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Water removal from raw milk at the point of production

Abstract

Milk processing plants are becoming fewer in number and larger in size. As a result, the distance the raw milk is transported from the point of production to the processing site increases. Because the major component in raw milk is water, the reduction of water at the production site would result in lower transportation costs as well as lower energy needs. Water can be removed from milk through a membrane filtration. This study showed that concentration of raw milk allowed for the microbes to partition into the milk solids fraction. Microbial numbers increased during refrigerated storage of this concentrated raw milk.; Dairy Day, 1999, Kansas State University, Manhattan, KS, 1999;

Keywords

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WATER REMOVAL FROM RAW MILK AT THE POINT OF PRODUCTION

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Summary

Milk processing plants are becoming fewer in number and larger in size. As a result, the distance the raw milk is transported from the point of production to the processing site increases. Because the major component in raw milk is water, the reduction of water at the production site would result in lower transportation costs as well as lower energy needs. Water can be removed from milk through a membrane filtration. This study showed that concentration of raw milk allowed for the microbes to partition into the milk solids fraction. Microbial numbers increased during refrigerated storage of this concentrated raw milk.

(Key Words: Ultrafiltration, Total Plate Counts, Coliform Counts.)

Introduction

The number of fluid milk processing plants has decreased steadily throughout the U.S. in the last 20 years. This decrease means that the distance that milk is transported from point of production (farm) to point of processing (plant) and transportation costs have increased.

Raw milk is a mixture of water, protein, lactose, fat, vitamins, and minerals. The greatest component by far is water, ranging from 83 to 87%. Almost all nonfluid dairy products (ice cream, cheese, yogurt) are concentrations of one (or more) component(s) of milk, which usually involve a water removal step during manufacturing. Reverse osmosis (RO) and/or ultrafiltration (UF) processing technologies are being used to remove water or water and some smaller sized components from milk or whey, the by-product of the cheese industry. In these processes, milk is passed over a membrane; membranes vary in pore size, so that specific-sized molecules (water, minerals, or lactose) can be removed from the milk. Thus, the milk product can be concentrated without a severe heat treatment. The fraction that passes through the membrane is called "permeate" and contains water and perhaps some lactose and minerals. The fraction that does not pass through the membrane is called "retentate" and contains the protein, fat, some lactose and minerals, and water. The selective removal of specific milk components has been exploited successfully in the cheese industry. But this technology also has applications on the farm, where partial water removal may result in decreased transportation and cooling costs and lower requirements for holding space.

Such a system is being utilized in New Mexico, where several farms use RO to remove some water before milk is sent to the cheese plant. The New Mexico Department of Agriculture and the U.S. Food and Drug Administration (FDA) placed strict processing requirements on this operation, such as maintaining milk temperature below 45°F at all times, using a maximum processing time of 8 minutes, and applying current raw milk standards for microbiological and somatic cell qualities to the retentate. At this point, FDA has given approval for the use of the RO retentate only for the cheese industry. However, the successful application of this technology easily could spread to other dairy foods industries. Thus, the objective of this study was to investigate how UF of raw milk affects microbial and somatic cell counts.

Procedures

Raw milk was obtained from the KSU Dairy Research and Teaching Center and transported to the KSU Dairy Plant. One hundred gallons were split equally. One 50-gal batch was left intact, whereas the other one was inoculated with a microbial culture to produce a raw milk product with higher microbial counts.

Fifty gallons of raw milk were ultrafiltered to 1.5× (37.5 gallons) and 2× (25 gallons) concentration within 24 hours of milking. Ultrafiltration was done on an ABCOR ultrafiltration pilot system using a spiral wound membrane (Koch Membrane System, Minneapolis, MN) operated at < 7°C at all times. Samples were collected at 1× (raw milk), 1.5× and 2× for both permeate (what went through the membrane) and retentate (concentrated raw milk). The samples were analyzed for coliform counts, total plate counts (TPC) of aerobic bacteria, and somatic cell counts as well as solids content. Bacterial counts were enumerated using appropriate Petri-Film®, and solids were determined in a forced air oven following standard methods at the KSU Dairy Plant. Somatic cell counts were quantified at the Heart of America DHIA Lab (Manhattan, KS) using Somacount 500 (Bently Instruments, Inc.). Samples were analyzed for microbial quality at three different times, immediately after processing and after 24 and 120 hrs (5 days) of refrigerated (<45°F) storage. Duplicate samples were assayed at all times, and results are reported as averages. Ultrafiltration was done on three different days in July, 1999 to achieve representative results. All results are reported as averages of the three replicates.

Results and Discussion

Table 1 shows the total solids of the permeate and retentate fractions of milk. The average total solids content of milk is 12.5%. The solids content of the permeate fraction shows that UF removes not only the water but also some of the solid material from milk, predominately lactose and minerals.

Table 1. Total Solids (%) of Retentate and Permeate Fractions of Raw Milk Ultrafiltered to Two Different Concentrations

	Concentration	
Fraction	1.5×	2.0×
Retentate	14.40 ± 0.30	19.58 ± 0.18
Permeate	5.45 ± 0.03	5.72 ± 0.19

Table 2 shows the results of the microbial partitioning after UF of raw milk. Almost all microbes partition into the retentate fraction. No differences in microbial numbers were detected between concentration samples, thus verifying that the pore size was smaller than the bacteria and would not allow the bacteria to concentrate into the permeate fraction. Thus, after one pass, theoretically, almost all of the microbes should be in the retentate fraction. This explains the fact that the numbers of microbes remain the same for the concentration factor as well as over UF time. However, during storage time, the microbial numbers increased (as expected), although temperatures were maintained below 45°F throughout the study. Because the microbial numbers in the retentate after 5 days of storage were less than 100,000 CFU/mL, this retentate would be considered legal, at least from a TPC standpoint for a single producer.

However, when the initial raw milk contained greater concentrations of bacteria, the acceptance results changed. Table 3 shows the results for milk that contained ~80,000 CFU/mL of bacteria. The same patterns emerge as shown in Table 2; the majority of the microbes partitioned into the retentate. The concentration factor had little effect on the microbial numbers, and they increased with time. Within 24 hrs, the microbial numbers of the retentate increased above the maximum for total number of aerobic bacteria allowable from a single producer. By 5 days of storage, this retentate had very high counts and would be considered unacceptable for a fluid milk processor.

Two obvious conclusions can be made from the results in Tables 2 and 3. One, UF needs to be done just before milk pickup (perhaps 4 to 6 hrs). Two, raw milk with high microbial counts may not be suitable for this technology, because the concentration process may induce higher counts than are acceptable for raw milk.

Table 2. Total Number of Aerobic Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltered Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	12,000		22,000		61,000	
1.5×	<1	18,000	4	30,000	11	64,000
2.0×	<1	17,000	6	39,000	11	62,000

Table 3. Total Number of Aerobic Bacteria (CFU/ml) in Inoculated Permeate (P) and Retentate (R) of Ultrafiltered, Inoculated Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	81,000		150,000		500,000	
1.5×	<1	90,000	4	170,000	17	560,000
2.0×	<1	97,000	4	260,000	16	570,000

Although no standards exist for coliform bacteria in raw milk, it is generally accepted that few fluid milk processors want to accept raw milk with coliform counts higher than 100 CFU/mL. High coliform counts can be responsible for unacceptable off flavors and odors and are indications of poor sanitation practices. Thus, coliform counts were tracked in this study and the results are shown in Tables 4 and 5 for the uninoculated and inoculated raw milk trials. As can be seen in these tables, the same patterns emerge as with the aerobic bacteria. The majority of coliforms will partition into the retentate and then will continue to multiply over time.

As with the bacteria, the somatic cells also partitioned into the retentate (Table 6). Because somatic cells should not increase during time nor could they be added artificially to the raw milk prior to UF, samples were checked only once. Inoculation with bacteria did not affect the partitioning of the SCC or the bacteria. Results generally remained the same. And for all samples, the retentate met the standard for SCC in raw milk.

Conclusions

This study shows the usefulness of UF just prior to milk pick-up. For a producer to use such technology on his/her operation certain guidelines should be in place, such as high quality milk (low microbial and somatic cell counts). Ultrafiltration should occur prior to pick up and be used within a short period of time at the processing facility. But as of today, this technology is not approved for on-farm use in Kansas. However, the results presented in this study show that high quality raw milk can be maintained while using this technology and result in a volume reduction. As more data are collected and critical control points established and controlled, the FDA will consider UF as an on-farm process.

Table 4. Total Number of Coliform Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltered Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	5		38		180	
1.5×	<1	6	<1	31	<1	150
2.0×	<1	6	<1	25	<1	140

Table 5. Total Number of Coliform Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltrated, Inoculated Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	19		28		750	
1.5×	<1	21	<1	31	<1	790
2.0×	<1	13	<1	25	<1	770

Table 6. SCC in Retentate and Permeate of Inoculated and Uninoculated Raw Milk

	Retentate		Permeate	
Concentration	Uninoculated	Inoculated	Uninoculated	Inoculated
Raw milk	315	320	0	0
1.5×	447	530	0	0
2.0×	443	361	0	0