UNIT 5 PASTEURIZATION

Structure

5.0 OBJECTIVES

After studying this unit, we should be able to:

- define and give the reasons for pasteurizing the milk
- explain the theory of pasteurization
- list important parts of a pasteurizer
- describe the procedure of operating a pasteurizer.

5.1 INTRODUCTION

Pasteurization is a key process in modern dairy plant operations and forms an integral part of manufacturing of various indigenous and western dairy products. Milk is a perfect medium for growth of micro-organisms, and growth of pathogenic organisms can cause diseases such as tuberculosis and typhus. Pasteurization kills the organisms responsible for spread of diseases through milk and makes it safe for consumption.

The word ‘pasteurization’ has been named after an eminent French scientist, Louis

Pasteur. In general terms it is heating milk or its products to such temperature, which destroys nearly all the microorganisms, present in it without affecting the composition or properties of the product. Thus it is important to monitor the pasteurization process as improperly/under pasteurized milk can cause the infection. This unit will give us working knowledge of pasteurization process. Let us understand the process.

5.2 DEFINITION AND PURPOSE OF PASTEURIZATION

Fresh milk produced from healthy milch animals generally contains minimum load of microorganisms. In the course of handling at the farm, milk is liable to be contaminated by various microorganisms mainly bacteria. Rapid chilling to below 4°C temperature slows down the growth of microorganisms in the milk. Milk must be treated by an established process so that all pathogenic microorganisms are killed before it is consumed as fluid milk. This is achieved by heat treatment. Pasteurization is one of the most important heat treatment processes. The term as applied to market milk refers to the process of heating every particle of milk to a temperature of at least 63°C (145.4°F) for 30 minutes or 71.7°C (161°F) for 15 seconds (or to the temp-time combination which is equally efficient) in properly designed equipment. Milk is immediately cooled to 4°C and stored in cold storage maintained at 4°±1°C.

As per definition of International Dairy Federation (IDF) "Pasteurization is a process applied to a product with an objective of minimizing possible health hazard arising from pathogenic microorganisms associated with milk by heat treatment, which is consistent with minimal chemical, physical and organoleptic changes in the product" The heat treatments suggested by the IDF for the pasteurization of milk are 15 seconds at 71.7°C=161°F or 30 minutes at 62.8°C=145°F can be regarded as "universal" reference treatments. Three aspects emerging from the definition are: (i) level and degree of heat treatment, (ii) minimum chemical, physical and organoleptic changes, and (iii) minimum health hazards. These are elaborated here.

i. Time-Temperature Combination

The time-temperature combinations normally used for pasteurization of fluid milk are as follows:

- 63°C (145.4°F) and held at that temperature for at least 30 minutes
- 72°C (161.6°F) and held at that temperature for at least 15 seconds.

The milk is then immediately cooled to a temperature not greater than 4°C. The selected heat treatment shall be applied only once. This means pasteurization includes heating to a specific time-temperature combination followed by immediate cooling to 4°C.

ii. Purpose

Milk is pasteurized for two purposes:

- To make safe for human consumption by destroying pathogenic microorganisms present in milk.
- To improve its keeping quality.

The most heat resistant pathogenic organism at pasteurization temperature is the Mycobacterium tuberculosis and hence this has been made as an index organism to achieve complete safety of milk. Any heat treatment, which will destroy this organism, can be relied upon to destroy all other pathogenic organisms as well as other organisms involved in milk spoilage. Some bacteria, call thermodurics (heat resisting) may survive during pasteurization but immediately cooling slows down their growth and thus prevents them causing spoilage such as flavour taint or souring. Although, the main purpose of heat treatment is to destroy all microorganisms capable of causing disease in humans but pasteurization has two additional benefits, i.e. the destruction of a large number of spoilage microorganisms present in raw milk and deactivation of some natural enzymes like lipases, which can adversely affect the quality of manufactured products, i.e. lipolysis or breakdown of fat into glycerol and free fatty acid. However, we must be clear that pasteurization is not a substitute for cleanliness during milk production. The pasteurization process should only be applied to raw milk obtained from healthy cow, which is clean, sweet and has a low bacterial count.

Check Your Progress 1

1. Give two reasons for pasteurizing the milk.

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2. Describe the time-temperature combination normally used for milk pasteurization.

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5.3 THEORY OF PASTEURIZATION

We have understood that heating milk to selected time-temperature combination effectuates pasteurization to ensure destruction of all pathogenic microorganisms. Theoretically, aspect of pasteurization is "the heat treatment applied to the milk to destroy pathogenic organisms". The process parameters of heat treatment or time-temperature combinations are elaborated below: (a) Limiting factors for heat treatment and (b) Types of heat treatment.

i. Limiting Factors for Heat Treatment

The upper and lower limits of temperature to pasteurization process are based on thermal death point of tubercle bacilli and beginning of reduction of the cream line. The thermal death time for tubercle bacilli provides the lower limit to heat treatment. The adverse effects on the commercial quality milk provide an upper limit for the possible time- temperature combinations used in pasteurization. As the cream line is the first quality to be affected, it is generally used as the standard indicator of changes in the chemical, biological and physical properties of milk caused by over heating.

In the early 1920's, North and Park performed extensive tests by heating milk samples containing tubercle bacilli at different time-temperature combinations that destroyed all the tubercle bacilli present in them. The time-temperature combinations that destroy all tubercle bacilli are taken as thermal death points. Table 5.1 shows a number of thermal death points for tubercle bacilli.

Table 5.1: Thermal Death Points for Tubercle Bacilli

Temperature		Time
°C	**°F**	
100.0	212	10 seconds

93.3	200	20 seconds
82.2	180	20 seconds
76.7	170	20 seconds
71.1	160	20 seconds
68.2	155	30 seconds
65.6	150	2 minutes
62.8	145	6 minutes
61.1	142	10 minutes
60.0	140	10 minutes
57.8	136	30 minutes
55.6	132	60 minutes

These thermal death points can also be plotted on a graph to give a thermal death line.

Safety margin: This is the additional amount of heat treatment (time and temperature above the thermal death point of the tubercle bacillus) so that, under no circumstances, will any tubercle bacilli be left alive after correct routine operation of a pasteurizer. Certainly, a more intense heat treatment would obtain more efficient antibacterial results than pasteurization. On the other hand, the milk is not inert to heating; over-heating adversely affects the appearance, taste, nutritional and technological value of milk. Combination of higher temperature and longer holding time-temperature are also recommended for HTST pasteurization of dairy products having higher contents of solids.

ii. Types of Heat Treatment

The heat treatment given in form of (i) holding and (ii) continuous correspondingly relate with two methods of pasteurization i.e.

- Batch, holding or Low Temperature Long Time (LTLT) method and
- Continuous, High Temperature Short Time (HTST) method.

In the batch method, the milk is heated to 63°C in a tank or vat equipped with a hot water or steam jacket and agitators to keep the milk agitated; held for 30 minutes and then partly cooled in the batch pasteurizer. The further cooling is done by surface/plate cooler. This method is mostly used for processing of around 5000 liters of milk.

High Temperature-Short Time (HTST) pasteurization is the process, which is commonly used now a day all over the world. Plate Heat Exchanger (PHE) is used to heat, hold and cool the milk. Milk is heated to a temperature of at least 72°C and held at that temperature for not less than 15 seconds and then immediately cooled to a temperature not greater than 4°C.

Check Your Progress 2

1. What are the different methods of pasteurization?

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2. Enumerate the temperature–time combination for the two methods of pasteurization.

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5.4 BATCH PASTEURIZER

The parts of a typical batch pasteurizer are following:

- Insulated outer casing
- Insulated hinged cover
- Stainless steel inner vessel
- Agitator and its motor
- Outlet cock and heating water distribution pipe.

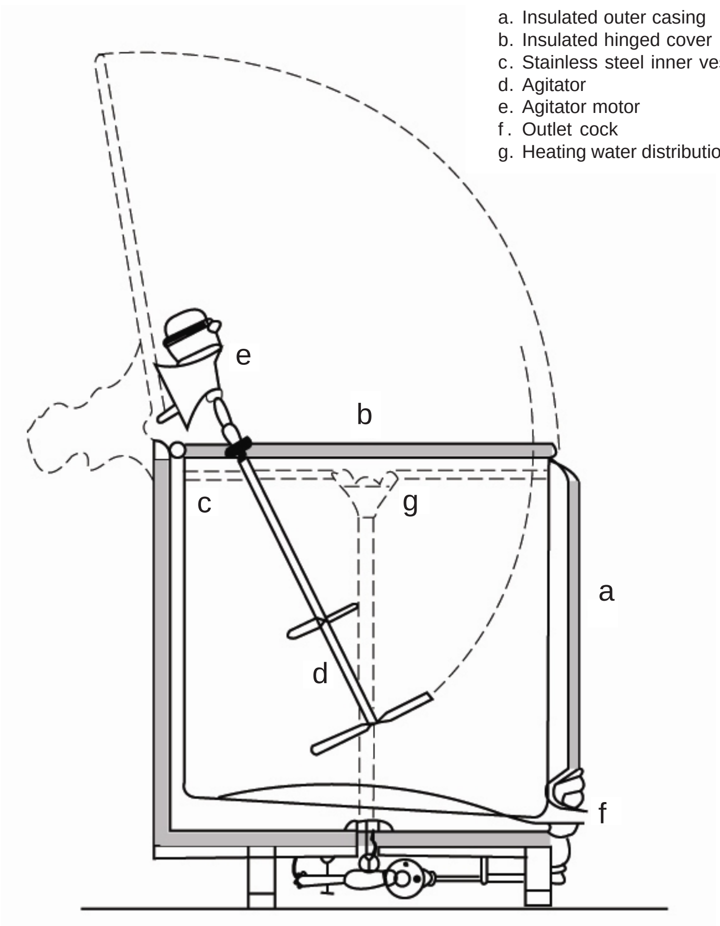

Figure 5.1: Batch Pasteurizer

This system is well suited for small-scale operation, where less than 3000 to 5000 litres of milk are available. The vat may be rectangular, but a vertical, cylindrical design is preferred for practical reasons. The vat normally consists of an inner vessel, surrounded by an insulated outer casting, thus forming a jacket, through which hot water or steam is passed (Figure 5.1). After the milk has reached the required temperature (63.0°C), it is usually held at that temperature for a certain fixed period (30 minutes). Thereafter, it is cooled as quickly as possible either by circulating refrigerant/chilled water or through plate/surface chiller. Cooling the milk after pasteurization by circulating a refrigerant – in most cases cold water –

through the jacket or the vat may take much time. Therefore, a separate small-capacity surface, tubular or plate cooler may be used to rapidly cool the milk to the required temperature. This system also has the advantage that the vat will be available sooner for the pasteurization of another batch of milk.

Batch pasteurizers have a small heating surface area relative to their contents. Heat transfer is greatly improved by agitating the milk. Agitators of different design are used for this purpose. They may even consist of double-walled paddles or other devices with internal steam or water circulation. Care must be taken to avoid foam formation during filling of vat. It is very difficult to heat the milk and foam together uniformly and consequently microorganisms present in the foam may survive pasteurization. If the inlet valve is at the bottom of the vat, foam formation can easily be prevented. A lid or cover on top of the vat promotes a uniform temperature of the contents and prevents skin formation on the milk.

5.5 HTST PASTEURIZER PLANT AND ITS COMPONENTS

The HTST system is the most common method used by the dairy plants for pasteurization of milk. The main advantage of HTST pasteurization is its capacity to heat treat milk quickly and adequately with built-in safeguards that prevent improper pasteurization due to under heating of milk. The HTST system employs plate heat exchangers for heating, regeneration and cooling. The system consists of feed pump, plate heat exchanger, holding section, flow diversion valve, instrumentation, essential services and piping system. The entire process is automatic and is ideal for handling of 5000 litres per hour (lph) or higher quantity of milk. This is a continuous flow process and also saves energy due to regeneration section (Figure 5.2). In order to understand a pasteurizer let us go systematically for:

Figure 5.2: Flow diagram of high temperature short time pasteurizer (H.T.S.T.)

- Flow diagram of process;
- Different compartments/sections;
- Plate heat exchanger, which is the main part; and
- Instrumentation

i. Flow diagram of pasteurization process

The schematic flow diagram of HTST pasteurization is given in Figure 5.3.

Raw milk enters the constant heat tank (balance tank), passes to the milk pump and then through a flow controller to the plate heat exchanger. The plate heat exchanger consists of regeneration section, heating, holding and cooling sections.

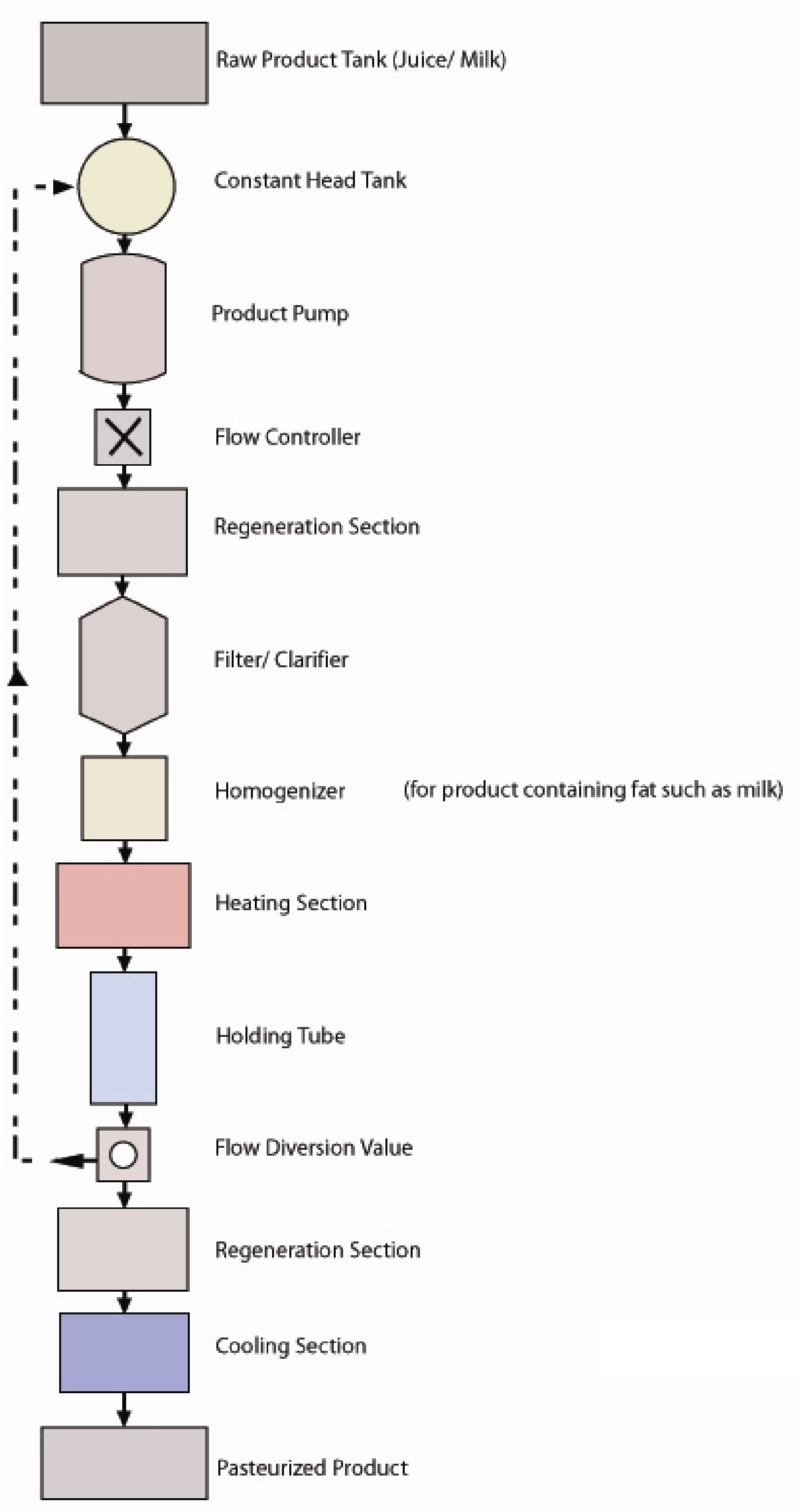

Figure 5.3: Flow Diagram of Pasteurization

The raw milk enters the pre-heating (regeneration section), where hot pasteurized milk (72°C) flows counter current to the raw cold milk, within adjacent plates, transferring heat for pre-heating of raw milk and pre-cooling of pasteurizing milk resulting in energy saving. The partially heated raw milk passes through a filter or clarifier and homogenizer. It then enters the heating section where it is heated to at least 72°C. The hot milk then passes through the holding section to ensure that the fastest moving particles of milk are held at 72°C for at least 15 seconds.

The flow diversion valve diverts the milk to constant head tank if it is not properly heated to pasteurization temperature. Properly pasteurized milk passes forward through the flow diversion valve into the regeneration section where it is cooled by incoming cold raw milk passing in the opposite direction on the other side of the plates. Milk enters the cooling section and is cooled at 4°C before storage.

An indicating thermometer situated at the outlet of the holding section measures the temperature of the hot milk and this is recorded on a revolving thermograph. If the temperature of the milk falls below 72°C, the hot milk-recording pen drops past the set pointer on the thermograph and this activates the flow diversion value, the safe-guard pen and an alarm bell. The flow diversion valve diverts the unheated milk into the constant head tank for re-circulation until the milk reaches the correcting temperature.

ii. Components of a HTST Pasteurization Plant

The complete pasteurizer plant consist of:

- Constant head tank
- Milk feed pump
- Flow controller
- Filters
- Clarifier
- Homogenizer
- Plate heat exchanger consisting of bank of plates compartmentalized into regeneration, heating, holding and cooling sections,
- Flow diversion valve
- Instruments associated with indicating controlling and/or recorded functions,
- Systems for providing steam, air, water, heating and cooling arrangements, and
- Piping system to link various components

iii. Plate Heat Exchanger (PHE)

The Plate Heat Exchanger consists of a bank of plates inter-connected (sections) held in a rigid frame (figure 5.4). The main function of the PHE is the exchange or transfer of heat from a hot liquid (hot water or hot pasteurized milk) to a cooler one (cold water, chilled water brine or raw milk) across a metal plate. Let us see how the heat is transferred through plates.

Plates: The plates are thin stainless steel sheets usually rectangular in shape. The plates are corrugated and cause a turbulent flow, which increases rate of heat exchange. The rate of heat exchange also depends on the surface area of the plate, the thickness and type of metal used in the plates, the rate and direction of flow of the liquids and the difference in temperature between the two liquids involved in the heat exchange process.

An approximate 3-8 mm space is maintained between the plates by a non-absorbent rubber seal, which is bonded around the edges of the plate. The liquids, which are sandwiched among the plates, enter and leave the interspaces through holes in the corners of the plates. Open and blind holes route the liquids from one set of plates

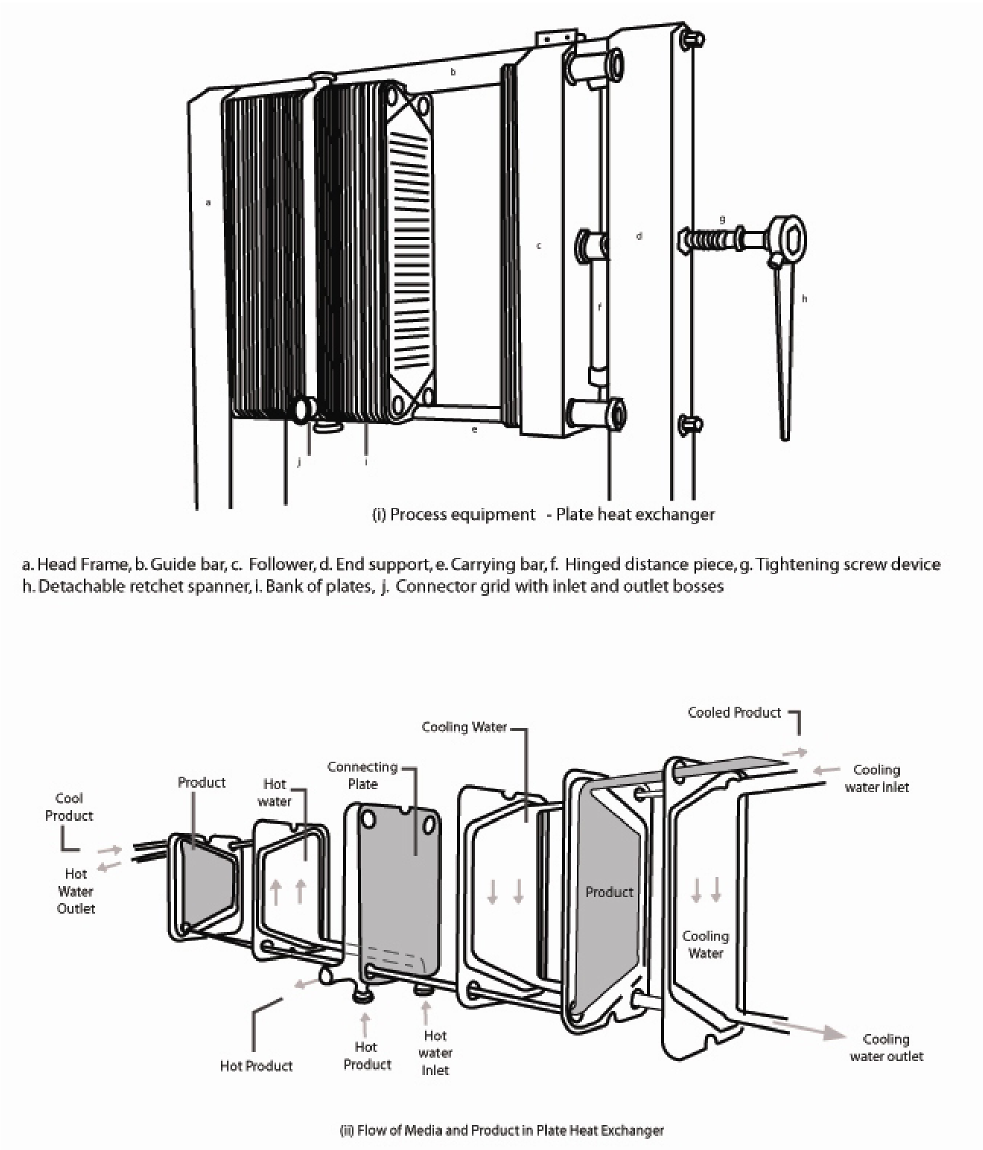

Figure 5.4: Plate Heat Exchanger

to another. The capacity of the pasteurizer is secured by a corresponding number of plates.

Regeneration sections: The bank of plates is usually divided into four sections separated by connector grids with inlet and outlet bosses. In the regeneration section, the incoming cold milk is heated by the hot pasteurized milk and the pasteurized milk is cooled by transferring heat to the cooling medium. This heat transfers process work most effectively when the two liquids involved flow in opposite direction, i.e. counter current flow on either side of the plates. Regeneration section raises the raw milk temperature from 4°C to 67°C and cools the pasteurized milk from 72°C to 10°C. Thus, PHE saves about 92% of heating and cooling energy. The regeneration efficiency is calculated by using the following formula:

% Regeneration = temperature increase due to regeneration/ total temperature increase

For example: The cold milk enters the pasteurizer at 4°C and attains a temperature of 60°C after regeneration. The final pasteurization temperature is 72°C. Calculate the regeneration efficiency.

Increase in Temperature due to regeneration: 60^0C-4^0C=56^0C

Total Temperature Increase: 72^0C-4^0C= 68^0C

% Regeneration efficiency: 56^0C/68^0C = 82.36%

Steam-heated hot water or vacuum steam is used in heating section to raise the partly heated raw milk to pasteurization temperature. The holding section is either plate type or tube type. The plate type will have a number of plates. The partly cooled pasteurized milk is further cooled in cooling section to 4°C.

iv. Instrumentation

The instruments associated with the pasteurization plant are used for performing three functions (Table 5.2).

Table 5.2: Instruments associated with pasteurizer and their functions

S.No.	Type of Instrument	Function(s)
1.	Indicating	Temperature (Milk, hot water, Chilled water), Steam & air pressure
2.	Controlling	Operating the flow diversion valve, operating the steam regulating valve in the heating system
3.	Recording functions	Recording the hot and cold milk temperatures and recording the frequency and duration of diversions

Check Your Progress 3

1. Describe the constructional and operational details of a batch pasteurizer.

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2. Describe the steps involved in the operation of a milk pasteurizer (HTST).

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5.6 OPERATION OF PASTEURIZATION PLANT

We have studied the importance of pasteurization process and the important components of a pasteurization plant. Now let us see the operations involved in running of a pasteurization plant and how to cope with operational problems.

i. Starting the Plant

The following steps should be followed to start the plant:

a) Start the air compressor;
b) Switch on the control panel mains;
c) Fill the hot water tank, start the hot water pump;
d) Open the air vents
e) Start flow of the milk to the float controlled balance tank
f) Start the milk pump
g) Close the air vents when the milk coming out from them indicates that all air has been displaced.

h) Set the temperature controller to maintain the milk at 72°C.
i) Turn on cold water and chilled water and hot water set.

ii. Shut down of the Plant

For shutting down the plant, at the end of the milk run:

a) Make available in the storage tank a sufficient quantity of water (approx. equal to the capacity of the plant).
b) As the last milk is leaving the float balance tank, tip in the water from the tank.
c) When the last of the water is leaving the float balance, turn the three-way cock at the finished milk outlet so that the flow is diverted to the floor.
d) Place a hose in the float balance tank and flush the plant thoroughly with water until the discharge from the finished milk outlet becomes clear.
e) Turn off the cold water, brine or chilled water in the cooling sections.
f) Shut off the steam supply to the hot water set.
g) Admit cold water to the hot water tank and run until the plant is cold.
h) Stop the milk and hot water pumps.
i) If brine is used, flush out with running water.
j) Turn off the air supply and the main electric switch at the panel.

Thereafter, the plant must be thoroughly cleaned.

iii. Cleaning and Sterilization of the Plant

- **Cleaning the plant**: Cleaning is done after completion of pasteurization process. The milk supply is stopped to constant head tank by turning off the valve of Raw Milk Storage Tank. Clarifier and homogenizer are stopped. The water is added to the constant head tank. Hot water temperature is set at 70°C. Primary detergent solution is circulated for 20-30 minutes. Flush the system with lukewarm water. Secondary detergent solution is circulated for 20-30 minutes. Flush the plant with water.
- **Sterilization**: The plant can be sterilized by hot water or sodium hypochlorite solution. The raw milk tank and pasteurized milk tank are bypassed and hot water (87-90°C) is circulated for 10 minutes. The sterilization is done before running the plant with milk for pasteurization.

iv. Pasteurization of milk

The operation of plant with the milk is called running of the plant. The plant is started. It is sterilized. The plant is run on water. The standardization is done to check the flow, operation of flow diversion valve, heating temperature and cooling temperature. The homogenizer pressure is also set in according to requirements. The flow of milk from raw milk tank to pasteurized milk tank is monitored.

v. Trouble shooting

Pasteurizing problems may occur during start up procedures or during the run. When a problem occurs it is important to be able to identify the problems from the symptoms, identify the cause of the problem and take the appropriate action towards solving the problem. If the problem causes a delay in processing it is advisable to turn off essential services such as steam and heating and cooling system to prevent burn on in the heating section and a freeze up in the cooling system. The common problems and their remedial measures are given in practical exercises. These could be grouped in three broad areas: (i) inadequacy in achieving temperature, (ii) chocking of plates and (iii) leaking plant assembly. The broad reasons for these are given here.

(i) **Inadequacy in achieving temperature :** The possible reasons are: inadequate steam supply, faulty temperature controllers, air in milk and improper assembly of plates.

(ii) **Chocking of plates :** Fouling, high milk temperature, high milk acidity and inadequate filtering of milk could be the reasons for chocking of the plant.

(iii) **Leaking plant assembly :** The reasons are: damaged and worn gaskets, damaged plates and wrongly fitted plates.

vi. Preventive maintenance

Preventive maintenance will help to control damage, excessive wear and tear and occurrence of accidents. Preventive maintenance can be divided into two areas, (i) avoiding damage to the plant and equipment and (ii) observations and inspection of plant and equipment. Avoiding damage consists of basically the careful handling of machinery and equipment. The regular inspection of the plant and equipment is important as a part of preventive maintenance, and may include:

a) Periodical tests may be made to check the flow rates of heating medium, cooling medium and milk.

b) The recording instruments such as thermometers, etc must be periodically checked for accuracy.

c) Air operated instruments should be supplied with clean air.

d) The plate surfaces and gaskets must be checked during the manual cleaning of plants.

e) Filter cloth/filters must be changed at regular intervals.

f) The faces of the plate bar and tightening spindle should be lightly coated with grease.

5.7 TEST FOR PASTEURIZATION EFFICIENCY

Phosphatase Test: Phosphatase test is done to determine whether milk has been properly pasteurized or not immediately after pasteurization of milk. The test is based on the principle that alkaline phosphatase, a natural enzyme present in raw milk, is simultaneously deactivated by heat treatment as specified for pasteurization. When milk-containing phosphatase is incubated with p-nitro phenyl di-sodium ortho phosphate, it hydrolyses the substrate and, as a result, para-nitro phenol is liberated which gives a yellow colour under alkaline condition of the test. The amount of the yellow colour present is directly proportional to the amount of phosphatase present in milk. The presence of yellow colour indicates inefficient pasteurization or post-pasteurization contamination of the milk. The intensity of the colour is compared with standard and lavibond comparator disc.

Check Your Progress 4

1. Name two methods for sterilizing the pasteurizer.

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2. Write the importance of phosphtase test.

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5.8 LET US SUM UP

Pasteurization is a key process in dairy plant operations in which heat treatment is given to milk to destroy all pathogenic bacteria. It extends the keeping quality of liquid milk by destroying most of the milk spoilage organisms. It safeguards public health and ensures good quality manufactured products. There are two methods of pasteurization of milk (i) Low Temperature Long Time (LTLT) method and (ii) High Temperature Short Time Method (HTST). LTLT method is used in dairy processing less than 5000 litres of milk. The most commonly method adopted consists of heating the milk in continuous flow to a minimum temperature of 72°C and maintaining it at this temperature for not less than 15 seconds after which the milk is rapidly cooled to 4°C. This is known as the High Temperature Short Time (HTST) process. The principal item of equipment required for HTST pasteurization is a Plate Heat Exchanger (PHE) and usually this is of the plate type. The main function of the PHE is to exchange or transfer of heat from a hot liquid to a cooler one. The bank of plates is grouped into different sections called as Regeneration, Heating and Cooling Section. The holding section can be either plate type or tube type.

Raw milk enters into Plant Heat exchange of the plate heat exchanger and its temperature is increased from 4°C to 67°C. The heated raw milk is further heated in heating section upto 72°C and kept for 15 seconds and then pass through Flow Diversion Valve (FDV) and milk is forwarded to regeneration section where properly pasteurized milk is cooled from 72°C to 10°C. The cooled milk enters the chilling section and is further cooled to 4°C. The pasteurization plant is equipped with instruments to indicate and control the temperature and also to performed the other related functions for efficient pasteurization of milk.

Different operations like starting, sterilizing, cleaning and running of the plant should be done in a correct way and the standardized procedure/steps should be followed as specified by the manufacturer of the plant.

The periodic inspection of the different components of the plant is essential to ensure it's proper functioning and trouble free service.

5.9 KEY WORDS

Corrugated	:	bent into regular curves, folds or grooves
Taint	:	objectionable foreign flavour
Thermal	:	determined, measured or operated by heat
Thermograph	:	a self-registering thermometer
Turbulence	:	violent commotion
Valve	:	a dense attached to a pipe to control the passage of air, steam or gas
Organoleptic	:	sensory properties flavour (smell & taste), colour and texture
Pathogen	:	an agent that causes diseases.

5.10 SOME USEFUL BOOKS

Dairy Handbook. (1985). Alfa-Laval, Food Eng AB, PO Box 64, Lund, S-22100, Sweden.

De, Sukumar. (1980). Outlines of Dairy Technology, Oxford University Press Bombay

ICAR. (2002). Handbook of Animal Husbandry, Third Revised Edition – New

Delhi Chapter on Dairying contributed by B. N. Mathur & D. K. Thompkinson

Khan M. E. (1998) Milk Processing, Dairy Technology Textbook for Class XI. NCERT, Delhi.

NDDB. (1980). Milk Processing Manual, NDDB, PO Box – 40, Anand

Manual for Milk Pasteurizer Operators. Victoria Milk Distribution Association.

5.11 ANSWERS TO CHECK YOUR PROGRESS

Your answer should include the following points:

Check Your Progress 1

1) i. To make safe for human consumption by destroying pathogenic microorganisms present in milk.

   ii. To improve the keeping quality of milk.

Check Your Progress 2

2) i. Batch, holding or Low Temperature Long Time (LTLT):63°C for 30 minutes.

   ii. Continuous, High Temperature Short Time (HTST): 72° C for 15 seconds.

Check Your Progress 3

3) i. The components of a pasteurization plant: milk feed pump, constant head tank, flow controller, plate heat exchanger, filter, clarifier, homogenizer, flow diversion valve, instruments to record temperatures, systems for heating and cooling and piping system.

Check Your Progress 4

4) i. Two methods are (i) Hot water sterilization, and (ii) Sodium hypo chloride sterilization.

   ii. Phosphatase test is done to determine whether milk has been properly pasteurized or not.