Combined Process for Removing Radioactive Iodine and Strontium from Milk by Ion Exchange

Abstract
Milk labeled in vitro containing iodine-131 and strontium-85 was passed through an anionic resin (fixed-bed contactor) in a chloride:phosphate:citrate cycle, acidified to pH 5.3 with citric acid, and passed through a cationic resin (pulsed-bed contactor) in a calcium:magnesium:potassium:sodium cycle. To acidify the milk, a metering system was developed, which maintained the pH of the milk between 5.25 and 5.40 during a 20-hr run. Analyses of the treated milk indicated that approximately 97% of the iodine-131 and 95% of the strontium-85 were removed. The anionic and cationic salt compositions and the microbiological flora of the milk were not significantly altered by resin treatment. Protein stability analyses indicated that the acidification caused some protein precipitation, while the flavor quality was acceptable provided the first 5% of the treated milk was discarded.

A combined fixed-bed process for the removal of iodine-131 (\textsuperscript{131}I) and strontium-85 (\textsuperscript{85}Sr) has been described by Heinemann et al. (3) and Walter et al. (5). Because of the limited capacity of the cationic resin to remove \textsuperscript{85}Sr, Edmondson (2) investigated a pulsed-bed cationic resin contactor that operated continuously. Dickerson et al. (1) described a process which removed approximately 97% of the \textsuperscript{85}Sr from milk using a modified pulsed-bed contactor.

The objectives of this investigation were to develop a combined process to remove \textsuperscript{131}I and \textsuperscript{85}Sr, using a fixed-bed anionic contactor and the modified pulsed-bed cationic contactor.

Experimental Procedure
The anionic contactor was a fixed-bed system constructed from glass pipe and fittings. A 50-mesh Teflon screen was used to support 3.8 liters of resin.

Continuous acid metering system. The acidification system used a 9-liter vat as the acid-milk mixing chamber, which was maintained at atmospheric pressure and contained a motor-driven flat-blade agitator. For startup, 9 liters of milk were batch acidified to pH 5.3, and then milk and acid were allowed to flow simultaneously into the acidified milk vortex. During steady-state conditions, acidified milk overflowed from a port on the outside edge of the vat into a surge tank (Fig. 1). This tank supplied acidified milk to the pulsed-bed contactor and eliminated the necessity of stopping the acid metering system during the cationic resin pulse for 20 sec after each 3-min period of operation. The citric acid (0.75M) was stored in a pressurized vessel and was transported by air pressure (4,900 g/cm² gauge) to the acidification vat through a metering valve, which was connected to a pH recorder and controller (Foxboro no. 9950GB-A4). The pH sensing element used was a single combination electrode (Beckman no. 39142).

The pulsed-bed cationic contactor has been described by Dickerson et al. (1), while a flow diagram of the combined process is shown in Figure 1. The first positive displacement pump delivered approximately 550 ml/min of milk continuously through the anionic contactor to the acidification vat. The second positive displacement pump delivered approximately 630 ml/min of acidified milk to the cationic contactor during the three-minute processing cycles and was automatically stopped during the 20-sec pulsing cycles.

Milk labeled in vitro was prepared by adding \textsuperscript{131}I and \textsuperscript{85}Sr of known activity (in sterile aqueous solutions) to raw milk and allowing the mixture to equilibrate with agitation at 3 C for 18 hr.

The anionic and cationic resins and the procedures used for their treatment before and after exposure to milk and during storage, as well as the procedures used for sampling and analyses of the milk, were the same as described (1, 3, 4). Protein stability was determined by measuring the volume of insoluble residue from 35 ml of milk at normal pH that had been centrifuged for 10 min at 825 g.

Results and Discussion
After several preliminary tests to identify satisfactory operating conditions, one 20-hr run was made. Milk samples were analyzed for radioactivity removed, anionic and cationic salt compositions, protein stability, microbiological flora, and flavor stability.

Chemistry. Analyses of milk samples for radioactivity showed removals of approximately 97% for \textsuperscript{131}I and 95% for \textsuperscript{85}Sr at flow rates of 0.12 and 0.30 resin bed volumes per minute,

\textsuperscript{1} Mention of a commercial product does not imply endorsement by the Public Health Service.
respectively. The major anionic and cationic salt compositions were not significantly altered by resin treatment; however, the citrate and potassium levels were approximately doubled because of the milk acidification necessary for adequate $^{90}$Sr removal.

To determine the magnitude of the deleterious effect of acidification on protein stability, treated milk samples were immediately neutralized to pH 6.7 and analyzed for insoluble residue. The insoluble residue for these samples ranged from 0.05 to 0.09 ml as compared to 0.03 ml for the control milk. These results indicated that despite thorough mixing of the milk and acid and immediate neutralization after resin processing, some protein precipitation occurred while the milk was at pH 5.3.

Microbiology. Theoretically, the pulsed-bed contactor could process milk for an indefinite period without a shutdown. From a practical standpoint, however, indefinite operation was not feasible because of bacterial buildup in the static milk pocket between the milk processing and milk rinsing sections of the contactor. This consideration led to identification of a 20-hr running time as realistic for this process, and the development of sanitary operating conditions was based on runs of this duration.

Samples of milk and resin were taken periodically from selected points throughout the combined process and examined for microorganisms. The standard plate counts of the treated milk were not significantly different from those of the control milk which verified that the 20-hr runs were feasible with reasonable attention given to the sanitary aspects of the process. The counts also showed that refrigeration prevented significant bacterial growth in the static milk pocket between the milk processing and milk rinsing sections.

Flavor. Treated milk samples were pasteurized at 62.8° C for 30 min and were evaluated for flavor by a panel considered representative of the average consumer. This panel could not differentiate between the flavor of treated and control milk; however, a severe flavor defect was encountered in the treated milk when the anionic resin was used more than once. Additional testing on a regenerated anionic resin indicated that the flavor was acceptable if the first five per cent of the treated milk was discarded. Additional research is needed to eliminate the flavor defect in the first five per cent of processed milk.

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FIG. 1. Flow diagram of combined process for radionuclide removal.
Rapid Evaluation of Milk Coagulating and Flavor Producing Enzymes for Cheese Manufacture

Abstract

A screening method is reported for rapidly indicating the suitability of various cheese ripening agents. Freshly ground mild cheese curd was inoculated with high levels of enzyme preparations, incubated at 21 C for three days and evaluated organoleptically. The method has the advantages of replacing long make and storage testing procedures and comparing treatments on a single homogeneous lot of cheese curd. The method should be useful in evaluating the role of various microorganisms and their enzyme systems in cheese ripening.

Experimental Procedures

The procedure we adapted involves grinding mild Colby or Cheddar cheese in a fine food grinder. The resultant paste is divided into 100-g aliquots and a slurry of the enzyme(s) in question is mixed into the paste with a mortar and pestle. The slurry is prepared by adding 1 ml water to the dry enzyme preparation. The enzyme levels used are generally three to four times those used in cheese manufacture. Thus, to check the bitter producing properties of rennet and compare this to other coagulants, we used 4 × 1.98, or 7.9 ml equivalent, per kg of cheese. Rather than use this volume of liquid, a high-test rennet powder is adjusted in coagulation strength and blended with the 1 ml sterile, distilled water. A control paste containing 1 ml added water is prepared with every series.

The pastes are packed tightly into screw-capped jars and held at 21 C for three days. Flavor is then evaluated.

Results and Discussion

The question of bitterness in normal cheese manufacture due to coagulant activity is subject to debate (2). When the high inoculation levels described herein are used even veal rennet can produce bitterness in the ground curd. While there is no clear definition of the disposition of rennin enzyme following cheese making, this test compares the bitterness produced by veal rennet to that produced by other enzymes, and hence, the degree of bitterness potential can be estimated.

Pepsin used for milk clotting has been obtained from several sources and evaluated using this screening test. One pepsin supplier was ruled out after abnormal flavor development was observed in the test method just described. The pepsin powder also had an objectionable odor. The degree of bitterness produced by products from the other suppliers was comparable to the rennet control.

Certain fungal milk clotting enzymes considered as substitutes for rennet cause very severe bitter changes in the paste. This has been correlated in actual cheesemaking trials. The milk clotting enzyme developed by Arima and Iwasaki (1) is more proteolytic than veal rennet but less than some other fungal rennet preparations. Three fungal coagulants are compared with veal rennet in Table 1. There is

References