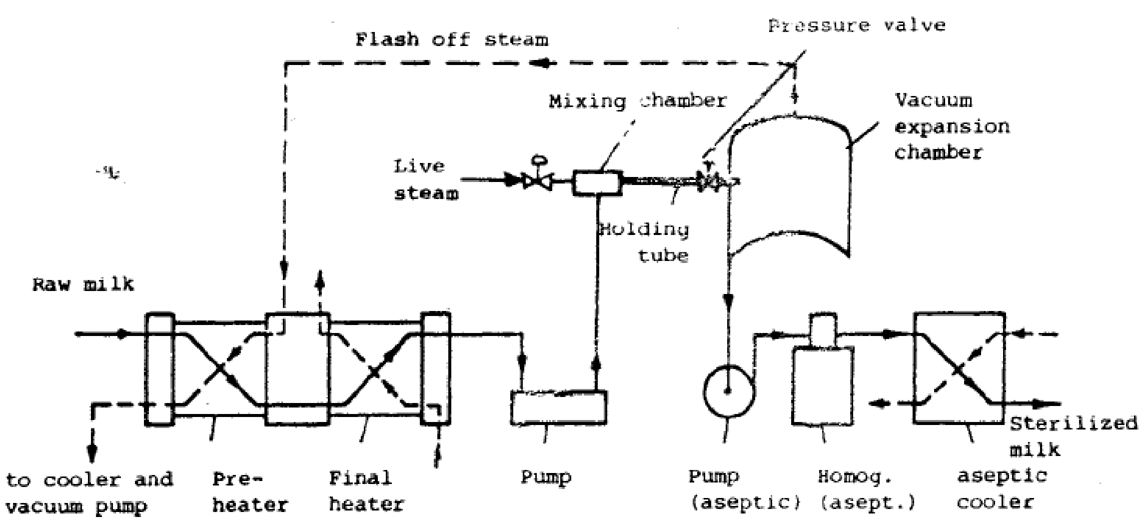

Fig.10.4 UHT heating with flash evaporation system (Courtesy: Kessler Inc.)

The fig.10.4 shown here is a direct heating method of UHT treatment of milk. Milk is preheated to around 80 ^{0}C. The milk is pumped to a mixing chamber where it is mixed with live steam. The pressure corresponds to UHT temperature required. The steam gets condensed by giving off the latent heat immediately after mixing with milk, thus heating the milk. Holding tube allows the mixture of milk and condensate to heat for 2-4 seconds. The mixture is then guided through a vacuum expansion chamber where exactly the same amount of condensate gets evaporated leaving behind the original amount of milk. The steam released in vacuum chamber is used to preheat the incoming milk for steam economy. The cold processed milk passes aseptically through pumps, homogenizer, cooler and aseptic tank, to aseptic packaging.

Another method of direct heating is milk *infusion* to live steam. The milk is allowed to pass through a steam pressure vessel where milk is heated to UHT temperature. Milk is fed in the form of film or in the form of fine droplets. Fine droplets allow faster heat transfer. There is no chance of over-heating of product. Other processing steps are same like steam injection system.

10.4.2 Indirect heating

Indirect method of UHT processing involves preheating, homogenization, UHT heating, holding, cooling and packaging. Plate heat exchanger is generally used to heat the milk. Shell and tube may also be used for this purpose. The homogenization step can be placed before or after UHT heating. If homogenization is done after heating, the process of homogenization must be of aseptic condition, thus increasing the cost. However, this prevents agglomeration of fat globules and prevents fat-protein or protein-protein interaction.

References

1. *Food Engineering and Dairy Technology* (1st Edition), H. G. Kessler, Verlag A Kessler Inc. Germany, Publ., 1981.
2. *Food Process Design*, Z.B. Maroulis and G.D. Saravacos, Marcel Dekker Inc. New York., Publ., 2003.