COMMERCIAL STERILIZATION AND ASEPTIC PACKAGING OF MILK PRODUCTS

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ABSTRACT

Milk is nature's most nearly perfect food and to utilize its nutritive values milk must be free from all pathogenic microorganisms. Pathogenic bacteria present, if any, in raw milk supplies are destroyed by the pasteurization process. Milk and its fluid products, so treated, possess on an average of 7-10 days shelflife, which in modern sophisticated distribution systems, is inadequate. Commercial sterilization in conjunction with aseptic packaging extend the shelflife of milk products to 90+ days. These products, excellent in performance, are not yet popular in the dairy case but, if consistent efforts are continued for their promotion, will win consumer's confidence. Increasing application of the sterilization process in the dairy industry has prompted marketing of numerous types and brands of sterilizing equipment. Every sterilization operation, due to differences in equipment and range of products manufactured, is faced with various problems in commercial applications of the process. Besides technical problems, label declaration and mode of distribution of these products cause legal complications in many areas of this country. Furthermore, no definition for commercially sterilized milk products aseptically packaged in flexible containers has been officially established by federal, state, and local regulatory agencies. Regardless of problems and challenges in commercial application of the sterilization process in the dairy industry, potential opportunities in this country for milk products, thus processed, are great.

INTRODUCTION

Milk is the most nearly perfect food but one of the most perishable. Microorganisms can cause foods in general and milk in particular to deteriorate. Therefore, it is necessary to destroy the organisms in milk to safeguard its healthfulness and prolong its shelflife, palatability, and wholesomeness. Application of heat is the most common method to destroy microorganisms in foods. With milk, destruction of any pathogenic organism that may be present is achieved by pasteurization which consists of heating the milk, holding it at a specific temperature, and subsequent cooling of the product.

There is no denying that the concept of pasteurization is excellent. Unfortunately, the process is not adequate for present-day merchandising of milk products. A recent study at the University of Florida (1) revealed that leaving regular pasteurized milk in a shopper's hot automobile encouraged growth of microorganisms that survived the pasteurization process or were present as post-pasteurization contaminants and thus considerably reduced subsequent shelflife. Even with refrigeration, certain microorganisms continue to grow, and consequently, milk products often develop undesirable characteristics with the lapse of time.

The average shelflife of pasteurized milk and its fluid products is about 7 to 10 days. Depending on the distribution area, 1 or 2 days elapse before the product is available to consumers. Nevertheless, this 7 to 10 days of shelflife may be more than adequate for regular pasteurized milk because of its high turnover at the retail level. But a 7-day shelflife often is not enough for products such as cream for whipping, coffee cream, and half and half because of their slower turnover.

Consequently, another method of processing to extend shelflife has been adopted by several dairy processors. Absolute sterility in a large volume of milk product is practically impossible. This is because the severe heating needed to achieve absolute sterility could profoundly alter the nutritive and organoleptic properties and render the product unfit for human consumption. Hence, the term sterilization as used in this paper refers to commercial sterilization. Most milk products are sterilized at temperatures between 275 and 300 F for 2 to 8 sec but they may still contain viable spores which normally don't grow to cause any subsequent spoilage of the product. Accordingly, a sterilized milk product need not be sterile to achieve a longer shelflife. These products, of course, should be free of harmful or proliferating organisms, and keep without deterioration for at least 30 days. However, with a proper combination of efficient sterilization and aseptic packaging systems, a shelflife of 90+ days can be achieved in milk products.

PROCESSING METHODS

Commercial sterilization of fluid milk products has recently been accepted in America. Several food manufacturers are focussing their efforts in this direction to meet the growing demand in the marketplace for such milk products. In recognition of this situation, several equipment manufacturers have de-
developed myriads of sterilization equipment and aseptic packaging machines.

**Sterilization systems**

A wide variety (sizes, shapes, and designs) of equipment is available for commercial sterilization of milk products. There are direct and indirect heating techniques and each imparts different characteristics to fluid milk products. Factors that should govern selection of a heating system include: (a) product considerations, (b) mechanical considerations, (c) automation, (d) economics, (e) legal considerations, and (f) correlation with packaging system.

**Direct heating methods.** (a) Steam injection technique. In this steam-into-milk process, sterilization is achieved by injecting high pressure steam into a line of constantly flowing product. The added steam is removed in a sterile vacuum chamber. This is also called “Superization.” (b) Steam infusion technique. In this milk-into-steam process the product is atomized into a pressurized steam chamber, then transferred into a sterile vacuum chamber where excess steam is removed.

In these direct heating systems the product is heated and cooled rapidly and is also deodorized in the evaporative cooling section. There is little product deposited on equipment surfaces because usually no metal surface is hotter than the product itself, and surfaces where deposits are likely to form are smaller because of the short time between heating and cooling. Thus, the chemical and physical changes in the product are less pronounced and natural color, flavor, and essential nutrients are preserved.

Direct heating methods are illegal in some countries (e.g., United Kingdom) as it is feared that impurities from steam may be carried into milk. Where sanctioned, the steam supply must be of culinary quality and the quantity of water before and after heating must be carefully controlled and maintained exactly.

These systems, however, are designed for both thin fluid products (e.g., coffee and whipping creams, half and half) and highly viscous products such as puddings but are best suited for extremely heat sensitive products like fortified skim milk.

**Indirect heating methods.** (a) Plate system. Most systems are similar in shape to the common pasteurizing press but different in design and capacity. The equipment consists of corrugated plates of stainless steel, joined in such a way that extremely thin layers of product are constantly in contact with the heat exchange surface. Because of this design feature relatively low pressure exists in the heat exchanger which means relatively low velocities and relatively low turbulence. This process is suitable for sterilizing all fluid milk products.

(b) Tubular system. This seamless tubular heat exchange system can withstand high pressure. The product flows at high velocity and results in extremely high heat transfer rates. Since high product pressure and turbulence virtually eliminate burn-on of product, this system is ideal for processing products without added emulsifiers or stabilizers and is, therefore, preferred for sterilization of half and half, coffee cream, whipping cream, etc.

(c) Scraped surface system. This system is designed to sterilize high viscosity products with or without particles, by continually scraping product off the heat exchange surface. Puddings and ice cream mixes can be easily and continuously sterilized in this system. Regeneration is not included hence, higher operation cost.

**Aseptic packaging system**

Packaging of sterilized milk products under aseptic conditions is essential for extending shelf life. The locked-in cooked flavor in metal cans and light-induced changes in glass containers of sterilized products stimulated research and development of a packaging system which could employ a flexible paper laminate container for packaging of such products. In early 1960 Tetra-Pak of Sweden introduced an aseptic packaging system which utilizes paper foil laminate to form a tetrahedron-shaped flexible container. This system has drawbacks such as size limitations and machine speed, and the containers also present problems to processors and consumers. As a result, the Ex-Cell-O corporation, after 5 years of study, planning, and fabrication, put into operation in 1968 an aseptic packaging system which uses comparatively rigid containers to package fluid milk products. The new machine is designated as the Pure-Pak NLL and its use assures extended shelflife for all sterilized products. This compact system forms, fills, seals, and codes 45 aluminum foil lined paper containers per minute in sizes from ½ pint through the quart.

Special features of this aseptic Pure-Pak packaging system are: (a) sterilized multifoil container blanks are loaded conventionally and bottom sealed, (b) bottom sealed containers are resterilized by chemical fogging, (c) containers are dried with hot sterile air, (d) containers are filled and sealed in a sterile air atmosphere, (e) a vacuum defoamer removes excess foam and helps secure an adequate top seal, and (f) individual containers are coded.

**COMMERCIAL APPLICATIONS AND ASSOCIATED PROBLEMS**

Nothing is perfect in this world including man and his creations. Sterilization and aseptic packaging of milk products are no exceptions to this axiom. These
processes usually work very well for dairy processors. However, consumers sometimes become disenchanted with sterilized milk products when they fail to live up to their expectations. Such complaints are generally caused by imperfections in the processing and packaging techniques. Imperfections oftentimes become inevitable when new processing techniques are applied to milk—one of nature’s most perishable foods.

Processors in the United States guarantee that sterilized milk products have a shelflife of 6 weeks, 3 months, and longer. It is not uncommon to find containers from the same batch of sterilized product which ‘spoil,’ prematurely whereas others stay fresh and are palatable far beyond their expiration dates. Some of the variables of vital importance in sterilization and aseptic packaging processes of milk products are described in the following discussion.

**Selection of raw material**

Not all types of raw milk, milk powder, and cream are suitable as ingredients for milk products to be sterilized. Suppose a raw fluid milk product contains 1,000 spores/ml, and is heated with a resultant sterilizing effect of 10 (spores reduced through 10 log cycles). The end product would have one spore in every 10,000 quarts produced. Consequently, if the raw product had only 10 spores/ml, and was processed in the same manner it would have only one surviving spore in one million quarts.

The first requisite in producing high quality sterilized products is to exercise care so only raw material with initial high quality is selected. This minimizes problems caused by bacterial, chemical, and physical deterioration. Hence, initial quality of raw products will determine the quality of finished sterilized milk products. The sterilization process, therefore, is more or less comparable to the process of dry cleaning. The more soiled the clothes, the less efficient the process.

**Selection of sterilization temperature**

In addition to initial bacterial load, especially spores, in milk products the number of organisms surviving sterilization depends on the sterilizing efficiency of sterilizers. A sterilizing effect of 10 at 295°F for 2 sec is considered adequate for most milk products. Nevertheless, the nature and properties of milk products (viscosity, solid contents, heat sensitivity, etc.) must be considered for satisfactory time-temperature determination in the sterilization process.

**Selection of homogenization sequence**

Homogenization of sterilized milk products containing fat is essential to protect stability of the emulsion during subsequent storage. Determination of homogenizing pressure is predicated by the characteristics desired in products. In general, homogenization before sterilization results in a coarse texture and increased sedimentation in products. Also, homogenization of heavy cream before sterilization often results in large fat globules and clusters, and increased gel structure. Effects of homogenization before sterilization are more pronounced when direct heating systems are used.

Homogenization after sterilization creates the need for an aseptic homogenizer or homogenizing valve to prevent post-sterilization contamination of products. Homogenization after sterilization avoids the emulsion destabilizing effects of the heat treatment, helps to obtain proper division and dispersion of fat globules, and reduces protein destabilization. Homogenization after sterilization is also needed to avoid ‘oiling off’ caused by steam employed in direct heating of coffee and whipping creams.

Double homogenization (before and after sterilization) yields products (i.e. coffee cream, and half and half) that are less stable in hot coffee than those homogenized only after sterilization.

**Selection of vacuum deaeration sequence**

The flavor of sterilized milk products has been described as cooked or ‘cabbage.’ Cooked flavor in products following sterilization is related to liberation of volatile sulfur compounds or free sulfhydryl groups. This defect can be reduced significantly by deaerating products at about 170°F during the sterilization process.

Deaeration of milk products, before sterilization, removes the occluded gas together with some of the volatile sulfhydryl compounds which may have been produced during regenerative heating. Deaeration at this stage provides residence time at an elevated temperature to heat-stabilize the product being processed and reduces its oxygen content which prevents further liberation of cooked flavor producing compounds during final sterilization. A level of 6 ppm oxygen is desirable to preserve optimum flavor in milk products.

Deaeration after sterilization removes all gases in addition to any sulfhydryl compounds produced at this stage. This imparts an excellent flavor to fortified skim milk.

An operating pressure on the vacuum deaerator should be maintained between 8-10 inches of mercury for all milk products except for those that are flavored artificially, in which case it should be kept below 4 inches. Under no circumstances should the pressure exceed 15 inches because any pressure above this limit would dehydrate the product.

**Cooling of products before packaging**

Cooling of milk products after final sterilization is...
necessary to prevent chemical, physical, and microbiological changes during subsequent storage of these products. Most low fat fluid milk products up to 70°F can be packaged aseptically in paper containers without a problem. However, half and half, and coffee and whipping creams must be packaged at 40°F or below to eliminate fat layer or plug formation induced by slow cooling of these products in containers during storage in the cold room. Homogenization helps to alleviate this problem to some extent but these products may be stored for weeks before becoming available to the consumers. Some stabilizers and emulsifiers also could be helpful but in certain areas, New York, for example, such additives are not permitted in fluid milk products.

**Pure-Pak machine and containers**

Sterilization along with aseptic packaging is a very sophisticated operation. Sterilized milk products must be packaged in containers that will maintain 'sterility' to extend their shelflife. Light-induced changes in the sterilized products packaged in glass jars, and cooked flavors locked in the canned products, have caused multi-foil laminated paper containers to become popular for packaging of these products.

Pure-Pak containers are most commonly employed in the U.S.A. for aseptic packaging of sterilized products. The standard Ex-Cell-O aseptic filler packages 45 units, whereas some of the modified fillers can handle as many as 75 units/min. Misformed or inadequately sealed containers may create spoilage problems because at high filler speed it is impossible for a machine operator to check each container. During operation of the filler, a partial or complete clogging of the peroxide spray nozzle results in failure to chemically sterilize the product contact surface of the container and so may cause spoilage of product. However, a signal device which alerts the operator to the malfunction of the peroxide spray nozzle during operation of the machine can remedy this problem.

Container blanks can be another potential problem. Those that are tightly packed in cartons are usually damaged (bent) and could represent as much as 10% of the total. If an operator attempts to utilize these containers after correcting them, the bottom will not be formed properly in 9 out of 10 instances. When misformed, these containers may not get a uniform peroxide spray or may get stuck and stop the Pure-Pak aseptic packaging machine. Each time the machine stops, at least four filled containers under the top heater will not be sealed, thus resulting in loss and waste.

Industry feels that much improvement is desired in packing blanks to eliminate 'troubleshooting' for damaged containers. Reinforcement and/or cushioning of corners of cartons may help to protect containers during transportation and storage. It is advantageous to discard damaged blanks rather than use them.

The fifth panel (vertical seam) of the container could also use some technological improvements. Milk products with low viscosity or high sugar content will 'wick' (seam leak) even during cold storage and can potentially jeopardize the entire batch of sterilized product. It is believed that skived edging (foil folded seam ends) of the fifth panel may be instrumental in curing the 'wicking' problem. Skived edged containers are relatively expensive but it could pay dividends in the long run by eliminating the 'wicking' problem.

**Testing sterility of finished products**

Highly heat resistant bacteria surviving in a large volume of sterilized milk product can be a potential nemesis for a processor. So can any contamination picked up by a product in the packaging station. When a very small number of bacteria live in a large volume of product without growing (one bacterium in 10,000 or one million quarts of product) detection of bacterial metabolic products is practically impossible. Therefore, a sample containing living bacteria could be declared sterile because it would be impossible to determine presence of bacteria in a large volume of product.

When a large volume of product is distributed into individual containers a few of the spores that are not destroyed by the sterilization process may be introduced into a very few containers while all other containers are free of the spores. Results from examination of these containers would be valid only for the sample tested and not for the entire contents of the container. In addition, results might be valid only for the container tested and not for the entire batch.

The most common method to ascertain if a product is sterile is to test it bacteriologically. The Standard Plate Count and incubation at 90°F of finished products are being investigated in various parts of the country as suitable methods for laboratory control and more experience is needed before any national consensus on testing techniques is established.

**Loading and unloading of finished products**

In addition to careful processing and packaging, proper loading and unloading of sterilized milk products are essential to prevent any damage that could introduce contamination into products at this point. Sterilized products must be carefully placed in the truck. Cases of products must be palletized so as not to damage the gable top of the containers. Excessive agitation of product resulting from bumpy roads
might cause churning of fat in high fat content milk products. Failure to exercise care and responsibility during loading, transport, and unloading of these products could cause several problems with a resultant high loss.

**Shoppers and sterilized products**

An American housewife is considered to be the most sophisticated shopper in the world. Besides freshness and wholesomeness, present-day shoppers are demanding extended shelflife milk products. Consequently, milk processors in America are attempting to achieve this goal by means of sterilization and aseptic packaging operations.

But shoppers seem to hesitate to pick up a container of sterilized product from the dairy case because they are seemingly not as familiar with the meaning of the word “sterilized” as they are with “pasteurized.” A majority of shoppers assume that something is either added to or removed from these products. It may be helpful for the processors to label these products “long life” rather than sterilized.

**Consideration for legal status**

The process of sterilization consists of applying thermal conditions as severe as possible while remaining within a range compatible with conservation of desirable organoleptic properties of milk products. National and international legal aspects must be taken into consideration to comply with requirements for processing, packaging, distributing, and marketing of sterilized milk products.

In the United Kingdom, ultra-high-temperature (UHT) milk is defined as milk which has been heat treated to not < 270 °F and held for not < 1 sec. In West Germany, UHT milk is defined as milk that must be heated to a temperature between 275 and 300 °F in approved equipment. The required holding time must be determined by an official test. Swedish Food Ordinances define sterilized milk as milk which has undergone such heat treatment as to render the product free from living bacteria. It may be sold only in sealed packs. In Denmark, UHT milk, if aseptically packaged in cartons, is treated as pasteurized milk for legal purposes. However, it is legally considered to be the same as in-bottle sterilized milk in the Netherlands. Generally, in Europe the term commercial sterilization implies that the product has been subjected to a processing temperature between 266 and 300 °F with a holding time of at least 1 sec.

In the United States, the sterilization process is still an ‘orphan’ in the sense that there is no official (Federal or State) definition for sterilized milk products which are aseptically packaged in flexible paper containers. However, each milk operation that is processing sterilized products in the nation has adopted time-temperature combinations dependent on the nature of products processed and the equipment employed.

**Future applications and opportunities**

Sterilization and aseptic packaging, being relatively new processes which are of particular importance in terms of milk utilization potential, fill a void in dairy technology by solving the often encountered problem of very short shelflife of fluid milk products. Basically, any liquid milk product or fluid food can be sterilized and packaged aseptically, thus offering very significant product range flexibility.

To be successful in sterilized milk products operation it is essential to have properly qualified, experienced operators and technicians. Enough volume to keep the equipment busy for most of the day is also required. Any enterprise that has nationwide distribution or that packages numerous private brands should be successful. Such processing techniques, if applied to a central manufacturing plant, could also be very useful for a multifood organization which has a sale outlets throughout the country.

Sterilized dairy products may have a bright future in the U.S.A. even though adequate refrigeration facilities are available in this country. The need for production of “long life” milk products has long been felt by dairy processors and distributors. Increased education about sterilized products will no doubt bring about a great demand for them, but it will take time.

The dairy industry may reap benefits from application of sterilization and aseptic packaging if proper emphasis is given to: (a) quality of raw materials; (b) efficiency of processing and packaging equipment; (c) formulation, processing, and packaging of products; and (d) careful handling of finished products.

**Reference**