Paper No. 7 Technology of Milk and Milk Products

Module No. 4 UHT milk and milk products

Introduction

Aseptic processing and packaging (APP) is one of the two major commercial sterilization methods, also called '***in-flow'*** sterilization. The other commonly used method is ***'in-container'*** sterilization, which generally refers to conventional canning processes. The term '***commercial sterilization'*** is defined as the absence of any microorganisms capable of reproducing in foods under non-refrigerated conditions of storage and distribution, instead of the absolute absence of every existing form of microbial life.

The first aseptically processed milk in metal cans was developed in Denmark by Jonas Nielsen in 1913, almost 100 years after 1810, when Nicholas Appert discovered the canning process. Consumer-size aseptic packages were first developed in the 1960s in Europe for the milk industry by Tetra Pak.

These days milk and some other food products are processed with UHT and aseptic processing in over 60 countries. The market share of UHT milk consumed varies considerably by country: Australia 9%, France 88%, Spain 83%, Germany 63%, Italy 55%, and the United Kingdom 5-13%.

Basis of UHT treatment

Heat treatment in the production of long life products is called '***sterilization***'. In such processes, the treated product is exposed to such intense heat treatment that the relevant microorganisms and most of the enzymes are inactivated, and the processed product is given excellent keeping qualities and can be stored for several months under ambient conditions. UHT processing uses continuous flow of milk, which renders less chemical change in comparison to retort processing.

In conventional canning process, the product is placed into a container (i.e. metal cans or glass bottle), before sealing and sterilization. However, in APP, the product and the package are continuously sterilized separately. The commercially sterile and cooled product is then filled into the pre-sterilized package in a sterile environment and hermetically sealed to produce a shelf-stable final product with extended shelf life, without the need of refrigerated storage.

The processing steps for UHT milk include preheating, homogenizing, holding at preheat temperature, heating to sterilization temperature, aseptic packaging and cooling.

Elements of Aseptic Processing System

A basic aseptic processing system consists of essential elements such as raw product supply tank, pumps with flow control, deaerator, heating section, holding tube, cooling section, back pressure valve, aseptic surge tank, and aseptic packaging system.

Flow control: Rotary positive displacement pumps are usually the most economical choice for processing homogeneous fluids or fluids with small particles (<3 μm) and the pressure drop in the system is less than 150 psi. Typically, these aseptic pumps have steam tracings around the seals and gaskets to maintain sterility in all critical areas.

Heating and cooling sections*:** There are two main technologies distinguished by the medium used for heating to the UHT, 'direct***' and '***indirect***' systems. Steam, hot water, and electricity are heating methods for UHT equipment.

Heating the product to the holding temperature and subsequently cooling it before packaging are carried out continuously using heat exchangers. These heat exchangers can be classified into two groups:

a. ***Direct heat exchangers***, where steam is condensed in the product for heating, and later evaporation removes vapor to cool. Direct heating can take place by the following:
   Steam injection (steam into product): For homogeneous and high-viscosity products sensitive to shear stress such as creams, desserts and viscous sauces.
   Steam infusion (product into steam): Also for homogeneous and high-viscosity products sensitive to shear stress such as creams and desserts.
b. ***Indirect heat exchangers***, where the product and the heat exchanging fluid are separated by the heating surface. Indirect heating can be done by the following:
   ***Plate heat exchangers*:** For homogeneous and low-viscosity products containing small particles up to 5 μm, such as dairy and juice products. Plate heat exchangers are frequently used for energy regeneration to reduce the cost of heating and cooling.
   ***Tubular heat exchangers*:** Not much applied for dairy products.
   ***Scraped surface heat exchangers*:** Not applied for dairy products

The sterilizers utilizing steam or hot water can be subcategorized as direct or indirect heating systems. In the indirect system, the product and heating medium do not have contact, as a barrier (stainless steel) is present. Indirect heating modes include indirect spiral tubes, indirect tubes, indirect plate, scraped surface and electricity. Indirect heating with electricity includes electric elements, conductive heating, and friction.

In '***direct systems'***, heating to and cooling from the high temperature is very fast due to transfer of the latent heats of condensation and evaporation, respectively, between the steam and liquid milk. Cooling is achieved in a vacuum chamber. Direct heating requires sterilization temperatures 3 to 4°C higher than indirect heating to achieve an equal sterilization effect because of the greater heat input during the heat-up phase of indirect heating.

Systems using a combination of direct and indirect heating are available commercially (e.g., the *High-Heat Infusion* system of APV and the *Tetra Therm Aseptic Plus Two* system of Tetra Pak).

Holding section: After heating, the product is held for a specified time in a holding tube to achieve commercial sterility and then cooled. The divert temperature is the temperature measured at the exit of the holding tube. The holding tube must be maintained under isobaric

conditions well above the vapor pressure of the product at the process temperature to prevent flashing or boiling. This is usually accomplished by a back-pressure valve.

Deaerators: Most aseptically processed products must be deaerated prior to thermal processing and packaging. The purpose of deaeration is to remove the entrapped air and minimize oxidative reactions that may reduce the quality of the product during processing and storage. Generally, the deaerator is a vessel maintained at a certain vacuum using a vacuum pump.

Aseptic surge tanks: These tanks are used to accumulate the sterile product prior to packaging. They provide flexibility to the process, when the flow rate of sterile product is not compatible with packaging capacity.

Comparison of Indirect vs. Direct heating systems

A direct heat exchanger is the most rapid method of heating and cooling, presents fewer problems with the formation of scale and burn-on (fouling) and has relatively low initial cost. Indirect heat exchangers give better heat recovery, tend to have a more stable output temperature, and are not prone to contamination from condensable in the steam.

Terminologies associated with UHT processing

Q10 values: It states how many times the speed of reaction increases, if the temperature of the system is raised by 10°C. The *Q*10 value for flavor changes, and for most chemical reactions, is around 2 to 3. It implies that if the temperature of a system is raised by 10°C, the speed of chemical reactions doubles or triples. *Q*10 values can also be determined for killing of bacterial spores and is normally found in the range of 8 to 30.

F0 value: It is defined as the number of minutes at 121.1°C (250°F) to which the process is equivalent to destroy the heat resistant spore forming microorganism. To obtain commercially sterile milk from good quality raw milk, a *F*0 value of 5 to 6 is required.

The F value is referred to as F0 value, when the reference temperature is 121°C (250°F) and the z value is 10°C (18°F). Different foods have different F0 values, because the thermal resistance of microorganisms can be influenced by a variety of factors.

B* value: It is based on the assumption that commercial sterility is achieved at 135°C for 10.1 s with a corresponding *z*-value of 10.5°C. This reference process is given a B* value of 1.0, representing a reduction of thermophilic spore count of 10^9 per unit.

D-value: It is defined as the required time to decrease microorganism numbers (sporeforming) 10-fold at a specified temperature. The D value is the time needed for a microbial population to be reduced by 90%, or 1-log cycle at a constant heating temperature T, and is given by equation:

$$D_T = \frac{\log_{10}No - \log_{10}N}{t}$$

where No is the initial number of microorganisms, N is the number of microorganisms surviving after time *t* at temperature T.

Z value: It is the change in temperature from T1 to T2 needed to change the D value by a factor of 10 from DT1 to DT2.

$$Z = \frac{T1-T2}{Log_{10}DT1 - Log_{10}DT2}$$

Packaging materials

Aseptic packaging can utilize less expensive and lighter-weight packaging materials such as plastic polymers, in addition to metal or glass containers. However, no single polymer has all the essential properties or meets all the packaging requirements for aseptic packaging. Therefore, a composite multilayered structure is often used to meet package design needs. For example, polyvinylidene chloride (PVDC) and ethylene vinyl alcohol (EVOH) have good barrier properties; high-density polyethylene (HDPE), low-density polyethylene (LDPE) and polypropylene (PP) have good sealing properties; and polyethylene teraphthalate (PET) or nylon has good mechanical and heat resistant properties. Therefore, composites using combinations of these packaging materials can create a heat-resistant rigid container with good sealing strength and gas barrier properties.

There are four types of aseptic packaging: (1) ***rigid contain***ers, such as metal cans, metal drums, glass bottles, and composites cans; (2) ***paperboard containers***, such as web-fed or roll-fed paper/foil/plastic cartons and preformed/machine-erected cartons; (3) ***semi-rigid plastic containers***, such as web-fed thermoformed or preformed cups, tubs, and trays; and (4) ***flexible plastic containers***, such as blow molded bottle, pouches, sachets, bag-in-box and bag-in-drum.

The most widespread consumer package for aseptic products is the paperboard laminated carton. The paper provides mechanical strength, good heat resistance and light protection, but it is coated with polymers due to its sensitivity to moisture. The aluminum foil layer acts as an excellent gas, water, and light barrier, especially when laminated between two plastic layers, and is very thermally stable.

Several kinds of semi-rigid plastic containers are now aseptically produced. HDPE and PP are the two most common thermoplastics used, and pigments are often added to better protect the contents from light. A current trend is the use of PET bottles for aseptically filled beverages, which allow consumers to see the product unlike in traditional aseptic juice box designs.

Sterilization of aseptic packages

Sterilization of packaging and food contact surfaces is essential in aseptic systems. A decimal reduction of six is required for sterile, neutral, low-acid products (pH > 4.5). Four main sterilization processes for packaging material are in industrial use, either individually or in combination:

Mechanical processes: Water rinsing/flushing, air blasting, brushing and ultrasound. Mechanical processes are used primarily for pre-cleaning and reduction of the initial microbial load.

Heat**:** Saturated steam, superheated steam, hot air, mixture of hot air and steam, and heat from extrusion during packaging formation. Since high temperature is used, it is not compatible with heat-sensitive plastics.

Irradiation processes**:** Ionizing rays, infrared rays and ultraviolet rays. They can be used mostly for heat-sensitive packaging materials or combined with other methods.

Chemical processes**:** Hydrogen peroxide (H_2O_2) is the most popular sterilization method for aseptic packaging, because it is relatively fast and efficient.

Combination of above**:** Hydrogen peroxide/heat and hydrogen peroxide/UV. Hydrogen peroxide/heat is very popular for the same reasons of hydrogen peroxide alone, except that heat can improve the efficiency further and/or dry the package. A synergistic effect between H_2O_2 and UV is achieved.

Sterilants that are commonly used at industrial level include chlorine, iodine, oxonia, food acids, ozone, H_2O_2, and UV light. The H_2O_2 has proved to be acceptable as package sterilant in the United States. The Food and Drug Administration (FDA) regulations in US specify that a maximum concentration of 35% H_2O_2 for sterilizing food contact surfaces. The residual level of H_2O_2 is regulated with a maximum level of 0.5 ppm. Infrared radiation and vaporized H_2O_2 have been utilized as sterilants for packaging materials. Many other chemicals such as peracetic acid, β-propiolactone, alcohol, chlorine, and its oxide, and ozone have potential for use in sterilizing AP materials.

Aseptic packaging systems

The equipment for aseptic packaging can be broadly classified into six basic categories.

a. ***Fill and seal*****:** Aseptic canning systems and systems using glass or preformed plastic containers (thermoformed, injection or blow molded) belong to this group. The preformed containers are sterilized, filled and then sealed in a sterile environment. Examples include Dole, Serac, Remy Metal Box (Freshfill), Gasti, Crosscheck, Hamba, Ampack and Remy.
b. ***Erect, fill and seal*****:** A knocked-down blank of incoming material is erected, sterilized, filled and sealed. Examples include KHS, SIGPKL-Combibloc and LiquiPak.
c. ***Form, fill and seal*****:** In this system, a roll of incoming material is sterilized, formed, filled and sealed in an aseptic environment. Typical systems include carton and pouch-forming equipment with examples such as Tetra-Pak, International Paper, Asepak, Impaco, Astepo, DuPont, Prodo-Pak and Thimmonier.
d. ***Thermoform, fill and seal***: Roll stock is sterilized or a sterile surface is provided. The material is then heated, thermoformed, filled and sealed in a sterile environment. Examples include Benco, Bosch, Conoffast, Thermoforming USA and IWRA-Hassia.
e. ***Blow mold, fill and seal*****:** The extrudable material is first blow molded. The product is then filled into the package and sealed before the molds are opened, or the sterile bottle is closed in the mold and delivered to a separate operation, where the sterile container is opened, filled and

sealed in an aseptic environment. The process can produce bottles and other semi-rigid containers. Examples include Rommellag, Holopack, Remy, Serac, Bottlepack and Side.

f. ***Bulk packaging and storage systems*:** Pre-sterilized (or in-line sterilized) bags are aseptically filled and sealed. Drums and totes are first sterilized and then filled and sealed under sterile conditions. The larger size storage tanks are usually sterilized by chemical disinfectants (e.g., iodophores) and/or heat and specially designed valves allow aseptic filling and closing. Examples include bag-in-box systems such as Scholle, FMC FoodTech-FranRica, DuPont Star Asept, Liqui-Box, ELPO and Rapak.

Advantages gained using APP

The advantages of APP include the following:

(a) pumpable foods can be heated rapidly to a very high temperature (e.g. 150°C), resulting in very short process times (i.e. holding times) to achieve commercial sterility, and then quickly cooled, without the long come-up and cool-down times that is the case with conventional canning process. This method results in preserving higher nutritional quality and has better sensory characteristics,

(b) A variety of packages can be used in aseptic packaging systems, ranging from traditional glass bottles and aluminum cans to the semi-rigid and flexible polymeric packages or composites of plastic/paperboard/metal; last two being lightweight packages,

(c) Room temperature can be used throughout storage and distribution, thus reducing energy consumption as compared to a refrigerated supply chain,

(d) Allows various package shapes and sizes to be used with functionalities such as microwavability, convenience, easy opening and pouring, and great consumer appeal,

(e) The process is faster and the overall cost is lower, because less energy is needed for sterilization, processing, packaging, storage and transportation.

Microbiology and chemistry of aseptic processing

The extent of thermal treatment needed for commercial sterilization depends on the microorganisms that survive and grow in a product. The most heat-resistant microorganism, known as target microorganism, is chosen to evaluate commercial sterilization conditions. The genera Bacillus and Clostridium are the primary spore-forming spoilage microbes.

D-values or destruction rates for nutrients are usually much greater than those for microorganism. This makes thermal processing feasible by reducing bacteria populations very fast, while retaining food quality. In general, the z values for microorganisms are 5–15°C, while for nutrients and other quality factors are 20–40°C or even higher. Thus, HTST and UHT processes are more effective in retaining nutrients and quality than LTLT processing.

Changes in milk as a result of UHT heating

The major challenge in UHT milk production is to impart sufficient heat treatment with minimal flavor change. Direct heating imparts less flavor change but requires more energy in comparison to indirect heating. The residence time is determined by hold tube volume, flow rate and flow rate attributes (viscosity) of specific products. Positive reactions in the hold tube include

destruction of bacteria, inactivation of enzymes and hydration of thickeners. Negative reactions include development of off-flavor, initiation of off-color and destruction of vitamins.

In general, the heating should be equivalent to a minimum of 9-log reduction of thermophilic spores (referred to as a B^* value > 1) and a maximum reduction of 3% in the level of thiamine (sometimes referred to as a Cook value i.e. $C^* < 1$).

Heat treatment involves two reactions: Type 1 reactions involve the denaturation, degradation, and inactivation of whey proteins, enzymes, and vitamins. Type 2 reactions involve the formation of lactulose, hydroxyl methyl furfural (HMF), furosine and others, which are not detected in the raw milk.

Physical changes: The unwanted physical attributes associated with UHT milk are brown color, sedimentation, protein destabilization, and fat separation. Direct heating after homogenization appears to cause reagglomeration of the small fat globules with the formation of a solid fat layer during storage. To prevent this fat separation, homogenization in direct UHT plants takes place in the downstream position (after the final heating step and vacuum cooling).

Chemical change: The production of free fatty acids (FFA) during storage is more noticeable in milk with higher fat content and is greater in milk produced in direct rather than indirect systems. Milk proteins change more than any other milk constituent due to UHT processing that contributes to loss of color, flavor, and nutrition, as well as gelation and sedimentation.

Direct heat processing imparts less adverse chemical changes compared to indirect heat processing. In an indirect continuous-flow coiled tube system, the process holding time accounted for >80%, the process heating time <10%, and the cooling phase <2% of the accumulated chemical changes. Chemical changes involve flavor, acidity (decreases upon direct UHT process), enzyme inactivation and vitamin decomposition.

The volatile sulfydryl compounds are liberated which influences the flavor of the heated milk, deposits form within the heat exchangers, and plasmin, which may cause deterioration of the product, is inhibited. The extent of denaturation of β-lactoglobulin in UHT milk can vary from as low as 35% in direct plants to close to 100% in indirect plants.

Most of CO_2 is lost on heating, with a consequent increase in pH. Milk oxidative rancidity is the reaction of oxygen on milk fat components resulting in short-chain aldehyde and ketone volatiles.

Heating has little effect on milk salts with two exceptions, carbonates and calcium phosphates. On heating, soluble calcium phosphate precipitates onto the casein micelles, with a concomitant decrease in the concentration of calcium ions and pH. Some calcium phosphate is rendered insoluble at the high temperatures used in UHT heating and deposits on the surfaces of the heat exchanger (fouling).

Enzyme inactivation: Enzyme inactivation is a positive chemical change of UHT processing. Thermal inactivation of a transglutaminase (TG) inhibitor provides improved cross-linking of

casein micelles, resulting in improved product texture. The milk alkaline proteinase, plasmin, and its inactive precursor, plasminogen, have considerable heat resistance. They are more susceptible to inactivation by indirect UHT processing than by direct heating. Heat-stable proteinases from pseudomonads were reported to retain 20 to 40% of their activity after exposure to UHT conditions of 140°C for 5 sec.

Destruction of vitamins: UHT processing reduces B vitamins by 10%, folic acid by 15% and vitamin C by 25%. The fat-soluble vitamins (A, D, E) and some of the water-soluble vitamins (pantothenic acid, nicotinic acid, riboflavin, and biotin) are largely unaffected by UHT treatment, but losses of 20 and 30%, respectively, in thiamine and vitamin B_{12} can occur during UHT treatment. The levels of ascorbic acid and folic acid are markedly reduced in UHT milk containing a significant level of oxygen during UHT processing and storage.

The nutritional value of proteins, minerals, and fats is affected minimally by UHT processing and is correlated to the storage temperatures, initial oxygen content and packaging choice.

Heat stability of milk

The heat stability of the milk is its ability to undergo high heat treatment without coagulating or gelling. Solutions to improve heat stability include preheating the product in the UHT processor, adjusting pH to the ideal heat stability maximum, and adding phosphate, buttermilk, or phospholipids.

Defects in UHT milk

Sometimes defects have been encountered in the UHT processed milk, especially during storage. These are discussed herein.

Cooked and stale flavor: At least two different types of flavors develop in UHT milk. The cooked or heated flavor develops during processing, and the stale flavor develops during storage. Volatile sulfur compounds produced mainly from denatured β-lactoglobulin are responsible for the cooked flavor, which disappears rapidly in the presence of oxygen or oxidizing agents. Aliphatic aldehydes are major contributors to the stale flavor. The heated flavor after UHT processing is due to sulfhydryl (-SH) groups, which oxidize 5 to 10 days after processing. The oxidation then gradually reduces the cooked flavor.

Chalky or astringent defect: UHT processing causes a slight increase in the size of the casein micelle due to its association with denatured whey proteins and calcium phosphate. This phenomenon can lead to a chalky or astringent defect in UHT milk (especially if heated by steam injection), which can be eliminated by homogenization after the high-heat treatment.

Sediment formation: Sediment is more prevalent in products that are more severely processed, that have a targeted pH of <6.6 and that have undergone direct instead for indirect UHT processing. Other factors affecting sedimentation include homogenization pressure that is used to control fat separation, time and temperature profile that is used to ensure product sterility.

Sedimentation in UHT milk is due to destabilization of casein micelles. Sedimentation occurs more readily in concentrated milk than in normal-strength milk.

Fat separation: Despite homogenization of milk in the UHT process, a layer of fat occasionally develops on the surface of the milk during storage. Less fat separation occurs in milk processed with direct steam injection than with indirect heating, due to the additional homogenization effect of the steam injection.

Gelation: Gelation during storage is a common problem of UHT milk, which ultimately limits its shelf life. Milk with a high preprocessing microbial count is more susceptible to gel formation than milk with a low count; plasmin has also been implicated. Microorganisms that produce heat-stable enzymes (proteolytic) cause the most serious gelation problems. Longer refrigeration times prior to sterilization allow increased growth of psychrotropic microorganisms and concomitant production of heat-stable enzymes, especially proteinases and lipases. The gelation occurred more readily at room temperatures (20-25°C) than at low (4°C) or high (35 to 40°C) temperatures. Milk sterilized by '*direct heating'* gels more rapidly during storage than milk treated by '*indirect*' methods. This effect appears to be due to the greater inactivation of the proteinases and greater stabilization of the casein micelle by complexing with denatured whey proteins during the more severe '*indirect heating'*.

UHT-processed skim milk is more susceptible to gelation than UHT whole milk. This can be attributed to an enhanced action of plasmin and bacterial proteinases in skim milk over whole milk.

Commercial sterility testing

An incubation and inspection program is recommended by FDA to verify sterility of aseptically packaged products. Quantitative methods include direct enumeration and viable enumeration. Viable cells are counted using standard plate counts, most probable number, membrane filtration, plate loop methods, or spiral plating. Qualitative methods include measuring metabolic activity or cellular constituents.

Ultra-pasteurization or Extended Shelf Life (ESL) processing

The most recent form of heat treatment introduced for milk and other liquid dairy products, such as custard, is ultrapasteurization or ESL processing, which provides additional shelf life for pasteurized products, which is beneficial to both consumers and retailers. ESL products are products that have been treated in a manner to reduce the microbial count beyond normal pasteurization, packaged under extreme hygienic conditions, and which have a defined prolonged shelf life under refrigeration conditions.

It is a continuous heat treatment of intensity between HTST pasteurization and UHT sterilization, and hence, the properties of ESL milk differ from those of both pasteurized and UHT milk. In particular, ESL milk does not have a strong cooked flavor characteristic of UHT milk. ESL milk can also be produced by microfiltration or centrifugation (bactofugation), with or without a pasteurization step.

A range of different temperature–time combinations have been suggested for producing ESL milk. Generally, temperatures >100°C for very short times are used, with the most common conditions being 120°C–130°C for ~1–4 s. This results in a reasonable extension of shelf life of milk, with little flavor impairment, provided of course that the final heating and initial cooling stages are not excessively long. This is most easily achieved by direct steam heating, either steam injection or steam infusion, e.g., in the APV Pure-Lac™, Instant Infusion, and High-Heat Infusion systems. However, many commercial ESL products are produced on plate and tubular indirect heating plants.

ESL milk is not 'commercially sterile', which means that some (spore-forming) bacteria that can grow at room temperature are not destroyed by the processing conditions. Consequently, all ESL products have to be stored under refrigeration. The shelf life of refrigerated ESL milk is variously cited from 14 to 90 days; a shelf life of up to ~ 40 days can be achieved with ultraclean packaging, while longer times are possible with aseptic packaging.

Failure rate in UHT products

The microbiological failure rate in UHT products is quite low (0.02%). Higher failure rates indicate significant inadequacies in the aseptic packaging step. The spores of some species such as *B. stearothermophilus* and *B. sporothermodurans* are extremely heat resistant and can resist UHT treatment conditions. The latter species is of particular concern to the dairy industry as it is mesophilic and hence can grow at the temperature at which UHT milk is normally stored.

Table 2. Potential failure modes of UHT processed milk

Type of failure	Reason for failure
Type 1	Raw ingredient, handling, storage, or batching issues
Type 2	Processor and filler cleaning in place, sanitation, preventive maintenance, and pre-sterilization issues.
Type 3	Thermal process heating cycle including regeneration.
Type 4	The cooling cycle including surge tanks.
Type 5	Sterilization issues with the package.
Type 6	Sterility loss in the aseptic zone or from environmental load.
Type 7	Loss of package integrity.

Other UHT dairy products

UHT dairy foods include milk, modified milks, flavored milks, puddings, custards, creams, ice-cream mixes, and whey-based drinks. Further products introduced were energy and sports drinks, yogurt and sauces. Ultra high temperature non-fat milk, milk, light cream, and 18% cream are used throughout the U.S. by the restaurant and food service industries.

UHT processed cheese

According to Joint FAO/WHO Food Standards Program, Processed Cheese means U.H.T., the product defined above and after being processed by heating at 135-145°C for 5 to 10 seconds or any other combination of time / temperature equivalent.

Extension of shelf life of processed cheese is achieved by heating up to 145°C. For prolonged standing times the UHT can be designed in a double UHT head execution. To reduce setting, product contact parts are PTFE coated. Prior to filling, the product has to be cooled down and deaerated by controlled vacuum, followed by an inclined creaming tank for structure rebuilding and viscosity development under ambient pressure. The Creaming Tank is equipped with a high efficiency creaming element and viscosity monitoring.

MAKLAD UHT cheese plant consists of a pre-heating section (tubular heat exchanger) in which the cold cheese-mix is preheated to about 70^{o}C by means of ambient vapour, which is generated by vacuum cooler. The preheated cheese-mixture is heated up to 145^{o}C by an injector by direct steam injection and in one process step. The cheese mixture moves through the heat-retaining zone, where the clostridial spores are inactivated. Post heat-retaining zone, the cheese is continuously cooled to about 90^{o}C by expansion cooling, under vacuum conditions. After UHT sterilization, the processed cheese mix is extremely liquid. Hence viscosity is increased to the desired level in a creaming tank, by using controlled mechanical agitation and monitoring viscosity by a viscometer. This is finally followed by filling and packing.

UHT cream

Cream having 15 to 30% milk fat or vegetable fat (imitation creamer) is UHT treated at 142^{o}C for 3 sec followed by aseptic homogenization at 200 kg/cm^{2} pressure at 70^{o}C. Then it is cooled to less than 10^{o}C and filled aseptically.

The UHT cream may be kept at ambient conditions however, it is best stored at temperature lower than 15^{o}C. Likewise, UHT whipping dairy cream is also commercially available.