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A Research Note

Laboratory-Scale System to Process Ultrahigh-Temperature Milk[1]

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ABSTRACT

A laboratory-scale, indirect, ultrahigh-temperature (UHT) system was constructed using stainless steel tubing (6.35 mm) as the barrier between the heating agent and the product. Nitrogen gas under 80 psi pressure propelled milk through the tubing of the system. The milk was preheated in a hot water bath, brought to sterilization temperature in an oil bath, and held at this temperature in a holding tube. After leaving the holding tube, the milk was cooled rapidly in an ice-water bath and aseptically collected in 250-ml amber colored glass bottles in a glove box. The system effectively sterilized milk with carefully controlled temperature and time.

A laboratory-scale, indirect ultrahigh-temperature (UHT) system, which offered several advantages as a research tool over larger laboratory or commercial systems, was designed and constructed at Kansas State University. First, accessibility of the system at our research facility allowed the opportunity to produce sterile milk under carefully controlled conditions. Second, the smallness of the unit allowed processing of small batches of milk (less than 1 L), thus enabling us to study a wide variety of sample treatments and processing conditions on the same lot of milk. Third, the system was inexpensive to construct and operate. This should allow more laboratories to have their own system for studying UHT milk. Fourth, it allowed us more direct experience with the UHT system.

MATERIALS AND METHOD

Design of the system

A schematic diagram of the indirect UHT system is shown in Fig. 1. The system was fabricated using 6.35 mm OD stainless steel, thin-walled, beverage tubing (Piping Alloy, Inc., Overland Park, KS) as a barrier between the heating agent and milk. Nitrogen gas from tank A under 80 psi pressure propelled milk, rinse water, or cleaning solution through the tubing of the system. A copper two-way valve was used to direct the gas from the nitrogen cylinder to the desired tank. Tank B, a 3-gal Millipore tank (Millipore Corporation, Bedford, MT), was filled with cleaning solution or water for cleaning or rinsing the system, and tank C, a Pepsi-Cola syrup container, held the milk to be processed. Both tanks B and C had stainless steel tubes that extended to the bottom of the tanks and allowed the product to be forced out under pressure. The flow from a specific tank was controlled by use of toggle valves positioned immediately at the outlets of each tank. The outlet tubing from each tank was joined by a Swagelok "T" fitting with a toggle valve immediately following the "T" fitting to stop the flow of any solution into the system, if desired.

A digital thermometer (F) Model 199-JC-X-X-DSS (Omega Engineering, Inc., Stanford, CT), was used to measure temperatures from four 1.59 mm (OD) Iron Constantan, 304 stainless steel sheathed, Type J thermocouples (Model 199-JC-X-X, Omega Engineering, Inc., Standford, CT), which were placed at locations 1, 2, 3, 4 in the sytem and used to monitor temperatures. All temperature probes were inserted into the system using stainless steel Swagelok fittings culminating into 6.35-mm Swagelok "T" fittings, which had their inner bodies drilled to 6.35 mm (ID).

Temperature probe #4 monitored the temperature of the preprocessed milk immediately before it was heated. The first stage of heating occurred as milk was circulated through 3.04 m of 6.35-mm stainless steel tubing of which 2.74 m formed eight, 11-cm diameter coils. The coils were immersed in a hot water bath (D) where the product was preheated to approximately 82°C as monitored by temperature probe #3. The product flowed through a similar tubing system, with 11 coils (8.5 cm-diameter), immersed in a hot oil bath (Fisher Hi-temp bath, Fisher Scientific) where the milk was brought to sterilization temperature (135°C in our study). The coils in the oil bath were spread 1 cm apart in the upper portion, but remained tightly coiled in the lower portion due to the internal shape of the oil bath. Spreading the coils allowed greater surface area for heat transfer, thereby heating the milk more efficiently. A variable speed stirrer (Eastern Industries, New Haven, CT) constantly stirred the oil to aid in maintaining an even temperature throughout the bath. Both the hot water bath and oil bath had metal lids covered with 2.5 cm of thick rubber for insulation.

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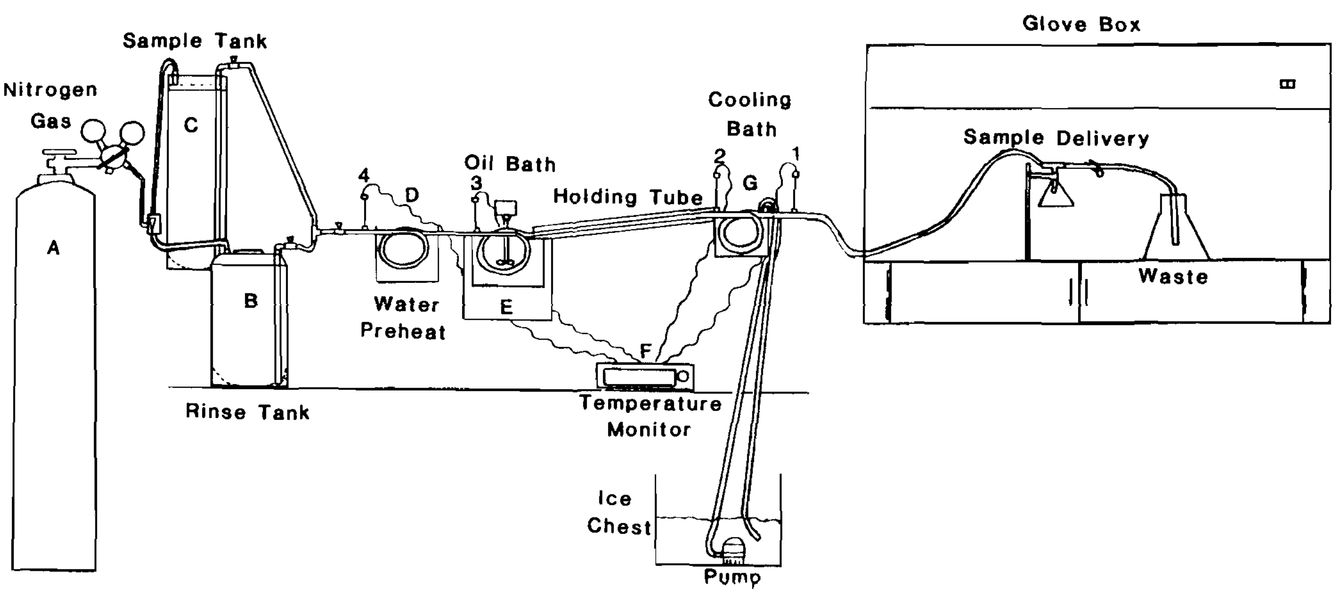

Figure 1. *Pilot size indirect UHT system.*

The milk could be held for a variable time (5 s in our study) as it passed through an insulated holding tube (F) 18 cm long with a 10-ml capacity. The holding tube was wrapped with asbestos and 1.5-cm thick rubber for insulation. Temperature probe #2 monitored the temperature of the milk as it left the holding tube to assure that the sterilization temperature had been maintained for the desired time.

After leaving the holding tube at the sterilization temperature (135°C), the milk was cooled rapidly to approximately 11°C by directing it through 2.74 m of coiled tubing in a circulating ice-water bath (G). Ice water in the cooling bath (a 2-qt aluminum pan) was fed from an ice chest by a small submersible-type pump (Little Giant Co., Oklahoma City, OK), which circulated cold water from the chest into the bath while a hose syphoned the water back into the chest. A stainless steel needle valve (Nupro), positioned after the cooling bath, was used to regulate the flow rate of milk through the system. The holding time was controlled by adjusting the flow rate (120 ml/min in our study). With the 10-ml capacity holding tube, the holding time was 5 s.

The sterilized milk was directed through 1.22 m of Tygon tubing into a glove box (Labconco Tissue Culture Enclosure, Labconco, Kansas City, MO) where it was either diverted to a waste flask using a pinchcock or aseptically collected in amber glass bottles. At the point where milk was collected, an inverted glass funnel with the tip broken off was placed around the outlet to reduce any possible contamination from air current. The outlet was held stationary and sample bottles were inserted underneath the funnel system.

One problem with this system that should be pointed out is the absence of a homogenizer. This was of no concern in processing skim or pasteurized-homogenized milk, but it was when raw milk was sterilized.

Cleaning procedure

The system could be operated approximately 3 h before cleaning was necessary due to some build-up of milk solids on the inner walls of the tubing. Immediately after a processing trial, the system was rinsed with water and then swept with 2.5 gal of a strong alkali solution (Klenzade-Kleer Brite formula HC-29 over 10% NaOH). Following the alkali treatment, the system was rinsed with 1 gal of water and then flushed with 2 gal of an acidic cleaning solution (Klenzade AC-3 Acid Detergent Cleaner). The system was rinsed again with 1 gal of water and sanitized with a 100 ppm chlorine sanitizer (Klenzade XY-12 Liquid Sanitizer). A final water rinse flushed chlorine from the system.

Sterilization procedure

Before the milk was processed, the system was sterilized. The tubing was disconnected immediately after the needle valve where Tygon tubing was connected, and all open ends were wrapped with aluminum foil. The Tygon tubing with its wrapped connectors, sample bottles, and waste flasks were sterilized at 121°C for 25 min. The hot water bath and the oil bath were brought up to temperature and the system was flushed with a 100 ppm chlorine sanitizer (Klenzade XY-12 Liquid Sanitizer), rinsed with clean water, and steam-sterilized at 140°C for 15 min. The glove box was sanitized with 500 ppm XY-12 Liquid Sanitizer (Klenzade) and exposed to UV light for 1 h before processing to kill any surface organisms. The previously disconnected (autoclaved) Tygon tubing and connector of the second section of the system were reconnected over a flame.

RESULTS AND DISCUSSION

One hundred forty bottles (250 ml each) of milk were processed with this indirect UHT system at 135°C for 5 s and remained sterile for at least 4 months at both 7° and 32°C storage temperatures (*1*). This system is useful for studying flavor changes in UHT milk in laboratory system.

REFERENCE

1. Wadsworth, K. D., and R. Bassette. 1985. Effect of oxygen on the development of off-flavors in ultra high-temperature milk. J. Food Prot. 48:487-493.