Effects of Milk Somatic Cell Count on Cottage Cheese Yield and Quality[1]

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ABSTRACT

Eight Holstein cows in midlactation were selected for low milk somatic cell count (SCC) and the absence of the pathogens that cause mastitis. Milk collection and cottage cheese manufacture from low SCC milk were replicated on each of 4 d (control period). Each cow was infused with 1000 cfu of *Streptococcus agalactiae*. One week after infusion, milk from the same eight cows was collected and commingled. On each of 4 d, cottage cheese was made from milk with high SCC (treatment period). A mass-balance protocol, accounting for protein and total solids, was used to determine recoveries in whey, wash water, and uncreamed curd. Actual yields, yields adjusted for composition, and theoretical yields of uncreamed curd were calculated. Mean milk SCC for the periods with the low SCC (control) and the high SCC (treatment) were 83×10^3 and 872×10^3 cells/ml, respectively. The recovery of protein in the uncreamed curd was higher during the low SCC period than during the high SCC period (75.85% vs. 74.35%). High SCC and the associated higher proteolytic activity caused higher protein loss in the whey and wash water and more curd fines. The percentage of total solids recovery in uncreamed curd was higher for high SCC milk because the lactose content of the high SCC milk was 0.27% lower than that of the low SCC milk. The moisture content of the curd was higher for the high SCC milk (82.75% vs. 83.81%). Proteolysis during refrigerated storage was faster in cottage cheese made from high SCC milk. The yield efficiency of uncreamed curd, adjusted for composition based on 81% moisture, was 4.34% lower for the cottage cheese curd made from high SCC milk.

(**Key words**: somatic cell counts, cheese yield, cheese composition, cottage cheese)

Abbreviation key: **TN** = total N.

INTRODUCTION

Mastitis is an inflammatory reaction of the mammary tissue in response to an infection; this inflammation is characterized by an influx of white blood cells into the mammary gland, followed by an increase in endogenous milk proteases (25). When milk SCC are <1,000,000/ml, plasmin is the most significant protease causing degradation of the milk casein (22). Barbano et al. (3) observed a decrease in casein as a percentage of true protein when milk SCC increased to >100,000 cells/ml. Casein loss into whey during Cheddar cheese making increased when milk SCC were >100,000 cells/ml (3). Many researchers (1, 12, 20, 24) have reported that milk with high SCC had a slower rate of curd formation and produced a softer curd. It is possible that growth of lactic acid bacteria is inhibited by the antibacterial compounds contained in white blood cells (11).

Cultured milk products such as cottage cheese should be made from fresh, high quality milk because any defects in the raw milk can affect the finished product (21). Lower quality milk, such as milk with high SCC, can increase the chance and frequency of flavor defects. Quality defects in cottage cheese that are related to high SCC in milk are likely to be caused by increased action of proteolytic enzymes. In the US at any given time, 40% of the cows are infected with a pathogenic bacteria, resulting in elevated milk SCC (4, 6). The consequent financial losses for farmers can be >$200/yr per cow, 75% of which is due to decreased milk production (8). Additional losses occur in cheese plants because of decreased cheese yields (3).

Previous research on the influence of milk SCC on cheese yield has been performed on cheese made with rennet (1, 3, 12, 18, 19, 20, 24), but no research has been done to determine the impact of high SCC on cheese made from acid coagulation of milk. The objective of this study was to determine the effects of milk

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with high SCC on cottage cheese yield, composition, and quality.

MATERIALS AND METHODS

Experimental Design

Milk was collected from the same eight cows throughout the study. Milk was collected on 2 d each week, and cottage cheese was manufactured twice a week for 2 wk during the period with low SCC milk (control). After the control period, the cows were infused with a mastitis-causing pathogen, *Streptococcus agalactiae*. After infusion, 1 wk elapsed before sample collection and cheese manufacture were initiated. Milk was also collected twice a week for 2 wk during the period with high SCC milk (treatment). The milk collected on each sampling day was split and was used to make two vats (i.e., duplicate cheese manufacture) of cottage cheese curd simultaneously. Data from the duplicate vats each day were averaged to produce four control and four treatment observations; data were analyzed using PROC GLM of SAS (23) for measurements of composition, recovery, and yield.

The rate of change in soluble N content of cottage cheese with time of refrigerated storage was determined by regression analysis. The slopes of the regression lines were compared using PROC GLM to determine whether control and treatment differed. Differences in milk yield for the control and treatment periods were also determined by regression analysis. The slopes for milk yield of the cows during the control period were compared with those for the same cows during the treatment period using PROC GLM. Main effects were cow, treatment, DIM, and the interaction between treatment and DIM.

Cow Management

Cow selection. Milk samples were collected from a large group of cows in midlactation, and milk SCC were determined [(2); method number 17.13.01, 978.26]. Aseptic milk samples were collected from cows with low SCC immediately after milking to check for the presence of mastitis-causing pathogens in their mammary glands. The teat ends were first sprayed with teat dip (0.25% iodine), dried with a paper towel, and then scrubbed with alcohol-moistened cotton gauze pads. A few milliliters of milk were expressed from each quarter into separate sterile plastic containers. Aseptic samples were cultured by Quality Milk Promotion Services Laboratory (Ithaca, NY). Aseptic milk samples were taken on 2 consecutive d. Based on SCC and bacterial culture test results, eight Holstein cows that had low milk SCC (<100,000 cells/ml) and an absence of mastitis-causing pathogens were selected for the experiment. Mean (±SD) DIM and daily milk yield for the 8 cows was 186 ± 21 DIM and 40 ± 5 kg, respectively, at the start of the experiment. We estimated that the eight cows would yield the amount of milk needed for pilot plant cottage cheese manufacture, even during the postinfusion (treatment) phase of the study, when milk yield per cow could drop 25 to 35% because of mastitis.

Housing, milking, and feeding. Cows were housed in a tie-stall barn approved by the American Association of Accreditation for Laboratory Animal Care (Rockville, MD). Cows were milked twice a day in a double-10 herringbone parlor (Delaval; Alfa-Laval, Agri Inc. Kansas City, MO) equipped with milk weigh jars and automatic removal of milking units. A computer-controlled, cow transponder identification system connected to the milk metering system (Alfa-Laval, Agri Inc.) was used to record daily milk weights for individual cows. After the infusion of *S. agalactiae*, cows were milked last in the herd of 340 milking cows to prevent spread of the contagious pathogens to other cows. Cows were fed for ad libitum consumption a total mixed diet that had been formulated to meet the nutritional requirements of a 600-kg cow yielding 42 kg of milk/d with 3.8% milk fat and 3.4% protein.

Infusion Procedure

Culture preparation. A frozen aliquot of *S. agalactiae* (Cornell 48 strain, ATCC 27956) culture was thawed, mixed into 6 ml of Todd-Hewitt broth (Difco Laboratory, Detroit, MI) and incubated overnight at 37°C. One milliliter of this overnight culture was added to 50 ml of Todd-Hewitt broth, and samples were incubated for 6 h at 37°C. A sample was prepared from the 6-h growth to establish the titer; 0.1 ml of the 6-h culture was placed into 0.9 ml of diluent. Based on the titer results, the 6-h culture was diluted in saline to 1000 cfu/ml of *S. agalactiae* infusion. Sixteen 3-ml syringes were filled with 1 ml of the *S. agalactiae* in saline and capped with a sterile plastic teat canula.

Infusion. Filled syringes were transported to the Cornell Research Dairy Farm on ice packs. Two hours after the p.m. milking, while the cows were in their stalls, aseptic milk samples were taken from all four quarters to ensure no mastitis-causing bacteria were present prior to the infusion of the *S. agalactiae*. After aseptic sampling, the right rear and the left front

quarters were scrubbed with alcohol-moistened cotton gauze. Using sterile, disposable, teat canulas, *S. agalactiae* was infused into the right rear and left front quarters. Finally, teats were dipped into 0.25% iodine teat dip. Aseptic quarter sampling was collected five times weekly for 3 wk to confirm the *S. agalactiae* infections.

Culture. A 10-μl aliquot of each quarter milk sample was spread onto a trypticase soy agar plate containing 5% sheep blood and 0.1% esculin (BBL Microbiology Systems, Cockeyville, MD). Plates were incubated aerobically at 37°C for 48 h and were examined for bacterial growth at 24 and 48 h of incubation. *Streptococcus agalactiae* was identified by colony structure, β-hemolysis, positive CAMP reaction, and the absence of esculin hydrolysis.

Cow health. Cows were monitored daily after infusion for signs of clinical mastitis. Daily rectal temperatures were performed on each cow, and cows were checked for signs of acute mastitis. Cows that showed signs of clinical or acute mastitis (i.e., clots or flakes in milk, red swollen quarter, fever, or off-feed) were moved to the ward for sick cows. Frequent milking with oxytocin for milk letdown was used to treat mastitis in these experimental cows. Two of the eight cows required this mastitis treatment. Their stay in the ward was 2 to 3 d before they were returned to their tie stall. These days were not scheduled for milk collection.

Cottage Cheese Making

Milk was collected separately for each cow at the p.m. milking, and milk was then cooled to 4°C. Milk was held overnight at 4°C in a walk-in cooler at the farm. Milk collection was repeated the next day at the a.m. milking, and all 16 milk cans were brought back to the Cornell Food Science Pilot Plant. Milk SCC were determined for each cow for each milking. During the control period, milk that had an SCC <150,000 cells/ml was commingled and used for cottage cheese manufacture. On 1 of the 4 d of cheese manufacture in the control period, one milking was excluded from one cow because the SCC of that sample was >150,000 cells/ml. During the high SCC period (treatment), milks from all cows at all milkings were commingled.

The procedure for the manufacture of cottage cheese was divided over 2 d. On d 1, the milk was separated into cream and skim milk, milk was pasteurized, and the cream dressing was made. To make cream dressing, the cold whole milk from individual cows was mixed in a vat and heated to 49°C; then, cream and skim milk were separated using a Delaval Tri-Process cream separator (model 340-A; Delaval, Poughkeepsie, NY). The weights for the skim milk and cream were checked to ensure a ratio of 9 to 1. The skim milk was put into a cheese vat, mixed, and sampled for analysis of milk fat by the Babcock method (16). Skim milk was pasteurized (PMS, Processing Machinery and Supply Co., Philadelphia, PA.) at 74°C for 16 s, cooled to 4°C, placed into sanitized milk cans, and stored overnight in a cooler (4°C). Simultaneously, the cream was mixed in a steam kettle, and a sample of cream was taken for milk fat analysis by the Babcock method [(2) method number 33.3.12, 920.11]. The 49°C, raw cream was batch pasteurized at 74°C for 30 min to inactivate milk lipases. After pasteurization, the cream was poured into a sanitized milk can, immersed in a vat containing ice water, and stirred occasionally. Based on fat concentration in the cream, 35 kg of cream dressing were made using the following ingredients: cream (to achieve 11% fat), skim milk, NDM (2.3% by weight), and salt (2.3% by weight). The cream dressing was batch pasteurized at 81°C in a steam kettle for 30 min. After pasteurization, the cream dressing was homogenized with a Gaulin two-stage homogenizer (APV Gaulin Inc., Everett, MA) at a total pressure of 17.3 kPa and then rapidly cooled in a vat containing ice water. The cream dressing was kept in a 4°C cooler until it was needed the next day.

On d 2, the cottage cheese curd was made from the skim milk and then mixed with the cream dressing. A mass-balance protocol was followed during cottage cheese manufacture to determine uncreamed curd yield. Approximately 70 kg of skim milk were weighed into each of the two cheese vats (model 4X; Kusel Equipment Co., Watertown, WI). All weights were determined to the nearest gram (model PE24; Mettler Instrument Corp., Hightstown, NJ). Skim milk was heated to 32°C in the cheese vat before inoculation with both M56 and M59 (0.5 ml of each culture/kg skim milk) commercial cottage cheese cultures (Rhône-Poulenc, Madison, WI). After 2 min of stirring, the milk was allowed to coagulate at 32°C. No rennet was used. The pH and temperature were monitored and recorded over a period of approximately 4 h. The curd was cut at pH 4.6 into 1.2-cm cubes with wire cheese knives. The cut curd was allowed to heal for 10 min. The cooking process was started by gently stirring the curd for 2 min at 32°C. Next, the temperature was raised in 5.5°C increments from 32°C to 57°C over 1.5 h while the curd plus whey were gently stirred. The temperature was maintained at 57°C, and the curd was stirred for another 15 min.

After the curd was cooked, the hot water was drained out of the jacket of the vat and replaced with cool water (10°C). A curd strainer was inserted into each vat, and a strainer lined with cheesecloth was used to collect the fines as the whey was drained. The fines were added back into the vat and considered in the weight of the curd. The curd was gently mixed and evenly distributed over the bottom of the vat to ensure good separation of whey. After 10 min of whey draining, the valve of the vat was shut, and approximately 90 kg of pasteurized water at 32°C were gently poured into each vat. The curd and wash water were stirred for 1 min and then held for 8 min without stirring, followed by stirring again for 1 min before draining. This process was repeated using 24°C and 4°C wash water for a total of three washes. The curd was gently mixed and evenly distributed over the bottom of the vat and allowed to drain for 30 min after the last wash. The weight of curd at this point was used for calculation of actual uncreamed curd yield. The weighed curd was blended in a ratio of 2 to 1 with cream dressing and left undisturbed for 30 min to allow absorption of the cream dressing by the curd. The creamed cottage cheese product was packaged in 340-g plastic snap-lid containers (Fabri-Kal Corporation, Kalamazoo, MI) and was stored at 4°C.

Sampling and Analyses

Curd pH was monitored during the coagulation process. Storage solution (3*M* KCl) and buffers (pH 4.0 and 7.0) used to calibrate the pH meter and electrode (model HA 405 DXK-58/120 Combination pH probe; Ingold Electronics Inc., Wilmington, MA) were tempered to the same temperature as the milk (32°C). Samples of skim milk, whey, wash water, uncreamed cheese curd, and creamed curd were collected from each vat of cheese for composition analysis. Skim milk (180 ml) was sampled after it was heated to 32°C but before the addition of the starter culture. All of the whey was collected separately from each vat, weighed, mixed, and sampled. For each vat, wash water from all three washes was collected, mixed, and sampled. The drain valve of the vat was closed, and the uncreamed curd was sampled after the last water wash. One person mixed the curd with a metal scoop, and another person collected uncreamed curd from different parts of the vat to ensure representative sampling. The curd sample was collected into a clear plastic bag.

Immediately after sampling, curd samples were blended in a food processor (model 286; Farberware, Bronx, NY) for 30 s, and TS were determined in quadruplicate by drying 2-g samples of uncreamed curd for 24 h in a 100°C forced-air oven (model OV-490A-2; Blue M, Blue Island, IL). The loss of moisture from the uncreamed curd caused by the continued syneresis after weighing (for yield) but occurring during subsequent sample handling and blending is a problem; thus, the blending step was done immediately. Despite the short time between sample collection and blending, a small amount of free liquid was present in the bottom of the clear plastic sample bags when the curd was transferred to the blender. The mean moisture loss from syneresis of the uncreamed curd from the time of sample collection to the point of blending was determined to be about 2.27% (e.g., from 85.00 to 82.73%). This adjustment for moisture decrease in the sample prior to analysis was made for the results for TS, protein, and fat of the uncreamed curd that were used to calculate mass balance for protein and solids.

Skim milk was tested for fat by the Babcock method (16), TS by oven-drying [(2) method number 33.2.44, 990.20], and total nitrogen (**TN**) by Kjeldahl [(2) method number 33.2.11, 991.20); noncasein N (14) and NPN [(2) method number 33.2.12, 991.21] were also determined. All analyses on skim milk were performed in duplicate. Casein nitrogen was calculated as the difference between TN and noncasein N. All N results are expressed as a protein equivalent (TN × 6.38). A sample of the starter culture was analyzed for TS and TN using the same methods that were used for skim milk. One composite sample of all the low SCC skim milks and one composite sample of the high SCC skim milks used for cottage cheese manufacture were analyzed for ash [(2) method number 33.2.10, 945.46] in quadruplicate; lactose was calculated by difference. Whey and wash water were analyzed in duplicate for fat, TN, and TS with the same methods used for the skim milk. The fat content of the uncreamed curd was determined in duplicate by ether extraction [(2) method number 33.2.26, 989.05] using a 7-g sample of uncreamed curd mixed with 3 ml of NH_4OH and 2 ml of boiling water. Kjeldahl analyses for TN [(2) method number 33.2.11, 991.20] were performed in triplicate, using a 2-g uncreamed curd sample weighed onto Whatman filter paper (number 42; Whatman Laboratory Division, Maidstone, England) and analyzed with the paper.

Standard plate counts were performed on the creamed cottage cheese. The effects of storage at 4°C on proteolysis in the creamed cottage cheese were measured at 7, 14, 28, and 56 d from all 8 d of cheese manufacture. Analyses of TN were performed in triplicate on creamed curd using the same method as for uncreamed curd. The amount of N that was solu-

ble at pH 4.6 and in 12% TCA was measured in duplicate by Kjeldahl [(2) method number 33.2.11, 991.20] using a 0.75-g sample size for pH 4.6%-soluble N and a 1.5-g sample size for 12% TCA-soluble N as indices of proteolysis (7). Sensory analysis was performed on creamed cottage cheese samples that were stored for 28 d. Untrained panelists (n = 40) were asked to indicate the perceived degree of rancidity and bitterness using a continuous line scale (0 mm to 150 mm; 0 = not detectable, and 150 = very strong).

Calculation of Recoveries and Yield

Total recoveries for protein (TN × 6.38), fat, and TS in the uncreamed curd were calculated taking into account the weights of samples removed during cheese making. The curd fines that had been collected during whey draining and water rinsing were added back to the curd in the vat. The weights of protein, fat, and TS that were recovered from the whey, wash water, and the uncreamed curd were determined and expressed as a percentage of the original protein, fat, or TS present in the skim milk plus starter.

Actual uncreamed curd yields were determined by dividing the weight of the uncreamed curd by the weight of the milk plus starter. Yield of the uncreamed curd, adjusted for moisture (MAY), was calculated to an 81% moisture (i.e., 19% TS); MAY = (actual yield × (percentage of TS in curd/100))/0.19. Theoretical uncreamed curd yields were determined for each vat using the following formula: (percentage casein in milk/0.9)/0.19, where the 0.9 factor assumes that 90% of the solids in the uncreamed curd are casein, and 0.19 factor assumes a target solids content of 19% in the uncreamed curd. The yield efficiency is the MAY divided by the theoretical yield (MAY/theoretical yield) × 100.

RESULTS AND DISCUSSION

Milk SCC and Milk Production

The SCC of the composite milk collected from the eight cows during the control period for each of the 4 d of cheese manufacture were 149,000, 40,000, 75,000, and 68,000 cells/ml; the mean was 83,000 cells/ml. The SCC of the composite milk collected from the eight cows during the treatment period for each of the 4 d of cheese manufacture were 1,187,000, 657,000, 985,000, and 661,000 cells/ml; the mean SCC were 872,500 cells/ml.

The least square means for the milk yield during the periods with low SCC (control) and high SCC (treatment) were 36.04 kg/d and 34.24 kg/d, representing a 5% decrease in milk yield. Values for the least square means were adjusted for stage of lactation, so the reported difference in milk yield was due to treatment. The difference in milk yield between the two periods was significant ($P < 0.05$).

Manufacture Time

The time from the addition of starter culture to the time the curd was cut at pH 4.6 was longer ($P < 0.05$) when milk had high SCC than when milk had low SCC; 275 ± 8 min versus 260 ± 3 min, respectively. The longer manufacturing time that is needed for cheese from milk with high SCC is consistent with the behavior of Cheddar cheese starter cultures (3). During the treatment period only, brown clumps of starter were observed floating on the surface of the milk during curd formation. The pH of these brown clumps was lower than the curd pH by about 0.3. However, no culture precipitation because of culture agglutination was observed on the bottom of the vat. Previous researchers (13) have reported starter culture agglutination in cottage cheese.

Chemical Composition

The pH of the skim milk with high SCC was higher ($P < 0.05$) than that of the skim milk with low SCC (Table 1), which is consistent with the results of a previous report (17). Percentages of TN and casein were higher for the high SCC skim milk (Table 1), but the casein as a percentage of either true protein or crude protein was lower for the milk with high SCC than the milk with low SCC, as reported previously (3, 17, 25). No difference in NPN, TS, and milk fat contents were detected between control and treatment skim milks. However, skim milk with the high SCC had a much lower estimated lactose content than did the milk with low SCC, even though the TS were almost identical. A lower lactose content of milk with high SCC has been reported previously (5, 10).

The percentages of protein and TS of the whey for the treatment period differed from the control period (Table 2). The whey from the curd made with high SCC milk was higher in protein but lower in TS percentage ($P < 0.05$). The protein and TS content of the three combined curd washes were higher in the treatment period. A much greater amount of fines was obvious during washing of the curd made from high SCC milk. In our pilot-scale cheese manufacture, most of these fines were recovered and added back to

TABLE 1. Composition of skim milk for periods with low milk SCC (control) or high milk SCC (treatment).

Skim milk	Control[1]	Treatment	LSD
	(%)		
pH	6.696[b]	6.751[a]	0.053
Protein (total N × 6.38)	3.265[b]	3.480[a]	0.072
Casein	2.466[b]	2.582[a]	0.083
NPN (× 6.38)	0.244	0.237	0.019
Casein, % of CP	75.534[a]	74.192[b]	1.113
Casein, % of true protein	81.646[a]	79.623[b]	1.030
TS	9.009	8.986	0.118
Milk fat	0.051	0.058	0.029
Ash[2]	0.722	0.742	NA[3]
Lactose[4]	4.977	4.707	NA

[a,b]Means within a row not sharing a common superscript differ ($P < 0.05$).

[1]For control and treatment, n = 4.

[2]Analyzed on one composite control sample and one composite treatment sample.

[3]Not applicable.

[4]Calculated by (mean TS – (mean total N + mean fat + ash)).

the curd. Loss of fines into the whey and wash water under conditions of commercial cheese manufacturing may be much larger than that loss in our study. The protein content of the uncreamed curd made with the high SCC milk was lower than from the uncreamed curd made with the low SCC milk because of the higher moisture percentages (i.e., lower solids) in the treatment curd (83.806% vs. 82.746%) and, possibly, the larger losses of protein during cheese making.

The fat content of the uncreamed curd was very low (as expected), and no significant differences between treatment and control were detected. Because of the low fat content of the skim milk, whey, and curd and the lack of significant differences, fat recovery data are not presented.

Recoveries and Yields

N recovery. The actual percentages of recoveries of N in whey, wash water, and curd are shown in Table 3. The sum of the actual recoveries for the control and treatment periods did not equal 100%, but no significant difference ($P > 0.05$) was detected in the total actual recovery of N between the control and treatment periods (15). Thus, the actual recoveries were adjusted by dividing the actual recovery in the whey, wash water, and curd by the mean actual total recovery on each making day. The means of the adjusted recoveries for each material allow a better comparison of data between studies when there are systematic low or high biases in total actual recovery between studies, but no significant difference were found in total actual recovery between treatments within a study. The adjusted recovery of N (i.e., protein) in the uncreamed curd was higher ($P < 0.05$) for the curd made from the low SCC milk than for curd made from the high SCC milk.

TS recovery. The actual percentages of recoveries of TS in whey, wash water, and curd are shown in Table 4. The sum of the actual recoveries for the control and treatment periods did not equal 100%. Because the total actual recoveries of total TS for the control and treatment periods did not differ ($P < 0.05$), the recoveries were adjusted as described for N. The proportion of solids lost in whey was significantly higher for the milk with low SCC, but that milk had a higher lactose content than did the milk with the high SCC (Table 1). The loss of TS in the wash water was higher for the milk with high SCC

TABLE 2. Composition of whey, wash water, and uncreamed curd from milk with low SCC (control) or high SCC (treatment).

	Control[1]	Treatment	LSD
	(%)		
Whey			
Protein (total N × 6.38)	0.888[b]	1.008[a]	0.020
TS	6.865[a]	6.760[b]	0.084
Fat	0.025	0.029	0.007
Wash water			
Protein (total N × 6.38)	0.080[b]	0.098[a]	0.018
TS	0.611[b]	0.689[a]	0.076
Fat	0.005[a]	0.002[b]	0.003
Uncreamed curd			
Protein (total N × 6.38)	15.558[a]	14.517[b]	1.002
TS	17.254[a]	16.194[b]	0.953
Fat	0.211	0.191	0.124

[a,b]Means within a row not sharing a common superscript differ ($P < 0.05$).

[1]For control and treatment, n = 4.

TABLE 3. Means and least significant differences of actual and adjusted recoveries for total N from milk with low SCC (control) or high SCC (treatment).

N Recovery	Control[1]	Treatment	LSD
	(%)		
Actual			
Whey	21.317	21.805	NA[2]
Wash water	3.259	3.928	NA
Curd	77.250	74.592	NA
Total	101.826	100.324	2.274
Adjusted			
Whey	21.202	21.570	0.802
Wash water	3.227	3.886	0.806
Curd	76.421[a]	73.807[b]	1.323
Total	100.850	99.263	

[a,b]Means within a row not sharing a common superscript differ ($P < 0.05$).

[1]For control and treatment, n = 4.

[2]Not applicable.

TABLE 4. Means and least significant differences of actual and adjusted recoveries for TS from milk with low SCC (control) or high SCC (treatment).

Solids recovery	Control[1]	Treatment	LSD
	(%)		
Actual			
Whey	59.856	56.717	NA[2]
Wash water	9.029	10.793	NA
Curd	31.117	32.295	NA
Total	100.002	99.805	0.578
Adjusted			
Whey	59.913[a]	56.772[b]	1.660
Wash water	9.038[b]	10.804[a]	1.306
Curd	31.147[b]	32.326[a]	0.929
Total	100.098	99.902	

[a,b]Means within a row not sharing a common superscript differ ($P < 0.05$).

[1]For control and treatment, n = 4.

[2]Not applicable.

than for the milk with low SCC. The proportion of TS that was present in the original skim milk recovered in the curd was significantly higher for the high SCC milk. This result is contrary to the significant difference in the recovery of protein (Table 3), and thus, the evaluation of yield efficiency for cottage cheese manufacture using only TS recovery can give misleading results if lactose contents of the milks used for cheese making differ.

Yields and efficiencies. The actual yield of the uncreamed curd from the milk with high SCC was higher than that from milk with low SCC (17.982% vs. 16.287%), but no significant difference was detected in moisture-adjusted yield of uncreamed curd (Table 5). The theoretical yield of uncreamed curd, calculated using the measured casein content of the skim milk, was also higher for the milk with high SCC. No significant difference in yield efficiency of the uncreamed curd was detected when the theoretical yield was based on the measured casein content of the skim milk.

To evaluate properly the impact of high milk SCC on yield efficiency, however, two important adjustments to yield must be made. The first adjustment is in the theoretical yield. The difference in casein as a percentage of true protein between the milks with high and low SCC was caused by the action of proteases associated with mastitis. Thus, the measured casein content of the milk with high SCC was obtained after partial casein hydrolysis, which underestimates what the theoretical yield would have been without mastitis. To correct for this underestimation, the theoretical yield was recalculated using an adjusted casein value in the equation for theoretical cheese yield for the milk with high SCC. The adjusted casein value was derived by multiplying the true protein content of the milk with high SCC by the value for casein as a percentage of true protein that was established for these cows during the control period. This adjustment was applied as described in prior work on Cheddar cheese (3). The theoretical yield for the uncreamed curd for the milk with high SCC increased from 15.101 to 15.484%, and yield efficiency decreased from 101.318 to 98.812% (Table 5).

The second adjustment to yield is necessary because of the difference in moisture content of the uncreamed curd between the control and treatment cheeses as well as their difference from the target

TABLE 5. Yields and efficiencies from milk with low SCC (control) or high SCC (treatment).

Yield and efficiency	Control[1]	Treatment	LSD
	(%)		
Basic			
Actual yield	16.287[b]	17.982[a]	1.092
Theoretical yield	14.421[b]	15.101[a]	0.486
Moisture-adjusted yield	14.779	15.302	0.615
Moisture-adjusted yield efficiency	102.496	101.318	2.743
Adjusted for control C/TP2			
Theoretical yield	14.421[b]	15.484[a]	0.403
Moisture-adjusted yield efficiency	102.493[a]	98.812[b]	3.137
Adjusted for control C/TP and solids in water phase of curd			
Moisture-adjusted yield	14.636	15.046	0.634
Moisture-adjusted yield efficiency	101.499[a]	97.161[b]	3.304

[a,b]Means within a row not sharing a common superscript differ ($P < 0.05$).

[1]For control and treatment, n = 4.

[2]C/TP = Casein as a percentage of total protein.

moisture in the theoretical yield formula. Calculation of the moisture-adjusted yield only cancels the difference in moisture content. Milk solids (primarily lactose and minerals) are dissolved in the moisture portion of the uncreamed curd. The treatment cheese had slightly more than 1% additional moisture than did the control cheese (Table 2). In addition, both treatment and control curds were higher in moisture than the 81% moisture target. Thus, the lactose and minerals contained in the extra moisture needed to be subtracted from the moisture-adjusted yield. To do this, dissolved solids contained in the moisture for both the control and the treatment cheese were subtracted from the original moisture-adjusted yield to bring them both to a 19% solids basis. The mean solids content of the water phase of the uncreamed curd in our study was approximately 1.81%. Thus, the moisture-adjusted yield (MAY), adjusted for solids in the water phase of the uncreamed curd, was calculated as follows

$$MAY = \frac{[(AY \times (TS\ curd/100)) - ((AY - MAY) \times 0.0181)]}{0.19}$$

where AY = the actual yield, 0.19 = target of 19% solids, and 0.0181 = mean solids concentration in the aqueous phase of the uncreamed curd in the present study. The 1.81% solids content of the liquid from the interior of the curd is similar to the value of 2.28% published previously by Emmons et al. (9).

The final yield efficiencies after both corrections were made are 101.499% for the low SCC milk and 97.161% for the high SCC milk, or a 4.34% lower ($P < 0.05$) cheese yield efficiency for the high SCC milk (Table 5). For an economic perspective, for every 45,000 kg of whole milk processed/d in a cottage cheese plant, the loss of revenue would be about $1066/d, assuming a 55:45 ratio of curd to cream dressing, a theoretical uncreamed curd yield of 14.5%, and a wholesale price of $2.30/kg of 4% fat creamed cottage cheese. This estimate of the decrease in cheese yield efficiency is conservative because the loss of fines during cheese manufacture under commercial conditions could be much larger than that occurring in our study.

Changes During Refrigerated Storage

At 28 d of storage, total plate counts were 1.05×10^4 and 2.93×10^4 cfu/ml for the creamed cottage cheese made from milk with low and high SCC, respectively. Coliform counts were <1.0/ml for both treatment and control. No difference in bitter and rancid off-flavors could be detected after 28 d of storage between creamed cottage cheese that was made from milk with low SCC or that was made from milk with high SCC. Variation in flavor scores among panelists was large, and, thus, the statistical power of the sensory analyses was relatively low.

The N that was soluble in 12% TCA and pH 4.6 acetate buffer was expressed as a percentage of TN in the creamed cottage cheese. As days of storage increased, the N that was soluble in 12% TCA for the creamed cottage cheese made from milk with the low SCC remained fairly stable but increased over time in the cottage cheese made from milk with high SCC

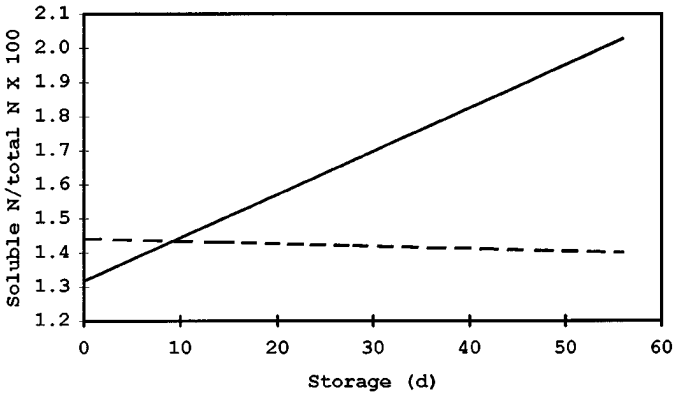

Figure 1. The effect of the duration of storage at 4°C on 12% TCA-soluble N content of creamed cottage cheese made from milk with low SCC (– – –) or high SCC (——). Slopes of the regression lines differ ($P < 0.05$).

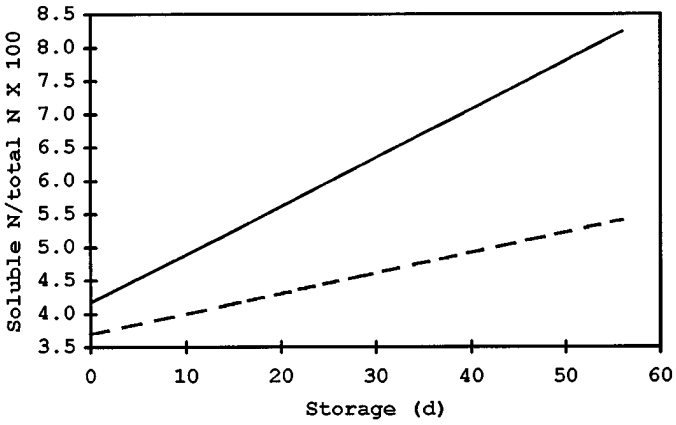

Figure 2. The effect of the duration of storage at 4°C on pH 4.6-soluble N content of creamed cottage cheese made from milk with low SCC (– – –) or high SCC (——). Slopes of the regression lines differ ($P < 0.05$).

(Figure 1). The N that was soluble at pH 4.6 increased over time for both the control and treatment cottage cheeses, but the rate of increase was greater for cottage cheese made during the treatment period (Figure 2). Proteolytic degradation of creamed cottage cheese as the duration of refrigerated storage (4°C) increased based on both pH 4.6-soluble N and 12% TCA-soluble N was faster ($P < 0.05$) for cheese made from milk with high SCC. This degradation may lead to flavor and texture defects.

CONCLUSIONS

An increase in SCC from 83,000 to 872,500 cells/ml influenced milk composition, cottage cheese composition, and cheese yield. The milk with high SCC was higher in protein, casein, and pH than was the milk with low SCC but lower in lactose and casein as a percentage of true protein. The TS in the skim milk was not influenced by SCC in our study. The uncreamed curd made from milk containing high SCC was higher in moisture but lower in total protein than was curd made from milk with low SCC. The enzymatic hydrolysis of protein during storage at 4°C was significantly faster in creamed cottage cheese made from milk with high SCC than from milk with low SCC.

Protein recovery was lower in the uncreamed curd made from milk with high SCC; in contrast, the recovery of TS was higher. The higher percentage of solids recovered in the uncreamed curd made from the milk with high SCC was caused by the lower lactose content of the skim milk. Thus, evaluation of cottage cheese yield, based on the recovery of TS in the curd alone, can give misleading results. After yield was adjusted for casein hydrolysis and for solids in the aqueous phase of the curd, cheese yield efficiency was significantly lower (101.5% vs. 97.16%), when cheese was made from milk with high SCC. This estimate may be conservative because loss of fines may be higher under conditions of commercial cheese manufacture.

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