UNIT 7 STERILIZATION AND ULTRA-HIGH-TEMPERATURE PROCESSING

Structure

7.0 OBJECTIVES

After reading this unit we should be able to:

- define sterilization.
- describe the theoretical basis for conventional sterilization and UHT processing.
- differentiate between in-package sterilization and UHT processing
- state the different types of sterilization systems and how they compare against each other.
- explain the changes in properties of milk that occur during sterilization and storage
- define aseptic packaging enumerate different packaging materials and sterilizing mediums available for aseptic packaging.

7.1 INTRODUCTION

We know milk is a highly perishable commodity. Its myriad nutrients makes it extremely favourable medium for the growth of microorganisms. It is, therefore, essential that milk is subjected to certain processing treatments for enhancing its keeping quality and ensuring safety to consumers.

Thermal processing is the most prevalent preservation process employed in the dairy and food industry. Starting from pasteurization, which is a mild heat processing technology, in-bottle/in-package sterilization emerged as a means of extending shelf life of milk for several weeks at room temperature. Considerable changes in nutritional and sensory quality due to severity of heat treatment in this process, restrict its application to only special milks. Ultra-high-temperature processing, a relatively new processing know-how, became popular as it uses very high temperature (140^{O}C) for short time (2 s) to sterilize milk. Such a time-temperature combination ensures minimal change in the product quality. Sterilized milk is then packaged in sterile container under aseptic conditions to prevent post-processing contamination. The product thus obtained has very long storage life.

7.2 STERILIZATION

i. Definition

Sterilized milk refers to a product obtained by heating milk in a container in a commercial cooker/ retort to temperatures of 110-130^{O}C for 10-30 min. The process is also referred as in-container sterilization. Sterilized milk is generally intended for prolonged storage at room temperature (up to 6 months). The major objective of heat sterilization is to destroy microbial and enzymatic activity. The length of time and magnitude of temperature employed during processing depend on the type of the product, number and heat resistance of microorganisms and enzymes present in milk. The heat resistance of microorganisms or enzymes is generally evaluated in terms of D-value or Z-value. Sterilization load or heat load for sterilization is generally expressed in terms of F_o value.

ii. Theoretical Basis

Clostridium botulinum is considered as the index organism for assessing thermal sterility in foods. Under anaerobic conditions, inside a sealed container, it can produce botulin, a toxin, which can be 65% fatal to humans. Therefore, destruction of this organism is a minimum requirement of heat sterilization. As milk is a low acid (pH>4.5) food, it is recommended to achieve 12 decimal reductions for *C. botulinum*. This can be achieved by heating the product at 121^{O}C for 3 min (F_o = 3). However, this minimum treatment may produce milk that is safe but not necessarily commercially sterile. This is so because there are more heat-resistant spores present in milk. There is *B. stearothermophilus* or *B. sporothermodurans*. These spores are not pathogenic. Their presence may require heat treatment equivalent to two (2) or more decimal reductions. This may correspond to an F_0 value of 8. Target spoilage rates should be less than one survivor in every 10,000 containers.

iii. Types of Sterilization Plants

Sterilizing retorts are either batch type or continuous in operation. Batch type sterilizers may be either vertical or horizontal. Horizontal retorts are easier to load or unload. They have facilities for agitating containers/cages. However, they require more floor space. Typically such horizontal retorts contain concentric cages. Cans are loaded horizontally into the annular space between the cages. When cages are full, the retort is sealed. The cages are supported by guide rails, which slowly rotate them. This stirring of the contents in cans facilitate proper heating. Continuous retorts are generally equipped with better controls. They cause very gradual change in pressure inside the cans. Thus products are heated more uniformly. Can seams are also subjected to less strain in comparison to batch process.

Continuous sterilizers: They are mainly of three types: (a) cooker-coolers; (b) hydrostatic sterilizers; and (c) rotary sterilizers. Cooker-coolers carry cans on a conveyor which pass through three sections of a tunnel. These sections are maintained at different pressures for preheating, sterilization and cooling. The hydrostatic sterilizer consists of a chamber equipped with provision for steam injection. The chamber that is partially full of water is connected to two water columns (12 to 18 meter tall, barometric leg) which are used to adjust pressure in the chamber. If the height of the water columns is changed, the steam pressure is changed and therefore the maximum attainable temperature changes. For example, to get a temperature of 116^{o}C, a difference in height between the two water columns should be 10.7 m while for attaining 121^{o}C temperature in the chamber, the water column difference should be 13.7 m. A conveyor with provision to accommodate cans of different sizes moves through the steam chamber carrying the food cans. The heating time could be regulated by varying the speed of the conveyor. Hydrostatic sterilizers are very flexible and suitable for large capacity plants. However, size of the structure and high capital costs are the major disadvantages of this system.

Continuous rotary sterilizer consists of several horizontal inter linked cylinders which allow for preheating, heating, precooling and cooling in upto four continuous stages. The vessel has a spiral track on the inner wall. A spoke or reel within the centre of the cooker causes the cans to roll along the spiral track. Rotary valves used to interconnect the shells, maintain pressure in the heating and cooling sections. Sealed cans are introduced directly from the sealing machines. The contents inside the cans are mixed as cans travel along the helix and therefore enhance heat transfer and ensure less heat damage to the product. Cans coming out of the cooker are directly taken to labelling and palletizing machine. Rotary sterilizers are particularly suitable for processing of milk and milk based products, which are extremely heat sensitive and susceptible to browning.

iv. Description of the Canning Process

Basic operations in conventional retorting/canning process include: preparation of the raw material, filling of the container, exhausting, sealing of container, sterilization, cooling of the cans, labelling and storage.

The preparation of raw materials refers to washing, peeling, cutting, blanching, pre-cooking, etc. in case of fruits, vegetables, meat, etc; and preheating, mixing, homogenization, etc; in case of milk. Filling of containers can be carried out either manually or mechanically. Correct and accurate filling is important from economic standpoint as well as for prevention of entrapment of large volume of air/ gas inside the can, which might decrease the intensity of heat treatment. Exhausting is an essential operation in the canning process and involves removal of air/ oxygen from the container before it is closed. Removal of air ensures minimum of strain on the can seams or pouch seals through expansion of air during heat processing. Removal of oxygen is essential to prevent internal corrosion of the container through oxidation and creation of vacuum inside the container while cooling. Absence of oxygen inside the container also delays oxidative deterioration of the product besides destruction of ascorbic acid.

After exhaustion, containers are sealed. Depending on the type of containers (metal cans, glass bottles, flexible pouches); sealing machines are chosen. Glass jars are normally vacuum-sealed while tins are closed with a double sealing on the seal side and may also be vacuum-sealed. Flexible retortable pouches are sealed by fusion of two thermoplastic materials through application of heat by heated plates or jaws.

Product in the closed containers is heated in the sterilizer in an atmosphere of saturated steam or hot water or air-steam mixture. The sterilizing action of steam depends on its latent heat of vaporization as it condenses on the surface of the can. Saturated steam condenses readily and is therefore an efficient sterilizing medium. Displacement of all air present in the retort by steam before the sterilizer is brought to operating temperature is a very essential step. This is also known as venting. The purpose of this processing step is to maintain uniform steam-air mixture in the sterilizer and prevent under processing. Sterilization temperature – time combination in retorts may vary from 110 – 130^{O}C for 10-30 min. Sterilized containers are then cooled and brought to room temperature for labelling and storage. Turbidity test developed by Aschaffenburg is conducted to ensure sterility of the product. This is an indirect test and it measures denatured whey proteins. Complete denaturation indicates that the milk is adequately sterilized.

v. Quality of Sterilized Milk

Sterilized milk has a rich creamy appearance and a distinct cooked flavour (rich, nutty, caramelized). It is considerably browner in colour than raw milk. The brown colour develops due to formation of coloured pigments resulting from interactions between free amino groups of proteins and aldehyde group of lactose through Maillard reactions. The intensity of cooked flavour and brown colour depends upon the severity of heat treatment. In-container sterilization causes loss of nearly half of the ascorbic acid (Vitamin C) and sizeable loss of thiamine (30-40%). Vitamin B_{12} is almost completely destroyed. Fat soluble vitamin A, carotene, riboflavin and nicotinic acid are not affected. Biological value of proteins is only marginally affected. Sterilized milk cannot be coagulated with rennet unless calcium chloride is added externally.

Check Your Progress 1

1. Define sterilized milk.

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2. Why *Clostridium botulinum* is so important in sterilization?

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3. How would you obtain commercially sterile milk?

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4. How does a batch type horizontal retort operate?

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5. What are the different types of continuous sterilizers? Why these are preferred over batch type system?

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6. How would you change the processing temperature in a hydrostatic sterilizer?

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7. Why rotary sterilizers are suitable for processing of milk and milk products?

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8. Why exhausting is an essential step in canning process?

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9. What is the purpose of venting?

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10. What is Aschaffenburg test?

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11. What is the most undesirable physical change in milk after conventional sterilization?

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7.3 UHT PROCESSING

i. Definition

UHT milk can be defined as a product obtained by heating milk in a continuous flow to a temperature in excess of 125°C for not less than two seconds and immediately packaging in sterile packages under aseptic conditions. In India, UHT milk is generally processed at 140°C for 2 seconds.

ii. Theoretical Basis

Heating of milk results in death of microorganisms. While some bacteria are destroyed by pasteurization (71.7°C/15 s) only, some survive this thermal treatment. *Bacillus subtilis* and *Bacillus stearothermophillus* spores are very heat resistant. Of the two, *Bacillus stearothermophillus* spores are most heat resistant. It is therefore, considered index organism for evaluating performance of UHT processing.

Heating of milk at higher temperatures also result in undesirable changes in chemical quality. Browning reactions are particularly important. Higher thermal load results in more browning and therefore loss of flavour and quality. In the temperature range of 100-120^{o}C, time required for death of almost all *B. stearothermophillus* spores are more. This may therefore result in more browning in the product. However, if milk is treated in the UHT range i.e. 135-150^{o}C for only few seconds, almost all spores may get killed and browning would be minimum. Loss of nutrients and total quality also will be minimum. A product processed in this temperature range will be thus microbiologically safe and yet superior in terms of overall quality.

iii. Types of Sterilization Plants

There are two types of UHT plants: Direct type and Indirect type. In direct type plants, heating is done by mixing product and steam. In indirect type plant, product is heated by steam or hot water without the two coming in direct contact. Heating in direct type plant is very rapid particularly between 80-140^{o}C and total heat load is less. Changes in the product quality are therefore minimum. In indirect plant, rise in temperature is very gradual. Therefore, heat load on the product is more. Changes in chemical quality are comparatively more in indirect type than in direct type plants.

(i) Direct Heating Plant: There are two types of direct heating plants (a) Injection type and (b) Infusion type.

Injection type: Processing is through steam-into-milk arrangement. Steam injector is the heart of this plant. Preheated milk at 80-90^{O}C enters the injector nozzles from one side. Steam at slightly higher pressure enters the injector from the other side. As the steam mixes with milk, steam condenses and the product is rapidly heated. Rapid condensation of steam prevents entry of air in holding tube. Air in holding tubes results in improper heating. Backpressure is maintained on the discharge side. Backpressure ensures that product does not boil in holding tube. Boiling may result in fouling and improper heating of milk. Several designs of injector are available.

Infusion type: In this system, milk is heated by milk-into-steam arrangement. The processing unit consists of a chamber filled with pressurized steam. Milk enters the chamber from the top. There are two alternative arrangements for distribution of milk. In the first type, milk flows to a hemispherical bowl with loose circular disc closing the top. When the bowl is full, milk overflows and falls in droplets through the steam environment. In an alternative arrangement, milk flows through a series of parallel and horizontal distribution tubes. These tubes have slits along the bottom and milk flows like a thin film through the chamber. As milk reaches the bottom of the chamber, it is heated to desired temperature. This system is particularly suitable for thicker liquids and for liquids suspended with smaller chunks.

Advantages and Disadvantages of Direct Heating System: During processing in direct type heating systems condensing of steam coming into product contact results in dilution of the product. To remove this excess of water from the product, cooling is done in an expansion cooling vessel. In expansion vessel, along with the evaporating water incondensable gases and undesirable flavour volatiles produced during heating are also removed. The product therefore tastes better. Steam injection induces formation of casein aggregates, which give “chalky” or “astringent” mouthfeel to the product. Aseptic homogenizer, which can safely homogenize the product after final heating section, is generally preferred with direct heating systems to overcome such defects in the product.

Rate of heating is very high (takes less than 1 sec to attain sterilization temperature). Thick/viscous liquid can also be easily processed. Deposit formation is minimum, hence plant can be operated for longer time without cleaning. Undesirable flavours are removed during flash cooling. Oxygen is removed during cooling, hence oxidized flavour defects are delayed during storage.

Cost of processing per unit volume of milk is high. Requires additional equipment (vacuum expansion chamber and aseptic homogenizer) – cost of plant is twice that of indirect type plant. Heat energy requirement is very high. Water and electricity (25-50% more than in direct type) consumption are high. Requires culinary steam and hence special boiler. Creates greater noise during operation.

(ii) Indirect Type Heating System: There are three types of indirect heating systems: (a) Plate heat exchangers (b) Tubular heat exchanger (c) Scraped surface heat exchanger.

Plate heat exchanger: This resembles plate heat exchanger of HTST plants. Several rectangular stainless steel plates with corrugations are arranged in sequence. These plates are then mechanically tightened to hold together. Corrugations on the plates induce turbulence and therefore result in high heat transfer. High temperature processing generates high internal pressure. The gaskets are therefore made of heat resistant materials such as medium nitrile rubber or resin cured butyl rubber. A major advantage of this plant is therefore simple design and comparatively less cost. If deposit formation is more, plates can be removed and manually cleaned.

Tubular heat exchanger: There are two types of tubular heat exchangers – (a) concentric tube, (b) shell and tube type. Concentric tube type heat exchangers comprise two or three stainless steel tube lengths put one inside another. Spacer is placed in each inner tube space to maintain them concentric. Several such multiple tubes are bound together and placed into an outer cylindrical housing. Two tube heat exchangers are used for simple cooling and heating. In triple tube heat exchanger, available heat transfer area is doubled. It is generally used in final cooling section. It is also suitable for processing of thick liquids, which generally reduces heat transfer rate. Product flows through the middle annular space. Heating or cooling medium passes through inner tube and outer annular space. In shell and tube type heat exchangers, 5-7 straight lengths of smaller tubes (10-15 mm internal diameter) are assembled in an outer tube. The smaller tubes are connected to large outer tube at both ends by a manifold. Product passes through the smaller tubes. Heating or cooling medium passes through the space around them in a counter current flow. Tubular heat exchangers are mechanically very strong and can withstand even very high internal pressure generated during homogenization (200-300 bar). Therefore the need for acquiring an aseptic homogenizer to be placed after heating section is totally eliminated. Instead, the high pressure reciprocating pump of an ordinary homogenizer can be placed before the sterile section. The homogenizing valve can be put at any point on the downstream side (even after final heating section). The problem of product contamination arises from the homogenization pump and not the valve. Therefore, with tubular heat exchangers, the product can be homogenized before sterilization, after sterilization or on both the occasions. Fat rich products like cream require homogenization after final heating to prevent re-association of fat globules due to high temperature processing after homogenization.

Scraped Surface Heat Exchanger (SSWE): It is a very specialized type of heat exchanger. It consists of a jacketed cylinder. A shaft passes along the axis of the cylinder. The shaft is supported by bearings at both ends of the cylinder. The shaft also carries several scrapper blades. As shaft rotates, scrapper blades provide turbulence and physically remove the product from the surface of the wall. The colder product subsequently replaces the heated product and the cycle continues. SSHE is used only for heating very thick liquids. SSHE units are very expensive and have poor energy conversion efficiency. The cost of processing is therefore very high.

Advantages and Disadvantages of Indirect Heating System: It is simple in design and requires less pumps and controls. It can regenerate 90% of the thermal energy requirement. It does not require aseptic homogenizer, which is very costly.

It does not require culinary steam and therefore special type of boiler. The indirect type plant is less noisy. It requires low initial capital and operational cost is also comparatively less.

In indirect type heat exchanger, rate of heat transfer is low. More heat load results in less acceptable product quality. Deposit formation is more and therefore plant requires frequent cleaning. For removal of dissolved oxygen from milk, additional equipment 'deaerator' is required.

iv. Changes in Milk during Processing

UHT processing does not cause reduction in biological value of proteins. There is only small loss of available lysine (6-7%). UHT processing changes the casein micelle structure. This slows rennet action during cheese manufacture. Serum proteins are denatured (direct processing – upto 50-75%, indirect processing upto 70-90%). Denatured serum proteins interact with casein and increase casein micelle size. This reflects more light and UHT milk appears whiter. Aggregates of denatured serum proteins and casein also give 'chalky' mouth feel to the product.

There is no physical or chemical change in milk fat. The total mineral content also does not change during UHT processing. The vitamin content of UHT milk is comparable to pasteurized milk. Losses in B-complex vitamins are not more than 10%. Folic acid and ascorbic acid are destroyed up to 15% and 25%, respectively. Fat soluble vitamins A, D, E and K are not affected by UHT processing. Fresh UHT milk has slightly cooked flavour. The cooked flavour is due to oxidotion of the SH (Sulphydryl) groups from the denatured serum proteins.

v. Changes in UHT Milk during Storage

Chemical, physical or sensory changes in stored UHT milk are dependent on storage temperature. Changes are rapid if storage temperature exceeds 30^{O}C. Browning reactions between protein and lactose progress during storage. At higher storage temperature (>30^{O}C) UHT milk may become little brown after 3-4 months. Refrigerated storage of raw milk before UHT processing favours growth of psychrotrophs. They liberate heat resistant proteases and lipases. Proteases that survive UHT treatment act on proteins during storage. Bitter peptides are released causing bitterness in the product. Extensive proteolysis and other physico-chemical changes occurring as a result of interaction of proteins and salts during storage may cause thickening or sweet curdling also referred as age thickening after longer storage (more than 6 months). Lipases surviving ultra-high-temperature treatment act on lipid fraction. Short and medium chain free fatty acids are released. Short chain fatty acids particularly butyric acids contribute to development of rancid flavour in the product. Air in the product or in the packet reacts with unsaturated fatty acids. This auto oxidation reaction causes formation of aldehydes and ketones. These compounds cause oxidative rancidity (flavour defect) in the product. The cooked flavour in UHT milk disappears in first few days and milk tastes best after this period. Few weeks after this, depending on the temperature of storage, oxidized flavour defects appear which becomes more pronounced with progressive storage. In milk stored for considerable period of time, which could be 3-4 months at >30^{O}C, stale flavour is a common defect. Several compounds that form during the progress of Maillard reactions in stored milk are associated with the appearance of this defect. Sometimes coconut like flavour defect also appears in UHT milk stored for longer period. Compounds such as d–dodelactone and d–dodecalactones are responsible for this.

Check Your Progress 2

1. Describe UHT milk.

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2. Why heating of milk above 130^{O}C is desirable?

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3. Why UHT processing is recommended for liquid milk marketing in India?

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4. Why quality of milk processed in direct type UHT plant is better?

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5. Why direct type UHT systems are commercially less successful?

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6. What types of special gaskets are required in plate heat exchanger of indirect heating systems and why?

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7. List the major reasons for commercial success of tubular heat exchanger in UHT plant.

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8. When would you like to use SSHE?

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9. Why UHT milk is whiter?

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10. What is age thickening and how it occurs?

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11. How rancid and oxidized flavour defects develop in UHT milk?

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7.4 ASEPTIC PACKAGING

Aseptic packaging can be defined as the process in which UHT processed or sterilized milk is filled in pre-sterilized containers under aseptic/sterile environment. This ensures that there is no post processing contamination of the milk so that the product has longer shelf life. Since aseptic packaging systems are complex, great care is needed to prevent contamination. Before the start of product packaging, trial runs are routinely conducted with sterile water. Critical parts of the filling machine and carton forming systems are thoroughly checked. The seal integrity of the package and overall microbial quality of the packaging material are monitored properly. Generally, for a good processing plant permissible spoilage rate is one in every 5000 sterilized, filled and sealed package of one litre carton.

i. Types of Sterilizing Medium

Sterilizing mediums to be used in aseptic packaging systems could be broadly classified under two categories: physical sterilization mediums and chemical sterilization mediums.

Physical sterilization mediums: Steam under pressure or hot water is the most simple and reliable sterilant for high sterilization efficiency in short time. In aseptic packaging, its use is however restricted to sterilization of the milk tubes and valve and fittings coming into product contact.

Dry heat/ super heated steam: Hot air is generally used to sterilize the closed space where the filling of milk takes place. Air heated to 300^{O}C may be taken to the areas surrounding electric resistances used for sealing the packages. Dry air at 330-350^{O}C is also used for sterilizing the milk filling tubes. Sterilized air (180-200^{O}C) is used for evaporating residual H_2O_2 (chemical sterilant) from the package.

Ultraviolet radiation: UV rays (optimum wavelength 250 nm) alone are not a very effective sterilizing medium for aseptic packaging units. Two major reasons for this are: (i) intensity of radiation is not uniform on the entire package surface (ii) bacteria adhering to packages could be protected by dirt/ dust particles present on the surface. UV radiations are therefore used as a complementary sterilizing medium.

Ionizing radiations: Gamma rays are often used for sterilizing packaging materials unable to withstand high temperature. Usually 2.5 Mrad intensity is suitable for sterilizing plastic laminates used in aseptic bag-in-box.

ii. Chemical Sterilization Mediums

Ethylene oxide: Ethylene oxide has slow sporicidal action. It is sometimes used as a pre-sterilization agent to reduce microbial load on packaging films so that a shorter time is required for final sterilization.

Hydrogen Peroxide (H_2O_2): H_2O_2 has poor sporicidal effect at room temperature. However, with increasing application temperature and concentration, sterilization performance improves. H_2O_2 is the most popular sterilant for aseptic packaging system. H_2O_2 is applied on the package surface by either dipping or spraying. As its boiling temperature is slightly above 100^{O}C, supply of heat by either sterilized hot air or infrared elements can evaporate the residual H_2O_2 from the package surface. Thus there is little H_2O_2 left for contaminating the product. Safety regulation recommended by IDF requires that atmospheric concentration of H_2O_2 in the packaging hall should not exceed 1 ppm. Further more, residual concentration in milk immediately after filling should not exceed 100 ppb and should reduce to 1 ppb within 24 hours. The most successful combination of sterilizing medium being used in commercial aseptic packaging units are H_2O_2 coupled with heat supplied by radiant heating element. Some packaging systems also use a combination of H_2O_2 and UV radiation.

Other sterilizing agents which are rarely used in such applications are sodium hypochlorite and per acetic acid. These agents leave the residues of chloride and acetic acid on the package, which may finally contaminate the product.

ii. Type of Packaging Materials

Metal container: Cans made of tin plate or drawn aluminium are generally used for packaging of condensed milk, viscous liquids and chunk-in-gravy type of products. These are expensive and unsuitable for low cost products like liquid milk. They are bulky and require large storage and shipment space. The empty cans are carried in a conveyor to a tunnel for sterilization with steam super heated with gas flame at atmospheric pressure and require about 40-45s. The cans then move to filling chamber for product filling. The can lids are separately sterilized, placed on the cans and seams sealed. The can sterilizing, filling and sealing zones are sterilized before the filling begins with the same mixture of superheated steam and flue gas, which fills them during operation. Cans have been used for in-package sterilization for a long time. Manufacturers of UHT milk who want to impress the consumers with the advantages of the new technology therefore do not prefer to use cans which are so identified with a old technology

Laminates/cartons: Different layers of flexible films of different materials viz. paper, polyethylene and aluminum foil are co-extruded to form a laminate. These materials have specific properties viz. water vapour transmission, burst strength, etc; and hence when co-extruded form an ideal packaging film. Such laminates could be 3, 4 or 5 ply and are generally used for products like, milk, cream, fruit juices, soups, etc. These laminates are supplied as film rolls, which can be mounted on FFS (form-fill-seal) machines. Alternatively, cartons made of laminates are supplied as preformed blanks, which are assembled into cartons for filling and sealing at the top.

Plastic films: Black and transparent polyethylene films are co-extruded for packaging of UHT processed milk intended for 2-3 weeks shelf life. The co-extruded film protects the product against light but not oxygen. The packaging machines also need to operate at not more than 45-50^{O}C filling environment. A co-extrusion of polyvinylidine chloride (PVDC) or ethylene vinyl alcohol (EVOH) with black or white polyethylene film is also used as packaging film. Such a combination imparts protection against oxygen as well as light and shelf life of milk can be extended upto 3 months.

Other forms of packaging materials : Preformed packages of different shapes and sizes are also used for aseptic packaging of value added dairy products. Blow-moulded plastic bottles of polyethylene or polypropylene are used as cheap substitutes. However, these are transparent and permeable to oxygen. Multilayer materials with better light and oxygen barrier properties have also been developed. Pre-formed plastic cups of polypropylene (PP) or polystyrene (PS) are now gaining popularity. Bulk filling bags are made of laminates of 3 or 4 layers of which one will be barrier material such as metalized polyester (polyester with a coating of aluminium particles) or ethyl vinyl alcohol (EVOH). The bag with filling valve is sterilized by r-radiation (2.5 Mrad dose) before shipping. Bags remain sealed and internal surface therefore remains sterile. At the filling station, the sterilized bags are opened, filled and sealed under aseptic condition. All product contact surfaces in the filler however need to be sterilized with steam before the filling operation begins.

iii. Description of the Packaging System

Most of the aseptic packaging machines being used in the country are of form-fill-seal (FFS) type. Packaging material used generally is laminate of polyethylene – paper – polyethylene – Al foil – polyethylene. Packaging film in the form of a roll is mounted on the packaging machine. The film moves continuously downward in the form of a strip and a shaping roll gives it a cylindrical shape. Heat sealing forms an overlapping longitudinal seal. Simultaneously extra polythene strip is heat bonded along inside of longitudinal seam. This is done to prevent filled product penetrating the paper layer. As this continuous cylinder moves downward, jaws at the bottom make transverse heat seal. The product is filled instantly and another jaw seals the package at the top. Depending on the type of machine, different shapes can be given to the package. The most popular is brick shaped package. Tetrahedron shapes were also being used some times back. Some new innovations that are now being used for packaging of fruit juices are Fino packs. To cut down on costs some dairies have introduced pillow packs for packaging of milk.

Check Your Progress 3

1. What is aseptic packaging?

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2. Why UV rays alone are not effective medium for package sterilization?

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3. When should ionizing radiations be used in aseptic packaging?

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4. What are the regulatory requirements for H_2O_2 levels during aseptic packaging?

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5. Why cans are not suitable for packaging of UHT processed milk?

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6. What types of laminates are generally used for packaging of UHT milk?

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7. What are the cheaper films available for packaging of UHT milk?

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8. What materials bulk filling bags are made of?

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9. How seals are formed on the FFS type machine?

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7.5 LET US SUM UP

Liquid milk is either subjected to pasteurization or sterilization for preservation and consumer safety. While pasteurization extends storage life of milk by a few days at refrigerated temperature, sterilization offers a far longer life. Conventional sterilization, which involves heating milk to 110-130^{o}C for 10-30 min, is generally employed for the manufacture of special milks like flavoured or chocolate milk. Equipments available are both batch and continuous type. Of the available types of sterilizers rotary sterilizer is preferred for processing of milk. However the technology is not suitable for plain liquid milk processing as considerable changes in nutritional quality takes place. Furthermore, milk becomes visibly brown due to higher intensity of Maillard reactions at conditions employed during in-package sterilization. Ultra high temperature (UHT) processing, a relatively new technology is a better alternative for plain liquid milk processing. It requires milk to be heated to 140^{o}C for 2 sec. Both direct type and indirect type systems are commercially available. Tubular heat exchangers are generally preferred for its manifold advantages. Processed milk is subsequently packaged in sterile containers under aseptic conditions. Form-fill-seal aseptic packaging machines, which are more popular use co extruded 3-5 ply laminates for packaging of liquid milk. UHT processing is slowly gaining popularity in our country and holds much promise for the future of Indian dairy industry.

7.6 KEY WORDS

Blow molding : It is a manufacturing process by which hollow plastic or glass objects are formed. In general there are three types of blow molding processes: extrusion, injection and stretch.

Canning	:	It refers to a preservation method whereby processed foods are put into metal cans or glass bottles, hermetically sealed to keep out air and then heated to specified temperature for definite time to destroy disease causing organisms and prevent spoilage.
Caramalization	:	It is the oxidation of sugar; a process that is extensively used in food processing for developing nutty flavours and brown colour. It is therefore a type of non-enzymatic reaction.
Culinary steam	:	It is super heated water under pressure suitable for direct food contact and require food grade equipment, clean water and sanitary condition for its production
D-value	:	It is time in minutes required for one log or 90% reduction of specific microbial population under specified lethal condition viz. constant temperature.
F_o- Value	:	It is sterilization value. One minute at 121.1^{o}C or an equivalent amount of heat is defined as one unit of F_o. Other equivalent temperature-time combinations are: 11.1^{o}C/10 min or 101.1/100 min.
Homogenization	:	It refers to a process in which milk is subjected to high shear at a temperature, which is above the melting point of the fat. Milk fat, which varies from 1 to 10 micron in size, are broken down into smaller particles and remain dispersed so that they don't rise to the top.
Latent heat	:	It is the quantity of heat absorbed or released by a subsance undergoing a change of state such as steam to water at constant temperature and pressure.
Lipases	:	They are the group of enzymes that catalyze the hydrolysis of fats into glycerol and fatty acids. Lipases are naturally present in milk and heat resistant lipases are liberated by psychrotrophs.
Maillard	:	It is a chemical reaction between an amino acid and a reducing sugar and requires addition of heat. The reactive carbonyl group of the sugar interacts with the free amino group of the amino acid and give rise to formation of compound, called melanoidins that impart brown colour.
Pasteurization	:	It is a processing treatment named after the inventor Luis Pasteur that requires milk to be heated to either 63^{o}C/30 min or 71.7^O/15 sec so that all pathogenic organisms are destroyed. Minimum time and temperature conditions are based on the requirements for the destruction of the most heat resistant pathogenic microorganism present in milk i.e. *Coxelliae*

burnettii and *Mycobacterium tuberculosis.*

Proteases : Any of the various enzymes that catalyze hydrolytic breakdown of proteins into peptides or amino acids. Proteases are naturally occurring in milk and heat resistant proteases are liberated by psychrotrophs.

Rennet : It is a substance containing rennin, an enzyme having the property of clotting or curdling milk. It is generally used in the manufacture of cheeses. Rennin is obtained from the stomach (abomasums) of milk fed calves.

Saturated steam : It is steam at temperature of the boiling point, which corresponds to its pressure.

Sterilization : It is a process by which all microorganisms present in milk (both vegetative and spores) are destroyed or are rendered incapable of growth so that milk can be stored for longer period without refrigeration.

Tetrahedron : It refers to a polyhedral shape composed of four triangle faces three of which meet at each vortex. It looks like a pyramid.

Turbidity : Having sediments or foreign particles stirred up or suspended, which give the liquid cloudy or unclear appearance.

Z-value : The number of degree of temperature change necessary to change the D-value by a factor of 10.

7.7 SOME USEFUL BOOKS

Ashton, T.R. and Romney, A.J.D (1981). In-container sterilization. In: Factors affecting the keeping quality of heat treated milk, IDF Bulletin, Doc.

Burton, H. (1988). Ultra-high-temperature processing of milk and milk products. Elsevier Applied Science, London.

Cerf, O. (1981). Aseptic packaging. In: New Monograph on UHT Milk, IDF Bulletin, Doc.

Lewis, M.J (2000). Improvements in the pasteurization and sterilization of milk. In: Dairy Processing: Improving quality, Gerrit Smit (ed.) Woodhouse Publishing Ltd., Cambridge, England.

7.8 ANSWERS TO CHECK YOUR PROGRESS

Your answer should include the following points:

Check Your Progress 1

1) i. Sterilized milk refers to a product obtained by heating milk in a sealed container in a commercial retort at temperatures of 110-130^{o}C for 10-30 min. The sterilized product can be stored for 4-6 months at room temperature without spoilage.

2) i. *Clostridium botulinum* can produce botulin, a toxin that is fatal to human. For ensuring safety of low acid foods like milk, 12 decimal reduction of

this organism equivalent to F_o of 3 is required which can be achieved by heating milk at 121°C for 3 min or such equivalent time-temperature combinations.

3) i. For obtaining commercially sterile milk a minimum of two (2) decimal reductions in counts of heat resistant *B. stearothermophilus* or *B. sporothermodurans* is necessary which may require a corresponding F_o value of 8.

4) i. Horizontal retorts are equipped with concentric cages, which are loaded with sealed cans. Guide rails provided in the retort help the cages rotate thereby ensuring stirring of the contents in can for proper heating.

5) i. Continuous sterilizers are broadly classified under three categories namely cooker-coolers, hydrostatic sterilizers and rotary sterilizers. Continuous sterilizers are preferred over batch types as these have better controls. As these sterilizers cause gradual change in pressure inside the cans, heating is more uniform which results in better quality product.

6) i. A hydrostatic sterilizer is connected to two water columns (12 to 18 meter tall barometric leg). Depending on the operating temperature required, the water levels in the two legs are changed to change the steam pressure inside the sterilizer chamber. Typical sterilization temperature of 121°C is attained if the water column difference is 13.7 m.

7) i. Rotary sterilizers have a spiral track on the inner wall of the vessel. A spoke within the vessel facilitate cans to roll along the track and the contents inside the cans are thoroughly mixed during heating. This ensures rapid heat transfer and less heat damage (particularly browning) to the products.

8) i. Exhausting involves removal of air/ oxygen from the can before sealing of cans. It ensures minimum strains on can seams through expansion of air during heating and therefore little chance of leakage of cans. It also prevents corrosion of containers through oxidation and delays oxidative deterioration of the product during storage.

9) i. Venting refers to displacement of air from the heating chamber of retort before the heating begins. This helps in maintaining uniform steam-air mixture in the sterilizer for efficient processing which is essential for good product quality.

10) i. Aschaffen burg developed a turbidity test to assess efficiency of sterilization. It measures the amount of denatured whey proteins. Complete denaturation indicates adequate sterilization.

11) i. The most undesirable physical change in milk after in-bottle sterilization is visible browning which occurs as a result of high intensity of Maillard reactions at time-temperature conditions followed during in-bottle sterilization.

Check Your Progress 2

1) i. UHT milk refers to a product obtained by heating milk in a continuous flow to a temperature in excess of 125°C for not less than 2 sec and subsequent packaging in sterile containers under aseptic conditions. Generally, UHT milk in India is processed at 140°C/ 2s.

2) i. Heating milk to temperature beyond 130°C results in several fold increase in the rate of destruction of spores like *B. Stearothermophilus*. At the same time, reactions responsible for browning or nutrient loss are accelerated to a lesser extent. Therefore at temperatures higher than 130°C, while spore destruction is maximum, change in total quality is minimum.

3) i. Tropical climatic conditions prevailing in India require refrigerated conditions during storage, transport and marketing of pasteurized milk, which is difficult to maintain due to frequent electricity failure. UHT milk can over come these problems and the product can be marketed to even places where there is no electricity.

4) i. In direct type UHT systems, milk is instantly heated (takes only 1 sec to reach 140^{o}C) and therefore heat damage to the products' quality is minimal. Furthermore, removal of oxygen and volatile compounds responsible for heated flavour result in improved taste and delayed oxidation during storage.

5) i. The direct type plant costs twice that of indirect type plant. Water and electricity requirements are more and therefore, cost of processing per unit volume of milk is high.

6) i. High temperature processing creates high internal pressures. Therefore, wherever plate type heat exchangers are used, the gaskets used are made of heat resistant materials like medium nitrile rubber or resin cured butyl rubber.

7) i. Tubular heat exchangers made of SS tubes have high mechanical strength, do not require gaskets and can withstand high internal pressures. Regeneration is possible up to 90% of the thermal energy requirements and fouling is less frequent. It is possible to use ordinary homogenizer by placing the high pressure pump before the sterilization section and homogenizing valve either before or after the final heating section. Therefore it offers versatility in operation and the need for acquiring expensive aseptic homogenizer is totally eliminated.

8) i. SSHE unit is very expensive and has poor energy conversion efficiency. It is therefore, to be used only for UHT processing of thick liquids, which cannot be otherwise, processed successfully in other heating systems.

9) i. During high temperature heating, serum proteins get denatured and form large size complexes. Denatured serum proteins also interact with casein and increase casein micelle size. They thus reflect more light and appear whiter.

10) i. Age thickening refers to progressive increase in viscosity of UHT milk during storage leading to formation of gel. The probable reasons are proteolysis by residual heat resistant proteases and physico-chemical changes involving interaction of proteins and salts in the stored milk.

11) i. Heat resistant lipases surviving UHT treatment act on lipid fraction and release short and medium chain fatty solids during storage of UHT milk. Therefore the released fatty acids particularly butyric acids impart rancid flavour. The residual oxygen in the milk and packet react with unsaturated fatty acids and forms different types of aldehydes and ketones, which lead to development of oxidative rancidity (flavour defect) in the product.

Check Your Progress 3

1) i. Aseptic packaging refers to packaging of a sterile product (read UHT milk) in pre-sterilized containers under aseptic environment so as to prevent post-processing contamination of the product and thus ensure long shelf life.

2) i. During exposure of the package surface to UV radiations the intensity of radiation is not uniform. The bacteria adhering to the package surface could also be protected from the radiations due to hindrances offered by dust and dirt particles present.

3) i. Ionizing radiations like g-rays are used for sterilizing packaging materials, which may not withstand high temperature exposure. It is particularly

suitable for pre-sterilization of plastic laminates used in bag-in-box packages suitable for bulk packaging of UHT processed products.

4) i. As per IDF requirements, residual H_2O_2 in the freshly packaged UHT milk should not exceed 100 ppb and should subsequently reduce to 1 ppb after 24 hours. The atmospheric concentration of H_2O_2 in the aseptic packaging hall must not be more than 1 pm.

5) i. Cans are expensive, bulky and require large storage and shipment space. Furthermore, they are so identified with in package sterilization that UHT processing plants do not find it attractive from marketing point of view.

6) i. Different packaging materials viz. paper, polyethylene and aluminium foil with specific properties such as water vapour transmission, burst strength etc. are co-extruded together into 3, 4 or 5 ply laminates. These laminates supplied in the form of film rolls are generally used in form-fill-seal (FFS) types of aseptic packaging machines.

7) i. Black and transparent polyethylene films are co-extruded and used for packaging of UHT milk intended for relatively short shelf life of 2-3 weeks. Other alternatives are films obtained by co-extrusion of polyvinylidine chloride (PVDC) or ethylene vinyl alcohol (EVOH) with black or white polyethylene films. These are generally used for products, which offer 2-3 months of shelf life.

8) i. Bulk filling bags are generally made of 3 or 4 layers of packaging materials of which one should be barrier materials such as metallized polyester (polyester with a coating of aluminium particles) or ethylene vinyl alcohol (EVOH).

9) i. The downward moving film of multi-layer laminate is given a cylindrical shape by a shaping roll. Heat sealing forms an overlapping longitudinal seal.

An extra polythene strip is heat bonded along inside of longitudinal seam. As the cylinder moves further, transverse heat seal is made by jaws first at the bottom and instantly after filling, at the top.

7.9 SOME MORE QUESTIONS TO CHECK YOUR PROGRESS

1. Define D, Z and F_o values
2. Draw a comparison between direct and indirect type UHT heating systems.
3. Explain the storage induced changes in flavour profile of UHT milk
4. What routine care is taken before starting the aseptic packaging of the product?
5. What are the different types of pre-formed packages and their materials of construction?