Chapter 7

Milk Pasteurization

Objective

Pasteurization is a heat treatment to destroy all pathogenic microorganisms present in the milk. This process makes milk safe to consume. This chapter deals with pasteurization process and equipment for pasteurization.

Introduction

The process of pasteurization was developed by French microbiologist *Louis Pasteur* in 1862. This process was used by *Louis* to prevent souring in the fermented beverages. This results in better shelf-life of the beverages.

Pasteurization is a thermal process of heating milk to a certain temperature, holding at that temperature for a specified period of time followed by rapid cooling. The purpose of pasteurization is to destroy pathogenic or disease causing microorganism. According to WHO definition "Pasteurization is a heat treatment aimed to reduce the number of harmful microorganisms in milk and cream to a level at which they do not constitute a significant health hazard". It is intended to result in an extended shelf-life of milk and in only minimal chemical, physical and organoleptic changes. Pasteurization conditions are designed to effectively destroy the organism *Mycobacterium tuberculosis*. Pasteurization of milk and cream results in a negative phosphatase reaction.

Difference Between Pasteurization and Sterilization

Pasteurization: Thermal process for destruction of pathogenic microorganisms

Sterilization: Sterilization is a more severe heat treatment designed to destroy all contaminating bacteria. It is generally done at high temperature than pasteurization.

Milk produced from healthy milch animals has low microbial count. During handling and transportation, milk may be contaminated by various microorganisms. Milk is good medium for growth of bacteria and other pathogenic microorganism because of its excellent nutrient profile (Table 7.1). Therefore milk must be thermally treated to make it safe for human consumption. Perishable nature of milk is due to the following factors:

a. Nutritional profile of milk

b. Warm temperatures due to tropical climate in India

c. Substantial contamination with microorganisms during milking, handling and transportation. Microorganism which can affect the storing quality of milk are:

- Bacteria
- Molds
- Yeasts
- Viruses

d. Prolonged time before cooling or processing. Therefore milk should be cooled to 4^o within 2 hours after milking.

Pasteurization of milk is required before packaging, distribution and marketing due to following reasons:

a. Health issues: Pasteurization as a thermal treatment makes milk safe for human consumption by destroying of pathogenic microorganism.

b. Food safety regulations: Food safety agency of many countries have made pasteurization compulsory for packaged milk (either in pouches or bottles).

c. To increase the keeping quality of milk: Shelf life of milk can be improved by destroying spoilage microorganism. Thermal treatment also deactivates enzymes like lipase present in milk, which causes fat breakdown in milk. Pasteurized milk is safe to drink for up to 5-20 days depending on the storage temperature. Shelf life of around 20 days can be achieved if pasteurized milk is continually refrigerated below 5^oC. Pasteurization improves the shelf life of milk and allow processed milk to be distributed and marketed to far off distances.

Table 7.1. Average composition of milk

Constituents	per 100 g	
	Cow Milk	Buffalo Milk
Water	86.6	84.2
Fat	4.6	6.5
Protein	3.4	3.9
Lactose (carbohydrate)	4.9	5.2
Ash	0.6	0.8

Pasteurization process may vary from country to country depending upon the regulations. Effective pasteurization of milk depends on the reliability of the time-temperature-pressure relationships. Microorganisms exhibit a range of temperature over which it can grow. Microorganisms can sustain certain maximum temperature but further rise in temperature will cause gradual destruction of microorganisms. The microbial destruction kinetics depends on the time-temperature combination employed for pasteurization.

Time-Temperature Combination for Pasteurization

Time temperature combination is very critical for the pasteurization process. The effect of time and temperature combination is different against the bacteria (Table 7.2). High temperature and prolonged heating is not recommended because of the following reasons:

- High temperature and prolonged heating causes cooked flavor which is undesirable to the consumers.
- Formation of creamline is undesirable.
- Physical and chemical changes should be minimum.

Milk pasteurization process was designed to provide a minimum temperature and time combination needed to inactivate the most heat-resistant, non-spore-forming, pathogenic microorganism. Initially the target organism was *Mycobacterium bovis* or *M. tuberculosis* responsible for tuberculosis. In early 1950s, the minimum pasteurization temperature was increased to destroy a slightly more heat-resistant organism *Coxiella burnetti*, responsible for Q-fever. Few regulatory agencies are planning to raise the required temperature of pasteurization to that now used in ultra-pasteurization for safeguard from more heat resistant bacteria. In case it happens in future, ultra pasteurization will be redefined as pasteurization.

To assess the adequacy of heat treatment during pasteurization, inactivation of Alkaline Phosphatase (ALP) enzyme is used as an indicator. The heat stability of ALP is greater than that of pathogens, the enzyme serves as an indicator of product safety.

Table 7.2. Time temperature combination for pasteurization and sterilization

Temperature	Time	Pasteurization Type
63°C	30 minutes	Batch Pasteurization
72°C	15 seconds	High Temperature Short Time Pasteurization (HTST)
89°C	1.0 second	Ultra Pasteurization (UP)
90°C	0.5 seconds	Ultra Pasteurization (UP)
94°C	0.1 seconds	Ultra Pasteurization (UP)
96°C	0.05 seconds	Ultra Pasteurization (UP)
100°C	0.01 seconds	Ultra Pasteurization (UP)
138°C	2.0 seconds	Ultra-high temperature (UHT) Sterilization

Methods

a. Batch Method (LTLT)

In Low Temperature Long Time (LTLT) method, milk is heated to 63°C in a jacketed tank or vat with agitator. Milk in the vat is heated using hot water or steam. At 63°C temperature, milk is held for 30 minutes and is allowed to cool. This method is used for processing milk upto 5000 liters.

b. Continuous (HTST)

High Temperature-Short Time (HTST) pasteurization is the most widely used method for commercial processing of milk. Milk is heated to a temperature of at least 72°C and is kept at that temperature for not less than 15 seconds. Milk is then immediately cooled to a temperature of less than 4°C.

Equipment

HTST pasteurization involves heating of milk at least 72°C and holding it for 15 sec. Plate heat exchanger (PHE) are used for milk pasteurization. PHE uses stainless steel plates (SS-316) to transfer heat between milk and heating/cooling medium.

In PHE, fluids are exposed to a much larger surface area over the plates resulting in higher heat transfer compared to conventional heat exchangers. It has a very high heat transfer coefficient on both sides of plates and are cost effective, easy to maintain and compact in design.

Plate Heat Exchangers

Stainless steel plates (Fig.7.2) are used in a plate heat exchanger to transfer heat between two fluids. Gap between the plates are 3-6 mm wide through which hot and cold fluids are

Fig.7.1. Plate heat exchanger

flown alternately (Fig.7.3). Plates of the heat exchanger provide a large surface area for heat transfer and are corrugated to cause turbulence in the flow. The fluids spread over the plates in the form of thin film. Due to large surface area and turbulence in flow, the rate of heat transfer is very high compared to other heat exchangers. Heat transfer from the hot to cold fluid is rapid and there is a quick rise in temperature of cold fluid.

Fig.7.2. Stainless steel plate used in plate heat exchanger (Source: Wikipedia)

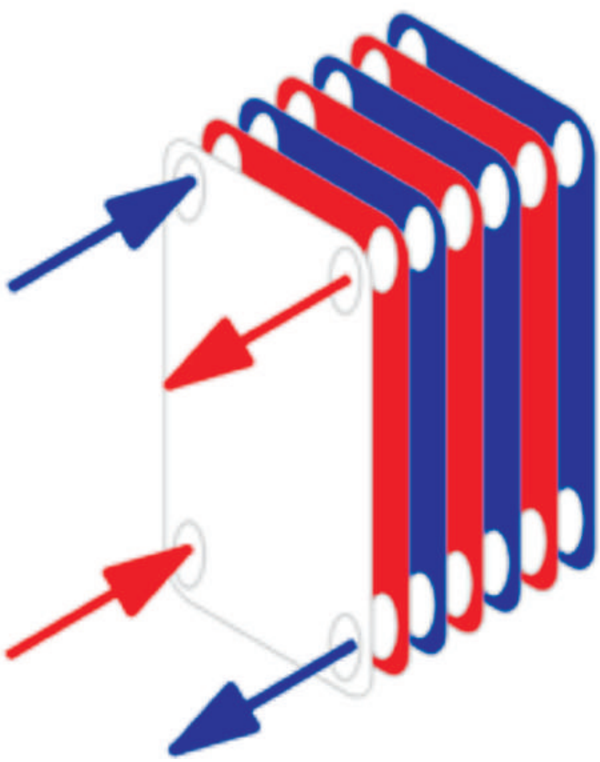


Fig.7.3. Flow arrangement of hot and cold fluid in a plate heat exchanger (Source: Wikipedia)

HTST Pasteurizer

Pasteurizer is the most important equipment for fluid milk processing (Fig.7.4). The different sections and components in HTST pasteurizer are shown in Fig.7.5. There are four main sections in a HTST pasteurizer: a. Regeneration, b. heating, c. holding d. chilling.

Fig.7.4. HTST pasteurizer

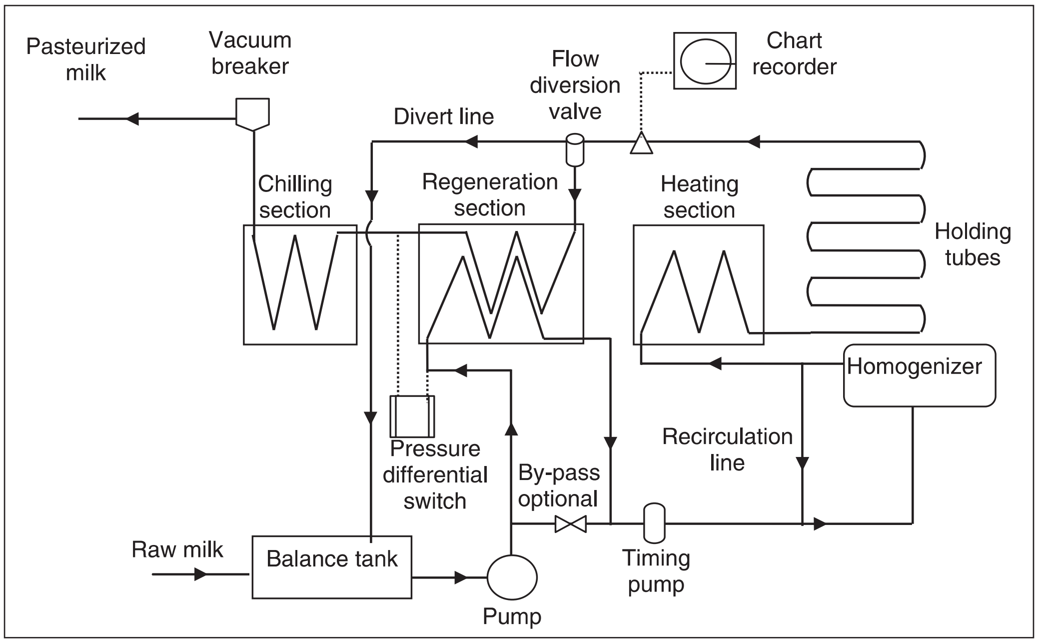


Fig.7.5. Components of a HTST pasteurizer

Construction of HTST Pasteurizer

i. Regenerative Heating

Raw milk at 4°C in the constant level balance tank (Fig.7.6) is pumped into the regeneration section of pasteurizer. Incoming milk is pre-heated to approximately 55 to 68°C by heat given up by hot pasteurized milk flowing in a counter current direction on the opposite sides of the plates. A positive displacement timing pump delivers milk to the rest of the HTST system under positive pressure.

Fig.7.6. Milk balance tank and feed pump

ii. Heating

In heating section raw milk is heated upto 72 °C by hot water (flow rate : 1:1.2 times of milk) on opposite sides of the plates.

iii. Holding

Milk is kept at 72°C for 15 sec, this is known as holding. Holding of milk can be in a chamber in the heat exchanger or in an external tube. External tube holding is generally preferred for milk pasteurization. Milk is flown through this holding tube (Fig.7.7) and is kept for at least 15 sec. The maximum velocity of milk in the holding tube depends on:

a. The speed/flowrate of the timing pump

b. Length and diameter of the holding tube

c. Friction factor of the internal surface of tube

Fig.7.7. Holding tubes

iv. Flow Diversion Valve (FDV)

A temperature sensor is located at the end of the holding tube and before the flow diversion valve (FDV). A FDV is shown in Fig.7.8. The temperature sensor sends the signal to the recorder-controller. The temperature of the milk is continuously recorded on a chart recorder by a pen plotter (Fig.7.9).

Fig.7.8. Flow diversion valve (FDV)

The FDV is in diverted flow position if the milk temperature is <72°C. If heat treatment is not adequate for pasteurization and milk temperature is <72°C, milk returns to the balance tank through divert line. The FDV switches to forward flow position if the milk temperature is more than preset cut-in temperature (>72°C).

v. Regenerative Cooling

Milk flows to the regeneration section where it is cooled at the temperature between 32 to 10°C by the incoming cold milk.

vi. Chilling

The warm milk is cooled to 4°C or below by chilled water (flow rate: 1:2 times of milk).

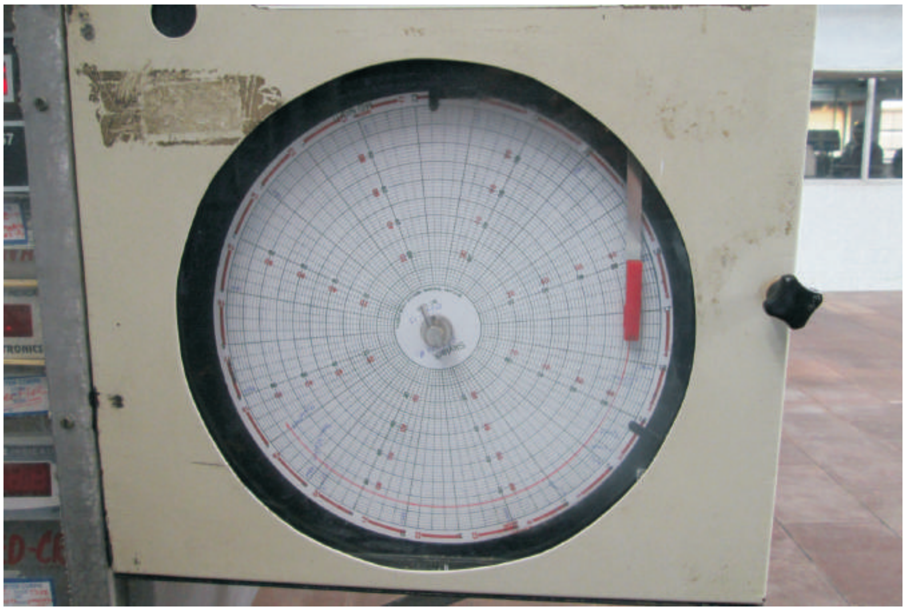


Fig.7.9. Chart recorder for temperature

vii. Vacuum Breaker

After chilling, pasteurized milk passes through a vacuum breaker which is at least 30 cm above the highest milk line in the HTST system and then to Pasteurized Milk Storage Tank (PMST).

viii. Pressure Differential Switch

The pressure difference between the incoming raw milk line and pasteurized milk line (at regeneration exit) is continuously monitored by pressure differential switch. A chart recorder is provided to record pressure difference. Pasteurized milk is kept at a pressure of 1 psi (pound per square inch) more than raw milk in regeneration section. This is done to prevent contamination of pasteurized milk with raw milk if any pin hole leak develops in thin plates. The pressure difference is maintained by:

a. For simple system: using timing pump

b. For complex system: differential pressure controllers and back pressure flow regulators at the chilling section outlet.

Regeneration Efficiency

The heating and the cooling regeneration features of the HTST unit offer important efficiencies by conserving heat, refrigeration, space, and time requirements. In regeneration section of the pasteurizer the incoming chilled raw milk at 4°C is heated by the outgoing pasteurized milk at 72°C. The advantages of regeneration are:

- Requirement of heat energy or steam gets reduced for heating of raw chilled milk.
- After pasteurization milk has to be chilled to 4°C for packaging. Pasteurized hot milk at 72°C is cooled first by raw milk and is further cooled to 4°C by chilled water. Thus the process of regeneration reduces the required of chilled water.
- Regeneration is done using plate heat exchanger (PHE). Another major advantage of using PHE for pasteurization is that heating, cooling and regeneration section are formed by segmenting plates of the PHE. Thus, such an arrangement eliminates the requirement of different heat exchangers and saves space.

Regeneration efficiency is a measure of heat recovered from the pasteurized hot milk by the incoming raw cold milk. It is calculated as:

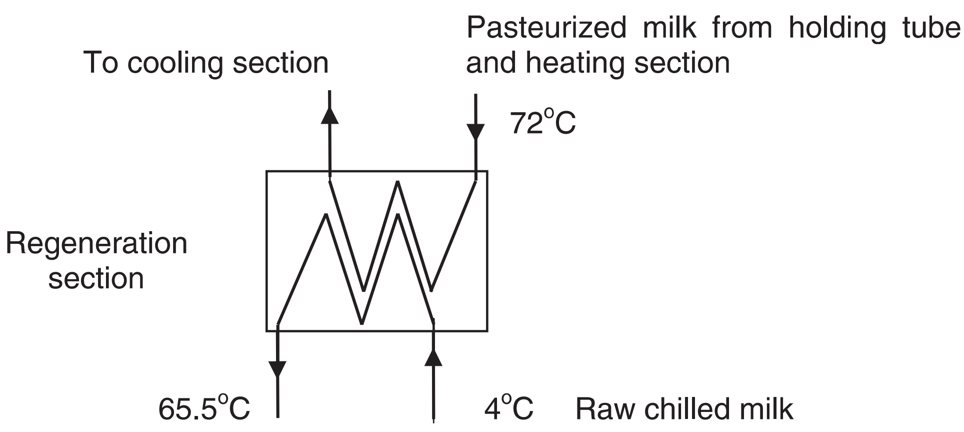
Regeneration efficiency $\eta = \frac{T_{or} - T_c}{T_h - T_c} \times 100$

T_{or} = Temperature of heated raw milk at regeneration outlet

T_h = Temperature of hot pasteurized milk

T_c = Temperature of incoming raw chilled milk

Numerical: According to the data provided in fig 7.5, calculate the regeneration efficiency of the pasteurizer.



Regeneration efficiency $\eta = \frac{65.5 - 4}{72 - 4} \times 100 = 90.44\%$

Phosphatase Test

Phosphatase test is used to determine the effectiveness of the pasteurization process. Alkaline phosphatase is a heat sensitive enzyme present in raw milk and is inactivated by pasteurization. The destruction kinetics of phosphatase enzyme and *Mycobacteriun tuberculosis* are almost the same. If any time-temperature combination results in inactivation of phosphate enzyme, it also indicates that the most heat resistant pathogen *Mycobacteriun tuberculosis* present in milk has been destroyed. Active phosphatase will be present in larger amounts than found in properly pasteurized milk if:

- Milk is contaminated with raw product.
- Milk is not held at the proper temperature (72^{o}C) for sufficient time (15 s).

If the concentration of phophatase enzyme is more than 4 ìg/litres in pasteurized milk, it means that milk is not pasteurized properly. The possible causes for positive phophatase test are:

1. Faulty operation of FDV
2. Pasteurization temperature is not set at 71.7^{o}C or above.
3. Cracks, pinholes on the plates of the heat exchanger.
4. Leaks in the valve seat of FDV.
5. Heated milk is not held for 15 s in the holding tubes.

REVIEW QUESTIONS

1. What is the purpose of pasteurization?
2. Briefly describe principle of pasteurization.
3. Briefly explain time temperature combination for pasteurization.
4. What is regeneration efficiency?
5. What is the purpose of holding tubes?
6. What is the function of flow diversion valve?
7. Write about phosphatise test.