

Which Milk is Fresh?

Research Article

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Abstract

The different heat treatments to which milk is subjected and their effects on milk were reviewed. Pasteurized and UHT milk which is mislabelled as 'fresh milk' in the Philippines were compared. The commercial heat treatment processes applied to milk are: pasteurization, ultra high temperature (UHT), ultra pasteurization or super pasteurization, sterilization, and innovative steam injection (ISI). It was shown that temperature heat processes alter the heat sensitive nutrients, physico-chemical and functional properties of milk. Higher amounts of lysinoalanine were found in UHT milk than in pasteurized milk. Further reduction in nutritional value of UHT milk occurs in supermarket shelves where it is kept until sold and consumed. While UHT treatment is suitable for tropical countries with high ambient temperatures and are unable to afford refrigeration during marketing and distribution, the nutritional quality of protein is very important because in these countries, protein intake is generally low due to poverty. The Philippine food regulatory agency allows the 'fresh milk' label on UHT milks marketed in the country. This practice does not properly inform the consumers about the product because such milks may have been in the supermarket shelves for 6 months or more and is therefore, no longer fresh. It also puts the locally produced fresh, pasteurized milk at a disadvantage. Although liquid milk for direct consumption is not covered by Codex commodity standards, use of terms like 'natural', 'pure', 'fresh', 'home made', and 'artisan' needs to be regulated in order to protect the consumers.

Key Words: pasteurization, super pasteurization, ultra pasteurization, ESL, UHT, ISI, sterilization, lysinoalanine, fresh, mislabeling

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Introduction

Milk being nature's nearly perfect food is intended as the first food of all new born mammalian species. Because of milk's nutritional importance and dairy development's contribution to a country's economic growth, developing country governments like the Philippines support local dairy industry development. Despite all claims however, about milk's nutritional benefits, annual per capita consumption in the Philippines was only 22 kg [1]. One factor for the unpopularity of milk among consumers is the lack of 'milkculture' or milk drinking habit among the people. Another factor, a major one which principally determines milk

and milk products consumption is the import dependence of the local dairy industry making dairy products unaffordable. Dairy products are the Philippines' 3rd largest agricultural import. The country's total milk supply in 2013 was 1.82 million metric tons and less than 1% of these is locally produced [1]. A significant amount of the Philippine fluid milk supply is UHT milk which is reconstituted/recombined from imported milk powder and milk fat. Thus the locally produced milk which finds good market in the specialty coffee shops still has to face competition with imported UHT milk mislabelled as 'fresh'. Local milk producers may be encouraged and locally produced liquid milk will have a competitive advantage if consumers are educated as to the real 'fresh' milk.

Fresh milk products, liquid milk for direct consumption, milk based drinks and milk based desserts are not covered by Codex commodity standards. The use of such terms like 'natural', 'pure', 'fresh', 'home made', 'artisan' may be regulated [2]. The term 'fresh' is allowed if it is in accordance with the national practices in the country where the food is sold [3].

This paper aims to explain the different heat treatments applied to milk as well as their effects on milk and to compare pasteurized versus UHT milk which is mislabelled as 'fresh milk' in the Philippines.

Heat Treatment Processes Applied to Milk and their Effects

Agewise, it was believed that milk was created for man's use as his natural and best food and that any alteration done to it, for example, by pasteurization was unwarranted and altogether sinful [4]. This belief however, did not hold for long as heat treatment

of milk was later realized to be essential to render milk safe for human consumption.

To date, the commercial heat treatment processes applied to milk are: pasteurization, ultra high temperature (UHT), ultra pasteurization or super pasteurization, sterilization [5,6], and innovative steam injection (ISI) [7], Table 1. All these heat treatment processes to which milk is subjected in order to render it safe and prolong its shelf-life, alter its physicochemical, nutritional and functional properties.

Pasteurization

Pasteurization is a heat treatment process applied to a product with the aim of minimizing public health hazards arising from pathogenic micro organisms associated with milk consistent with minimal chemical, physical and organoleptic changes in the product [8]. There are two methods of pasteurization: LTLT (Low Temperature, Long Time) and HTST (High Temperature Short Time). The LTLT or holder method of pasteurization involves heating milk to 63°C and holding at such temperature for 30 minutes. The HTST method of pasteurization involves heating milk at 72-75°C for 15-20 seconds before it is cooled. Pasteurization kills most of the microorganisms in milk but does not render the

milk sterile. Hence, pasteurized milk must be kept refrigerated, $\leq 4^{\circ}\text{C}$ throughout distribution and storage. In the European Union, 30,000 cfu ml⁻¹ is the upper limit for standard plate count of pasteurized milk and 20,000 cfu ml⁻¹ in the United States. Pasteurization is a relatively mild form of heat treatment, and most consumers would probably find difficulty distinguishing between raw and pasteurized milks. Pasteurized milk has no readily apparent cooked flavour; no active sulphhydryl groups are found. Whey protein denaturation is low (between 5 and 15 percent), and there is relatively little loss of the heat sensitive nutrients. The rennet coagulation properties are not affected. Enzymes are not normally a problem with pasteurized milk, mainly because the milk is used soon after processing [9]. The US FDA defines pasteurization as: heating every particle of milk or milk product, in a properly designed and operated equipment to one of the temperatures in Table 2 and held continuously at or above that temperature for at least the corresponding specified time [10].

Ultrapasteurization or superpasteurization

Ultrapasteurization or superpasteurization involves heating at temperatures above those used for pasteurization yet below those used for UHT processing. Such treatment prevents thermal alteration of the sensory properties and extends the shelf life be-

Table1. The time-temperature involved in the commercial heat treatment processes [6,7]

Process	Temperature	Time
LTLT (low temperature long time) Pasteurization	63°C	30 minutes
HTST (high temperature short time) Pasteurization of milk	72-75°C	15-20 seconds
HTST Pasteurization of cream, etc.	80°C	1-5 seconds
Ultra pasteurization	125-128°C	2-4 seconds
UHT (ultra high temperature)	135-140°C	A few seconds
Sterilization (in container)	115-120°C	20-30 minutes
ISI (innovative steam injection)	150-200°C	Less than 0.1 second

Table2. Time-temperature relationship for pasteurization as specified by US FDA's Grade A Pasteurized Milk Ordinance [11]

Temperature, °C	Time
63 ^a	30 minutes
77 ^a	15 seconds
89	1 second
90	0.5 second
94	0.1 second
96	0.05 second
100	0.01 second

^aIf the fat content of the milk product is 10% or more, or if it contains added sweeteners, the specified temperature shall be increased by 3°C.

ment is called ultra pasteurized, super pasteurized, extended shelf life (ESL) or extended long life milk. Super pasteurized milk is designed to have a shelf life of up to 90 days at refrigerated temperatures and have sensory properties superior to those of UHT milk [5]. Super pasteurized milk is processed at 125-138°C for 2-4 seconds [12].

Innovative Steam Injection (ISI)

ISI is based on existing UHT equipment, but very short heating is combined with very high temperatures: less than 0.1 sec at 150

to 200°C [7]. The heating is directly followed by flash cooling in a vacuum vessel. With ISI, a significant inactivation of heat resistant spores can be achieved while preserving the functionality of important ingredients. ISI results in less than 25% denaturation of whey proteins, greater than 6 log reduction in *Bacillus stearothermophilus* spores and 3 to 4 log reduction in *B. thermodurans* spores. For sustained stability at room temperature, the enzymes that cause spoilage must also be inactivated. The extremely heat resistant enzyme plasmin, the instigator of bitter taste, plays the leading role here in milk products. Plasmin is not inactivated by pasteurization, but this is unimportant in pasteurized milk because the ac-

yond that of HTST pasteurized milk. Milk subjected to this treativity of plasmin is minimal under refrigerated conditions under which pasteurized milk is stored. Besides, the germination of *B. cereus* spores will limit the shelf life long before the plasmin activity takes effect. To obtain an ISI milk that is stable for months at room temperature, an additional preheating step is necessary for the inactivation of plasmin. If preheating is performed, the ISI milk has under chilled condition, a substantially longer shelf life of 60 days.

Pasteurization causes only minor nutritional losses. The typical percent loss of some vitamins following pasteurization of milk are presented in Table3.

UHT Treatment

UHT treatment which renders the milk commercially sterile and shelf stable is the most common commercial heat process employed. UHT treatment made possible milk's availability worldwide especially in countries where milk is not produced. Because of the severity of heat treatment, the nutritional value of UHT processed milk is considerably reduced and further reduction in nutritive value occurs in supermarket shelves where it is kept until consumed.

The legal designation of UHT milk varies from country to country. In the United Kingdom, it is defined as the milk heated to no less than 135°C for at least 1 second and elsewhere processes vary

from 130 to 150°C for 1 to 4 seconds. A more practical definition was given by Dr. Harold Burton, a pioneer of UHT milk processing- "a treatment in which product is heated to a temperature of 135 to 150°C in continuous flow in a heat exchanger for a sufficient length of time to achieve commercial sterility with an acceptable amount of change in the product [13].

Filipino (people of the Philippines) consumers are misled into buying UHT- processed milk because they are mislabelled 'fresh'. Such milk may have been in the supermarket shelves for 6 months or more and is therefore, no longer fresh. Moreover, the nutritional content of UHT-processed milk is considerably reduced from the heat treatment it undergoes and during the long storage life, Tables 4 and 5.

As can be noted, there were greater losses in Vitamin C, folacin, B₁₂, riboflavin, and thiamine in UHT than in pasteurized milk. The total loss of Vitamin C can be attributed to the heat instability of the oxidized form, dehydroascorbic acid and can be minimized by limiting the dissolved oxygen content of milk during handling [13].

UHT processing results in moderate denaturation of whey proteins, denaturation levels ranged from 25 to 80 %, depending on the process employed [16]. Heat treatment of milk above 75°C, affects sulphur containing amino acids resulting to volatile compounds such as hydrogen sulphide and mercaptans that gives the typical cooked flavour to sterilized milk. The compounds formed

Table3. Typical percent (%) loss of some vitamins following pasteurization of milk [12]

Vitamins	%Loss
A	Not significant
B ₁	10
B ₆	1-5
B ₉	3-5
B ₁₂	1-10
C	5-20
D	Not significant

Table4. Percent (%) nutrient losses during the processing of pasteurized and UHT milk [14;13;15;16;17;18]

Nutrients	Pasteurized Milk	UHT Milk
Water Soluble Vitamins		
Ascorbic Acid	10-25 %	15-25 % (Direct), 31.6 % (indirect)
Folacin	0-12%	10-20 %
Vitamin B ₁₂	0-<10 %	0-30 %
Vitamin B ₆	0-<10 %	0-10 %
Riboflavin	0-<1 %	0-10 %
Thiamine	0-10 %	<10-18 %
Other Water Soluble Vitamins		
Niacin	No loss	<10 %
Panthothenic Acid		
Fat Soluble Vitamins		
Vitamin A	No significant loss	No significant loss
Protein and Amino Acids	No significant loss	No significant loss
Minerals and Trace Elements	No considerable variation in calcium	With considerable variation in calcium

Table5. Effects of heat treatment on lysine and Maillard reaction products formed from lysine [19]

Product	Heat Treatment	Lysine mg kg-1 CP	Lysinoalanine mg kg-1 CP	Furosine mg kg-1 CP	Blocked Lysine, %
Milk	Pasteurization	90±5.3	48±26		
	UHT	88±6.1	90±40	1431±494	2.7±0.9
		88±4.0		1050± 1000	2±2

during the later stages of Maillard reaction are resistant to enzymic attack during digestion and thus lysine availability is reduced (Table 5). Lysine losses in UHT processed milk is about 4 % as compared to losses during milk pasteurization of 1 to 2 % [16].

Maillard reactions continue during storage. While UHT treatment is suitable for tropical countries with high ambient temperatures and are unable to afford refrigeration during marketing and distribution, the nutritional quality of protein is very important because in these countries, protein intake is generally low due to poverty.

Ascorbic acid loss was high during storage, for both pasteurized and UHT milk (Table 6). Most of the Vitamin C loss during storage seemed to occur in milk packaged in materials other than paper (in polyethylene or glass) [15; 20; 21] when these packages are exposed to light. For UHT milk, the content and availability of oxygen were the factors most detrimental to the stability of vitamin C. In general, milk with high oxygen content were processed in UHT plants without vacuum flash down system (most indirect processes) or packed into containers with head spaces of air. If the milk is saturated with oxygen, virtually all of the ascorbic and folic acid will be lost within a few minutes of storage [16]. Exposure to light was cited as the main factor for riboflavin loss for both pasteurized and UHT milk [15] and so with vitamin A [28].

Maillard reactions continue during storage of UHT milk with their rate being dependent on storage conditions. The nutritional quality of proteins is slowly degraded as a result of these reactions with, for example, caseins being resistant to enzymic digestion. After extended storage at high temperatures (6 months at 30 to 37°C) up to 30 % of the lysine may become unavailable. This storage temperature approximates ambient temperature in the tropics and thus lysine losses in unrefrigerated UHT milks could reach significant levels [16].

Sterilization

Sterilization involves heat treatment in excess of 100°C and packaging in air tight containers either before or after heat treatment. If packaging done after heat treatment, aseptic packaging is very important. Such milks are called sterilized milk. Sterilized milk is not necessarily free of microorganisms and is said to be commercially sterile. However, those microorganisms which survive the heat treatment are unlikely to proliferate during storage and cause spoilage of the milk [9].

Continuous sterilization, in-container sterilization in autoclaves at 105 to 120°C for 10 to 40 minutes, and ultra high temperature treatment (UHT) are used to sterilize milk and milk prod-

Table6. Percent(%) nutrient losses during the storage of pasteurized and UHT milk [20;21;15;22;23;24;25;26;27;17]

Nutrients	Pasteurized Milk	UHT Milk
Water Soluble Vitamins		
Ascorbic Acid	15-95 % plastic package, 54-84 % paper package	0-80 %
Folacin	No significant loss	No significant loss
Vitamin B ₁₂	No significant loss	0-100 %
Vitamin B ₆	No significant loss	14-50 %
Riboflavin	4.5-15 %	0-<10 %
Thiamine	< 10 %	10-18 %
Other Water Soluble Vitamins (Niacin, Panthothenic Acid, Biotin)	Niacin- no significant loss	Niacin- 10 %, Panthothenic Acid-0-30%, Biotin-no significant loss
Fat Soluble Vitamins	0-<10 %- not fortified	0-62 %- not fortified
Vitamin A	20-95 %- fortified	11-90 %- fortified
Protein & Amino Acids	No significant loss (lysine, methionine, cysteine)	0-<5 %

ucts. Shorter holding periods are used with higher temperatures. The objective of sterilization is to produce a long life product by destruction of microorganisms of public health significance and microorganisms capable of spoilage. The US Food and Drug Administration requires temperature-time combinations that will ensure a reduction of *Clostridium botulinum* spores by 12 log. However, in order to obtain commercial long-life stable milk and milk products, the thermal treatment conditions required to deliver a 12 log reduction of *Clostridium botulinum* have to be extended depending on the product, for example, for sterile milk,

the conditions are based on the reduction of thermophilic spores by 9 log [29]. The high temperature used induce a number of physical and chemical changes in the milk (Table 7).

Sterilized milks prepared by direct UHT method are shelf stable for up to 12 to 6 months at a storage temperature of 4 and 20°C, respectively, while that produced by the indirect process is shelf stable for more than 12 months at 4°C and up to one year at 20°C. Sporicidal effect of UHT and retort sterilization are equal. Adverse effects on color, flavour and nutritional value are

Table7. Some chemical, enzymatic and physical phenomena that occur during manufacturing and storage of sterilized milk products [30].

Component or Property	Phenomena
Proteins	Unfolding, denaturation (50-85 %), formation of complexes with κ -casein, increase in proportion of non- sedimentable casein, proteolysis during storage, increase in proportion of NPN and noncasein N, polymerization during storage, formation of lactulosyl lysine and fructosyl lysine during storage
Minerals	Decrease in proportion of ionic Ca and Mg due to precipitation as PO_4 during processing, partial reversal of the latter during storage
Lactose	Maillard reaction, isomerization to lactulose
Rennet coagulation time	Increases with both UHT and retort sterilization
Sensitivity to alcohol	UHT milk: increases during storage Retort sterilized milk: unchanged during storage
Sensitivity to Ca	UHT: significant increase during storage Retort: some increase during storage
Lipids	Lipolysis by heat resistant or reactivated lipases during storage

significantly lower in the UHT process.

Age gelation is an irreversible phenomena that occurs during storage of sterilized milk and this is affected by the combined influence of a multitude of variables related to milk composition and quality as well as to process and storage conditions. Seasonality, breed and stage in the lactation cycle and health of the animal affect gelation properties of sterilized milk products, through their influence on milk composition and physico-chemical properties. The gelation-free storage time of sterilized milk is inversely related to the microbiological load in the milk especially the presence of microorganisms that produce stable proteases, such as those originating from psychrotrophs.

Temperatures used for milk sterilization introduce a whitening effect which has been attributed to the time and temperature dependent effect on mineral distribution and especially on denaturation of whey proteins, especially β -lactoglobulin and the formation of complexes between the latter and κ -casein at the surface of the casein micelles. Such interactions modify the light reflectance properties of milk, hence make sterilized milk whiter.

Intensity of flavour notes typical to UHT and in-container sterilized milk has been shown to correlate well with the accumulation of lactulose. Flavour acceptability of sterilized milk is critically dependent on the level of free-SH groups, originating from the effect of heat treatment on whey protein, and are responsible for the strong hydrogen sulphide odour of fresh sterilized milk. The level of these compounds declines rapidly, due to oxidation, with storage time, at a rate that is proportionately related to the level of oxygen in the product. The rate and extent of Maillard reaction that occurs during storage contributes to the decline of flavour quality of UHT milk [30].

Oil soluble vitamins (A, D, E) as well as some water soluble vitamins (riboflavin, nicotinic acid, biotin) are heat stable and are not adversely affected by either in-container or UHT process. Folic acid, vitamin B₁₂ and ascorbic acid are lost to different extents. Vitamin C loss is due not only to heat treatment but also oxidation prior to heat treatment. The oxidized form is heat labile and is likely to be completely destroyed during UHT process while loss of only 10-20 % of the reduced form can be expected. Loss of vitamin B₁₂ is linked to oxidative destruction of vitamin C. The loss of folic acid is limited by the protection provided by the reduced form of vitamin C, and thus, destruction of the latter will affect the loss of the former [31,32].

Lipolysis was cited as one of the factors to consider in certain milk applications such as foaming, along with fats and proteins, as well as their interaction with other components and environmental factors such as temperature (microwave heating), levels of free fatty acids/titratable acidity and pH [33,34]

Conclusions

Loss of ascorbic acid, folacin, vitamin B₁₂, riboflavin, thiamine, niacin and pantothenic acid and effect on calcium was greater in UHT than in pasteurized milk. More losses of ascorbic acid, vitamins B₁₂, B₆, thiamine, niacin, pantothenic acid, and vitamin A were reported during storage of UHT milk. Higher amounts of bound lysine (lysinoalanine) was found in UHT than in pasteurized milk. Moreover, properties such as rennet coagulation time, flavour and foam ability were adversely affected during manufacturing and storage of sterilized milk products. Thus, it was shown that commercial heat treatment processes alter the heat sensitive nutrients, physico-chemical and functional properties of milk.

The Philippine food regulatory agency allows the 'fresh milk' label on UHT milks marketed in the country. This practice does not properly inform the consumers about the product because such milks may have been in the supermarket shelves for 6 months or more and is therefore, no longer fresh, besides putting the locally produced fresh milk at a disadvantage. The food regulatory agency and a multinational company that supplies large volume of UHT milk contends that 'fresh' may be used provided the said product still conform with the definition of milk which comes from the cow and has not less than the required fat and MSNF. The decision however, was silent about recombined and reconstituted UHT milks which are also mislabelled as 'fresh'. While liquid milk for direct consumption is not covered by Codex commodity standards, use of terms like 'natural', 'pure', 'fresh', 'home made', and 'artisan' must be regulated to protect consumers.

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