1983

Ultrafiltration of Skim Milk Prior to Cottage Cheese Making

Izhar H. Athar
South Dakota State University

ULTRAFILTRATION OF SKIM MILK PRIOR
TO COTTAGE CHEESE MAKING.

BY

IZHAR H. ATHAR

A thesis submitted
in partial fulfillment of the requirements for the
degree of Master of Science
Major in Dairy Science
South Dakota State University
1983

ULTRAFILTRATION OF SKIM MILK PRIOR
TO COTTAGE CHEESE MAKING.

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Kenneth R. Spurgeon Date
Thesis Advisor

John G. Parsons Date
Head, Dairy Science Dept.

ACKNOWLEDGMENTS

Deepest gratitude and indebtedness to Dr. Kenneth R. Spurgeon for his sympathetic supervision, invaluable and ever-inspiring guidance throughout my graduate program and research project.

Sincere appreciation is extended to Dr. Thomas M. Gilmore for his stimulation and encouragement.

Gratitude is similarly expressed to Dr. John G. Parsons for his help and counsel throughout the course of my graduate program and to Mr. Shirley W. Seas for his aid in the use of the SDSU Dairy Products Laboratory. Thanks are given to Dr. Robert Baer and Dr. George Torrey for their aid in the preparation of this manuscript.

A special appreciation is extended to Dr. Andrew Clark for the statistical analyses and help in data interpretation. The expertise of Dr. W. Lee Tucker in the design of the project is acknowledged. Gratitude is expressed to Nordica International and Valley Queen Cheese Factory for providing the SDSU Dairy Science Department with funds for the purchase of an ultrafiltration unit. Especially, thanks are also expressed to Nordica International for the supply of bulk culture for this project.

A special thanks is extended to Laura Lardy for her patience and skill in typing of this thesis.

Finally, this thesis is dedicated to my parents and my wife for their patience, understanding, and encouragement throughout the graduate program.

IHA

TABLE OF CONTENTS

Page

INTRODUCTION 1

LITERATURE REVIEW. 4

Milk Components and Cottage Cheese Yield 4

Ultrafiltration in the Dairy Industry. 7

Ultrafiltration of Milk. 9

Preparation of Various Types of Cheese with Ultrafiltration. 18

Semisoft and Soft Cheeses With UF. 19

Processed Cheese Made With UF. 22

Cheddar Cheese With UF 23

Cottage Cheese With UF 26

Legal Composition of Cottage Cheese. 29

MATERIALS AND METHODS. 30

Experimental Procedure 30

Sample Collection. 38

Compositional Analysis 38

Expression of Cottage Cheese Yield 39

Organoleptic Evaluation. 39

Statistical Analysis 40

RESULTS AND DISCUSSION 41

Cheese Milk Composition. 41

Curd Composition 44

Whey Composition 46

TABLE OF CONTENTS

(continued)

Page

Cottage Cheese Yields 48

Organoleptic Evaluation 51

Microbiological Analysis. 54

Cheese Making Characteristics 57

SUMMARY 58

Specific Conclusions. 59

REFERENCES. 61

APPENDIX. 69

LIST OF TABLES

TABLE		Page
1	Typical composition of skim milk, cottage cheese curd, and cottage cheese, creamed.	4
2	Possible products from ultrafiltration permeate.	9
3	Typical compositions of concentrate and permeate from UF concentration of skim milk.	13
4	Composition of skim milk, unconcentrated or concentrated by ultrafiltration, used in the manufacture of cottage cheese	42
5	Composition of curd of cottage cheese manufactured with and without ultrafiltration of skim milk precursor . . .	45
6	Compositions of wheys from cottage cheese manufactured with or without ultrafiltration.	47
7	Average yields of cottage cheese curd manufactured from skim milk with or without ultrafiltration.	49
8	Mean scores of organoleptic evaluation of creamed cottage cheese manufactured from skim milk with and without ultrafiltration.	53
9	Standard plate counts (SPC) of skim milk and coliform counts of skim milk and curd obtained from ultrafiltrated and non-ultrafiltrated skim milk	55
10	Standard plate counts (SPC) of skim milk and coliform counts of skim milk and curd obtained from ultrafiltrated and non-ultrafiltrated skim milk	56

LIST OF FIGURES

FIGURE		Page
1	Abcor Spiral Wound UF Model 1/1 Sanitary Pilot Plant Unit	31
2	Flow diagram of milk treatment and cottage cheese manufacture.	34

LIST OF APPENDIX FIGURES

FIGURE | Page

1 American Dairy Science Association product score card for cottage cheese 70

LIST OF APPENDIX TABLES

TABLE		Page
1	Composition of non-ultrafiltrated skim milks used to manufacture cottage cheese (Control 1 for UF 25%). . . .	72
2	Composition of ultrafiltrated skim milks used to manufacture cottage cheese (UF 25%).	73
3	Composition of non-ultrafiltrated skim milks used for manufacture of cottage cheese (Control 2 for UF 33%) . .	74
4	Composition of ultrafiltrated skim milk used to manufacture cottage cheese (UF 33%).	75
5	Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%)	76
6	Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%). .	77
7	Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%)	78
8	Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%). .	79
9	Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%)	80
10	Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%). .	81
11	Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%)	82
12	Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%). .	83
13	Yields of cottage cheese made from skim milk with and without ultrafiltration.	84

LIST OF APPENDIX FIGURES

FIGURE		Page
1	American Dairy Science Association product score card for cottage cheese	70

LIST OF APPENDIX TABLES

TABLE		Page
1	Composition of non-ultrafiltrated skim milks used to manufacture cottage cheese (Control 1 for UF 25%). . . .	72
2	Composition of ultrafiltrated skim milks used to manufacture cottage cheese (UF 25%).	73
3	Composition of non-ultrafiltrated skim milks used for manufacture of cottage cheese (Control 2 for UF 33%) . .	74
4	Composition of ultrafiltrated skim milk used to manufacture cottage cheese (UF 33%).	75
5	Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%)	76
6	Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%). .	77
7	Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%)	78
8	Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%). .	79
9	Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%)	80
10	Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%). .	81
11	Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%)	82
12	Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%). .	83
13	Yields of cottage cheese made from skim milk with and without ultrafiltration.	84

LIST OF APPENDIX TABLES

(continued)

TABLES Page

14 Yields of cottage cheese made from skim milk with and without ultrafiltration 85

INTRODUCTION

Cottage cheese has the largest sales volume potential of all cultured dairy products in the United States today. Moreover, it can be a highly profitable product if proper control is exercised during its manufacturing (46).

Commercial production of cottage cheese utilizes a significant portion of the total fluid milk produced in the U.S.A. After the 1955's, yearly per capita consumption of cottage cheese increased from 1.77 kg (3.9 lb) to a high of 2.45 kg (5.4 lb) in 1972 (67). Consumer demand for lower fat dairy products gradually increased, which put more pricing emphasis on the nonfat milk solids. This caused a marked increase in the price of cottage cheese, which depressed the yearly per capita consumption to 1.95 kg (4.3 lb) by 1981 (67).

Poor yields are a problem of major concern in the cottage cheese industry today. In the 1950's, yield factors of 1.8 to 1.85 kg of 20% solids curd per kg milk solids were commonplace and at that time skim milk usually contained between 9 and 10% total solids. During the 1960's yields dropped to 1.7 to 1.75 kg of 20% solids curd per kg milk solids (5, 44). Any increase in cheese yield and/or decrease in costs of production would improve profit for cheese producers and help maintain lower consumer prices.

Most of the studies on cheese making have indicated the decreases in product yields during the past decades (4, 22, 66, 86, 91) were due to: 1) use of larger vats and mechanical agitators has become widespread, resulting in greater yield losses as curd fines; 2) a change in relative price supports of butter and nonfat dry milk (NFDM) increased the price of the latter, so many manufacturers of cottage cheese determined that fortification of skim milk with NFDM was no longer economically sound and the practice was discontinued. Hence, cottage cheese yields failed to reach projected levels, especially during hot, dry summer months when the total solids content of milk tended to be low (15, 66, 91); and 3) composition of the milk supply has changed as production per cow increased. Lower solids-not-fat (SNF) in milk directly affects the recovery of milk solids in the cheese curd. Of particular interest to a cottage cheese manufacturer has been the decrease in casein content of milk, for casein comprises nearly 78% of the cottage cheese solids. Milk today (91) is more likely to contain 2.31% casein rather than the 2.5% listed in earlier references (42, 100).

Currently, the methods of cottage cheese manufacture convert an average of only 74.9% of milk protein into cottage cheese, while the balance of the proteins remain in the whey (66, 86). The proteins lost in whey are mainly α-lactalbumin and β-lactoglobulin which remain soluble under the conditions of cottage cheese manufacture and thus do not become part of the curd (50). They may be an added expense rather than a benefit to the dairy industry, since these proteins as whey solids must either be processed further, disposed of as waste, or both. Processing cottage cheese whey is expensive and difficult because it is both dilute (94% water) and highly acidic (pH 4.6) (10, 50). Whey proteins can be concentrated and removed from whey after cheese making (33, 50) or they may be recovered in the cheese by concentration in the milk with ultrafiltration (UF) (34, 43, 44, 47, 60) prior to cheesemaking.

Ultrafiltration is a continuous method for separating high molecular weight solutes from fluid streams. Its ability to fractionate and concentrate complex fluids has led to several applications of ultrafiltration in the dairy industry (8, 23, 40, 62). Ultrafiltrating milk will raise the protein content; the milk can then be used to make ripened types of cheeses. Milk concentrated by ultrafiltration requires less rennet and starter culture for cheese manufacture than does a conventional milk; moreover, processes based on ultrafiltrated milk produce less whey than do traditional processes (19, 20, 44, 47, 63). The use of ultrafiltrated milk in the production of cultured dairy products gives yields as much as 20% greater (44, 47, 56) due to the retention in the cultured products of proteins which normally would be lost in whey in traditional manufacturing processes.

The present investigation was designed 1) to study the increase in total solids in starting skim milk after using UF to remove 25% (UF 25%) and 33% (UF 33%) of skim milk volume as permeate; 2) to explore the possibility that concentrating skim milk may increase cottage cheese yield; and 3) to determine if the acceptability of cottage cheeses which were obtained from UF concentrated skim milk were inferior, equal, or superior to those of cottage cheese manufactured without UF treatment of the skim milk.

LITERATURE REVIEW

Milk Components and Cottage Cheese Yield

The manufacture of cottage cheese is based upon a process designed to recover in the curd only the major protein component of milk, casein. However, small amounts of other constituents including other proteins can be entrapped in the curd. Therefore, the origins of inefficient protein recovery in the cottage cheese industry are inherent in the method used to produce the curd, even though it is tailored to the characteristics of the starting material, milk (25).

Milk is a complex mixture which contains proteins (casein, α-lactalbumin, and β-lactoglobulin) in colloidal suspension; fat, as an emulsion with water as the continuous phase; and lactose and most mineral salts in true aqueous solution. Some of the nutritionally important vitamins are in solution in the water; vitamins A, D, E, and K are fat soluble and so are removed when milk is skimmed (42, 100).

Cottage cheese is made from skim milk. Typical compositions of skim milk, cottage cheese curd, and creamed cottage cheese are shown in Table 1 (75).

TABLE 1. Typical composition of skim milk, cottage cheese curd, and cottage cheese, creamed[a].

Products	Water	Fat	Protein	Carbohydrate total	Ash
	(%)				
Skim milk	90.8	.2	3.4	4.8	.8
Cottage cheese curd	79.8	.4	17.3	1.8	.7
Cottage cheese, creamed	79.0	4.5	12.5	2.7	1.4

[a](75).

Over the last 36 yr, the United States (U.S.) milk supply has changed in composition so present day milk contains lower percentages of casein (4, 91). The solids-not-fat (SNF) portion of milk today contains 26% casein, whereas 36 yr ago casein represented 28.5% of the SNF in milk (4, 91). South Dakota milk has been shown to contain an average of 2.31% casein and 8.33% SNF (91). Variations in the casein content of milk usually account for variations in cottage cheese yields (4, 15, 55, 58), since coagulation of casein in the skim milk is the basis for cottage cheese manufacture (28, 95, 96, 100). Lactose, whey proteins, and minerals largely remain in the whey but, nonetheless, they contribute approximately 15% of the solids portion of the curd; whereas casein contributes approximately 85% of the curd solids (4, 69).

Bender and Tuckey (9) reported efficiency of milk solids recovery in the curd increased as the solids and casein contents of the skim milk increased. Skim milk containing 8.92% total solids yielded 32.2% recovery of solids in curd, while 9.71% total solids skim milk yielded 38.8% recovery of milk solids. Most of the reports on yield efficiency have indicated this basis for general recommendation of increasing the solids content in skim milk used for cottage cheese manufacture (2, 5, 15, 58, 66, 73, 77, 85, 86, 95, 100, 101, 103). Some researchers (4, 28) have felt the total solids in the skim milk should be adjusted to at least 9%; while Angevine (5) set 8.8 to 8.9% total solids as minimum for cottage cheese manufacture. An upper limit of total solids desirable in skim milk is 11% (15, 58). Other researchers have specified 9.5% as the most desirable total solids in skim milk used to manufacture cottage cheese (66, 100, 103).

Solids contents from 9 to 12% reconstituted skim milk have usually provided the most desirable curd (103). Emmons (28) reviewed the manufacture of cottage cheese from reconstituted nonfat dry milk (NFDM) and indicated varying degrees of success. He found most problems encountered in the manufacture of cottage cheese from NFDM usually could be explained by the heat treatment history of the milk.

Mickelson (66) stated fortifying skim milk with NFDM for cottage cheese manufacturing was common practice; but gradually consumer demand for lower fat dairy products increased and the United States Department of Agriculture changed the relative support prices of butter and NFDM, which brought a marked increase in the price of NFDM by the late 1960's and early 1970's. Some manufacturers translated those changes into economics and discontinued the practice of adding NFDM to skim milk to be made into cottage cheese.

Two other possible methods of composition adjustment of cheese milk are through the addition of low heat condensed skim milk (15) or via ultrafiltration of milk (11, 17, 18, 19, 20, 47, 48, 59, 60, 62, 72). However, condensed skim milk is a relatively small segment of the dairy industry and probably is not readily available to most cottage cheese manufacturers (67). It has been found (54) vacuum concentration of milk prior to cheese making can result in increase of yield. This process also leads to increased productivity, since more cheese can be produced in the equipment without increase in labor. Whey handling cost would also be decreased as there is less whey volume from the concentrated milk.

Concentration of milk by ultrafiltration has been reported (36, 38, 43, 44, 47, 56, 63, 88, 104) to give those advantages mentioned in connection with thermal/vacuum concentration of milk for cheese making, but with less expenditure of energy. Ultrafiltration was a more energy efficient method of concentrating milk than was vacuum evaporation prior to improvements in the latter in recent years. High energy costs are one of the greatest problems in the dairy industry (31, 71), particularly the cheese industry, in an era of energy shortages. Ultrafiltration should be considered as a means to make more cheese per vat through applying its techniques to reduce milk volume while increasing the total solids contents of the milk (53, 71).

Ultrafiltration in the Dairy Industry

Ultrafiltration (UF) and reverse osmosis (RO) are molecular filtration processes which use selectively permeable membranes to effect the separation. Both techniques can be applied to concentrating and fractionating of liquid dairy products without thermal denaturation or degradation of heat sensitive components such as protein or vitamins. The separation occurs with no change in phase, which offers certain advantages when compared to evaporation. Reverse osmosis membranes are usually permeable only to water; the more open UF membranes will pass some minerals but at the expense of lactose permeation. Ultrafiltration primarily concentrates milk proteins while removing some of the soluble constituents, so milk thus treated would be adapted best to use in making cheese or products which are based on milk proteins (8, 36, 68).

The number of RO and UF membranes installed in the world dairy industry during the last 10 yr has increased exponentially (8, 14 59, 68). Important progress has been made in membrane conception and equipment through a better understanding of the mechanisms and of fouling of membranes during ultrafiltration. The membrane separation processes are used for the concentration and fractionation of skim milk and whey and have found widespread application in the dairy industry (11, 62, 68).

Ultrafiltration is used to concentrate and fractionate fat and protein components of milk and milk products or whey before evaporation, drying, or culturing. Reverse osmosis is used mainly for removing water prior to evaporating or drying (8, 23, 68). During ultrafiltration, much of the water of milk together with lactose and soluble mineral salts move through the membranes and are collected in the form of a clear, slightly yellow liquid, the permeate. It contains 4.56% lactose, 5.25% total solids, .02% nonprotein nitrogen, .06% total nitrogen, and no milk fat (36, 104). The biological oxygen demand (BOD) of the permeate is large, in the region of 2500 mg/liter, and hence is little less than that of the original whey. It is therefore necessary to utilize permeate both from the nutritional and the pollutional aspects. A list of products possible from further processing of the permeate is shown in Table 2 (16, 37, 50).

TABLE 2. Possible products from ultrafiltration permeate.

Process	Products
Evaporation plus spray drying	80% lactose powder
Crystallization, washing, centrifuging, and drying	Crystalline lactose powder, edible grade
Fermentation with *Saccharomyces fragilis* or other yeast; centrifuging and drying	Yeast protein
Enzymic or acid hydrolysis	Glucose/galactose syrup
Fermentation	Lactic acid
Fermentation	Ethanol and vinegar

The proteins, the mineral salts which are in colloidal form associated with proteins, and the fat (if whole milk be ultrafiltrated) cannot go across the membrane. They stay with reduced fluid volume and form the "retentate". In retentate, the protein content may be two, three, or even six times the protein content of the original milk. Such retentates have a composition which is very close or identical to the composition of certain cheeses. These retentates have been used successfully in the manufacture of liquid and semiliquid dairy products such as ymer, yogurt, quarg, and soft cheeses. They are also used in the production of hard cheeses (37, 38, 43, 44, 51).

Ultrafiltration of Milk

As noted earlier, ultrafiltration of milk prior to cheese making has been reported to result in greater incorporation of whey proteins into cheese (13, 43, 44, 47, 56, 60, 61, 62, 64), thus increasing yield and reversing the trend toward declining yield and profit. Ultrafiltration as applied to cheese milk not only increases the solids content of the milk but it alters the ratios of the components comprising total solids. Both casein and whey protein are concentrated through partial removal of mass such as lactose, nonprotein nitrogen, and salts (62). In brief, ultrafiltration is used to produce protein-enriched milk concentrates.

The effect of temperature, operating pressure, feed flow rate, and retentate concentration on the permeate flux (rate of passage through the ultrafiltration membrane) from milk are similar to those for the ultrafiltration of whey (90, 94). However, the permeate fluxes in the ultrafiltration of milk are much lower than those for whey due to the higher protein content in skim milk. An increase in the temperature of the skim milk increases the ultrafiltration permeate flux (90, 94). Indeed, the flux has been found to be linearly dependent on temperature from 10 to 40^{o}C in reverse osmosis of skim milk (34). It was more economical to operate at 50^{o}C than 5^{o}C when skim milk was ultrafiltrated. The permeate flux was four to five times higher at 50^{o}C than at 5^{o}C. At 50^{o}C most bacterial growth was inhibited. As the temperature was increased to 50^{o}C, only minor changes in the protein quality of the retentates (74) were observed. During concentration of raw skim milk at 60^{o}C by UF and diafiltration (concentration by UF, dilution with water, and reconcentration) by using an open tubular Abcor UF Unit, researchers observed an increased flux rate, improved microbiological quality, and expanded possibility of denaturing whey protein but with no adverse effect on the product composition at this higher processing temperature (90).

Delaney and Donnelly (23) suggested that both reverse osmosis and ultrafiltration of skim milk should be conducted at high temperature. However, limitations are imposed on the operation temperature by the membrane stability, protein stability, and solubility of the milk components. It was shown (23) that at about 40°C the calcium phosphate in the skim milk retentate can precipitate and cause membrane fouling. An alteration in protein stability also can affect the product composition and properties. The ultrafiltration flux increased with an increase of pressure (23). Concentrating milks with initial composition ranging from that of skim milk to that of whole milk showed as the fat content was increased the average flux decreased. The highest flux was obtained in the ultrafiltration of skim milk and the lowest during the ultrafiltration of whole milk.

Ultrafiltration of milk was studied by Short et la. (87) on a De-Danske Sukkerfabrikker (DDS) plate and frame system. They found to optimize the flux when concentrating the skim milk two fold (2x) or three fold (3x) the milk should be of the highest quality and at its natural pH (6.7). Operation at the maximum temperature of 50°C maximized the flux and minimized continuing microbial spoilage by mesophilic organisms.

Short et al. also found (87) that operating at maximum flux maximized ash retention and caused lactose retention to be essentially zero, while it had no effect on protein retention. The retention of the water soluble vitamins, ascorbic acid and riboflavin, and the retention of calcium and phosphorus depended on the membrane used and on the thickness of the protein gel layer. It was also found diafiltration increased the protein-to-lactose ratio in the retentate (94). The rate of flux decreased as the amount of solids in the retentate increased. With the increase of protein concentration, the boundary layer increased in thickness, which increased the resistence to permeate flux (34). Marshall et al. (59) reported on ultrafiltration of pasteurized whole and skim milk using Abcor and DDS pilot plant UF models; they suggested modifications of milk composition are readily achieved by ultrafiltration. They (59) also proposed such composition modifications as a pretreatment of milk for cheese making to achieve benefits such as lower vat volume required, reduction in quantity of rennet, salt, and other additives, and production of much less whey. It was observed (59) that at 50^{o}C the flux achieved in treating whole milk was 19.8 liters/m^2 per hour in Abcor UF models. Despite the high milk fat concentration, the membrane could be cleaned readily using a solution of Triton X-100 followed by a normal detergent containing enzymes. Skim milk was concentrated using each pilot plant as a single feed and bleed module. The average flux was lower and less microbiological spoilage occurred. Pasteurized skim milk was concentrated to give a 2.4 fold increase in total protein. The average fluxes were 27.7 liters/m^2 per hour in the Abcor and 25.2 liters/m^2 per hour in the DDS unit. The rejections of protein, ash, and total solids were the same in each plant: .993, .589, and .624, respectively. Despite continuous operation for more than 9 h at 50°C, total plate counts of the ultrafiltration concentrate were generally less than 10^4/ml. The pH of the concentrate changed by less than .1. Typical compositions for concentrate and permeate obtained from skim milk are shown in Table 3 (59).

TABLE 3. Typical compositions of concentrate and permeate from UF concentration of skim milk[a].

Components	Concentrate	Permeate
	(%)	
Total solids	14.9	5.38
Protein (TN - NPN) x 6.38	9.1	.06
Ash	1.2	.49
Lactose	4.6	4.56

[a](59).

Analyses of retentate collected from milk at temperatures up to 110°C indicated temperature changes affected the inorganic composition of milk drastically as compared to cooler milk. At 93.3°C, the amount of calcium passing into the ultrafitrate was approximately 50% and phosphate above 82% of that found to pass at 26.6°C. The hydrogen ion concentration of retentate collected at 93.3°C was at least double that of retentate collected at

26.6°C (83).

Viscosities of ultrafiltrated fluid dairy products increased with concentration due to the predominant effect of concentrating milk protein, especially casein. The significant increase in viscosity of skim milk ultrafiltrate above 12 to 15% proteins indicated (41) ultrafiltration alone will not be suitable for manufacture of hard cheeses without further whey drainage. However, suitability of UF for production of cream and Camembert cheese, as well as yogurt and other cultured dairy products with relatively high moisture contents, has been demonstrated (18, 34, 44, 47). Viscosity of ultrafiltrated skim milk is affected by alteration of pH resulting in changes in casein micelle structure. Both raising and lowering the pH from the normal range increases the viscosity. Severe changes in the pH may result in several fold increases of viscosity due to casein precipiation (41).

Covacevich and Kosikowski (17) studied the physical and microbial properties of pasteurized skim milk for cheese making after direct ultrafiltration, diafiltration, or ultrafiltration accompanied by simultaneous fermentation of retentate with concentration to maximum. Protein was increased to 72 to 74% of the dry matter in direct ultrafiltration retentates. Single diafiltration with or without simultaneous fermentation increased protein to 83.5% and double diafiltration, to 88%. Lactose was reduced from 20% in the dry matter in direct ultrafiltration retentate to 9.0 and 4.7% with single and double diafiltration, respectively. The mineral content was not affected markedly by diafiltration. Permeation rate correlations with the logarithm of total solids or protein in retentate were statistically significant. Refractive index readings during concentration also gave statistically significant correlation with total solids (r^2=.99).

Double diafiltration with simultaneous partial fermentation of skim milk retentate reduced the buffering capacity of ultrafiltrated retentate and suppressed the survival and growth of enteropathogenic *Escherichia coli* in Camembert cheese made by an ultrafiltration process (80). Hydrolysis of lactose in ultrafiltered retentate did not increase starter culture activity against *E. coli* survival and growth in UF Camembert cheese (80). The buffer, lactic fermentation potential, and rennet coagulation of direct ultrafiltration retentate of skim milk were studied (21) and it was found retentate concentrated five fold (18.5% total solids) and acidified directly displayed a dB/dpH value at pH 5.1 seven times greater than the original skim milk. The buffering capabilities rose exponentially with increasing total solids. Rennet-coagulation behavior of ultrafiltration retentate was similar to that of milk. Reduction of 50% in amount of rennet extended coagulation time by a factor of 1.9 $\pm$ .05.

Glover (36) conducted a study on concentrating whole milk by reverse osmosis and ultrafiltration. Whole milk was concentrated two fold, using a flat sheet ultrafiltration membrane operated at 2.1093 kg/cm^2 (30 psig) and in the temperature range of 25^oC to 37^oC. Glover observed an increase in permeate flux when the feed temperature was increased, but temperatures higher than 38^oC caused physical damage to the fat globules. Under constant operating conditions, it was observed the flux for skim milk was 25% greater than that for whole milk; the flux for whey was three times larger. It was concluded the ultrafiltration of whole milk was hindered to some extent by the presence of fat globules, but the dominant resistance arose from the presence of the proteins.

Effect of temperature and membrane pore size on permeation flux rate and microbial quality of the retentate and permeates during ultrafiltration of skim milk were investigated (45). Standard plate counts of the retentate obtained during ultrafiltration at 15°C were lower than standard plate counts at 45°C. Permeate flux rates were almost four times greater at 45°C than at 15°C with both small and large pore membranes.

Yan et al. (104) demonstrated the technical feasibility of concentrating and fractionating whole milk by ultrafiltration using portable units for on-farm use. Whole milk concentrate containing 21.5% total solids and 8.6% protein were prepared. This study indicated on-farm ultrafiltration of whole milk prior to cheese making reduced storage, refrigeration, and transportation requirements by 50 to 70%. A spiral wound UF module has been used to concentrate fresh pasteurized homogenized whole milk. Although milk fat lowered the permeate flux below that achieved with skim milk, it did not cause severe membrane fouling that would exclude the applicability of UF to whole milk. Ultrafiltration of milk on the farm was reported by Slack (88); milk volume reductions of one-half to two-thirds by ultrafiltration on-farm were feasible technologically and economically if milk volume per farm was sufficiently large and consumption of UF permeate by cows was equivalent to or greater than quantities generated by ultrafiltration.

Standardizing protein in milk is feasible through protein adjustment by ultrafiltration over a relatively broad range without detectable organoleptic consequence (76). The introduction of protein standardization is gaining favor because many foods now require protein fortification as a result of demand and price of individual food constituents having changed to favor high protein content (76). Concentrate prepared by ultrafiltration was found to be more heat-stable than that prepared by conventional evaporation. It was suggested that a novel range of sterile milk products could be prepared from ultrafiltration concentrate because of the high protein and low lactose content of the concentrate. These products might be nutritionally more attractive than those prepared from conventional concentrates (65).

The best temperature for storage of ultrafiltrate of raw skim milk (concentrated to 19% T.S.) has been shown by Garcia-Ortiz et al. (35) to be $4^{o}C$. Acidity development with concentrate milk was negligible after 2 days at $12^{o}C$, 4 days at $7^{o}C$, or 6 days at $4^{o}C$. Thereafter, the acidity development became more rapid than in nonconcentrated skim milk. They also found the increase in noncasein nitrogen during storage to be markedly less in the UF concentrate than in the original skim milk. The liquid retentate prior to starter and rennet addition can be frozen and stored for several months at -30°C or can be dehydrated and held for long periods without change in quality or performance. Either form can be used for the production of new high protein foods destined to help alleviate food shortages in developing countries (47).

Preparation of Various Types of Cheese with Ultrafiltration

Ultrafiltration of milk for cheese making was extensively employed on an industrial scale (109,000 metric tons) by 1981. Fresh and soft cheeses were made through this process, but the main application of UF in the cheese industry was for Feta cheese (83,460 metric tons in 1981) (64).

A French scientist discovered (61) fine quality fresh and ripened cheese could be made continuously or batchwise by the ultrafiltration of milk and milk products. A liquid product with the same composition as a cheese can be obtained by ultrafiltration of milk under appropriate conditions. After renneting and addition of starter, soft, fresh, or ripened cheeses have been prepared successfully from the precheese concentrate. Both cows' and goats' milk have been used as starting material. Preparation of a liquid precheese offers advantages compared to the standard process in which rennet is added to cheese milk. These include an increase in yield due to retention of soluble protein in the curd, better adjustment of the weight of each cheese, use of much less rennet, less space for equipment and handling, and whey with a lower biological oxygen demand (BOD) than normal whey

(47, 61).

Mann (56) reviewed recent developments in the use of ultrafiltration in the manufacture of cheese, including quarg, white pickled cheese, Camembert, Swiss, brie, Mozzarella, and a processed cheese base. Increases in cheese yields, up to 30% in the case of quarg, were claimed to be achieved when using ultrafiltration (56). It was reported ultrafiltration before fermentation retained all the protein and resulted in increases in cheese yields. However, the product had unacceptable organoleptic properties, mainly because casein-bound calcium was released as the pH declined during fermentation. This calcium was lost in the whey during traditional quarg manufacture. However, when UF concentration was carried out to a protein content of 12% with milk partially fermented to a pH of 5.7 to 5.9 followed by fermentation of the retentate to pH 4.5, a product was obtained which was almost indistinguishable from quarg produced by the conventional method.

Semisoft and Soft Cheeses With UF

As noted before, following ultrafiltration more cheese is produced from a given volume of milk as α-lactalbumin and β-lactoglobulin are retained after coagulation in the retentate. A report of Camembert cheese (47) being made by ultrafiltration indicated cheese yield was increased 15%. In making goats' milk Camembert cheese, even more yield was realized (47) as the proportion of lactalbumin and lactoglobulin to casein is higher in goats' milk. Skim milk retentates from ultrafiltration were used in combination with cream (67% fat) to prepare a liquid precheese mixture which with the addition of rennet, lactic starter culture, and spores of the mold, Penicillium candidum, was transformed readily into Camembert cheese upon ripening. It was observed that yield increased from the retention of soluble milk proteins, and the amount of rennet could be reduced in comparison to the conventional Camembert process (47).

Rash and Kosikowski (79) studied the behavior of an enteropathogenic E. coli (EEC) serotype in Camembert cheese made from ultrafiltrated milk. It was observed UF cheese milk mixture resulted in greater E. coli survival and growth in Camembert cheese than occurred in the Camembert cheeses made conventionally (79).

A method for the production of Domashii cheese employing ultrafiltration involved pasteurization of skim milk at 72 to 74°C with 18 to 20 sec holding; ultrafiltration at 50 to 55°C; incubation and coagulation of concentrated (6.0 ± 2%) protein with a starter, rennet, and $CaCl_2$; cutting the coagulum at pH 4.7 to 4.8; and addition of 20 to 30% water (in relation to the weight of the concentration). Scalding was done at 44 to 46°C (12). The successful manufacture of Domiati cheese from ultrafiltered buffalos' milk has also been reported (1).

In a study of Ricotta cheese, about 40 kg of cheese milk per hour per m^2 of membrane were ultrafiltrated at 30°C until the required composition for Ricotta cheese was obtained. At 55°C, this rate was increased to approximately 60 kg per hour per m^2 membrane. Precipitation of liquid precheese occurred quickly at 78 to 80°C and texture quality of the resulting cheese was similar to that of traditional Ricotta cheeses. The flavor and texture of the cheeses obtained by ultrafiltration and heat treating the liquid precheese at optimum pH and temperature were preferred to fresh commercial Ricotta cheese by 70% of the persons on a taste panel. Shelf-life was at least 9 wk at $4^{o}C$ for hot pack containers of Ricotta cheese produced by ultrafiltration. It was suggested if the product were produced in a closed contaminant free system, this might lead to an even longer shelf-life (63).

Pasteurizated skim milk batches were concentrated by ultrafiltration in an Abcor UF 22S unit at $50^{o}C$ to a maximum of 27.6% solids (18). The UF retentate was standardized with 67 to 69% fat cream and with permeate or water to give a mixture complying with cream cheese standards. This standardized mixture was inoculated with lactic acid cultures and processed into hot pack cream cheese according to industrial practices. The resulting cheese showed excellent shelf-life and smoothness comparable with standard commercial cream cheese, but it had much greater hardness of body. Some advantages observed were: greater efficiency in the utilization of milk solids, flexibility of standardization, and elimination of the whey draining step. It was suggested that active cultures were necessary to achieve the proper pH because slower cultures showed difficulty in overcoming the strong buffering capacity of the hot pack cream cheese retentate (18).

Mozzarella type cheeses prepared with retentate from diafiltration displayed good to excellent flavor and body. The cheeses stretched satisfactorily after 24 h at $5^{o}C$ and improved for up to 4 wk.

Meltdown of cheese 1 day old was relatively unsatisfactory, but meltdown improved significantly after 4 wk at 5°C. Cheeses of pH 5.1 gave better meltdown than those of pH 5.2 (20). Mozzarella cheese displayed a greater potential for being made by ultrafiltration than did Cheddar cheese made from ultrafiltrated milk (53). The yield of medium soft cheese was 41% greater than that made from normal whole milk and production time was half that of the normal process (38).

Process Cheese Made With UF

An effective method for producing process Cheddar cheese utilizing plain and enzyme treated retentate was studied by Sood and Kosikowski (89). Raw skim milk, selectively ultrafiltrated at 60°C was mixed with plastic cream, pasteurized, and homogenized. It was then blended in a Hobart mixer with ripened Cheddar cheese. The solids were adjusted with freeze dried retentate and it was then processed at 75°C for 10 min. The product, containing up to 40% retentate, was as acceptable as commercial process cheese. At 80% retentate substitution, process cheese showed an undesirable long-grain texture and bland flavor.

Retentate containing small amounts of added fungal protease and lipase preparation was stored at 45°C for 24 h then made into good quality process cheese (89). Up to 60% enzyme-treated retentate substitution improved flavor compared to commercial process cheese or to process cheese with 40% plain retentate. Double diafiltered retentate additions produced process cheese of poor melting qualities. Whole milk of normal pH or acidified to pH 5.7 was concentrated by ultrafiltration to 40% original milk weight, diafiltered at constant volume until a desired ratio of lactose to buffer capacity was established, concentrated by ultrafiltration to 20% original milk weight, and retentates were inoculated with cheese starter and incubated to ferment the residual lactose completely. Fermented retentates were converted to cheese base in a swept surface vacuum pan evaporator. The product, which is a potential replacement for the immature natural cheese component of processed cheese blends, had the same pH and gross composition as Cheddar cheese. It also had good flavor and stability but lacked normal cheese body and texture characteristics. This process gave cheese base yield 16 to 18% greater than could be expected from a conventional cheese making process. Unacidified milk offered process advantage compared with pH 5.7 milks (30), but the products were similar in quality. A blend of 80% base curd and 20% aged Cheddar cheese produced good flavor process cheese and process cheese food. The body of the process cheese was excessively firm, but that of the process cheese food was satisfactory (30).

Cheddar Cheese With UF

A retentate produced by the ultrafiltration of milk was studied (97) in relation to its coagulation by rennet. Retentate were produced by concentrating whole milk 4.8 fold at 50°C in a batch UF plant. After rennet addition, the retentate viscosity fell slightly at first and then rose as in non-concentrated milk. The rate of k-casein cleavage was linear with time until approaching clotting time, and clotting thus occurred with less k-casein cleavage than in non-concentrated milk. It was determined that the firmer the coagulum when it was cut, the higher the moisture content of the resulting curd. The relationship between curd firmness value and moisture content was linear. Using .1% rennet addition, the earliest time at which the coagulum was firm enough to be cut was 10 min. The moisture level of the resulting cheese increased from 40 to 43%. The effect was pronounced when lower rennet levels were used (97, 98).

Skim milk was concentrated (20) selectively by various types of ultrafiltration to the maximum amount of protein normally present in Cheddar cheese and freeze dried. Later, thawed retentates were blended in various combinations to give precheese mixtures of 60.5% total solids and converted into Cheddar cheese by the method described by Covacevich and Kosikowski (20). Retentate made by a single diafiltration and homogenization gave the most acceptable Cheddar cheese of various ultrafiltration treatments but even this cheese was crumbly and corky in body and lacked typical cheese flavor when compared to conventionally made Cheddar. In fresh cheese, volatile fatty acids and soluble nitrogen were higher in cheese made by ultrafiltration; but during ripening, they lagged behind the control (20).

Sutherland and Jameson (93) concentrated whole milk 4.8 fold by ultrafiltration with systematic variation of lactose and mineral levels achieved by adjustment of level of diafiltration and the milk pH. The retentate was converted to Cheddar cheese by a procedure based on conventional Cheddar cheese manufacture. This yielded cheeses which resembled conventionally made Cheddar. There were small volumes of protein-enriched whey. The cheeses had normal fat level, slightly elevated moisture level, and widely varying pH, calcium (Ca), phosphorus (P), lactose, and lactate levels. Calcium lactate crystals were evident at maturity in cheeses made without diafiltration. The Ca and P levels in cheeses were highly correlated with their level in the retentate, while cheese moisture levels were inversely correlated with Ca and P levels. In organoleptic grading, some of the cheeses were considered to be acceptable as Cheddar cheese. It was suggested (93) that for the manufacture of Cheddar cheese by this method, ultrafiltration of whole milk should be carried out at pH 6.2 to 6.4 with sufficient diafiltration to yield retentate containing 3.3% lactose. When Cheddar cheese was made (57) from milks which were prepared at 1.7 to 4 fold the initial concentration by combining cream with skim milk concentrated with ultrafiltration, it was observed that starter growth was unaffected; but the increased buffering capacity in the more concentrated milk resulted in a slower decline in pH and higher pH value in cheese. Curd formation was faster despite the use of reduced amounts of rennet (57).

With milk concentration more than two fold, large amounts of fat were lost in the whey (57); so the cheese had less fat than normally. Fat losses may have been partially related to the lower degree of aggregation of the casein micelles when the curd was cut. As the concentration factor of the milk increased, the rate of casein breakdown, the intensity of Cheddar flavor, and the levels of H_2S and methanethiol in the cheese decreased.

The concept of Maubois, Mocquat, and Vassal (MMV) was applied (61) to Cheddar, Mozzarella, and cottage cheese by Covacevich and Kosikowski (20). Mozzarella cheese was produced satisfactorily but Cheddar and cottage cheese proved too difficult to make properly and satisfactorily (48, 53). This problem was overcome by fortifying a normal precheese retentate (51) with water and fresh pasteurized heavy cream. Reconstituted creamed retentates of ultrafiltration were converted to ripened cheese by Cheddar manufacturing principles. Initially, the fresh cheeses resembled normal Cheddar but during ripening they were transformed into Gouda-Swiss types with pH rising rapidly from 5.2 to approximately 6.8. As total milk solids increased in reconstituted retentates, cheese moisture decreased and cheese volume rose to provide high yield. Cheese yields observed were 1.21 to 1.32 kg cheese per kg total solids. Rennet curd of higher total solids retentate formed more rapidly than normal, and curds were hard.

Cottage Cheese With UF

Cottage cheese manufacturing practices greatly influence its yield, as well as consistency and texture (24, 26, 29, 39, 46, 70, 99, 102). Emmons et al. (27) studied the influence of total solids, amount of rennet, and pH at cutting on curd firmness. Randolph and

Kristofferson (78) observed continued holding of the curd at 48.9°C (120°F) resulted in significant firming; and increased retention of cream dressing resulted in a decreased curd firmness (26). The firmness of the curd particles influences creaming of dry cottage cheese curd and subsequent retention of the cream (26). The yield of cottage cheese curd from skim milk in which more than 80% of the lactose had been hydrolyzed by using β-galactosidase (Maxilact) was compared to yield from untreated skim milk. There was no significant difference in yield of curd from the untreated skim milk versus the lactose hydrolyzed skim milk. There were no significant differences in mean setting times and organoleptic qualities of the cottage cheese (32).

Cottage cheese was made from skim milk retentates (13% TS) which were obtained by ultrafiltration of skim milk at 4.6°C, 21°C, and 49°C. Large curd creamed cottage cheese was prepared successfully from each retentate. Cooking temperature and/or time needed to be reduced because of initially firm curd. With two fold concentrated retentate, unmanageably large amounts of curd were produced per unit volume. This led to localized over heating and difficulties in agitation. This process also resulted in a tougher curd. Microbiological analyses in this study indicated that ultrafiltration in the range of 20 to 25°C was undesirable. High temperature (50 to 55°C) processing gave high permeate flux rate and bacterial growth was inhibited in this temperature range, although precautions would be necessary to avoid accumulation of thermophilic species (60).

Covacevich and Kosikowski (19) also explored the possibilities of making cottage cheese with retentates of maximum protein concentration (15%) obtained by direct ultrafiltration, single and double diafiltration, and simultaneous fermentation with or without diafiltration. The flavor of cottage cheeses made from single layer cooked retentate obtained by diafiltration with simultaneous fermentation approached those conventionally manufactured; but the curd was uniformly smooth and tough, displayed a gelatin like quality, and was capable of minimum dressing absorption. Cottage cheese from the retentates of high protein concentration displayed consistently lower scores for color and general appearance. It was predicted from this study (19) future success of making cottage cheese from skim milk concentrated retentate will depend upon solving problems of cooking curds and developing proper texture and cream absorption.

Kosikowski (52) studied characteristics of cottage cheese made from skim milk retentates concentrated approximately 6.5:1 by ultrafiltration and then reconstituted with water or permeate to mixtures of 3.1 to 5.2% and 3.56 to 7.08% protein, respectively, before converting into cottage cheese. The resulting cottage cheeses displayed good to excellent flavor and generally soft body and smooth textures. Total solids, fat, protein, and ash of cottage cheeses increased with total protein of the cheesemaking mixtures. Thirteen to 23.0 kg uncreamed cottage cheese were obtained per 100 kg reconstituted skim milk retentate mixture, and cheese yields efficiency ranged from 3.9 to 4.7 kg cheese/kg total protein. Whey from cottage cheese made from retentate which had been reconstituted with skim milk contained 6.2 to 7.5% total solids, whereas with water-reconstituted retentate the whey contained 1.94 to 2.9% total solids. It was observed when whey protein levels in the mixture rose beyond 4.5%, the curd became tough and more difficult to cut smoothly.

Ultrafiltration of skim milk through an appropriate membrane produced a retentate which could be converted into cottage cheese with appropriate bacterial cultures; and the permeate could be used in cottage cheese cream dressing. Creamed cottage cheese contains about 35% dressing and 70% of this dressing can be sweet permeate. For every 45.4 kg of creamed cottage cheese made, 13.2 kg of it can be sweet permeate. In such an application, about 91 million kg of sweet permeate could be utilized in the U.S.A. annually (105).

Legal Composition of Cottage Cheese

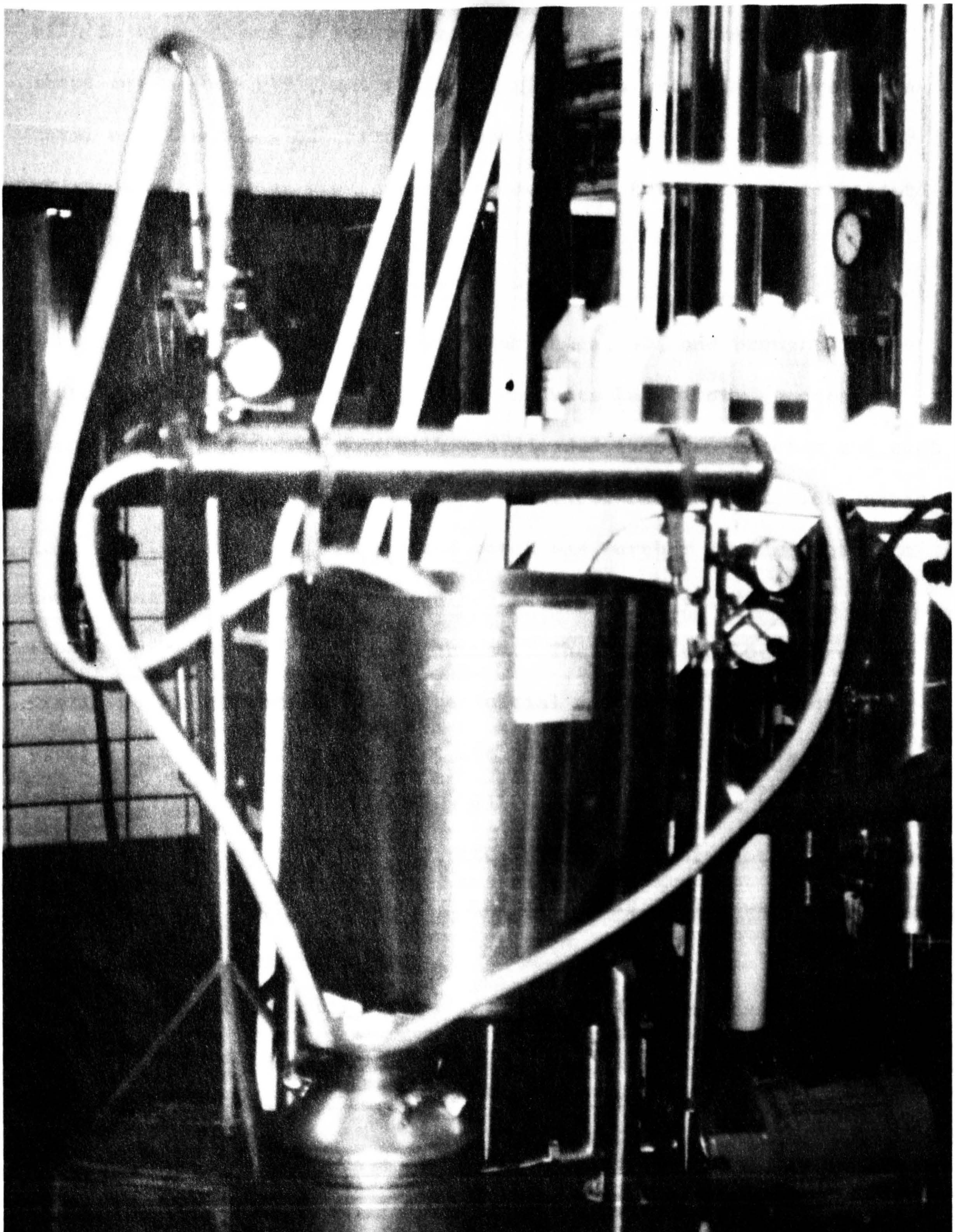
By Federal and South Dakota standards, cottage cheese may be made from sweet skim milk, concentrated skim milk, and/or nonfat dry milk. The finished cottage cheese must not contain more than 80% moisture. If creamed, it must contain not less than 4% by weight of milk fat. Lowfat creamed cottage cheese may contain 1% or 2% milk fat if so labelled (49).

MATERIALS AND METHODS

Experimental Procedure

Two preliminary trials on manufacturing of cottage cheese from ultrafiltrated skim milk were performed before conducting the main research. The skim milks were concentrated by ultrafiltration (UF), using an Abcor Sprial Wound UF Model 1/1 Sanitary Pilot Plant Unit as shown in Figure 1 (81). Permeates were removed in the amount of 50 and 67% of the initial weight of the skim milk at 50^{o}C. Inlet pressure on the membrane system was maintained at 2.8 kg/cm^{a} (40 psi) and outlet pressure at 1.4 kg/cm^{2} (20 psi) [i.e., (inlet pressure + outlet pressure)/2 = 2.1 kg/cm^{2} (30 psi)]. Ultrafiltration concentrated skim milks were then converted into cottage cheese. A conventional short set procedure (49, 103) for making cottage cheese was used. In each case (50 and 67% concentration), the coagulum produced was difficult to cut smoothly. The resultant curds were also difficult to manage and stir properly during cooking. The curds had gelatin-like characteristics and rubbery texture. The absorption of creaming mixture into the curds was slower and/or less in amount and the resulting flavor was different than that of cottage cheese produced from unconcentrated skim milk. Because of these results, it was elected to use 1.5 and 1.75 fold concentrations for the main research. The Pilot Plant UF Unit was used to remove 25% (UF 25%) and 33% (UF 33%) of the weight of skim milk as permeate at 50^{o}C, maintaining an average system pressure of 2.1 kg/cm^{2} (30 psi) on membranes. Cottage cheese was made in two 208 liter pilot plant vats with unconcentrated skim

Figure 1. Abcor Spiral Wound UF Model 1/1 Sanitary Pilot Plant Unit.

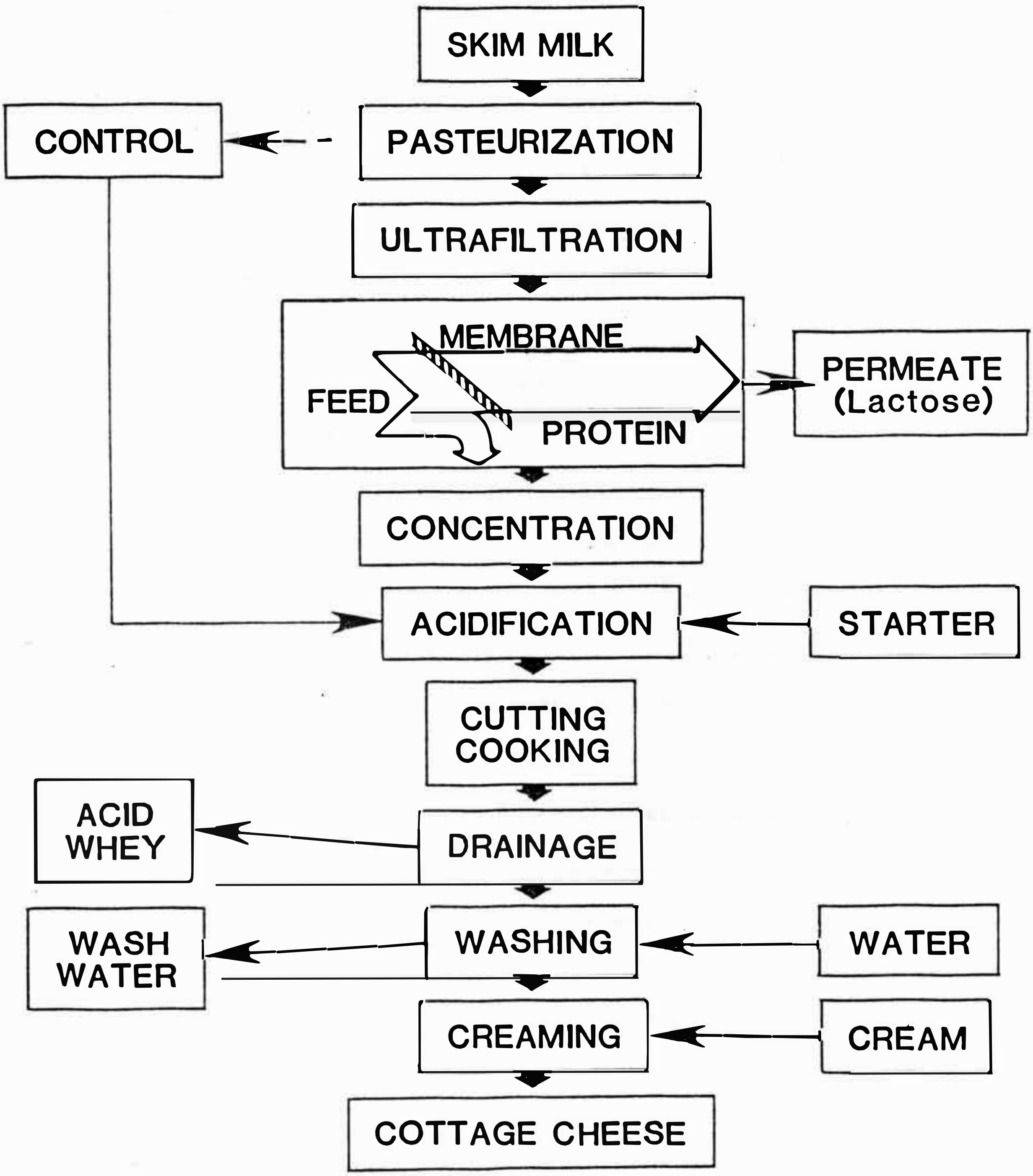


milk in one vat and UF concentrated skim milk in the other, using a short set method (49), and following the steps shown in Figure 2. A total of 32 batches of cottage cheese were made during a period of 8 wk, four batches per week, to get enough data for meaningful statistical analyses of results.

Raw fresh skim milk (540 kg) for this study was obtained each week from Land O'Lakes' dairy plant at Volga, SD, and brought to the South Dakota State University Dairy Products Laboratory (processing plant). The 540 kg of skim milk was divided into two batches and each pasteurized at 63°C for 30 min in a 400 liter Dairy Craft, Inc. stainless steel vat. Each pasteurized batch was further divided into two lots. One lot of each batch was cooled immediately and stored at 2 to 3°C until made into cottage cheese. The other two lots were ultrafiltrated to remove 25% of the initial weight (1.5 fold concentration) as permeate from the first lot and 33% of the initial weight (1.75 fold concentration) of skim milk as permeate from the second lot. After ultrafilration, UF concentrated skim milks were cooled to 4°C, transferred into sanitized 37.8 liter milk cans, which were labelled as to contents, and also stored at 2 to 3°C.

Manufacturing of the cottage cheese was initiated by transferring 100 kg unconcentrated skim milk into one vat and an equal amount of UF-concentrated skim milk (retentate) into the other vat. Alternating the type of milk used on a given day in each vat avoided errors favoring any single treatment due to operator fatique or characteristics of an individual vat. The temperature of the milk

Figure 2. Flow diagram of milk treatment and cottage cheese manufacture.


SKIM MILK
CONTROL
PASTEURIZATION
ULTRAFILTRATION
MEMBRANE
FEED
PROTEIN
PERMEATE (Lactose)
CONCENTRATION
ACIDIFICATION
STARTER
CUTTING COOKING
ACID WHEY
DRAINAGE
WASH WATER
WASHING
WATER
CREAMING
CREAM
COTTAGE CHEESE

in each vat was adjusted to 32.2°C. Bulk starter culture obtained from Nordica International via a truck from Terrace Park Dairy, Sioux Falls, SD was added to the vats at the rate of 3% of the weight of milk in a vat and mixed thoroughly with the milk. Before adding the starter, 2.9 g calcium chloride (.003%) was mixed into the milk in each vat. After 30 min, .25 ml [1 ml per 455 kg (1000 lb)] single strength rennet extract (Rennet Extract, Marschall Division, Miles Laboratories, Madison, WI) diluted with 25 ml water was thoroughly stirred into the inoculated skim milk in each vat. Vats were then covered and the contents allowed to remain undisturbed for about 3.5 h. Samples were then taken 10 to 15 cm (4 to 6 in) below the surface of coagulum with sterile pipets periodically and tested for pH and titratable acidity. Titratable acidity values were not satisfactory as a measure of acid development because of the higher protein content of the retentates and so were not used to determine cutting point. Instead, an ORION Research Digital ionalyzer/501 was used to measure pH which was used as a criterion for the time for cutting the coagulum. The curds of unconcentrated skim milk (control) were cut at pH 4.6 to 4.65; while the curds of UF-concentrated milks were cut at pH 4.7 to 4.75. Cutting of the coagulum began with a lengthwise cut with the horizonal knife, followed by a lengthwise cut with the vertical knife, and was finished with crosswise cuts with the vertical knife. The curd was allowed to sit undisturbed for 15 to 20 min to heal. The curd was then cooked with the temperature of the product being raised at specific rates during 15 min periods: 2.8°C in the 1st 15 min, 4.4°C during the 2nd 15 min, 5.6°C during the 3rd 15 min, and 6.7°C per 15 min until completion of cooking. A manually operated stainless steel paddle facilitated stirring. Heating was accomplished by introducing water and steam into the water jacket of the vat in such relative amounts that the temperature of the blend promoted the prescribed rate of heating of product. The curd of UF-concentrated skim milks gave desirable firmness nad texture when heated to 52°C, whereas best curd properties resulted when the unconcentrated batches were heated to 57°C. Endpoint of cooking was determined by firmness of the curd after cooling several pieces of curd in 10°C water (96). Upon completion of cooking, the curd were held in hot whey approximately 20 min before partially draining the whey to the level of curd exposure. Stirring ceased 5 min prior to start of whey drainage to allow settling of curd fines. A stainless steel sieve inside the outlet allowed whey drainage with retention of the curd. Three cold acidified chlorinated washes followed. The cold acidified chlorinated water was prepared by acidifying water to pH 5 with phosphoric acid, adding chlorine to level of 10 ppm, and cooling to 3 to 4°C. The curd was allowed to remain 15 to 20 min in each wash water, then the water was drained to the level of the curd and the next wash water was added. After removing thelast washing, the curd was ditched and allowed to drain for 30 min, then curd was thoroughly mixed, sampled, and transferred into a 18.9 liter plastic container and weighed for yield determination. The curds were creamed at the rate of 67 parts of curd and 33 parts of dressing mixture containing 22.5% total solids (46). Creamed cottage cheeses were evaluated organoleptically as fresh and after 7 days of storage.

Sample Collection

Cheese milk, curd, and whey were sampled in duplicate and placed in 532 ml (18 oz) Whirl-Pak plastic bags. One set of samples was frozen and stored for later analysis while the other was used fresh for standard plate and coliform counts, total solids, and protein determination. Milk samples were taken from vats before adjusting the temperature to 32°C and before addition of any additive such as $CaCl_2$ and culture. Milk samples for standard plates and coliform counts were taken before and after ultrafiltration. Curd was mixed well after draining and representative samples were obtained. Drained whey was collected in 37.8 liter (10 gal) milk cans, stirred, and representative samples were obtained immediately.

Compositional Analysis

Total protein values in the milk and whey were determined according to the Association of Official Analytical Chemists (AOAC) Kjeldahl procedure (6). Casein and whey protein fractions were derived by Rowland's method (84). Analysis of curd proteins were conducted as with milk after blending 25.0 g curd with 75.0 g of .05 M sodium hydroxide in accordance with the procedure of Mickelson (66).

The Mojonnier procedures (6, 7) were used to determine fat and total solids of all stored milk, curd, and whey samples. Solids-not-fat (SNF) was calculated as difference between total solids and fat. Ash content was determined by the AOAC official method (6), using Vycor glass crucibles. The differences between the solids-not-fat and the sum of the total of proteins and ash were assumed to be lactose. Procedures in the APHA Standard Methods for Examination of Dairy Products (3) were used for the Standard Plate Count (SPC) and coliform counts in the products. The medium for coliform counts was violet red bile agar.

Expression of Cottage Cheese Yield

Yield data were calculated in three ways, as: 1) kg 20% solids curd per 100 kg skim milk, 2) kg 20% solids curd per kg skim milk solids, and 3) percent of initial skim milk solids recovered in the curd (69, 82). The first likely is the most used by cheesemakers; but, it does not consider differences in the composition of skim milk. The latter two are a better measure of the efficiency and feasibility of a given procedure.

Organoleptic Evaluation

The creamed cottage cheeses were organoleptically evaluated by members of the Dairy Manufacturing Faculty of South Dakota State University. The panel consisted of three to four experienced judges. All samples were evaluated when fresh and after 1 wk of storage.

Samples from the current week and those from the previous week were evaluated during a given judging session. Each sample had the same rate of creaming mixture added. Samples were numerically coded from 1 to 8 to prevent identification of which cottage cheese any given sample represented. The samples were evaluated for flavor, body and texture, and appearance and color; and the scores were recorded on American Dairy Science Association cottage cheese score cards (Appendix Figure 3). The flavor scores were based on 10 points for perfect flavor and 5 points for body and texture without defect. Flavor, body and texture, and appearance and color defects were indicated. The means of all scores from all the judges were compiled and coded onto a computer analysis sheet.

Statistical Analysis

Statistical analyses of the data utilized the least square analysis of variance for a two factor (ultrafiltrated milk and replication) design experiment (92).

RESULTS AND DISCUSSION

Cottage cheese manufactured from skim milk with 25% of its volume removed by ultrafiltration (UF 25%) was compared in yield and quality to cottage cheese manufactured from a portion of the same skim milk without ultrafiltration treatment, but using the same culture and environmental conditions. Similarily, skim milk concentrated by removing 33% of original volume by UF (UF 33%) was converted into cottage cheese which was compared in yield and quality with cottage cheese from unconcentrated skim milk from the same lot. However, the cheeses obtained from UF 25% and UF 33% were not compared to each other; rather, each pair of variables was considered separately.

Cheese Milk Composition

Variation in the solids content of skim milk usually accounts for variation in cottage cheese curd yields (15). The total solids contents of skim milk used in this study was higher than expected; for Spurgeon et al. (91) found the average SNF in South Dakota milk was 8.33% in contrast to 9.5% total solids contents of skim milk reported earlier (22, 44). The mean compositional values (average of eight replications) of skim milk used in this study are given in Table 4. The skim milk ultrafiltrated to remove 25% of its weight (UF 25%) and its unconcentrated control skim milk had total solids contents 9.74 and 8.91%, respectively. The total solids for UF 33% skim milk and its unconcentrated control skim milk were 10.38 and 9.02%. The unconcentrated skim milk (Control 1) contained 3.05% total protein,

TABLE 4. Composition of skim milk, unconcentrated or concentrated by ultrafiltration, used in the manufacture of cottage cheese.

Component	Control 1[a]	UF 25%[a]	SE[b]	Control 2[a]	UF 33%[a]	SE[b]
	(%)			(%)		
Total solids	8.91[c]	9.74[d]	.087	9.02[c]	10.38[d]	.037
Fat	.12[c]	.17[d]	.003	.13[c]	.19[d]	.009
SNF	8.97[c]	9.57[d]	.089	8.89[c]	10.19[d]	.040
Total protein	3.05[c]	3.97[d]	.033	3.14[c]	4.66[d]	.059
Casein	2.23[c]	2.91[d]	.026	2.24[c]	3.48[d]	.077
Whey protein	.83[c]	1.05[d]	.021	.90[c]	1.18[d]	.028
Lactose	5.05[c]	4.89[c]	.064	5.06[e]	4.70[f]	.079
Ash	.68[e]	.73[f]	.011	.69[c]	.82[d]	.013

[a]Means of eight replications.

[b]Standard error.

[c,d]Means for given treatment with different superscripts differ ($P<.01$).

[e,f]Means with different superscripts differ ($P<.05$).

[c,c]Means with same superscripts do not differ from each other.

2.23% casein, and .83% whey protein; and Control 2 contained 3.14% total protein, 2.24% casein, and .90% whey proteins. The protein contents in fresh skim milk were lower than values cited in earlier literature (42, 100), but they were typical for skim milk currently obtained during the summer months when the protein contents are usually the lowest (22, 91). Ultrafiltrated skim milk with 25% of its weight removed as permeate contained 3.97% total protein, 2.91% casein, and 1.05% whey proteins. Similarily, when skim milk from the same lot as Control 2 was concentrated with ultrafiltration by removing 33% as permeate (UF 33%), the total protein increased from 3.41 to 4.66%, casein protein increased from 2.24 to 3.48%, and whey protein increased to 1.18% from .9% whey protein in unconcentrated skim milk. Indeed, the data in Table 4 show that all the components of skim milk, including ash but excepting lactose were increased in concentration by removing permeate via UF. In UF-concentrated skim milks, ash contents were .73% (UF 25%) and .82% (UF 33%), respectively; these values were definitely higher than their controls which contained .68 and .69% ash, respectively. The ash contents in UF-concentrated milks were also higher than the normal ash content of .70% (100). These changes were in agreement with reports that in ultrafiltrated milk, the total solids, fat, total proteins, and ash contents were increased and lactose decreased (47, 51, 52, 93). The increase in the total solids, fat, SNF, total protein, casein, and whey protein, and even ash percent were found statistically significant ($P<.01$) in UF 25% skim milk; whereas decreases in lactose were nonsignificant. In case of UF 33% skim milk, increases in all components and decrease in lactose were significant (P<.01) when compared with values in the control of unconcentrated skim milk.

Curd Composition

Values for the composition of the cottage cheese curd produced in this study are shown in Table 5. The total solids of the curds obtained from skim milk ultrafiltrated to remove 25 or 33% of its weight as permeate (UF 25% and UF 33%) were significantly higher (P<.01) than those of cottage cheese from the respective control skim milks without ultrafiltration. The total solids of the curds produced in this study were 19.24, 20.96, 19.59, and 21.80%, which were similar to reported values for cottage cheese curd (52, 66, 75, 86, 100). Since the time and temperature of cooking and the resulting moisture were variable, a more meaningful comparison was possible by computing all components and yields to a 20% total solids basis. Fat contents of the curd obtained from UF-concentrated skim milks were significantly higher (P<.01) than fat percentages in cottage cheese curd from unconcentrated skim milks. Fat values were found to compare closely with usually published values (52, 58, 66, 100). The skim milk concentrated 25% with subsequent manufacturing into cottage cheese produced a curd containing higher protein (P<.05) (17.90%) and ash (.68%) than the curd obtained from unconcentrated skim milk, which contained 16.90% total protein, and .5% ash. Similarly, increase in total solids value from 19.59 to 21.80% were found in curd from UF 33%

TABLE 5. Composition of curd of cottage cheese manufactured with and without ultrafiltration of skim milk precursor.

Component[a]	Control 1[b]	UF 25%[b]	SE[c]	Control 2[b]	UF 33%	SE[c]
	(%)			(%)		
Total solids	19.14[d]	20.96[e]	.259	19.59[d]	21.80[e]	.293
Fat	.46[d]	.61[e]	.020	.49[d]	.74[e]	.013
SNF	19.54[d]	19.39[e]	.020	19.51[d]	19.26[e]	.013
Total protein	16.90[f]	17.90[g]	.245	16.90[f]	18.15[g]	.308
Lactose	2.14[d]	.82[e]	.237	1.98[d]	.23[e]	.307
Ash	.50[d]	.68[e]	.021	.62[f]	.88[g]	.034

[a]All curd components except total solids are calculated to a 20% total curd solids basis.

[b]Means of eight replications.

[c]Standard error.

[d,e]Means with different superscripts differ ($P<.01$).

[f,g]Means with different superscripts differ ($P<.05$).

skim milk. The differences were attributed to the higher content of the respective components in ultrafiltrated skim milks used for making cottage cheese. Conversely, lactose values were significantly ($P<.01$) lower in curd from skim milk which was ultrafiltrated. These results are in accord with reports total solids, fat, protein, and ash of cottage cheese curd increased with the increase of total solids in skim milk with ultrafiltration (20, 44, 47, 52). Higher levels of milk components, except lactose, which decreased, during ultrafiltration agreed with findings of Kosikowski (52) and other researchers (64, 93, 104).

Whey Composition

Average compositions of the cottage cheese wheys from the skim milk, with and without ultrafiltration, are shown in Table 6 with standard error of least square means. The wheys produced from UF 25% and UF 33% skim milks contained higher percentages of total solids (6.69 and 6.84%), total protein (1.11 and 1.29%), and ash (.70 and .76%) than did whey from their counterparts which were not ultrafiltrated. Percentages of total solids in whey from UF 25% were not significantly higher; whereas the total solids contents of wheys from UF 33% were significantly ($P<.01$) greater. Although wheys from ultrafiltrated skim milk contained more SNF and less lactose, the differences were not statistically significant; whereas significantly more total protein occurred in whey from UF 25% ($P<.05$) and UF 33% ($P<.01$) than in wheys from their respective control skim milks. The values

TABLE 6. Compositions of wheys from cottage cheese manufactured with or without ultrafiltration.

Component	Control 1[a]	UF 25%[a]	SE[b]	Control 2[a]	UF 33%[a]	SE[b]
	(%)			(%)		
Total solids	6.58[c]	6.69[c]	.085	6.60[c]	6.84[d]	.033
Fat	.02[c]	.02[c]	.002	.02[c]	.03[d]	.003
SNF	6.56[c]	6.67[c]	.138	6.58[c]	6.81[c]	.089
Total protein	.89[c]	1.11[d]	.034	.92[e]	1.29[f]	.031
Lactose	4.98[c]	4.86[c]	.119	4.99[c]	4.76[c]	.089
Ash	.69[c]	.70[c]	.013	.66[c]	.76[d]	.011

[a] Means of eight replications.

[b] Standard error.

[c,d] Means with different superscripts differ ($P<.05$).

[e,f] Means with different superscripts differ ($P<.01$).

[c,c] Means with same superscripts were not different from each other.

in Table 6 indicated with the increased total solids in ultrafiltrated skim milk, the resulting whey contained higher total solids and total protein and comparatively less volume than did wheys produced from unconcentrated milk. These results agreed with results of Kosikowski (47, 51, 52) who conducted studies on Cheddar cheese and cottage cheese after reconstituting highly concentrated retentate with water and permeate. The higher solids in whey produced from UF-concentrated milk would be beneficial if whey is to be dried or utilized in food product (52, 64), as compared to the whey which is produced by conventional methods and contains less solids (10, 50).

Cottage Cheese Yields

Average cottage yields are reported in Table 7 with standard error of least square means. Cottage cheese yields are commonly expressed as kg of 20% solids curd per 100 kg milk. However, this expression does not show how efficient the manufacturing procedure was in converting the solids available in the milk to cottage cheese. Therefore, yield is also expressed as kg 20% solids curd per kg of milk solids, and as percent recovery of milk solids. Together, the three methods of yields determination used serve to complement each other and provide a complete picture of the yield (55, 66, 82).

The potential yield of cottage cheese is directly related to the composition of the starting skim milk, particularly to the quantity of casein present (4). Accordingly, ultrafiltrated skim milks produced more kilograms of 20% solids curd per 100 kg ultrafiltrated

TABLE 7. Average yields of cottage cheese curd manufactured from skim milk with or without ultrafiltration[a].

Basis of yield computation[b]	Skim milk not ultrafiltrated	UF 25%[h]	SE[c]	Skim milk not ultrafiltrated	UF 33%[h]	SE[c]
kg 20% solids curd per 100 kg milk	14.76[f]	17.82[g]	.506	14.81[f]	19.23[g]	.240
kg 20% solids per kg milk solids	1.69[d]	1.84[d]	.063	1.65[f]	1.86[g]	.020
Recovery of milk solids into cottage cheese (%)	32.62[d]	35.43[e]	.673	32.41[f]	39.31[g]	.497

[a]Means of eight replications.

[b]Calculated to 20% solids curd.

[c]Standard error.

[d,e]Means with different superscripts differ ($P<.05$).

[f,g]Means with different superscripts differ ($P<.01$).

[d,d]Means with same superscripts do not differ (NS).

[h]25% or 33% of weight of skim milk removed by ultrafiltration.

skim milk than were yielded by the untreated skim milks; 17.82 versus 14.76 kg from UF 25% and its control skim milk, and 19.23 versus 14.81 kg from UF 33% and its control skim milk. Average percent recovery of milk solids into the curd were 35.43% from UF 25% skim milks and 39.31% from UF 33% skim milks, respectively. These recoveries were significantly (P<.01) greater than the percentages of solids recovered from their respective control skim milks. Ultrafiltrated 25% skim milks did not yield significantly more kilograms of 20% solids curd per kilogram of solids than the untreated skim milks, but UF 33% skim milks produced more (P<.05) on this basis than the non-ultrafiltrated controls.

To recapitulate and summarize, greater cottage cheese yields and recovery of milk solids as cottage cheese were obtained from skim milks which had been ultrafiltrated to remove 25% (UF 25%) or 33% (UF 33%) of their weight before they were made into cottage cheese. These benefits were significant (P<.01) by the three methods of calculation when UF 33% was the substrate. Yields of cottage cheese per 100 kg of substrate and percent recovery of solids as cottage cheese were significantly better from UF 25% skim milk than from its unconcentrated control; but differences in kilograms cottage cheese per kilograms of milk solids were not significant.

Yields of cottage cheese reported in this study (Table 7) compare very closely with those of Satterness et al. (86). The average yield of 17.82 kg 20% curd per 100 kg UF 25% skim milk; 14.76 kg curd per 100 kg milk from its control; and 19.23 kg 20% curd per

100 kg UF 33% skim milk were quite acceptable.

Wilster (103) reported that 14 to 16 kg 20% solids curd per 100 kg skim milk is satisfactory. Lundstedt (55) stated that 36 yr ago, 36% recoveries of milk solids in the curd were common. However, in 1973 a typical recovery of solids was 33%. Angevine (4) stated that yield factors of 1.7 to 1.75 kg curd per kilogram milk solids were difficult to obtain. The results shown in Table 7 reveal that the amount of cottage cheese curd obtained, calculated as kilograms 20% solids curd, rose almost proportionally to solids in the substrate when made from UF-concentrated skim milk with increase of total solids in the retentate up to 10.38%. There were satisfactory percentages of recovery of milk solids in curd during cottage cheese making from the UF-concentrated skim milks as compared with recoveries from unconcentreated milk. The results are in line with the results obtained by Kosikowski when making cottage cheese from reconstituted retentate (52).

Organoleptic Evaluation

A panel of three or four experienced judges evaluated the creamed curd produced each week. The flavor scores were based on a hedonic scale, 10 being a perfect score. Average score of flavor, body and texture, and appearance and color of fresh and 1 wk old creamed cottage cheese as assigned by the Dairy Science Department panel, using the American Dairy Science Association (ADSA) cottage cheese score card (Appendix Figure 1) are shown in Table 8. There were no significant differences (P<.01) between scores of the cottage cheese from UF 33% and its control fresh as well as after 7 days. However, statistically significant differences occurred in flavor scores of the fresh cottage cheese from UF 25% when compared with that from it control. In some UF batches, some foreign flavor was noticed by judges during evaluation. This foreign flavor may have penetrated into milk during ultrafiltration from the membranes of the ultrafiltration unit. Membranes of the ultrafiltration pilot plant unit have to remain wet in 200 ppm chlorinated solution between processing periods. The chlorine may have caused a foreign flavor in the UF cottage cheese curd. Statistical analysis of the flavor scores of 1 wk old cottage cheese showed that there were no significant differences between the flavor score of cottage cheese prepared from UF 25% and its Control 1. This may have been due to the volatilization of chlorine or the more complete absorption of the dressing mixture after a wk. There were no significant differences in scores for body and texture, and appearance and color of creamed cottage cheese obtained from UF-concentrated milks and the samples of creamed cottage cheese obtained from unconcentrated skim milks. The most common defect of "shattered curd" were noted in batches from unconcentrated skim milk and in some of creamed cottage cheese from UF-concentrated skim milk. This may hve been due to not cuttin the coagulum at exactly the proper pH. Slow and/or less aborption of creaming

TABLE 8. Mean scores of organoleptic evaluation of creamed cottage cheese manufactured from skim milk without and with ultrafiltration.

	Substrate			Substrate		
	Control 1[a]	UF 25%[a,h]	SE[b]	Control 2[a]	UF 33%[a,h]	SE[b]
	(fresh)					
Flavor	8.84[c]	8.13[d]	.104	8.48[g]	8.19[g]	.324
Body and texture	4.15[e]	4.84[f]	.078	3.94[g]	3.80[g]	.083
Appearance and color	4.04[g]	4.00[g]	.055	4.96[g]	4.03[g]	.069
	(after 7 days)					
Flavor	8.60[g]	8.54[g]	.184	8.70[g]	7.70[g]	.353
Body and texture	4.14[g]	3.92[g]	.186	4.00[g]	3.70[g]	.154
Appearance and color	4.06[g]	4.00[g]	.042	3.84[g]	3.92[g]	.108

[a]Means of eight replications.

[b]Standard error.

[c,d]Means with different superscripts differ (P<.01).

[e,f]Means with different superscripts differ (P<.05).

[g,g]Means with same superscripts do not differ from each other.

[h]Skim milks ultrafiltrated to remove 25% and 33% of weight, respectively.

mixture were also observed by the judges in creamed cottage cheese from concentrated skim milk. Cream separation was observed in freshly creamed cottage cheeses whereas no such criticism was pointed out in evaluations after a week. Overall, the quality of all the samples produced from UF-concentrated and unconcentrated milk was thought to be quite acceptable by judges. Over the extent of 8 wk of evaluation, the judges found no marked differences in curd quality and appearance between creamed cottage cheese produced by UF-concentrated skim milk and unconcentrated skim milk.

Microbiological Analysis

All the skim milk samples taken before and after ultrafiltration were cultured for standard plate counts and coliform counts. Samples of curd were also plated for coliform counts before mixing with the creaming mixture. The results are shown in Tables 9 and 10. The results revealed that total counts were comparatively lower in UF-concentrated milk as compared with their respective unconcentrated controls. Ultrafiltration for short time at higher temperature ($50^{o}C$) inhibited the bacterial growth and maintained sanitary conditions during processing and so helped to reduce the number of microorganisms. Such results were also found in similar studies of ultrafiltration of milk by other workers (60, 79, 80, 87).

Most of the samples of skim milk with and without ultrafiltration as well as the samples of the curd contained less than one coliform per gram. This indicated proper post-pasteurization sanitary

TABLE 9. Standard plate counts (SPC) of skim milk and coliform counts of skim milk and curd obtained from ultrafiltrated and non-ultrafiltrated skim milk.

Replication	Control 1[a] Skim milk SPC	Control 1[a] Skim milk Coliform	Control 1[a] Cottage cheese curd Coliform	UF 25%[b] Skim milk SPC	UF 25%[b] Skim milk Coliform	UF 25%[b] Cottage cheese curd Coliform
	— (colonies/ml) —		(colonies/g)	— (colonies/ml) —		(colonies/g)
1	1925	<1	<10	360	<1	<10
2	4800	<1	<10	4500	<1	30
3	5200	<1	<10	420	<1	<10
4	980	<1	<10	360	<1	<10
5	4800	<1	<10	800	5	180
6	1500	<1	<10	3320	<1	<10
7	30200	<1	<10	11400	3	150
8	1720	<1	50	1430	<1	<10

[a] Skim milk not ultrafiltrated.

[b] Skim milk reduced in weight 25% by ultrafiltration.

TABLE 10. Standard plate counts (SPC) of skim milk and coliform counts of skim milk and curd obtained from ultrafiltrated and non-ultrafiltrated skim milk.

Replications	Control 2[a]			UF 33%[b]		
	Skim milk		Cottage cheese curd	Skim milk		Cottage cheese curd
	SPC	Coliform	Coliform	SPC	Coliform	Coliform
	— (colonies/ml) —		(colonies/g)	— (colonies/ml) —		(colonies/g)
1	20200	<1	<10	10500	<1	<10
2	8000	2	50	4800	6	50
3	1400	<1	<10	300	<1	<10
4	2160	<1	<10	450	<1	<10
5	1550	<1	<10	12300	12	<10
6	7180	<1	<10	5360	<1	<10
7	18100	2	100	25300	4	30
8	1880	<1	150	1000	<1	<10

[a]Skim milk not ultrafiltrated.

[b]Skim milk reduced in weight 33% by ultrafiltration.

practices; preventing recontamination during the manufacturing processes resulted in low bacterial counts and usually products free from coliform organisms, although there were some coliform counts above the legal 10 per gram. It was not determined if these were Escherichia or Aerobacter.

Cheese Making Characteristics

Cottage cheeses were manufactured by short set methods as described by Kosikowski (49). Some modification and adjustments in the method were made to obtain acceptable quality of cottage cheese from UF concentrated skim milks. Times for cutting curds at optimum pH were not so variable. With UF-concentrated skim milks, the cutting time was 265 min, and with unconcentrated skim milks it was 250 min. However, the coagula of unconcentrated skim milks were cut at pH 4.6 to 4.65, whereas the coagula of UF-concentrated milks were ready to cut at pH 4.7 to 4.75. During manual cutting, more resistance was encountered with curd from UF-concentrated skim milk as compared to that without ultrafiltration. When cooking the curd at 52^{o}C, acceptable texture occurred more quickly with increasing total solids in the starting skim milk with ultrafiltration than with the curds obtained from unconcentrated skim milk, which were cooked to 57^{o}C to get the desirable firmness and texture of the curd. Small amounts of calcium chloride were also added to all batches to eliminate body softness, as mentioned by Kosikowski (52). The techniques were similar to those applied by Kosikowski (52) while manufacturing cottage cheese from retentate reconstituted with water and permeate.

SUMMARY

The objectives of this research were to study the possibility of increasing the yield of cottage cheese per unit of skim milk by concentrating the skim milk with ultrafiltration prior to cottage cheese making. An Abcor Spiral Wound UF Model 1/1 Sanitary Pilot Plant Unit was used to increase the total solids in the starting skim milk whilst removing some of the lactose and minerals that would normally go into the whey. Five hundred forty kilograms of fresh raw skim milk were divided into two batches which were pasteurized separately at 63°C for 30 min. Each batch was further divided into two lots after pasteurization. One lot of each batch was cooled immediately and kept as control. The other two lots were ultrafiltered at 50°C to remove 25 and 33% permeate. After ultrafiltration, each lot was immediately cooled and stored at 4°C. During the subsequent 2 days, UF-concentrated and control skim milk were made into cottage cheese, using an ultrafiltrated skim milk and an unconcentrated skim milk in side by side 208 liter stainless steel vats. A total of 32 vats of cottage cheese were made to provide eight replications, using 100 kg ultrafiltrated or an equal volume unconcentrated skim milk per vat each time. The curds of ultrafiltrated skim milk were cut at pH 4.7 to 4.75 and gave a desirable firmness and texture when cooked to 52°C; whereas the normal skim milk batches were cut at pH 4.6 to 4.65 and cooked to 57°C for best curd properties. Compositional analyses performed on the milks,

curds, and wheys included tests for total solids, fat, total nitrogen, and ash. Noncasein nitrogen and whey nitrogen of milk were also determined. The cottage cheese yields were calculated as kg 20% solids curd per 100 kg skim milk, kg 20% solids curd per kg skim milk solids, and as percent recovery of skim milk solids.

Finally, creamed curd from each lot was evaluated 3 to 4 h after creaming ("Fresh") and 1 wk later by a panel of 3 or 4 experienced judges. The ADSA score card for cottage cheese was used for recording results of evaluations.

Specific Conclusions

1. Fat, total protein, and ash were retained and their concentrations increased in ultrafiltrated skim milks; this resulted in a higher total solids content. Conversely, lactose was removed to a marked extent.

2. Lower cooking temperature and less manufacturing time were necessary with UF-treated skim milk to preclude excess firmness and rubbery texture of the curd. Such reductions in manufacturing time and greater cottage cheese output per vat would result in more plant capacity.

3. When UF-concentrated skim milks, with 25 or 33% of the initial weight removed as permeate, were converted into cottage cheese curds, the yield of the curd was significantly ($P<.01$) increased above yields from like amounts of unconcentrated skim milk.

4. Creamed cottage cheese made from skim milk concentrated by removing 25 or 33% as permeate was equally acceptable on the basis of flavor, body and texture, and appearance and color when compared with cottage cheese from unconcentrated skim milks.

5. Calculations done subsequently to writing previous sections of this thesis indicate in these trials losses of skim milk solids were excessive (up to 6%) in the ultrafiltration step because of retention of skim milk in the UF unit, stickage, and transfer spillage. In an operation of commercial volume, such losses would be relatively unimportant and more cottage cheese would be obtained from a given initial volume of skim milk if it were ultrafiltrated prior to being made into cottage cheese. Hence, the technique should be considered by commercial plants.

6. It seems probable more concentration of the skim milk than was used in this research would be feasible. More research is needed to develop best techniques and determine best concentration levels for use of ultrafiltration of skim milk for cottage cheese.

7. Accurate comparative cost and return figures need to be developed to guide a given dairy in deciding whether to use ultrafiltration as part of its cottage cheese making process.

REFERENCES

1 Abd-El-Salam, M. H. 1981. Manufacture of Domiati cheese from ultrafiltrated buffalo's milk. Egypt J. Dairy Sci. 9(2):151.

2 American Dry Milk Institute, Inc. 1961. Nonfat dry milk in manufacture of cultured buttermilk, cottage cheese, and dairy products. Bulletin No. 651, ADMI, Chicago, IL.

3 American Public Health Association. 1978. Standard methods for the examination of dairy products. 14th ed. Am. Publ. Health Assoc., Washington, DC.

4 Angevine, N. C. 1974. 1974 yields of cottage cheese. Cult. Dairy Prod. J. 9(2):9.

5 Angevine, N. C. 1976. Cures for some cottage cheese problems. Cult. Dairy Prod. J. 11(2):14.

6 Association of Official Analytical Chemists. 1980. Official methods of analysis. 13th ed. Assoc. Offic. Anal. Chem., Washington, DC.

7 Atherton, H. V., and J. A. Newlander. 1977. Chemistry and testing of dairy products. 4th ed. AVI Publ. Co., Westport, CT.

8 Beaton, N. C. 1979. Ultrafiltration and reverse osmosis in the dairy products industry -- An introduction to sanitary considerations. J. Food Prot. 42(7):584.

9 Bender, J. H., and S. L. Tuckey. 1957. Relationship between certain skim milk constituents and yield of cottage cheese. J. Dairy Sci. 47:713.

10 Bernstein, S., and P. E. Plantz. 1977. Ferments whey into yeasts. Food Engineering 49(11):74.

11 Bundgaard, A. G., O. J. Olson, and R. F. Madsen. 1972. Ultrafiltration and hyperfiltration of skim milk for production of various dairy products. Dairy Ind. 37(10):539.

12 Chagarovskii, A. P., and N. N. Lipatov. 1982. Production of Domashnii cheese from skim milk concentrate obtained by ultrafiltration. Molochnaya Promyshlennost 24(9):82. Abstracted <u>in</u> Dairy Sci. Abstracts 45(4):240.

13 Chandan, R. 1982. Can ultrafiltration give cheesemakers the cutting edge. Dairy Record 83(12):144.

14 Cooper, A. R. 1979. Ultrafiltrate membranes and applications. Pages 305-373 in Polymer Science and Technology, Volume 13, Plenum Press, New York and London.

15 Cordes, W. A. 1959. Factors affecting the yield of cottage cheese. J. Dairy Sci. 42:2012.

16 Coton, S. G. 1980. The utilization of permeate from the ultrafiltration of whey and skim milk. J. Soc. Dairy Technol. 33:89.

17 Covacevich, H. R., and F. V. Kosikowski. 1977. Skim milk concentration for cheese making by alternative ultrafiltration procedures. J. Food Sci. 42:1359.

18 Covacevich, H. R., and F. V. Kosikowski. 1977. Cream cheese by ultrafiltration. J. Food Sci. 42:1362.

19 Covacevich, H. R., and F. V. Kosikowski. 1978. Cottage cheese by ultrafiltration. J. Dairy Sci. 61:529.

20 Covacevich, H. R., and F. V. Kosikowski. 1978. Mozzarella and Cheddar cheese manufacture by ultrafiltration principles. J. Dairy Sci. 61:701.

21 Covacevich, H. R., and F. V. Kosikowski. 1979. Buffer, lactic fermentation, and rennet coagulation properties of skim milk retentates produced by ultrafiltration. J. Dairy Sci. 62:204.

22 Custer, E. W. 1979. The effect of milk composition on the yield and quality of cheese. II. The effect of breed. J. Dairy Sci. 62(Suppl. 1):48. (Abstr.)

23 Delaney, R. A. M., and J. K. Donnelly. 1977. Application of reverse osmosis in the dairy industry. Pages 417-443 in Reverse osmosis and synthetic membranes: theory, technology, and engineering. ed. Sourirajan, S. National Research Council of Canada, Ottawa.

24 Dunkley, W. L., and D. R. Patterson. 1977. Relations among manufacturing procedures and properties of cottage cheese. J. Dairy Sci. 60:1824.

25 Dybing, S. T., J. G. Parsons, J. H. Martin, and K. R. Spurgeon. 1982. Effect of sodium hexametaphosphate on cottage cheese yields. J. Dairy Sci. 65:544.

26 Emmons, D. B., and W. V. Price. 1959. A curd firmness test for cottage cheese. J. Dairy Sci. 42:553.

27 Emmons, D. B., W. V. Price, and A. M. Swanson. 1959. Tests to measure synersis and firmness of cottage cheese coagulum and their application in the curd making process. J. Dairy Sci. 42:866.

28 Emmons, D. B. 1960. Manufacture of cottage cheese. Can. Dairy and Ice Cream J. 39(7):21.

29 Emmons, D. B., and W. V. Price. 1960. Observations on creaming of cottage cheese. J. Dairy Sci. 43:931.

30 Ernstrom, C. A., B. J. Sutherland, and G. W. Jameson. 1980. Cheese base for processing a high yield product from whole milk by ultrafiltration. J. Dairy Sci. 63:228.

31 Evers, M. J. 1980, Reducing wastes in the modern product plant. Phase III. Cult. Dairy Prod. J. 15(3):15.

32 Fedrick, I. A., and D. B. Houlihan. 1981. The effect of lactose hydrolysis on the yield of cottage cheese curd. Austr. J. Dairy Technol. 36(3):104.

33 Fenton-May, R. I., C. G. Hill, and C. H. Amundson. 1971. Use of ultrafiltration/reverse osmosis system for the concentration and fractionation of whey. J. Food Sci. 36:14.

34 Fenton-May, R. I., C. G. Hill, C. H. Amundson, M. H. Lopez, and P. D. Auclaire. 1972. Concentration and fractionation of skim milk by reverse osmosis and ultrafiltration. J. Dairy Sci. 55:1561.

35 Garcia-Ortiz, R., J. Hardy, and F. Weber. 1980. Physicochemical aspects of the cold storage of concentrate obtained by the ultrafiltration of raw milk. Revue Laitiere Francaise, 384:17. Cited in (88).

36 Glover, F. A. 1971. Concentration of milk by ultrafiltration and reverse osmosis. J. Dairy Res. 38:373.

37 Glover, F. A., P. J. Skudder, P. H. Stothart, and E. W. Evans. 1978. Review of the progress of dairy science. Reverse osmosis and ultrafiltration in dairying. J. Dairy Res. 45:291.

38 Hellen, R. C. F., A. B. Valerce, F. A. Glover, and P. J. Skudder. 1974. Use of milk concentrated by ultrafiltration for making hard cheese, soft cheese, and yoghurt. J. Soc. Dairy Technol. 27(7):151.

39 Hinds, H. 1971. Cottage cheese curd washing and handling. Cult. Dairy Prod. J. 6(2):21.

40 Horton, B. S. 1982. Reverse osmosis and ultrafiltration today. Dairy Record 83(12):126.

41 Jelen, P. 1979. Physiochemical properties of milk and whey in membrane processing. J. Dairy Sci. 62:1343.

42 Jenness, R., and S. Patton. 1959. Principles of dairy chemistry. John Wiley and Sons, Inc., New York.

43 Jepsen, S. 1977. Membrane filtration in the manufacture of cultured milk products. Yogurt, ymer, and Camembert cheese. Cult. Dairy Prod. J. 12(3):14.

44 Jepsen, S. 1979. Membrane filtration in the manufacture of cultured milk products. Yogurt, cottage cheese. Cult. Dairy Prod. J. 14(4):5.

45 Kapsimalis, D. J., and R. R. Zall. 1981. Ultrafiltration of skim milk at refrigerated temperatures. J. Dairy Sci. 64:1945.

46 Kemp, A. R., and J. R. Schultz. 1979. Increasing cottage cheese profitability. Cult. Dairy Prod. J. 14(1):15.

47 Kosikowski, F. V. 1974. Cheese making by ultrafiltration. J. Dairy Sci. 57:488.

48 Kosikowski, F. V. 1975. The manufacture of Mozzarella and related cheese by ultrafiltration. Cult. Dairy Prod J. 10(4):15.

49 Kosikowski, F. V. 1977. Cheese and fermented milk foods. 2nd ed. Edwards Bros. Inc, Ann Arbor, MI.

50 Kosikowski, F. V. 1979. Whey utilization and whey products. J. Dairy Sci. 62:1149.

51 Kosikowski, F. V. 1980. Cheddar cheese from water reconstituted retentate. J. Dairy Sci. 63:195.

52 Kosikowski, F. V. 1982. Characteristics of cottage cheese from water and permeate reconstituted retentates. J. Dairy Sci. 65:1705.

53 Kosikowski, F. V. 1982. Getting top yield and the highest quality. Dairy Field 165(8):51.

54 Krasheninin, P. F., and N. F. Gorelova. 1977. Utilization of major milk constituents in the manufacture of Rossiioskii cheese. Trudy, Usesoyuznyi Novchnoissledovalel skii Institut Moslodel noi i Syrodel' noi Promyshlennosti No. 21:21-26, 105-106. Abstracted in Dairy Sci. Abstr. 41(12):7461.

55 Lundstedt, E. 1973. Calculation of yield of cottage cheese. Cult. Dairy Prod. J. 8(2):19.

56 Mann, E. J. 1982. Ultrafiltration of milk for cheese making. Dairy Ind. Intern. 47(12):11.

57 Margaret, L. G., F. A. Glover, E. M. W. Scurlock, R. J. Marshall, and D. S. Hatfield. 1981. Effect of use of milk concentrated by ultrafiltration on the manufacture and ripening of Cheddar cheese. J. Dairy Res. 48:334.

58 Marshall, R. T. 1971. The importance of solids-not-fat in the manufacturing of cottage cheese. Cult. Dairy Prod. J. 6(1):18.

59 Marshall, K. R., J. A. Kavanagh, and R. K. Doughty. 1976. Ultrafiltration of milk. New Zealand Dairy Res. Instit. Ann. Report 47:67.

60 Matthews, M. E., S. E. So, C. H. Amundson, and C. G. Hill, Jr. 1976. Cottage cheese from ultrafiltration of skim milk. J. Food Sci. 41:619.

61 Maubois, J. L., G. Mocquat, and L. Vassal. 1969. Procede de traitements duelait et des sous produits laitiers. French Patent No. 2052121. Cited in (68).

62 Maubois, J. L., and G. Mocquat. 1975. Application of membrane ultrafiltration to prepare various types of cheese. J. Dairy Sci. 58:1001.

63 Maubois, J. L., and F. V. Kosikowski. 1978. Making Ricotta cheese by ultrafiltration. J. Dairy Sci. 61:881.

64 Maubois, J. L., and G. Brule. 1982. Utilization of membrane technique for separation, purification, and fractionation of milk protein. Lait (1982) 62:484-510. Abstracted in Dairy Sci. Abstr. 45(3):211.

65 Maurice, S. A. W., and M. D. Donald. 1980. Effect of concentration by ultrafiltration on the heat stability of milk. J. Dairy Res. 47:327.

66 Mickelson, R. 1974. Factors affecting the yield of cottage cheese. Contribution 903. Dept. Dairy and Poultry Sci., Kansas State Univ., Manhattan.

67 Milk Industry Foundation. 1982. Milk facts. M.I.F., 910 Seventeenth Street, N.W., Washington, DC.

68 Mocquat, G. 1979. Present potential of ultrafiltration in cheese making. Page 611 in Paper No. 1979-79, Proceedings, First Biennial Marschall Int. Cheese Conf., Madison, WI.

69 Nielsen, V. H. 1974. Determining cottage cheese yield. Am. Dairy Rev. 36(5):36.

70 Olson, N. F. 1978. Essentials of cheese making. Effects of process variability on cottage cheese properties. Dairy Field 161(3):70.

71 Olson, N. F. 1980. Energy concern re-emphasized at Wisconsin dairy conference. Dairy Field 163(3):68A-68B.

72 Olson, N. F. 1980. Retaining whey protein in cheese. Dairy Field 163(5):74.

73 Pearson, A. M., and H. Saar. 1960. The manufacture of cottage cheese from dry skim milk. Can. Dairy and Ice Cream J. 39(1):53.

74 Pompei, C., P. Resmini, and C. Peri. 1973. Skim milk protein recovery and purification by ultrafiltration. Influence of temperature on permeation rate. J. Food Sci. 38:867.

75 Posati, L. P., and M. L. Orr. 1976. Composition of foods - Dairy and egg products. Raw, processed, prepared. Agric. Handbook No. 8-1, US Dep. Agric., Washington, DC.

76 Poulson, P. R. 1978. Feasibility of ultrafiltration for standardizing protein in milk. J. Dairy Sci. 61:807.

77 Price, W. V., A. M. Swanson, and D. B. Emmons. 1959. Recent developments in cottage cheese manufacturing procedures. J. Dairy Sci. 42:2005.

78 Randolph, H. E., and T. Kristofferson. 1961. Characteristics of commercial nonfat dry milk for cottage cheese. J. Dairy Sci. 44:833.

79 Rash, K. E., and F. V. Kosikowski. 1982. Behavior of enteropathogenic _Escherichia coli_ in Camembert cheese made from ultrafiltered milk. J. Food Sci. 47:732.

80 Rash, K. E., and F. V. Kosikowski. 1982. Influence of diafiltration, lactose hydrolysis, and carbon dioxide on enteropathogenic _Escherichia coli_ in Camembert cheese made from ultrafiltered milk. J. Food Sci. 47:733.

81 Robert, M. T., Jr. 1980. Customer-installed sanitary ultrafiltration system utilizing spiral-wound modules. Instruction Bulletin. Abcor, Inc., 850 Main Street, Wilmington, MA 01887

82 Ronald, R. 1980. Estimating and calculating cottage cheese yields. Am. Dairy Rev. 42(1):18A.

83 Rose, D., and H. Tessier. 1959. Composition of ultrafiltrates from milk heated at 80^{o}F to 230^{o}F in relation to heat stability. J. Dairy Sci. 42:969.

84 Rowland, S. J. 1938. The determination of nitrogen distribution in milk. J. Dairy Res. 9:42.

85 Sandine, W. E. 1975. Quality cottage cheese. Cult. Dairy Prod. J. 10(2):12.

86 Satterness, D. E., J. G. Parsons, J. H. Martin, and K. R. Spurgeon. 1978. Yields of cottage cheese made with culture and direct acidification. Cult. Dairy Prod. J. 13(1):8.

87 Short, J. L., M. E. Matthews, D. J. Stanley, and R. H. Fletcher. 1980. Performance characteristics of plate and frame system for ultrafiltration of separated milk. New Zealand J. Dairy Sci. Technol. 57:67.

88 Slack, A. 1981. Ultrafiltration of raw whole milk on the farm. M.S. Thesis, Univ. of Wisconsin, Madison.

89 Sood, V. K., and F. V. Kosikowski. 1979. Process cheddar cheese from plain and enzyme treated retentate. J. Dairy Sci. 62:1713.

90 Sood, V. K., and F. V. Kosikowski. 1979. Ultrafiltration of skim milk at high temperature. J. Food Prot. 42(12):958.

91 Spurgeon, K. R., J. J. Yee, and J. H. Martin. 1981. Selection of milk for maximum yield of cheese and other dairy products. Cult. Dairy Prod. J. 16(8):5.

92 Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York, NY.

93 Sutherland, B. J., and G. W. Jameson. 1981. Composition of hard cheese manufactured by ultrafiltration. Austr. J. Dairy Technol. 36:136.

94 Tompson, S. J., and J. M. DeMan. 1975. Concentration and fractionation of milk by ultrafiltration. J. Can. Inst. Food Sci. and Technol. 8(2):113.

95 Tuckey, S. L. 1959. Problems in cottage cheese production for 1959. J. Dairy Sci. 42:1246.

96 Tuckey, S. L. 1964. Properties of casein important in making cottage cheese. J. Dairy Sci. 47:324.

97 Vanleeuwen, H. J. 1982. Coagulation of renneted retentate. Page 457 in Brief Communications, Vol. 1 Book 1. XXI Int. Dairy Cong., Moscow.

98 Vanleeuwen, H. J. 1982. Factors affecting the synersis of rennet. Coagulated retentate. Page 458 in Brief Communications, Vol. 1 Book 1. XXI Int. Dairy Cong., Moscow.

99 Vasavanda, P. C. 1980. Objective measurement of cottage cheese texture. Cult. Dairy Prod. J. 15(3):8.

100 Webb, B. H., A. H. Johnson, and J. A. Alford. 1974. Fundamentals of dairy chemistry. 2nd ed. AVI Publ. Co., Westport, CT.

101 Whitaker, R. 1956. The selection and use of nonfat dry milk in manufacturing of cottage cheese. J. Dairy Sci. 39:231.

102 White, C. H., and B. W. Ray. 1977. Influence of heat-treatment and methods of acidification of milk on manufacture and properties of cottage cheese. J. Dairy Sci. 60:1236.

103 Wilster, G. H. 1980. Practical cheese making. 13th ed. OSU Bookstore, Inc., Oregon State Univ., Corvallis.

104 Yan, S. H., C. G. Hill, and C. H. Anderson. 1979. Ultrafiltration of whole milk. J. Dairy Sci. 62:23.

105 Zall, R. R. 1979. Cottage cheese waste. How to deal with it. Am. Dairy Rev. 41(12):70D-70L.

APPENDIX

APPENDIX FIGURE 1. American Dairy Science Association product score card for cottage cheese.

CONTEST

Date ____________ ADSA COTTAGE CHEESE SCORE CARD DISA______ Contestant No. ___

PERFECT SCORE	CRITICISMS	Sample No. 1	2	3	4	5	6	7	8	9	10	TOTAL GRADES
FLAVOR	CONTESTANT SCORE											
	GRADE SCORE											
	GRADE CRITICISM											
	ACID											
	BITTER											
NO CRITICISM 10	COARSE											
	FEED											
	FERMENTED/FRUITY											
	FLAT											
	FOREIGN											
	HIGH SALT											
	LACKS FINE FLAVOR (Diacetyl)											
NORMAL RANGE 1-10	LACKS FRESHNESS											
	MALTY											
	METALLIC											
	MUSTY											
	OXIDIZED											
	RANCID											
	UNCLEAN											
	YEASTY											
BODY AND TEXTURE	CONTESTANT SCORE											
	GRADE SCORE											
NO CRITICISM 5	GRADE CRITICISM											
	FIRM/RUBBERY											
	GELATINOUS											
	MEALY/GRAINY											
NORMAL RANGE 1-5	PASTY											
	WEAK/SOFT											
APPEARANCE AND COLOR	CONTESTANT SCORE											
	GRADE SCORE											
	GRADE CRITICISM											
NO CRITICISM 10	FREE CREAM											
	FREE WHEY											
	LACKS CREAM											
	MATTED											
NORMAL RANGE 1-5	SHATTERED CURD											
	SLIMY											
	SURFACE DISCOLORED											
	TRANSLUCENT											
	UNNATURAL COLOR											
PACKAGE	ALLOWED PERFECT IN CONTEST	X	X	X	X	X	X	X	X	X	X	
TOTAL	TOTAL SCORE OF EACH SAMPLE											
	TOTAL GRADE PER SAMPLE											

FINAL GRADE ________

RANK ________

TEAM RANK

CODE	GRADE
1	
2	
3	
TOTAL	
RANK	

APPENDIX TABLE 1. Composition of non-ultrafiltrated skim milks used to manufacture cottage cheese (Control 1 for UF 25%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Casein[a]	Whey protein[a]	Lactose[a,b]	Ash[a]
	(%)							
1	9.22	.15	9.07	3.29	2.43	.86	5.03	.75
2	9.00	.12	8.88	3.14	2.31	.83	5.12	.62
3	8.75	.09	8.66	2.96	2.16	.80	5.05	.65
4	9.07	.10	8.97	3.02	2.19	.83	5.36	.59
5	9.07	.13	8.94	3.05	2.18	.87	5.19	.70
6	8.61	.12	8.49	2.89	2.08	.81	4.78	.66
7	8.98	.15	8.83	3.12	2.34	.88	4.99	.72
8	8.60	.09	8.51	2.92	2.15	.77	4.84	.75
Average	8.91	.12	8.79	3.05	2.23	.83	5.04	.68

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 2. Composition of ultrafiltrated skim milks used to manufacture cottage cheese (UF 25%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Casein[a]	Whey protein[a]	Lactose[a,b]	Ash[a]
	(%)							
1	9.87	.22	9.65	3.98	2.99	.99	4.90	.77
2	9.62	.18	9.44	4.06	3.10	.96	4.71	.67
3	9.53	.12	9.41	3.89	2.76	1.13	4.83	.69
4	9.80	.15	9.65	3.98	2.88	1.00	4.97	.70
5	9.82	.18	9.64	3.83	2.72	1.11	5.11	.70
6	9.27	.16	9.11	3.81	2.74	1.07	4.49	.74
7	9.72	.20	9.50	4.13	3.11	1.02	4.88	.75
8	10.28	.12	10.16	4.05	2.95	1.10	5.24	.87
Average	9.74	.17	9.57	3.97	2.91	1.05	4.89	.74

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total solids - percent ash).

APPENDIX TABLE 3. Composition of non-ultrafiltrated skim milks used for manufacture of cottage cheese (Control 2 for UF 33%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Casein[a]	Whey protein[a]	Lactose[a,b]	Ash[a]
	(%)							
1	9.20	.13	9.07	3.26	2.36	.90	5.06	.75
2	9.04	.15	8.89	3.24	2.39	.85	5.03	.62
3	8.87	.09	8.78	3.12	2.22	.90	5.03	.63
4	8.92	.12	8.80	3.21	2.35	.86	4.97	.62
5	9.04	.16	8.88	3.00	2.07	.93	5.21	.67
6	8.68	.08	8.60	2.99	2.12	.87	4.85	.76
7	9.02	.13	8.89	3.05	2.14	.91	5.12	.72
8	9.35	.17	9.18	3.22	2.27	.95	5.18	.78
Average	9.02	.13	8.89	3.14	2.24	.90	5.06	.69

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 4. Composition of ultrafiltrated skim milk used to manufacture cottage cheese (UF 33%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Casein[a]	Whey protein[a]	Lactose[a,b]	Ash[a]
	(%)							
1	10.62	.25	10.37	5.18	4.11	1.07	4.37	.82
2	10.33	.19	10.14	4.50	3.39	1.11	4.97	.67
3	10.13	.13	10.00	4.43	3.10	1.33	4.82	.75
4	10.53	.17	10.36	4.57	3.49	1.08	5.03	.76
5	10.27	.28	9.99	4.73	3.57	1.16	4.37	.89
6	10.22	.12	10.10	4.50	3.17	1.33	4.70	.90
7	10.23	.20	10.03	4.44	3.20	1.24	4.71	.88
8	10.71	.22	10.49	4.92	3.77	1.15	4.66	.91
Average	10.38	.19	10.18	4.66	3.48	1.18	4.70	.82

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 5. Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%).

Replication	Total solids[a]	Fat[a,b]	Solids-not-fat[a,b]	Total protein[a,b]	Lactose[a,b,c]	Ash[a,b]
	(%)					
1	19.22	.47	19.53	16.61	2.55	.37
2	18.72	.45	19.55	15.37	3.93	.25
3	20.16	.47	19.53	18.08	.91	.54
4	18.53	.43	19.57	17.44	1.49	.64
5	18.77	.45	19.55	17.93	1.15	.47
6	19.30	.47	19.53	16.77	2.18	.58
7	19.51	.48	19.52	17.18	1.65	.68
8	18.91	.46	19.54	15.84	3.23	.48
Average	19.14	.46	19.54	16.90	2.14	.50

[a]Average of duplicate analyses.

[b]Adjusted to 20% total solids.

[c]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 6. Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%).

Replication	Total solids[a]	Fat[a,b]	Solids-not-fat[a,b]	Total protein[a,b]	Lactose[a,b,c]	Ash[a,b]
	(%)					
1	19.18	.51	19.49	18.05	1.03	.41
2	19.74	.51	19.49	18.38	.55	.56
3	22.38	.76	19.24	17.76	.75	.73
4	20.89	.62	19.38	18.08	.57	.73
5	22.11	.66	19.34	18.25	.38	.71
6	20.54	.61	19.39	17.70	.91	.78
7	21.88	.62	19.38	17.86	.70	.82
8	20.92	.59	19.41	17.12	1.64	.66
Average	20.96	.61	19.39	17.90	.82	.68

[a]Average of duplicate analyses.

[b]Adjusted to 20% total solids.

[c]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 7. Composition of curd resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%).

Replication	Total solids[a]	Fat[a,b]	Solids-not-fat[a,b]	Total protein[a,b]	Lactose[a,b,c]	Ash[a,b]
	(%)					
1	18.86	.45	19.55	17.05	1.92	.58
2	20.66	.51	19.49	15.81	3.30	.38
3	20.45	.54	19.46	17.80	.93	.73
4	19.61	.48	19.52	15.59	3.30	.63
5	19.03	.48	19.52	16.95	1.99	.58
6	19.93	.49	19.51	18.02	.80	.69
7	19.25	.53	19.47	18.32	.33	.81
8	18.90	.48	19.52	15.69	3.24	.59
Average	19.59	.49	19.51	16.90	1.98	.62

[a]Average of duplicate analyses.

[b]Adjusted to 20% total solids.

[c]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 8. Composition of curd resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%).

Replication	Total solids[a]	Fat[a,b]	Solids-not-fat[a,b]	Total protein[a,b]	Lactose[a,b,c]	Ash[a,b]
	(%)					
1	21.81	.78	19.22	18.09	.34	.79
2	20.43	.71	19.29	18.36	.23	.70
3	21.66	.72	19.28	18.00	.50	.78
4	22.21	.75	19.25	18.31	.15	.79
5	21.59	.73	19.27	18.14	.13	1.00
6	22.47	.77	19.23	17.99	.10	1.14
7	22.74	.71	19.29	18.07	.15	1.07
8	21.45	.71	19.29	18.26	.27	.76
Average	21.79	.73	19.26	18.15	.23	.88

[a]Average of duplicate analyses.

[b]Adjusted to 20% total solids.

[c]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 9. Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 1 for UF 25%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Lactose[a,b]	Ash[a]
	(%)					
1	6.75	.03	6.72	.91	5.07	.74
2	6.61	.01	6.60	.78	5.23	.59
3	6.05	.02	6.03	.82	4.67	.54
4	6.55	.01	6.54	.83	5.01	.70
5	7.49	.02	7.47	1.06	5.63	.78
6	6.49	.01	6.48	.92	4.93	.63
7	6.42	.02	6.40	.98	4.67	.75
8	6.29	.01	6.28	.84	4.62	.82
Average	6.58	.02	6.56	.89	4.98	.69

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 10. Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 25%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Lactose[a,b]	Ash[a]
	(%)					
1	6.61	.04	6.57	1.11	4.72	.74
2	6.64	.02	6.62	.91	5.13	.58
3	6.59	.02	6.57	.97	5.00	.60
4	6.79	.03	6.76	1.03	4.97	.76
5	6.47	.01	6.46	1.30	4.49	.67
6	6.52	.02	6.50	1.10	4.79	.61
7	6.73	.03	6.70	1.05	4.88	.77
8	7.17	.02	7.15	1.37	4.93	.85
Average	6.69	.02	6.67	1.11	4.86	.70

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 11. Composition of whey resulting from the manufacture of cottage cheese from skim milk with no ultrafiltration (Control 2 for UF 33%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Lactose[a,b]	Ash[a]
	(%)					
1	6.69	.02	6.67	.87	5.07	.73
2	6.61	.01	6.60	.86	5.14	.60
3	6.61	.03	6.58	.91	5.02	.65
4	6.59	.02	6.57	.93	4.95	.69
5	5.83	.01	5.83	.77	4.48	.48
6	6.44	.01	6.43	.99	4.82	.62
7	7.02	.04	6.98	1.00	5.23	.75
8	6.99	.02	6.97	.99	5.20	.78
Average	6.60	.02	6.58	.92	4.99	.66

[a] Average of duplicate analyses.

[b] Percent lactose = percent solids-not-fat - (percent total protein + percent ash).

APPENDIX TABLE 12. Composition of whey resulting from the manufacture of cottage cheese from ultrafiltrated skim milk (UF 33%).

Replication	Total solids[a]	Fat[a]	Solids-not-fat[a]	Total protein[a]	Lactose[a,b]	Ash[a]
	(%)					
1	6.86	.06	6.80	1.28	4.79	.73
2	6.87	.03	6.84	1.21	4.96	.67
3	6.70	.04	6.66	1.14	4.74	.78
4	6.90	.02	6.88	1.08	5.07	.73
5	6.12	.01	6.11	1.52	3.79	.80
6	6.92	.02	6.90	1.37	4.78	.75
7	7.10	.06	7.04	1.20	5.04	.80
8	7.26	.03	7.23	1.51	4.87	.85
Average	6.84	.03	6.81	1.29	4.76	.76

[a]Average of duplicate analyses.

[b]Percent lactose = percent solids-not-fat - (percent total protein + percnet ash).

APPENDIX TABLE 13. Yields of cottage cheese made from skim milk with and without ultrafiltration.

Replication	Control[a]			UF 25%[b]		
	kg 20% curd/100 kg skim milk	kg 20% curd/kg skim milk solids	% recovery of skim milk solids	kg 20% curd/100 kg skim milk	kg 20% curd/kg skim milk solids	% recovery of skim milk solids
1	15.85	1.73	33.46	18.33	1.86	36.16
2	15.43	1.72	32.65	16.05	1.68	33.22
3	14.18	1.84	36.97	16.68	1.76	38.11
4	14.64	1.62	30.53	17.47	1.79	37.02
5	13.78	1.52	29.01	16.36	1.67	35.99
6	14.10	1.64	31.90	19.53	2.11	35.34
7	15.09	1.68	33.09	21.79	2.25	34.54
8	14.99	1.74	33.33	16.35	1.60	33.03
Average	14.76	1.69	32.62	17.82	1.84	35.43

[a]Skim milk not ultrafiltrated.

[b]Skim milk reduced in weight 25% by ultrafiltration.

APPENDIX TABLE 14. Yields of cottage cheese made from skim milk with and without ultrafiltration.

Replication	Control 2[a] kg 20% curd/100 kg skim milk	Control 2[a] kg 20% curd/kg skim milk solids	Control 2[a] % recovery of skim milk solids	UF 33%[b] kg 20% curd/100 kg skim milk	UF 33%[b] kg 20% curd/kg skim milk solids	UF 33%[b] % recovery of skim milk solids
1	16.60	1.82	34.97	22.29	2.11	44.99
2	15.52	1.72	35.20	19.98	1.95	39.54
3	14.48	1.63	33.16	19.05	1.89	39.98
4	14.74	1.65	32.51	18.55	1.77	38.31
5	14.16	1.57	30.25	16.98	1.66	35.14
6	13.08	1.51	30.09	18.25	1.79	39.02
7	15.54	1.73	33.48	19.17	1.88	39.75
8	14.37	1.54	29.59	19.63	1.83	37.75
Average	14.81	1.65	32.41	19.24	1.86	39.31

[a]Skim milk not ultrafiltrated.

[b]Skim milk reduced in weight 33% by ultrafiltration.