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Performance evaluation of helical triple tube ultra-high-temperature milk sterilizer

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Abstract
Ultra high temperature (UHT) sterilization of milk is a continuous process in which milk is heated to kill all type of microbes to get shelf stable packed product at ambient temperature with a minimum change in organoleptic qualities. In this study, a helical triple tube UHT milk sterilizer having capacity of 135 l/h was used for sterilization of milk for its performance evaluation. The sterilizer consists of heating section, holding section and cooling section. In heating section, the preheated milk at 90 °C was heated to sterilization temperature of 145 °C, then in holding section kept for 2 s at sterilization temperature of 145 °C to achieve 8 log cycle reduction of *B. stearothermophilus* as index microorganism followed by cooling in cooling section from 145 °C to 90 °C. Sterilized milk was packed aseptically in glass bottle for standard plate count, color measurement and viscosity measurement at 15 days interval up to two months. The performance of the helical triple tube UHT milk sterilizer was found satisfactory, since the UHT milk was microbiolocally safe, free from drastic colour change and gelation after two months under ambient storage condition.

Keywords: UHT, color, viscosity, plate count, heat transfer

1. Introduction
Milk is an excellent, near ideal liquid food universally accepted for its high nutritive value, flavour and palatability. India is the largest milk producing country of the world with annual milk production of 160 million tones, which is 17% of total world milk production. With increased production of milk, its preservation is essential for increased shelf life and higher return as milk is highly perishable and has a limited shelf life. Milk preservation prior to distribution and sale is a major problem in India due to the high temperatures of tropics and lack of sufficient cold chain and refrigerated transportation system. Extension of shelf life of milk can be accomplished by UHT sterilization of milk. UHT sterilization of milk is a process in which milk is heated to a temperature of 135–150 °C in a continuous flow in a heat exchanger and held at that temperature for a few seconds to produce a satisfactory level of commercial sterility with an acceptable amount of change in the product. A basic principle underlying UHT processing is that, for an equal bactericidal effect, a high-temperature, short-time treatment causes less chemical change than a low-temperature, long-time treatment. UHT sterilization of milk is the most effective treatment for long shelf life at room temperature. UHT processed milk is completely free from microorganisms to the level of "commercial sterility" and is almost similar to original milk in appearance. The sterilized milk remains safe for consumption for several weeks at room temperature (Pien, 1955) [8]. The use of UHT treatment varies around the world. In Germany, France, and Spain, more than 50% of liquid milk is consumed in UHT form. The main aim of UHT processing is to minimize final count of the survivor micro organisms, inactivation of enzymes, minimum nutritional degradation and maintenance of orgenoleptic qualities. UHT milk is whiter, less caramelized, has less protein denatured and minimum loss of heat sensitive vitamins (Walstra and Jenness, 1984) [9]. The UHT milk can be stored under non-refrigerated condition up to 2-3 months and can be transported at room temperature. Among indirect heat exchangers used for UHT milk manufacturing, helical triple tube heat exchanger is a novel approach of manufacturing UHT milk. A triple concentric tube heat exchanger is an improved version of the double tube heat exchanger which is used for sterilization of milk. A laboratory type helical triple tube UHT sterilizer of length 2.28 m with a holding section of length 1.06 m and a cooling section of 2.08 m length was used for performance testing. It consists of heating section, holding section and cooling section. The heating section consists of three helically coiled tubes. The holding

section consists of only single tube through which only heated milk flows. The cooling section consists of two tubes in which water flows through annulus and milk flows through inner tube. UHT milk is a product suitable for prolonged storage in which the original properties as they appear after sterilization are preserved unchanged. Furthermore, these original properties must be such that the product is fit for sale immediately after processing and does not alter. It should therefore, be organoleptically and microbiologically stable and fit for human consumption. There are certain defects which occur after sterilization like color change and gelation that develops during storage. Burton (1969) [2] observed the age gelation in UHT milk is an important problem because it signifies the final limit of storage life. This phenomenon increases milk viscosity during storage and eventually results in a loss of fluidity with the formation of a gel (Datta and Deeth, 2001) [3]. Good quality UHT milk can be expected from a well-performed milk sterilizer. The main objective of this study was to evaluate the performance of helical triple tube UHT milk sterilizer in respect of microbiological and organoleptic quality of UHT milk.

2. Materials and Methods

2.1 Helical Triple Tube UHT Milk Sterilizer set up: The experimental set-up of the UHT milk sterilizer is shown in Fig. 1. It consists of a heating section, a holding section and a cooling section. Milk flows in the middle annular portion of the heat exchanger and the heating media (steam) flow in the innermost tube and also in the outermost annulus. A steam-jacketed pan was attached to a centrifugal pump to pump milk from the pan to the heating section of the sterilizer. Five thermocouples were connected at the inlet and outlet of the heating section, the outlet of the holding section, the outlet of the cooling section and in the steam condensate to record observations during the experiment. A digital temperature indicator was used to indicate temperature. Two Bourdon tube pressure gauges were fixed at the inlet and outlet of the heating section to record pressures during the experiment. An electrode steam boiler was used to supply steam to the heating section of the sterilizer. The working pressure range of such a boiler is 0–10 bar and the electric supply is 3-phase, 440 V and 50 Hz. A nozzle was fitted with a discharge tube for easy packaging. The testing was carried out with raw clarified whole milk collected from the local market. Prior to the experiment, the heat exchanger was sterilized by using hot water at 150 °C. A flow control valve was used to regulate flow of sterilized milk and also to maintain back pressure. That setting of the flow control valve was used for a final experiment where the desired sterilization temperature of milk was attained. Glass bottles and caps were sterilized in an autoclave at 15 psi pressure for 15 min for packaging the milk.

Prior to sterilization of milk, the milk was preheated in a steam-jacketed pan to 90 °C to minimize the fouling problem in the heat exchanger and the developed cultures of *B. stearothermophilus* (10^8 cfu/ml) was inoculated. Preheated milk was pumped to the heating section of the sterilizer for final heating to the sterilization temperature using steam at 160°C. Heating was followed by holding in the holding section at the sterilization temperature to attain perfect sterility. The sterilizer temperature and residence time used were 145 °C and 2 s. Then the sterilized milk was cooled to 90 °C in the cooling section using tap water and aseptically packed into glass bottles using two spirit lamps at the nozzle tip and then capped using a capping machine in aseptic environment. Packed milk was cooled to room temperature and stored for quality evaluation at regular intervals of 15 days up to two months storage periods.

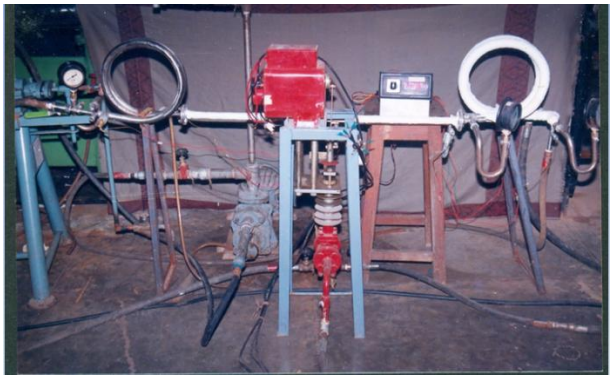

Fig 1: Helical triple tubes UHT milk sterilizer set-up

2.2 Bacteriological quality evaluation of UHT Milk

The bacteriological quality evaluation of UHT Milk samples was carried out by the plate count method (Indian Standards, 1962) at 15-day intervals for two months to find the surviving residual bacteria during the storage period at room temperature. A dilution technique was followed to ease in counting the colonies. The plating was done in sterile conditions and then incubated in an incubation chamber maintained at 37 °C for a period of 24–48 h. The colony count was done using a magnifying glass for ease in counting.

2.3 Evaluation of color change in UHT Milk

Color of milk changes during sterilization as well as during storage period due to non-enzymatic browning reaction. To measure the extent of the color change for quality control, Hunter's Lab Colorimeter was used. Under color measurement, yellowness index and whiteness index was measured. The whiteness index measures the degree of whiteness of a product while the yellowness index measures the degree of yellowness of a product. The yellowness index and the whiteness index of UHT sterilized milk samples were measured. This step was repeated for measuring the color index for the UHT processed milk throughout storage at 15-day intervals for two months. Before measuring the color, container was properly cleaned with tissue paper and then calibrated with black and white plate. After that 150 ml sample of raw whole milk and sterilized milk was taken in container separately covering the bottom surface well to ensure better result and then measured yellowness index and whiteness index.

2.4 Measurement of viscosity of UHT Milk

The viscosity of UHT processed milk increases during storage, leading to gelation. This increase in viscosity is mainly due to presence of heat resistive enzymes. To estimate the shelf life of UHT milk, viscosity of processed milk was measured at regular interval of 15 days up to two month by a Brookfield Dial Viscometer. The viscosity of raw milk was also measured.

3. Results and Discussion

3.1 Bacteriological Effectiveness of UHT Milk Sterilizer

The results of plate count of sterilized milk samples are given in Table 1. It was found that the number of residual bacteria in sterilized milk immediately after processing and throughout storage period up to two months is zero, which indicates the effectiveness of sterilization of milk. From Table 1, the

sterilizing value of the index organism (*B. stearothermophilus*) was found to be 8. Hence, UHT milk sterilizer was found to be perfect with respect to the microbial effectiveness of process.

Table 1: Bacterial count (cell / ml) for UHT samples

Days	UHT milk
	B. Stearothermophilus
0	0
15	0
30	0
45	0
60	0

3.2 Color Change in UHT Processed Milk

The whiteness index (WIe) and yellowness index (YIe) were measured at 15 days interval up to two months. Fig. 2 shows the variation of whiteness index of UHT milk during storage period. From the plot, it is observed that, the whiteness index decreases slowly throughout the storage period. This could be also due to browning reaction. Fig. 3 shows the variation of yellowness index of UHT milk during storage period. From the plot, it is observed that the yellowness index of milk increases slowly throughout the storage period. This increase is due to increase in non-enzymatic browning reaction which is prevalent during storage period. But over all, there was no marked change in color indices during the storage period.

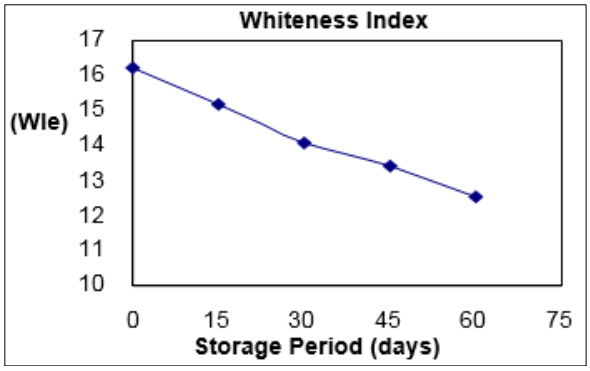

Fig 2: variation of whiteness index of UHT milk with storage period

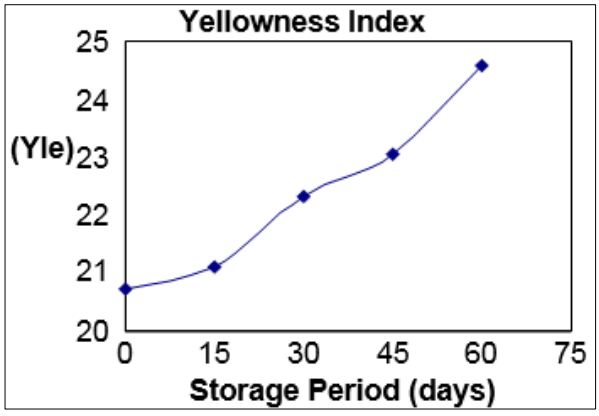

Fig 3: variation of yellowness index of UHT milk with storage period

3.3 Changes in viscosity of UHT Processed Milk

Fig. 4 shows the variation of viscosity of UHT milk during storage period. From Fig. 4, it is clear that the viscosity increases slightly with storage period up to two months. The gradual increase of viscosity in UHT milk during storage could be due to presence of heat resistive bacterial enzyme or due to casein serum protein complex formation. The progressive rise in viscosity during storage period leads to gelation. Usually gelling starts for UHT milk concentrate above 200 cp of viscosity (Hinrichs, 2000) [4]. Since viscosity of UHT processed milk after two months of storage period (i.e. 3.08 cp) was far below the value of 200 cp, it was free from gelation. It was found that there was no remarkable change in viscosity and it was completely stable after two months of storage at room temperature.

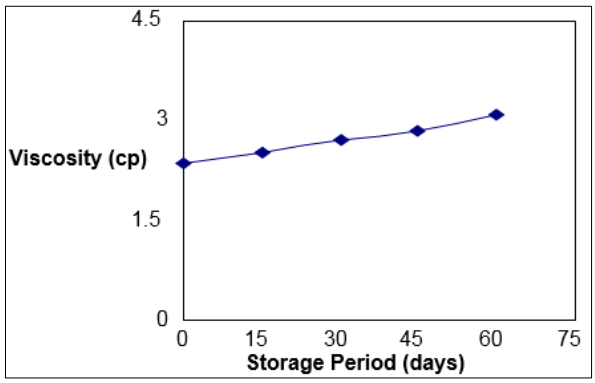

Fig 4: variation of viscosity of UHT milk with storage period

4. Conclusion

The helical triple tubes UHT milk sterilizer was used for sterilizing raw milk and sterilized milk was aseptically packed in glass bottle to study quality of milk. The milk samples were analyzed for total count, color change and viscosity change for two months of storage at 15 days interval. After conducting plate count, it was found that the number of cell was 0 after sterilization, which signifies the perfectness of sterilization. UHT processed milk was found microbiologically and organoleptically safe up to two months of storage period. From organoleptic point of view, the UHT processed milk was acceptable for about two months as it was free from gelation. As far as color change was concerned, it was also free from drastic color change. Overall, the helical triple tube UHT milk sterilizer was found suitable for production of UHT milk.

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