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The UHT Processing of Non-Viscous Liquid Products

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Abstract

Ultra high temperature (UHT) processing is a technique for preservation of food and beverage products in which microorganisms are destroyed by brief but intense heating. It is a continuous process that takes place in a closed system to prevent contamination of the product by exposure to airborne microorganisms. Aseptic packaging of the product in a hermetically sealed container to prevent reinfection is an integral part of the process. This report presents brief discussions of history and developments of UHT processing, selection of proper time-temperature combination of heat treatments of UHT liquid products, process description, changes in nutritional values of products during processing and storage, some biochemical and physical aspects and regulations pertaining to UHT products. This report primarily covers the pasteurization process of non-viscous liquid products, which involves heating the product long enough to destroy pathogens.

Key words: liquid foods, non-viscous, review, pasteurization, UHT processing

Introduction

UHT processing may be described as either a pasteurization or sterilization process. UHT processes are not new, dating back to the early 1900s. It was however, the development of effective heat exchangers and advancements in the aseptic cartooning system that led to the commercial success of UHT processing. The primary purpose of the UHT treatment is the reduction of viable microorganisms and spores. Selection of appropriate time-temperature combination is required for thermal destruction of microorganisms. The interest in and development of UHT pasteurization have culminated in legal standards. There are several established methods available to thermally sterilize and cool a food product. The basic UHT methods are: (a) direct heating with steam injection or infusion, and (b) indirect heating with tubular or plate heat exchanger.

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The UHT processing conditions affect the various nutrients of food. While the nutritive value of some components such as fat, fat-soluble vitamins, carbohydrates and minerals are essentially unaffected; the values of other components such as water-soluble vitamins and proteins are adversely affected. Other changes in UHT products occur during storage. Storage temperature, oxygen availability and exposure to light are some of the factors that are responsible for these changes. Heat treatment and storage also affect the quality related aspects, such as color, flavor and texture. Higher processing temperatures result in enzyme inactivation, sedimentation and gelation that affects the texture of the product. Color and flavor changes occur as a result of complex chemical reaction and are readily detected by the consumers. Due to the differences in the severity of heat treatment process wide variations are seen in these changes. In some countries, government regulations may prescribe nutritional and quality related aspects. All UHT systems are required to meet the legal pasteurization requirements that vary from country to country.

History of UHT Processing

UHT processing systems were developed even before the benefits of UHT were recognized. Continuous-flow sterilizers were constructed and patented in the beginning of this century. In 1913, Jonas Nielsen developed the first recorded UHT processing plant and later he also developed an aseptic canning system (Burton, 1988). In 1927, Grindrod developed a steam injection system that was capable of heating milk to 110°C. Indirect and direct heating systems were developed and tested for use at high temperatures.

Two separate events resulted in the modernization of UHT processing. The first event was the development of concentric-tube UHT sterilizers by Geber. Stork & Co's Apparatenfabriek, Amsterdam. These sterilizers were used for the pasteurization of milk before in-bottle sterilization in batch or continuous autoclaves. The second event was the development of the Uperization steam into milk UHT system by Alpura AG and Sulzer AG in Switzerland (Burton, 1988). The use of aseptically canned milk began in the early 1950s; however, due to the cost of cans this system turned out to be uneconomical. The development for aseptic cartooning continued and in 1961 Tetra Pak developed and marketed the first aseptically cartooned milk. The development of wide range of heat exchangers suitable for UHT processing and the advancement in aseptic cartooning system led to the commercial success of aseptic processing worldwide (Burton, 1988).

Types of dairy products which are now UHT processed and then aseptically filled include whole, separated and flavored milks; coffee and whipping creams; concentrated milks; recombined milks; milk based custards and whey-based drinks. Some of the non-dairy products that are aseptically processed include eggs, fruit juices, and wines.

Pasteurization of liquid whole eggs and liquid yolk was first utilized by egg product industry in 1930s. Initially batch-type pasteurizers were used and operated at temperatures up to 60°C. Later plate type HTST pasteurizers were used, in which operating temperatures were carefully controlled (Cunningham, 1986).

Time-temperature Combination

There is a difference in specifications for time-temperature of heat treatments for UHT products and ultrapasteurized products. The Grade A Pasteurized Milk Ordinance (PMO) specifies standards for time-temperature of heat treatments for pasteurization and ultrapasteurization. U.S. Federal Standards of Identity (1985, PMO) stipulated that a product labeled "ultra-pasteurized" must have been heated to 137.8°C or above for at least 2 seconds (Westhoff, 1978). Also ultrapasteurized products need to be refrigerated. However, processes for UHT products are not detailed in regulations for thermally processed low acid foods. Processing authorities specify, for an individual product or a group of products, the temperature and time of heat treatment and other processing conditions appropriate for the equipment to be used. UHT products have extended shelf life without refrigeration.

Two basically different processes have been labeled UHT. The first UHT-sterilization, involves heating milk to a high enough temperature for a long enough time to produce a commercially sterile product. Sterilization uses temperatures in the range of 135 to 150°C for shorter holding times of less than 2 seconds. The other UHT-pasteurization, principally used in North America, involves heating milk long enough to destroy pathogens (Burton, 1973).

The interest in and development of UHT pasteurization time-temperature combinations of milk has resulted in legal standards that are give in Table 1 (Westhoff, 1978). In the absence of data on thermal destruction of pathogenic organisms at UHT temperatures, these standards were developed by extrapolating existing data, with the addition of a wide margin of safety (Westhoff, 1978). Later other studies indicated that these time-temperature standards for UHT pasteurization of milk and milk products by plate heat exchangers are acceptable and are minimum combinations for UHT pasteurization by steam injection.

A few countries have legal definitions for UHT milk, probably, because defining a sterile product is difficult (Westhoff, 1978) and also because the filling

Table 1. Current minimum pasteurization standards

Methods and product	Time/temperature
Vat or batch pasteurization	
Milk	30 min/62.8°C
Cream	30 min/65.6°C
Ice cream mix	30 min/68.3°C
HTST pasteurization	
Milk	15 s/71.7°C
Cream	15 s/74.4°C
Ice cream mix	15 s/79.4°C
UHT pasteurization	
All products	1.0 s/88.3°C
	0.5 s/90.3°C
	0.1 s/93.9°C
	0.05 s/95.6°C
	0.01 s/100°C
Ultra-pasteurized	
All products	2 s/137.8°C

From Westhoff (1978).

Table 2. Legal definitions of UHT milk

Country	Definition
United Kingdom	Milk that has been heated to not less than 132.2°C and held for not less than 1 s.
West Germany	Milk must be heated to 135-148.9°C in approved equipment. Holding time determined for each system.
Sweden	Milk that has undergone such a heat treatment so as to render the product free from living bacteria.
Denmark	If aseptically package in cartons, it is treated as pasteurized milk for legal purposes.
United States	No official definition for sterilizing milk aseptically packaged in flexible containers for non-refrigerated distributions.

From Westhoff (1978).

system which affects the bacteriological quality of milk cannot be controlled by the "definite temperature for a definite time" description (Burton, 1969). Various legal definitions of UHT milk are listed in Table 2 (Westhoff, 1978).

In case of eggs the main objective of the time-temperature treatment is to effectively kill most of the salmonellae that may be present in contaminated eggs. USDA requires that liquid whole egg be heated to at least 60°C and held for no less than 3.5 minutes for the average moving element. However in United Kingdom, pasteurization temperatures of 64°C for 2.5 minutes is considered adequate to accomplish satisfactory for salmonellae reduction in the egg. Whole egg pasteurization requirements for other countries are 66 to 68°C for 3 minutes in Poland, 63°C for 2.5 minutes in China, 62°C for 2.5 minutes in Australia and 65 to 69°C for 90 to 180 seconds in Denmark. Those for U.S. the temperature and holding times listed in Table 3 are minimum (Cunningham, 1986).

Process Description

UHT processes can be classified as either directly heated or indirectly heated according to the heat exchangers used (Bhamidipati and Singh, 1995).

Indirect Systems

In these systems the product is heated through a heat-conducting barrier, usually stainless steel, which separates the heating agent from the product. For non-viscous products such as dairy and juice products plate and tubular heat exchanger are used. Plate heat exchangers consist of a number of corrugated, gasketed, thin plates ordered together in a frame such that the product flows on one side of the plate, and the heating or cooling fluid flows on the other side. In cases where product is prone to fouling, hot water is used as heating medium. These exchangers are usually used for regeneration where product-to-product heat exchange is used to cool the product and at the same time heat the cold product. Tubular heat exchangers use concentric tubes to separate the product from the heating/cooling medium or consist of a coiled tube in a shell. The best-known and most applied process for continuous heating of foods is tubular heat exchanger.

Direct Systems

In processes using direct heat, product is mixed with saturated steam under pressure and heated rapidly as steam condenses. Direct systems are classified

Table 3. Pasteurization requirements for liquid egg products

	Minimum temp. requirement (°C)	Minimum holding time	
		Fastest particle (min)	Average particle (min)
Albumen (without use of chemicals)	57	1.75	3.5
	56	3.1	6.2
Whole egg	60	1.75	3.5
Whole egg blends (less than 2% added non egg ingredients)	61	1.75	3.5
	60	3.1	6.2
Fortified whole eggs and blend (24 to 38% egg solids, 2 to 12% added non egg ingredients)	62	1.75	3.5
	61	3.1	6.2
Salt whole egg (with 2% or more salt added)	63	1.75	3.5
	62	3.1	6.2
Sugar whole egg (2 to 12% sugar added)	61	1.75	3.5
	60	3.1	6.2
Plain yolk	61	1.75	3.5
	60	3.1	6.2
Sugar yolk (2% or more sugar added)	63	1.75	3.5
	62	3.1	6.2
Salt yolk (2 to 12% salt added)	63	1.75	3.5
	62	3.1	6.2

From Cunningham (1986).

into steam injection and steam infusion. Steam injection is used for sterilizing milk product, beverages and other products that are not viscous. In steam injection, steam is injected into the product, which increases the product temperature. After product is preheated, it is passed into heating unit where it is injected with saturated steam that condenses to raise the product temperature. The final heating causes considerable dilution of the product. The product after being held for the desired time is then flashed into an expansion vessel where it is cooled immediately. The vacuum in the expansion vessel is normally controlled so that exact amount of water added as condensed steam is removed from the product (Burton, 1988). In case of formulated foods, the initial amount of water added is adjusted in such a manner that the final product has the right constitution. In steam infusion, the product is exposed to heat in a steam chamber. A product film is introduced into a

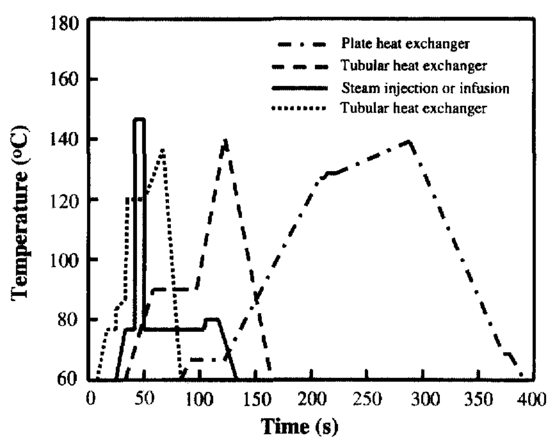

Fig. 1. Temperature-time curves for some commercial UHT heat exchangers.

controlled, pressurized atmosphere of saturated steam. The product absorbs steam through infusion that results in the increase of product temperature. The condensed steam results in extra moisture that is removed by flash cooling.

Figure 1 shows the time-temperature curves for some commercial UHT heat exchangers. The tubular and the direct steam heating systems provide the shortest processing times, while the plate heat exchange system provides the gradual thermal profile.

Nutrition Aspects

During the processing of milk many chemical reactions occur which result in the loss of its nutritive value. While the nutritive value of some components such as fat, fat-soluble vitamins, carbohydrates and minerals remain almost unaffected, other components such as proteins and water-soluble vitamins change considerably (Porter *et al.*, 1972). Some changes in the nutritive value also occur during storage. The major factors that contribute to some of the changes are greatly affected. Some of the changes are temperature, exposure to light and oxygen. During storage vitamin components are greatly affected. Some losses also occur in proteins.

Vitamins

The data on the effects of UHT processing on vitamins varies considerably. The loss of vitamins during processing depends on several factors such as severity of the heat treatment, exposure to oxygen and light before and after processing, and so on. In general, it has been seen that the vitamins are more stable under UHT processing conditions than under other low heat treatment (Van Eekelen *et al.*, 1965).

Losses of fat-soluble vitamins A, D, E and β-carotene are found to be negligible during sterilization conditions (Burton, 1969). However Van Eekelen *et al.* (1965) have reported that upon prolonged sterilization, vitamin A and carotene losses are upon 35%. The fat-soluble vitamins are found to be stable during storage with the exception of vitamin A, which is destroyed by light at room temperature (Casuret *et al.*, 1961).

Some of the water soluble vitamins such as pantothenic acid, nicotinic acid and biotin are heat-stable and are nor affected by UHT processing (Van Eekelen *et al.*, 1965) and storage (Burton, 1969). Heat stable riboflavin is susceptible to light and is lost up to 60% during storage (Van Eekelen *et al.*, 1965). Thiamine losses greater than 20% during different UHT treatments and up to 50% with prolonged sterilization have also been reported. Van Eekelen *et al.* (1965) have reported that for vitamin B_6 losses varied considerably. They speculated that the differences in the results could be due to the type of assay procedure used, storage time of product and differences in the original amount of vitamin in the product.

Folic acid, ascorbic acid and vitamin B_{12} losses are interrelated, through a complex series of reactions which heat is the only factor. Heat stable ascorbic acid upon oxidation forms dehydroascorbic acid, which is heat-labile. It is this form of ascorbic acid that is lost during heat treatments and storage (Burton, 1969). Folic acid and vitamin B_{12} are heat-labile. Presence of ascorbic acid prevents the loss of folic acid during processing and storage. However in presence of dehydroascorbic acid, folic acid is lost. Oxidative degradation of ascorbic aid also results in the loss of vitamin B_{12}. Van Eekelen *et al.* (1965) have reported that vitamin B_{12} losses are at maximum during storage. Burton (1973) has reported that about 30% vitamin B_{12} losses occur during UHT conditions.

Minerals and Fats

UHT processing has negligible effect on the minerals (Borton, 1969). Studies with rats indicated that the availability of calcium is unaffected by UHT processing. However, Hansen and Melo (1977) found that milk processed at 143°C for 8-10 seconds losses significant amount of free calcium. Pellet and Donath (1974) did a study of calcium and phosphorus was higher with UHT milk than with pasteurized milk.

UHT processing results in the loss of polyunsaturated fatty acid in the milk triglycerides. 33% linoleic acid, 13% linolenic acid and up to 7% arachidonic acid are lost during processing (Pol and Groot, 1960). Processing also results in loss of individual free fatty acids up to 30% (Withycombe and Lindsay, 1969). Schmidt and Renner (1978a,b) have reported development of some free fatty acids during storage. They found that development of free fatty acids is rapid with higher storage temperatures, with direct processing and with higher fat milks.

Proteins

The nutritional components that undergo the greatest change during processing and storage are proteins. Severe heat treatments result in the denaturation of whey proteins of milk causing them to form complexes not only with themselves but also with caseins and fat globules. These complexes are affected by heating. The whey proteins differ in their heat sensitivities, Bovine Serum Albumin is most heat-sensitive, α-lactalbumin and β-lactoglobulin are heat-stable. Studies on denaturation of individual whey proteins have indicated that kinetics of the proteins differ depending on whether the heat treatments are below or above 90 or 100°C. Processing also increases the size and changes the composition of casein aggregates (Burton, 1969). Proportion of casein aggregates in affected with increase in storage time of UHT milk.

Nutritive value of milk is impaired during UHT processing. Lysine levels are reduced by sterilization; however, methionine and tryptophan, which are heat-labile amino acids, are not much affected (Van Eekelen *et al*, 1965). On the other hand, Aboshama and Hansen (1977) observed for the other amino acids during processing or storage (Van Eekelen *et al.*, 1965).

Animal studies of UHT milk have indicated that the biological value, protein efficiency ratio and digestibility coefficient are not effected by UHT sterilization (Burton, 1969; Porter *et al.*, 1972). However, it was found that the growth supporting value of the milk proteins decrease with the denaturation of serum proteins. It was concluded that denaturation is not a significant factor in human infant nutrition (Burton, 1969; Porter *et al.*, 1979). A study done with newborn infants have shown that children drinking UHT milk gained more weight per day as compared to the children drinking pasteurized milk (Anon., 1979). Also UHT milk tends to cause fewer digestive problems.

Effect of Pasteurization on Eggs

It has been reported that heating egg white in the pasteurization range of 54 to 60°C damages foaming power. Workers agree that egg white is impaired when heated for several minutes above 57°C. However, heating improves foaming properties of yolk-contaminated egg white. Egg white at pH 9 tends to increase in viscosity when heated to 56.7 to 57.2°C and coagulates rapidly at 60°C. When pasteurized in the range of 56 to 66°C, whole eggs denature which is evident by the change in viscosity. Above this range, fractional precipitation of proteins occurs and coagulation takes place rapidly above 73°C. Cakes made from whole eggs pasteurized between 57 and 66°C for 3 minutes had better volumes and sponginess. Also pasteurization of 61°C for 3 minutes did not have any adverse effects on the custard making properties of liquid whole eggs. The performance and stability of pasteurized liquid whole egg was reviewed and it was concluded that whole egg commercially pasteurized in the U. S. performed satisfactorily in baking tests (Cunningham, 1986). Woodward and Cotterill (1983) observed changes in electrophoretic and chromatographic patterns in whole eggs heated form 57 to 87°C for 3.5 minutes. Livetins and some globulins were most heat-sensitive, while conalbumin and ovalbumin were most stable.

Biochemical and Physical Aspects

Enzyme Inactivation

Plasminogen activators (PA) and proteinases are naturally present in the milk. Heat stability studies have indicated that native PA are not affected by pasteurization and are not inactivated by UHT dairy processing conditions (Lu and Nielsen, 1993). Kiermeier and Doruk (1972) have demonstrated that β-glucuronidase in milk is completely inactivated by pasteurization (63°C for 30 min or 72°C for 15 s) but not always fully by UHT processing. Greenbank and Pallansch (1962) found that heating whole milk to 90°C for 15 s inactivated xanthine oxidase. Peroxidases are almost always destroyed and proteases are usually destroyed at UHT sterilization temperatures. No reactivation of peroxidases has been observed under any storage condition. Phosphatase activity is always zero after milk has been sterilized but may be reactivated after prolonged storage. It is observed that greater storage time and temperature lead to higher degree of reactivation of enzyme (Mehta, 1980).

Sedimentation and Gelation

The intense heating during UHT processing results in the denaturation of heat sensitive proteins or precipitation of salts in milk, which leads to the formation of sediments (Mehta, 1980). Rate of sedimentation is greatly enhanced at higher sterilization temperatures. Maximum sedimentation in UHT processing at 140, 145 or 150°C occurs with a 4 sec holding time (Burton, 1969). Salts affect sedimentation; while calcium promotes sedimentation and addition of sodium citrate or bicarbonate inhibit sedimentation (Hsu, 1970). Indirect heating has been found to cause more sedimentation than direct heating (Burton, 1969). Studies by Perkin *et al.* (1973) have indicated that directly heated UHT milk gave twice as much sediment as indirectly heated milk. As a result of sedimentation a chalky texture is found in milks that are directly processed by UHT.

Gelation in milk and milk products is another important problem since it limits the shelf life of the product (Burton, 1969; Dunkley and Stevenson, 1987). Sensitivity to gelation is greater with UHT processing than with sterilization in a container. Andrews and Cheeseman (1972) believed gelation is a first step towards sedimentation. They think that gelation is either due to Maillard reaction or is the result of physical forces of association, such as hydrophobic bonding between casein and lactose. There are conflicting reports about proteolysis being the cause of gelation. Some researchers have suggested that both coagulation and development of bitter flavor might be caused by protein changes and might be related. Studies have indicated that reactive sulfhydral groups may contribute to instability of milk protein leading to gelation and/or deposit formation. Varying heat treatment improves control of gelation; however, adding phosphatase provides the best control (Mehta, 1980).

Color and Fat Separation

Color of UHT milk is influenced by many factors. The appearance primarily depends on the size gradient of the fat globules, distribution of milk proteins and the browning reaction (Mehta, 1980). UHT milk is whiter than its corresponding raw milk. Whitening is believed to be caused by denaturation and subsequent coagulation of soluble protein components of milk, which increase the amount of opaque particles in milk (Burton, 1969). Size of fat globules also affects color of milk.

In case of juices, aseptic processing initially produces a high quality product. However, differences in color arise during storage. For products containing sugars and proteins, e.g., citrus juices, color change due to Maillard reaction is a major concern. Degradation of anthocyanins also results in color changes in fruit juices especially in cranberry and blueberry juices. Reduced storage temperature, reduction of oxygen in a package by proper product deaeration, use of minimal headspace and use of oxygen impermeable container are some of the ways by which color changes can be minimized in aseptically packaged beverages (Toledo, 1986).

High temperatures of processing reduce the cream line in whole milk (Burton, 1969). The stability of fat dispersion can be increased by proper homogenization. Homogenization at 211 kg/cm^2 and 71-77°C with the homogenizer located downstream from the heater greatly reduces fat separation in milk (Hsu, 1970).

Flavor Changes

The bottom line for acceptance of UHT products appears to be their flavor. Flavor differences between UHT milk and flesh-pasteurized milk are statistically significant as given in Table 4 (Amantea, 1983). Also, the more severe the heat treatment, the greater and more significant is the flavor difference.

The dominant characteristic of freshly processed UHT milk is a cooked flavor (Dunkley and Stevenson, 1987). Intensity of cooked flavor decreases with increase in storage time and later other characteristics become evident. These vary in origin and sensory

Table 4. Sensory evaluation of UHT milk vs. pasteurized milk

Methods of UHT heat treatment	Percent of panelists recognizing a difference between UHT milk and pasteurized milk	
	After 10 days of storage	After 4 weeks of storage
Direct	73[a]	83[a]
Indirect	88[a]	90[a]

[a]Significant at P<0.001, From Amantea (1983).

properties and include "UHT flavor" and stale flavor. The latter limits the shelf life of the product. Generally during the first few weeks of storage, flavor acceptability increases as the intensity of cooked flavor are due to many factors, some of which are: properties of milk, intensity of heat treatment, type of processing equipment, type of package, concentration of oxygen and time and temperature of storage.

Pasteurized milk has a bland flavor that differs from raw milk flavor. At higher processing temperatures "cooked flavor" becomes apparent which is caused by hydrogen sulfide (H_2S) formed by thermal degradation of β-lactoglobulin and proteins from fat globule membrane. Processing with UHT results in a typical "UHT-milk" flavor caused by ketones, lactones and sulfur compounds. Milk lipids are the most important source of UHT flavor. Sterilization of milk results in "caramelized flavor". Overall flavor impression results from the caramelization and Maillard reactions.

With increase in heat treatment of milk the concentration of H_2S rises. However, during severe heat treatment concentration of H_2S falls due to its reaction with other milk components. Processing and packaging influence the intensity of cooked flavor. The cooked flavor can be reduced by use of chemical additives or by aseptic addition of sulfhydral oxidase after UHT treatment. However unlike stale flavor, cooked flavor is not a serious limitation to the acceptability of the product.

Processing and storage conditions influence the concentrations of lactones, aldehydes, and ketones that are formed during heat treatment and storage. Formation of such compounds is also dependent on the fatty acid composition (Mehta, 1980). However, contribution of these compounds to stale flavor is still being debated. Oxidized flavor is not as serious a problem with UHT as with pasteurized milk because UHT milk has reducing substances (Hostetler, 1972). These reducing substances are probably sulfhydral in nature.

A cooked flavor has been often noticed in UHT-treated eggs because of liberation of volatile sulfhydral compounds. This is not much of a problem where a vacuum deaerator is part of the UHT processing system because the deaerator reduces the amount of compounds producing such an off-flavor in the finished product (Aggarwal, 1974). Cold storage of the product helps in improving the flavor by permitting oxidation of sulfhydral compounds.

Literature (Lund and Lawler, 1966) on aseptic and cold filled canned juices claimed that the process "produces a product with the flavor of unheated juice". A detectable flavor difference is found between HTST heated and cold-filled juice as compared to unheated juices. Toledo (1986) used a triangle test to compare the flavor of aseptically canned and unheated orange and apple juices. Panelists easily identified heated orange juice but could not identify of between heated and unheated apple juice. Comparisons were also made between flavors of aseptically packaged juices and those hot filled. Panelists were not able to differentiate between flavor of hot filled and aseptically packaged orange and apple juices. It has been observed that flavor changes continue to occur in canned products after processing. Flavor change during ambient storage temperature can negate the advantages of aseptic processing. Therefore, reducing storage temperature and using oxygen impermeable containers can help maintain flavor quality in aseptically packaged beverages (Toledo, 1986)

Regulations

Food and Drug Administration

Regulations for UHT milk and milk-based products that contain little or no meat or poultry are contained in the Title 21 of the *Code of Federal Regulations* (CFR), parts 108, 113 and 114. Section 113.40 (g) lists requirement for aseptic processing and packaging systems. If provisions could not be made in milk regulations, an alternative might be to consider the product covered by the *Code of Federal Regulations* 21 CFR 10.1, Part 128 B - Thermally processed Low-Acid Foods Packaged in Hermetically Sealed Containers. FDA defines "hermetically sealed" as "a container which has been designed and intended to be secure against the entry of microorganisms, and to maintain the commercial sterility of its contents after processing".

Actually in the U.S., UHT milk products which are aseptically filled and which are to be distributed without refrigeration are to be treated as low-acid canned foods and must be given a heat treatment process appropriate to the sterilization of a low-acid food. Details of the mechanical design of the plant are specified in the Grade A PMO of US Public Health Service and the FDA and USDA guidelines cited and also the requirements between PMO and 21 CFR 113. There it is required that PMO and 21 CFR 113 should be revised so that these regulations become compatible and up-to-date.

State Regulations

Generally state regulations have had little effect on aseptic processing of food products. Two major exceptions include PMO-regulated products in states where the PMO is adopted and enforced, and products produced in California, where the state Department of Health Services issues all process for acidified and low acid foods produced in California, and State Department of Food and Agriculture has regulations similar to those in the PMO.

Regulations for Liquid Whole Eggs

Pasteurization of egg products in U.S. became virtually mandatory on June 1, 1966. Regulations were passed for USDA inspected plants, new FDA standards of identify for egg products were adopted and some state laws were enacted requiring pasteurization, such as California Senate Bill No. 643. In the U.S., present pasteurization requirements for whole eggs are described in Section 55.101 paragraph (6) of the Regulations Governing Grading and Inspection of egg products. The temperatures and times listed in Table 3 are minimum (Cunningham, 1986).

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