INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

University of Alberta

The Application of Ultrafiltration in the Manufacture of Cream Cheese

by

Hasan H. Salhab ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Food Science and Technology

Department of Agricultural, Food and Nutritional Science

Edmonton, Alberta

Spring 1998

National Library of Canada
Acquisitions and Bibliographic Services
395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale du Canada
Acquisitions et services bibliographiques
395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre reference

Our file Notre reference

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-28984-2

Canada

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled The application of ultrafiltration in the manufacture of cream cheese by Hasan Salhab in partial fulfillment of the requirements for the degree of Master of Science in Food Science and Technology.

Supervisor
Dr. Lech Ozimek
Associate professor

Chairman
Dr. Michael E. Stiles
Professor

Dr. Feral Temelli
Associate professor

Dr. Scott R. Jeffrey
Associate professor

Date:

In memory of my Great Aunt and paternal Grandparents who died while I was completing my degree and who were always proud of me

To my maternal Grandmother Najah

To my mother Nawal

To my aunts Siham and Hayat and their families

To my father Hani, two sisters: Daad and Nada, brother Adib and brother-in-law Jamal

To Dr. Fady I. Sharara and Madam Roula Sharara

To Dr. Nizar M. Dalloul and Madam Joumana Dalloul

To the future generation: Aya, Karim, Yasmeen, Tamara, Nazik, and the soon to be born baby (ies)

To all of you, I love you very much and I appreciate your strong support

Abstract

In the last two decades, the ultrafiltration (UF) process has proven to be successful in the dairy industry and particularly in cheesemaking. Ultrafiltration allows the concentration, separation and recovery of individual milk components. The application of UF process accounts for about 3 % of total world cheese production and it is postulated that this process contributes to higher cheese yield. An accurate assessment of the cheese yield produced by the traditional method as compared to the UF method in cream cheese making is crucial in the evaluation of milk component utilization and cheese production costs.

This research was conducted to manufacture cream cheese by traditional method from skim milk and from ultrafiltered skim milk (retentate) as a source of proteins and butter oil as source of fat. Research was carried out to determine and compare the cheese yields and milk component recovery (fat and proteins) in both methods.

In conclusion, the application of UF in recombined cream cheese making resulted in higher cheese yield by 14.5%. Total nitrogen (TN) and fat recoveries in UF cheese were higher by 12% and 6.5% respectively.

Acknowledgement

I would like to thank Dr. R. T. Hardin for his help during statistical analysis of the data. Also, I would like to thank Dr. M. E. Stiles for his help and support.

I am greatly in debt to the generous assistance of Dr. Nizar M. Dalloul for both his financial support and for treating me like a brother. Also, I cannot forget Dr. Fady Sharara and Madam Roula Sharara for their encouragement and advice through out a very critical period of my life.

Table of Contents

Chapter			Page
Chapter 1 – A brief review of the ultrafiltration process, the physico-chemical properties of milk concentrated by ultrafiltration, cream cheese manufacture and cheese yield			1
1.1	Introduction		1
1.2	Ultrafiltration		
	1.2.1	Terminology	3
	1.2.2	Membrane configuration and design systems	6
	1.2.3	Membrane types or generations	7
	1.2.4	Membrane cleaning and sanitation	8
1.3	Physico-chemical properties of retentate		9
	1.3.1	Chemical composition of retentate	9
	1.3.2	Buffering capacity and pH	10
	1.3.3	Rheology	10
	1.3.4	Renneting and syneresis	13
1.4	Cream cheese		14
	1.4.1	Introduction and definition	14
	1.4.2	Traditional cream cheese	15
	1.4.3	UF cream cheese	17
1.5	Cheese yield		17
	1.5.1	Definition and historical developments	17
	1.5.2	Factors affecting cheese yield	18
		1.5.2.1 The effects of milk composition and quality on cheese yield	19
		1.5.2.2 Cheese-making factors and their effects on cheese yield	20
	1.5.3	The economical importance of cheese yield	21
1.6	Research objectives		21
1.7	Bibliography		34
Chapter 2 – The application of butter oil in the manufacture of cream cheese by the traditional method and its effect on cheese yield			45
2.1	Introduction		45
2.2	Material and methods		46
	2.2.1	Materials	46
	2.2.2	Methods	46
		2.2.2.1 Bulk starter culture preparation	46
		2.2.2.2 Cream cheese manufacture by the traditional method	46

2.2.2.3 Analytical methods 47
2.2.2.4 Calculations of cheese yield, total nitrogen (TN) and fat recoveries 48
2.2.2.5 Statistical analysis 49
2.3 Results and discussion 49
2.4 Conclusions 53
2.5 Bibliography 62

Chapter 3 – UF cream cheese: Manufacture, composition and yield 66

3.1 Introduction 66
3.2 Materials and methods 68
3.2.1 Materials 68
3.2.2 Methods 68
3.2.2.1 Bulk starter preparation 68
3.2.2.2 Retentate preparation at skim milk's physiological pH = 6.7 68
3.2.2.3 Retentate preparation from coagulated skim milk (pH=4.6) 69
3.2.2.4 UF cream cheese making from retentate (pH = 6.7) 69
3.2.2.5 Membranes cleaning 70
3.2.2.6 Analytical methods 70
3.2.2.7 UF cheese yield calculations, total nitrogen (TN) and fat recoveries 71
3.2.2.8 Statistical analysis 72
3.3 Results and discussion 72
3.3.1 Retentate obtained at milk physiological pH 72
3.3.2 Concentration of coagulated skim milk (pH = 4.6) 74
3.3.3 Difficulties in expressing UF cheese yield 75
3.4 Conclusions 76
3.5 Bibliography 87

Chapter 4 – Comparisons between the traditional and UF cream cheese yield and milk component recoveries 91

4.1 Introduction 91
4.2 Statistical analysis 92
4.3 Discussion 92
4.4 Future recommendations 93
4.5 Bibliography 99

List of Tables

Table	Page
Table 1-1 Gross chemical composition of major milk components	23
Table 1-2 Dispersion of milk components	25
Table 1-3 Advantages and disadvantages of membrane configurations	26
Table 1-4 Composition of skim milk and UF skim milk retentate	28
Table 1-5 Typical cream cheese composition	29
Table 1-6 Different methods of expressing cheese yield at plant level	30
Table 1-7 Different methods of expressing cheese yield in research reports	31
Table 2-1 Chemical analysis of standardized milk used in the manufacture traditional cream cheese (%)	54
Table 2-2 Chemical analysis of the traditional cream cheese (% product)	55
Table 2-3 Chemical analysis of the traditional cream cheese (% dry matter)	56
Table 2-4 Chemical analysis of cream cheese whey obtained from traditional cream cheese (% product)	57
Table 2-5 Chemical analysis of cream cheese whey obtained from traditional cream cheese (% dry matter)	58
Table 2-6 Traditional cream cheese yield, protein and fat recoveries measured from mass balance	59
Table 2-7 Comparisons of cream cheese manufactured in this study and at Cornell University	60
Table 3-1 Chemical composition of skim milk used in manufacture of UF cream cheese (% product)	77
Table 3-2 Chemical analysis of the UF retentate (% product)	78
Table 3-3 Chemical analysis of the UF retentate (% dry matter)	79
Table 3-4 Chemical analysis of the UF cream cheese (% product)	80
Table 3-5 Chemical analysis of the UF cream cheese (% dry matter)	81
Table 3-6 Chemical analysis of the UF cream cheese permeates (% product)	82
Table 3-7 Chemical analysis of the UF cream cheese permeates (% dry matter)	83
Table 3-8 UF cream cheese yield, protein and fat recoveries measured from the mass balance	84
Table 4-1 Comparisons between the means of the traditional and UF cheese yield (actual and adjusted), TN and fat recoveries	94

List of Figures

Figure	Page
Fig. 1-1 Schematic presentation of ultrafiltration	32
Fig. 1-2 UF Cheese varieties and their percentages	33
Fig. 2-1 Technological steps and mass balance flow chart during the manufacture of traditional cream cheese	61
Fig. 3-1 Applications for ultrafiltration in cheesemaking	85
Fig. 3-2 Mass balance flow chart for the UF cream cheese	86
Fig. 4-1 Comparison of Traditional vs. UF actual cheese yield (% m/m)	95
Fig. 4-2 Comparison of the moisture adjusted Traditional vs. UF cheese yields (% m/m)	96
Fig. 4-3 Comparison of total nitrogen (TN) recoveries in Traditional vs. UF cream cheese (% m/m)	97
Fig. 4-4 Comparison of fat recoveries in Traditional vs. UF cream cheese (% m/m)	98

Chapter 1 – Introduction

A brief review of the ultrafiltration process, physico-chemical properties of milk concentrated by ultrafiltration, cream cheese manufacture and cheese yield

1.1 Introduction

Milk is a mammal's first food after birth. Cows' milk contains relatively large amounts of the fifty-five essential nutritional elements; however, it is not a complete food as it lacks vitamin D and iron (Amiot, 1985). In the USA, milk proteins supply more than 22% of the recommended daily protein allowances, which amounts, in adults, to 0.8 g proteins per kilogram of live weight per day (Amiot, 1985).

Over the last two decades, ultrafiltration, a pressure-driven membrane process, has been used in various industrial applications. The dairy industry has been the major adopter of this technology. Ultrafiltration concentrates and separates molecules in solution based on differences in their molecular weight in conjunction with membrane molecular weight cut-off and other operational parameters.

The average chemical composition of the major milk components is presented in Table 1-1. Milk components are present in various physical forms (Table 1-2). Fat globules are emulsions greater than 1 μm in diameter while casein micelles are suspensions between 10 nm to 200 nm in diameter. Whey proteins, lactose, and minerals are in true-solution (Reil, 1985). The combination of these different dispersions allows for the deferential concentration, separation and/or isolation of milk components in a purely physical manner without changing their biological or nutritional value. The

physico-chemical characteristics of the obtained retentate or concentrate have a profound effect on the quality of the final cheese product.

Cream cheese, a soft type cheese, is consumed fresh or as a dessert. Ultrafiltration has allowed for the complete retention of whey proteins (Lelievre and Lawrence, 1988) which are normally lost during the process of cheese making. This process results in a higher cheese yield. Ultrafiltration technology has been applied to the manufacturing of several types of soft cheeses (Maubois and Mocquot, 1975). This research deals with the application of ultrafiltration in cream cheese making.

This chapter provides background information on the effect of membrane processing (ultrafiltration-UF) on physico-chemical properties of retentate and its applications in cheese manufacturing. Historical developments in cheese yield are discussed.

1.2 Ultrafiltration

Ultrafiltration is a crossflow membrane system in which the feed flows in a parallel manner to the membrane (Fig. 1-1). It can concentrate, fractionate and separate organic components simultaneously, without phase change, by passing the feed stream over a semi-permeable membrane which divides the stream into two effluents: the retentate or the concentrate and the permeate or the filtrate (Fig. 1-1). The concentration, fractionation and separation of individual milk components are based mainly on their molecular weight, the sieving process, in conjunction with their physico-chemical properties, the membrane surface structure and the interactions between these components and the membrane itself (Sourirajan, 1977). Typically, the molecular weight

cut-off of ultrafiltration membranes is in the range of 10,000–100,000 D and a pore size of 10^{-2} to 10^{-1} μm. The applied pressure ranges from 50 psi to 145 psi. Ultrafiltration temperature is in the range of 2 to 4°C or 50 to 55°C, i.e., below and above the optimum microbial growth temperatures (Kosikowski, 1973). These temperature ranges are acceptable for minimizing microbial growth during ultrafiltration and are easily attainable in any dairy. Concentrating skim milk by ultrafiltration at 50°C has been shown to reduce the bacterial multiplication factor (F) to less than 1 (Maubois and Mocquot, 1971).

Ultrafiltration as a membrane process for cheesemaking started in France in 1969. This process was called the MMV process, referring to its three inventors: Maubois, Mocquot, and Vassal (Kosikowski, 1985). Since then, significant developments in this process have been made in order to tailor its application to a wide range of cheese varieties such as fresh soft (Quark and cream cheese), semi-hard (Mozzarella, St. Paulin, and Havarti) and hard cheeses (Cheddar) as well as other fermented dairy products such as yogurt. The main advantages of ultrafiltration are a higher cheese yield due to the incorporation of whey proteins, better cheese weight adjustments and more product uniformity. Moreover, less rennet, starter culture, salt and fewer colors are required for manufacture of UF cheese compared to traditional cheese. Furthermore, less space and handling are required and less biological oxygen demand is found in the permeate than in whey (Maubois and Mocquot, 1975).

1.2.1 Terminology

This section will define and elaborate on some of the most common and important technical terms that are encountered during membrane processing.

a) *Concentration factor (CF):* the ratio of solute concentration in the retentate and feed stream. Concentration may be on a mass or volume basis.

$$CF = \frac{\text{Initial volume}}{\text{Final volume}} \qquad \text{(Eq. 1-1)}$$

b) *Concentration polarization (CP):* localized accumulation of solutes at the surface of the membrane in a gradient manner, the highest concentration being at the membrane surface. Concentration polarization lowers the flux and increases the hydrodynamic resistance. However, it is a reversible phenomenon. Concentration polarization is regarded as the accelerator or promoter of fouling. A rise in the concentration of the solutes at the membrane interface leads to the destabilization of these solutes and consequently to the initiation of fouling (Aimar and Sanchez, 1989). In practice, it is hard to differentiate between concentration polarization and fouling in chronological order.

c) *Crossflow filtration:* refers to a membrane filtration pressure-driven process in which the feed is applied tangentially over the surface of the membrane. Examples include, in addition to ultrafiltration (UF), reverse osmosis (RO), nanofiltration (NF), and microfiltration (MF).

d) *Diafiltration (D):* the addition of water or a solvent to the retentate to wash minerals, lactose, and other dissolved solids (Sutherland and Jameson, 1981).

$$D = 1 + \frac{\text{volume of diafiltration}}{\text{volume of final retentate}} \qquad \text{(Eq. 1-2)}$$

e) *Donnan exclusion:* ion exclusion due to the presence of fixed charge groups on the membrane.

f) *Flux (J):* the permeation rate of filtrate through a membrane area, measured in units of volume or mass per unit of area per unit of time.

g) *Fouling:* the deposition, crystallization and/or precipitation of solutes on the surface and in the pores of the membrane, manifested by a gradual decline in the flux. It is an irreversible phenomenon. The nature and extent of membrane fouling are determined by the chemical nature of the membranes, membrane-solute and solute-solute interactions (Cheryan, 1986). Fouling is a coating that covers the membranes each time they are used and very quickly changes the original membranes' permeability and selectivity. These modifications affect the effectiveness of the separation process. The modifications are mechanical compacting of the membranes and the chemical interactions between the membranous material and the fluids (Aimar and Sanchez, 1989).

h) *Hold-up volume:* the volume of concentrate that remains in the system at the end of the operation.

i) *Module:* the assembly that contains the membranes.

j) *Molecular weight cut off (MWCO):* the designation for the smallest molecular weight component retained at a retention coefficient of 0.95 (Renner and Abd El-Salam, 1991).

k) *Permeate (P):* the stream that passes or filtrates through the membrane.

l) *Rejection coefficient (σ_i):* a quantitative measure to characterize the membrane's ability to reject a solute at specific operating parameters. It can be expressed by the following equation:

$$\sigma_i = 1 - \left[\frac{Cp}{Cr}\right]_i \qquad \text{(Eq. 1-3)}$$

where Cp and Cr are the concentration of species i in the permeate and retentate respectively at any given time (Breslau, 1982).

m) *Residence time:* the time required for the material to pass through the module from the feed inlet to the retentate outlet.

n) *Retentate (R) or concentrate:* the stream that contains the solutes rejected by the membrane.

o) *Transmembrane pressure (TSMP):* the average of the inlet and outlet pressures on the membrane at the retentate side minus the pressure at the permeate side (Breslau, 1982).

$$TSMP = \frac{P_{inlet} + P_{outlet}}{2} - (P_{permeate\ side}) \qquad \text{(Eq. 1-4)}$$

1.2.2 Membrane configurations and design systems

There are four membrane systems:

a) plate and frame

b) spiral wound

c) tubular

d) hollow fiber

The choice of the system is largely dictated by its application. In principal, any of the above-mentioned membrane configurations could be used for reverse osmosis, ultrafiltration or microfiltration. However, it is worth noting that spiral wound systems are by far the most widely used membranes world-wide, mainly in reverse osmosis and nanofiltration (Bird, 1994). Plate and frame membranes are mostly used in ultrafiltration, while tubular membranes are utilized in microfiltration. The main advantages and disadvantages of these systems are summarized in Table 1-3.

1.2.3 Membrane types or generations

Membrane choice is critical not only from the point of view of fouling but equally with regard to the success of the separation process. Ultrafiltration membranes have developed in three stages (Macrae *et al.*, 1993):

a) *Cellulose acetate membranes:* They were the first commercially developed UF membranes. Their poor thermal and chemical tolerance rendered them of no practical use to the dairy industry.

b) *Polysulphone membranes:* These were the second generation of membranes developed. They are widely used and believed to be the most common type of membrane on the market. They can withstand high cleaning temperatures and wide ranges of pH. However, they can not withstand very high pressures, and they are not as easily cleaned as the third generation mineral membranes.

c) *Mineral or ceramic membranes:* These are the most recent on the market.

They are composed of inorganic materials, which render them free of the disadvantages of polymers. They can tolerate the entire pH range and temperatures up to 400°C. They can be autoclaved or sterilized. The main limitations of such membranes are that they are very expensive and come only in tubular configurations.

1.2.4 Membranes cleaning and sanitation

The dairy industry requires high levels of sanitation and cleanliness. With the progressive increase in the use of MF, UF and RO by this industry, an evaluation of the cleaning chemicals, sanitizers, as well as cleaning procedures is crucial (Smith and Bradley Jr., 1987). Cleansing is essential to restore membranes' permeability and selectivity but is costly in terms of time, energy, chemicals and water requirements. Cleaning must be efficient, fast and non corrosive to membranes and to other installations and must meet sanitary standards (Daufin *et al.*, 1992; Bohner and Bradley Jr., 1991). The determination of what constitutes adequate cleaning has relied on indirect indicators such as sight, smell, permeate flux, final product quality, microbial swabbing and scanning electron microscopy (Smith and Bradley Jr., 1988).

One of the most important limitations on the wide spread use of the UF technology is the flux decline. The cost and efficiency of membrane processing is dependent on the flux. The flux is dependent on the membrane used, processing parameters such as pH and temperature (St-Gelais *et al.*, 1992), and the fluid to be processed (Eckner and Zottola, 1992). One study indicated that when skim milk was concentrated to 4.5–5 ×, 67–95% of flux decline was due to gelling and concentration

polarization and 5–30% was due to fouling which is only removed by cleaning (Eckner and Zottola, 1993).

The hygienic operation of ultrafiltration plants depends on three factors (Cotton, 1974):

a) *temperature of operation,*

b) *residence time and*

c) *general plant design.*

Experiments have shown that different membranes with the same MWCO exhibit different bacterial retention and that the unit configuration plays an important role in terms of bacterial retention (Eckner and Zottola, 1991). Tubular membranes are more easily cleaned than plate and frame or spirally wound ones especially when they are heavily fouled because they do not have dead spaces (El-Gazzar and Marth, 1991).

1.3 Physico-chemical properties of retentate

1.3.1 Chemical composition of retentate

The results of Srilaorkul *et al.* (1989) for the composition of skim milk retentate produced by concentrating skim milk to different degrees are presented in Table 1-4. Caseins, fat and whey proteins are almost completely retained by the UF membranes, while NPN remains constant irrelevant of the concentration factor. Lactose content decreases with concentration, whereas minerals such as calcium, phosphorus, magnesium and potassium increase with a rise in the concentration factor. These findings are in agreement with numerous studies in which complete rejection of fat (≥ 99.9%) and proteins (≥ 98%) were observed (Sutherland and Jameson, 1981; Ernstrom *et al.*, 1980).

Glover (1985) has reported a 10% retention of lactose even though it is assumed that lactose passes freely through the membranes. A high level of lactose in the retentate can cause excessive acidity and textural defects in cheese made from it, but through diafiltration it is possible to correct residual lactose level in the final cheese product (Covacevich, 1981). Premaratne and Cousin (1991) reported partial concentration of minerals and reduction in B vitamins (thiamin, riboflavin, pantothenic acid, and biotin) with increases in concentration.

1.3.2 Buffering capacity and pH

The increase in protein and mineral content in the UF retentate increases its buffering capacity (Srilaorkul *et al.*, 1989). The principal buffering species in milk and retentate are proteins and phosphates (Sutherland and Jameson, 1981). The buffering capacity increases with an increase in concentration factor (Srilaorkul, 1990). This increase in the buffering capacity will affect the fermentation process, since the desired pH will not be attained, leading to texture and flavour defects (Lawrence *et al.*, 1983). The buffering capacity of skim milk concentrated five times is the highest at pH 5.1-5.3 and is six to seven times higher than that of ordinary skim milk at the same pH (Covacevich and Kosikowski, 1979; Mistry and Kosikowski, 1985). Although bacterial growth at pH 5.1–5.3 in skim milk retentate (5.8 ×) was found to be significantly reduced, lactic acid production continued (Mistry and Kosikowski, 1985). Diafiltration and/or acidification prior to concentration (Brulé *et al.*, 1974) can easily reduce the adverse effects of high buffering capacity.

1.3.3 Rheology

Rheology is the study of deformation and the flow of matter. Deformation is related to solids such as cheese while flow is related to liquids such as fluid milk (Shoemaker *et al.*, 1992). Stress is a force applied to a surface area; in other words, it is a pressure. It can be tangential and denoted by τ or uniaxial and denoted by σ (deMan, 1976). In membrane processing the tangential stress is of primary importance since the process itself is one of tangential filtration. The deformation caused by this stress is defined as the shear strain and denoted by γ (Prentice, 1992). Strain is the change in shape or size of a body in response to the applied force. It is a nondimensional parameter and is expressed as the ratio or percentage of the original size or shape of the body as compared to the size or shape after the stress is applied (Szczesniak, 1983). If the material is fluid, then viscosity (η) is defined as the resistance to flow of fluid material and measured as the ratio of shear stress (τ) to shear rate ($d\gamma/dt$) (Eq. 1-5). Viscosity is expressed in Pa.s (pascal-second) or P (poise). Shear rate ($d\gamma/dt$) is the difference in velocity of flow across two parallel planes divided by the distance between these planes. Shear rate is expressed in reciprocal seconds s^{-1} (Renner and Abd El-Salam, 1991):

$$\eta = \frac{\tau}{d\gamma/dt} \qquad \text{(Eq. 1-5)}$$

Viscosity is an important factor that determines the flow conditions and the rate of mass and heat transfer during dairy processing (Goff and Hill, 1993). The relationship between shear stress and shear rate can be used to define the flow properties of materials. Newtonian flow occurs when the shear rate is directly proportional to shear stress and

viscosity is independent of the shear rate within the laminar flow range (Renner and Abd El-Salam, 1991) and hence satisfies Eq. 1-5. Typical examples of materials exhibiting Newtonian flow behaviour are water, whey and milk. However, most foods are non-Newtonian in their flow pattern such that the ratio of shear rate and shear stress is not a constant value. Thus, different viscosities will be obtained at different shear rates. In order to differentiate the measured viscosities at various shear rates and the "true" viscosity of a Newtonian fluid, the term "apparent viscosity" is used. The non-Newtonian flow behaviour is divided into three categories (Renner and Abd El-Salam, 1991):

1) Plastic

2) Pseudoplastic

3) Dilatant

Retentate is a non-Newtonian fluid and is described as pseudoplastic (shear thinning) in that viscosity decreases with increases in the shear rate or the velocity of the moving liquid (Kristensen *et al.*, 1981). The "power law" model (Eq. 1-6) can describe pseudoplastic behaviour:

$$\tau = k\left[\frac{d\gamma}{dt}\right]^{n} \qquad \text{(Eq. 1-6)}$$

where k is the consistency index and n is the flow behaviour index with both parameters being dimensionless. Both k and n are empirical constants at a given concentration factor and temperature and are inversely related to each other. The viscosity of retentates will increase with increased casein content (Stepp and Smith, 1991). This non-Newtonian behaviour will be enhanced with a decrease in temperature (Goudédranche *et al.*, 1980).

Both the increase in the dry matter or concentration factor and the ratio of protein to fat are of extreme importance in increasing viscosity (Albertsen *et al.*, 1983). Albertsen *et al.* (1983) have obtained a viscosity of approximately 1500 cP for skim milk retentate at 37.5% dry matter, whole milk concentrate at 47.5% dry matter with a protein to fat ratio (P/F) of 1.3, and high fat milk concentrate at 56.5% dry matter with a P/F of 0.5. Clearly the initial milk composition is of extreme importance.

1.3.4 Renneting and syneresis

The effects of UF on milk coagulation kinetics, curd firmness, and whey separation have been studied extensively. It is well known that the physico-chemical properties of cheese milk such as substratum concentration, pH and temperature and other factors such as the coagulating enzyme used, homogenization pressure, and pasteurization have an influence on the coagulation kinetics. It has been found that increased protein concentration coupled with decreased pH will accelerate milk clotting (Lucisano *et al.*, 1985). However, Culioli and Sherman (1978) have found that the clotting time increases with an increase in the protein content and decreases with an increase in rennet concentrations. They have attributed this observation to the increase in the viscosity of retentate, which will retard the flocculation of the casein micelles. In normal milk the clotting is not observed until 85–90% of the enzymatic phase (κ-casein proteolysis) of the renneting process is completed (Chaplin and Green, 1980). Garnot *et al.* (1982) found that in concentrated milk the degree of proteolysis at coagulation time decreased as the protein content increased. Dalgleish (1981) proposed that about 50% of the casein micelles might be modified enzymatically in four-fold milk concentrates.

Calcium plays an important role in the coagulation mechanism. During the concentration process, the colloidal calcium is completely retained with the protein, resulting in a constant ratio of calcium to proteins (Brulé *et al.*, 1974). Cheese made with UF retentates exhibits a high rate of coagulum firming due to high protein and calcium contents (Casiraghi and Lucisano, 1991). Mechanical and thermal stresses associated with UF result in a slight reduction in curd firmness and whey separation rate (Casiraghi *et al.*, 1989). Syneresis was found to follow the first order kinetics (Eq. 1-7) (Peri *et al.*, 1985):

$$(V_\infty - V_t) = V_\infty \cdot e^{-kt} \qquad \text{(Eq. 1-7)}$$

where V_t: is the volume of whey released at time t,

V_∞: is the total drainable whey volume, and

k is a constant describing the kinetics of whey release.

The rate of syneresis was independent of concentration and pH. However, V_∞ decreased with an increase in protein concentration and increased with a decrease in pH (Peri *et al.*, 1985). One can conclude from the above that the degrees of concentration and pH are the major factors that control the moisture content of UF cheese. Cheese moisture has a profound effect on the organoleptic and textural properties of cheese.

1.4 Cream cheese

1.4.1 Introduction and definition

Cream cheese is a soft unripened cheese that is well known for its smooth texture and sweet acidic taste. It is available in many forms from plain to flavoured and is very

similar to many French types of soft cheeses such as Petit Suisse, Gervais or Fromage Frais. Cream cheese is used to make cheesecakes, salads, spreads and dips (Kosikowski, 1978) and is one of the most popular soft cheeses in North America (Tewari and Singh, 1991). The Canadian standards of identity for cream cheese indicate that it should contain at least 30% fat and not more than 55% moisture. Salts, stabilizers and preservatives may be added. Typical gross chemical composition of cream cheese is given in Table 1-5.

1.4.2 Traditional cream cheese

A typical method for the manufacture of cream cheese is as follows (Lundstedt, 1954):

1) *Milk standardization*: to a fat content of 12%
2) *Pasteurization:* at 65°C for 30 minutes.
3) *Homogenization:* single stage at 1800 psi pressure at 50°C.
4) *Cooling:* to about 22°C (setting temperature)
5) *Inoculation:* with the lactic acid bacteria
6) *Incubation:* for 16-18 hours until pH 4.6.
7) *Heating:* the acidified gel to about 54°C or until separation.
8) *Draining:* in bags, ice and pressed overnight.

Factors contributing to the final body and texture of cream cheese have been studied by Lundstedt (1954) and include the source and amount of fat, the percentage of non-fat solids, heat treatments, homogenization pressures, and pH. The sources of milk fat are cream (30–40% fat), plastic cream (60–70% fat) or butter oil (99% fat) (Lundstedt, 1954). In Canada, vegetable oil is not allowed as a source of fat in cream cheese. It has

been found that the use of different fat sources in cream cheese making has no significant effect on the sensory characteristics of the final product (Hallal and Al-Omar, 1987). However, varying costs and the aim of obtaining an optimum fat to non-fat solids (SNF) ratio, which will yield high quality cheese within the legal limits, dictate the choice of these different ingredients. Lundstedt (1954) found that butter oil could not be used for more than 30% of the total butterfat content without having an adverse effect on the taste as well as the texture of cream cheese.

The choice of the starter culture depends greatly on the manufacturing parameters such as heat treatments of the curd, the desired pH, and acidity required within certain time limits for the given cheese. The lactic starter bacteria produce lactic acid to give a final pH of 4.6 and titratable acidity of 0.65%. Also, they will ferment the citrates to produce flavour and aroma compounds such as diacetyl (Parducho and Felizmenio, 1982). The principal flavour components recognized in cultured buttermilk, cultured cream, and cream cheese are diacetyl, volatile acids such as acetic, propionic, butyric, and valeric, and lactic acid (Gordon and Shapton, 1977).

Cream cheese is a perishable product and has been classified into two categories (Kosikowski, 1978):

a) *Cold pack:* in which the additives such as salt, stabilizers, and preservatives are added to the cold dry curd after draining. Finally, the curd is kneaded.

b) *Hot pack:* the cold curd is cooked in a kettle with agitation, during which the preservatives are added. The hot pack method increases the shelf life of the cheese up to three months, while the maximum shelf life using cold pack method is three weeks.

Salts, stabilizers and preservatives are added to the maximum legal levels. Salts enhance the flavour. With high moisture content and a pH of 4.6, close to the isoelectric point of caseins, cream cheese will separate into coagulated proteins and free fat when subjected to thermal processing (Buchheim and Thomasow, 1984). Stabilizers are used to prevent water exudation and to obtain a good body and texture.

1.4.3 UF cream cheese

It has been estimated that about 3% of the total world cheese production are made using ultrafiltration that amounts to an annual output of 400.000 tonnes (Kjaergaard Jensen *et al.*, 1988). Membrane ultrafiltration has been successfully applied in the manufacture of soft cheeses such as Camembert, feta and cream cheese (Maubois, 1980). In Denmark, UF feta, a soft type of cheese, is widely produced with the annual export reaching 100.000 tonnes (Qvist *et al.*, 1987). Covacevich and Kosikowski (1977) first proposed the manufacture of cream cheese using ultrafiltration. The cheese varieties commonly made by UF and their percentages are presented in Figure 1-2.

In traditional cheese making, rennet and/or lactic acid bacteria coagulate milk. The concentration takes place after whey drainage. Ultrafiltration substitutes the whey drainage for soft cheese varieties (Maubois and Mocquot, 1975).

1.5 Cheese yield

1.5.1 Definition and historical developments

Cheese yield is the quantity of cheese obtained from a given quantity of milk and can be expressed in two ways (Dumais *et al.*, 1985):

a) *Percentage yield (milk basis):* conventionally expressed as kg of cheese obtained from 100 kg milk.

b) *Percentage yield (milk component basis):* expressed as kg of cheese obtained from 100 kg milk fat, casein, or non-fat solids.

Some of the most important methods of expressing cheese yield recommended by the International Dairy Federation (IDF) and which can be used at both plant and research levels are presented in Tables 1–6 and 1–7.

Historically, one of the major reasons for estimating or calculating the cheese milk yielding capacity is the need for a more fair and accurate method of payment for milk at a cheese factory than a mere mass of milk (Van Slyke and Price, 1932). In chronological order, payment plans for cheese milk have developed in the following order:

a) mass of milk

b) amount of fat in milk

c) relative values of fat and other cheese solids based on yield and composition of cheese.

d) amount of fat and casein in milk (most preferable, IDF 1993 special issue).

1.5.2 Factors affecting cheese yield

Factors affecting the cheese yield are grouped in two main headings: *milk composition* and *cheesemaking conditions* (Lucey and Kelly, 1994). The factors contributing to cheese yield can be summarized as (Van Slyke and Price, 1932):

a) The sum of fat and protein in milk – the cheese milk yielding potential.

b) The percentage of milk constituents lost in the whey.

c) *The amount of moisture retained in the cheese.*

1.5.2.1 The effects of milk composition and quality on cheese yield

It is well known that milk composition is the most important factor affecting cheese yield. Milk composition is largely influenced by:

a) *The breed of the cow*

b) *Stage of lactation*

c) *Seasonal variations (climate and feed)*

d) *Differences in individual cows*

e) *Physiological conditions and disease problems (example, mastitis)*

f) *Age of the cow*

g) *Milking procedure (intervals)*

The amount of casein, fat, and insoluble salts in milk largely determines the *cheese yield*, while the relative proportions of these 'cheese solids' determine the *cheese composition* and *quality* (Van Slyke and Price, 1932). One of the most frequently asked questions is "Which is more important as far as cheese yield is concerned, casein or fat?" There is no satisfactory answer to this question. It depends on cheese variety, the technology used, as well as economics (IDF, 1993). Casein is the more important factor for cheese yield rather than fat as casein forms the structural matrix of cheese that retains fat and moisture. The fat contributes only its weight to cheese yield, while casein contributes both its weight and associated moisture. Casein becomes relatively less important when the cheese milk is standardized to a certain fat/casein ratio as opposed to when the milk is not standardized. In cottage cheese and quark, for example, casein is the major

component contributing to cheese yield. However, in a product such as cream cheese, which is high in fat and moisture, fat is the relatively more important constituent, comprising a minimum of 67% of the dry matter.

Milk quality has a profound influence on the casein loss. Casein is lost usually as casein fines or as soluble nitrogenous compounds. A curd strainer or "fine saver" recovers the fines but the soluble components are very difficult to recover. The two most important reasons for high soluble casein losses are high somatic cell counts in the milk (Barbano *et al.*, 1991) and high psychrotrophic bacteria counts (Hicks *et al.*, 1982). In both cases the casein is hydrolyzed by the proteolytic enzymes produced by these bacteria.

1.5.2.2 Cheese-making factors and their effect on cheese yield

Cheese composition depends primarily on the composition of the starting milk provided that there are no excessive losses of casein and fat in the cheese making process. Milk rich in fat will yield cheese that is high in fat in proportion to other components (Van Slyke and Price, 1932). The loss of fat in cheese making is quite independent of the amount of fat in milk. Variations that occur in fat loss are attributed to microbial content or to a fault in the cheesemaking methods (Van Slyke and Price, 1932). Curd fine losses are inevitable and are normally a function of the mechanical design and operation of cutting and stirring. The moisture content of cheese bears no relationship to the water content of milk, but is controlled by operational parameters in cheese making such as degree of firmness of the cutting curd, the type and level of starter bacteria used,

temperature, pH, acidity, time, amount of salts, and the condition and design of the equipment (Van Slyke and Price, 1932).

1.5.3 The economic importance of cheese yield

Cheese yield is very important to the dairy industry. Predetermining cheese yield, before the manufacture of cheese, is necessary for the design of the mechanization of the cheese process (Maubois *et al.*, 1970). The profitability of a cheese plant is influenced by the cost of milk per kilogram of cheese (IDF, 1993). Increasing cheese yield is one measure to keep this cost as low as possible. Small variations in cheese yield, at the national level, are worth millions of dollars (Emmons *et al.*, 1990).

1.6 Research objectives

The bakery and confectionery industries are creating a steadily increasing demand for soft cream cheese. Ultrafiltration technology has proven its success in concentrating milk proteins for cheese making, especially for soft type cheeses such as cream cheese. Thus, ultrafiltration will lead to an increase in cheese yield as compared to cream cheese manufactured in the traditional manner. It has been reported that up to a 20% increase in cheese yield might be expected due to the application of membrane processing (Dejmek, 1986). The main factor that contributes to cheese yield increase is the whey protein recovery.

In countries where the fluid milk supply does not meet the demand, most dairy products are manufactured from recombined dairy ingredients. In developed countries, excess milk plasma is stored in the form of skim milk powder, while excess of fat is

stored in the form of butter or butter oil. In Asia. for example. cream cheese might be manufactured from reconstituted skim milk powder. and butter or butter oil may be used as a milk fat source.

Research was undertaken to manufacture cream cheese using the traditional method and also by applying the ultrafiltration (UF method) using fresh and pasteurized skim milk as a source of proteins and butter oil as a source of fat.

The specific research objectives were the following:

1) To study the utilization of butter oil as source of fat in the manufacture of cream cheese by the traditional method.
2) To produce cream cheese from UF retentate and butter oil.
3) To compare the cream cheese yields resulting from the traditional and ultrafiltration methods
4) To determine the percentage recovery of milk components.

Table 1-1. Average gross chemical composition of major cow's milk components.

Milk Constituents		
Name		Content ($g.kg^{-1}$)
Water		860
Lactose		46
Protein		
1) Casein		26
α_{s1}-casein	10.0	
α_{s2}-casein	2.6	
β-casein	10.1	
κ-casein	3.3	
2) Whey proteins		6.4
β-lactoglobulin	3.2	
α-lactalbumin	1.2	
lactoferrin	0.1	
blood serum albumin	0.4	
immunoglobulins	0.7	
Proteose-Peptone	0.8	
3) Enzymes		traces
4) Milk fat globular membranes proteins		traces
Fat		38.3
1) Triglycerides	38	
2) phospholipids	0.3	
Citrate		1.6
Some of the minerals		
1) Ca		1.3
2) P		0.9

Table 1-1. Gross chemical composition of major milk components (continued).

Milk Constituents		
Name		Content ($g.kg^{-1}$)
3)	Na	0.4
4)	K	1.5
5)	Cl	1.1

Adapted from (Walstra and Jenness, 1984).

Table 1-2. Dispersion of milk components.

Dispersion	Size	Components
solvent		water
	0 nm **reverse osmosis**	
true solution		lactose, salts
	1 nm **ultrafiltration**	
colloidal solution		albumins, globulins soluble casein colloidal phosphate
	10 nm	
colloidal suspension		casein micelles (30 – 300 nm)
	200 nm	
suspension		bacteria (cocci)
	1 μm	
emulsion		fat globules, bacteria (rods)
	10 μm	

Adapted from (Riel, 1985)

Table 1-3. Advantages and disadvantages of membrane configurations.

Membrane configuration	Advantages	Disadvantages
Spiral wound	• Minimum floor space • High surface area per volume ratio • Low capital and operational costs • Low hold up volume	• Difficult to process fluids which are high in suspended solids • Difficult to process viscous products • Difficult to clean
Plate and frame	• Economic energy consumption • No special pump • Low hold up volume • Minimum floor space • Membrane replacement is easy	• Fairly difficult to clean • Susceptible to plugging
Tubular	• Handle feed with large suspended particles • Easy to clean (CIP) • Membranes can be replaced easily	• Need efficient pumps that can generate high velocity flow rates • High energy consumption • Low surface area to volume ratio • Greater floor space • High hold up volume

Table 1-3. (continued)

Membrane Configuration	Advantages	Disadvantages
Hollow fiber	• High surface area per volume • Low hold up volume • Back flushing cleaning • Low energy consumption	Damage of a single fiber requires the replacement of the entire cartridge High susceptibility to plugging Difficult to handle viscous solutions

Adapted from (Macrae *et al.*, 1993; Glover, 1985; Paulson *et al.*, 1984)

Table 1-4. Composition of skim milk and UF skim milk retentate.

CF*	DM	Casein	Whey Proteins	Fat	NPN	Lactose	Ash	Ca	P	Mg	K	Na
	(%)							(mg/100g)				
1	8.82	2.55	0.54	0.06	0.16	5.03	0.76	125.1	96.9	10.7	162.3	44.5
2	13.08	5.20	1.49	0.15	0.16	4.98	1.11	237.0	163.3	15.1	179.2	50.0
3	16.2	7.34	1.83	0.44	0.13	4.89	1.32	319.9	212.5	18.6	185.6	52.3
4	19.11	9.13	2.43	0.88	0.14	4.87	1.51	411.3	256.9	21.1	195.3	55.6
5	22.92	12.62	2.52	1.03	0.15	4.73	1.88	551.3	329.5	24.4	206.8	59.4

Adapted from (Srilaorkul *et al.*, 1989)

* CF – volume concentration factor

Table 1-5. Typical traditional cream cheese composition.

Component	per 100 g cream cheese
Total solids	46 g
Protein	8 g
Fat	31 g
Ash	1.55 g
Ca	100 mg
Mg	10 mg

Table 1-6. Different methods of expressing cheese yield at plant level.

1. Actual yield
2. Yield adjusted to constant or standard composition
3. Yield adjusted for losses of fat and/or fat-free dry curd
4. Fully adjusted yield
5. Theoretical yield – based on milk composition
6. Actual yield – as percentage of theoretical yield
7. Yield adjusted to standard composition – as percentage of theoretical yield
8. Yield adjusted for losses – as percentage of theoretical yield
9. Fully adjusted yield as percentage theoretical yield

Adapted from (IDF. 1993)

Table 1-7. Different methods of expressing cheese yield in research reports.

Necessary

1. Actual yield of cheese – kg per 100 kg milk.
2. Composition of cheese – fat, moisture, salt.
3. Composition of milk – fat, total crude protein and/or casein.
4. Fat, total nitrogen as protein and total solids content of whey.

Recommended

5. Recovery of fat as cheese and as whey.
6. Recovery of protein as cheese and whey (nitrogen × 6.38).
7. Yield of cheese adjusted to standard composition of moisture (accounting for whey solids) and salt.
8. Expressing yield(s) as percentage of theoretical yield as estimated by yield formula(e) from composition of milk.
9. Curd fines in whey (fat-free dry curd).

Optional

10. Yield of cheese adjusted for losses of fat and/or fat-free dry curd in whey.
11. Composition – adjusted yield of cheese, further adjusted for losses of fat and/or curd in whey.
12. Yield of dry cheese (if important in relevant market).
13. Yield of dry cheese, after first adjusting the yield of actual cheese for losses of fat and/or curd in whey, to constant moisture

Adapted from (IDF, 1993)

Fig. 1-1. Schematic presentation of ultrafiltration (Adapted from Renner and Abd El-Salam, 1991).

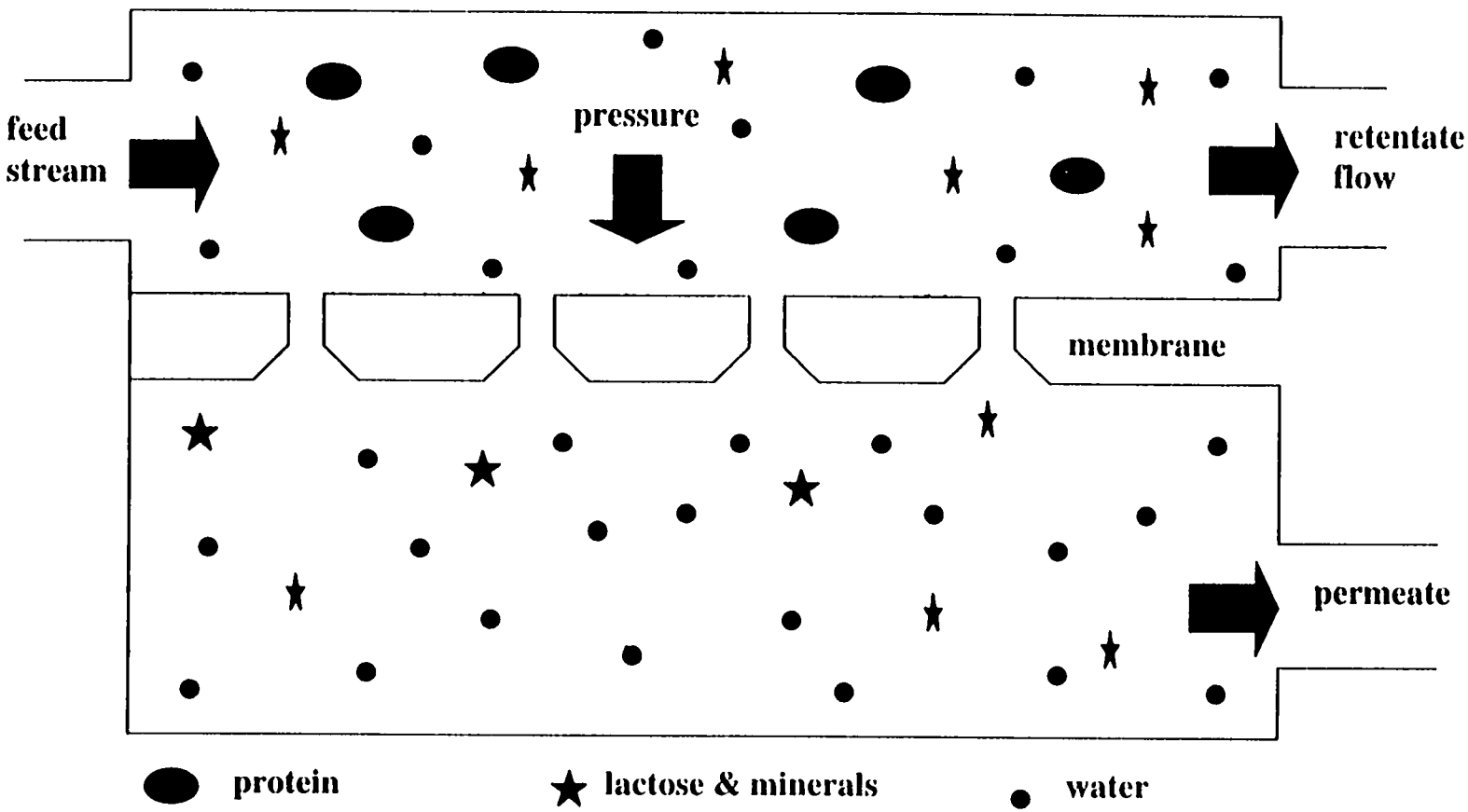
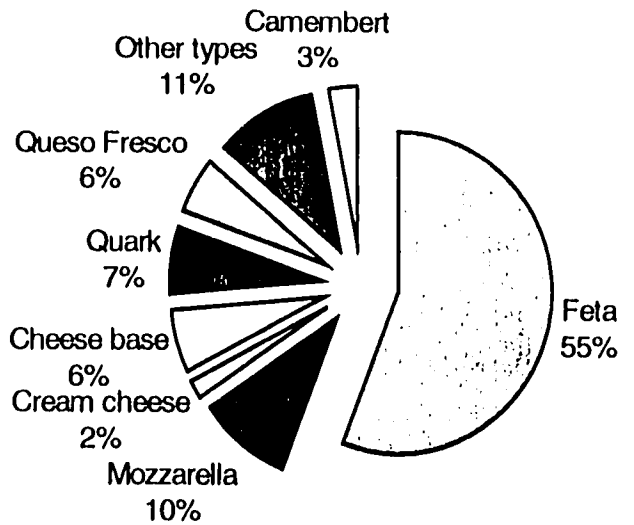


Fig. 1-2. UF Cheese varieties and their percentages (Adapted from Kjaergaard Jensen *et al.*, 1988).



1.7 Bibliography

Aimar, P., and V. Sanchez. 1989. Le colmatage des membranes d'ultrafiltration et de microfiltration. Belgian J. Food Chem. Biotechnol. 44:203-214.

Albertsen, K., S. Kristensen, and R. F. Madsen. 1983. Rheological properties of ultrafiltered milk products and their importance in the ultrafiltration process. Page 138-147 *in* Physico-chemical aspects of dehydrated protein rich milk products. Proceedings of IDF-Symposium. Helsingör, Denmark.

Amiot, J. 1985. Nutritional value of milk and dairy products. Page 52-54 *in* Dairy Science and Technology: Principles and Applications. J.-P. Julien, J. P. Nadeau, R. Dumais, ed. La Fondation de Technologie Laitière du Quebec, Inc., Québec.

Barbano, D. M., R. R. Rasmussen, and J. M. Lynch. 1991. Influence of milk somatic cell count and milk age on cheese yield. J. Dairy Sci. 74:369-388.

Bird, J. 1994. The application of membrane systems in the dairy industry. J. Soc. Dairy Sci. 46:16-23.

Bohner, H. F., and R. L. Bradley Jr. 1991. Corrosivity of chlorine dioxide used as sanitizer in ultrafiltration systems. J. Dairy Sci. 74:3348-3352.

Breslau, B. R. 1982. Ultrafiltration: theory and practice. Proceedings of the Corn Refiners Association Scientific Conference, Lincolnshire, Illinois, June 16-18.

Brulé, G., J. L. Maubois, and J. Fauquant. 1974. Etude de la teneur en éléments minéraux des produits obtenus lors de l'ultrafiltration du lait sur membrane. Le Lait 54:600-615.

Buchheim, W., and J. Thomasow. 1984. Structural changes in Cream cheese induced by thermal processing and emulsifying salts. North European Dairy J. 50:38-44.

Casiraghi, E., and M. Lucisano. 1991. Rennet coagulation of milk retentates. Effect of the addition of sodium chloride and citrate before ultrafiltration. Milchwissenschaft 46:775-778.

Casiraghi, E., M. Lucisano, and L. Piazza. 1989. Rennet coagulation of milk retentates. 1. Effect of thermal and mechanical stresses associated with ultrafiltration. J. Dairy Sci. 72:2452-2456.

Chaplin, B., and M. L. Green. 1980. Determination of the proportions of κ-casein hydrolyzed by rennet on coagulation of skim milk. J. Dairy Res. 47:351-358.

Cheryan, M. 1986. Fouling of ultrafiltration membranes. Page 171-174 *in* Ultrafiltration Handbook. Technomic Publ. Co., Inc., Lancaster, PA.

Cotton, S. G. 1974. Ultrafiltration – fractionation applications. J. Soc. Dairy Technol. 27:121-127.

Covacevich, H. R. 1981. Recent experiences in pasta filata cheese making by ultrafiltration. Page 237-244 *in* 2nd Biennial Marschall International Cheese Conference, Madison, WI.

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. 62:204-207.

Covacevich, H. R., and F. V. Kosikowski. 1977. Cream cheese by ultrafiltration. J. Food Sci. 42:1362-1372.

Culioli, J., and P. Sherman. 1978. Rheological aspects of the renneting of milk concentrated by ultrafiltration. J. Texture Stud. 9:257-281.

Dalgleish, D. G. 1981. Effect of milk concentration on the nature of curd formed during renneting – a theoretical discussion. J. Dairy Res. 48:65-69.

Daufin, G., U. Merin, F-L. Kerherve, J-P. Labbe, A. Quemerais, and C. Bousser. 1992. Efficiency of cleaning agents for an inorganic membrane after milk ultrafiltration. J. Dairy Res. 59:29-38.

Dejmek, P. 1986. Milk saving in cheesemaking by ultrafiltration. Milchwissenschaft 41:686-688.

deMan, J. M. 1976. Mechanical properties of foods. Page 8-27 *in* Rheology and Texture in Food Quality. J. M. deMan, P. W. Voisey, V. F. Rasper, and D. W. Stanley, ed. AVI Publ. Co., Inc., Westport, Connecticut.

Dumais, R., J. A. Blais, and F. Conrad. 1985. Cheese. Page 261-263 *in* Dairy Science and Technology: Principles and Applications. J.-P. Julien, J. P. Nadeau, R. Dumais, ed. La Fondation de Technologie Laitière du Quebec, Inc., Québec.

Eckner, K. F., and E. A. Zottola. 1993. Effects of temperature and pH during membrane concentration of skim milk on fouling and cleaning efficiency. Milchwissenschaft 48:187-191.

Eckner, K. F., and E. A. Zottola. 1992. Modeling flux of skim milk as a function of pH, acidulant, and temperature. J. Dairy Sci. 75:2952-2958.

Eckner, K. F., and E. A. Zottola. 1991. Potential for the low-temperature pasteurization of dairy fluids using membrane processing. J. Food Prot. 54:793-797.

El-Gazzar, F. E., and E. H. Marth. 1991. Ultrafiltration and reverse osmosis in dairy technology: A review. J. Food Prot. 54:801-809.

Emmons, D. G., C. A. Ernstrom, C., Lacroix, and P. Verret. 1990. Predictive formulas for yield of cheese from composition of milk: A review. J. Dairy Sci. 73:1365-1394.

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. 63:228-234.

Garnot, P., T. C. Rank, and N. F. Olson. 1982. Influence of protein and fat contents of ultrafiltered milk on rheological properties of gels formed by chymosin. J. Dairy Sci. 65:2267-2273.

Glover, F. A. 1985. The processes. Page 38-44 *in* Ultrafiltration and Reverse Osmosis for the Dairy Industry. National Institute for Research in Dairying, Reading, England.

Goff, H. D., and A. R. Hill. 1993. Chemistry and physics. Page 50 *in* Dairy Science and Technology Handbook. Y. H. Hui, ed. vol. 1. VCH Publ., Inc., New York, NY.

Gordon, J. F., and N. Shapton. 1977. Characteristics and use of starters for the manufacture of yoghurt, cottage cheese, cultured buttermilk and other fermented products. J. Soc. Dairy Technol. 30:15-22.

Goudédranche, H., J.-L. Maubois, P. Ducruet, and M. Mahaut. 1980. Utilization of the new mineral UF membranes for making semi-hard cheeses. Desalination 35:243-258.

Hallal, A. M., and M. E. Al-Omar. 1987. The use of different fat sources in cream cheese.(Zanco) Iraqi J. Agr. Sci. 5:121-132.

Hicks, C. L., M. Allauddin, B. E. Langlois, and J. O'Leary. 1982. Psychrotrophic bacteria reduce cheese yield. J. Food Prot. 45:331-334.

International Dairy Federation. 1993. Factors affecting the yield of cheese. Int. Dairy Fed. Special Issue No. 9301. Int. Dairy Fed., Brussels, Belgium.

Kjaergaard Jensen, G., P. M. Olsen, and G. Hyldig. 1988. Development in the manufacture of cheese from ultrafiltered milk. Scand. Dairy Ind. Annual 2:39-42.

Kosikowski, F. V. 1985. Ultrafiltration of milk on French farms and in the making of a new specialty cheese industry. J. Dairy Sci. 68:2403-2410.

Kosikowski, F. V. 1978. Bakers', Neufchatel, and Cream cheese. Page 144-167 *in* Cheese and Fermented Milk Foods. 2nd ed. 2nd print. Kosikowski and Assoc., New York, NY.

Kosikowski, F. V. 1973. Cheesemaking by ultrafiltration. J. Dairy Sci. 57:488-491.

Kristensen, A. S., W. K. Nielsen, and R. F. Madsen. 1981. New DDS ultrafiltration module for high concentration of milk products in connection with production of cheese. North European Dairy J. 47:268-274.

Lawrence, R. C., J. Gilles, and L. K. Creamer. 1983. The relationship between cheese texture and flavor. N. Z. J. Dairy Sci. Technol. 18:175-190.

Lelievre, J., and R. C. Lawrence. 1988. Manufacture of cheese from milk concentrated by Ultrafiltration. J. Dairy Res. 55:465-478.

Lucey, J., and J. Kelly. 1994. Cheese yield. J Soc. Dairy Technol. 47:1-14.

Lucisano, M., C. Peri, and E. Donati. 1985. Studies on coagulation of milk ultrafiltration retentates. I. Coagulation kinetics. Milchwissenschaft 40:600-604.

Lundstedt, E. 1954. Manufacture of quality Cream cheese: a means of utilizing some of our excess milk fat. J. Dairy Sci. 37:243-246.

Macrae, R., R. K. Robinson, and M. J. Sadler. 1993. Page 2975-2985 *in* Encyclopaedia of Food Science, Food Technology, and Nutrition. vol. 5. Academic Press Inc., London.

Maubois, J.-L. 1980. Recent developments of membrane ultrafiltration in the dairy industry. Page 305 *in* Ultrafiltration Membrane and Applications. A. R. Cooper, ed. Plenum Publ. Co., New York, NY.

Maubois, J.-L., and G. Mocquot. 1975. Application of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001-1007.

Maubois, J.-L., and G. Mocquot. 1971. Préparation de fromage à partir de pré-fromage liquide obtenu par ultrafiltration du lait. Le Lait 51:495-533.

Maubois, J.-L., G. Ricordeau, and G. Mocquot. 1970. Etude des rendements en fromagerie de Camembert et de Saint-Paulin. Le Lait 50:351-373.

Mistry, V. V., and F. V. Kosikowski. 1985. Growth of lactic acid bacteria in highly concentrated ultrafiltered skim milk retentates. J. Dairy Sci. 68:2536-2543.

Parducho, R., and J. L. Felizmenio. 1982. Cream cheese. I. Use of *Streptococcus cremoris*, *S. diacetylactis* and *Lactobacillus helveticus* as starters. Kalikasan Philipp. J. Biol. 11:284-292.

Paulson, D. J., R. L. Wilson, and D. D. Spatz. 1984. Crossflow membrane technology and its applications. Food Technol. 38(12):77-87,111.

Peri. C.. M. Lucisano. and E. Donati. 1985. Studies on coagulation of milk ultrafiltration retentates. II. Kinetics of whey syneresis. Milchwissenschaft 40:650-652.

Premaratne. R. J.. and M. A. Cousin. 1991. Changes in the chemical composition during ultrafiltration of skim milk. J. Dairy Sci. 74:788-795.

Prentice. J. H. 1992. Viscoelasticity. Page 5-9 *in* Dairy Rheology: A Concise Guide. Y. H. Hui. ed. VCH Publ.. Inc.. New York. NY.

Qvist. K. B.. D. Thomsen. and E. Høier. 1987. Effect of ultrafiltered milk and use of different starters on the manufacture. fermentation and ripening of Havarti cheese. J. Dairy Res. 54:437-446.

Renner. E. . and M. H. Abd El-Salam. 1991. Basic principles. Page 10-15 *in* Application of Ultrafiltration in the Dairy Industry. Elsevier Applied Science Publ.. New York.

Riel. R. 1985. Composition and physico-chemical structure of milk. Page 1-20 *in* Dairy Science and Technology: Principles and Applications. J-P. Julien. J. P. Nadeau. R. Dumais. ed. La Fondation de Technologie Laitière du Quebec. Inc.. Qué.

Shoemaker. C. F.. J. Nantz. S. Bonnans. and A. C. Noble. 1992. Rheological characterization of dairy products. Food Technol. 46(1):98-102.

Sourirajan, S. 1977. Reverse osmosis – a general separation technique. Page 1-4 *in* Reverse Osmosis and Synthetic Membranes. S. Sourirajan, ed. NRC Publ., Ottawa.

Smith, K. E., and R. L. Bradley Jr. 1987. Evaluation of efficacy of four commercial enzyme-based cleaners of ultrafiltration systems. J. Dairy Sci. 70:1168-1177.

Smith, K. E., and R. L. Bradley Jr. 1988. Evaluation of three different cleaners recommended for ultrafiltration systems by direct observations of commercial scale spiral wound ultrafiltration membranes. J. Food Prot. 51:89-104.

Srilaorkul, S. 1990. Physical, Chemical and Structural Properties of Ultrafiltered Milk. Ph.D. dissertation. University of Alberta, Edmonton, Canada.

Srilaorkul, S., L. Ozimek, and M. E. Stiles. 1989. Growth and activity of *Lactococcus lactis* spp. *cremoris* in ultrafiltered skim milk. J. Dairy Sci. 72:2435-2443.

Stepp, B. L., and D. E. Smith. 1991. Effect of concentration and temperature on the density and viscosity of skim milk retentates. Milchwissenschaft 46:484-487.

St-Gelais, D., S. Haché, and M. Gros-Louis. 1992. Combined effects of temperature, acidification, and diafiltration on composition of skim milk retentate and permeate. J. Dairy Sci. 75:1167-1172.

Sutherland, B. J., and G. W. Jameson. 1981. Composition of hard cheese manufactured by ultrafiltration. Aust. J. Dairy Technol. 36:136-143.

Szczesniak, A. S. 1983. Physical properties of foods: What they are and their relation to other food properties. Page 20-28 *in* Physical Properties of Foods. M. Peleg, and E. B. Bagley, ed. AVI Publ. Co., Inc., Westport, Connecticut.

Tewari, B. D., and S. Singh. 1991. Cream cheese production: a review. Indian J. Dairy Sci. 44:348-351.

Van Slyke, L. L., and W. V. Price. 1932. Cheese. Orange Judd Publ. Co., Inc. N. Y.

Walstra, P., and R. Jenness. 1984. Pages 15 and 107 *in* Dairy Chemistry and Physics. John Wiley & Sons, Inc., Toronto, Canada.

Chapter 2

The application of butter oil in the manufacture of cream cheese using the traditional method and its effect on cheese yield

2.1 Introduction

According to the Food and Agriculture Organization/World Health Organization Joint Committee Report on the Code of Principles concerning Milk and Milk Products, Standard No. A6 1963, "cheese" is a fresh or matured product obtained by draining after the coagulation of milk, cream, skimmed or partially skimmed milk, buttermilk or combination of some or all of these products. In general, cheese is the result of dehydration or concentration process in which casein, fat and colloidal salts of the milk are concentrated from six to twelve fold by the removal of about 90% of the water, most of the lactose, the whey proteins and some soluble salts (Solorza and Bell, 1995). This process involves several interrelated operations such as coagulation, acidification, syneresis, molding and pressing (Lucey and Fox, 1993). In the UK, soft cheese refers to cheese which is easily deformed by applying moderate pressure, but does not include whey cheese, processed cheese or cheese spread, and any reference to soft cheese includes a reference to cream cheese or curd cheese (Galloway, 1995). Soft cheese can be fresh or ripened including mould ripened varieties. Cream cheese belongs to the fresh, soft and acid precipitated cheese category.

The objectives of this study were to manufacture cream cheese by the traditional method using butter oil as a source of fat and to measure the effects of butter oil utilization on cheese yield and milk component recoveries.

2.2 Materials and methods

2.2.1 Materials

The main sources of ingredients used in cheese manufacture were fresh and pasteurized skim milk from Lucerne Foods (Edmonton), butter oil (> 99% MF) from Dairyworlds Foods (Edmonton), and commercial freeze-dried lactic acid starter culture (Flora Danica) from Chr. Hansen's Laboratory, Inc., (Mississauga, Ontario). Flora Danica was used throughout the study, consisting of the following bacteria: *Lactococcus lactis ssp. lactis*, *Lactococcus lactis ssp. cremoris*, *Lactococcus lactis ssp. diacetylactis*, and *Leuconostoc cremoris*. Commercial UHT milk (Dairyworlds Foods) was used as a bulk starter culture medium. Muslin cloth was used to separate the curd from the whey.

2.2.2 Methods

2.2.2.1 Bulk starter culture preparation

About 0.01 g of the Flora Danica freeze-dried culture was aseptically transferred into 1 liter of UHT milk and incubated at 22°C for 16 hours or until a pH = 4.6 was obtained.

2.2.2.2 Cream cheese manufacture by the traditional method

Four liters of fresh and pasteurized skim milk were used in each of the nine traditional cream cheese experiments. Samples consisting of 100-ml each of skim and standardized milk were taken in each experiment and placed in a freezer at -20°C for later chemical analysis. The remaining skim milk was weighed and heated up to 50°C. The warm skim milk was standardized with butter oil to about 12% MF, mixed using a

polytron (medium speed for 5 min) and then homogenized at 1500 psi. The mass of the standardized milk obtained after homogenization and sampling was recorded. The warm standardized milk was cooled rapidly to about 22°C, inoculated with 1% (v/w) bulk starter culture, and incubated at this temperature for 16 hours or until a pH = 4.6 was attained. The coagulated gel (pH=4.6) was cut and cooked in a steam jacketed kettle to a maximum of 54°C or until the whey was completely separated. This mixture of curd and whey was drained in muslin cloth and left overnight in a cold room (4 C) to drain. The mass of whey and cream cheese obtained was recorded. The necessary corrections for mass losses due to evaporation, spills or leftovers were made. The analysis of standardized milk, cream cheese, and whey was completed within 2 days, except for Ca and Mg. All analyses were done in triplicate except for fat, which was done in duplicate. A flow chart describing the cream cheese making process using the traditional method is presented in Figure 2-1.

2.2.2.3 Analytical methods

Protein (TN × 6.38) was determined using the macro-Kjeldahl procedure (A.O.A.C., 1990).

Fat was analyzed by the Mojonnier ether extraction method (Bradley Jr. *et al.*, 1993).

Total solids were measured by the forced air oven method (A.O.A.C., 1990).

Ash samples were dried at 100°C for 4 hours and then ashed at 550°C for 12 hours.

Ca and Mg were analyzed according to the procedure of Brulé *et al.* (1974) using a Perkin-Elmer 4000 Spectrophotometer (Perkin-Elmer, 1982).

2.2.2.4 Calculations of cheese yield, total nitrogen (TN), and fat recoveries

Actual and moisture-adjusted cheese yields were expressed as kg cheese/100 kg standardized milk as follows (IDF, 1993):

$$\text{Actual cheese yield} = \left[\frac{\text{mass of cheese obtained}}{\text{mass of standardized milk}}\right] \times 100 \qquad \text{(Eq. 2-1)}$$

$$\text{Moisture adjusted cheese yield} = \text{actual yield} \times \left[\frac{100 - \text{actual moisture}}{100 - \text{desired moisture}}\right] \qquad \text{(Eq. 2-2)}$$

Percentages of fat and nitrogen recoveries were expressed as follows:

$$\text{Fat recovery (\%)} = \left[\frac{\text{mass of fat in cheese}}{\text{mass of fat in milk}}\right] \times 100 \qquad \text{(Eq. 2-3)}$$

$$\text{TN recovery (\%)} = \left[\frac{\text{mass of TN milk} - \text{mass of TN whey}}{\text{mass of TN milk}}\right] \times 100 \qquad \text{(Eq. 2-4)}$$

2.2.2.5 Statistical analysis

Standard deviations of the data presented were determined using Excel (Microsoft Office 97).

2.3 Results and discussion

Nine repeated traditional cream cheese experiments were reported. Standardized milk (12% MF), cream cheese, and whey were analyzed for percentages (m/m) of total solids, TN, fat, ash, Ca and Mg. The chemical composition of the standardized milk is presented in Table 2-1. After standardizing skim milk to about 12% milk fat, the ratio of crude proteins to fat was, on average, 0.24 ± 0.01. Barbano (1997) has proposed a casein to fat ratio of 0.18 in cream cheese making. The two ratios 0.24 and 0.18 are very comparable if whey and non protein nitrogen are added to the latter ratio. The ash, Ca and Mg mean concentrations in standardized milk were in the expected range. This indicates that the atomic absorption spectrophotometer was highly sensitive in terms of mineral measurements and that only small amounts were lost in the process of ashing and preparing samples (Moreno-Rojas *et al.*, 1995; 1994).

Table 2-2 provides the gross chemical composition of traditional cream cheese (% product basis). The chemical composition of cream cheese reported in the literature varies widely (Tewari and Singh, 1991). Cream cheese composition, on average, is 33.5% fat, 54% moisture, 9.8% protein, 0.75% salt and 0.3% gum (Kosikowski, 1978). For any cheese variety, there are at least two controlling factors: the fat and moisture levels. The fat concentration is expressed as percentages of product or dry matter. The moisture is expressed as a percentage of product, non-fat solids, or casein basis. The chemical composition of the cream cheese obtained (Table 2-2) satisfied the Canadian

Standards of Identity for cream cheese (fat ≥ 30% and moisture ≤ 55% on a product basis). The mean values from nine experiments were 35 ± 2.9% fat, 53 ± 2% moisture, 7.5 ± 0.61% protein, and 0.53 ± 0.03% ash (salt was not added to cheese). These results are very similar to the ones reported by Kosikowski (1978). Also, commercial cream cheese composition (Table 1-5) was very close to the results reported in Table 2-2. The protein content of the traditional cream cheese was lower than that of the commercial cream cheese by about 0.5%. In contrast, the fat content was higher than that of commercial cream cheese.

Lawrence and Gilles (1980) have suggested the use of compositional analysis as an aid to assess cheese quality. The authors recommend the use of FDM (fat in dry matter), MFFC (moisture in fat free cheese), S/M (salt in moisture) and pH rather than the absolute values of fat, moisture and salt as parameters to grade cheese. Equations 2-4 and 2-5 define the terms FDM and MFFC respectively. FDM and MFFC are preferred for historical and technological reasons (Lawrence *et al.*, 1983). Standardizing the cheese milk can directly control the FDM in cheese but not the fat level (Lelievre and Gilles, 1982). The effect of moisture per unit of SNF (solids non fat) contributes more to cheese flavour than moisture alone since most enzymatic reactions take place in the casein and moisture mixtures (Lawrence and Gilles, 1980).

The chemical composition of the cream cheeses is also reported on a dry matter basis in Table 2-3. The FDM and MFFC were 74.73% and 81.75% respectively.

$$FDM = \frac{Fat}{100 - Moisture} \times 100 \qquad \text{(Eq. 2-4)}$$

$$MFFC = \frac{Moisture}{100 - Fat} \times 100 \qquad \text{(Eq. 2-5)}$$

Many factors may affect cheese composition and quality including the following:

1) Source of milk fat.

2) Pasteurization temperature.

3) Percentage of milk fat and not-fat solids.

4) Pressure and temperature of homogenization,

5) pH at time of cooking and

6) *Cooking temperature.*

The chemical compositions of whey on a product and dry matter basis are presented in Tables 2-4 and 2-5 respectively. The protein losses in the whey were consistent (0.75%) with less than a 2% variation. The fat losses were less than expected for this type of cheese, probably because the muslin cloth trapped most of the fat and prevented it from passing into the whey. The mineral content of the cream cheese whey (acid whey pH = 4.6) was very close to the original mineral content of the skim milk. Most of the minerals associated with proteins such as Ca are solubilized during the acidification process and lost in the whey (Walstra and Jenness, 1984). It is interesting to note that the Mg content in the standardized milk, cheese and whey amounted to approximately one tenth of the respective Ca content. On a dry matter basis, the protein

and ash content of the whey were about 12% of whey total solids (Table 2-5). The fat content, as mentioned, was lower than expected. From the given results, one can expect that ultrafiltration will increase the cheese yield from 16-20% due to complete retention of whey proteins and associated minerals and fats (Maubois and Mocquot, 1975).

The principle of mass balance as described by Lelievre (1983) and Lelievre *et al.* (1986) was used to calculate the cheese yield and percentage recoveries of milk components. The masses of standardized milk, cream cheese, and whey were recorded and presented together with the actual and adjusted cheese yield, TN, and fat recoveries in Table 2-6. Section 2.2.2.4 deals with the calculation of traditional cheese yield and component recoveries. The actual and adjusted cheese yields were 32.26 and 33.65 kg/100 kg, respectively. TN and fat recoveries were 83.2% and 93.5%, respectively. These results compared well with the results reported in the literature. Singh and Tewari (1990) found that the yield of cream cheese from cows' milk of different fat levels ranged from 31.0 to 36.2%, indicating that the cream cheese yield is directly related to the fat levels. Barbano (1997) obtained a cream cheese yield of 31.69-33.55 lbs/100 lbs of standardized milk (12% MF). This cheese yield range was due to the increase in casein content from 2.13% to 2.25% while maintaining the casein to fat ratio constant at 0.18 level. Barbano has proven that the casein content is of great importance to cheese yield. Table 2-7 provides a comparison between results in this study and those obtained at Cornell University. The fat recoveries were 93.5% in our study as compared to 92% in the Cornell study. This may have a bearing on the difference in cheese yield. The results may indicate that the homogenization pressure applied may contribute to the higher fat retention (Abd El-Salam and El-Shibiny, 1982; Korolczuk and Mahaut, 1992). Other

possible sources of variation in fat recovery are the methods used for fat analysis and how the fat recovery was calculated. We calculated the fat recovery by dividing the mass of fat in cheese by the mass of fat in the milk as recommended by Banks *et al.* (1984). Barbano (1997) calculated the fat recovery by subtracting the mass of fat content in the whey from that of milk and dividing the result by the mass of fat in milk. The average TN recoveries were 83.2%. It has been reported in the literature that the TN recoveries in traditional soft ripened cheese and soft fresh cheese were 77% and 83%, respectively (Maubois and Mocquot, 1975; Maubois *et al.*, 1970). Therefore, the results of this study on TN recoveries are very similar to the values reported elsewhere.

2.4 Conclusions

Cream cheese was manufactured from skim milk and butter oil as a source of milk fat. This process mimicked cream cheese making in non-dairy countries where milk and other dairy ingredients are in limited supply. Such countries may cover their shortages by using recombined skim milk powder and standardizing the fat level with butter oil.

The actual and moisture adjusted cream cheese yield were 32.26 % and 33.65 % respectively. The TN % and fat % recoveries were 83.2% and 93.5 % respectively. The results are in accordance with values reported in the literature. The use of butter oil may not have any adverse effect on the TN recoveries since our results were similar to those reported by Maubois and Mocquot (1975) and Maubois *et al.* (1970).

Table 2-1. Chemical analysis of standardized milk used in the manufacture of traditional cream cheese (%).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	.	0.46	2.96	12.08	.	.	.
2	.	0.45	2.87	11.86	.	.	.
3	.	0.44	2.82	12.50	.	.	.
4	20.20	0.45	2.86	12.74	0.63	105.95	10.92
5	20.16	0.45	2.88	12.38	0.64	117.43	9.98
6	19.22	0.45	2.87	12.16	0.63	113.23	11.06
7	.	0.46	2.95	12.53	0.65	98.55	8.93
8	.	0.46	2.95	12.29	0.64	104.75	8.95
9.	.	0.44	2.82	10.50	0.65	102.65	8.90
Average of 9 experiments	19.86 ± 0.55	0.45 ± 0.01	2.89 ± 0.05	12.11 ± 0.62	0.64 ± 0.01	107.09 ± 6.38	9.79 ± 0.93

* %Protein = %TN × 6.38

Table 2-2. Chemical analysis of the traditional cream cheese (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	45.88	1.42	9.05	33.67	0.57	80.98	6.89
2	45.39	1.11	7.06	34.25	0.56	80.20	8.54
3	45.78	1.13	7.22	34.17	0.50	75.76	8.16
4	50.00	1.19	7.57	39.39	0.51	78.82	7.26
5	50.27	1.17	7.45	39.52	0.49	77.67	7.32
6	46.19	1.14	7.246	32.56	0.50	84.76	7.08
7	48.89	1.17	7.47	37.38	0.54	78.65	7.51
8	45.42	1.11	7.07	34.30	0.56	77.66	8.16
9	45.29	1.14	7.28	31.37	0.55	76.69	8.77
Average of 9 experiments	47.01 ± 2.08	1.17 ± 0.1	7.49 ± 0.61	35.18 ± 2.9	0.53 ± 0.03	79.02 ± 2.69	7.74 ± 0.68

* %Protein = %TN × 6.38

Table 2-3. Chemical analysis of the traditional cream cheese (% dry matter).

Experiment	TN %	Protein %	Fat %	Ash %	Ca (mg / 100 g dry matter)	Mg (mg /100 g dry matter)
1	3.09	19.73	73.39	1.24	176.5	15.02
2	2.44	15.55	75.46	1.23	176.69	18.81
3	2.47	15.77	74.64	1.09	165.487	17.82
4	2.37	15.14	78.78	1.02	157.64	14.52
5	2.32	14.82	78.62	0.97	154.51	14.56
6	2.46	15.68	70.49	1.08	183.5	15.33
7	2.39	15.27	76.46	1.11	160.87	15.36
8	2.44	15.57	75.51	1.22	171	17.97
9	2.52	16.07	69.26	1.21	169.33	19.36
Average of 9 experiments	2.50 ± 0.23	15.96 ± 1.46	74.73 ± 3.26	1.13 ± 0.1	168.39 ± 9.64	16.53 ± 1.94

Table 2-4. Chemical analysis of cream cheese whey obtained from traditional cream cheese (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	6.32	0.12	0.77	0.08	0.79	123.53	11.15
2	6.12	0.12	0.74	0.02	0.69	116.81	10.87
3	6.37	0.12	0.74	0.05	0.70	115.83	10.7
4	6.43	0.12	0.75	0.06	0.74	126.62	11.51
5	6.31	0.12	0.75	0.04	0.73	127.87	11.67
6	6.28	0.11	0.73	0.06	0.74	123.86	10.56
7	5.90	0.12	0.76	0.04	0.70	123.86	14.24
8	5.95	0.12	0.77	0.05	0.73	124.05	11.41
9	6.04	0.12	0.78	0.03	0.75	120.45	10.63
Average of 9 experiments	6.19 ± 0.19	0.12	0.75 ± 0.02	0.05 ± 0.02	0.73 ± 0.03	122.16 ± 4.11	11.42 ± 1.13

* %Protein = %TN × 6.38

Table2-5. Chemical analysis of cream cheese whey obtained from traditional cream cheese (% dry matter).

Experiment	TN %	Protein %	Fat %	Ash %	Ca (mg / 100 g dry matter)	Mg (mg /100 g dry matter)
1	1.91	12.18	1.27	12.50	1954.59	176.42
2	1.90	12.09	0.33	11.27	1908.66	177.61
3	1.82	11.62	0.78	10.99	1818.37	167.98
4	1.83	11.66	0.97	11.51	1969.21	179.01
5	1.86	11.89	0.66	11.57	2026.47	184.95
6	1.82	11.62	0.90	11.78	1918.15	168.15
7	2.01	12.8	0.74	11.86	2099.32	241.36
8	2.03	12.95	0.77	12.27	2086.63	191.93
9	2.02	12.91	0.50	12.47	1994.21	176.00
Average of 9 experiments	1.91 ± 0.09	12.19 ± 0.56	0.77 ± 0.27	11.8 ± 0.53	1975.07 ± 89.13	184.82 ± 22.48

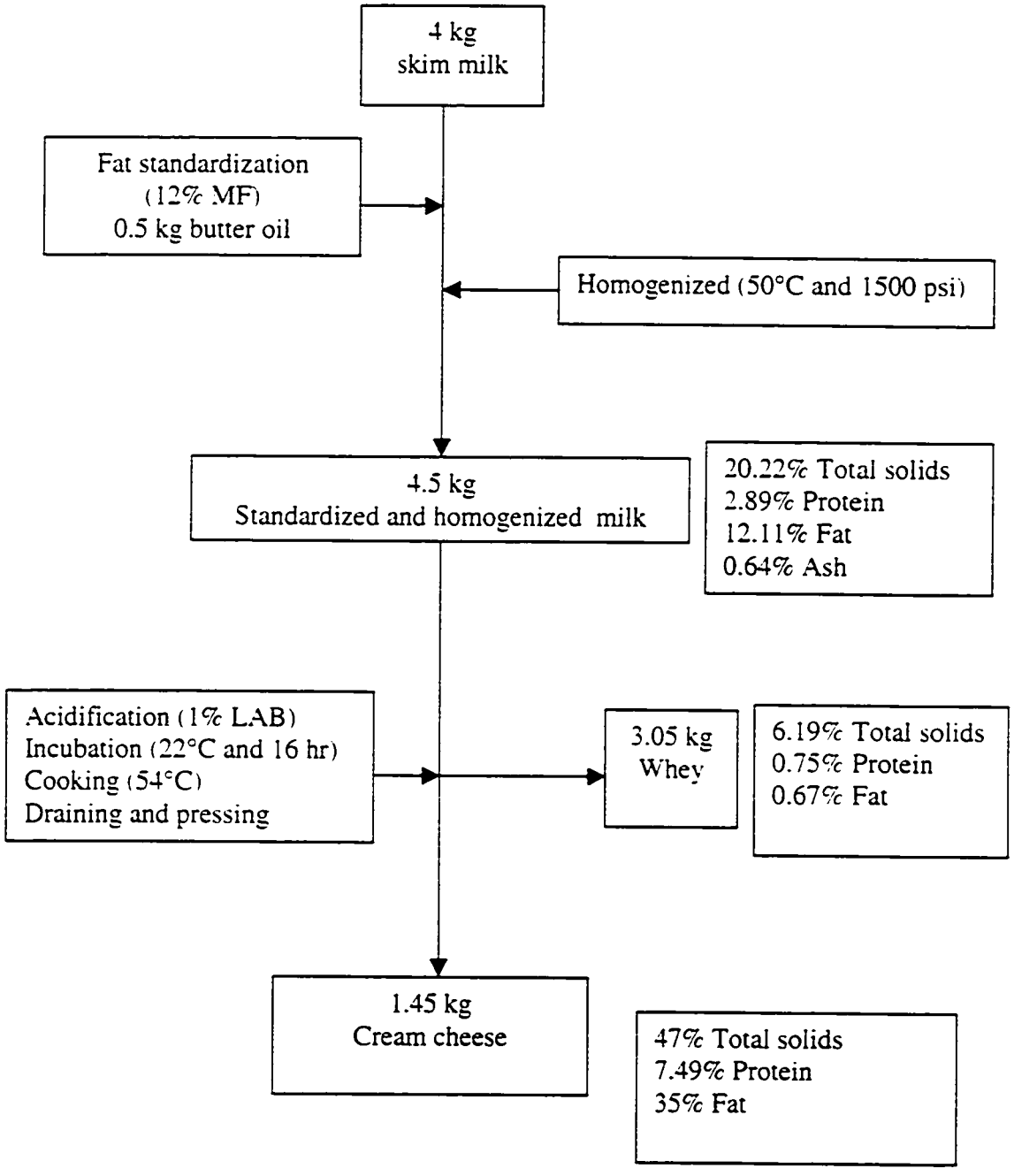
Table 2-6. Traditional cream cheese yield, protein and fat recoveries measured from mass balance

Experiment	Skim milk (kg)	Standardized milk (kg)	Whey (kg)	Cheese (kg)	Actual yield (kg/100 kg)	Adj. yield (kg/100 kg)	TN recovery (%)	Fat recovery (%)
1	4.08	4.22	2.61	1.47	34.76	35.44	83.88	96.90
2	3.72	4.08	2.62	1.33	32.49	32.77	83.46	93.82
3	3.68	4.04	2.60	1.31	32.32	32.88	83.13	88.36
4	3.84	4.01	2.67	1.20	29.98	33.31	82.56	92.70
5	3.83	4.08	2.70	1.23	30.28	33.83	82.75	96.67
6	3.80	4.09	2.64	1.31	32.11	32.96	83.60	86.03
7	3.88	4.11	2.67	1.30	31.60	34.33	83.39	94.30
8	3.90	4.12	2.55	1.43	34.77	35.09	83.84	97.05
9	3.89	4.18	2.70	1.34	32.07	32.28	82.15	95.86
Average of 9 experiments	3.85 ± 0.12	4.11 ± 0.06	2.64 ± 0.049	1.32 ± 0.08	32.26 ± 1.67	33.65 ± 1.1	83.19 ± 0.56	93.52 ± 3.7

Table 2-7. Comparisons of traditional cream cheese manufactured in this study and at Cornell University (Barbano, 1997)

	University of Alberta Alberta Dairy Council Research Unit	Cornell University Northeast Dairy Foods Research Center
Milk fat standardization	12 %	12 %
Source of fat	Butter oil (> 99% MF)	Cream (35% MF)
Homogenization	Yes	No
Moisture adjustment	55%	54%
Fat in Dry Matter (FDM)	74.8%	74.5%
Fat recovery	93.5%	92.0%
TN recovery	83.2%	Not mentioned
Adjusted cheese yield kg/100 kg standardized milk	33.65	31.69-33.55

Fig. 2-1. Technological steps and mass balance flow chart during the manufacture of the traditional cream cheese.



2.5 Bibliography

Abd El-Salam, M. H., and S. El-Shibiny. 1982. Manufacture of pickled soft cheese from recombined milk. I. Effect of homogenization pressure. Egyptian J. Dairy Sci. 10:55-59.

Association of Official Analytical Chemists (A.O.A.C.). 1990. Official methods of Analysis. 15th ed. Assoc. Official Anal. Chem., Arlington, VA.

Banks, J. M., D. D. Muir, and A. Y. Tamime. 1984. Equations for estimation of the efficiency of Cheddar cheese production. Dairy Ind. Int. 49:14-17.

Barbano, D. M. 1997. Practical formulas for prediction of cheese yield: Mozzarella, Cheddar, Cream and Cottage cheeses. Cheese Manufacturers' Short Course. Cornell University, Ithaca, NY.

Bradley Jr., R. L., E. Arnold Jr., D. M. Barbano, R. G. Semerad, D. E. Smith, and B. K. Vines. 1993. Chemical and physical methods. Page 474-479 *in* Standard Methods for the Examination of Dairy Products. R. T. Marshall ed. 16th ed. American Public Health Association, Washington, D.C.

Brulé, G., J. L. Maubois, and J. Fauquant. 1974. Etude de la teneur en éléments minéraux des produits obtenus lors de l'ultrafiltration du lait sur membrane. Le Lait 54:600-615.

Galloway, J. H. 1995. Production of soft cheese. J. Soc. Dairy Technol. 48:36-43.

International Dairy Federation. 1993. Factors affecting the yield of cheese. Int. Dairy Fed. Special Issue No. 9301. Int. Dairy Fed., Brussels, Belgium.

Korolczuk, J., and M. Mahaut. 1992. Effect of homogenization of milk on the consistency of UF fresh cheese. Milchwissenschaft 47:225-227.

Kosikowski, F. V. 1978. Bakers', Neufchatel, and Cream cheese. Page 144-167 *in* Cheese and Fermented Milk Foods. 2nd ed. 2nd print. Kosikowski and Assoc., New York, NY.

Lawrence, R. C., J. Gilles, and L. K. Creamer. 1983. The relationship between cheese texture and flavour. N. Z. J. Dairy Sci and Technol. 18:175-190.

Lawrence, R. C., and J. Gilles. 1980. The assessment of the potential quality of young Cheddar cheese. N. Z. J. Dairy Sci and Technol. 15:1-12.

Lelievre, J., M. Iyer, and R. J. Bennett. 1986. The effect of ultrafiltration per se on the suitability of milk for Cheddar cheese manufacture. N. Z. J. Dairy Sci and Technol. 21:157-164.

Lelievre, J. 1983. Prediction of Cheddar cheese yield. N. Z. J. Dairy Sci. Technol. 18:169-172.

Lelievre, J., and J. Gilles. 1982. The relationship between the grade (product value) and composition of young commercial Cheddar cheese. N. Z. J. Dairy Technol. 17:69-75.

Lucey, J. A., and P. F. Fox. 1993. Importance of calcium and phosphate in cheese manufacture: A review. J. Dairy Sci. 76:1714-1724.

Maubois, J.-L., and G. Mocquot. 1975. Application of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001-1007.

Maubois, J.-L., G. Ricordeau, and G. Mocquot. 1970. Etude des rendements en fromagerie de Camembert et de Saint-Paulin. Le Lait 50:351-373.

Moreno-Rojas, R., M. A. Amaro-Lopez, R. H. Garcia-Gimeno, and G. Zurera-Cosano. 1995. Effects of Manchego-type cheese-making process on contents of mineral elements. Food chem. 53:435-439.

Moreno-Rojas, R., M. A. Amaro-Lopez, R. H. Garcia-Gimeno, and G. Zurera-Cosano. 1994. Calcium, magnesium, manganese, sodium, and potassium variations in Manchego-type cheese during ripening. Food chem. 50:373-378.

Perkin-Elmer. 1982. Analysis of milk. Page FP12 *in* Analytical Methods for Atomic Absorption Spectrophotometry. Perkin-Elmer, Norwalk, CT.

Singh, S., and B. D. Tewari. 1990. Optimization of manufacturing technique for Cream cheese. Indian J. Dairy Sci. 43:428-432.

Solorza, F. J., and A. E. Bell. 1995. Effect of calcium, fat and total solids on the rheology of a model soft cheese system. J. Soc. Dairy Technol. 48:133-139.

Tewari, B. D., and S. Singh. 1991. Cream cheese production – A review. Indian J. Dairy Sci. 44:348-351.

Walstra, P., and R. Jenness. 1984. Page 54 *in* Dairy Chemistry and Physics. John Wiley & Sons, Inc., Toronto, Canada.

Chapter 3

UF cream cheese: Manufacture, composition, and yield

3.1 Introduction

Ultrafiltration is a membrane process that has a wide range of applications in the dairy industry. It can be used to clarify, concentrate and fractionate emulsified and colloidal phase components of milk (Srilaorkul *et al.*, 1989; Fenton-May *et al.*, 1972). The most important advantage of concentrating milk by ultrafiltration for the production of cheese is the ability to retain some water-soluble components, particularly whey proteins, and to reduce the losses of insoluble casein, fat and fines (Iyer and Lelievre, 1987). In addition, the ultrafiltration technology increases the efficiency of continuous processing operations, improves product consistency, and reduces the problem of whey disposal (Sachdeva *et al.*, 1992).

The applications of ultrafiltration in cheese making have expanded in the last two decades to include soft, semi-hard, and hard cheese varieties. The utilization of ultrafiltration is determined primarily by the extent or degree of milk concentration and can be summarized in the following (Shaw, 1986):

1) Low concentrated retentates (LCR): Milk is pre-concentrated up to two times. The retentate is processed using the conventional cheesemaking equipment. There is little or no increase in cheese yield; however, the production rate of cheese per cheese vat is increased.

2) Medium concentrated retentates (MCR): Milk concentration of two to six times is achieved. Conventional cheesemaking equipment cannot be used to process the retentate. In this category, whey drainage is carried out after milk concentration to bring the final

concentration of protein and fat in the retentate as close as possible to the final cheese composition. A famous example of this group is the APV-SiroCurd process for cheddar cheese making. An increase of 6-8% in cheese yield is expected (Jameson, 1987).

3) Liquid pre-cheese (LPC): Milk is concentrated by ultrafiltration to get milk retentate or concentrate with protein and fat levels close to those in the final cheese product. This method is especially useful in the manufacture of a wide variety of fresh soft cheeses in which there is little or no whey drainage. This approach has the potential to increase cheese yield by up to 16-18% (Maubois and Mocquot, 1975).

4) Whey protein concentrate: Whey proteins from cheesemaking are concentrated and returned to the cheese vat as slurry.

A summary of the various applications of ultrafiltration in cheese manufacture is presented in Figure 3-1.

This study was undertaken to manufacture UF cream cheese from skim milk (pH=6.7) concentrated 4 × weight concentration factor (WCF) and standardized using butter oil as a source of milk fat. An estimate of the UF cheese yield and percentage recovery of TN and fat is calculated from the mass balance of milk components. An attempt was also made to concentrate coagulated skim milk (pH=4.6) 4 × (WCF) using a mineral membranes and then standardize the acid retentate with butter oil for 30% milk fat.

3.2 Materials and methods

3.2.1 Materials

The main sources of ingredients used in cheese manufacture were fresh and pasteurized skim milk from Lucerne Foods (Edmonton), butter oil (> 99% MF) from Dairyworlds Foods (Edmonton), and commercial freeze-dried lactic acid starter culture (Flora Danica) from Chr. Hansen's Laboratory, Inc., (Mississauga, Ontario). Flora Danica was used in some experiments, consisting of the following bacteria: *Lactococcus lactis ssp. lactis*, *Lactococcus lactis ssp. cremoris*, *Lactococcus lactis ssp. diacetylactis*, and *Leuconostoc cremoris*. Commercial UHT milk (Dairyworlds Foods) was used as a bulk starter culture medium.

In experiments 1 to 11, food grade lactic acid solution (UFL Foods, Edmonton) was used as acidifying agent. In experiments 12 to 14, the lactic acid bacteria mentioned above were used for acidification.

3.2.2 Methods

3.2.2.1 Bulk starter preparation

About 0.01 g of the Flora Danica freeze-dried culture was aseptically transferred into 1 liter UHT milk and incubated at 22°C for 16 hours or until a pH = 4.6 was obtained.

3.2.2.2 Retentate preparation at skim milk's physiological pH = 6.7

The ultrafiltration unit was a DDS-20 LAB module (De Danske Sukkerfabbrikker, Nakskov, DK) fitted with polysulphone membranes GR 60-PP. The

membrane area and MWCO were 0.72 m^2 and 20,000 for experiments 1 to 11 and 0.36 m^2 and 25,000 for experiments 12 to 14 respectively. The ultrafiltration was carried out at 55 psi transmembrane pressure (TSMP) and a temperature of 50-55°C. Skim milk was concentrated up to 4 × (weight concentration factor, WCF).

3.2.2.3 Retentate preparation from coagulated skim milk (pH = 4.6)

Sixteen liters of skim milk were inoculated with 1% (w/v) bulk starter culture and incubated for 16 hours at 22°C until the pH reached 4.6. Ultrafiltration was conducted on a Carbosep-S7 unit fitted with mineral membranes (zirconium oxide) of MWCO 70,000. The membrane area was 0.16 m^2 and the transmembrane pressure was 60 psi.

3.2.2.4 UF cream cheese making from retentate (pH = 6.7)

The retentate was standardized to 30% MF using butter oil. Then the standardized retentate was homogenized at 50°C and 1500 psi. The acidifying agent used was either food grade lactic acid solution or lactic acid produced from lactic acid bacteria. For experiments 1 to 11, the standardized retentates were rapidly cooled to about 22°C, acidified with lactic acid solution with continuos mixing and pH reading until a stable pH reading of about 4.6 was obtained and cooked in a steam jacketed kettle (Goren, USA) at 85°C. For experiments 12 to 14 the standardized and cooled retentates were inoculated with 2% bulk starter culture and incubated at 22°C until pH reached 4.6. Similarly, the acidified curd was cooked to about 85°C. In both cases the cooked curd was immediately homogenized twice at 2000 and 500 psi, respectively. A detailed flow chart describing the UF cream cheese process is presented in Figure 3-2.

3.2.2.5 Membrane cleansing

The following steps were used to clean and sterilize the ultrafiltration membranes:

1) Flush with warm water until all products are removed.
2) Caustic cleaning (0.5% NaOH or Ultrasil 11) at 55°C, minimum pressure and circulate for 30 minutes.
3) Drain caustic solution and rinse with warm water for 30 min at least twice.
4) Acid cleaning (0.1% HCl, 0.5% HNO_3, or Ultrasil 75) at 55°C, minimum pressure and circulate for 30 minutes.
5) Drain acid solution and proceed as mentioned in step 3.
6) Caustic and EDTA cleaning (0.5% NaOH or Ultrasil 11 and 0.5% EDTA) at 75°C, minimum pressure and circulate for 30 minutes.
7) Drain cleaning solution and repeat as step 3.
8) Disinfect (1% of 40% formalin or 200 ppm sodium hypochlorite)

In a few cases, an enzyme-based cleaner, Duozyme, was used at the beginning of the cleaning procedure. The enzyme was used according to the manufacturer's instructions, circulated in the UF unit and left in the system overnight. The next day, the cleaning commenced as mentioned above.

3.2.2.6 Analytical methods

Protein (TN × 6.38) was determined using the macro-Kjeldahl procedure (A.O.A.C., 1990).

Fat was analyzed by the Mojonnier ether extraction method (Bradley Jr. *et al.*, 1993).

Total solids were measured by the forced air oven method (A.O.A.C., 1990).

Ash samples were dried at 100°C for 4 hours and then ashed at 550°C for 12 hours.

Ca and Mg were analyzed according to the procedure of Brulé *et al.* (1974) using a Perkin-Elmer 4000 Spectrophotometer (Perkin-Elmer, 1982).

3.2.2.7 UF cheese yield calculations, total nitrogen (TN) and fat recoveries

Actual and moisture-adjusted cheese yields were expressed as kg cheese/100 kg skim milk as follows:

$$\text{Actual cheese yield} = \left[\frac{\text{Mass of cheese obtained}}{\text{mass of skim milk}}\right] \times 100 \qquad \text{(Eq. 3-1)}$$

$$\text{Moisture adjusted cheese yield} = \text{actual yield} \times \left[\frac{100 - \text{actual moisture}}{100 - \text{desired moisture}}\right] \qquad \text{(Eq. 3-2)}$$

Percentages of nitrogen recoveries were expressed as follows:

$$\text{TN recovery (\%)} = \left[\frac{\text{mass of TN milk} - \text{mass of TN permeate}}{\text{mass of TN milk}}\right] \times 100 \qquad \text{(Eq. 3-3)}$$

Percentage of fat recovery was assumed to be 100%.

3.2.2.8 Statistical analysis

Standard deviations of the data presented were determined using Excel (Microsoft Office 97). Statistical test was conducted to determine whether there are any statistically significant differences between the use of lactic acid solution in experiments 1 to 11 and the use of lactic acid bacteria in experiments 12 to 14 on cheese yield and milk component recovery.

3.3 Results and discussion

3.3.1 Retentate obtained at milk physiological pH

Cream cheese was manufactured from skim milk (pH=6.7), concentrated 4 × (WCF) and standardized to approximately 30% milk fat using butter oil. Lactic acid solution or lactic acid bacteria were used as the acidifying agent. A total of fourteen experiments were conducted. No statistically significant differences between the use of lactic acid solution and lactic acid bacteria on cheese yield and milk component recovery was observed. So the fourteen experiments were grouped together.

Skim milk, retentates, cheeses and permeates were analyzed for total solids, TN, fat, ash, Ca and Mg. Table 3-1 provides the chemical composition of the skim milk used in these experiments. Chemical analyses of retentates on a product and dry matter basis are reported in Tables 3-2 and 3-3, respectively. The protein content of the retentate was approximately 12%, with a protein concentration factor of 3.6. On a dry matter basis, the protein content of the retentates was about 63%, with a coefficient of variation of 2%. The Ca content was about 400 mg/100 g retentate and 1925 mg/100 g dry retentate. The analyses of UF cream cheese on both a product and dry matter basis are given in Tables

3-4 and 3-5, respectively. The protein and fat contents of the UF cream cheese on a product basis were 8.58% and 33.33%, respectively. These values are very comparable to the protein and fat levels of commercial cream cheese (Table 1-5). The Ca concentration in the UF cream cheese was 265 mg/100g cheese and 525 mg/100 g dry cheese. Comparing the Ca content of traditional and UF cream cheese (Tables 2-2, 2-3, 3-4 and 3-5) a 212% increase in the Ca content of the UF cream cheese relative to the traditional cheese is evident. Permeate analyses (% g/100 g permeate and % g/100 dry permeate) are presented in Tables 3-6 and 3-7, respectively. The average amount of protein lost into the permeate (Table 3-6) was 0.3%. Notice that the percentage losses of proteins in experiments 1 to 11 were the highest and in experiments 12 to 14 the lowest, despite the fact that the MWCO of the first eleven experiments was 20.000 compared to 25.000 for the last three experiments. The UF membranes used in experiments 1 to 11 were relatively old, which may explain the differences that occurred. The Ca content of the permeate (17 g/100 g permeate) indicates that ≈ 91% of the milk Ca are recovered by the membranes and end up in the retentates and in the cheese.

The protein concentration factor (a) presented in Table 3-3 was calculated as reported by Brulé *et al.* (1974) according to the following formula (Eq. 3-4):

$$SC\ retentate = a(SC\ milk - SC\ permeate) + SC\ permeate \quad \text{.....(Eq. 3-4)}$$

SC = solids content
a = protein concentration factor (retentate/milk)

Factor (a) represents the ratio of the masses of milk prior to ultrafiltration and the concentrate obtained. The determination of these masses is not easy at an industrial scale. The concentration factor (a) can be calculated from any of the solids components.

For example:

1) The protein concentration factor calculated from the retentates:

$$11.81 = a(3.28 - 0.3) + 0.3 \quad \Rightarrow a = 3.6$$

2) If we want to check the accuracy of this factor (a =3.6), the Ca content of the retentate is the following:

Ca content of retentate = 3.6(122.07 – 17.32) + 17.32 = 394.42 mg/100 g retentate

394.42 ≈ 400.41 mg/100 g retentate (Table 3-2)

3.3.2 Concentration of coagulated skim milk (pH=4.6)

About two thirds of the calcium in milk is bound to proteins, and when milk is concentrated, the colloidal Ca is fully retained while the soluble Ca freely permeates through the membranes (Casiraghi *et al.*, 1987). A high Ca content of cheese may lead to bitterness due to a high concentration of calcium lactate (Brulé *et al.*, 1974; Brulé *et al.*, 1975; Mahaut *et al.*, 1982).

To reduce the Ca content in the final cheese product, an attempt was made to concentrate coagulated skim milk (pH=4.6) up to 4 × (WCF) using mineral membranes as suggested by Mahaut *et al.* (1982). Milk acidification will lead to the solubilization of colloidal Ca (Walstra and Jenness, 1984), and, thus, when it is concentrated, the soluble Ca will partition between the permeate and retentate. Acidification prior to concentration will render the concentration of calcium lactate in the retentate identical to the aqueous phase of the traditional cheese curd (Goudédranche *et al.*, 1981).

The mineral membranes have shown superiority to the organic membranes (polysulphone) in terms of their mechanical resistance and cleanliness, especially when they come into contact with highly viscous materials (Ducruet *et al.*, 1981).

Unfortunately, it was not possible to concentrate coagulated skim milk (pH=4.6) 4 × (WCF). The maximum concentration attained was about 2 × (WCF) after 13 hours of circulation. The most probable reason for this failure was the high hold up volume to membrane area (Glover, 1985; Paulson *et al.*, 1984). Practically, this means that more membrane area for the same volume of milk to be concentrated is needed. The Carbosep S7 module used had a membrane area of 0.16 m^2 and a minimum hold up volume of 3 liters. This implies that 12 liters of coagulated skim milk, after 4 × concentration (WCF), will be held up in the system. So the minimum volume required was at least 16 liters. This volume was too high to be concentrated within a reasonable time using a 0.16 m^2 membrane area.

3.3.3 Difficulties in expressing UF cheese yield

Comparing the UF cheese yield to the traditional one is a difficult task. Some researchers have summarized the problems and difficulties in expressing UF cheese yield in relation to the conventional one (Sutherland *et al.*, 1994):

1) The difficulty in comparing, fairly, the UF cheese yield to the conventional cheese yield:

1.1) The cheese milk to be ultrafiltered is standardized to different fat and protein levels - for technological reasons - than the milk that is to undergo traditional cheese making.

1.2) The UF cheese obtained at the end is characterized by a different chemical composition, mainly due to the incorporation of whey proteins, as compared to the traditional cheese.

2) Conventional cheese yield is a dynamic process. Yield increases as our knowledge of technological developments increases rather than being a fixed benchmark. Thus, there is not a fixed reference point with which to compare the UF cheese yield.

Some solutions to tackle such problems have been proposed. Dejmek (1986) suggested neglecting the fat component, as a first order approximation, and expressed the cheese yield as a percentage of milk saving. The author assumed that the price value of fat in whey does not differ much from the fat price value in milk. Others have proposed expressing yield differences in terms of component recovery in cheese (Sutherland *et al.*, 1994).

In the current study, the UF cheese yield was calculated from the mass balance of milk components (Lelievre, 1983; Lelievre *et al.*, 1986) as shown in Table 3-8. Cheese yield, TN and fat recoveries were calculated as mentioned in section 3.2.2.7.

3.4 Conclusions

A total of fourteen UF cream cheese experiments were done using butter oil as a source of milk fat. The Ca content of the UF cheese made from milk concentrated at physiological pH 6.7 and then undergoing the process of acidification with no further whey drainage was 212% greater than the level normally found in traditional cream cheese. This high level of Ca is the cause of bitterness due to a high concentration of

calcium lactate in the aqueous cheese phase. Ultrafiltration of coagulated skim milk (pH=4.6) can solve the problem provided that the right UF module is available.

The protein losses into the permeate were the highest in experiments 1 to 11 (Table 3-6), which may have lowered the overall average percent TN recovery from about 95% to 93% (Table 3-8). We started from skim milk approximately 0% fat and no fat was lost in the permeate. Fat was added to the retentate. So it was safe to assume 100% fat recovery. The actual cheese yield and moisture-adjusted cheese yield were 35.34 ± 2.85% and 38.56 ± 3.2%, respectively.

Table 3-1. Chemical analysis of skim milk used in the manufacture of UF cream cheese (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	9.04	0.52	3.34	0.05	.	.	.
2	8.98	0.52	3.33	0.05	.	.	.
3	9.08	0.49	3.16	0.20	.	.	.
4	9.10	0.52	3.34	0.10	.	.	.
5	9.08	0.49	3.16	0.04	.	.	.
6	9.07	0.52	3.32	0.07	.	.	.
7	9.04	0.51	3.24	0.10	.	.	.
8	9.04	0.51	3.24	0.07	.	.	.
9	9.03	0.52	3.31	0.08	0.74	.	.
10	9.05	0.52	3.33	0.09	0.77	.	.
11	9.08	0.50	3.21	0.08	.	.	.
12	9.71	0.51	3.25	.	0.79	124.25	11.85
13	8.90	0.52	3.32	.	0.75	123.23	11.75
14	8.92	0.52	3.33	.	0.74	118.72	11.32
Average of 14 experiments	9.08 ± 0.19	0.51 ± 0.01	3.28 ± 0.07	0.08 ± 0.04	0.76 ± 0.02	122.07 ± 2.94	11.64 ± 0.28

* %Protein = %TN × 6.38

Table 3-2. Chemical analysis of the UF retentate (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	18.60	1.86	11.87	0.22	.	.	.
2	18.20	1.77	11.32	0.17	.	.	.
3	17.37	1.63	10.40	0.60	.	.	.
4	17.55	1.66	10.60	0.32	.	.	.
5	18.11	1.83	11.69	0.26	.	.	.
6	17.98	1.77	11.28	0.28	.	.	.
7	18.05	1.76	11.24	0.26	.	.	.
8	17.54	1.69	10.78	0.25	.	.	.
9	17.14	1.67	10.68	0.20	1.37	.	.
10	18.51	1.86	11.86	0.24	1.47	.	.
11	21.87	2.27	14.46	0.34	1.49	.	.
12	18.08	1.75	11.15	.	1.52	353.48	25.01
13	23.21	2.35	15.01	.	1.85	444.03	31.42
14	21.17	2.03	12.94	.	1.75	403.72	28.57
Average of 14 experiment	18.81 ± 1.86	1.85 ± 0.22	11.81 ± 1.40	0.29 ± 0.12	1.58 ± 0.18	400.41 ± 45.37	28.33 ± 3.21

* %Protein = %TN × 6.38

Table 3-3. Chemical analysis of the UF retentate (% dry matter).

Experiment	(a) protein conc. factor	TN (%)	Protein (%)	Fat (%)	Ash (%)	Ca (mg/100 g dry matter)	Mg (mg/100 g dry matter)
1	3.55	10.00	63.82	1.18	.	.	.
2	3.40	9.75	62.20	0.93	.	.	.
3	3.29	9.38	59.87	3.45	.	.	.
4	3.17	9.47	60.40	1.82	.	.	.
5	3.70	10.12	64.55	1.44	.	.	.
6	3.40	9.83	62.74	1.56	.	.	.
7	3.47	9.76	62.27	1.44	.	.	.
8	3.33	9.63	61.46	1.43	.	.	.
9	3.23	9.77	62.31	1.17	8.00	.	.
10	3.56	10.04	64.07	1.30	7.94	.	.
11	4.51	10.36	66.12	1.55	6.81	.	.
12	3.43	9.66	61.65	.	8.41	1955.09	138.33
13	4.53	10.14	64.67	.	7.97	1913.10	135.37
14	3.88	9.58	61.10	.	8.27	1907.04	134.96
Average of 14 experiments	3.60	9.82 ± 0.28	62.66 ± 1.78	1.57 ± 0.67	7.90 ± 0.56	1925.08 ± 26.17	136.22 ± 1.84

Table 3-4. Chemical analysis of the UF cream cheese (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	55.26	1.44	9.18	39.50	1.78	265.94	14.30
2	49.03	1.50	9.55	32.00	1.89	234.42	12.73
3	46.31	1.25	8.01	31.00	1.85	238.72	13.03
4	46.38	1.30	8.28	30.50	1.74	187.26	15.52
5	51.47	1.36	8.65	35.00	2.01	268.24	15.00
6	49.00	1.32	8.45	34.00	1.92	295.65	20.45
7	50.08	1.31	8.39	34.50	1.92	247.00	15.86
8	45.22	1.25	7.95	30.00	1.66	246.23	13.64
9	46.27	1.28	8.15	33.00	1.74	.	.
10	46.19	1.37	8.74	31.00	1.72	.	.
11	52.30	1.33	8.49	30.60	1.59	.	.
12	47.03	1.31	8.39	32.65	1.11	254.25	18.01
13	52.80	1.38	8.78	37.47	1.11	265.98	18.84
14	51.44	1.43	9.12	35.40	1.17	273.74	19.39
Average of 14 experiments	49.20 ± 3.1	1.34 ± 0.07	8.58 ± 0.44	33.33 ± 2.83	1.66 ± 0.31	264.66 ± 9.81	18.75 ± 0.7

* %Protein = %TN × 6.38

Table 3-5. Chemical analysis of the UF cream cheese (% dry matter).

Experiment	TN (%)	Protein (%)	Fat (%)	Ash (%)	Ca (mg/100 g dry matter)	Mg (mg/100 g dry matter)
1	2.60	16.61	71.48	3.22	481.25	25.88
2	3.05	19.48	65.27	3.85	478.12	25.14
3	2.71	17.30	66.94	4.00	515.48	28.14
4	2.80	17.85	65.76	3.75	403.75	33.46
5	2.63	16.81	68.00	3.91	521.16	29.14
6	2.70	17.25	69.39	3.92	603.37	41.74
7	2.63	16.75	68.90	3.83	493.21	31.67
8	2.76	17.58	66.34	3.67	544.52	30.16
9	2.76	17.61	71.32	3.76	.	.
10	2.97	18.92	67.11	3.72	.	.
11	2.54	16.23	58.51	3.04	.	.
12	2.79	17.83	69.42	2.36	540.61	38.29
13	2.61	16.63	70.97	2.10	503.75	35.68
14	2.79	17.73	68.82	2.27	532.15	37.69
Average of 14 experiments	2.74 ± 0.14	17.47 ± 0.90	67.73 ± 3.32	3.39 ± 0.67	525.51 ± 49.94	32.53 ± 5.29

Table 3-6. Chemical analysis of the UF cream cheese permeates (% product).

Experiment	TS	TN	Protein*	Fat	Ash	Ca (mg/100g)	Mg (mg/100g)
1	5.30	0.05	0.33	0.05	.	.	.
2	5.65	0.05	0.35	0.06	.	.	.
3	5.82	0.06	0.38	0.05	.	.	.
4	5.60	0.05	0.35	0.06	.	.	.
5	5.32	0.05	0.33	0.04	.	.	.
6	5.60	0.05	0.35	0.07	.	.	.
7	5.50	0.05	0.33	0.05	.	.	.
8	5.31	0.04	0.29	0.04	.	.	.
9	4.64	0.04	0.23	0.02	0.41	.	.
10	5.56	0.05	0.31	0.04	0.49	.	.
11	5.61	0.06	0.41	0.09	0.52	.	.
12	4.76	0.03	0.19	.	0.40	18.43	5.49
13	5.05	0.03	0.20	.	0.40	18.48	5.50
14	4.80	0.03	0.19	.	0.39	15.05	4.48
Average of 14 experiments	5.32 ± 0.37	0.05 ± 0.01	0.30 ± 0.07	0.05 ± 0.02	0.44 ± 0.055	17.32 ± 1.97	5.16 ± 0.59

* %Protein = %TN × 6.38

Table 3-7. Chemical analysis of the UF cream cheese permeates (% dry matter).

Experiment	TN (%)	Protein (%)	Fat (%)	Ash (%)	Ca (mg/100 g dry matter)	Mg (mg/100 g dry matter)
1	0.98	6.23	0.94	.	.	.
2	0.97	6.20	1.06	.	.	.
3	1.02	6.53	0.86	.	.	.
4	0.98	6.25	1.07	.	.	.
5	0.97	6.20	0.75	.	.	.
6	0.98	6.25	1.25	.	.	.
7	0.94	6.00	0.91	.	.	.
8	0.86	5.46	0.75	.	.	.
9	0.78	4.96	0.43	8.84	.	.
10	0.87	5.58	0.72	8.81	.	.
11	1.15	7.31	1.60	9.27	.	.
12	0.63	4.00	.	8.40	387.20	115.34
13	0.61	3.86	.	7.92	365.94	108.91
14	0.61	3.90	.	8.13	313.54	93.33
Average of 14 experiments	0.88 ± 0.17	5.62 ± 1.07	0.94 ± 0.31	8.56 ± 0.5	355.56 ± 37.9	105.86 ± 11.31

Table 3-8. UF cream cheese yield, protein and fat recoveries measured from mass balance.

Experiment	Skim milk (kg)	Permeate (kg)	Retentate (kg)	Cheese (kg)	Actual Yield (kg/100kg)	Adj. Yield (kg/100 kg)	TN recovery (%)	Fat recovery (%)
1	12.40	9.30	3.1	4.43	35.71	43.86	92.59	100
2	12.29	9.39	2.90	4.14	33.67	36.68	91.97	100
3	12.30	8.97	3.33	4.45	36.21	37.27	91.23	100
4	12.07	8.77	3.30	4.72	39.07	40.27	92.38	100
5	12.30	9.20	3.10	4.43	36.02	41.19	92.19	100
6	12.20	9.03	3.16	4.52	37.06	40.35	92.19	100
7	12.10	8.89	3.22	4.59	37.96	42.24	92.52	100
8	12.25	8.94	3.31	4.72	38.55	38.74	93.46	100
9	16.33	12.26	4.07	5.81	35.58	36.58	94.78	100
10	16.34	12.51	3.84	5.48	33.53	34.42	92.88	100
11	16.23	12.16	4.10	5.86	36.13	41.99	90.43	100
12	16.04	12.05	3.94	5.76	35.57	37.18	95.61	100
13	16.00	12.53	3.47	4.96	31.01	36.39	95.39	100
14	16.07	12.85	3.22	4.60	28.64	32.74	95.52	100
Average	13.92	10.49	3.43	4.89	35.34 ± 2.85	38.56 ± 3.2	93.08 ± 1.64	100

Fig. 3-1. Applications for ultrafiltration in cheesemaking

Cheese varieties prepared from LCR:

Cheddar	Brick
Cottage cheese	Colby
Mozarella	Edam
Saint Paulin	Quarg

Cheese varieties prepared from MCR:

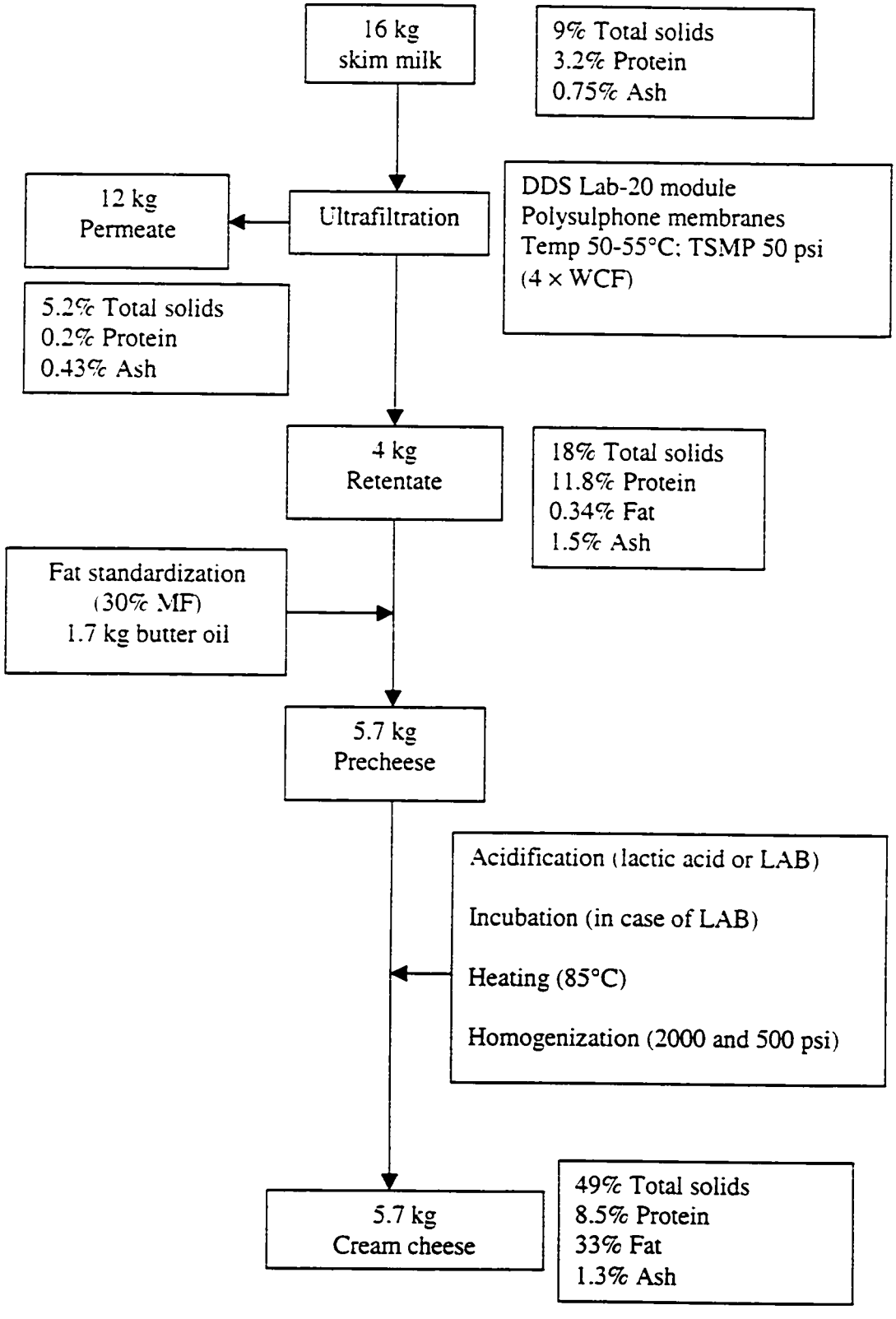
Cheddar	Gouda
Feta	Blue cheese
Havarti	

Cheese varieties prepared from LPC:

Camembert	Mascarpone
Quarg	Feta
Saint Maure	Mozarella
Ricotta	Saint Paulin
Cream Cheese	

Adapted from (Rosenberg, 1995).

Fig. 3-2. Mass balance flow chart for the UF cream cheese.



3.5 Bibliography

Association of Official Analytical Chemists (A.O.A.C.). 1990. Official methods of Analysis. 15th ed. Assoc. Official Anal. Chem., Arlington, VA.

Bradley Jr., R. L., E. Arnold Jr., D. M. Barbano, R. G. Semerad, D. E. Smith, and B. K. Vines. 1993. Chemical and physical methods. Page 474-479 *in* Standard Methods for the Examination of Dairy Products. R. T. Marshall ed. 16th ed. American Public Health Association, Washington, D.C.

Brulé, G., J.-L. Maubois, and J. Fauquant. 1974. Etude de la teneur en éléments minéraux des produits obtenus lors de l'ultrafiltration du lait sur membrane. Le Lait 54:600-615.

Brulé, G., J.-L. Maubois, J. Vandeweghe, J. Fauquant, and H. Goudedranche. 1975. Utilisation de l'ultrafiltration sur membrane pour la fabrication de fromage du type pate fraiches. Revue Laitiere Française 328:117-122.

Casiraghi, E. M., C. Peri, and L. Piazza. 1987. Effect of calcium equilibria on the rate of syneresis and on the firmness of curds obtained from milk UF retentates. Milchwissenschaft 42:232-235.

Dejmek, P. 1986. Milk saving in cheesemaking by ultrafiltration. Milchwissenschaft 41:686-688.

Ducruet, P., J.-L. Maubois, H. Goudédranche, and R. Pannetier. 1981. Eléments de fabrication de fromages à pâte demi-dure et à ouverture propionique selon le procédé MMV. La Technique Laitiere 957:13-16.

Fenton-May, R. I., C. G. Hill Jr., C. H. Amundson, M. H. Lopez, and P. D. Auclair. 1972. Concentration and fractionation of skimmilk by reverse osmosis and ultrafiltration. J. Dairy Sci. 55:1561-1566.

Glover, F. A. 1985. The processes. Page 38-44 *in* Ultrafiltration and Reverse Osmosis for the Dairy Industry. National Institute for Research in Dairying, Reading, England.

Goudédranche, H., J.-L. Maubois, P. Ducruet, and M. Mahaut. 1981. Utilisation de nouvelles membranes minérales d'ultrafiltration pour la fabrication de fromages du type Saint-Paulin. La Technique Laitiére 950:7-13.

Iyer, M., and J. Lelievre. 1987. Yield of Cheddar cheese manufactured from milk concentrated by ultrafiltration. J. Soc. Dairy Technol. 40:45-50.

Jameson, G. W. 1987. Manufacture of Cheddar cheese from milk concentrated by ultrafiltration: the development and evaluation of a process. Food Technol. Aust. 39:560-564.

Lelievre, J., M. Iyer, and R. J. Bennett. 1986. The effect of ultrafiltration per se on the suitability of milk for Cheddar cheese manufacture. N. Z. J. Dairy Sci. Technol. 21:157-164.

Lelievre, J. 1983. Prediction of cheddar cheese yield. N. Z. J. Dairy Sci. Technol. 18:169-172.

Mahaut, M., J.-L. Maubois, A. Zink, R. Pannetier, and R. Veyre. 1982. Eléments de fabrication de fromages frais par ultrafiltration sur membrane de coagulum de lait. La Technique Laitiere 961:9-13.

Maubois, J. -L., and G. Mocquot. 1975. Application of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001-1007.

Paulson, D. J., R. L. Wilson, and D. D. Spatz. 1984. Crossflow membrane technology and its applications. Food Technol. 38(12):77-87,111.

Perkin-Elmer. 1982. Analysis of milk. Page FP12 *in* Analytical Methods for Atomic Absorption Spectrophotometry. Perkin-Elmer, Norwalk, CT.

Rosenberg, M. 1995. Current and future applications for membrane processes in the dairy industry. Trends Food Sci. Technol. 6:12-19.

Sachdeva, S., H. Reuter, D. Prokopek, and H. Klobes. 1992. Ultrafiltration of heated, acidic and coagulated skim milk with different modules. Part1: Plate and frame type module. Kieler Milchwirtschaftliche Forschungsberichte 44:17-26.

Shaw, M. B. 1986. Modern cheesemaking: soft cheeses. Page 210 *in* Modern Dairy Technology. R. K. Robinson, ed. Elsevier Applied Science Publ. New York.

Srilaorkul, S., L. Ozimek, F. Wolfe, and J. Dziuba. 1989. The effect of ultrafiltration on physicochemical properties of retentate. Can. Inst. Food Sci. Technol. J. 22:56-62.

Sutherland, B. J., G. W. Jameson, and J. J. Mayes. 1994. Measuring cheese yield increase obtained by ultrafiltration. Page 409-413 *in* Cheese yield and factors affecting its control. Int. Dairy Fed. Special Issue No. 9402. Int. Dairy Fed., Brussels, Belgium.

Walstra, P., and R. Jenness. 1984. Page 53 *in* Dairy Chemistry and Physics. John Wiley & Sons, Inc., Toronto, Canada.

Chapter 4

Comparisons between the traditional and UF cream cheese yield and milk component recoveries

4.1 Introduction

The French research group led by Jean Louis Maubois introduced the utilization of ultrafiltration for cheese making in 1969. Their purpose was to increase cheese yield mainly due to the incorporation of whey proteins. They have developed what is known as the MMV process (Maubois *et al.*, 1969). In this process, milk is concentrated up to certain levels close to those of the final cheese composition. The retentate in this case is called the precheese when there is little or no whey drainage. Then, starter culture and rennet are added. Finally, the curd is salted if necessary. The closer the composition of the precheese to the final cheese composition, the higher the cheese yield. It has been reported that a 16-20% increase in cheese yield (Maubois and Mocquot, 1975) can be achieved. Kirk Jakobsen (1984, 1985) reported that milk concentration by ultrafiltration could increase cheese yield up to 22%. Kosikowski (1986) has mentioned that such a maximum increase in cheese yield cannot be achieved due to the fact that the whey protein content in milk varies from cow to cow and from breed to breed and there might be some small amounts of protein-rich whey leaching out of certain fresh cheeses.

This chapter will provide a comparison between cream cheese manufacture using the conventional method and UF and their effects on cheese yield and milk component recoveries. The chapter concludes with recommendations for the future.

4.2 Statistical analysis

The data were statistically analyzed using SAS® (SAS, 1996). A simple one-way ANOVA method was constructed. The two methods of cream cheese making (traditional and UF) were compared against their respective cheese yields and the percentages of TN and Fat recoveries means.

4.3. Discussion

Table 4-1 summarizes the means of actual and moisture adjusted cheese yields, TN and fat recoveries of traditional and UF cream cheese. The actual and moisture adjusted cheese yield as well as the TN and fat means for UF cream cheese were highly significantly different ($P<0.01$) from those of the traditional ones.

The percent increase in total nitrogen (TN) and fat levels in the UF cream cheese as compared to the traditional cheese was 11.88% and 6.48% respectively. UF % TN recovery was 93% slightly lower from the 95-96% TN recovery reported by Maubois and Mocquot (1975).

The actual cheese yield difference between the UF and traditional method was 9.5%. Cheese yield varies tremendously for many reasons:

1) *Milk composition (protein/casein and fat),*
2) *Cheese composition (moisture and salt) and*
3) *Fat and curd losses in whey.*

Thus, the expression of the actual cheese yield is rather meaningless (IDF, 1993).

The percent difference between the moisture adjusted UF and traditional cheese yields was 14.58%. This value is slightly less than the 16% increase in yield mentioned in

the literature (Maubois and Mocquot, 1975). The lower nitrogen recovery may be a contributing factor to the lower cheese yield claimed elsewhere.

The percentage differences in actual and moisture-adjusted cheese yield, TN and fat recoveries are presented in Figures 4-1, 4-2, 4-3, and 4-4, respectively.

4.4 Future recommendations

The application of ultrafiltration in soft cheesemaking has been a great success. Camembert in France, feta in Denmark and cream cheese in the United States are some of the common examples of soft cheeses processed by Ultrafiltration (Kosikowski, 1986). In Canada, the use of ultrafiltration at an industrial scale is still not widely implemented. About 70% of the cheese manufactured in Canada are cheddar cheese. The APV-SiroCurd process for making cheddar cheese by ultrafiltration is very expensive, and the cost will not be offset unless the process is adopted by large-scale industries. However small and medium scale dairy industries can adopt ultrafiltration technology to manufacture soft type specialty cheeses.

This study was an initial attempt to assess the potential application of butter oil in the manufacture of recombined cream cheese and to measure the increase of cheese yield due to ultrafiltration and the recovery of milk components. Yet further research is necessary to determine the economical feasibility of the ultrafiltration process and to analyze the sensory and rheological properties of the obtained products.

Table 4-1 Comparisons between the means of the traditional and UF cheese yield (actual and adjusted), TN and fat recoveries (P<0.01).

%	Traditional		Ultrafiltration		% difference
	Mean*	S.D	Mean*	S.D	
Actual cheese yield	32.26[a]	0.82	35.34[b]	0.66	9.52
Moisture adjusted cheese yield	33.65[a]	0.87	38.56[b]	0.70	14.59
TN recoveries	83.19[a]	0.45	93.08[b]	0.36	11.88
Fat recoveries	93.52[a]	0.81	100.00[b]	0.65	6.48

* Means in the same row with different superscript are significantly different at P<0.01.

Fig. 4-1. Comparison of Traditional vs. UF actual cheese yields (%m/m).

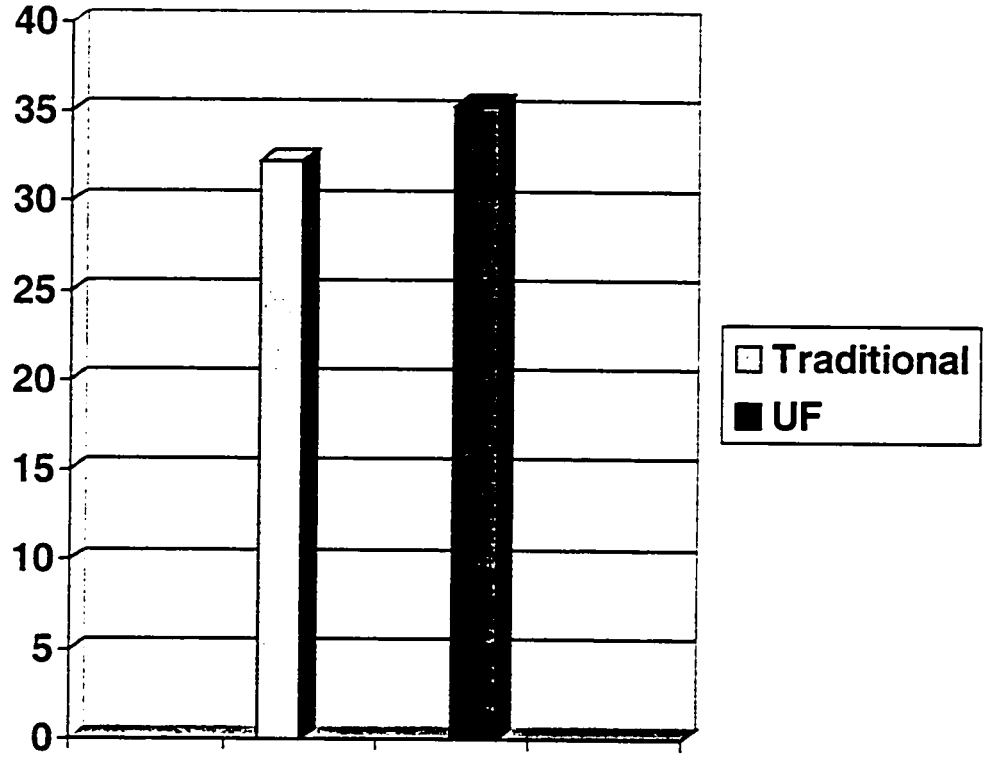


Fig. 4-2. Comparison of the moisture adjusted Traditional vs. UF cheese yields (% m/m).

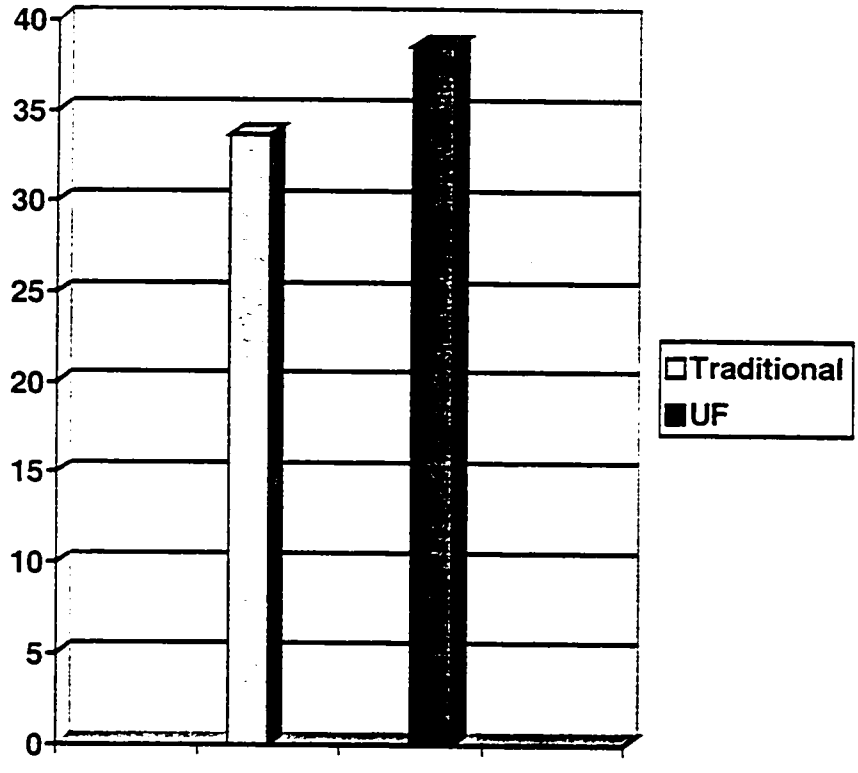


Fig. 4-3. Comparison of total nitrogen (TN) recoveries in Traditional vs. UF cream cheese (%).

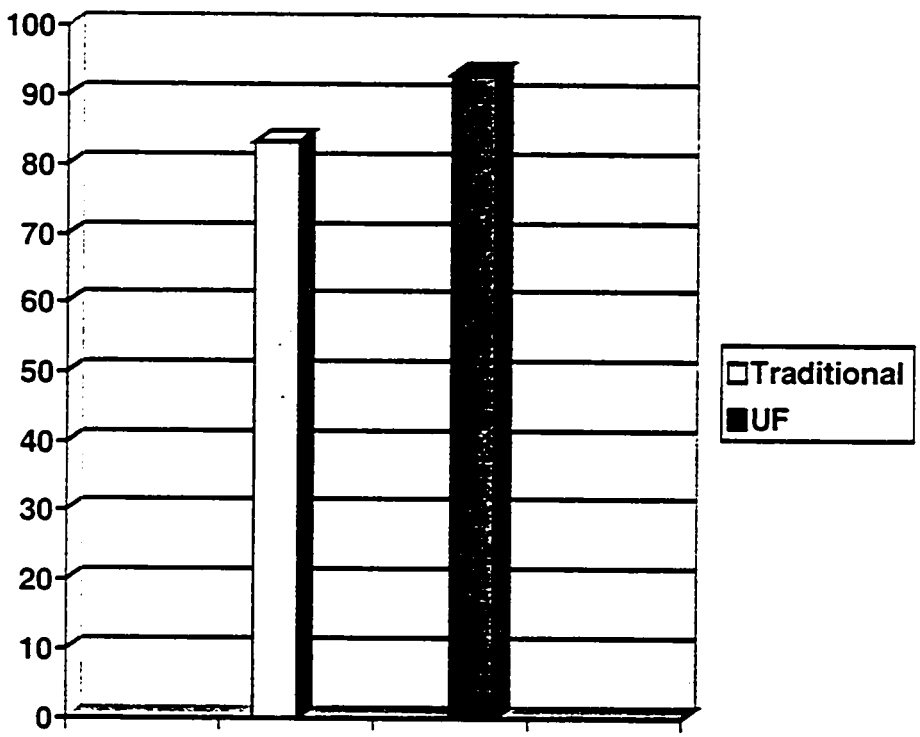
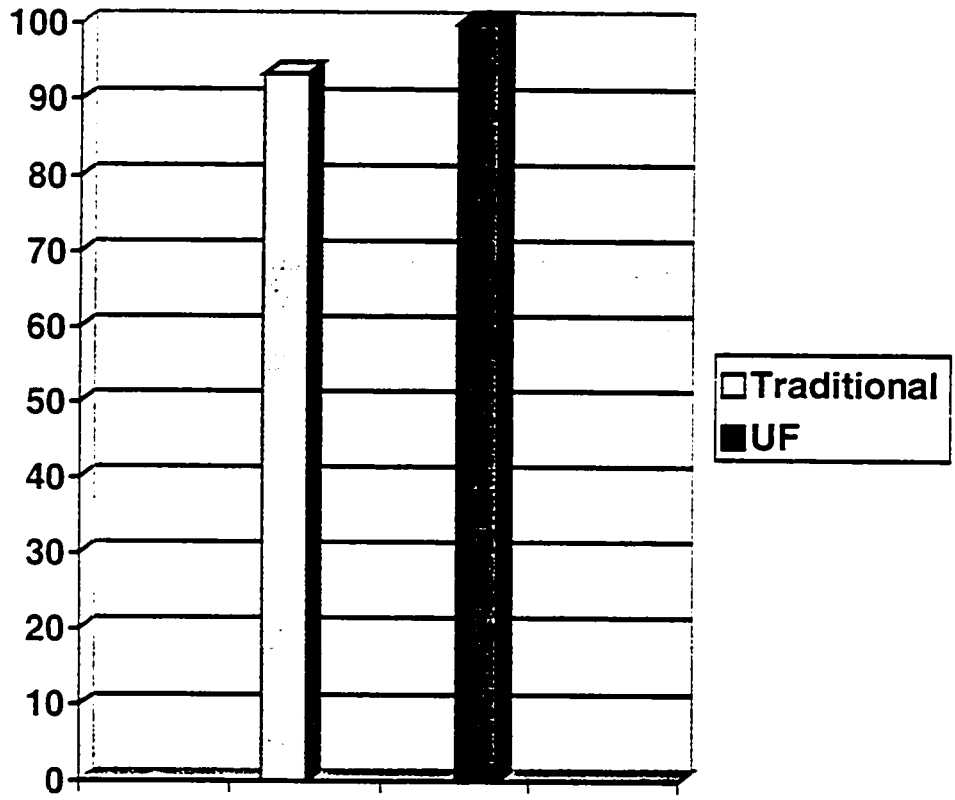


Fig. 4-4. Comparison of milk fat recoveries in Traditional vs. UF cream cheese (%).



4.5 Bibliography

International Dairy Federation. 1993. Factors affecting the yield of cheese. Int. Dairy Fed. Special Issue No. 9301. Int. Dairy Fed., Brussels, Belgium.

Kirk Jakobsen, M. 1984. Yield and economics of cheese production by means of ultrafiltration. Danish Dairy Industries Worldwide. pp. 78-79, 81-82.

Kirk Jakobsen, M. 1985. Manufacture of cheese from ultrafiltered milk where a part of the concentration is carried out through syneresis. North European Dairy Journal. 2:38-52.

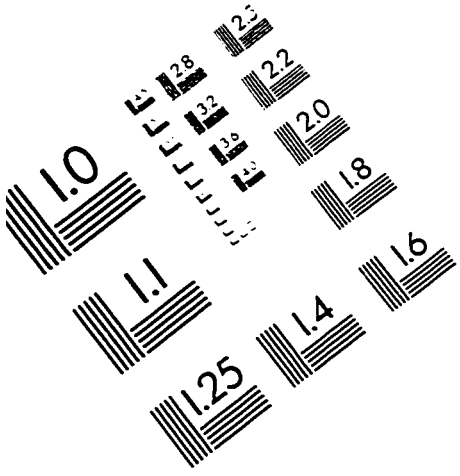
Kosikowski, F. 1986. New cheese-making procedures utilizing ultrafiltration. Food Technol. 40(6):71-77.

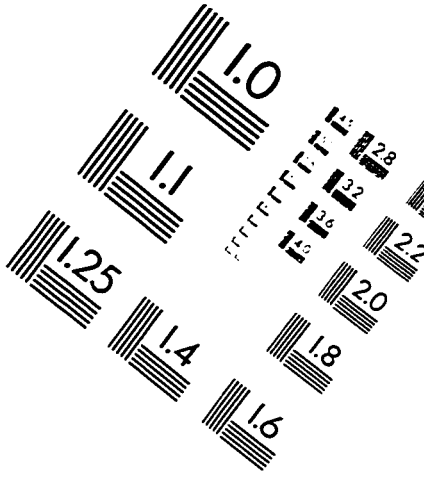
Maubois, J.-L., and G. Mocquot. 1975. Application of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001-1007.

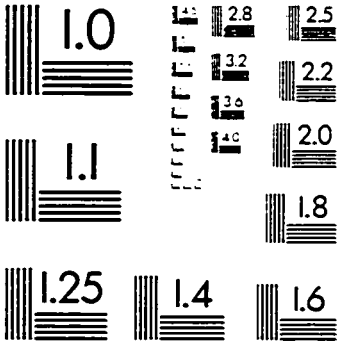
Maubois, J.-L., G. Mocquot, and L. Vassal. 1969. A method for processing milk and dairy products. French Patent 2,052,121.

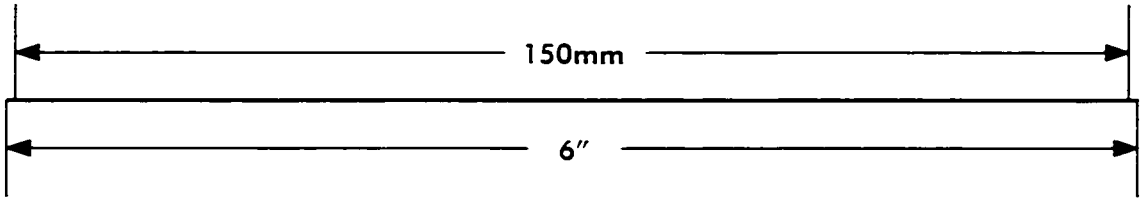
SAS® User's Guide: Statistics, version 6.12 Edition. 1996. SAS Inst., Inc., Cary, NC.

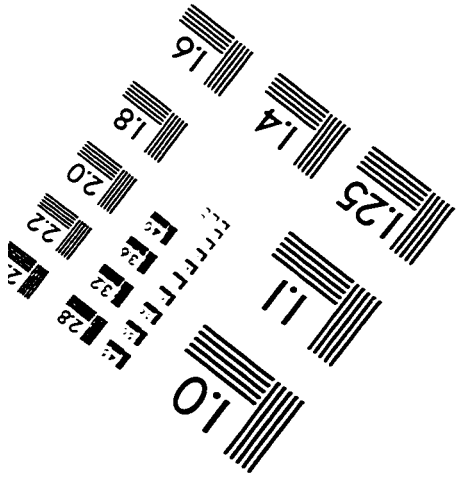
IMAGE EVALUATION
TEST TARGET (QA-3)

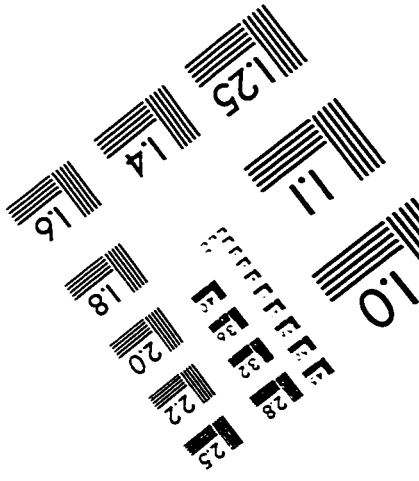












APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

© 1993, Applied Image, Inc., All Rights Reserved