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Cottage Cheese from Ultrafiltered Skimmilk by Direct Acidification

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COTTAGE CHEESE FROM ULTRAFILTERED SKIMMILK

BY DIRECT ACIDIFICATION

by

Jorge Ricardo Ocampo-Garcia

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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To my family

for brightening my life

Man should not be measured by

his technical knowledge

but by his understanding of human values

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J. Ocampo

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ABSTRACT

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Direct Acidification

by

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Pasteurized skimmilk at 4°C was acidified to pH 5.8 with 85.5% phosphoric acid (136g H_3PO_4/100 kg skimmilk), then warmed to 54°C and ultrafiltered to a protein concentration 9.1 ± 0.2%. The retentate was heated to 76.5°C for 16 s then cooled to 2°C. Phosphoric acid (85.5%) was added at a rate of 3.41g per kg retentate. The acidified retentate was slowly warmed to 29.5°C (3°C/5 min) when the pH was checked. The pH at this point was no lower than 5.4. Heating was continued until a temperature of 32.2°C was reached. Glucono delta lactone was added to the retentate (17.6 g/kg retentate) and left undisturbed for approximately 80 min. The curd was cut at pH 4.7 with 0.64 cm curd knives and allowed 10 min for syneresis. Permeate obtained from the same lot of milk was acidified to pH 4.8 (66 g H_3PO_4/100 kg permeate), then added to the curd at 32.2°C (three parts permeate to four parts retentate) and used as a cooking vehicle. The curd was cooked to 59°C in 90 min. The curd was held at 59°C for 10 min, drained and washed once with ice water. Cream dressing containing 12.5% fat and 3% salt was used at the rate of two parts curd to one part dressing.

Control cottage cheese was produced by a direct acid method from the same skimmilk used to produce ultrafiltered curd.

Use of ultrafiltered skimmilk retentate for cottage cheese making resulted in 2.24% more curd (corrected to 20% solids) and 2.24% more curd per kg original milk protein than the control. However, satisfactory firmness in UF curd required slightly more than 20% solids in the final product. Sensory evaluations indicated that creamed cottage cheese was not significantly different ($p < 0.05$) from control cheese, but was better than commercial cottage cheese samples selected from the local market.

(72 pages)

INTRODUCTION

The practical application of membrane ultrafiltration (UF) in the manufacture of different types of cheese was reported by Maubois and Mocquot (50).

Ultrafiltration of milk as part of the cheese making procedure continues to attract the attention of dairy researchers as well as the cheese industry. Ultrafiltration is now used in the manufacture of high moisture cheese varieties such as feta, camembert, and ricotta (50). Cottage cheese curd with 80% moisture should be a good candidate for using this process of concentration.

To be considered attractive for cottage cheese, the process must result in a product that is at least as acceptable as curd made by traditional processes. It also must provide some advantages over traditional processes with respect to increased yield and/or reduced cost of manufacture. Increased yield, vat efficiency and its potential application in continuous curd manufacture offer important possibilities for use of UF in cottage cheese making. Several applications of membrane processes for cheese making are found in the literature. In contrast, very little information is available on skimmilk retentate used for cottage cheese manufacture.

Matthews, et al. (49) manufactured cottage cheese from retentate and suggested that a concentration ratio for skimmilk of 1:2 (6.2% protein) was the apparent upper limit for obtaining a good quality product. They improved vat efficiency, but did not show any increased yield (49).

Studies with retentates (15% protein) by Covacevich and

Kosikowski (14) have shown the possibility of making ultrafiltered curd into whipped cream cottage cheese with improved color and appearance.

Possible yield increases of 12.4 and 15.3 from 16% total solids (TS) retentate (9.3% protein) from cultured and direct acid cottage cheese respectively, were reported by Narasimhan (58).

Raynes (65) found that cottage cheese curds made from three-fold concentration (9.2% protein) retentates were not easy to cut with 0.64 centimeter or quarter-inch curd knives. Also after dressing was added, the texture became soft, pasty and sticky. These resulted in a gradual translucence during storage.

Texture and cream absorption by curd appear to be the principal problems in making cottage cheese from skimmilk retentates (14,49,58). Further success in making cottage cheese from skimmilk retentates depends upon solving problems of cooking curds and developing proper texture and cream absorption, (14). Covacevich and Kosikowski (14) reported consistently less whiteness, less acceptable appearance and tougher texture than conventional commercial cottage cheese when skimmilk retentate was used.

The purpose of this study was to develop a procedure for the manufacture of cottage cheese by direct acidification from preacidified, ultrafiltered skimmilk retentate (three-fold concentration), then compare the yield and quality of product with that of conventional cottage cheese.

LITERATURE REVIEW

Cottage cheese is the soft, uncured cheese prepared by mixing cottage cheese dry curd with a creaming mixture. The milk fat content is no less than 4% by weight of the finished food (11).

Lowfat cottage cheese is the food prepared from the same ingredients and in the same manner as prescribed for cottage cheese. Its content of milkfat is not less than 0.5% and not more than 2% by weight. Its moisture content is not more than 82.5% (11).

Cottage cheese is conventionally made from skimmilk by the addition of starter culture and small amounts of rennet. However, the use of starter cultures for acid production may involve difficulties such as agglutination of starter bacteria, lack of product uniformity, slow acid production, etc. (23). To eliminate these problems, direct acidification has been approved as an alternative (23).

Ultrafiltration is a process by which small molecules are separated from large molecules by passing a solution under pressure through a designated molecular weight cut-off membrane (30). Recently ultrafiltration has been applied to dairy products for concentration of whey protein, skimmilk protein, and as a first step in cheese making (51,30,60).

Advantages of Membrane Ultrafiltration

One of the main advantages of ultrafiltration of milk for cheese making is increased cheese yield. This increase is due to improved retention of proteins and fat in the cheese (49).

This process also results in increased production per vat of retentate which increases plant capacity with the same cheese making equipment. Ultrafiltration units occupy less floor space than cheese vats. This provides a substantial economy in investment for construction. Also, ultrafiltration equipment can be controlled automatically and offers potential application in continuous processes. Reduction in labor costs can be expected (49,32). Reduction in cost of 20% was reported when ultrafiltration was used for making feta cheese in comparison with conventional techniques (81). Chambers and Marks (9) reported that cottage cheese from ultrafiltration can reduce energy usage by 1614 Btu/kg of product when compared with standard techniques. Ultrafiltration on the dairy farm offers the ability to use permeate for animal feed, requires less holding tank capacity, uses less energy to keep the retentate refrigerated and reduces the cost of shipping retentates to cheese plants (91).

The economy of ultrafiltration is based, among other things, upon much lower rennet consumption than in conventional processes (39). Rennet requirements are inversely proportional to the degree of concentration and to the protein content of the milk. Rennet levels can be adjusted in order to maintain the usual clotting time (77). Hence, ultrafiltration may save up to 80% of rennet needed for making cheese.

Lack of uniformity in milk supply can be solved by using ultrafiltration. Standardizing the protein content in milk without detectable organoleptic consequence is one solution proposed by Poulsen (63).

The concentration of milk without chemical damage and flavor changes caused by heating can be another advantage of UF in the dairy industry (30).

Pollution of cheese factory effluent is reduced due to less protein in permeate than in whey, hence there is a lower biological oxygen demand (30,48).

Cottage Cheese Making with Starter

Manufacture of cottage cheese with starter organisms involves the use of mixed strain acid-producers like Streptococcus lactis and Streptococcus cremoris and a flavor-producer, Leuconostoc citrovorum. Bulk starter is prepared by heating skimmilk to 91°C for 30 to 60 min, cooling to 21°C, then innoculating with 1% stock starter culture. The innoculated skimmilk is incubated at 21°C (23,70) until the pH is 4.6-4.8 and then refrigerated.

Different combinations of time, temperature and percent culture innoculum are used for cottage cheese manufacture. There is a short set method in which skimmilk is innoculated with 5% culture and allowed to set for 4-6 h at 32°C. The long set method requires 12-16 h at 22°C with 1 to 2% innoculum. Each yields an equally high quality cheese curd and the selection of the method depends on the schedule of personnel in the plant (5,23,70). After cutting the curd, the cooking procedure is essentially the same for each method. The whey is drained and the curd washed to remove excess acid and lactose, and finally creamed (23).

The successful manufacture of cottage cheese with starter organisms depends on the activity of the bacteria culture (5,23). Lactic cultures are the source of most problems associated with the traditional method (5,21,45,71). Some strains can agglutinate and precipitate out of skimmilk, causing sedimentation on the bottom of the vat and slow acid production (23). Agglutination of starter bacteria also results in a shattered and mealy curd. Lack of product uniformity due to variation in behavior of cultures also results (24). Proteolytic activity of some strains of starter bacteria affect the curd strength of cottage cheese and titratable acidity of whey (23,34). When improper combinations of lactic cultures with aroma bacteria are used, floating of curd and excessive foaming can occur during cooking (71). Lactic cultures can be inhibited by antibiotics and bacteriophage (23,45), reducing the production of acid. Growth of contaminating organisms during long setting periods may produce bitter flavors in the cheese. These problems make the traditional method difficult to control and to standardize.

Cottage Cheese Making without Starter

Chemical Acidification

A number of workers (19,25,53,80,85) have produced cheese by chemical acidification. Three approaches have been used.

i) Direct addition of acid

ii) Acidification by ester hydrolysis

iii) Combination of direct acid and ester hydrolysis for acid production.

Direct Addition of Acid

Ernstrom (24) found that milk at refrigeration temperatures could be acidified to the isoelectric point of casein without causing coagulation. He used hydrochloric acid because it was very inexpensive. Little (43) patented a process for cottage cheese production by coagulation of cold acidified milk with the addition of large amounts of rennet (10 to 66 ml/454 kg). Several patents were obtained (42,84,86,87) but the process had limited commercial application. One reason was, at that time, Federal laws did not permit the use of chemical acidulents in cheese making, and lower quality body and texture was found when compared with traditionally-produced cheese. However, Born and Muck (8) reported that consumer acceptance of cottage cheese made by direct acidification was not significantly lower than traditionally-produced cheese.

Hydrolysis of Acid Anhydrides

The selection of compounds which hydrolyze slowly to produce acids was investigated by Deane and Hammond (17). Glucono delta lactone (GDL) and meso-lactide were allowed to hydrolyze to their corresponding acids in undisturbed skimmilk for the production of cottage cheese. The curd obtained with this method was smooth, uniform and very similar to that produced by starter culture (17). However, the use of these anhydrides was limited by their high cost and the time required for hydrolysis.

Combination of Direct Acid and Anhydride Hydrolysis

The use of liquid acids and acid anhydrides was used early for the production of Cheddar type cheese (46). Loter and Schafer (44) and Corbin (13) both patented a similar method in which phosphoric acid and glucono delta lactone were used for acidification of skimmilk in the production of cottage cheese. This process came to be the Vitex/American Direct set method (19). At present this method is used in several cheese plants with successful results (2,3,19,74). Actually about 30% of the cottage cheese in the United States is made using this method (Michael Gerson, Carlin Foods, St. Louis, Mo. Personal Communication, 1986).

Advantages of Direct Acidification

A major benefit of the direct acid process is the reduction in process time (27). Other benefits include more efficient equipment utilization, improved cheese consistency, improved process control and production rates, and the elimination of problems associated with culture growth (28). The yields obtained by this method are significantly higher than those obtained by culture methods (29,80). Geilman (27) showed that yield increases were due to better protein recovery. However there is some disagreement (89). Satterness (73) did not find any significant difference in yield between the two processes. Some differences in manufacturing procedure and differences in the method of calculating yield may have contributed to different conclusions between the two methods of acidification (27). The differences could have resulted from 1) exclusion of weight of acidifying agents as part of milk solids, 2) use of cold skimmilk to disperse GDL instead of cold water, 3) differences in moisture adjustment of the two curds. Reduced yield in cultured cottage cheese may have been due to bacterial proteinase activity and to changes in the proportion of Prt+ vs Prt- cells during culture maintenance (67).

Disadvantages of Direct Acidification

Texture and body of direct acidification (DA) cottage cheese have sometimes been found inferior to traditional cottage cheese (25,73,85,89). However, quality of direct acid cottage cheese is not significantly different from traditional cultured cheese (8,27). Prices of ingredients per kilogram of cheese for DA were higher than costs of traditional culture methods of acidification. Nutritional quality has been considered. McDonough and Alford (52) found no significant difference between protein efficiency ratio (PER) of DA versus traditional cottage cheese, although the vitamin content was slightly higher. Other workers (69,82) found no significant differences in calcium, magnesium, phosphorous and iron retention between the two types of cheese.

Heat Treatment of Skimmilk

Increasing cottage cheese yields by heating skimmilk to temperatures where whey proteins are denatured and included in the curd, has attracted the attention of the dairy industry. Normal pasteurization temperatures for skimmilk are 61.7 to 62.8°C for 30 min or 71.7 to 72.2°C for 15 s (23). At higher temperatures (80°C) denaturation of whey proteins occurs (33). Excessive heating of skimmilk results in a soft curd that breaks when cut, and does not reach the desired firmness when cooked. Serum protein denaturation greater than 10% with heat treated skimmilk is not satisfactory for cottage cheese manufacture (57). β -lactoglobulin is the most abundant whey protein. During heat treatment β -lactoglobulin denatures above 80°C, due to disulfide interchanges. Destabilization of the residual protein structure occurs near 140°C (88). The rate of heat denaturation depends on pH. β -lactoglobulin is most stable in pH range of 5.0 to 7.0 with a maximum at pH 6.0. It is most sensitive to heat at pH 4.0 (18). At high temperatures, β -lactoglobulin and k-casein interact with each other resulting in loss of solubility (76). α -lactalbumin is the smallest and most heat-resistant whey protein. The cysteine residues are mainly responsible for its stability (18). However during heat treatment α-lactalbumin and β -lactoglobulin interact and form a complex with k-casein. Some α-lactalbumin and β -lactoglobulin will pass through the ultrafiltration (UF) membrane during concentration (6,61). Heat treatment may decrease these losses.

Heating skimmilk to 79.4°C for 30 min results in 10% greater curd yield than when heating is limited to pasteurization. This is due to heat denaturation of the whey protein and its inclusion in the curd. However, the finished product is usually mealy. Also the pH of the cheese is higher than normal because the pH at the acid coagulation (AC) endpoint (5.2) (best pH to cut cottage cheese curd) is higher than the AC endpoint in unheated milk (22).

White and Ray (89) reported the manufacture of cottage cheese by continuous fermentation using different heat treatments (73.8°C/17 s; 100°C/7.9 s; 120°C/7.9 s; 135°C/3.9 s) of skimmilk. Increasing heat treatments resulted in high moisture in the curd and long cooking times. Low temperatures (73.8°C and 100°C) gave the best body and texture scores. At constant moisture levels, the two lower temperatures showed slightly greater cheese yields. However pasteurizing the skimmilk at 100°C for 7.9 s resulted in the best yield.

Heat Treatment of Retentate

The effect of heat on concentrated skimmilk for cottage cheese making was studied by Emmons et al. (22). Pasteurized (60°C/30 min) skimmilk was divided into four lots and concentrated to 47.6, 43.5, 43.9 and 40.1% total solids (TS). Each concentrated lot was divided into five portions; one portion was used as a control and the other four portions heated to 54.4, 60, 65.6 or 71.1°C for 15 min, cooled and diluted to 8.8% TS, for cottage cheese manufacture. They did not observe any significant difference in the amount of undenatured whey proteins. However they reported that the control had the best curd quality. Heating the concentrated skimmilk to 71.1°C for 15 min had a deleterious effect on curd quality (mealy and soft) (22). Increasing TS generally limits the effect of heat on the rate of protein denaturation (37). Increase in ionic strength and low pH decreases β -lactoglobulin denaturation in skimmilk concentrate (92). Green et al. (31) observed that when skimmilk was acidified to pH 6.0 before ultrafiltration (1 to 4x) it gelled under all heat treatment conditions used (100°C and 119°C for 15 min and 140°C for 4 s). However, they established that less denaturation of whey proteins occurs when the milk is concentrated (31). Birkkjaer, (7) suggested that heating retentate to 77°C for 1 min can reduce bacterial counts and improve the body and texture of cheese. The use of higher temperatures (90°C - 95°C) reduces cheese quality. Maubois and Mocquot (50) observed the restoration of curd-forming ability in ultra-high temperature (UHT) milk concentrated by ultrafiltration. Similar results are obtained when retentate prepared by UF of normal milk is treated by UHT (50). Shammet (79) reported that 76.7°C for 16 s was the best heat treatment for preacidified retentate (38% TS) pH 6.0, to make white soft cheese (Middle Eastern type). Extending the heating time of retentates increased mealiness of the finished product. This does not support Anis and Ernstrom (1) who stated that heating retentates (40% TS) at 82.2°C for 30 min improved the texture and the body of Domiati cheese.

Cottage Cheese from Ultrafiltered Skimmilk

Maubois and Mocquot (51) used skimmilk retentate (27% TS) in combination with cream and obtained a product with the same composition as a soft cheese. Matthews et al. (49) used retentate (6.4% protein) from skimmilk to make cottage cheese. They found no difficulty in curd formation; however, they observed slow acid production which was attributed to lactic starter culture. After cutting, agitation was difficult to initiate without matting the curd. Flavor and texture scores were not significantly different from the control. Total solids in the curd were 21-23%. When yields were adjusted to 20% TS, yield increases of 3.07, 4.87 and 5.86% greater than control were obtained. They concluded that yield improvement per vat was the major advantage (50% increase). The extent of UF was limited by the amount of curd that could be handled in the vat without matting during cooking. In this study, whey proteins were expelled from the curd during cooking resulting in potential yield losses (49).

Covacevich and Kosikowski (14) produced cottage cheese from fermented retentates (15% protein). Yields were 7.8 and 2.3% higher than conventional cottage cheese (control). The experimental cheese curd had a lighter color, gelatinous appearance and absorbed cream poorly. These defects were attributed to high pH. By making ultrafiltrated curds into whipped cream, cottage cheese color and appearance improved. Proper texture and cream absorption need to be improved before making cottage cheese from high protein retentates (5x).

Narasimhan (58) reported increased yields over cultured cottage cheese (control) made from skimmilk when retentate contained 16 and 20% T.S. The yields were 12.4, 15.3, 5.6, and 1.6% for 16% cultured, 16% direct acid, 20% cultured and 20% direct acid cottage cheese respectively. This was attributed to entrapment of whey proteins in the curd and reduced syneresis of whey. Lower yield increases from 20% retentates were due to shattering of curd during cooking, and the diffusion of the whey proteins (58). Cultured cottage cheese from retentates was as good as that obtained from skimmilk. Direct acid cottage cheese was significantly lower in quality. Problems with lactic culture growth in retentate and the use of nonconventional cooking methods must be solved to obtain maximum benefit from UF.

Raynes (65) found that cottage cheese curds made from heat-treated retentates were not easy to cut with 0.64 cm knives. The cheese had a good texture and body, however a gradual translucency developed in the curd during storage. The texture became soft and pasty and the UF curd absorbed all the dressing causing a sticky appearance.

Recently Kealey and Kosikowski (38) used retentate to supplement skimmilk to produce industrial cottage cheese of comparable quality to cheese made from unsupplemented control skimmilk.

Lactic Fermentation of Ultrafiltered Skimmilk

Many workers have observed the adverse effect on lactic cultures when concentrated skimmilk and retentates are used as growth media (40,41,49,58). Cox (16) studied the growth of *S. Lactis*, *S. diacetylactis*, and *S. cremoris* strains in concentrated milk and found that growth of all strains was inhibited when TS exceeded 36% (12.96% protein). Pulay and Krasz (64) observed an increase in acid production by mixed starter cultures when total solids were increased from 28 to 32% (10.08 to 11.52% protein), but decreased above that level. Collins (12) intended to make cottage cheese from skimmilk fortified to 12, 15 and 18% TS (4.32, 5.40, and

6.38% protein) with nonfat dry milk. In skimmilk containing 15 and 18% TS, the pH decreased very slowly after 5.0 when 6% culture was used. pH changes are slower when retentate is used rather than normal milk. Longer incubation periods are required (15,55). As a consequence, retentates demand more starter bacteria for lactic acid production and more time during cheese manufacturing (35,54). Hickey et al. (35) used retentate (5x) and observed an increased concentration of lactic acid with minimum change in pH. Apparently UF caused stimulation of growth and acid production above their normal levels in a milk substrate. Buffer capacity is due to protein concentration, insoluble calcium and phosphate salts. Large amounts of acid are required to lower the pH in retentates (54). When milk is concentrated to 5x, its buffer capacity is seven times higher than normal milk (54). Mistry and Kosikowski (56) measured pH change during fermentation of UF retentate with lactic cultures. The pH resisted change below pH 5.2. Even after 8.5 h the pH did not reach 4.6 while control required 6 h.

Narasimhan and Ernstrom (59) also reported slow acid production when retentate was used in cottage cheese manufacture. They attributed the problem to the high concentration of colloidal calcium phosphate (90). Addition of phosphate to skimmilk slows lactic cultures, and the removal of phosphate from retentates enhanced acid production. Soluble phosphates were major factors in inhibiting acid production by lactic cultures. This explains the inhibition encountered below pH 5.0 when colloidal calcium phosphate is solubilized.

Recently Pope (62) stimulated Streptococcus cremoris UC310 by adding 0.02% yeast extract to 5x retentate and reduced the time to reach pH 5.1 from 24 to 10 h. In addition, he observed that preacidification of milk to pH 5.8 prior to ultrafiltration reduced the demand for high acid production by cultures during cheese making.

MATERIALS AND METHODS

Skimmilk

Raw whole milk was obtained from Utah State University Dairy Farm. This milk was separated and the skimmilk pasteurized at 63°C for 30 min and divided into two lots. One lot was ultrafiltered to 9.1 ± 0.2% protein and made into cottage cheese. The other was made directly into cottage cheese. Both lots were stored at 2°C until used.

Manufacture of Cottage Cheese (control)

Skimmilk at 2°C was acidified with phosphoric acid (Vitex 750) to pH 5.5 following the Vitex Direct set method (19). The factor (0.00893308)(kilograms of skimmilk) was used to determine total kilograms of acid to add. The phosphoric acid was diluted five times with water. The acidified skimmilk was slowly stirred and warmed (3°C/5 min) to 32.2°C.

Rennet and glucono delta lactone were calculated using the following factors (19):

kilograms of GDL (powder) = (kilograms of skim milk) x (0.011525462)

milliliters of rennet = (kilograms of skim milk)(0.00639)

Rennet and GDL were diluted five times with ice water and added to the acidified skimmilk, agitated for no more than 5 min and allowed to stand at 32.2°C for exactly one hour before the curd was cut with 0.64 cm curd knives. The curd and whey were gently stirred while heating to a temperature of 54.5°C over a period of 1 h 30 min or until a desired firmness was reached. The whey was drained and the curd washed with an equal amount of ice water as the whey drained, agitated for about 5 min and drained.

Cream dressing containing 12.5% fat and 3% salt was prepared according to Manus (47) and used at the rate of two parts curd to one part dressing.

Manufacture of Cottage Cheese from Ultrafiltered Skimmilk

Manufacture Procedure

The manufacture of cottage cheese from ultrafiltered skimmilk is shown in Figure 1. Skimmilk was acidified to pH 5.8 prior to ultrafiltration with 85.5% phosphoric acid (136 g H_3PO_4/100 kg skimmilk). Acidification was at 4°C to prevent localized coagulation of protein.

Ultrafiltration was by a batch method using an Abcor HFK-130 single stage, spiral wound, polysulfone membrane with a molecular weight cut-off of 10,000 daltons with 5 m^2 of filtering surface (Figure 2). A balance tank and centrifugal pump were used for recirculation. An inlet pressure of 420 kPa (60 psi) and outlet pressure of 280 kPa (40 psi) were used throughout the process.

Protein content in the retentate was adjusted to 9.1 ± 0.2% by adding permeate from the same lot of milk.

Membranes were cleaned as follows: water rinse; alkaline wash (NaOH, pH = 11.5) and chlorine (300 ml/80 lt of water) for 30 min; water rinse; acid wash (HNO_3, pH = 1.5) for 30 min; water

Figure 1. Manufacture of cottage cheese from ultrafiltered skimmilk by direct acidification.

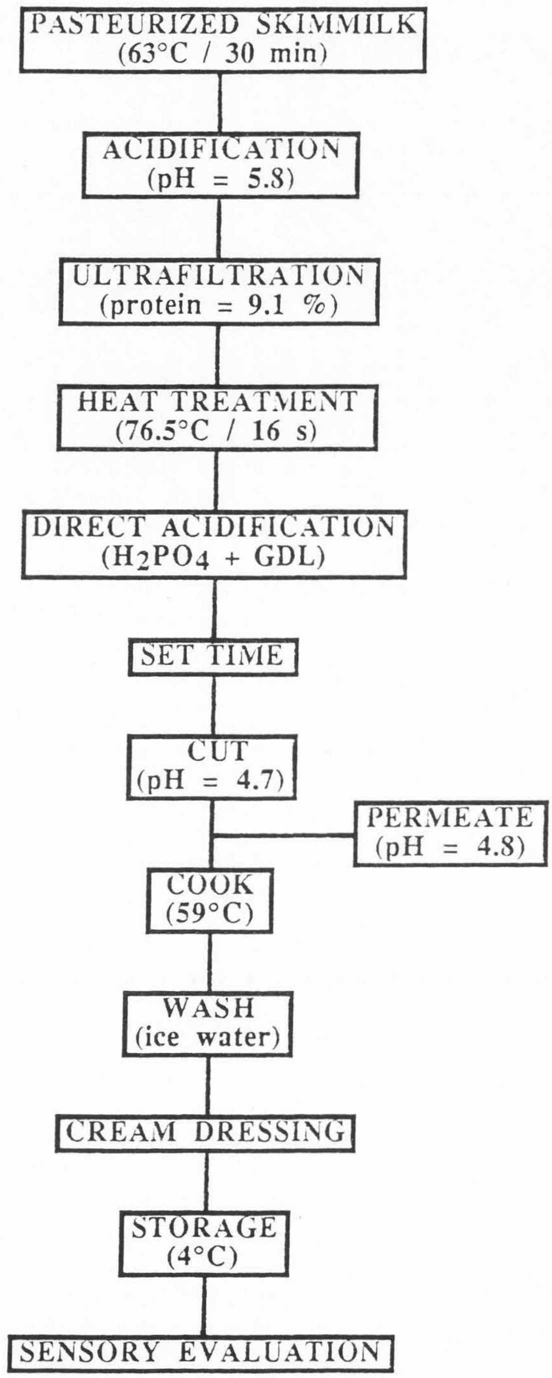
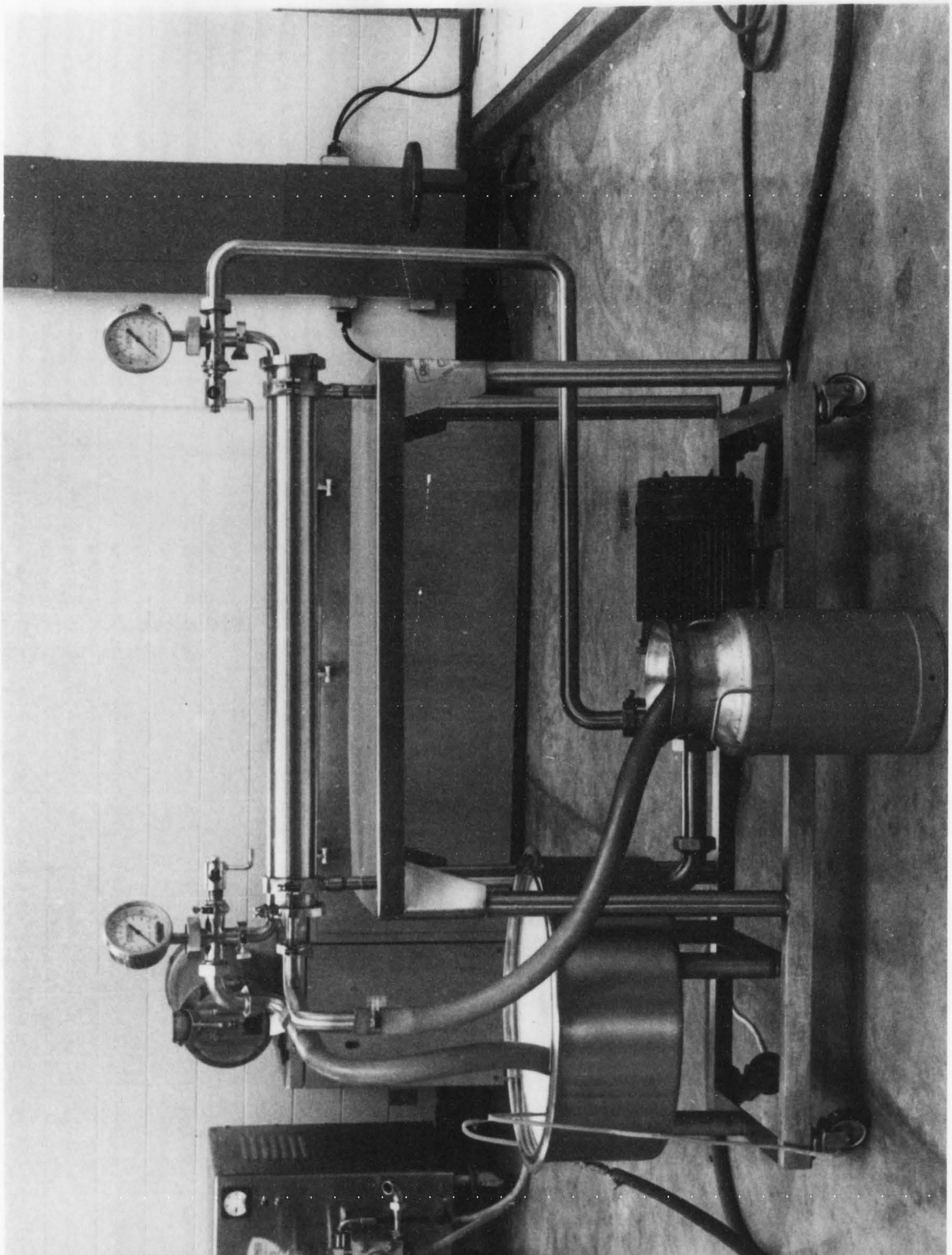

PASTEURIZED SKIMMILK
(63°C / 30 min)
ACIDIFICATION
(pH = 5.8)
ULTRAFILTRATION
(protein = 9.1 %)
HEAT TREATMENT
(76.5°C / 16 s)
DIRECT ACIDIFICATION
(H_2PO_4 + GDL)
SET TIME
CUT
(pH = 4.7)
PERMEATE
(pH = 4.8)
COOK
(59°C)
WASH
(ice water)
CREAM DRESSING
STORAGE
(4°C)
SENSORY EVALUATION

Figure 2. Ultrafiltration unit



rinse. Equipment was sanitized immediately before use with water containing 200 ppm chlorine. Deionized water at 54.5°C was used for washing and sanitizing the ultrafiltration membrane.

Heat Treatment of Retentate

A series of preliminary experiments were performed to study the effect of heat treatment of retentate on firmness of curd at cutting, and texture and body of the final product.

A high temperature, short time, plate heat exchanger (Pasilac Therm A/S KD 6000 Kolding, Denmark) consisting of a regeneration unit and heating section heated by circulating hot water from a water bath controlled by a steam thermo device, was used.

Retentate was heated at 65, 72.5, 78.5 and 80°C for 16 s and used for cottage cheese manufacture. Curd from the 65 and 72.5°C treatment was too tough to cut with knives. Curd from the 78.5 to 80°C treatment was too weak and soft. The temperature which resulted in the best cutting curd was 76.5 for 16 s.

Cheese Making Procedure

Retentate was acidified at 2°C with 85.5% phosphoric acid (341 g per H_3PO_4/100 kg retentate) diluted five times with water and stirred continuously for 5 min. The acidified retentate was slowly warmed to 29.5°C (3°C/5 min). The pH at this point was no lower than 5.4. This was necessary to prevent precipitation of casein. Heating was continued until a temperature of 32.2°C was reached. Glucono delta lactone was diluted five times with ice water and added to the retentate (1.76 kg/100 kg retentate), stirred for no more than 5 min and left undisturbed for approximately 80 min. The curd was cut at pH 4.7 with 0.64 cm curd knives and allowed to syneresis for 10 min. Permeate (32.2°C) obtained from the same lot of milk was acidified to pH 4.7 (66 g H_3PO_4/100 kg permeate), then added to the curd (three parts permeate to four parts retentate), as a cooking vehicle. The curd was cooked to 59°C in one hour 50 min according to Table 1.

Table 1. Cooking rate during cottage cheese manufacture

Time	Temperature (°C)	Increase (°C/5 min)
0:00 - 0:30	32.2 - 35.5	0.5
0:30 - 1:00	35.5 - 42.2	1.1
1:00 - 1:50	42.2 - 59.0	1.6

The curd was held at 59°C for 10 min then drained and washed once with an amount of ice water equal to the whey drained.

The dressing was prepared and added to the curd as described for the control.

Creamed cottage cheese from UF skimmilk and control were packaged in 0.5 kg containers and stored at 4°C for one week before compositional analysis and sensory evaluation.

Composition Analysis

Moisture

Moisture was determined on 2.5 to 3.0 g of skimmilk or permeate, or 2.0 to 2.5 g of retentate or curd. Samples were weighed in an aluminum pan, evaporated on a steam bath, and dried for three hours at 100 ± 2°C in a forced draft oven (Thelco model 28 - GCA Precision Scientific) (66). All samples were cooled in a glass desiccator prior to final weighing. Moisture determinations were in triplicate.

Samples revealing discrepancies were repeated until close agreement was achieved.

Fat

Fat was determined by the Mojonnier modification of the Roese-Gottlieb method (26) using samples of approximately 10 g for milk and permeate and 2.5 g for retentate and cheese.

Method of homogenizing samples before weighing depended upon sample consistency. Skimmilk and permeate samples were warmed and mixed in plastic bags. Retentate samples were warmed and mixed with a spatula. Cheese samples were chopped and mixed with a blender.

Protein

Nitrogen was estimated by semi-micro Kjeldahl procedure (36) using automatic Kjeltec equipment (Kjeltec Auto 1030 Analyzer, Tecator, Inc.). Determinations were in triplicate and protein content was calculated by multiplying the nitrogen content of the sample by 6.38. Non-casein nitrogen determinations were by the procedure of Rowland (68) with some modification. Filtration was with Whatman No. 4 filter paper followed by Gelman 0.2 millipore filter paper to ensure that the filtrate was totally devoid of precipitated casein. Casein nitrogen was calculated as the difference between total nitrogen and non-casein nitrogen. Whey protein nitrogen was determined as the difference between total nitrogen and the nitrogen from casein and non-protein nitrogen.

Lactose

Lactose was estimated by Shaffer-Somogyi method (78) using 2 g samples and expressed as percent anhydrous lactose.

Calcium

Calcium was determined by atomic absorption (AA) spectrometry using a AA model 457 AA/AE spectrophotometer (Instrumentation Laboratory Inc.) (4).

Samples were digested by wet ashing (10). Ten milliliters concentrated nitric acid (16 M) was added to 1 g of all samples and digested for 48 h at 100°C or until a clear pale yellow solution was obtained.

Salts were dissolved in distilled, deionized water and made to 50 ml. The samples were diluted with 1000 ppm lanthanum oxide solution to bring the calcium concentration into the linear range of the spectrophotometer and reduce AA interference (75).

pH

pH values of skimmilk were determined before and after acidification, and at the time of UF. pH of retentate, permeate and cheese were also determined. A glass electrode and potentiometer

(Model 811, Orion Research, Cambridge, MA 02139) were used for pH measurements.

Sensory Evaluation

Cottage cheese from retentate, control and three selected commercial brands (one directly set and two cultured) were evaluated by a trained panel of four judges after one week of storage. The judges evaluated the finished product for flavor, appearance/color, body/texture and overall, using a grading scale of 1 = poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent.

Statistical Analysis

The taste panel parameters were analyzed by repeated measurement design with blocking across time to determine sources of variation (72). Treatment means were compared by the Least Significant Difference (LSD) method (20,83) for those treatments which had significant F-ratios.

RESULTS AND DISCUSSION

Manufacture of Cottage Cheese

The most frequent problem encountered during the manufacture of cottage cheese from 3x retentate (9.2% protein) is the formation of a very tough curd at pH 4.7. The curd was not cuttable with conventional curd knives. This problem was reduced by heat treatment of the retentate prior to cheese making. The heat treatment was very critical because too much heat destroyed curd formation and resulted in excessive loss of fines. Too little heat left the curd too tough to cut. A heat treatment of 76.5°C for 16 seconds was found to be most suitable. Variations of as much as 2°C either way caused problems. Use of rennet made the curd even more tough to cut. Acidification of the skimmilk to pH 5.8 prior to ultrafiltration corrected the problem of translucent and sticky curd after addition of cream dressing (R. Raynes, Utah State University, Personal Communication, 1984) and helped in the production of good quality cottage cheese curd from retentate.

The adjustment of retentate by protein instead of TS helped to control closely the amount of phosphoric acid and GDL that was used with this method and, consequently, setting time of the retentate and the final cook temperature were similar when different skimmilk was used.

Acidification with phosphoric acid to a pH lower than 5.4 resulted in protein precipitation. Hence decreased curd strength increased amount of fines during cooking and a soft texture was observed in the final product.

The final curd was smooth and firm during cutting. Hence it was difficult to cut curd with conventional curd knives. In this study, cooking of the curd to temperatures in the range of 58.5 to 59.5 was critical in order to achieve the desired final texture of cottage cheese. Curds cooked to a final cook temperature below 58.5°C were judged too soft and weak; curds cooked to temperatures over 59.5°C were found to be too firm and mealy.

Composition Analysis

The composition of skimmilk used in this study is shown in Table 2. Total solids varied from 8.62 to 9.0%, protein from 3.16 to 3.27%, fat from 0.15 to 0.76%, lactose from 4.48 to 4.62% and calcium from 0.129 to 0.130%.

Mean composition of uncreamed cottage cheese is shown in Table 3. Uncreamed cottage cheese made from UF retentate was lower in moisture than the corresponding control curd in all three trials. This reflected the fact that it was necessary to cook the UF curd to 59°C in order to obtain satisfactory firmness, while the control curd was satisfactorily cooked at 57.2°C. Some preliminary experiments indicated that if cooked to less than 59°C, UF curd was still less than 80% moisture and lacked the desired meatiness of good curd. As a result of this moisture difference the percent protein in the UF curd was higher than in the control.

When all the curd was corrected to 80% moisture as shown in Table 4, there was no significant difference in protein between the

Table 2. Composition of skimmilk

		Trial I	Trial II	Trial III
%				
Total solids	AV	9.00	8.72	8.62
	SD	0.008	0.02	0.04
Protein	AV	3.27	3.25	3.16
	SD	0.02	0.03	0.01
Fat	AV	0.76	0.15	0.26
	SD	0.009	0.009	0.008
Lactose	AV	4.48	4.62	4.58
	SD	0.05	0.02	0.04
Calcium	AV	0.129	0.131	0.130
	SD	0.0001	0.002	0.004

AV = Average

SD = Standard Deviation

Table 3. Mean composition of uncreamed cottage cheese

%		Control	UF	LSD
Moisture	AV	78.93	76.98	N.S.
	SD	0.87	0.29	
Protein	AV	17.22	19.04	1.10
	SD	0.60	0.22	
Fat	AV	1.19	1.13	N.S.
	SD	0.18	0.11	
Lactose	AV	1.29	1.58	N.S.
	SD	0.11	0.35	
Calcium	AV	0.048	0.087	0.01
	SD	0.007	0.005	
Whey protein	AV	0.5755	0.6687	N.S.
	SD	0.035	0.006	

AV = Average
SD = Standard Deviation

Table 4. Mean composition of uncreamed cottage cheese (adjusted to 80% moisture)

%		Control	UF	LSD
Moisture	AV	80.00	80.00	-
Protein	AV	16.99	18.15	N.S.
	SD	0.42	0.13	
Fat	AV	1.17	1.09	N.S.
	SD	0.17	0.11	
Lactose	AV	1.27	1.52	N.S.
	SD	0.12	0.33	
Calcium	AV	0.048	0.084	0.040
	SD	0.006	0.005	
Whey protein	AV	0.546	0.594	N.S.
	SD	0.028	0.017	

AV = Average

SD = Standard Deviation

UF and regular curd. Calcium content was significantly higher ($p < 0.2$) than in control. Matthews et al. (49) reported higher concentration of calcium in uncreamed UF cottage cheese (2x) than regular cheese. He attributed it to less solubility of ionic calcium at higher temperature (49°C) which resulted in association with colloidal milk proteins. However, protein, fat, whey protein and lactose in both UF and control cheese were not significantly different ($p < 0.05$).

The composition of both creamed UF and control cottage cheese (Table 5) met U.S. legal standards of identity (11).

Cottage Cheese Yield

Since it was impossible to recover all the retentate from the small batch ultrafiltration unit, it was necessary to determine the amount of available retentate by using protein as a reference constituent. Protein in the original milk minus the protein in the permeate and permeate rinse water represented the protein in the retentate. By testing the protein content of the retentate, it was possible to compute the amount of retentate that should result from the UF process. The results of three trials are illustrated in Table 6.

Because of the difficulty of getting good UF curd with 20% TS, it was necessary to adjust actual yields to a constant total solids of 20% for adequate yield comparison. Actual and adjusted yields are shown in Table 6. Actual yields of UF cheese were 0.7, 7.8, and 10.4% less than the control, while curd adjusted to 80% was 1.71,

Table 5. Mean composition of cottage cheese

%		Control	UF
Moisture	AV	77.93	76.98
	SD	1.17	0.29
Protein	AV	12.69	13.76
	SD	0.08	0.41
Fat	AV	5.34	5.13
	SD	0.77	1.03
Lactose	AV	2.10	2.28
	SD	0.34	0.34
Calcium	AV	0.069	0.095
	SD	0.006	0.008

AV = Average

SD = Standard Deviation

Table 6. Cottage cheese yield

	Trial I		Trial II		Trial III	
	Control	UF	Control	UF	Control	UF
Milk (kg)	186.14	186.14	181.83	181.83	180.01	180.01
protein (%)	3.27	3.27	3.25	3.25	3.16	3.16
protein (kg)	6.09	6.09	5.91	5.91	5.69	5.69
Permeate + rinse (kg)		123.17		118.95		124.17
protein (%)		0.26		0.26		0.29
protein (kg)		0.32		0.30		0.35
Retentate (kg)		62.58		61.55		59.40
protein (%)		9.22		9.11		9.02
protein (kg)		5.77		5.61		5.34
Actual Yield	14.20	14.01	14.60	13.46	14.60	13.08
% Total Solids	22.12	22.73	21.09	23.41	20.00	22.91
Adjusted Yield (20% TS)	15.70	15.97	15.40	15.77	14.60	14.98
% increase		1.71		2.43		2.59
kg curd/kg protein	4.802	4.884	4.736	4.850	4.62	4.74
% increase		1.71		2.41		2.60

2.43 and 2.5% greater than the control. Also, the amount of cheese (adjusted to 80% moisture) produced per kilogram milk protein was significantly higher ($p < 0.05$) in UF than control cottage cheese.

Sensory Analysis

Flavor

Mean flavor scores are shown in Figure 3. At $\alpha = 0.05$ level, there were no significant differences among the cheeses. There were significant differences among judges and trials. UF cottage cheese had a very good flavor quality, as did the control cheese.

Appearance and Color

Mean appearance and color scores are shown in Figure 4. At $\alpha = 0.05$, no significant difference was observed among judges. However, there were significant differences among cheese samples and trials. No significant difference was observed between control and UF cheeses which were judged very good. The UF cottage cheese was graded better than two of the three commercial samples and no different than the third.

Body and Texture

Mean body and texture scores are shown in Figure 5. At $\alpha = 0.05$, no significant differences were observed among judges. However, there were significant differences among cheese samples and trials. No significant differences were observed between UF and control cheeses which were judged very good. The UF cottage cheese

Figure 3. Means for flavor of cottage cheese samples: control, ultrafiltered, brand A directly set, brand B directly set and brand C cultured skimmilk. Bars with the same letter are not significantly different ($p < 0.05$). Quality code is: 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.

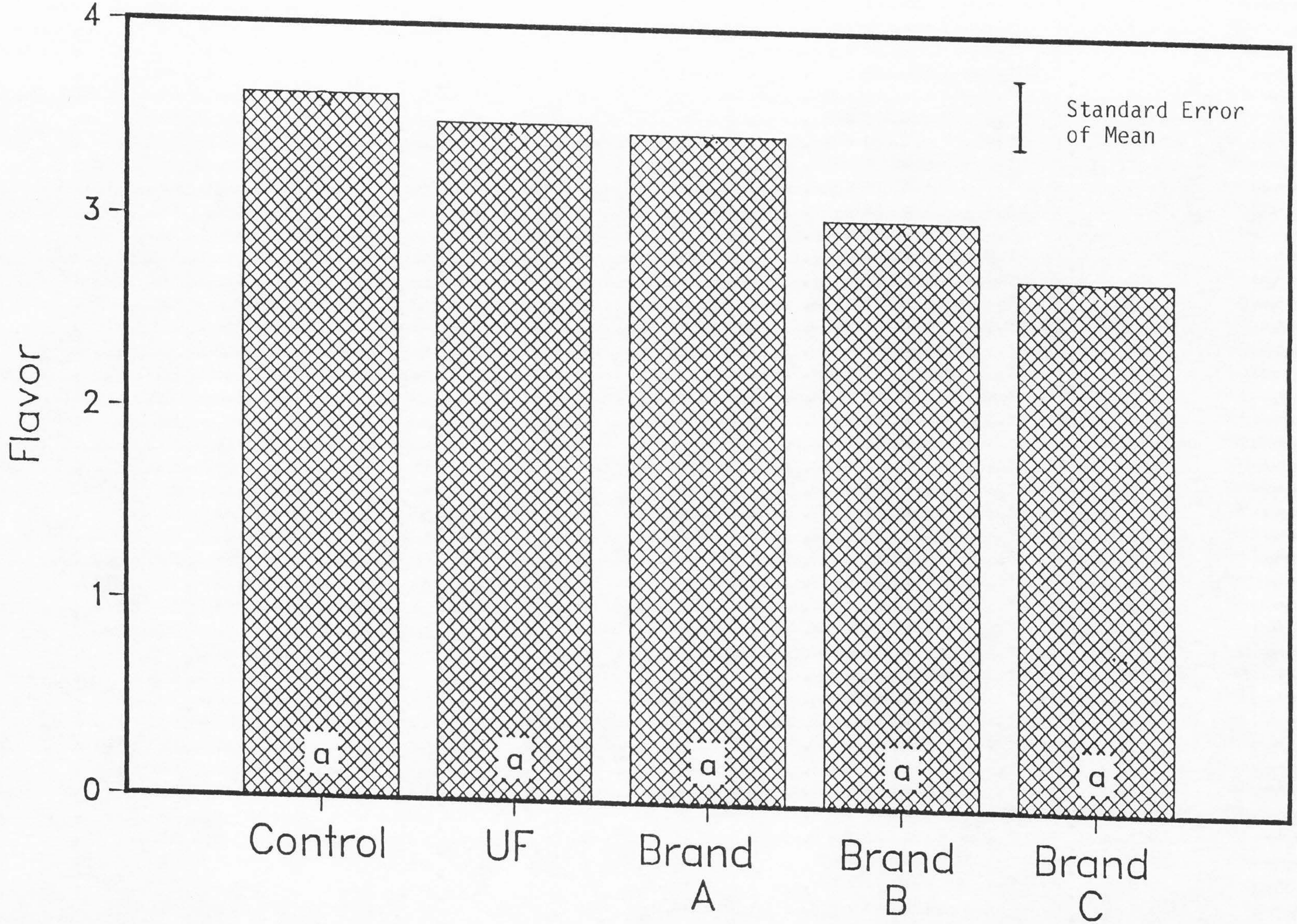
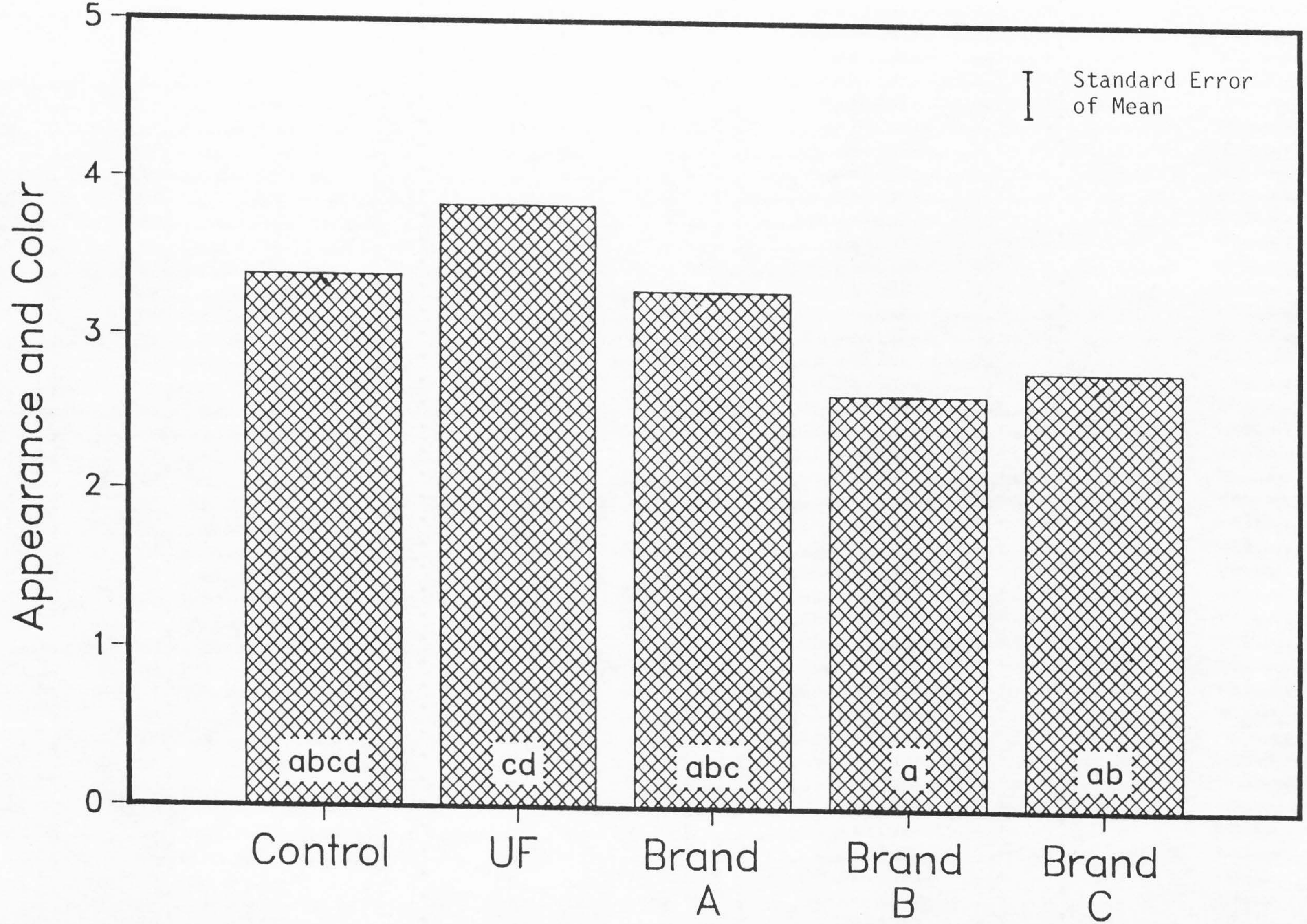

Flavor
4
3
2
1
0
Standard Error of Mean
a
a
a
a
a
Control
UF
Brand A
Brand B
Brand C

Figure 4. Means for appearance and color of cottage cheese samples: control, ultrafiltered, brand A directly set, brand B directly set and brand C cultured skimmilk. Bars with the same letter are not significantly different ($p < 0.05$). Quality code is: 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.


Standard Error
of Mean
Appearance and Color
5
4
3
2
1
0
abcd
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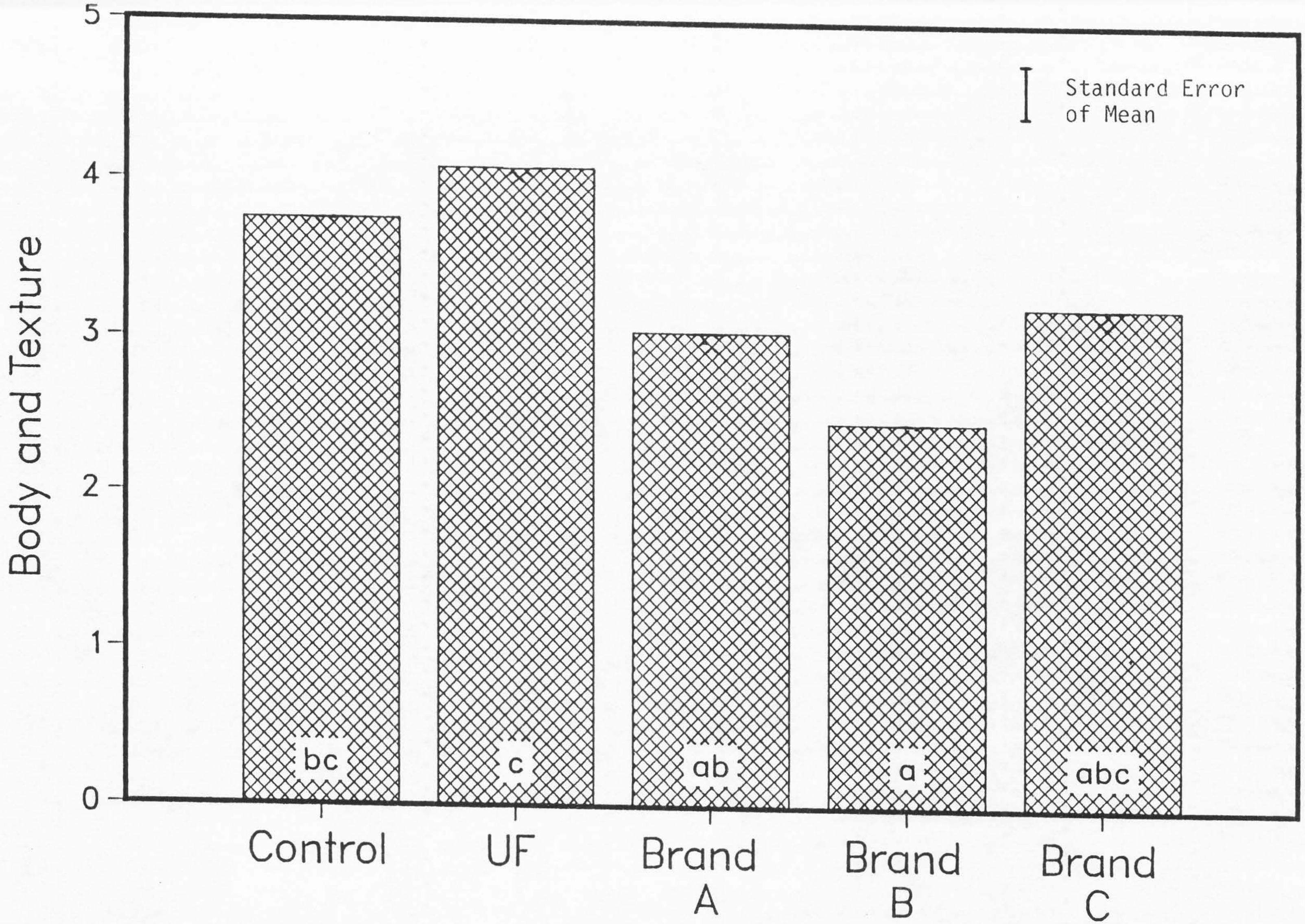
abc
a
ab
Control
UF
Brand
A
Brand
B
Brand
C

Figure 5. Means for body and texture of cottage cheese samples: control, ultrafiltered, brand A directly set, brand B directly set and brand C cultured skimmilk. Bars with the same letter are not significantly different ($p < 0.05$). Quality code is: 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.


Standard Error of Mean
Body and Texture
5
4
3
2
1
0
bc
c
ab
a
abc
Control
UF
Brand A
Brand B
Brand C

was better than two of the three commercial samples and equal to the third.

Overall

Mean overall scores are shown in Figure 6. At $\alpha = 0.05$, no significant difference was observed among judges. However, the cheese and trials were significantly different from each other. No significant difference was observed between UF and control cheeses which were judged very good. Both were better than two of three commercial samples and equal to the third.

Differences observed among trials probably resulted from the use of different skimmilk in each trial.

These evaluations indicate that the quality of direct acid UF cottage cheese was as good as cheese made from normal skimmilk from the same lot. Control and experimental cheeses were judged as good or better than commercial cottage cheese manufactured in this area.

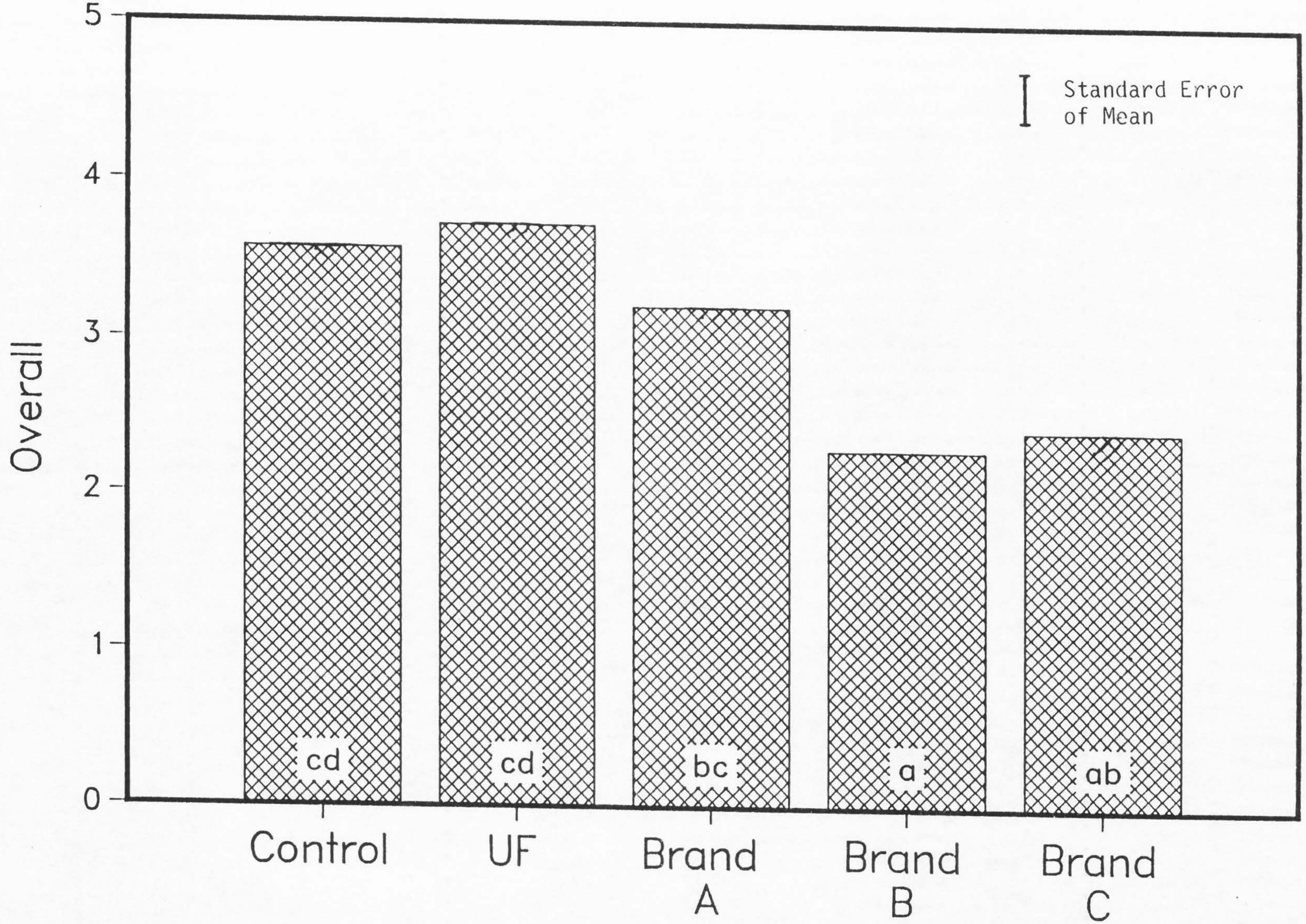
Sensory scores are summarized in Appendix 6.

General Observations

It was difficult to produce UF cottage cheese curd with a total solids less than 22-23%. Therefore the slight yield increase that was realized by adjusting to 20% total solids probably could not be attained under plant conditions.

Excellent firmness of UF cottage cheese curd at cutting makes it a good candidate for continuous cottage cheese making by the Ernstrom (25) process. It is recommended that efforts be made to use UF skimmilk in the continuous process based on complete acidification of cold retentate, then warming in a tubular heat exchanger (25).

Figure 6. Means for overall of cottage cheese samples: control, ultrafiltered, brand A directly set, brand B directly set and brand C cultured skimmilk. Bars with the same letter are not significantly different ($p < 0.05$). Quality code is: 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.


Standard Error
of Mean
Overall
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Control
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CONCLUSIONS

1. Cottage cheese with good texture and flavor was made from UF skimmilk retentate (9.1% protein).
2. The uncreamed cottage cheese made by ultrafiltered retentate was always higher than 20% total solids. When not corrected to 20% total solids, there was no increase in yield over control.
3. When corrected to 20% total solids, yields of UF curd averaged 2.24% greater than the control per 100 kg skimmilk and also 2.24% greater based on yield per kilogram original milk protein.
4. Unheated retentate formed a curd that was too tough to cut. Heating to 76.5°C for 16 s improved cuttability. Heating to higher temperature resulted in weak, shattered curd.
5. The UF process resulted in increased production per vat of retentate (45% volume reduction).
6. Cottage cheese curd made from unacidified ultrafiltered retentate became transparent and gelatinous after creaming. This problem was eliminated by acidification of skimmilk (pH 5.8) before ultrafiltration.

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APPENDIXES

Appendix 1

Cottage Cheese Score Card

Name ______________________________ Date _____________

Evaluate the following samples for the given criticisms placing a checkmark to the right of the appropriate criticisms. Enter a numerical value to the right of "score" for each category based on the following scale:

Score	Description
5	Excellent
4	Very good
3	Good
2	Fair
1	Poor

If no criticisms are checked, then a score of 5 is given.

COTTAGE CHEESE SCORE CARD

Perfect Score	Criticisms	Sample No. 1	2	3	4	5
Flavor	Contestant Score					
	Grade Score					
	Grade Criticism					
	Acid					
	Bitter					
	Diacetyl					
	Feed					
	Fermented/Fruity					
	Flat					
	Foreign					
	High Salt					
	Lacks Freshness					
	Malty					
	Metallic					
	Musty					
	Oxidized					
	Rancid					
	Unclean					
	Yeasty					
	Lacks Fine Flavor					
Body and Texture	Contestant Score					
	Grade Score					
	Grade Criticism					
	Firm/Rubbery					
	Gelatinous					
	Mealy/Grainy					
	Pasty					
	Weak/Soft					
Appearance & Color	Contestant Score					
	Grade Score					
	Grade Criticism					
	Free Cream					
	Free Whey					
	Lacks Cream					
	Matted					
	Shattered Curd					
	Slimy					
	Surface discolored					
	Translucent					
	Unnatural Color					
	Allowed perfect in contest	5.0	5.0	5.0	5.0	5.0
OVERALL	Contestant score					

Appendix 2

Statistical Tables

Table 7. Analysis of variance of moisture of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	5.6842	5.6842	7.966	N.S.
Trial	2	1.0690	0.5345	0.7491	N.S.
Error	2	1.4270	0.7135		
Total	5				

Table 8. Analysis of variance of protein of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	4.9323	4.9323	21.03	0.0469
Trial	2	0.7663	0.3832	1.63	N.S.
Error	2	0.4690	0.2345		
Total	5				

Table 9. Analysis of variance of fat of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	0.0043	0.0043	0.2774	N.S.
Trial	2	0.1051	0.0526	3.390	N.S.
Error	2	0.031	0.0155		
Total	5				

Table 10. Analysis of variance of lactose of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	0.1262	0.1262	2.59	N.S.
Trial	2	0.3008	0.1504	3.09	N.S.
Error	2	0.0973	0.0487		
Total	5				

Table 11. Analysis of variance of calcium of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	2.20×10^{-3}	2.20×10^{-3}	110	0.0094
Trial	2	1.23×10^{-4}	6.15×10^{-5}	3.075	N.S.
Error	2	4.0×10^{-5}	2.0×10^{-5}		
Total	5				

Table 12. Analysis of variance of whey protein of uncreamed cottage cheese

SV	df	SS	MS	F	Significant alpha level
Treatment	1	4.196×10^{-5}	4.1958	2.3283	N.S.
Trial	2	2.7958	1.3979	0.7757	N.S.
Error	2	3.6042	1.8021		
Total	5				

Table 13. Analysis of variance of protein of uncreamed cottage cheese (adjusted to 80% moisture)

SV	df	SS	MS	F	Significant alpha level
Treatment	1	2.6666	2.6666	16.96	N.S.
Trial	2	0.4392	0.2196	1.40	N.S.
Error	2	0.3145	0.1572		
Total	5				

Table 14. Analysis of variance of fat of uncreamed cottage cheese (adjusted to 80% moisture)

SV	df	SS	MS	F	Significant alpha level
Treatment	1	4.7833×10^{-3}	4.7833×10^{-3}	0.52	N.S.
Trial	2	100.0833×10^{-3}	50.0417×10^{-3}	5.43	N.S.
Error	2	18.4166×10^{-3}	9.2083×10^{-3}		
Total	5				

Table 15. Analysis of variance of lactose of uncreamed cottage cheese (adjusted to 80% moisture)

SV	df	SS	MS	F	Significant alpha level
Treatment	1	0.091233	0.0912	2.3030	N.S.
Trial	2	0.2956	0.1479	3.7348	N.S.
Error	2	0.07927	0.0396		
Total	5				

Table 16. Analysis of variance of calcium of uncreamed cottage cheese (adjusted to 80% moisture)

SV	df	SS	MS	F	Significant alpha level
Treatment	1	1.9473×10^{-3}	1.9473×10^{-3}	62.18	0.019
Trial	2	0.1073×10^{-3}	0.0537×10^{-3}	1.72	N.S.
Error	2	0.06267×10^{-3}	0.03134×10^{-3}		
Total	5				

Table 17. Analysis of variance of whey protein of uncreamed cottage cheese (adjusted to 80% moisture)

SV	df	SS	MS	F	Significant alpha level
Treatment	1	2.1235×10^{-4}	2.1235×10^{-4}	14.20	N.S.
Trial	2	0.458×10^{-4}	0.229×10^{-4}	1.53	N.S.
Error	2	0.299×10^{-4}	0.1495×10^{-4}		
Total	5				

Table 18. Analysis of variance of mean weight of uncreamed cottage cheese per 100 kg of skim milk.

Source	df	MS	F	Significant alpha level
Treatment	1	0.1734	94.75	0.0109
Trial	2	0.5955	325.41	0.0044
Error	2	0.0018		
Total	5			

Table 19. Analysis of variance of mean weight of uncreamed cottage cheese per kg of protein.

SV	df	MS	F	Significant alpha level
Treatment	1	0.2204	259.29	0.0047
Trial	2	0.0101	11.88	N.S.
Error	2	0.0009		
Total	5			

Table 20. Analysis of variance of sensory evaluation for flavor of cottage cheese samples.

SV	df	MS	F	Significant alpha-level
Treatment	4	0.7145	0.4633	N.S.
Judge	3	8.004	5.1893	0.0136
Error A	12	1.5424		
Trial	2	1.9542	5.0800	0.0139
Trial x Treatment	8	0.3396	0.8828	N.S.
Error B	30	0.3847		
Total	59			

Table 21. Analysis of variance of sensory evaluation for appearance and color of cottage cheese samples.

SV	df	MS	F	Significant alpha level
Treatment	4	4.2042	3.6960	0.0373
Judge	3	0.6444	0.5665	N.S.
Error A	12	1.1375		
Trial	2	1.6625	3.7520	0.0374
Trial x Treatment	8	0.8604	1.9418	N.S.
Error B	30	0.4431		
Total	59	0.9475		

Table 22. Analysis of variance of sensory evaluation for body and texture of cottage cheese samples.

SV	df	MS	F	Significant alpha level
Treatment	4	4.9104	3.7473	0.0358
Judge	3	4.550	3.4720	N.S.
Error A	12	1.3104		
Trial	2	1.6667	3.6367	0.0407
Trial x Treatment	8	1.1104	2.4229	0.0398
Error B	30	0.4583		
Total	59	1.2150		

Table 23. Analysis of variance of sensory evaluation for overall of cottage cheese samples.

SV	df	MS	F	Significant alpha level
Treatment	4	4.8063	4.5866	0.0196
Judge	3	1.5010	1.4324	N.S.
Error A	12	1.0479		
Trial	2	6.3542	18.1031	0.0005
Trial x Treatment	8	1.1313	3.2231	0.0094
Error B	30	0.3510		
Total	59	0.9493		

Appendix 3

Composition of Uncreamed Cottage Cheese

%		Trial I Control	Trial I UF	Trial II Control	Trial II UF	Trial III Control	Trial III UF
Moisture	AV	77.88	77.27	78.91	76.59	80.00	77.09
	SD	0.22	0.021	0.04	0.009	0.23	0.13
Protein	AV	17.83	19.32	17.44	18.79	16.40	19.00
	SD	0.25	0.25	0.25	0.24	0.23	0.22
Fat	AV	1.32	1.29	1.31	1.07	0.93	1.04
	SD	0.016	0.026	0.029	0.017	0.012	0.017
Lactose	AV	1.14	1.10	1.40	1.73	1.33	1.91
	SD	0.05	0.017	0.057	0.07	0.04	0.06
Calcium	AV	0.0525	0.0932	0.0533	0.0823	0.039	0.085
	SD	0.003	0.003	0.004	0.0002	0.0002	0.0002
Whey Protein	AV	0.5767	0.6627	0.6176	0.6776	0.5321	0.6658
	SD	0.02	0.059	0.02	0.021	0.01	0.029

AV = Average
SD = Standard Deviation

Appendix 4

Composition of Cottage Cheese

%		Trial I Control	Trial I UF	Trial II Control	Trial II UF	Trial III Control	Trial III UF
Moisture	AV	76.24	77.27	78.70	76.59	78.83	77.09
	SD	0.05	0.02	0.16	0.009	0.05	0.13
Protein	AV	12.70	13.18	12.78	14.04	12.59	14.06
	SD	0.009	0.02	0.06	0.03	0.03	0.08
Fat	AV	5.93	6.57	5.84	4.62	4.26	4.21
	SD	0.12	0.03	0.05	0.11	0.13	0.13
Lactose	AV	1.63	1.81	2.40	2.56	2.28	2.50
	SD	0.13	0.009	0.13	0.13	0.05	0.11
Calcium	AV	0.075	0.106	0.070	0.090	0.061	0.089
	SD	0.0003	0.0002	0.0004	0.002	0.0004	0.002

AV = Average

SD = Standard Deviation

Appendix 5

Composition of Uncreamed Cottage Cheese (adjusted to 80% moisture)

	Trial I		Trial II		Trial III	
%	Control	UF	Control	UF	Control	UF
Moisture	80.00	80.00	80.00	80.00	80.00	80.00
Protein	17.36	18.16	17.20	17.99	16.40	18.31
Fat	1.29	1.25	1.29	1.02	0.93	1.00
Lactose	1.11	1.06	1.38	1.66	1.33	1.84
Calcium	0.052	0.090	0.052	0.079	0.039	0.082
Whey protein	0.521	0.583	0.586	0.619	0.532	0.581

Appendix 6

Mean Sensory Scores for Cottage Cheese Samples

Samples	Flavor	Appearance & Color	Body & Texture	Overall
Control	$3.63^{a} \pm 0.062$	$3.38^{abc} \pm 0.056$	$3.75^{bc} \pm 0.015$	$3.58^{c} \pm 0.032$
UF	$3.50^{a} \pm 0.077$	$3.80^{c} \pm 0.023$	$4.08^{c} \pm 0.023$	$3.73^{c} \pm 0.044$
Commercial A	$3.46^{a} \pm 0.062$	$3.29^{abc} \pm 0.062$	$3.04^{ab} \pm 0.062$	$3.21^{bc} \pm 0.058$
Commercial B	$3.04^{a} \pm 0.032$	$2.63^{a} \pm 0.015$	$2.46^{a} \pm 0.024$	$2.29^{a} \pm 0.023$
Commercial C	$2.75^{a} \pm 0.053$	$2.79^{ab} \pm 0.112$	$3.21^{abc} \pm 0.109$	$2.42^{ab} \pm 0.099$
LSD	0.990	0.853	0.916	0.819

Means in the same column with the same letter are not significantly different ($p < 0.05$). Each mean is the average of 12 responses.

Product was rated on a grading scale of 1 = poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent