Factors Affecting Keeping the Quality of Heat-Treated Milk

1.0 Pasteurised milk:

Pasteurised milk has a relatively short shelf life. In the USA it is generally expected to remain drinkable for 16 - 18 days or even longer. In European countries the expected shelf life is 10 to 14 days. In some countries, the expected shelf life is only 3 to 5 days, or even less.

Under excellent processing and refrigeration conditions, the maximum shelf life of commercially produced pasteurised milk stored constantly under refrigeration from the time of filling, may be considered to be approximately 21 days. Under good conditions, which reflect the average state of affairs pertaining in Europe, then the shelf life could be expected to be from 10 to 14 days. A shorter keeping quality of 3 to 7 days under refrigerated storage could, in certain countries, be considered sufficiently long and satisfactory, whilst in others a 2 to 3 day shelf life is customary and generally regarded as being acceptable. To a processor the desirable shelf life is often very much a function of the length of the distribution and marketing networks and frequency of deliveries to shops and consumers.

For the average consumer, the shelf life of pasteurised milk is determined by its organoleptic qualities, which are visual appearance, smell and flavour. A number of factors influence the organoleptic quality.

The character of the bacterial flora in the raw milk, at the time of processing, has a significant influence on organoleptic quality. The composition of the bacterial flora is dependent on the hygienic quality of the milk at the point of production and the care and attention it has received during handling until processing. The bacterial load present in the raw milk is a function of the hygienic condition of the personnel and equipment used for handling the milk, and the elapsed time between milking and cooling the milk to below 5ºC.

The elapsed time between milking and pasteurization profoundly influences the bacterial load in the raw milk. Consequently, the hygienic quality will be influenced by the bacteriological condition of the surfaces of plant and equipment with which the milk comes in contact. The sanitary condition of items of equipment, including milking clusters, teat cups, pipes and tubing, milk lines, farm storage tanks, pumps, transport tankers, milk churns together with the time/temperature duration of the contact with these items of equipment are the determining factors in determining the bacterial load in the raw milk. To this must be added the state of health of the udder, where excessive numbers of microorganisms in the milk cistern, duct and teat canal udder will lead to the presence of high numbers of microorganisms in the milk as it is milked. Milk when produced in the secretory cells within the alveoli of the udder tissue, is virtually free of microorganisms. Microorganisms accumulate in the milk as it passes through the milk ducts within the udder.

Further influences upon the quality of the milk are due to the type, nature and concentration of the naturally occurring and/or bacteriologically developed lipases and proteases that are present in the raw milk, and the effects of the heat-stable enzymes that survive the heat treatment and continue their activity in the post pasteurised milk. The rate and intensity of the enzymatic activity is related to the composition of the bacterial flora and the resulting enzymatic content in the milk. These are influenced by the time and temperature conditions that were imposed upon the milk before and after pasteurisation.

The efficiency of handling and treatment of the milk, which includes the preparation of the plant for use and the suitability of the process plant equipment together with the overall level of technological skill of the operators, are additional factors that influence the product quality.

The essential aim of the processor must be to reduce the level of bacteriological contamination in the post-pasteurised milk to the minimum possible. The final packaged product must be handled with care to reduce multiplication of the bacterial flora to the minimum possible.

Milk is a biological medium. It is not stable but is constantly undergoing change due to the accumulation of metabolic products resulting from microbial growth and enzymatic activity deriving from bacterial sources. This activity causes changes in the physico-chemical character of the milk.

2.0 Effects of pretreatment handling and storage

Milk on arrival at the dairy plant is either processed immediately or passed through a plate cooler and stored at low temperature until processed. The milk is generally clarified before pasteurisation.

The keeping quality of the finished pasteurised milk will be influenced by its bacteriological load and chemical composition at the time of milking, the mechanical and thermal treatment it subsequently receives and the microbiological condition of the equipment.

Severe mechanical agitation, as produced by pumping and turbulent flow conditions, especially when combined with fluctuating thermal conditions, can have a pronounced detrimental effect on certain milk components. Such treatment can cause churning and damage to the milk fat globule membrane and so encourage lipolytic activity by the naturally occurring lipase present in the milk. The resulting hydrolysis of some of the fat molecules will lead to a flavour defect, detected as a bitter taste which subsequently may become more pronounced due to further activity by bacterial lipases.

In practice, activation of the enzyme usually arises through excessive turbulence caused by incorrectly designed and poorly installed pipelines systems at the both the farm and the processing dairy levels. It can also take place when the milk is allowed to splash in the farm tank, due to insufficient depth of the milk above the agitator, and when a second milking is dumped onto the surface of a previous milking at about 10-12°C. Freezing and thawing, together with excessive and prolonged agitation in storage tanks are conducive to lipolysis.

3.0 Effects of processing

3.1 Pasteurisation

The most common method of pasteurisation in use in dairies is the High Temperature Short Time process using a plate heat exchanger. This process involves heating the milk to a certain temperature, holding at that temperature under continuous flow conditions for a fixed period of time sufficient to ensure the destruction of pathogenic organisms present, after which it is cooled. An additional objective is to improve keeping quality by reducing the bacterial load in the milk.

There are two distinct purposes for the process of milk pasteurization:

1. **Public Health Aspect** - to make milk and milk products safe for human consumption by destroying all bacteria that may be harmful to health (pathogens)
2. **Keeping Quality Aspect** - to improve the keeping quality of milk and milk products. Pasteurization can destroy some undesirable enzymes and many spoilage bacteria. Shelf life can be 7, 10, 14 or up to 16 days.

Since the original public health safety aim of pasteurization was to kill tubercle bacteria that might be present, by heat treatment, the temperature/time combination chosen was set at 72°C for 16 seconds. These time/temperature conditions inactivate alkaline phosphatase, which occurs naturally in raw milk. Consequently, there is often a minimum requirement for measuring the efficiency of the pasteurisation process which is that pasteurised milk must give a negative phosphatase test. In order to provide a safety margin, necessary because of mechanical inadequacies of pasteurisation equipment, it is usual within processing plants to require a temperature/time relationship that is above the minimum requirement. In order to improve the keeping quality of pasteurised drinking milk, it is desirable for the processor to use higher pasteurisation temperatures, so improving the bacterial destruction efficiency of the pasteurisation process and consequently obtaining a lower bacterial load in the milk at the pasteuriser outlet. Care must be taken not to cause an undesirable flavour change.

3.2 Homogenisation

The use of polyethylene sachets and paperboard cartons for milk packaging, makes it essential that the milk be homogenized.. This is because in non-homogenized milk the rising fat adheres to the container walls making the product unattractive to the consumer.

Homogenisation is a mechanical treatment causing rupture of fat globule membranes and under certain circumstances, subsequent lipolytic activity. By placing the homogeniser upstream from the pasteuriser, the heat treatment following homogenization effectively inactivates the lipase and prevents lipolytic degradation of the milk.

It is generally assumed that the pasteurisation process is sufficient to inactivate lipase, but the possibility of reactivation should be taken into account. It has been shown that a temperature/time combination of 75°C/20 seconds inactivates 90% of the enzyme, but the remaining 10% produced a rancid flavour after 2 days. Complete elimination of lipolytic activity occurred after a treatment of 80°C for 20 seconds.

Homogenisation makes the milk more susceptible to light-induced oxidation, though the effect is not significant since the product is invariably consumed before it becomes detectable.

3.3 Microbiological effects

The bacterial load and composition of the bacterial flora in raw milk is directly influenced by the handling and sanitary condition of the equipment with which the milk comes in contact. The bacterial flora are composed of the natural microflora of raw milk which are not significant, but other undesirable types are likely to be present, represented by Pseudomonas and other psychrotrophic organisms that are able to multiply at refrigeration temperatures. Many psychrotrophs produce heat-resistant lipases and proteinases.

In efficiently refrigerated pasteurised milk, the shelf life is largely determined by the growth of psychrotrophic bacteria. In milk that is virtually free from post-pasteurisation contamination, subsequent spoilage is regarded as being due to psychrotrophic thermodurics deriving from the raw milk. Any increase in the psychrotrophic count by recontamination due to unsanitary equipment and practices between the exit of the pasteurizer and the sealing of the package, will substantially reduce keeping quality.

Consequently, recontamination of pasteurised milk is the predominant cause of early spoilage. As temperature increases during distribution, mesophilic bacteria will play a more significant part in the spoilage process. This applies to any delivery system of limited cooling capacity. Shelf life times will not exceed a few days and raw milk bacteria surviving pasteurisation will be as important as recontamination. Thus, depending on the average storage temperatures, the responsible organisms for pasteurised milk spoilage may vary.

4.0 Bacteriological quality of the raw milk

Spoilage of pasteurised milk due to the growth of raw milk bacteria is restricted to thermoduric organisms. The aerobic spore-formers are represented by Streptococcus thermophilus, enterococci, micrococci, Microbacterium and Alcaligenes. At heat treatment temperatures above 80°C, streptococci, micrococci and Alcaligenes largely do not survive. Consequently, in milk pasteurized in this temperature region, these organisms do not have a role in spoilage. The thermoduric organisms, Microbacterium and Alcaligenes, are known to be also psychrotrophic, and therefore will reduce the shelf life of non-recontaminated, refrigerated pasteurised milk.

5.0 Heat treatment

The predominant thermoduric organisms surviving the pasteurization process are Streptococcus thermophilus, certain micrococci and microbacteria. Spores of bacilli and clostridia are not destroyed by pasteurisation. Clostridia, because of the oxygen content of fluid milk, will rarely develop, but aerobic spore formers, such as Bacillus spp. grow rapidly in milk. Thus aerobic spore formers may spoil refrigerated pasteurised milk as well as milk sold at higher temperatures. Some psychrotrophic spore formers are able to grow rapidly at 5°C to 7°C, though at a slower rate than other psychrotrophs, e.g. Pseudomonas.

6.0 Post heat-treatment and packaging

Poor sanitary condition of the pipes, valves, tanks, pumps and filling machines through which the milk passes, can be significantly detrimental to product keeping quality. Heavy recontamination of pasteurised milk is due to ineffective cleaning procedures used for the equipment. Computerized control of CIP systems, combined with carefully planned cycle parameters and efficient pre-processing sanitization of lines, valves and fillers will significantly improve the bacteriological condition of the processing equipment. Manually controlled cleaning routines will always suffer from fluctuations in the bacteriological status of the equipment.

Pitting and crevices caused by corrosion can be a source of heavy contamination. Particular attention should be paid to the cooling section of pasteurisation plants. Defective heat exchangers can affect keeping quality and cause a hygiene problem.

Plastic or polyethylene packaging usually does not constitute a bacteriological problem, since these products are manufactured using a heat process. Glass bottles, when poorly cleaned, can be a significant cause of reduced shelf life.

7.0 Storage and distribution

There is a direct relationship between temperature and shelf life. Any increase in storage temperature will decrease the shelf life. During the passage of pasteurised milk through the plant, its temperature will invariably increase slightly. The extent of temperature increase will depend on the length of the pipelines, storage tank design and volume, holding time before filling and filling machine design. Milk which has risen in temperature before filling is difficult to rapidly cool down again after it has been crated and placed in the cold store. This problem can be attended to by placing a plate cooler between the storage tank and the filling machines. The plate cooler, using a water/glycol cooling mixture, will be able to reduce the milk temperature significantly immediately before filling. An additional advantage to installing a plate cooler on the line to the fillers is that the milk may be circulated through the cooler constantly. Using a glycol plate cooler of this type, the filling temperature can be expected to be approximately 2ºC.

The ambient temperature has a significant influence on the temperature rise of liquid milk during distribution, and depends on the type of vehicle used. Air temperatures of 25-30°C can cause an increase in milk temperature of 6-7°C per hour, while outdoor temperatures of 15-20°C can give an increase of 0.5-4°C per hour. This effect is partially reduced by using insulated vehicles. Refrigerated vehicles are the optimal solution to effective distribution, though the drivers require monitoring to ensure that the desired temperature is maintained throughout the distribution route.

The temperature of refrigerators and display cabinets in shops must be monitored. The persons responsible for these installations should be required to maintain the temperature below 6°C.