A STUDY OF SOME ASPECTS OF THE QUALITY AND YIELD OF CHEDDAR CHEESE MADE FROM MILK CONCENTRATED BY ULTRAFILTRATION

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ABSTRACT

Ultrafiltration (UF) is a concentration and separation process which operates at the molecular level. It has been successfully applied to certain soft cheese varieties with the primary advantage of increased yields. When applied to Cheddar, which is a hard variety, problems are encountered. These are lack of flavour and texture development, lack of economically viable yield increase and practical problems in handling of UF curd.

An investigation was undertaken to study the application of UF technology to the manufacture of Cheddar cheese. The emphasis was on the biochemical and biophysical problems in UF Cheddar and the possible yield advantages in making the product.

Results suggest that UF per se does not contribute to problems in the quality of UF Cheddar. No major problems were encountered in the cheesemaking process or in final cheese quality when cheese was made from 2:1 UF retentate using conventional method and equipment. There were, however, no yield advantages. When 3:1 and 5:1 retentates were used, some modification in the method of manufacture, particularly in the cutting time and cutting device, was necessary. The quality of cheese obtained from 3:1 retentate was found to be inferior while that from 5:1 retentate was comparable with respect to the control cheeses.

The biochemical and biophysical problems associated with the quality of UF Cheddar could be overcome to a large extent by adjusting the amount of starter and rennet added on the basis of quantity of milk prior to UF. This yields Cheddar of normal one-day pH but with residual rennet concentration much higher than that in the conventional product. The higher level is probably required to overcome the 'dilution' effect of the extra whey proteins present in the UF product. This 'dilution' effect may be partly due to

the difficulty of rennet diffusion in UF Cheddar and partly a result of a decrease in concentration of flavour compounds due to the presence of extra whey proteins. The results show that substantial savings in rennet are not possible in cheesemaking from 5:1 UF retentate. The results also suggest that it is possible to make UF Cheddar with a required residual rennet concentration by regulating the amount of rennet added to the retentate and draining the whey at a predetermined pH.

The yield advantage in cheesemaking from 5:1 retentate (if UF Cheddar is made to normal MNFS of 53.5%) was limited to 4% largely because only one third of the whey proteins of UF milk was retained in the cheese. Theoretical analysis of mass balance data indicated that this yield advantage could be improved to about 6% by reducing 'fines' losses and to about 8% by decreasing fat losses as compared with the conventional process.

Given the current state of UF cheesemaking technology, it is possible that reductions in losses in conventional cheese-making plants may prove to be a more profitable method of increasing yields of Cheddar cheese than the use of UF cheesemaking methods.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS USED

(in alphabetical order)

Abbreviation	Full form
BSA	Bovine serum albumin
Ca/P	Calcium/phosphorus
Ca/SNFNS	Calcium in solids-not-fat-not-salt
CF	Concentration factor
CFU	Colony forming unit
CN	Casein nitrogen
DF	Diafiltration
NCN	Non-casein nitrogen
NPN	Non-protein nitrogen
NSLAB	Non-starter lactic acid bacteria
RCT	Rennet clotting time
SD	Standard deviation
Sl	Slightly
SNF	Solids-not-fat
SNFNS	Solids-not-fat-not-salt
TN	Total nitrogen
UF	Ultrafiltration
WP	Whey protein
WPN	Whey protein nitrogen
WPSM	Whey protein supplemented milk
WPSR	Whey protein supplemented 2:1 retentate
α−La	Alpha lactalbumin
β−Lg	Beta lactoglobulin
FDM	Fat in dry matter
MNFS	Moisture in non-fat solids
RU	Rennet Units
S/M	Salt in moisture
WPC	Whey protein concentrate

CHAPTER 1
INTRODUCTION

The introduction of ultrafiltration (UF) in the cheese industry has signalled an era of innovation. The application of this new membrane technology has several potential advantages, the most important being increases in yield through the incorporation of whey proteins. In conventional cheesemaking, these whey proteins, which constitute about 20% of the total milk protein, are lost in the whey. The extent of the yield advantage depends largely on the amount of moisture expelled during cheesemaking from the UF retentate. This in turn depends on the type of cheese (soft or hard) and the degree of concentration of milk.

The maximum degree of volumetric concentration by UF commercially feasible at present is about 5:1 and the resulting retentate contains about 38-40% solids (Sutherland and Jameson, 1981; Van Leeuwen et al, 1984). This solids level falls in the range of total solids for most soft cheese varieties (Jameson, 1983; Glover, 1985). It should therefore be possible to convert the retentate to certain soft varieties of cheese with little or no loss of moisture. Maximum yield increases are attained through the incorporation of most of the water soluble solids-non-fat components, chiefly the whey proteins. For making hard varieties like Cheddar (64-66% solids) from the 5:1 retentate, some loss of moisture is unavoidable and therefore yield advantages are less attractive.

However, since Cheddar is the most popular of all cheese varieties, there has been worldwide interest in the application of UF to Cheddar cheesemaking. Research work has been concentrated on two main areas:
(i) Partial UF (approximately 2:1) of milk on the farm, (Slack et al, 1983; Kosikowski, 1985) transportation of the retentate to the cheese factory and subsequent conversion to Cheddar cheese using conventional method and equipment (Fergusson, 1985). In this case there is no yield advantage. However, there are savings in chilling, storage

and transport costs of the milk and an increase in throughput of the cheese factory. This application is less attractive for most dairy companies in New Zealand because of shorter distances involved in milk transportation.

(ii) Concentration of milk to the maximum degree of UF commercially attainable at present (approximately 5:1) and converting the retentate to Cheddar cheese with slight modifications in the manufacturing method and equipment (Sutherland and Jameson, 1981; Van Leeuwen et al, 1984; Green, 1985). Some problems reported in this area appear to be associated with lack of flavour and texture development (Green et al, 1981a; Hickey et al, 1983a), lack of viable yield increase (Green et al, 1981a) and engineering problems in handling of UF curd (Sutherland and Jameson, 1981; Van Leeuwen et al, 1984). Some of these problems may be interrelated.

A study of literature indicates that no systematic investigations have been carried out to study the problems in the quality of UF Cheddar or to assess potential yield advantages in making the product. There is a need to identify the origin of the biochemical and biophysical problems associated with the quality of UF Cheddar and scientifically investigate the effect of various factors. Such information is likely to assist in better understanding of the problems and in measures to overcome them. Further, there is a need to estimate potential yield advantages in making UF Cheddar since the magnitude of the yield increase will largely determine the viability of the process.

If the problems associated with the quality of UF Cheddar are insurmountable and/or the potential yield advantages are commercially not significant, little purpose will be served by attempting to overcome the engineering problems.

It is hoped that this investigation will generate some basic data towards an understanding of the fundamental problems in making Cheddar cheese from UF milk.

CHAPTER 2

A REVIEW OF ASPECTS OF CHEESEMAKING USING MILK CONCENTRATED BY ULTRAFILTRATION

2.1 Scope of the Review

Many investigators have studied the manufacture of cheese from milk concentrated by ultrafiltration (UF). This has led to commercial UF processes for making certain soft cheese varieties. Such cheeses are commonly known as UF cheeses. However, problems still remain with the manufacture of most hard UF cheese types.

UF cheesemaking has been reviewed in detail by a number of authors (Glover et al, 1978; Maubois, 1978; Mocquot, 1979; Jameson, 1983; Glover, 1985). The present review is confined to aspects of the subject which are of most immediate relevance to the current research project - namely, the manufacture of Cheddar cheese from UF milk. The review consists of the following sections:-

(1) Principles of UF
(2) Effect of UF on components of milk
(3) Advantages of using UF milk for cheesemaking
(4) Manufacture of different cheese varieties from UF milk
(5) Problems in UF Cheddar manufacture.

2.2 Principles of UF

UF is a concentration and selective separation process that operates at the molecular level. The principle underlying the process is that the liquid to be treated is fed under pressure across the surface of a semi-permeable membrane. As a consequence, water and low molar mass solutes pass through the membrane to form the permeate. The remaining components of the feed are therefore concentrated. These form the retentate.

The driving force for UF is the pressure gradient across the membrane. This force must be significantly greater than the difference in osmotic pressure between the concentrate and permeate streams. Since the small molecules largely responsible for osmotic pressure pass through the membrane, the pressures required to drive the concentration process are relatively low (about 500 kpa). The extent to which low molar mass solutes are separated from the retentate depends on the membrane characteristics. Although in commercial practice, membranes are characterised in terms of the approximate molar masses of components they will retain, it is the other factors such as the molecular size, the shape and to a lesser extent the electrical charge of the solute that determine the ability of molecules to permeate through the membranes.

The membranes used by the dairy industry for UF of milk generally have a molar mass cut off range of about 18,000 - 20,000 daltons. Thus when UF is applied to whole milk, low molar mass components such as water, lactose and soluble minerals comprise the permeate while the larger components like fat, casein, whey proteins and colloidal minerals are concentrated to form the retentate. If the flux of low molar mass solutes in milk across the membrane is completely unhindered, the molarity of these components should be the same in the permeate and retentate fractions. However, in practice it is found that there is a slight selective retention of some components. This is defined by the retention coefficient (R):

$$R = \frac{C_f - C_p}{C_f}$$

where C_f = concentration of the molecule in the feed
C_p = concentration of the molecule in the permeate.

The concentrations need to be expressed in terms of water phase and not as absolute concentrations. For lactose, retention coefficients of 2 - 10% have been found i.e. for

every 100 units of lactose carried into the permeate per unit water, 2 - 10 extra units of lactose are retained in the retentate. The value of R generally increases gradually during the concentration process. An extension of UF, known as diafiltration (DF) is sometimes employed to remove further water soluble components from the retentate or feed. Water is added to the retentate either at the end of UF or continuously as UF proceeds. When this water flows through the UF membrane it carries some of the water soluble components with it. In this way the concentration of water soluble components of the retentate can be regulated. DF is an important means of controlling the lactose content of the retentate used for UF cheesemaking.

2.3 Effects of UF on the Components of Milk

The physico-chemical effects of UF on milk which are of prime concern to cheesemaking are the changes occurring in the fat globules and in the whey proteins. Other changes such as loss of ascorbic acid and other water soluble vitamins in the permeate have been reported (Green et al, 1984) but are of lesser importance in the present context.

2.3.1 **Fat globules:** During UF, milk flows through restricted pathways in the valves of the UF plant. This causes disruption of fat globule membranes and a reduction in globule sizes (Green et al, 1984). The effect amounts to a 'partial' homogenization. The significance of this effect to cheesemaking is discussed later in the thesis (see Chapter 4).

2.3.2 Whey **proteins:** When proteins are subjected to high shear forces, protein denaturation may occur. This is known as shear denaturation (Thomas et al, 1979). It is possible that shear denaturation of whey proteins in milk may occur in UF equipment. This would be most likely when long residence times at 50 - 55^{o}C are used to obtain high retentate concentrations.

The incorporation of air into the feed or concentrate stream of the UF equipment (due to a leak in the suction line) may give rise to a 'bubbling' effect which can lead to denaturation of whey proteins at the liquid-air interface. Such denaturation may take place relatively easily since the denaturation of β-lactoglobulin by simple 'shaking' has been reported (Reese and Robbins, 1981). Denaturation may also occur due to heating. UF of milk is generally carried out at 50 - 55°C but if slightly higher temperatures (>63°C) with long residence times are employed during UF, some denaturation appears possible (Kreula et al, 1974).

The significance of these changes to the cheesemaking properties of milk and cheese quality are discussed later in the thesis (Section 2.6.1.3 of this chapter). The microbiological effects of UF on retentate quality and its significance to cheesemaking are discussed later (Section 2.6.1.4 of this chapter).

2.4 Advantages of using UF Milk in Cheesemaking

Potential benefits of UF cheesemaking are summarised as follows:

2.4.1 Yield increase: As far as New Zealand is concerned, the main advantage in making cheese from UF milk is the yield increase. This increase results from the retention of extra whey proteins and minerals and also better recovery of fat. In addition, the whey proteins bring in extra moisture (Green et al, 1981a). The extent of the yield increase, however, depends largely on the quantity of whey proteins incorporated. Yield increases for cheese varieties reported in the literature are sometimes not comparable because the basis for yield calculation are often different or sometimes not reported. One point which is clear from the literature is that for soft and semi-soft cheese varieties (40 - 45% solids) higher yield increases have been attained by use of UF retentate of about 40% solids and with little or no loss

of whey. For example, yield increase of up to 30% have been reported for Feta cheese (Hansen, 1977). For semi-hard varieties (45 - 56% solids) like Blue cheese, the yield increases have been limited to 5.5 - 13.5% (Jepsen, 1977; Mahaut and Maubois, 1978) because only some of the whey proteins could be retained. For hard cheese varieties (60 - 66% solids) like Cheddar made from retentate of about 40% solids (5:1 concentration) yield increases of 8 - 10% have been reported (Jameson, 1984) although theoretical calculations earlier (Sutherland and Jameson, 1981) had predicted a maximum of 14%.

2.4.2 Savings in rennet: In conventional cheesemaking the bulk of the rennet added to cheesemilk is lost in the whey. When cheese is made from UF retentate, the amount of whey generated (per kg of cheese) is considerably reduced and higher proportions of added rennet are retained in the cheese. Depending on the type of cheese and the amount of whey lost, rennet savings up to 70 - 80% are possible (Glover, 1985). For Cheddar from 5:1 retentate savings may be lower - 40 to 60%. However, these savings have to be considered in conjunction with residual rennet concentration in cheese and its effect on proteolysis. (This is discussed in Chapters 7 and 8.)

2.4.3 More useful byproducts: Both the permeate and the whey obtained during UF cheesemaking are claimed to form the basis of more useful byproducts than does conventional whey (Muller, 1984). The permeate obtained during UF poses fewer pollution problems than conventional whey (Glover, 1985) and can be put to a variety of uses (Cotton, 1980).

2.4.4 Continuous operation: The development of specialised equipment for coagulation, syneresis and cooking of UF curd for Cheddar obtained from 5:1 retentate may enable the whole cheesemaking process to be made continuous (Jameson, 1984). Additional benefits may include automatic control of the process and better control of important parameters such as pH and moisture content.

2.4.5 **Savings in time:** In conventional Cheddar manufacture time is needed to remove moisture from the curd. In the manufacture of Cheddar from UF retentate, the bulk of the moisture is removed during UF itself. Therefore, the overall manufacturing time can be reduced by up to one hour (Jameson, 1984) provided UF and cheesemaking proceed simultaneously.

2.4.6 **Increased throughput:** UF of milk to 1.7:1 concentration (about 16% solids) permits use of conventional methods and equipment and results in increased throughput of most equipment in the cheese factory (Fergusson, 1985). This advantage might be important to a cheese factory considering expansion in capacity but having limitations of space. High permeation rates during UF to a low concentration permit the capital costs to be kept to a minimum. For cheese factories in New Zealand, this advantage may not be of great interest.

2.4.7 **Elimination of washing step:** For some cheese varieties like Havarti, the washing step in traditional method may be replaced by a diafiltration step (after UF) in cheesemaking from UF milk. In general, this might help reduce fat losses and also facilitate the production by removing the washing step.

2.4.8 **Enclosed system:** A continuous UF Cheddar system is fully enclosed between the milk pasteurizer and the point at which the coagulum is cut. This is likely to reduce the dangers of contamination and bacteriophage (Jameson, 1984).

2.5 Manufacture of Different Cheese Varieties from UF Concentrated Milk

The success of the application of UF to cheesemaking depends on:

(1) Type of cheese (soft or hard)

(2) Whether any proteolysis takes place before the cheese is consumed (Lelievre, personal communication).

UF has been successfully applied to soft and semisoft varieties like Cottage, Herve and Quarg. All these varieties are generally consumed fresh with little or no proteolysis. A few semi-hard and hard cheeses can be made using UF. However, these do not undergo proteolysis. For example, in UF Feta cheese, the high salt-in-moisture retards proteolysis. The production of a 'cheesebase' which has a composition similar to that of Cheddar has been reported (Ernstrom et al, 1980). It does not undergo proteolysis because evaporation destroys all the enzymes responsible for proteolysis. The product lacks the body and flavour characteristics of normal Cheddar but is suitable for use in processed cheese. However, if used in high proportions in the processed cheese mix, the presence of whey proteins may cause some problems. It is possible to make UF Mozzarella cheese which appears very similar to the conventional product. However, problems are encountered with its melting and stretching properties (Covacevich and Kosikowski, 1978).

Hard varieties of cheese which undergo a long period of maturation and proteolysis before consumption appear to be the most difficult to make using UF (Green et al, 1981a; Sutherland and Jameson, 1981; Green, 1985).

2.6 Problems in the Application of UF to Cheddar Cheesemaking

The manufacture of Cheddar cheese from milk concentrated by UF presents various problems. For convenience these problems have been broadly classified into three groups:

(A) Problems associated with quality of UF Cheddar

(B) Engineering problems

(C) Economic problems.

The above mentioned problems are next discussed in detail. It must be emphasized that most of these problems and the factors which affect them, although discussed separately, are interrelated.

2.6.1 Problems associated with the quality of UF Cheddar

This group of problems concerns the flavour, body and texture of UF cheese. Literature reports suggest that UF Cheddar has an atypical flavour (Green et al, 1981a), mealy and slightly crumbly texture and 'dry' and 'curdy' body (Glover, 1985). The causes of these defects is not known although a number of inter-related factors have been suggested to have an effect. These factors are discussed below:

2.6.1.1 Starter growth in and buffering capacity of retentate and their effect on the residual minerals in the cheese

The growth of lactic acid bacteria in UF retentates has been studied by several workers (Narasimhan and Ernstrom, 1977; Tayfour et al, 1981; Hickey et al, 1983a; Mistry and Kosikowski, 1983, 1985a,b, 1986a). In general, starter bacteria have been shown to grow well in UF retentates. In UF cheesemaking, however, higher demands are placed on the starter organisms to produce more lactic acid in order to counteract the high buffering capacity in the retentate and in the curd.

The principle buffering components in milk and retentate are protein and phosphate; there is also a small buffering effect due to presence of organic acids (Morr et al, 1973). In traditional Cheddar cheese manufacture, the acid development by the starter organisms, the buffering effects and the rate and extent of syneresis are coordinated so that the desired pH is obtained during, and at the end of, cheesemaking. In UF cheesemaking it is necessary to compensate for the increased buffering capacity in UF retentate (Brule et al, 1974; Sutherland and Jameson, 1981; Green et al, 1981a; Mistry and Kosikowski, 1985b) and for the change in the pattern of syneresis, to prevent a high one-day pH in the cheese (Green et al, 1981a; Sutherland and Jameson, 1981).

One possible method of lowering the one-day pH of UF Cheddar is by decreasing the milk pH prior to UF (Sutherland

and Jameson, 1981). This also affects the mineral content of UF cheese, as discussed later.

It is also possible to lower one-day pH of UF Cheddar by enhanced starter activity. Such enhancement can possibly be achieved by:

(a) Priming i.e. allowing the starter to grow in the retentate for a period before rennet addition (Van Leeuwen et al, 1984).

(b) Increasing the size of the inoculum (Mistry and Kosikowski, 1986b). The buffering capacity of the retentate also influences the mineral content of UF cheese. This may be important since, according to Lawrence et al (1983), the mineral content of cheese influences the basic structure of the product and hence its rheological properties (Sutherland and Jameson, 1981).

For traditional Cheddar, values of calcium content (180 - 220 mM/Kg) calcium to solids-not-fat-not-salt (Ca/SNFNS) ratio (2.4 - 2.5) and calcium to phosphorus (Ca/P) ratio (1.41 - 1.63) are typical (Sutherland and Jameson, 1981).

For UF Cheddar, higher calcium and Ca/SNFNS values have been found and UF of milk at pH 6.35 - 6.45 has been recommended (Sutherland and Jameson, 1981) to allow more calcium to be lost in the permeate. Similarly, problems due to higher Ca/P values for UF Cheddar have been corrected by decreasing the milk pH to 6.2 - 6.45 prior to UF (Sutherland and Jameson, 1981). Priming of retentate and higher level of starter addition are two other possible means of manipulating Ca/P and Ca/SNFNS ratios.

The mechanism by which calcium affects cheese texture is not properly understood. The Ca/SNFNS ratio is considered to play an important role in cheese texture (Lawrence et al, 1983; Creamer et al, 1985). There are conflicting reports on the significance of Ca/SNF ratio in cheese proteolysis. Fox (1970) and O'Keefe et al (1975) suggest that lower Ca/SNF ratios allow the proteolytic

enzymes easier access to the casein fractions. This view is not supported by Lawrence et al (1983).

According to Lawrence et al (1984), a major difficulty in UF cheese manufacture lies in attaining the right balance between factors such as starter activity, syneresis and the rate and extent of the acid development. This balance is necessary to achieve the correct Ca/SNF ratio, the correct pH and hence the required basic structure in the cheese. Without the correct basic structure after manufacture, it is suggested that the cheese will not mature to give a product of satisfactory texture and flavour (Lawrence et al, 1984).

2.6.1.2 Residual lactose and lactate in cheese

The residual lactose content of the curd controls, to a great extent, the change in pH of the cheese in the first few days of ripening (Dolby et al, 1937). In addition, high lactose contents can lead to calcium lactate precipitation (Pearce et al, 1973). This defect is known to occur in conventionally made cheese (Farrer and Hollenberg, 1960) where lactate levels during the first few days of maturation are about 1.0% (Czulak, 1969).

UF retentate generally has 5% lactose in the aqueous phase and calculations suggest that this may yield 1.8% lactic acid in the final cheese (Mistry and Kosikowski, 1985b). Such cheese would probably be excessively sour and would be expected to show calcium lactate precipitation (Sutherland and Jameson, 1981).

A reduction in lactose content of UF Cheddar is therefore desirable and this can be achieved by (a) diafiltration of retentate (Sutherland and Jameson, 1981) or (b) washing the cut curd after rennet coagulation of the retentate (Sutherland and Jameson, 1980). The latter option results in flushing out of whey proteins and a decrease in yield.

2.6.1.3 Effect of whey proteins

The whey proteins in the cheese may be present either in their native form or in a denatured form. Literature reports suggest that in their denatured form, whey proteins may cause defects in flavour and texture (Wingfield et al, 1979; Banks and Muir, 1985; Brown and Ernstrom, 1982). Information on the specific effect of undenatured whey proteins on Cheddar quality is lacking. For some cheese varieties, whey proteins in their native form have been reported to have beneficial effects on texture and flavour. One report on UF Gouda cheese suggests that the inclusion of whey proteins results in softer and smoother consistency as compared to 20% FDM Gouda (Boer and Nooy 1980a, b). Most research workers have reported that the whey proteins in the curd and cheese are resistant to proteolysis (Jost et al, 1976; O'Keefe et al, 1978; Koning et al, 1981) and act as inert fillers in semi-hard (Edam and Gouda) cheese (Koning et al, 1981). However, it has been suggested that the non-starter lactic acid bacteria (NSLAB) may be able to hydrolyse the whey proteins (El-Soda et al, 1982; Hickey and Broome, 1984) in UF cheese, but this needs to be confirmed. This degradation, if confirmed, could have a direct effect on UF Cheddar flavour. Some indirect effects are possible such as:

(i) A dilution effect i.e. lowering the effective concentration of flavour compounds (Koning et al, 1981).

(ii) Physical interference by making casein less accessible to enzyme action.

(iii) Inhibition of plasmin (alkaline milk protease) by β-lactoglobulin.

According to Creamer (1971, 1974), plasmin plays only a limited role in normal Cheddar proteolysis by degrading β-casein. In UF Cheddar, however, it may play an important role since it is expected to be present in higher amount due to the concentration during UF. On the other hand, plasmin activity is inhibited by β-lactoglobulin (Snoeren et al, 1980), which is present in higher proportion in UF Cheddar as compared with control Cheddar (Koning et al, 1981). In UF Cheddar therefore, it is possible that these two factors

may, to a large extent, cancel each other.

2.6.1.4 Microbiology of the retentate and UF cheese

In normal cheesemaking, most of the micro-organisms in milk are entrapped and concentrated in the curd when it is cut. Literature reports on the microbiology of UF cheesemaking are lacking but it is probable that this concentration occurs in two stages - firstly, during UF and secondly, when the UF curd is cut. It is possibly for this reason that the total count of UF Cheddar is found to be similar to that of normal Cheddar (Hickey et al, 1983b). Amongst the cheese microflora, the starter organisms play a major role in secondary proteolysis during cheese ripening (Fryer, 1969; Visser, 1977a,b; Rank et al, 1985). However, it is possible that the growth of thermophiles during UF (Huffman and Powell, personal communication) may have an influence on the flavour of UF Cheddar.

2.6.1.5 Problems in flavour and texture development

Cheddar cheese flavour is complex and the specific contribution of various compounds to flavour has not yet been established. Most research workers consider that amino acids provide the important background flavour upon which characteristic flavour is superimposed (Aston and Dulley, 1982). However, other workers consider a water soluble fraction containing salts, amino acids and peptides as the main contributor to intensity of flavour in Cheddar cheese (McGugan et al, 1979).

Literature reports on flavour of UF Cheddar are few. Some workers have reported a lack of flavour development in UF Cheddar (Green et al 1981a; Hickey et al, 1983b) and attributed this to a lack of rennet activity in cheese (Green et al, 1981a) presumably because of a lower rate of rennet addition to UF retentate.

Problems in the texture of UF Cheddar are possibly related to the proteolysis which, in turn, may be affected by several factors such as the presence of whey proteins (as

discussed earlier) and rennet activity. Another factor possibly affecting proteolysis is the concentration of proteinase and/or peptidase inhibitors in milk (Mclean and Ellis, 1975) by UF and consequent slowing of the release of free amino acids (Hickey et al, 1983b).

Overall, it does seem likely that the rate of proteolysis (and therefore flavour and texture development) in UF Cheddar is slightly retarded and the introduction of measures to increase this rate may be necessary (Covacevich and Kosikowski, 1978). Increasing the amount of rennet (Green et al, 1981a), addition of a small amount of neutrase (Green, 1985) and addition of small amounts of proteinases to the curd at salting (Green et al, 1981a) are some of the measures suggested.

2.6.2 **Engineering Problems:** These problems concern the viscosity of UF retentate and cutting, handling and cooking of UF curd.

2.6.2.1 **Viscosity of UF retentate:** When the protein content of UF retentate exceeds 10 - 12%, there is a dramatic increase in its viscosity (Maubois and Mocquot, 1974). For example, there is a 10-fold increase in viscosity (from 1.2 cP to 12 cP) at 50^{o}C when the protein concentration increases from 3% to 18%. At 15^{o}C this increase is from 2cP to 200 cP. Such large increases in viscosity impose an upper limit of concentration by UF as just under 20% protein (Glover, 1985).

It is obvious from these viscosity values that pumping and mixing this viscous retentate will be difficult. Correct pump selection is necessary.

2.6.2.2 **Cutting UF curd:** Since the UF retentate sets much faster than milk on rennet addition (Van Leeuwen et al, 1984) it has a coarser protein network and differs in basic structure in comparison to normal curd (Green et al, 1981b). Physico-chemical properties of UF curd such as firmness,

susceptibility to damage, refusion of curd particles and rate and volume of whey released also differ from those of normal curd (Van Leeuwen et al, 1984).

Conventional cheese knives are therefore unsuitable for cutting UF curd; special cutting devices are needed (Sutherland and Jameson, 1981). One such device has been described by Van Leeuwen et al (1984). It consists of a stainless steel box with two adjacent open faces with monofilament nylon wires at 10 mm distances.

The duration of time between rennet addition and cutting affects cheese yield and cheese quality. For normal Cheddar, the cutting time is generally 2.2 - 3.5 times the rennet clotting time (RCT). This period is considered too long for UF retentate and could affect the cutting and subsequent syneresis. There is a suggestion that cutting time for UF retentate should be 1.2 - 2.2 times RCT (Van Leeuwen et al, 1984).

2.6.2.3 **Handling and cooking UF curd**

The internal structure of UF curd is fragile. In addition, the 'cushioning' effect of whey during curd handling is small because of the much lower rate and volume of whey release as compared with that in conventional cheesemaking. Thus, there is need for gentle handling of UF curd especially in the initial stages after cutting. Also, as a result of the small amount of whey released (per kg of curd) there is a need for suitable modification of heat transfer mechanisms to attain the scalding temperature at the desired rate without upsetting curd structure. A device designed for cooking UF curd has been described (Van Leeuwen et al, 1984). It consists of a stainless steel cylinder fitted with four vanes, and rotated at 3 rpm. The curd particles in the rotating cylinder are slowly heated by applying heat from outside the drum.

2.6.2.4 Losses of fat and curd fines associated with UF curd handling

The use of conventional methods and equipment to make UF Cheddar results in high fat and casein fine losses (Green et al, 1981a) but slight modifications in cutting, cooking and handling of UF curd can help bring these losses to normal levels (Sutherland and Jameson, 1981; Green, 1985). The significance of these losses to cheese yield are discussed later (Chapter 9).

2.6.3 Economic Problems

The success of the application of UF to Cheddar cheese-making depends on the economic viability of the process. This would be largely governed by the magnitude of the yield increase. The yield increase needs to be sufficiently high to justify the high capital costs required for the purchase of UF equipment and special cheese manufacturing plant. In addition, there should be no significant loss of quality of product. Calculations based on a variety of assumptions suggest that a yield increase of 8% may be economically viable under certain conditions (Jameson, 1984).

In addition to the problems mentioned above, the seasonal variation in milk composition may pose problems in obtaining retentate of required composition during the dairying season. This may cause difficulty in obtaining UF Cheddar of uniform quality and composition.

CHAPTER 3

SCOPE AND OBJECTIVES OF THE PRESENT INVESTIGATION

The scope of the present investigation was primarily to study the factors influencing the problems in the quality of UF Cheddar and to assess potential yield advantages in Cheddar cheesemaking from UF milk. The following were the broad objectives:

(i) to investigate some of the problems associated with the quality of UF Cheddar,

(ii) to study specific factors which may contribute to these problems,

(iii) to investigate possible solutions to some of these problems,

(iv) to assess potential yield advantages in Cheddar cheesemaking from UF milk and theoretically investigate means of further improving these yield advantages.

CHAPTER 4
EFFECT OF ULTRAFILTRATION PER SE ON THE QUALITY AND YIELD OF CHEDDAR CHEESE

4.1 Introduction:

The problems associated with UF Cheddar cheese manufacture and quality were discussed earlier (Chapter 2). The origin of these problems is not known. One factor may be the process of UF itself. The changes occurring in certain milk components during UF, particularly those in the whey proteins and the fat, may be important to cheesemaking. The possible significance of the changes in the whey protein on cheese quality were discussed earlier (Chapter 2). The 'partial' homogenization of fat during UF (Green et al, 1984) may affect the elasticity and moisture holding properties of the curd and the texture and flavour of the final cheese (Peters, 1956). Therefore, the effect of UF per se on the quality and yield of Cheddar cheese was investigated in the present experiment.

4.2 Experimental Plan

Pasteurized and standardized milk was divided into two lots. One lot was kept as control. The other lot was subjected to 5:1 UF and all the permeate was collected. On completion of UF the permeate and retentate were mixed to form a 'milk equivalent'. Cheddar was then made from the 'milk equivalent' and control using conventional methods.

4.3 Experimental

The cheeses from (a) control milk (b) milk equivalent were made simultaneously on the same day in 350 l vats in the New Zealand Dairy Research Institute (NZDRI) pilot plant. Five trials were done over two seasons at different times of the season.

4.3.1 **Milk supply:** Bulk whole milk was obtained from the NZDRI supply delivered from the Manawatu Cooperative Dairy Company each morning. The milk (800 kg) was then pasteurized at 72°C/15 seconds (Alfa Laval unit with a capacity of 2,600 kg/hour) and standardized to a casein:fat ratio of about 0.68 using pasteurized skim milk. The resultant milk was cooled to 7°C, transferred to refrigerated vats equipped with stirrers and stored overnight at 2 - 4°C before use.

4.3.2 **Ultrafiltration:** The UF unit used was an Alfa-Laval UFS-4 having 4 cartridges containing PM-30 membranes with cut off range of 30,000 daltons (Figure 4.1). It essentially consists of a balance tank with a feed pump, recirculation loop, recirculation pump and the membrane cartridges. The membrane area per cartridge is 1.4m^2 and the 4 cartridges are connected in parallel. The UF unit was conditioned as per manufacturer's instructions by circulating a mixture of caustic soda (0.5% w/v) and sodium hypochlorite (0.1% v/v) in soft water (50°C) for 30 minutes. The UF unit was then rinsed with water. About 400 kg of milk was heated to 50 $\pm$ 1°C in a plate heat exchanger (using hot water at about 70°C). The milk was then accurately weighed in cans and tipped into the balance tank of the pre-conditioned UF unit.

UF* was started and inlet and outlet pressures were adjusted to 2.4 bar and 1.0 bar respectively. The permeate outlet port was opened and the permeate collected in cans placed on a weighing balance so that the quantity of permeate could be closely monitored. (Initial permeation rates were 4.5 - 4.8 l/min or 48.2 - 51.4 l/m^2/hr). UF was continued until a 5:1 concentration was attained i.e. 320 kg permeate obtained from 400 kg milk. This normally required 90 - 110 minutes. At this stage UF was stopped by closing the permeate port. The inlet and outlet pressures were decreased to 1.8 bar and 0.6 bar respectively.

4.3.3 **Preparation of milk equivalent:** The permeate removed during UF was added back to the retentate in the balance

* UF was a batch operation

Figure 4.1 Ultrafiltration unit used for UF of milk for all experiments.

Make: Alfa Laval

Type: UFS-4

Membranes: Four cartridges of PM-30 membranes with molar mass cut-off range of 30,000 daltons.

Membrane area: 1.4 m^2 per cartridge; Total 5.6m^2.

tank. The permeate and retentate were then thoroughly mixed by using a plunger. The resultant fluid was then further mixed by recirculation for 5 - 10 minutes in the UF unit with no permeate removal.

4.3.4 Pasteurization: The control milk and the milk equivalent were repasteurized under the conditions described previously. The outlet temperature of the milk from the pasteurizer was adjusted to 32°C and 350 kg of each of the milks was placed in the two cheese vats. For mass balance trials this milk was accurately weighed. Every care was taken to prevent dilution of milk during repasteurization. The pasteurizer was thoroughly flushed with water in between the pasteurization of the two lots of milk.

4.3.5 Cheesemaking: The basic method used was that of Pearce and Gilles (1979). The following is an account of the main steps in the procedure:

The milks in the two vats were tempered to 32°C. Starter (Streptococcus cremoris: DRI strains 584 and 134 in ratio 1:2) was added at 2% w/w of the milk. Five minutes later, calf rennet (from NZ Coop. rennet company, Eltham, with approximate strength of 62 Ru/ml) was added at 16 ml/100 litres of milk. The coagulated milks were cut about 40 minutes after rennet addition using 9 mm cheese knives. The resultant curds and whey were subjected to gentle mechanical agitation and the temperature raised slowly to 38°C at a rate of approximately 0.2° C/minute. The temperature was then maintained at 38°C and the whey was drained after about 2 hours and 40 minutes from rennet addition. Following dry stirring, the curd was allowed to knit and cheddaring continued for a further 2 hours. The curd was milled at 0.55 - 0.60% titratable acidity (TA) and salted at 0.61 - 0.68% TA using 25 g salt per kg of the curd. The time from rennet addition to salting was typically 5 hours. About 20 - 25 minutes after salting the curds were hooped (18 - 20 kg curd/hoop), pressed for 5 minutes in a large horizontal pneumatic press, dressed and pressed overnight at

40 p.s.i. at ambient temperatures.

The next morning the cheese was removed from the press, sampled and packed by wrapping in paraform waxcoated film. The cheeses were placed in cardboard cartons and held at 13°C for about 30 days and then at 7°C for the next 6 - 9 months.

4.4 Analytical Methods

This section is discussed in 3 parts:

4.4.1 Chemical methods.
4.4.2 Methods for organoleptic assessments of cheese:
(i) Sensory grading method
(ii)Sensory panel method
4.4.3 Methods for assessing proteolysis in cheese during maturation.

4.4.1 Chemical methods

The milks and wheys were analysed for total solids, fat, total nitrogen (TN), non-casein nitrogen (NCN), non-protein nitrogen (NPN) and calcium. During cheesemaking the TA and pH of milk/whey were measured.

The 1-day cheeses were analysed for moisture, fat, TN, calcium, salt and pH. Standard methods as detailed in the NZ Dairy Division Manual (NZDDM) were followed (Table 4.1.A and 4.1.B).

4.4.1.1 Milk and Whey

Table 4.1.A Chemical methods for analysis of milk and whey

Particulars	Method	Reference	Principle of method and deviations (if any)
1. Total solids	NZDDM 1.12.a	FIL - IDF 21-1962	Drying in oven for 5 hours at 103°C
2. Fat	NZDDM 1.4.1a Rose-Gottlieb	IDF 1A-1969	Fat is extracted from an ammoniacal alcoholic solution of the sample with diethyl ether and petroleum ether, the solvents evaporated and the residue weighed.
3. Nitrogen			
(a) Total nitrogen (TN)	NZDDM 1.11.1a Kjeldhal	FIL - IDF 20-1962	A weighed sample is catalytically digested with sulphuric acid, converting the organic nitrogen into ammoniacal nitrogen. The ammonia is released by the addition of sodium hydroxide, distilled and absorbed in boric acid and then titrated.
(b) Non-casein nitrogen (NCN)	NZDDM 1.11.4a Kjeldahl	FIL - IDF 29-1964	Casein is precipitated with acetic acid-acetate buffer and filtered off. The nitrogen content of the filtrate is determined.
(c)Non-protein nitrogen (NPN)	NZDDM 1.11.5a Kjeldahl		Proteins in sample precipitated with trichloroacetic acid and filtered off. NPN in the filtrate is determined by the Kjeldahl method.

4. Calcium	NZDDM 1.2.1a Complexo-metric method	Pearce (1977)	A sodium hydroxide/EDTA solution of the sample is back titrated with a standard calcium solution using Patton and Reed's indicator.*
5. Titratable acidity (TA)	NZDDM 1.1.1a	BS 1741: 1963 Part 2,19.	The sample is diluted with an equal volume of water and titrated with standard alkali to a phenol-phthalein end point.
6. pH			Direct reading using a pH meter (PHM 80 Portable pH meter, Radio-meter, Copenhagen).

* At pH greater than 13.1 any Mg present has no effect on calcium determination (Pearce, 1977).

4.4.1.2 Cheese

Table 4.1.B Chemical methods for analysis of cheese

Particulars	Method	Reference	Principle of the method and deviations (if any)
1. Moisture	NZDDM 4.4.3.0 Gravimetric		Drying in oven at 105°C for 16 hours.
2. Fat	NZDDM 4.1.1a solvent extraction	FIL - IDF 5A-1969 BS 770-1976	Fat is extracted from an HCl digest of the sample with diethyl ether and petroleum ether, the solvents evaporated and the residue weighed.
3. Salt	NZDDM 4.7.1a Volhard	FIL - IDF 17A-1972	Organic matter in the sample is destroyed using nitric acid and potassium permanganate. The liberated salt is determined by silver nitrate/ammonium thiocyanate titration.
4. Calcium	NZDDM 4.4.8.1	Pearce (1977)	Grated cheese is dissolved in HCl and diluted with water. NaOH is added and titrated against EDTA.
5. pH	NZDDM 4.5.1a		Direct reading utilizing the EMF between a glass electrode and a reference electrode using a pH meter.
6. TN	NZDDM 1.11.19 Semi-micro Kjeldahl	FIL - IDF 20-1962	Same as for milk. 1 - 1.5 g sample was taken for analysis.

4.4.2 Methods for organoleptic assessment of cheese

4.4.2.1 Sensory grading of cheese

The cheeses were graded at 35 days, 3 months and 6 months of age by an official grader of the NZ Dairy Division. Flavour was scored on 0 - 10 scale while texture was scored on 0 - 5 scale. The grading method is described in detail in Appendix IA. Salient points of the grading method are listed below:

1. All cheeses were graded at 10 - 13^{o}C.
2. The cheeses were plugged 15 - 30 minutes prior to examination.
3. Plugs were visually examined for colour and appearance.
4. Flavour was assessed by sniffing and tasting.
5. Body and texture were assessed by rubbing a portion of the sample between the thumb and forefinger.
6. Grade scores and comments of the grader were noted.
7. Sample presentation was random and the origin of the cheese samples was not revealed to the grader.

4.4.2.2 Test method for sensory panel

The cheese (3 replicates) at 3 and 6 months of age were also assessed for various flavour and texture attributes by a trained panel of judges at the NZDRI sensory evaluation laboratory. Panelists were selected from the staff members of NZDRI following the method outlined by Zook and Wessman (1977). Details of the training and final selection of panelists are described in Appendix IB.

The cheeses were sampled on the day of the evaluation and stored in the refrigerator (4^{o}C) until approximately half an hour before the panel session. The samples were then brought to ambient temperature (22^{o}C) and cut into rectangles (1.5 cm x 1.5 cm x 5 cm) to serve to the panelists. Evaluations took place in the NZDRI sensory panel room, in air-conditioned booths and under standard white incandescent lighting. The number of panelists taking

part in each session was 8 - 10. Sample presentation was randomised. 2 - 3 cheese samples were evaluated at each session.

The cheeses were evaluated for textural characteristics of firmness, rubberiness, crumbliness, smoothness, stickiness and 'bittiness' and for flavour characteristics of acid/sour, fruity/fermented, sulphide, sharpness and bitterness. Evaluations were done on a 0 - 10 scale where 0 = absent and 10 = intense. The questionnaire used and definitions of sensory terms are shown in Appendix 1C and 1D. The data were statistically analysed on the computer and 'F' ratios (for testing significance) were calculated.

4.4.3 Method of assessing proteolysis in cheese during maturation

A wide range of methods is available to determine the extent of proteolysis in cheese. The urea gel electrophoresis method of Richardson and Pearce (1981) was chosen because it provided information on the decrease in the intensity of α_{s1} and β-casein. The gels were photographed to allow densitometry to be done, if needed. Salient points of the method are listed below:

1. Grated cheese samples were dissolved in urea buffer and centrifuged. The fatty layer was removed.
2. Polyacrylamide urea gels were set with slots for 8 samples.
3. 50 µl of samples (or 1 mg of cheese) was applied to 6 of the slots while standard casein was applied to 2 slots.
4. Electrophoresis was run for 3 - 4 hours.
5. The gel was removed, labelled, stained with amido black for one hour, and destained by using 3% acetic acid solution.
6. The destained gels were photographed.

4.5 Results and Discussion

For the sake of convenience, the results* are discussed in four sections as follows:

5.1 Milk composition and cheesemaking

5.2 Cheese composition

5.3 Mass balance and cheese yield

5.4 Cheese quality (grading, sensory panel and proteolysis).

4.5.1 Milk composition and cheesemaking

Table 4.2 Milk composition

Particulars	Control milk	Milk equivalent
Total solids %	12.46 ± 0.37	12.39 ± 0.39
Fat %	4.01 ± 0.26	3.95 ± 0.25
TN %	0.568 ± 0.021	0.560 ± 0.020
NCN %	0.137 ± 0.007	0.134 ± 0.005
NPN %	0.033 ± 0.001	0.033 ± 0.001
Calcium mM/kg	32.1 ± 0.62	31.5 ± 0.76

As expected, the compositions of milk and milk equivalent were similar (Table 4.2). During cheesemaking the gels obtained on rennet addition were also similar as judged by visual inspection. In addition, no differences were observed in cheddaring patterns of the two curds.

The titratable acidity of the wheys at different stages of cheesemaking also followed a similar pattern (Figure 4.2). In apparent contrast, it has been reported that milk equivalent is a better growth medium for starter micro-organisms (Hickey et al, 1983a). However, the diafiltration step used by Hickey et al (1983a) could possibly have either removed inhibitory substances from, or released growth stimulating factors into, the milk. It is also possible that growth enhancement of Streptococcus cremoris is strain dependent.

* Average (mean ± standard deviation) results are reported for this investigation as well as for all subsequent ones in the chapters that follow.

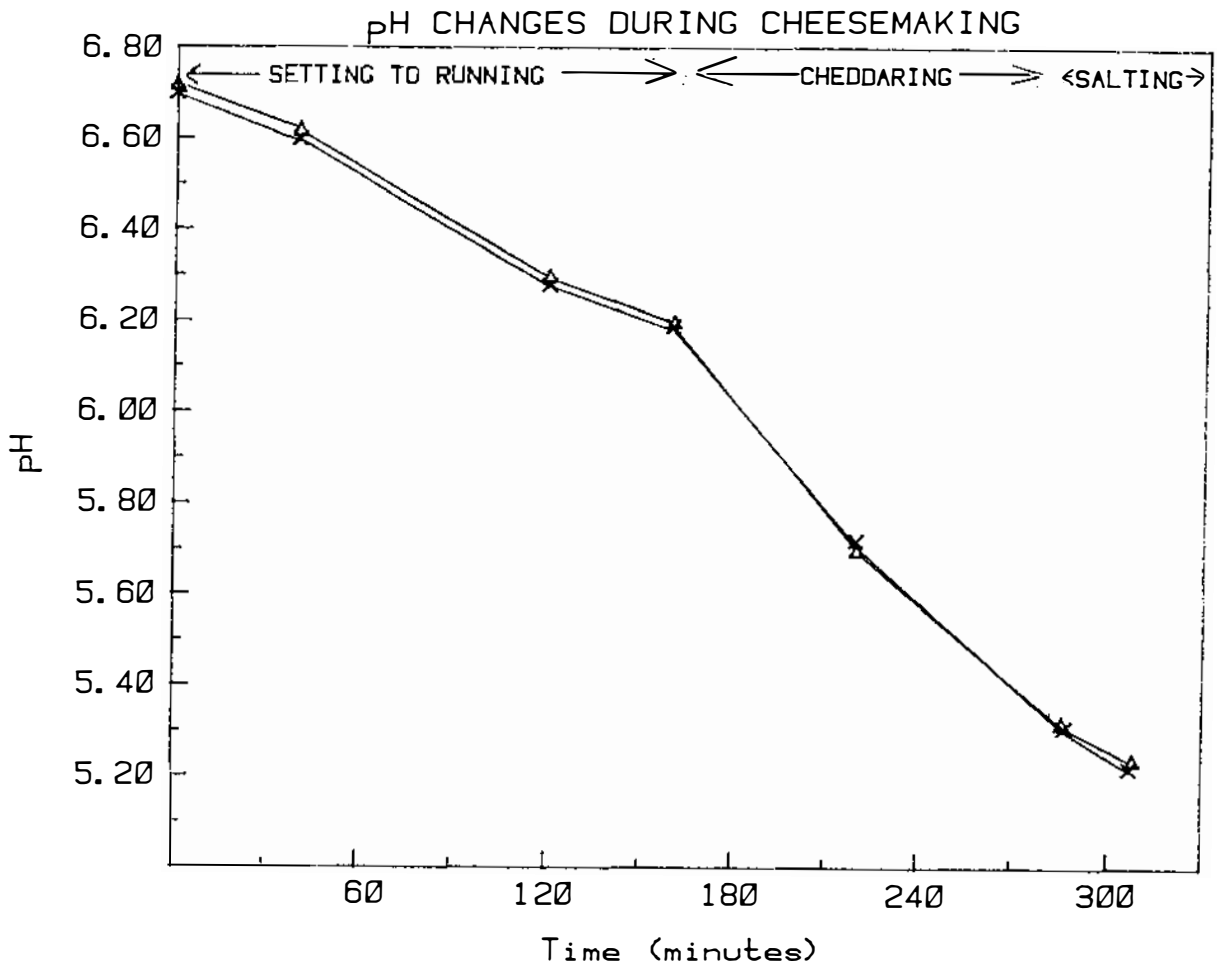


Figure 4.2 Comparison of pH changes during cheesemaking from control milk (x —— x) and milk equivalent (Δ —— Δ). Initial determination was done on the milk and subsequent ones on the whey.

4.5.2 Cheese composition

The average compositions of the cheeses from the two treatments were similar (Table 4.3).

Statistical analysis of the compositional data showed that the treatment source of variation was not significant for any of the compositional attributes. This was expected since the milk compositions were similar and they had behaved in a similar fashion during cheesemaking. In addition, there were no significant differences in the whey compositions (Table 4.4).

Table 4.3 Cheese composition

Treatment	Control Cheddar	Milk equivalent Cheddar
FDM %	51.36 ± 1.86	51.80 ± 1.84
MNFS %	53.76 ± 0.16	53.56 ± 0.96
S/M %	4.54 ± 0.27	4.59 ± 0.26
1-day pH	5.10 ± 0.02	5.11 ± 0.04
TN %	4.18 ± 0.09	4.18 ± 0.18
Ca mM/kg	198 ± 4.0	197 ± 8.2
Ca/SNFNS	2.70 ± 0.02	2.69 ± 0.07

Table 4.4 Whey composition

Particulars	Control whey	Milk equivalent whey
Total solids %	6.63 ± 0.17	6.60 ± 0.14
Fat %	0.43 ± 0.06	0.47 ± 0.06
TN %	0.170 ± 0.003	0.164 ± 0.008
NCN %	0.156 ± 0.002	0.152 ± 0.006
NPN %	0.048 ± 0.001	0.047 ± 0.003
Calcium mM/kg	11.0 ± 0.2	11.0 ± 0.1

4.5.3 Mass balance and cheese yield

For two of the trials, a mass balance was carried out. Retention of total solids, fat, SNF, TN, casein nitrogen (CN) and whey protein nitrogen (WPN) in the cheeses were calculated as a percentage of their content in milk. A standard method was followed for calculations (Table 4.5) as reported by Lelievre et al (1983).

Table 4.5 Sample mass balance calculation for total solids

	Control		Milk equivalent	
	kg x %	Total kg	kg x %	Total kg
Milk + starter	306 x 12.10	37.026	306 x 12.15	37.179
Whey	282.5 x 6.44	18.193	279.0 x 6.47	18.051
Cheese	27.634 x 64.5	17.824	27.909 x 63.8	17.806
% retention in cheese	48.14		47.89	
% accounted for in cheese and whey	97.3		96.4	

The retention of CN and WPN was calculated on the basis of losses occurring during manufacture (Table 4.6). This was done in view of the problems experienced in accurate determination of NCN in cheese by standard methods.

Table 4.6 Sample mass balance calculations for casein nitrogen

	Control		Milk equivalent	
	Kg x %	Total kg	kg x %	Total kg
Milk + starter	306 x 0.382	1.1689	306 x 0.385	1.1781
Whey	282.5 x 0.014	0.0400	279 x 0.014	0.0391
Cheese (by difference: (milk+starter - whey)	1.1689-0.0400	1.1289	1.1781-0.0391	1.1390
% retention in cheese	96.58		96.70	

Briefly, casein retention was calculated as follows:

$$\% \text{ casein retention} = \frac{(\text{Milk TN}-\text{Milk NCN})-(\text{Whey TN}-\text{Whey NCN})}{\text{Milk TN} - \text{Milk NCN}} \times 100$$

However, this formula does not take into account the macropeptide cleaved from the k-casein since this macropeptide would be a part of the NCN fraction of the whey. Hence this approach measures the total casein losses excluding those due to the macropeptide.

The average percentage retention of various milk constituents in cheese was similar for the two treatments (Table 4.7).

Table 4.7 Mass balance

Percentage recovery in cheese:

Treatment	Control	Milk equivalent
Total solids	50.01 ± 1.87	50.53 ± 2.64
Fat	88.36 ± 1.15	87.52 ± 0.22
SNF	34.13 ± 1.89	34.22 ± 2.27
TN	70.88 ± 1.03	71.22 ± 0.72
CN	97.13 ± 0.55	97.18 ± 0.48
WPN	6.73 ± 0.82	6.75 ± 1.71

The retention of fat in cheese was not significantly affected by the partial homogenization of fat that is reported to occur during UF. This result on fat retention is in agreement with that of Green (1985). The retention of the remaining milk constituents studied for the two treatments were also similar. Clearly, the changes which may be occurring in the non-fat milk components during UF do not significantly influence their retention in the cheese.

The yield of cheese from the two treatments was similar (Table 4.8). This was to be expected since physico-chemical changes in milk components during UF (Green et al, 1984) were unlikely to affect cheese yield significantly.

Table 4.8 Yield of cheese

Yield	Control Cheddar	Milk equivalent Cheddar
Kg cheese/100 kg milk	10.24 ± 0.64	10.11 ± 0.77
Kg cheese (adjusted to 36.0% moisture) per 100 kg milk	10.23 ± 0.73	10.20 ± 0.90

Table 4.9 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
1	Control	Normal (6)	Normal (3)	Normal (7)	Sl.pasty (3)	Normal (7)	Sl.mealy (3) Lacks plasticity Sl.floury
	Milk equivalent	Normal (6)	Normal (3)	Normal (7)	Better (4) Texture	Normal (6)	More plastic(4) Better than control
2	Control	Normal (6)	Normal (3)	Normal (7)	Normal (3)	Normal (7)	Tender (3) Sl.weak
	Milk equivalent	Normal (6)	Normal (3)	Normal (7)	Normal (3)	Normal (7)	Good (3) plasticity
3	Control	Normal (7)	Normal (3)	Normal (7)	Normal (3)	Sl.sour (7) cheesy	Sl.tender (3)
	Milk equivalent	Normal (7)	Normal (3)	Normal (7)	Sl.lumpy (3)	Sl.bland (6) Sl.sour	Tender (3)
4	Control	Normal (6)	Floury (2)	Sl.sour (6) Sl.fermented	Floury (3)	Sl.sour (7)	Powdery (3) Pasty
	Milk equivalent	Sl.bitter (6)	Normal (3)	Sl.bitter (6)	Tender (3) Sl.mealy	Sl.unchar- (6) acteristic	Sl.mealy (3)
5	Control	Normal (5)	Mealy (3)	Normal (7)	Pasty (3)	Normal (7) Sl.sulphide	Pasty (3)
	Milk equivalent	Sl.oxidized(5) Sl.oily	Sl.mealy (3) Tender	Sl.metallic(6)	Pasty (3)	Sl.bitter (7) Sl.astringent	Mealy (3) Pasty

Note: Figures in brackets refer to grade scores

4.5.4 Cheese quality

4.5.4.1 Grading

There were no gross differences in the flavour and texture of cheeses for the two treatments (Table 4.9). Some minor differences, especially in flavour, were noticed but these were not significant. These were probably associated with fat damage and microbiological changes that occur during the pumping and holding stages of UF (Huffman and Powell, personal communication). The effects due to these changes were likely to persist even though both milks were pasteurized prior to cheesemaking.

The grade scores were statistically analysed (Table 4.10).

Table 4.10 Statistical analysis of grade scores

Grade characteristic	'F' ratio for treatment source of variation
Flavour	12.79*
Texture	2.51ns

ns: not significant
*: significant at 5% level of significance

The small effects of UF on flavour were likely to be of less significance in commercial production because of the much lower residence time of milk in a commercial scale continuous UF system.

4.5.4.2 Sensory panel

Results of the sensory panel (Table 4.11) indicated that there were no significant differences in any of the flavour and texture attributes. Results also showed that rubberiness decreased as the cheeses matured.

Table 4.11: Cheese sensory panel

(a) mean texture scores*

Attribute	Treatment Control	Milk equivalent	'F' value
Firmness	5.6	5.9	15.03 ns
Rubberiness	2.7	3.1	3.93 ns
Crumbliness	3.0	2.8	0.13 ns
Smoothness	4.2	4.1	1.01 ns
Stickiness	3.6	3.6	0.04 ns
Residual mouthfeel	2.7	2.9	1.42 ns

(b) mean flavour scores*

Acid/sour	4.1	4.1	0.00 ns
Fruity/fermented	2.6	2.4	1.88 ns
Sulphide	0.5	0.8	0.69 ns
Sharpness	1.0	1.0	0.11 ns
Bitterness	0.5	0.5	0.25 ns

*Mean scores from three replicates averaged over three and six month analysis.

These results from the sensory panel confirm, to some extent, the findings from the grading data that UF *per se* has no effect on the textural attributes of the cheese. The data on flavour showed that the dairy division grader picked up some minor differences while the taste panel found no significant differences. It must be pointed out that quality assessment as judged by the grader is different from the quality attributes judged by the panel. Therefore, the

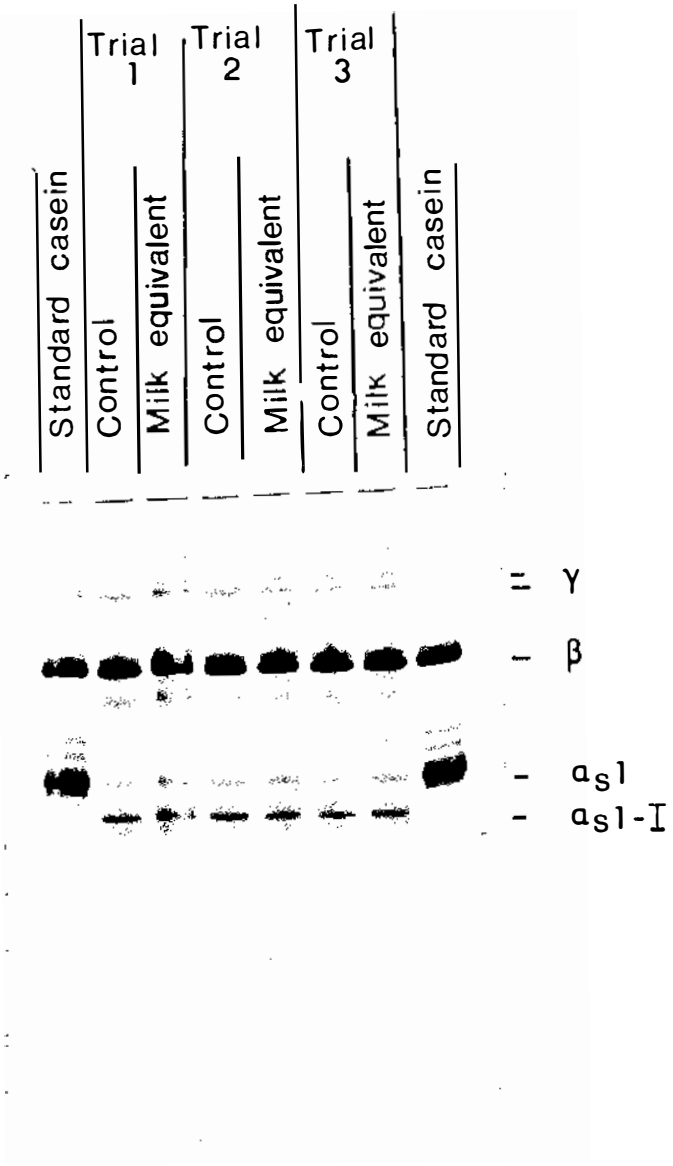


Figure 4.3 Polyacrylamide gel electrophoresis of cheese made from milk and milk equivalent. The age of the cheese is about 4 months.

results of the grading cannot be directly compared with those from the sensory panel. Nevertheless, both results suggested that UF per se did not significantly affect the organoleptic quality of the cheese.

4.5.4.3 Proteolysis

The breakdown of α_{s1} and β-caseins were similar for the two treatments at the same stage of cheese maturation (Figure 4.3). This electrophoresis data supported the grading and sensory panel data and suggested that proteolysis in the cheeses from the two treatments followed a similar pattern.

4.6 Conclusion

The results of the present study suggest that UF itself does not alter the suitability of milk for conventional Cheddar manufacture. The effect of UF per se on Cheddar composition, yield, flavour and texture was not significant.

However, the findings of the present investigation may not apply to Cheddar manufacture from UF retentate since the bulk of the whey proteins were lost in the whey. Indeed, the primary objective of UF cheesemaking is to increase yields by incorporation of whey proteins. In UF Cheddar, the whey proteins may be present in undenatured or in denatured form. Undenatured whey proteins are reported to act as inert fillers in hard cheeses (O'Keefe et al, 1978; Koning et al, 1981). On the other hand, if the whey proteins have been modified during UF treatment either by the action of shear or by denaturation at the air-water interface, they are likely to give rise to flavour problems in the cheeses (Bachmann et al, 1976; Brown and Ernstrom, 1977; Bucheim and Jelen, 1978). Similarly, partial homogenization of fat during UF may make the UF curd more susceptible to fat leakage, compounding the problems in fat losses (Green et al, 1981a). Hence the mode of action of UF equipment may possibly have an effect on UF Cheddar quality and yield. There is a suggestion that UF plant for cheese

manufacture must be designed for minimum homogenization (Jameson, 1984).

The results of the present investigation indicate that further work is needed to study the contribution of factors other than UF *per se* to the problems associated with the quality of UF Cheddar.

CHAPTER 5

EFFECT OF USE OF 2:1 ULTRAFILTERED MILK ON THE QUALITY AND YIELD OF CHEDDAR CHEESE

5.1 Introduction.

It was shown earlier (Chapter 4) that UF *per se* does not appear to contribute to the problems associated with UF Cheddar manufacture and quality. These problems are most obvious when UF retentate of high CF (4:1 to 5:1) is used for cheesemaking (Green *et al*, 1981a; Sutherland and Jameson, 1981; Green, 1985; Glover, 1985). Some of the problems are still apparent when cheese is made from retentate of low CF (~ 2:1) despite the fact that conventional methods and equipment are used (Chapman *et al*, 1974; Green *et al*, 1981a) to make the product. A lack of flavour in 2:1 UF Cheddar (Chapman *et al*, 1974; Nichols, personal communication) in conjunction with a decline in breakdown of both α_{s1} and β-casein have been reported (Green *et al*, 1981a). The reasons for this lack of breakdown are not fully understood. Lower residual rennet in the cheese has been suggested as the main cause (Green *et al*, 1981a). Another factor may be that in the 2:1 UF Cheddar-making carried out previously the level of starter was also, in effect, reduced. This may have been responsible for the high 1-day pH of the cheese made by Green *et al* (1981a). The present chapter describes cheesemaking trials in which the levels of rennet and starter added were based on the volume of milk prior to UF, i.e. the same to both the 2:1 retentate and the control.

5.2 Experimental.

Six trials were done during the 1984-85 season.

5.2.1 Milk Supply. Same as described in Chapter 4. About 200 l milk was needed for each of the trials.

5.2.2 **Ultrafiltration.** Same as described in Chapter 4 except that 120 kg milk was subjected to 2:1 UF.

5.2.3 **Cheesemaking.** As described in Chapter 4 except for the differences mentioned below.

(1) Small vats (maximum capacity 80 litres) were used.

(2) 50 kg control milk and 25 kg 2:1 UF retentate were used for cheesemaking.

(3) Starter was added at 2% w/w on the basis of the milk quantity before UF.

(4) Rennet:casein ratio was kept the same for both treatments, i.e. 8 ml rennet was added to each of the two vats containing 50 kg control milk and 25 kg 2:1 retentate.

(5) The curd formed from 2:1 retentate was cut 25-30 minutes after rennet addition and left undisturbed for the next 10-15 minutes. This was done because the UF curd was too firm to cut at a time similar to control i.e. 40 minutes after rennet addition. This observation is in accordance with those of other workers (Culioli and Sherman, 1978; Garnot and Corre, 1980) who reported that UF curd is firmer and less elastic as compared with conventional curd.

(6) The curds and wheys were stirred manually using a ladle.

(7) The 2:1 UF curd was not dry stirred after whey drainage. This was done since preliminary trials had shown that with similar dry stirring of control and 2:1 UF curd, the 2:1 UF Cheddar had lower MNFS.

(8) Small hoops (about 5 kg cheese) were used.

(9) For pressing, a vertical pneumatic press was used.

(10) The cheeses were packed in polythene bags and

ripened at 13°C for about 6-9 months.

5.3 Analytical Methods.

The milks and wheys were analysed for total solids, fat, TN, NCN, NPN and calcium. The cheeses were analysed for moisture, fat, TN, pH, salt and calcium. The cheeses were graded for quality attributes and also put through a sensory panel (at 6 months of age only). Methods for all the above analyses have been described previously (Chapter 4).

5.4 Results and Discussion.

For convenience, average results are presented, since these show the main trends and avoid unnecessary detail.

The results are discussed in 5 sections:-

5.4.1 Milk and retentate composition
5.4.2 Cheese manufacture
5.4.3 Cheese composition
5.4.4 Mass balance and cheese yield
5.4.5 Cheese quality (grading and sensory panel).

5.4.1 Milk and retentate composition.

As expected, the UF of milk resulted in two-fold increase in the fat, the casein and the whey protein percentage in the retentate (Table 5.1). However, the increase in percentage of TN and NCN in the retentate was not in proportion to the CF probably because of loss of some low molar mass components in the permeate (Green et al, 1984).

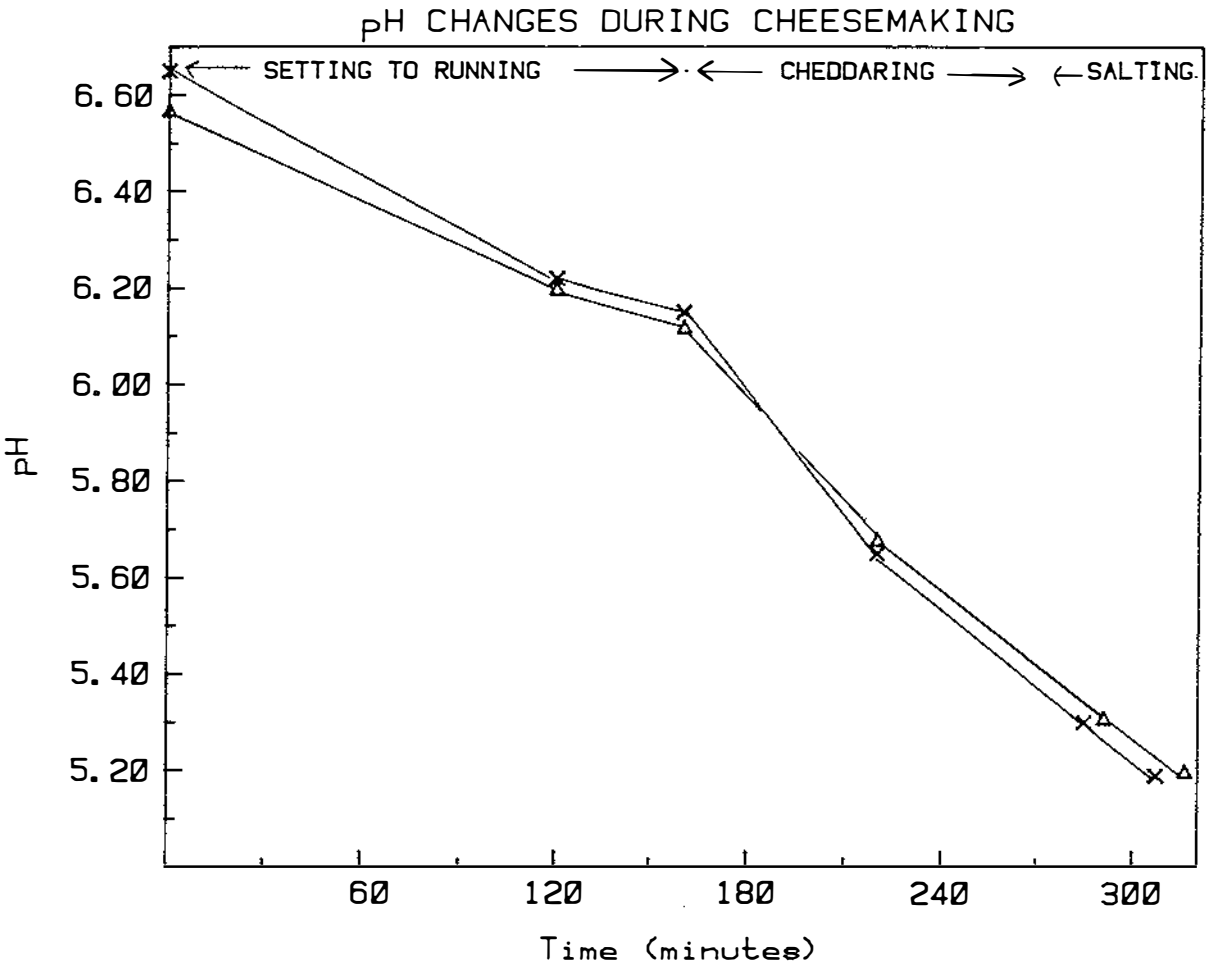


Figure 5.1 Comparison of pH changes during cheesemaking from control milk (x — x) and 2:1 UF retentate (Δ — Δ). Initial determination was done on the milk/retentate and subsequent ones on the whey.

5.4.2 Cheese manufacture.

The 2:1 retentate presented no major problems during cheesemaking. The UF curd before cutting, appeared to be slightly firmer than the control curd on subjective examination. The pH changes followed a similar pattern (Figure 5.1) in both vats. Since the total buffering (the components of milk primarily responsible for buffering i.e. the protein and phosphate would be present in similar amounts in 50 kg control milk and 25 kg 2:1 retentate) and the total kg starter added was similar in the two vats, it appears from these pH changes that there were no gross differences in the acid production between the two vats. Other workers have reported a stimulation in growth of starter organisms in UF retentates (Hickey et al, 1983a). As discussed earlier, it is possible that the diafiltration step used by these workers either removed inhibitory substances from, or released stimulating substances into the retentate. Alternatively, the stimulation in growth of starter organisms in retentate could be strain dependent.

Table 5.1 Milk and retentate composition

Particulars	Control milk	2:1 UF retentate
Total solids %	12.68 ± 0.25	19.26 ± 0.58
Fat %	3.81 ± 0.15	7.55 ± 0.36
TN %	0.548 ± 0.007	1.060 ± 0.032
NCN %	0.138 ± 0.002	0.244 ± 0.007
NPN %	0.030 ± 0.001	0.029 ± 0.001
Calcium mM/kg	31.4 ± 0.7	45.6 ± 0.9

Table 5.2 Cheese composition

Particulars	Control Cheddar	2:1 UF Cheddar
FDM %	53.62 ± 1.14	53.14 ± 1.14
MNFS %	53.49 ± 0.96	52.95 ± 1.04
S/M %	4.85 ± 0.09	4.78 ± 0.09
1-day pH	5.08 ± 0.02	5.10 ± 0.02
TN %	4.00 ± 0.15	4.04 ± 0.13
Calcium mM/kg	182 ± 3.5	185 ± 3.5
Ca/SNFNS	2.57 ± 0.11	2.55 ± 0.11

5.4.3 Cheese Composition

The cheeses from the two treatments had similar compositions (Table 5.2). The lower average MNFS of UF Cheddar reflected the tendency of 2:1 UF curd to retain less moisture as compared with the control curd. This was despite attempts to bring MNFS of the cheeses closer to each other by subjecting the control curd to extra dry stirring after whey drainage.

In view of the high 1-day pH of 2:1 UF Cheddar reported by Green et al (1981a), it appears that the higher level of starter addition employed in the present investigation helped decrease 1-day pH of 2:1 UF Cheddar to normal levels.

5.4.4 Mass balance and cheese yield

The retention of various milk constituents in the cheese was similar for the two treatments (Table 5.3). The fat recovery in 2:1 UF Cheddar was only slightly lower than the control suggesting that the ability of casein to entrap fat (Green et al, 1981a) in 2:1 retentate was not significantly impaired. These results are in agreement with those of Chapman et al (1974) and Green et al (1981a). The WPN recovery in 2:1 UF Cheddar was only slightly higher than the control indicating that the amount of moisture lost during 2:1 UF cheesemaking was large enough to ensure loss of most of the whey proteins into the whey.

The yield of cheese from the two treatments was similar (Table 5.4). This was expected since mass balance results had shown that the recovery of various milk constituents was alike for the two treatments and MNFS of cheeses were close.

Table 5.3 Mass balance

Percentage recovery in cheese

Treatment	Control	2:1 UF
Total solids	51.09 ± 1.16	66.85 ± 0.66
		*51.19 ± 1.14
Fat	90.40 ± 1.06	89.26 ± 1.14
TN	73.04 ± 1.73	75.70 ± 0.46
CN	96.73 ± 1.11	97.00 ± 0.96
WPN	5.53 ± 1.09	7.96 ± 1.52
SNF	34.12 ± 0.76	52.24 ± 0.56
		*34.59 ± 0.62

* Calculated on the basis of the content in control milk for comparison purposes.

Table 5.4 Yield of cheese

Yield	Control	2:1 UF
Kg cheese per 100kg milk	10.02 ± 0.32	9.98 ± 0.34
Kg cheese (adjusted to 36.0% moisture) per 100kg milk	10.36 ± 0.29	10.44 ± 0.58

Table 5.5 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
1	Control	Normal (6) Sl.sour	Sl.tender (2) Sl.mealy	Normal (6) Sl.sour	Sl.tender (2) Sl.pasty	Normal (6) Sl.sharp	Sl.tender (2) Sl.mealy
	2:1 UF	Normal (6)	Sl.tender (2)	Normal (6) Sl.sour	Sl.tender (2) Sl.mealy	Normal (6)	Sl.tender (2) Sl.pasty
2	Control	Normal (6) Sl.sour	Sl.mealy (2) Sl.loose	Normal (6)	Sl.loose (3) Sl.tender	Sl.aromatic(5) Sl.sweet	Sl.mealy (3) Sl.pasty
	2:1 UF	Normal (6)	Sl.lumpy (2) Sl.mealy	Sl.bland (6)	Sl.firm (3) Smooth	Sl.bitter (5) Sl.aromatic	Sl.lumpy (3) Sl.loose
3	Control	Normal (6) Sl.sour	Sl.tender (2) Sl.loose	Normal (6) Sl.sour	Sl.tender (2)	Normal (6) Sl.sharp	Sl.tender (2) Sl.mealy
	2:1 UF	Normal (6)	Sl.tender (3)	Normal (6) Sl.bland	Sl.tender (2) Smooth	Normal (6) Sl.sharp	Smooth (2) Sl.pasty

Note: Figures in brackets refer to grade scores

Table 5.5 Grading of cheese (continued from previous page)

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
4	Control	Normal (6)	Sl.tender (3) Sl.mealy	Normal (6)	Sl.mealy (2)	Normal (6) Sl.sharp	Sl.tender (2) Sl.pasty
	2:1 UF	Normal (6)	Sl.lumpy (2) Sl.mealy	Sl.bland (6)	Sl.lumpy (3) Sl.mealy	Normal (6) Sl.sharp	Sl.mealy (2)
5	Control	Normal (6)	Sl.mealy (2) Sl.tender	Normal (6)	Sl.tender (2) Sl.mealy	Normal (6)	Sl.tender (2)
	2:1 UF	Sl.bland (6)	Sl.mealy (2)	Sl.bland (6)	Sl.tender (2) Sl.pasty	Sl.bland (6)	Sl.tender (2) Sl.pasty
6	Control	Sl.bitter (5)	Sl.tender (2) Sl.loose	Normal (5) Sl.bitter	Sl.tender (2) Sl.loose	Normal (5) Sl.bitter	Sl.tender (2) Sl.loose
	2:1 UF	Normal (6) Sl.sour	Sl.firm (2) Sl.mealy	Normal (5) Sl.sour	Sl.firm (2) Sl.mealy	Sl.sour (5)	Sl.mealy (2)

Note: Figures in brackets refer to grade scores

5.4.5 Cheese quality

5.4.5.1 Sensory evaluation

The results of the cheese grading suggested that the cheeses from the two treatments had similar flavours and textures to each other throughout the maturation (Table 5.5). This finding was confirmed by the results of the sensory panel. The UF Cheddar was significantly smoother and more crumbly ($p<0.05$) than the control Cheddar (Table 5.6A). Differences in other texture attributes were not statistically significant. In terms of flavour, the taste panel found the control and UF Cheddars to be similar (Table 5.6B).

These results confirm the suggestion of Green et al (1981a) that increased residual rennet concentration in UF cheese may be helpful in overcoming some of the problems related to lack of flavour development. The effect of residual rennet concentration has been further investigated as reported later (Chapter 7 and 8).

Table 5.6 Cheese sensory panel

A. Mean texture scores

	TRIAL 1			TRIAL 2		
Attribute	Control	2:1UF	'F'value	Control	2:1UF	'F'value
Firmness	5.2	5.3	0.18 ns	NA	NA	NA
Rubberiness	1.9	1.4	1.39 ns	NA	NA	NA
Crumbliness	5.1	4.4	5.33 *	NA	NA	NA
Smoothness	3.2	3.8	8.00 *	NA	NA	NA
Stickiness	4.0	4.0	0.00 ns	NA	NA	NA
Residual mouthfeel	4.3	4.3	0.00 ns	NA	NA	NA

Note: NA - not available; ns - not significant;
* - significant at 5% level of significance.

Table 5.6 Cheese sensory panel

B. Mean flavour scores

Attribute	TRIAL 1 Control	2:1UF	'F'value	TRIAL 2 Control	2:1UF	'F'Value
Acid/sour	5.1	4.3	7.84 *	5.6	5.2	0.44 ns
Fruity/ fermented	2.9	2.9	0.00 ns	3.0	2.1	1.10 ns
Sulphide	1.2	1.0	0.11 ns	4.6	7.8	5.03 ns
Sharpness	0.9	0.2	4.00 ns	1.8	2.0	0.16 ns
Bitterness	0.6	0.3	2.29 ns	0.5	1.5	3.50 ns

Note: ns - not significant; * - significant at 5% level of significance.

5.5 Implications

Although there appear to be no yield advantages, the results of the present investigation have other implications. For example, a cheese factory considering expansion in capacity but having limitations of space may find it advantageous to install a UF plant and make cheese from 2:1 UF retentate using conventional method and equipment. The capital cost of the UF plant could be kept to a minimum due to high flux rates during UF (Fergusson, 1985).

In recent years there has been some interest shown in on-farm UF of cheesemilk (Kosikowski, 1985). If milk can be concentrated by UF to 2:1 level on the farm, savings in chilling, storage and transport costs are possible. However, detailed economic studies may need to be carried out. In New Zealand, for example, shorter distances involved in milk transportation may make this application less attractive. Further research is needed to study the economics of the whole operation.

CHAPTER 6

EFFECT OF WHEY PROTEINS ON THE QUALITY OF CHEDDAR CHEESE

6.1 Introduction

It was shown earlier that UF *per se* does not appear to contribute to the problems associated with UF Cheddar quality (Chapter 4). It was also shown that some of these problems reported to occur to a degree in 2:1 UF Cheddar could be overcome by alteration in the level of starter and rennet addition (Chapter 5). The Cheddar cheese obtained in the latter investigation from 2:1 retentate had a low whey protein content. Cheddar cheese made from more concentrated milks (about 5:1 UF) would be expected to have higher levels of whey proteins. Therefore one factor which could possibly contribute to the quality problems reported in 5:1 UF Cheddar is the presence of extra whey proteins - about 1/3 of that present in milk (see Chapter 7). It is important to understand the effect of whey proteins on the quality of UF Cheddar. This basic information is needed first, because if it is found that the whey proteins adversely influence UF Cheddar quality, little purpose will be served by solving the engineering problems discussed earlier (Chapter 2) in the first instance.

The ideal experimental system to study the role of the whey proteins would be Cheddar made by conventional methods, and therefore in all ways a normal product, but containing whey proteins in the amounts present in UF cheese. This is impossible to achieve in practice. Therefore different experimental designs are necessary. In the present investigation three approaches were considered to study the problem:

(i) The addition of whey protein powder to the milk.

(ii) The addition of whey protein powder to partially ultrafiltered milk.

(iii) The addition of whey protein concentrate to cheese slurries.

These approaches were by no means ideal and involved compromises. In the first and second avenues of attacking the problem, various assumptions were involved. Firstly, it was assumed that the loss of whey proteins during Cheddar cheese manufacture is in proportion to the moisture loss. Therefore, the addition of extra whey proteins to the milk will result in cheese, made by conventional method and equipment, with a higher whey protein content. Secondly, it was assumed, at least in the first instance, that the alteration in the casein:whey protein ratio will not significantly influence the cheesemaking properties of the milk.

The third approach involved addition of whey protein concentrate (WPC) to the Cheddar cheese slurries. The slurry system was used as a 'model' to study the effect of whey proteins on cheese ripening since it permitted incorporation of whey proteins into the slurry with ease. Basically, the slurry technique is a means of accelerated ripening such that the biochemical reactions in normal cheese ripening are speeded up. Hence the biochemical pathways are reported to remain the same (Samples, 1985) but the reactions proceed at a faster rate. In this approach it was assumed that the role of whey proteins in the slurry system is similar to their role in Cheddar cheese.

Each of these approaches is discussed in this chapter.

6.2 Section 1: Addition of whey protein powder to cheese milk

6.2.1 Introduction

During normal Cheddar cheesemaking it is estimated that about 5% of the whey proteins in milk are retained in the cheese (Lelievre et al, 1983). Assuming that this estimate is applicable to milk supplemented with whey protein, it is possible to obtain cheese with extra whey proteins by the addition of whey proteins to milk. Calculations suggest

that in order to obtain Cheddar cheese with whey protein levels similar to that in 5:1 UF Cheddar, there is a need to add about 4% w/v whey protein (or about 5% whey protein powder* with 80% whey protein) to milk (see Appendix II E for calculations). However, a preliminary trial showed that such large amounts of whey protein powder prevented the coagulation of milk when rennet was added. Subsequently, some laboratory scale experiments were done to determine the maximum possible addition of whey protein powder to milk. The results of these experiments suggested that the optimum level of addition from the standpoint of obtaining gel of sufficient strength was about 1% (Table 6.1). Other

Table 6.1 Effect of whey protein powder on the strength (by visual examination) of the gel obtained by addition of rennet to milk

S.No	Quantity of milk (ml)	Whey Protein powder added %	Whey Protein powder added g	Rennet ml	$CaCl_2$ mg	Visual examination of the gel after incubation ($32^{o}C$/40 min)
1	200	-	-	0.032	-	Normal
2	200	1	2	0.032	-	Normal
3	200	2	4	0.032	-	Slightly soft
4	200	4	8	0.032	-	Slightly soft
5	200	6	12	0.032	-	Soft
6	200	8	16	0.032	-	Very soft
7	200	9	18	0.032	-	Very soft
8	200	10	20	0.032	-	Very soft
9	200	-	-	0.032	40	Normal
10	200	1	2	0.032	40	Normal
11	200	2	4	0.032	40	Slightly soft
12	200	4	8	0.032	40	Slightly soft
13	200	6	12	0.032	40	Soft
14	200	8	16	0.032	40	Very soft
15	200	9	18	0.032	40	Very soft
16	200	10	20	0.032	40	Very soft

* Alacen 343 supplied by New Zealand Dairy Board. See Appendix IID for the chemical composition.

techniques such as raising the setting temperature to 34°C, increasing setting time to 60 minutes, adding various levels of calcium chloride (0.02 - 1.0% w/v) did not help in improving gel strength significantly. This approach was therefore abandoned. However, cheeses were made from milk supplemented with whey protein powder (0.8 - 0.9% w/v). This corresponded to a whey protein level in milk equivalent to that in 2:1 retentate. The quality of these cheeses was compared with those obtained from whey protein supplemented 2:1 retentate as discussed in Section 6.3.5.5.

6.3 Section 2: Addition of whey protein powder to partially ultrafiltered milk

6.3.1 Introduction

The addition of large quantities of whey protein powder to milk leads to problems in cheesemaking as a result of a loss of gel strength (Section 1 of this chapter). One of the means of improving gel strength is by partial UF of milk. An additional advantage of partial UF of milk is that the amount of moisture lost (per kilogram of cheese) is lower. Hence high whey protein retentions would be expected. The addition of whey protein powder to partially ultrafiltered milk offers a means of studying the effect of whey proteins on Cheddar quality.

6.3.2 Experimental Plan

2:1 UF was chosen as the level of partial UF since results of a previous experiment (Chapter 5) suggested that Cheddar of satisfactory quality can be made from 2:1 UF retentate using conventional method and equipment. Whey protein powder was blended into 2:1 retentate such that the total whey protein content of the retentate was equivalent to that in 4:1 to 5:1 UF retentate. Using conventional methods, Cheddar cheese was made simultaneously from (i) control milk and (ii) whey protein supplemented 2:1

retentate (WPSR). The quality of cheese from the two treatments was compared.

6.3.3 Experimental

Three trials were done during 1984-5 season.

6.3.3.1 **Milk supply:** As described in Chapter 4. About 200 l milk was needed for each of the trials.

6.3.3.2 **Ultrafiltration:** As described in Chapter 4 except that 120 kg milk was concentrated by UF to 2:1 level.

6.3.3.3 **Whey protein blending:** 25 kg of 2:1 retentate was placed in a small reconstitution vat. As per calculations, 0.44 kg whey protein powder (Alacen 343 supplied by New Zealand Dairy Board; see Appendix II D for composition of whey protein powder) was weighed and blended into the retentate. This raised the whey protein level in the 2:1 retentate equivalent to that in 4:1 or 5:1 retentate. The bulk of the whey proteins in the whey protein powder were in undenatured form (Harper, personal communication).

6.3.3.4 **Cheesemaking:** As described previously (Chapter 5). Both the control and WPSR curds were subjected to similar dry stirring operations.

6.3.4 Analytical methods

The milks, retentates and wheys were analysed for total solids, fat, TN, NCN, NPN and calcium. The cheeses were analysed for moisture, fat, TN, pH, salt and calcium. The cheeses were graded during the maturation period. Methods for all the above analyses have been described previously (Chapter 4).

6.3.5 Results and discussion

In this investigation, apart from the control and WPSR treatments, cheese was also made from 2:1 retentate (considered as second control). Results of this part of the experiment were included with those of a more extensive investigation reported earlier (Chapter 5).

The results presented in this chapter include those from the control and WPSR treatments only. The results on the quality of cheese from 2:1 retentate and whey protein supplemented milk (from section 6.2 of this chapter) have been included to provide a basis for comparison. For convenience average results are presented because these show the main trends and avoid unnecessary detail. These are discussed in five sections:

6.3.5.1 Milk composition
6.3.5.2 Cheese manufacture
6.3.5.3 Cheese composition
6.3.5.4 Mass balance and cheese yield
6.4.5.5 Cheese quality

6.3.5.1 **Milk composition:** The fat and casein content of WPSR was twice that of the control while the whey protein content was approximately four times that of the control (Table 6.2).

6.3.5.2 **Cheese manufacture:** There were no major problems encountered in cheesemaking from WPSR. The WPSR curd was slightly softer and more fragile in comparison to the control curd according to subjective assessment. The pH changes during cheesemaking followed almost identical patterns (Figure 6.1).

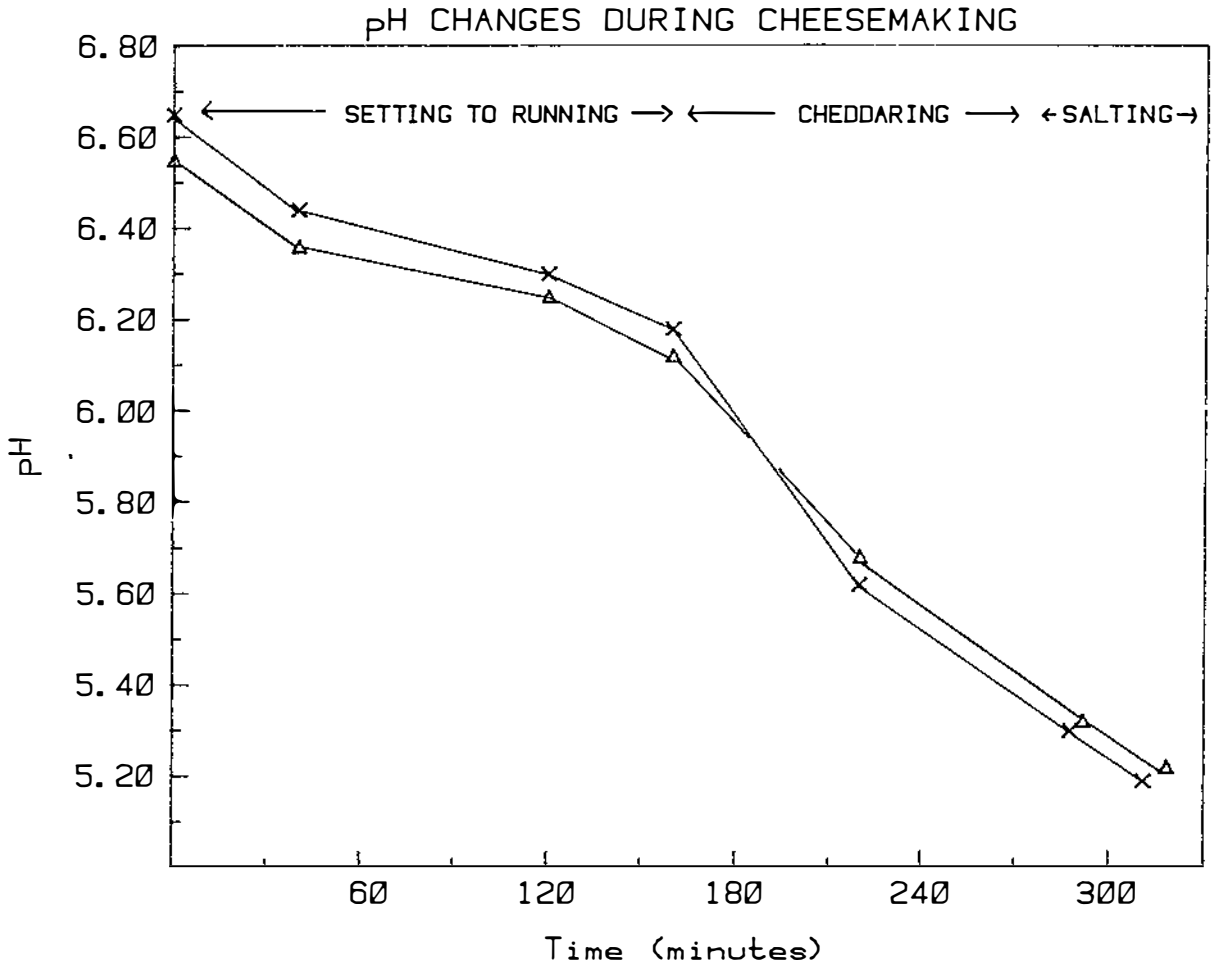


Figure 6.1 Comparison of pH changes during cheesemaking from control (x —— x) and whey protein supplemented 2:1 retentate (Δ —— Δ). Initial determination was done on the milk/retentate and subsequent ones on the whey.

Table 6.2 Milk and whey protein supplemented retentate composition

Particulars	Control milk	Whey protein supplemented retentate
Total solids %	12.45 ± 0.04	19.90 ± 0.11
Fat %	3.68 ± 0.05	7.23 ± 0.12
TN %	0.548 ± 0.010	1.250 ± 0.030
NCN %	0.136 ± 0.001	0.454 ± 0.019
NPN %	0.030 ± 0.001	0.030 ± 0.001
Calcium mM/kg	31.9 ± 0.6	46.9 ± 0.7

6.3.5.3 Cheese composition: The cheeses from the two treatments had similar compositions (Table 6.3). The lower FDM in WPSR Cheddar could be due to slightly higher fat losses in the whey and/or to the marginally higher whey protein content of the cheese.

Table 6.3 Cheese composition

Particulars	Control Cheddar	WPSR Cheddar
FDM %	52.77 ± 0.43	51.33 ± 0.31
MNFS %	53.89 ± 0.71	53.86 ± 0.94
S/M %	4.86 ± 0.12	4.92 ± 0.11
1-day pH	5.06 ± 0.01	5.02 ± 0.01
TN %	4.12 ± 0.01	4.20 ± 0.05
Calcium mM/kg	182 ± 3.3	186 ± 4.2
Ca/SNFNS	2.54 ± 0.06	2.55 ± 0.05

6.2.5.4 Mass balance and cheese yield: The results of the mass balance suggested that the recovery of total solids, SNF and TN in WPSR Cheddar was lower than that in the control (Table 6.4). This was possibly due to loss of the bulk of the whey proteins in the liquid whey. This observation was

Table 6.4 Mass balance

Percentage recovery in cheese

Particulars	Control cheddar	WPSR Cheddar
Total solids	50.16 ± 0.20	61.82 ± 0.20
		*49.97 ± 0.20
Fat	89.61 ± 0.54	86.97 ± 0.58
SNF	33.62 ± 0.20	47.38 ± 0.31
		*34.51 ± 0.19
TN	72.46 ± 0.48	64.62 ± 0.91
CN	96.1 ± 0.2	96.0 ± 0.1
WPN	5.86 ± 1.19	14.86 ± 1.56

* Calculated on the basis of content in original milk for comparison purposes

backed by the whey compositions (Table 6.5). It is possible that the presence of extra whey proteins influenced the ability of the casein network to bind fat (Green et al, 1981b) thereby affecting fat recovery. The percentage recovery of WPN in WPSR Cheddar was only slightly higher than the control suggesting that the quantity of moisture

Table 6.5 Whey composition

Particulars	Control whey	WPSR whey
Total solids %	6.58 ± 0.02	9.48 ± 0.10
Fat %	0.31 ± 0.02	0.82 ± 0.06
TN %	0.171 ± 0.001	0.518 ± 0.019
NCN %	0.153 ± 0.000	0.479 ± 0.017
NPN %	0.045 ± 0.001	0.059 ± 0.002

lost was still large enough to ensure loss of most of the whey proteins. The differences in the recovery of various milk constituents between the two treatments were possibly too small to influence cheese yield significantly (Table 6.6).

Table 6.7 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
1	Control	Normal (6)	Sl.mealy (3) Sl.loose	Normal (6)	Sl.loose (3) Sl.tender	Normal (6) Sl.aromatic	Sl.mealy (3)
	WPSR	Sl.sour (5) Sl.bland	Sl.mealy (2) Sl.crumbly	Sl.sour (5) Sl.unclean	Sl.lumpy (2) Sl.pasty	Sour (5) Sl.bitter	Mealy (2) pasty
	2:1 UF	Normal (6)	Sl.tender (3)	Normal (6)	Sl.mealy (2)	Normal (6) Sl.sour	Sl.tender (3)
	WPSM	Sl.sour (5) Sl.bitter	Sl.mealy (2) Sl.floury	Sl.sour (5) Sl.bitter	Weak (2) Pasty	Sour (4) Unclean	Pasty (2) Floury
2	Control	Normal (6)	Sl.tender (3) Sl.mealy	Normal (6)	Sl.mealy (2) Sl.pasty	Normal (6) Sl.fruity	Sl.tender (2) Sl.pasty
	WPSR	Sl.bitter (5) Sl.sour	Sl.curdy (2) Sl.floury	Sl.sour (5) Sl.bitter	Sl.mealy (2) Sl.lumpy	Sour (5) Sl.bitter	Weak (2) Pasty
	2:1 UF	Normal (6) Sl.bland	Sl.tender (3)	Normal (6)	Sl.mealy (2)	Normal (6) Sl.sour	Sl.tender (3)
	WPSM	Sl.sour (5) Sl.bitter	Sl.mealy (2) Sl.floury	Sl.sour (5) Sl.bitter	Sl.pasty (2) Weak	Sour (5) Sl.bitter	Weak (2) Sl.pasty

Note: Figures in brackets refer to grade scores

WPSM is whey protein supplemented milk

Table 6.7 Grading of cheese
(Continued from previous page)

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
3	Control	Normal (6) Sl.bland	Sl.tender (2) Sl.mealy	Normal (6) Sl.sour	Sl.tender (3) Sl.mealy	Normal (5) Sl.fruity	Sl.tender (3)
	WPSR	Sl.sour (5)	Sl.lumpy (2) Sl.loose	Sl.sour (5) Sl.bitter	Weak (2) Pasty	Sl.sour (5) Sl.unclean	Weak (2) Pasty
	2:1 UF	Normal (6) Sl.sour	Sl.tender (3)	Normal (6) Sl.sour	Sl.tender (3)	Normal (5) Sl.fruity	Sl.tender (3)
	WPSM	Sl.sour (5) Sl.bitter	Mealy (2) Sl.floury	Sour (5) Sl.bitter	Weak (2) Pasty	Sl.sour (5) Sl.unclean	Weak (2) Sl.pasty

Note: Figure in brackets refer to grade scores

WPSM is whey protein supplemented milk

Table 6.6 Yield of cheese

Yield	Control Cheddar	WPSR Cheddar
kg cheese per 100 kg milk	9.76 ± 0.12	9.84 ± 0.17
kg cheese (adjusted to 36.0% moisture) per 100 kg milk	9.88 ± 0.07	9.72 ± 0.10

6.3.5.5 Cheese quality: During the course of the cheese maturation, the control Cheddar had a better texture and flavour than that of WPSR Cheddar (Table 6.7). The lower flavour score in WPSR Cheddar was possibly due to a 'sour' flavour defect. Statistical analysis of grade scores confirmed that WPSR Cheddar had significantly lower ($p < 0.05$) grade scores for flavour and texture as compared with the control Cheddar. In contrast, the 2:1 Cheddar had flavour and texture identical to that of the control. However, the defects observed in the WPSR were also evident in cheese made from whey protein supplemented milk (Table 6.7). These results suggested that the addition of even small amounts of whey protein in dried form to the milk or retentate leads to flavour and texture problems in the cheese. This is consistent with reports of other research workers (Wingfield et al, 1979).

Therefore, the results of the present investigation were inconclusive since the source of the added whey protein was having an effect on the quality of the cheese. The addition of whey protein in whey protein concentrate (WPC) form to the retentate was considered but given up owing to practical difficulties. One major difficulty was that the UF plant was used for concentration of milk and due to time constraints could not be used for preparation of WPC as well.

6.3.6 Conclusion

The results of the present investigation suggest that when 2:1 UF retentate supplemented with whey protein in dried form is used for Cheddar cheesemaking, there is some loss of quality in the resultant cheese. The same effect is observed when cheese is made from milk supplemented with whey protein in dried form. On the basis of these results, it is not possible to comment whether similar problems will arise when the source of the whey protein incorporated into the cheese is the milk itself. Further work is needed to study the problem. One possible way of further investigating the problem is to add whey protein to 2:1 retentate in WPC form.

6.4 Section 3: Addition of whey protein concentrate to cheese slurries

6.4.1 Introduction

Research on the study of the effect of whey proteins on Cheddar cheese quality is difficult owing to problems associated with the incorporation of undenatured whey proteins into the cheese using conventional methods and equipment (Section 1 and 2 of this chapter). A technique devised for accelerated cheese ripening (Kristoffersen et al, 1967) by making slurries from cheese curd provides a means of studying the influence of whey proteins on Cheddar cheese quality. If it is found that the presence of whey proteins influences the biochemical reactions in the slurries, a similar effect may be expected in the cheese. One major advantage of using the slurry system for such an investigation is the ease with which the whey proteins can be incorporated into the slurries. An additional advantage is that the effect of denatured and undenatured whey proteins incorporated at various levels can be studied. One disadvantage is that the slurry method provides no information on the effect of whey proteins on the texture of the cheese.

6.4.2 Experimental plan

Basically the slurry technique involves blending two parts of one-day old, salted and pressed Cheddar curd with one part of 5.2% NaCl solution. The resultant homogeneous slurry is stored at about 30°C until the flavour becomes similar to that of mild Cheddar cheese.

The experimental plan was to substitute part or whole of the water normally added to the slurries, with WPC having whey proteins in denatured or undenatured form. Three levels of substitution were chosen - 1/4, 1/2 and full - such that the whey protein level in the slurry corresponded to whey protein recovery in UF Cheddar of approximately 20, 40 and 80% respectively. Therefore, in all there were seven treatments - one control and three each (at the three levels of substitution) of denatured and undenatured whey proteins.

6.4.3 Experimental

Three trials were done during 1985-86 season. For making slurries, the method of Huffman and Kristoffersen (1984) which is based on that of Kristoffersen et al (1967) was used. The important steps are briefly described below.

6.4.3.1 Preparation of Cheddar cheese: Cheddar cheese was made in the pilot plant of the N.Z.D.R.I. as described previously (Chapter 4). After overnight pressing, about half of one block of 20 kg was cut, wrapped in presterilized aluminium sheets and transferred to the nearby Food Microbiology Laboratory at Massey University.

6.4.3.2 Pretreatment of WPC: About 10-12 kg of WPC from lactic acid casein whey with 13-14% solids (about 60-70% total protein on dry matter (DM basis) was obtained from the pilot plant of N.Z.D.R.I. It was subjected to the following pretreatments:

6.4.3.2.1 Diafiltration: The WPC was diafiltered against milk salt solution (Jenness and Koops, 1962) in a DDS Lab-20

module to yield WPC with a solids content of 12-13% and protein content of 85-90% (DM basis).

6.4.3.2.2 Centrifugation: It was important that the total bacterial count of WPC be brought to a minimum (preferably nil) so that the contribution of these organisms to the biochemical reactions in slurries be insignificant. Heat sterilization of WPC was ruled out because it would lead to heat denaturation of the whey proteins. Chemical sterilization was likely to inhibit growth of microorganisms in slurries to which WPC was added. Use of millipore filter to remove bacteria from a dilute solution of WPC and then freeze concentration of WPC under aseptic conditions was attempted but abandoned on account of practical difficulties. The only practical solution appeared to be application of centrifugal force to centrifuge out the bacteria. The WPC was therefore centrifuged at 16,000 x g (Sorvall SS-3 Automatic centrifuge with GSA rotor) in sterile polysulphone bottles (250 ml capacity) for 20 min. The top 120 - 130 ml from each bottle was aseptically drawn out and used for addition to slurries. On an average the total count (standard methods agar, 'Gibco', Gibco Laboratories, Wisconsin, USA, 30^{o}C/3-5 days) of this portion was 30-40 cfu/ml compared with an initial count (prior to centrifugation) of WPC of 3,000 - 6,000 cfu/ml.

6.4.3.3 Slurry calculations: The first step in slurry calculations was to determine moisture and salt content of the cheese and total solids and TN in the WPC. Sample slurry calculations are shown in Appendix II A. The target was to obtain slurries for all treatments with 40.0% solids and 4.2% salt-in-moisture. For each treatment, the quantity of ingredients to be added was tabulated (Table 6.8).

6.4.3.4 Heat denaturation: For treatments X, Y and Z, (Table 6.8) calculated amounts of diafiltered and centrifuged WPC were placed in three clean 'Agee' glass jars (1 l capacity). Whey proteins were denatured by heating in an autoclave to 95^{o}C for 30 minutes (Tumerman and Webb, 1965).

Table 6.8 Ingredients for making slurries

S.No.	Ingredient	Treatments: Control A*	Undenatured WPC B*	Undenatured WPC C*	Undenatured WPC D*	Denatured WPC X*	Denatured WPC Y*	Denatured WPC Z*
1	Cheddar cheese 1 day old (g)	600	600	600	600	600	600	600
2	Water (g)	372	302.3	232.5	93.0	302.3	232.5	93.0
3	Undenatured WPC (g)	-	93.0	186.0	372.0	-	-	-
4	Denatured WPC (g)	-	-	-	-	93.0	186.0	372.0
5	Salt (g)	13.9	14.6	15.2	16.4	14.6	15.2	16.4
6	Corresponding whey protein % retention in cheese	-	20	40	80	20	40	80

* see experimental plan

6.4.3.5 Slurry **making:** Slurries for the seven treatments were made using the ingredients listed in Table 6.8 by following the method of Kristoffersen et al (1967).

6.4.3.6 **Incubation:** The slurries in sealed glass jars were incubated at 30°C in a water bath for 6-9 days. During each of those days, the slurries were thoroughly mixed under aseptic conditions for 1-2 minutes, sampled and re-incubated. The day the slurries were made was considered as day 0. Incubation continued for 6-9 days.

6.4.4 Analysis of slurries

6.4.4.1 Chemical: The slurries were analysed for total solids, fat and salt at day 0. TN was determined on day 0, day 3 and day 6. The pH was measured on each day. For all these analyses, the methods outlined for cheese were used as described in Chapter 4. Soluble nitrogen (SN) was determined at day 0, day 3 and day 6 by a method based on that of Vakaleris and Price (1959). Salient points of the method are given below:

(i) A sodium citrate extract of the slurry was obtained.

(ii) Dilute hydrochloric acid was added, pH adjusted to 4.4 $\pm$ 0.05 and the mixture filtered.

(iii) The nitrogen content of the filtrate (termed as soluble nitrogen) was determined by semimicro-Kjeldahl method. SN was expressed as a percentage of TN.

6.4.4.2 Taste panel: A panel of 6-8 judges was trained to assess the intensity of various flavour attributes in slurries on a 0-8 hedonic scale with 0 = absent and 8 = very pronounced. The training method used was as described for cheese taste panel (Chapter 4). The flavour attributes assessed were acid/sour, bitter, diacetyl, fruity, lipolytic rancidity, salty and unclean. In addition, the judges were also asked to give an overall score to the slurries based on the resemblance of slurry flavour to typical Cheddar flavour. The score sheet is shown in Appendix II B. Taste panel was done at day 0, day 3 and day 6. Sample presentation was random and the origin of samples was not revealed to the panelists.

6.4.5 Results and discussion

Average results are discussed since these show the main trends. These results are discussed in three sections:

6.4.5.1 Chemical composition of slurries
6.4.5.2 Proteolysis in slurries
6.4.5.3 Taste panel measurements on slurries

6.4.5.1 Chemical composition of slurries: The total solids, FDM and S/M of slurries for the seven treatments were similar (Table 6.9). As expected, there was a gradual decline in FDM values with increase in proportion of whey proteins. The conditions for biochemical activities in various slurries appeared to be similar as far as values for total solids, S/M and pH were concerned.

Table 6.9 Chemical composition of slurries

	Treatments						
	Control	Undenatured WPC			Denatured WPC		
Particulars	A*	B*	C*	D*	X*	Y*	Z*
Total solids	39.73 ±0.66	40.20 ±0.82	40.63 ±0.62	40.27 ±0.94	40.60 ±1.07	40.57 ±0.83	40.43 ±0.09
FDM	52.19 ±0.54	51.83 ±0.78	51.43 ±0.32	50.25 ±0.01	51.58 ±0.50	51.03 ±0.49	50.37 ±0.20
S/M	4.21 ±0.01	4.24 ±0.03	4.16 ±0.03	4.16 ±0.06	4.18 ±0.01	4.23 ±0.02	4.22 ±0.03
pH (day 0)	5.02 ±0.02	5.01 ±0.02	5.00 ±0.03	5.02 ±0.02	5.01 ±0.02	5.02 ±0.022	5.02 ±0.01

* see experimental plan

6.4.5.2 **Proteolysis in slurries:** The slurries with added undenatured whey proteins (treatment B, C and D) had progressively higher SN values compared with the control (treatment A) even at day 0 (Table 6.10). This was probably because the whey proteins were also extracted along with other SN during analysis. The slurries with added denatured whey proteins (treatment X, Y and Z) had SN similar to the control at day 0 suggesting that, as expected, the denatured whey proteins did not appear in the sodium citrate-hydrochloric acid extract.

As ripening progressed, the rate of increase of SN in slurries with added undenatured whey proteins was similar to that in the control. Since the whey proteins largely appeared to be included in the SN fraction at day 0, it was not possible to determine from the SN values at day 3 and day 6 whether or not the undenatured whey proteins were undergoing proteolysis. Literature reports suggest that undenatured whey proteins resist proteolysis by rennet and starter enzymes (Jost et al, 1976; O'Keefe et al, 1978; Koning et al, 1981). The results of the present investigation, therefore, indicate that in a slurry system, the presence of undenatured whey proteins does not significantly influence the rate of release of SN from the casein fractions.

The rate of release of SN in slurries with denatured whey proteins was higher than that in the control. There are two possible explanations. Firstly, the presence of denatured whey protein accelerated the release of SN from the casein fractions. There is no evidence in the literature to support this possibility. In fact, the presence of denatured β-lactoglobulin is said to inhibit plasmin (Snoeren et al, 1980) which according to Creamer (1971, 1974) is responsible for β-casein proteolysis. Therefore, the presence of denatured whey protein might be expected to slightly retard the release of SN from the casein. Secondly, the extra SN may have come from the proteolysis of the whey proteins. This is more likely since it has been

suggested that heat denaturation of the whey proteins causes alteration in their secondary and tertiary structure (Tumerman and Webb, 1965). It is possible that this may lead to uncoiling of the protein, making sites which were otherwise hidden, available for enzyme action. Therefore, it appears that denatured whey proteins may undergo proteolysis in a slurry and possibly cheese system.

Table 6.10 Soluble nitrogen as a percentage of total nitrogen in slurries during ripening

	Control	Undenatured whey protein			Denatured whey protein		
Day	A*	B*	C*	D*	X*	Y*	Z*
0	8.87 ±0.99	13.39 ±0.86	17.76 ±1.25	25.00 ±0.65	8.77 ±1.04	8.63 ±0.98	7.94 ±0.94
3	18.11 ±0.74	22.88 ±0.65	26.54 ±0.68	33.12 ±0.22	19.75 ±0.93	20.18 ±0.72	21.10 ±0.42
6	30.97 ±0.51	36.38 ±0.72	38.38 ±0.43	42.88 ±0.35	33.85 ±1.67	36.60 ±0.74	42.25 ±0.31

* see experimental plan

While care must be exercised in extrapolating these results to a UF Cheddar system, the following points may be mentioned:

(i) Denatured whey proteins may undergo proteolysis in UF Cheddar according to slurry experiments.

(ii) Whey proteins (denatured and undenatured) may not significantly influence proteolysis of most casein fractions. However, the proportion of both plasmin and also β-lactoglobulin in UF cheese may be higher than in normal Cheddar. As discussed earlier (Chapter 2), the net effect on β-casein proteolysis may depend on the relative propor-

tions of each and on other factors such as pH, S/M and MNFS.

(iii) Undenatured whey protein in UF Cheddar may 'dilute' the substrate making the casein fractions less accessible to enzyme action.

(iv) Undenatured whey proteins may have a 'dilution' effect on the flavour compounds formed in the cheese (Koning et al, 1981) and therefore may decrease the intensity of the flavour.

The results of the present investigation suggest that the whey proteins may not directly contribute to the lack of breakdown reported in UF Cheddar.

6.4.5.3 Taste panel: There were no significant differences between treatments in the average scores for various flavour attributes (Table 6.11). Initially the slurries with added WPC (both denatured and undenatured) had slightly higher scores for acid and bitter flavour attributes, possibly because of some contribution to slurry flavour by WPC itself. However, as proteolysis proceeded, differences in scores between treatments became random and smaller possibly due to the development of other flavours (Kristoffersen et al, 1967). There were no significant off flavours found in any of the slurries. While it is possible that the panelists were unable to pick up some off flavours in the slurries due to the difficulties in the sensory evaluation of the slurries, it is likely that the hydrolysis of denatured whey proteins did not give rise to off flavours.

Statistical analysis of the taste panel data indicated that for all flavour attributes, except diacetyl, various treatments did not significantly influence the scores. The average scores for all flavour attributes are shown in Appendix II C.

Table 6.11 Average taste panel scores of slurries

Flavour Attribute	Days	Treatment: Control A*	Undenatured WPC B*	Undenatured WPC C*	Undenatured WPC D*	Denatured WPC X*	Denatured WPC Y*	Denatured WPC Z*
	0	2.94	3.06	3.39	3.50	3.61	3.22	3.17
Acid	3	2.94	3.39	3.28	3.44	3.06	3.28	3.17
	6	3.06	3.17	3.39	3.33	3.00	2.94	3.78
	0	0.67	1.33	1.00	0.61	0.94	0.72	0.94
Bitter	3	1.22	1.44	1.61	1.44	1.67	1.44	1.28
	6	1.56	1.72	1.39	1.50	1.39	1.28	1.61
	0	4.61	4.06	3.94	3.89	4.11	3.72	4.06
Salty	3	3.78	3.83	3.94	3.67	4.00	3.78	3.83
	6	4.00	4.00	3.83	3.78	4.00	3.83	3.94
Overall	0	2.89	3.17	3.06	3.11	3.67	3.17	3.22
Score	3	3.33	2.89	3.22	3.22	3.00	3.50	3.61
	6	4.00	3.94	4.06	4.17	4.22	4.56	4.44

* See experimental plan

6.4.6 Conclusion

The results of the present study suggest that in a slurry system denatured whey proteins undergo proteolysis while undenatured whey proteins remain intact. However, proteolysis of denatured whey proteins does not give rise to significant off flavours in slurries. It is possible that similar biochemical reactions may take place in UF Cheddar. Although the products of proteolysis of denatured whey proteins do not appear to yield off-flavours, they may still influence the flavour of Cheddar cheese.** For this reason there may be a need to minimise denaturation of whey proteins during UF cheesemaking. Further work is needed to determine the effects of denatured and undenatured whey proteins on UF Cheddar cheese flavour and texture.

** by inhibiting plasmin.

6.5 Overall conclusion to Chapter 6

The results of the present investigation show that study on the effect of whey proteins on Cheddar cheese quality is difficult because of the large number of factors involved. It appears that in small proportions, the effect of whey proteins on UF Cheddar cheese quality may be negligible. In larger proportions, the effect on cheese flavour may depend on the physical state (denatured or undenatured) of the whey proteins (Jameson, 1983). In addition there may be an indirect effect due to 'dilution' of the flavour compounds (Koning et al, 1981), and of the substrate. It appears that the effect on the texture of UF Cheddar cheese may not be of major concern (Boer and Nooy, 1980a, b) as long as the proportion of whey proteins does not exceed a certain limit. Further research is needed to determine the limit.

CHAPTER 7

EFFECT OF DEGREE OF ULTRAFILTRATION ON THE QUALITY OF CHEDDAR CHEESE

7.1 Introduction

It was shown earlier (Chapter 5) that Cheddar cheese of satisfactory quality can be made from 2:1 UF retentate. However, at low CF (2:1) there appear to be no yield advantages. Indeed, the primary objective of UF cheesemaking is to increase yield by incorporating some of the whey proteins into the cheese. In order to increase recovery of whey proteins, UF retentate of high CF (5:1) needs to be used for cheesemaking. Thus conventional methods and equipment can no longer be used and modified cheesemaking methods are necessary. Also, at high CF, the problems associated with the quality of UF Cheddar become more severe with literature reports suggesting high one-day pH and slower breakdown of casein components (Green et al, 1981a), and atypical flavour and texture (Glover, 1985). Decreased residual rennet concentration in UF Cheddar has been suggested as one of the main causes (Green et al, 1981a). It is not known to what extent the extra whey proteins contribute to these problems. The work done in our laboratory demonstrated the difficulties in obtaining this information. These difficulties are primarily those concerning the incorporation of undenatured whey proteins in high proportions into the cheese using conventional cheese-making methods. However, results did suggest that in small proportions the whey proteins have a negligible effect on cheese quality (Chapter 5). In cheese slurries with denatured whey protein at higher concentration (than in 2:1 UF) more extensive proteolysis was observed than in control slurries. It is possible that hydrolysis of denatured whey protein may have an effect on the quality of the cheese.

In an earlier investigation (Chapter 5) it was shown that some of the problems in the quality of 2:1 UF Cheddar can be overcome by the addition of starter and rennet on the basis of milk quantity prior to UF. Information on optimum

residual rennet concentration and rennet retention in 5:1 UF Cheddar is lacking. However, if the situation is examined logically two important points emerge. Firstly, a greater proportion of the added rennet is expected to be retained in 5:1 UF curd because of smaller quantities of moisture lost. Secondly, the presence of extra whey proteins in the UF cheese might dilute the substrate and thereby raise the desired residual rennet concentration. In the present investigation, therefore, both rennet and starter were added on the basis of milk quantity prior to UF.

The objective of the present investigation was to study the effect of degree of UF on the quality of Cheddar cheese.

7.2 Experimental Plan

Pasteurized and standardized milk was divided into two lots. One lot was retained as control. From the other lot, 3:1 and 5:1 retentates were obtained by UF. Cheddar cheese was made simultaneously from the control, 3:1 and 5:1 retentates. There were slight modifications in the method of cheese manufacture from the retentates (discussed in section 7.3.3.1 of this chapter). The quality of Cheddars from the three treatments was compared. The choice of 5:1 as the highest degree of UF was obvious since 5:1 is the maximum degree of UF commercially attainable at present. Since three vats were available to make cheeses, an intermediate concentration factor, 3:1, was also included in the experimental plan.

7.3 Experimental

Nine trials were done spread over the 1984-85 and 1985-86 seasons.

7.3.1 Milk Supply: Same as described in Chapter 4. About 350 kg milk was needed for each trial.

7.3.2 Ultrafiltration: Same as described in Chapter 4 except that:

(i) 250-300 kg milk was placed in the UF plant.

(ii) It was subjected to 3:1 UF and about 20 kg retentate removed.

(iii) UF was continued to the 5:1 level.

7.3.3 Cheesemaking: For the control the basic method was the same as mentioned in Chapter 5. Modifications in the method used for the control were necessary for the retentates (Table 7.1). The main features of the cheesemaking methods used are summarised in the following section.

Table 7.1 Summary of cheesemaking conditions

Particulars	Vat 1 (Control)	Vat 2	Vat 3
Degree of UF	1:1	3:1	5:1
Quantity of milk/retentate (kg)	50.00	16.70	10.00
Quantity of starter (kg)	1.00	1.00	1.00
Quantity of rennet (ml)	8.00	8.00	8.00
Setting temperature (^{o}C)	32.0	32.0	32.0
Ratio			
Time of cutting:Rennet clotting time	2.5-3.5	1.8-2.5	1.2-2.2
Cooking temperature (^{o}C)	38.0	38.0	38.0
Time set to run (minutes)	160	160	160
Milling pH	5.30-5.35	5.30-5.35	5.30-5.35
Salting pH	5.20-5.25	5.20-5.25	5.20-5.25

7.3.3.1 The modification of the basic cheesemaking procedure needed for manufacture of cheese from UF retentates

The procedure used for cheesemaking from UF retentate is briefly discussed below.

7.3.3.1.1 Level of starter addition: For UF Cheddar, the level of starter addition used by most research workers has generally been about 2% (w/v) of the retentate (Chapman et al, 1974; Green et al, 1981a, b; Green, 1985) although frozen starter concentrate (equivalent to 4% (w/v) non-concentrated starter) has also been used (Sutherland and Jameson, 1981). In the present investigation, starter was added at 2% (w/w) based on the milk quantity prior to UF. This was considered as one of the methods to counteract the effect of high buffering capacity in retentates as discusssed previously (Chapter 2).

7.3.3.1.2 Level of rennet addition and time of cutting: As discussed earlier (Chapter 2), 5:1 UF retentate is too firm to cut 40 minutes after rennet addition if the rennet:casein ratio is kept at normal level (Culioli and Sherman, 1978; Garnot and Corre, 1980). To overcome this difficulty, it has been suggested (Green et al, 1981a) that two approaches may be helpful:

(i) Decreasing setting temperature to 27-29^{o}C so that setting is delayed. Rennet:casein ratio is kept the same as that in the control.

(ii) Retaining the normal setting temperature (32^{o}C) but decreasing the rennet:casein ratio to obtain a gel similar to that from the control 40 minutes after rennet addition.

The first approach appears to have two disadvantages - one is related to the problems associated with increased viscosity of the retentate and the other is concerned with the possible alteration of the microflora of the curd and the cheese. It is not surprising that this approach has not been considered favourably by most research workers.

In the second approach, some workers have decreased rennet amounts in proportion to CF while others have altered rennet amounts to obtain rennet clotting time (RCT) similar to normal milk. One disadvantage of this approach is possible reduced residual rennet concentration in the cheese (Green et al, 1981a).

For the present investigation, a third approach was tried and preliminary experiments indicated that it worked satisfactorily. The setting temperature and rennet:casein ratio were kept the same as the control but the cutting time was decreased to 1.2-2.2 times RCT. The 3:1 retentate was set in 10-15 minutes and cut at 18-25 minutes after rennet addition. The 5:1 retentate was set in 6-10 minutes and cut in 10-20 minutes.

The advantage with this approach was that normal setting temperatures could be used and problems related to cutting a 'firmer' UF curd were minimised. Furthermore, the residual rennet concentration of UF cheese would not be lower but might be higher than that of the control.

7.3.3.1.3 Device for cutting: Preliminary trials confirmed that normal cheese knives are unsuitable for cutting 3:1 and 5:1 curds. The vertical cutting could be performed using a normal kitchen knife. However, the horizontal cutting was difficult to accomplish considering the fragile nature of the curd (Van Leeuwen et al, 1984). A simple device was designed for the horizontal cutting (Figure 7.1).

It essentially consists of two thin aluminium plates connected with aluminium wire (diameter 0.6 mm). The length of the wire could be adjusted by wrapping it around the plates. The depth of the 5:1 retentate in the vat was 20-30 mm. For the cutting, one plate was held in each hand with the wire stretched horizontally just over the curd. It was lowered into the curd till the plates touched the bottom of the vat. With the help of the aluminium plates, the wire was pulled along the length of the vat to achieve one

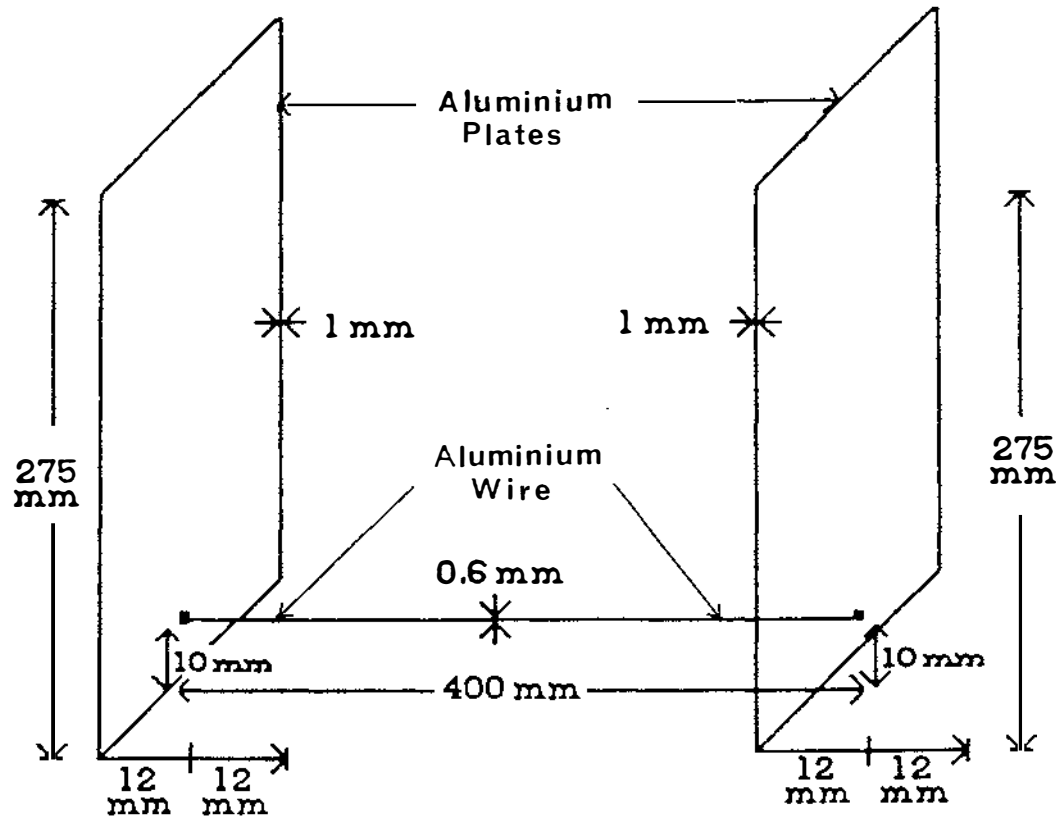


Figure 7.1 Schematic diagram of wire grid used for horizontal cutting of curd obtained from 3:1 and 5:1 UF retentates.

horizontal cut. For 3:1 curd, this operation was performed twice at depths of approximately 10 and 20 mm. The curds were then cut vertically at approximately 10 mm spacings using the ordinary kitchen knife.

7.3.3.1.4 Curd handling after cutting: The significance of proper handling of UF curd after cutting on losses of fat and fines was discussed earlier (Chapter 2). The 3:1 and 5:1 curds were left undisturbed for 20-35 minutes. After this period, the curd particles were gently segregated from each other by hand to promote syneresis.

7.3.3.1.5 Cooking: The curds and wheys were gently hand stirred, and temperature raised slowly to 38^{o}C in 30-35 minutes (at about 0.2^{o}C/min) by circulating warm water in the double jacket. Slow hand stirring continued till the stage of whey drainage at approximately 160 minutes after rennet addition. Cooking of the 3:1 curd was easier than that of the 5:1 curd because of larger amounts of whey.

7.3.3.1.6 Cheddaring: The Cheddaring process for both UF curds was similar to the control. The Cheddaring process was monitored by following the pH (Green et al, 1981a), although the titratable acidity was also determined. The curds from all three vats were milled and salted at a pH of 5.30 - 5.35 and 5.20 - 5.25 respectively.

7.4 Analytical methods

7.4.1 Chemical analysis of milks, retentates and wheys

The milks, retentates and wheys were analysed for total solids, fat, TN, NCN, NPN and calcium. The methods described previously (Chapter 4) were used. However for retentates the quantity of sample taken was suitably decreased for the first five tests mentioned above. For the test on calcium content retentates were suitably diluted with distilled water prior to testing.

7.4.2 Chemical analysis of cheeses

The cheeses were analysed for moisture, fat, TN, salt, calcium and pH by methods described previously (Chapter 4).

7.4.3 Residual rennet concentration in cheese

The residual rennet concentration in cheese was measured by the k-casein method of Holmes et al, (1977). Salient points of the method are given below:

(i) k-casein was prepared by the method of Zittle and Custer (1962) using fresh skim milk.

(ii) An extract of cheese sample was obtained using citrate buffer (pH 5.9) supplemented with 0.3% polyethylene glycol to prevent loss of enzyme activity (Friedenthal and Visser, 1985).

(iii) k-casein Agarose gel was prepared and dispensed into small tubes (10 mm diameter, 4 cm long).

(iv) 100 . µl of various rennet dilutions (for standard curve) were applied to the top of the k-casein Agarose gel (in duplicate).

(v) 100 µl of each of the cheese sample extracts were applied to k-casein Agarose gel (in duplicate).

(vi) All tubes were capped and incubated at 37^{o}C for 18-20 hours.

(vii) The depth of the hazy 'cloud' for standard rennet dilutions (Figure 7.2) and cheese samples (Figure 7.4) was measured using a pair of Vernier calipers. This depth is directly correlated with the rennet concentration.

(viii) The data for rennet dilutions were plotted on semi-logarithmic graph paper and residual rennet concentration in cheese samples was estimated from the standard curve (Figure 7.3).

7.4.4 Cheese grading: The cheeses were graded as described previously (Chapter 4). The only exception was that the grading was done by a panel of 3-4 expert judges. This was done since the cheese grader from the Ministry of Agriculture and Fisheries was not available. The comments of the judges were summarised and the scores for flavour and texture averaged to the nearest whole number.

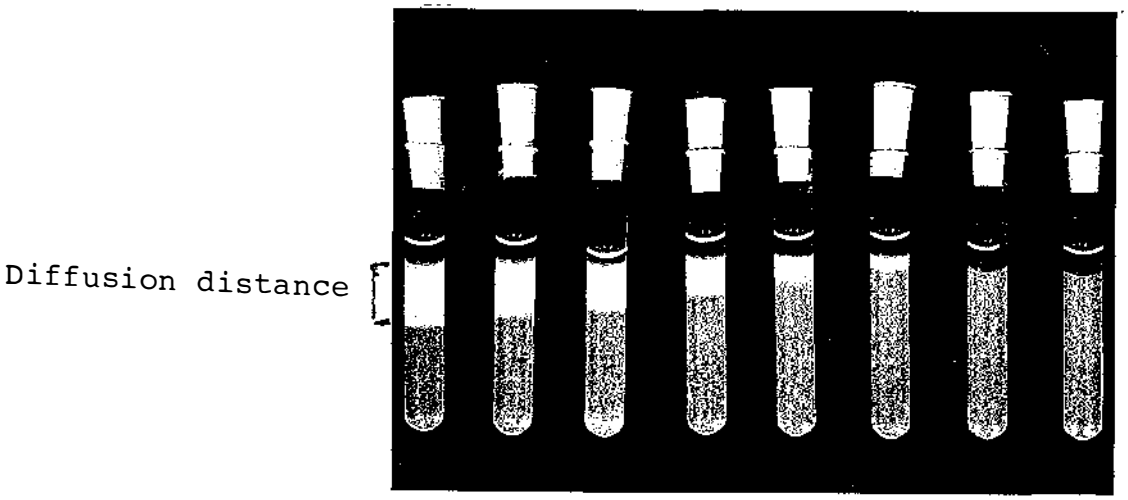


Figure 7.2 Diffusion tubes (for standard curve) filled with k-casein/agarose gel showing the diffusion of rennet. Calf rennet was diluted with citrate buffer to give a range of rennet concentrations (0.3, 0.075, 0.019, 0.0048, 0.0012, 0.0003 and 0.000075 RU/ml). 100 µl of these dilutions was applied to the gel. The last tube on the right is the blank. The diffusion distance (white band of precipitated k-casein) was measured using a pair of vernier calipers. For the standard curve, average values were plotted on semi-logarithmic paper with diffusion distance (mm) on the x-axis and rennet concentration (RU/ml) on the y-axis.

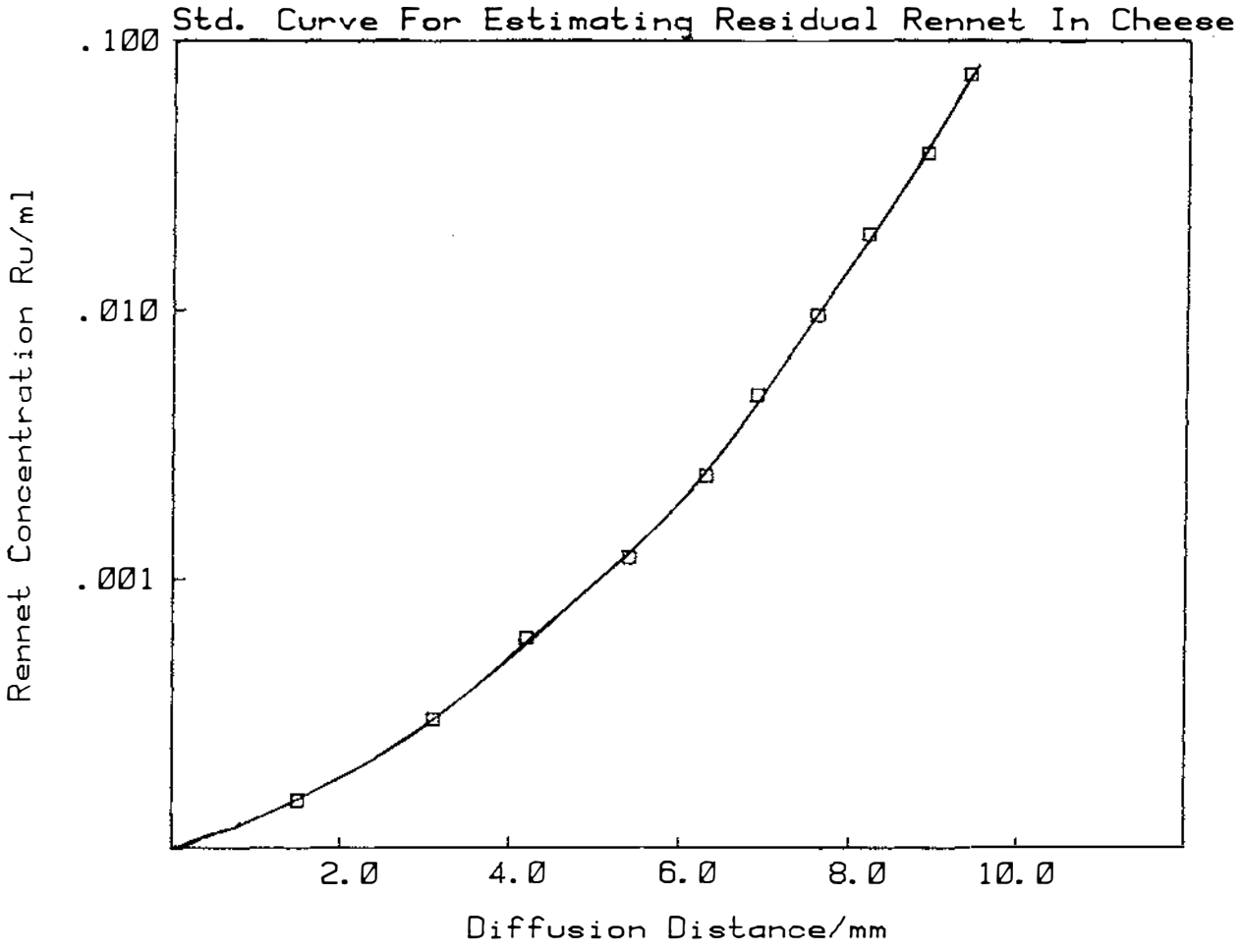


Figure 7.3 Standard curve for estimating residual rennet concentration in cheese samples.

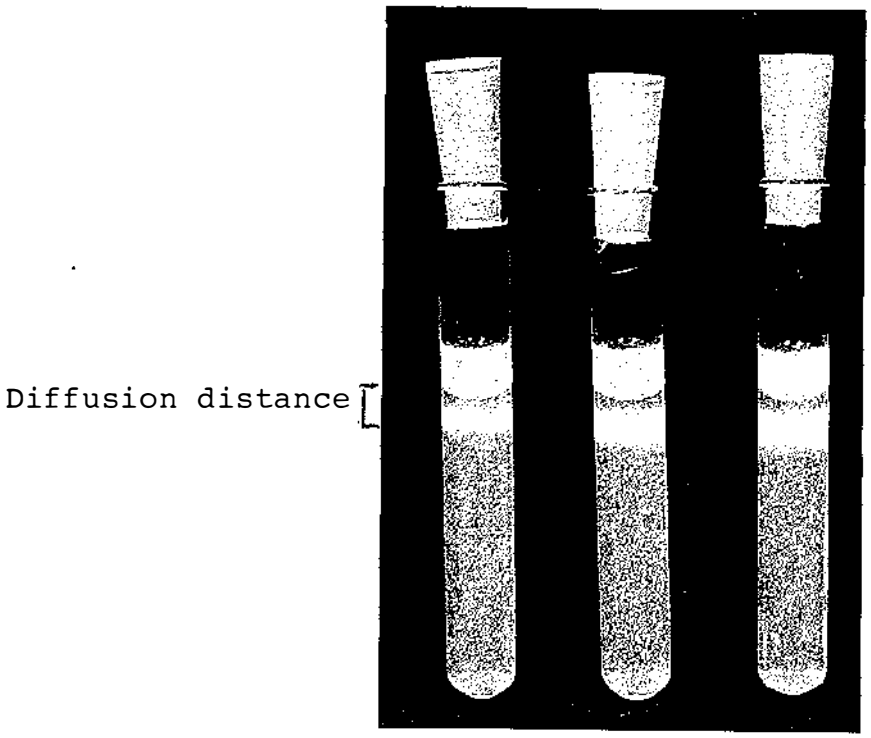


Figure 7.4 Diffusion tubes filled with k-casein/agarose gel showing the diffusion of rennet from the control. 3:1 UF and 5:1 UF cheese extracts. 100 µl of citrate buffer extracts of cheese samples were applied. The diffusion distance from the extract-gel interface to the bottom of the 'cloud' was measured. Note that a part of the precipitated k-casein 'cloud' near the extract-gel interface has solubilized, possibly because of further proteolysis of para-k-casein. The diffusion distance was then used to estimate the residual rennet concentration in the cheese samples using the standard curve (see Figure 7.3).

7.4.5 **Cheese sensory panel:** The panel described previously (Chapter 4) was used. Two additional terms, mealiness and grittiness were included in the questionnaire for texture (Appendix III A). This was necessary to cover the defects encountered in UF Cheddars in the present investigation. Definitions for these terms are shown in Appendix III B.

7.4.6 **Proteolysis in cheese:** The following methods were used to study proteolysis in the cheese:

7.4.6.1 **Polyacrylamide gel electrophoresis:** This was selected as one of the methods to study proteolysis since the breakdown of specific casein fractions was of interest in the present investigation. The method has been described previously (Chapter 4).

7.4.6.2 **Polyacrylamide thick slab gel electrophoresis:** This was done to study the breakdown of undenatured whey proteins. The method does not work for denatured whey proteins. The approach is based on that of Darling and Butcher (1976) but uses a slab instead of cylinders of polyacrylamide gel and includes a stacking gel to facilitate the removal of the slot former and to improve resolution. Salient points of the method are given below:

(i) A water extract of the cheese sample was obtained by dissolving it in deionised water and subjecting it to centrifugation (7700 x g) for 10 minutes in a SS34 rotor of a Sorvall centrifuge (E.I. du Pont de Nemours and Co. Inc., Wilmington, Delaware, U.S.A.). The fatty layer was removed.

(ii) The apparatus for vertical thick slab electrophoresis was assembled. It was the same as that used for polyacrylamide gel electrophoresis (Chapter 4) described by Richardson and Pearce (1981).

(iii) Separating gel, stacking gel and electrode chamber buffer were prepared (see Appendix III D).

(iv) Three separate gels were required to be poured.

(a) 15 ml of separating gel as a plug with the apparatus held 30° from the horizontal.

(b) Approximately 60 ml of separating gel with the apparatus held vertically and filled up to 1-2 cm from the top.

(c) 50 ml of stacking gel with the apparatus held horizontally. Slot former (8 slots) was carefully inserted.

Each of the pours was allowed to set (approximately 20-30 minutes) before the next one was poured.

(v) Slot former was carefully removed and 50 µl of the sample (6 slots) and standard whey protein solutions (2 slots) were applied to the gels.

(vi) Power supply (60 mA and 200 volts/gel) and cooling water were connected.

(vii) The voltage was applied and electrophoresis occurred for approximately 5 hours.

(viii) The gels were removed, labelled, stained (amido black) and destained (3% acetic acid) as described previously (Chapter 4) for polyacrylamide urea gels.

(ix) The gels were photographed.

7.4.6.3 Acid-soluble proteins, peptides and amino acids

The method described by Creamer et al (1985) was used. Salient points of the method are as follows:

(i) Cheese extract was obtained as for polyacrylamide gel electrophoresis.

(ii) 1.00 ml of the extract was mixed with 10 ml acetic acid buffer (1% v/v) and centrifuged (12000 x g).

(iii) 100 µl of the clear supernatant was diluted in 10.0 ml water.

(iv) 2.00 ml of this mixture (in triplicate) was mixed with 2.00 ml borate buffer and 1.50 ml fluorescamine.

(v) Fluorescence of resultant mixture was immediately measured using a Hitachi-Perkin Elmer MPFZA fluorescence spectrophotometer.

(vi) The fluorescence of samples was compared with those from the standard (solutions containing glycine in place of dissolved cheese).

(vii) Results were expressed in terms of moles of free amino groups (i.e. as glycine) per kg of cheese.

7.5 Results and discussion

For convenience average results are presented since these show the main trends and avoid unnecessary detail. The results are discussed in six sections:

7.5.1 Milk and retentate composition
7.5.2 Cheese manufacture
7.5.3 Cheese composition
7.5.4 Residual rennet concentration
7.5.5 Cheese proteolysis
7.5.6 Cheese quality

The results on mass balance and yield are discussed in a subsequent chapter (Chapter 9).

7.5.1 Milk and retentate composition

As expected, the increase in the percentage content of fat, casein and whey protein in the retentates was in proportion to the CF (Table 7.2).

The proportion of increase in TN and NCN content of retentates was slightly lower than the CF possibly because of loss of some low molar mass nitrogenous compounds such as NPN and proteose-peptone in the permeate as suggested by Green et al (1984).

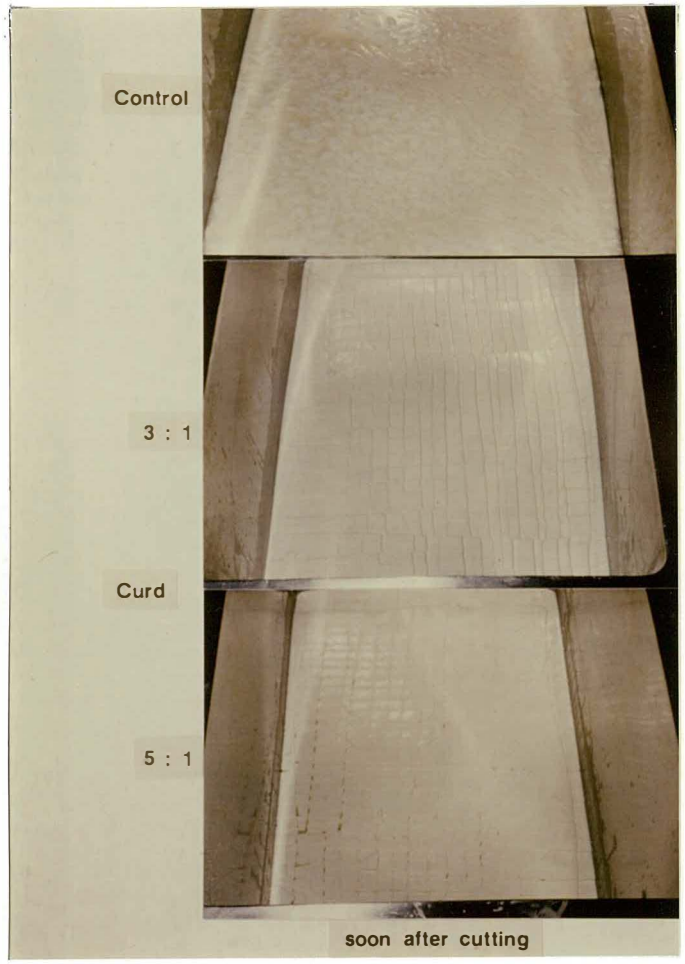
Table 7.2 Milk and retentate composition

Particulars	Control milk	3:1 retentate	5:1 retentate
Total solids %	12.59 ± 0.26	26.63 ± 1.02	37.87 ± 0.66
Fat %	3.90 ± 0.19	11.89 ± 0.73	18.98 ± 0.98
TN %	0.529 ± 0.010	1.521 ± 0.036	2.345 ± 0.048
NCN %	0.134 ± 0.005	0.341 ± 0.015	0.516 ± 0.018
NPN %	0.030 ± 0.003	0.032 ± 0.003	0.034 ± 0.003
Calcium mM/kg	32.3 ± 1.0	67.0 ± 2.8	103.9 ± 4.0

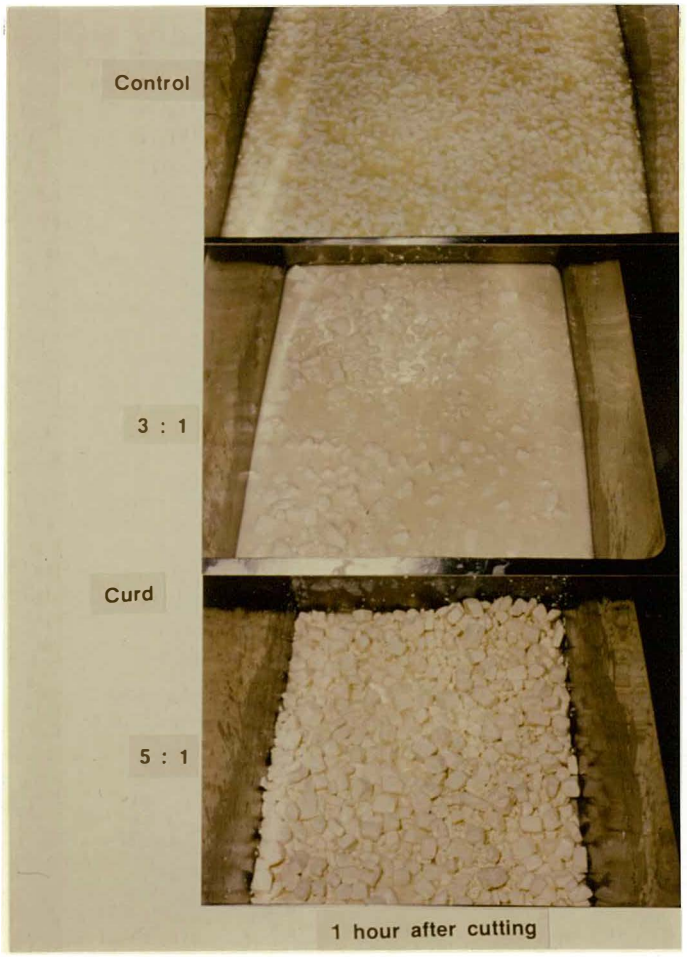
7.5.2 Cheese manufacture

For one typical trial, photographs showing the various stages of cheesemaking are shown in Figure 7.5.

On rennet addition, subjective assessment suggested marked differences in the rate of setting and the firmness of the gels. This is in accordance with the observations of other workers (Culioli and Sherman, 1978; Garnot and Corre, 1980) who reported that UF curd is firmer and less elastic than conventional curd. The change in coagulation pattern necessitated alterations in the cutting and handling of the UF curds as discussed earlier. There were small differences in the pH of milks and wheys between treatments (Figure 7.6). As discussed in Chapter 5, the total buffering and total kg starter added were similar in the three vats. The differences recorded were probably due to differences in the growth and acid production of starter organisms in the milk and retentates (Hickey et al, 1983a; Mistry and Kosikowski, 1985a, b). During Cheddaring the UF curd particles did not knit together as well as those of the control suggesting differences in the syneresis and the surface properties of

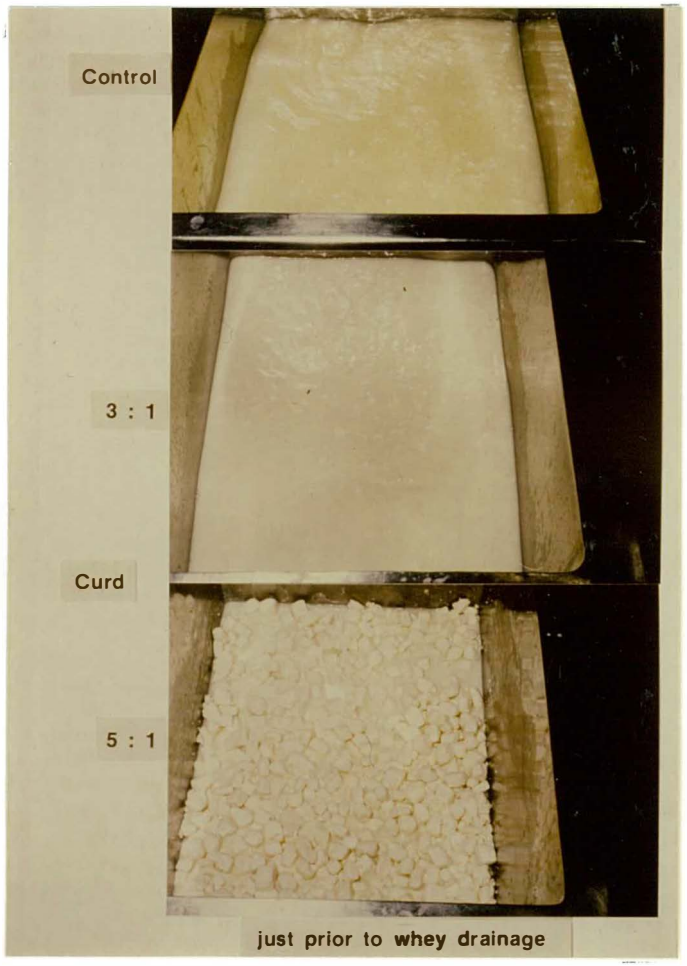


(A)

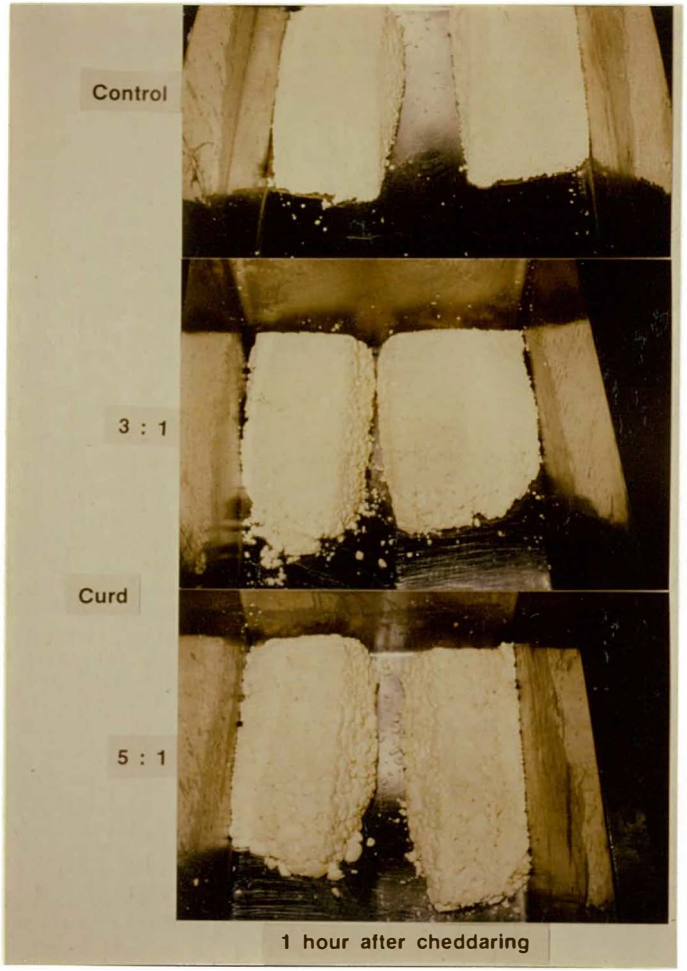


(B)

Figure 7.5A and 7.5B Control, 3:1 and 5:1 curds (A) soon after cutting (B) one hour after cutting.

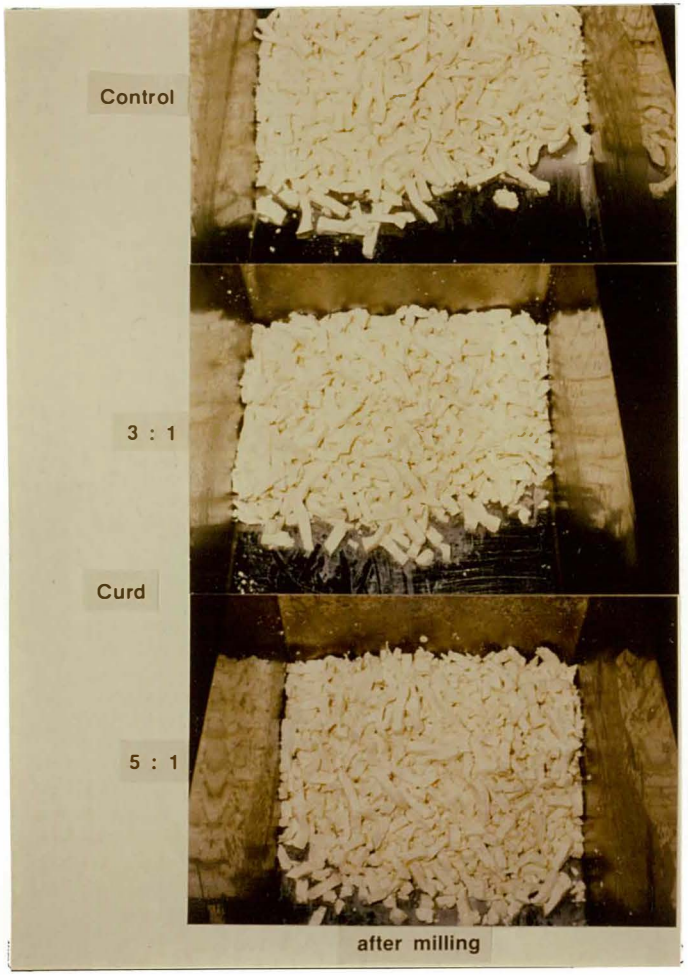


(C)

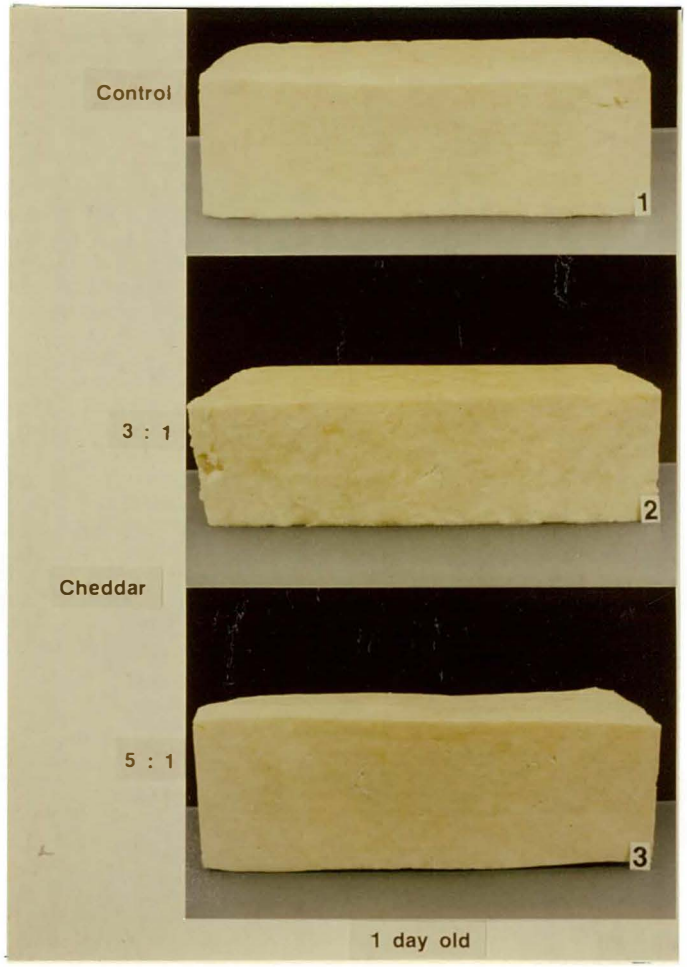


(D)

Figure 7.5C and 7.5D Control, 3:1 and 5:1 curds (C) just prior to whey drainage and (D) one hour after Cheddaring.



(E)



(F)

Figure 7.5E and 7.5F Control, 3:1 and 5:1 (E) Curds after milling and (F) one day old cheeses.

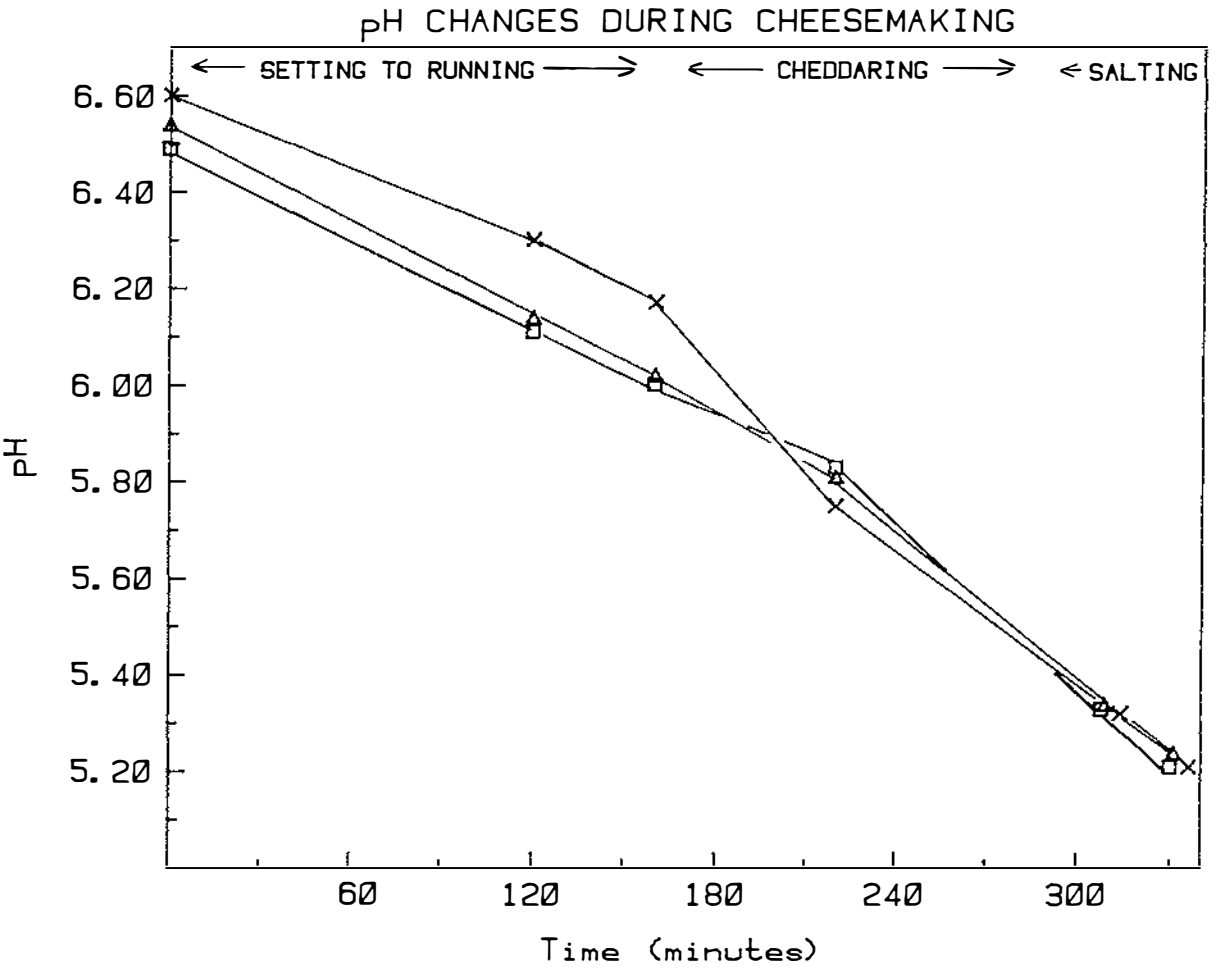


Figure 7.6 Comparison of pH changes during cheesemaking from control milk (x —— x), 3:1 UF (Δ —— Δ) and 5:1 UF retentate (□ —— □). Initial determination was done on the milk/retentate and subsequent ones on the whey.

the curd particles from different treatments. The total time taken to attain the desired milling and salting pH was similar for the three treatments.

7.5.3 Cheese composition

There were some differences in the composition of cheeses from the three treatments (Table 7.3). The cheeses from the control and the 5:1 treatments were similar in composition except for the higher TN and calcium in the latter. The FDM in 3:1 Cheddar was lower than that from the other two treatments possibly because of higher fat losses. This also resulted in a proportionate increase in TN % of 3:1 Cheddar. The cheeses with higher FDM had higher MNFS suggesting that these two composition characteristics were interlinked (Lelievre, 1983a). However, differences in both FDM and MNFS between treatments were too small to be significant. The values for calcium suggested that with an increase in CF there was a proportionate increase in the calcium content of UF Cheddar. However, calcium values for cheeses from all three treatments were within the range of 180-210mM/kg for normal Cheddars (Creamer et al, 1985). These calcium values for 5:1 Cheddar are similar to those found by Sutherland and Jameson (1981).

Table 7.3 Cheese compositions

Treatment	Control	3:1	5:1
FDM %	53.69 ± 1.51	51.69 ± 1.79	51.96 ± 1.69
MNFS %	53.76 ± 0.91	52.84 ± 1.11	53.23 ± 0.72
S/M %	4.95 ± 0.10	5.09 ± 0.13	5.05 ± 0.21
pH 1-day	5.07 ± 0.02	5.11 ± 0.02	5.12 ± 0.02
TN %	3.90 ± 0.11	4.20 ± 0.13	4.02 ± 0.10
Calcium mM/kg	182.0 ± 2.3	198.0 ± 4.1	209.0 ± 4.4
Ca/SNFNS	2.62 ± 0.15	2.60 ± 0.07	2.87 ± 0.08

The 1-day pH values of 5:1 Cheddars found in the present investigation are lower than those reported by other workers (Green et al, 1981a; Sutherland and Jameson, 1981). The results of the present investigation suggest that measures to compensate for the higher buffering in the retentates, such as addition of increased amounts of starter, can help in decreasing 1-day pH and calcium content of UF Cheddar to levels found in normal Cheddar.

7.5.5 Residual rennet concentration in cheese

There were large differences in residual rennet concentration of cheeses from the three treatments (Table 7.4). These differences were probably due to two reasons. Firstly, the smaller amounts of moisture lost from the more concentrated milks permitted a greater proportion of rennet to be retained in the cheese. Secondly, the lower pH of curd at the stage of whey drainage allowed more rennet to be associated with the casein (Creamer et al, 1985). These results indicated that residual rennet concentration in UF Cheddar can be regulated by varying the amount added to the retentate and by altering the pH at drainage.

Table 7.4 Residual rennet concentration in cheese

Particulars	Control	3:1	5:1
Residual rennet concentration RU/1000 kg cheese	11.9 ± 2.7	25.3 ± 2.9	34.1 ± 4.2
pH at whey drainage	6.17	6.02	6.00

A similar result is obtained when the total residual rennet in cheese is expressed as a percentage of that added to the milk or retentate (Table 7.5). These values are not in agreement with those of Green et al (1981a) who reported

a percentage retention of 2.7 ± 0.6 for Cheddars from control milk and UF retentates (up to 4:1 UF). These differences in results could be attributed to differences in the type of assay used. It is also possible that percentage residual rennet retained in UF cheese was influenced by the rate of addition to the retentate. In the present investigation, the rate of rennet addition was much higher than that employed by Green et al (1981a).

Table 7.5 Percentage rennet retention in cheese

Particulars	Control	3:1 UF	5:1 UF
Rennet retention (% of that added)	12.3 ± 2.9	25.8 ± 3.4	36.1 ± 4.8
Ratio of % rennet retention in UF to that in control		2.11	2.95

7.5.5 Proteolysis

Interpretation of the proteolysis was based on visual examination of the gels since facilities for densitometric analysis were not available. It appeared that the rate of loss of α_{s1} casein was the highest in 5:1 and lowest in control Cheddar (Figure 7.7). This was probably because of much higher residual rennet levels (Table 7.4) in the 5:1 Cheddar as compared with the control. In the present investigation the Cheddars from the three treatments had similar pH at different stages of maturation (Figure 7.8) and it is unlikely that this factor influenced the differences in the proteolysis of α_{s1} casein between treatments (Creamer and Richardson, 1974). However, despite the faster breakdown of α_{s1} casein, no significant bitter flavours were observed in any of the UF Cheddars. The reason for this is not known. It is possible that the bitter peptides were quickly broken down to non-bitter peptides by starter enzymes and therefore escaped detection during grading and

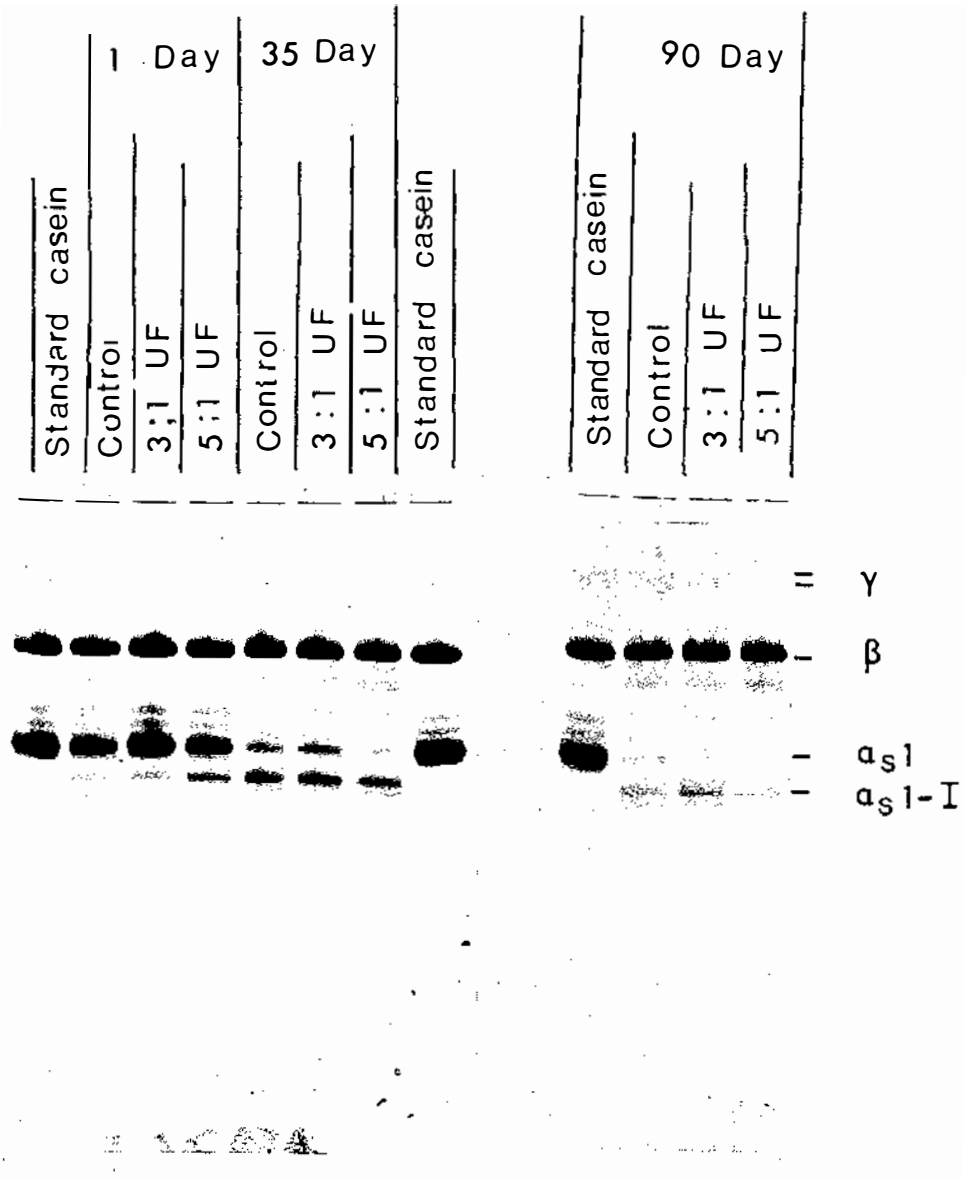


Figure 7.7 Polyacrylamide gel electrophoresis of cheese made from control milk, 3:1 UF and 5:1 UF retentate at different stages of maturation.

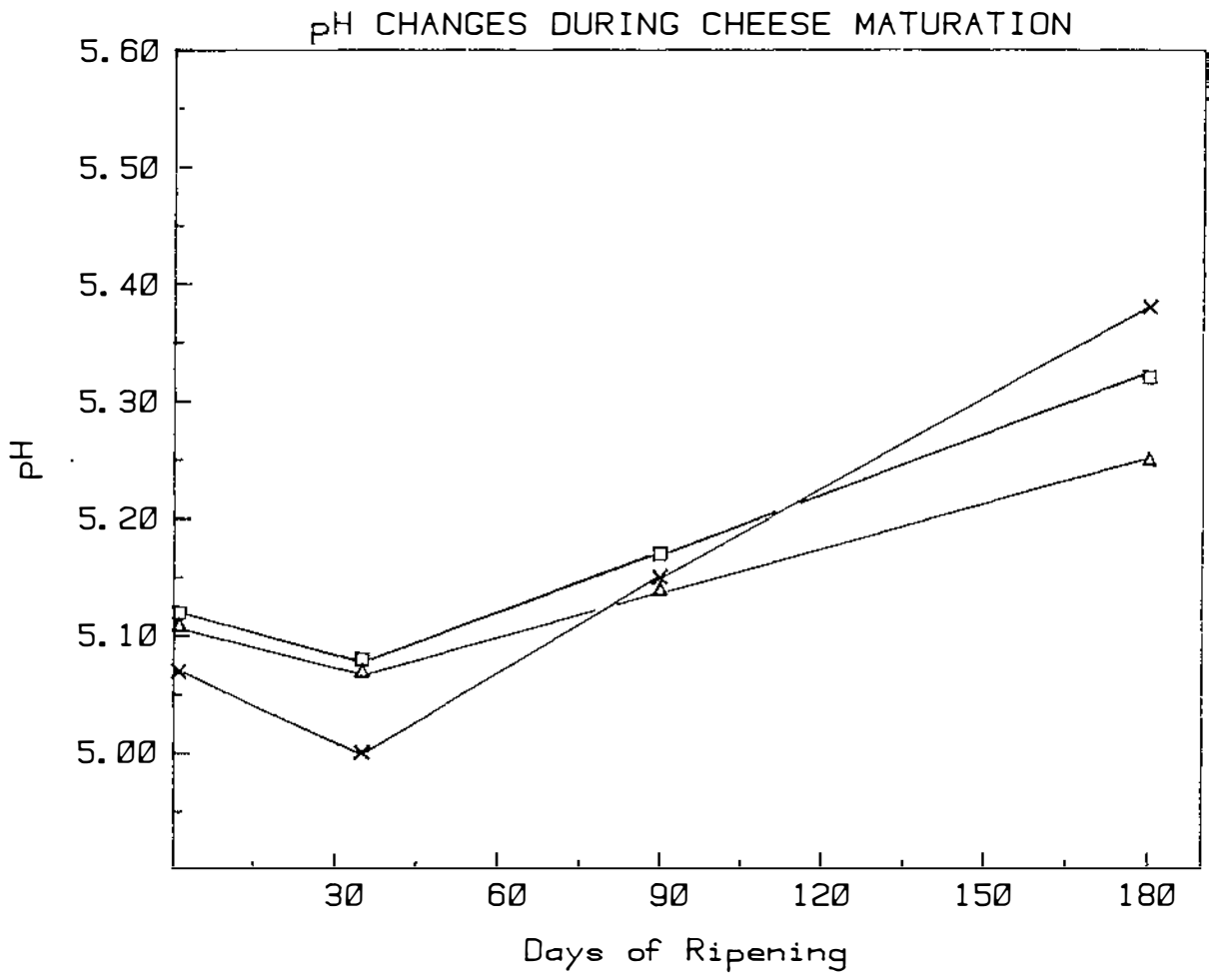


Figure 7.8 Comparison of pH changes during maturation in the control (x——x), 3:1 (△——△) and 5:1 Cheddar (□——□).

sensory evaluation. It is also possible that the presence of whey proteins had the effect of somewhat masking some of the bitter flavours. These results on α_{s1} casein breakdown are in agreement with those of Gripon et al (1975); Kleter (1976); O'Keefe et al, 1976, 1978, and Koning et al (1981) who stated that the coagulant used is the principal agent responsible for formation of large peptides from α_{s1} casein.

The proteolysis of β-casein followed a different trend. Initially there was very little breakdown in cheeses from any of the three treatments. But after 3 months, the proteolysis of β-casein was higher in the 5:1 Cheddar than in the control. As discussed earlier (Chapter 2), if plasmin degrades β-casein in Cheddar cheese as claimed by Creamer (1971, 1974), its activity in UF Cheddar would be expected to be inhibited by β-lactoglobulin (Snoeren et al, 1980). Therefore the higher β-casein breakdown observed in 5:1 UF Cheddar in the present investigation was possibly due to higher levels of residual rennet, even though the enzymes of rennet break down β-casein slowly (Phelan et al, 1973).

It is clear from Figure 7.9 that the concentration of whey proteins increased with CF, i.e. whey protein content in 5:1 Cheddar was higher than that in the control. Results of the present investigation suggest that the whey proteins resisted proteolysis and except for a minor breakdown of α-lactalbumin for all treatments at the 3-month stage, remained largely intact. This result is in agreement with those of other research workers (Jost et al, 1976; O'Keefe et al, 1978; Koning et al, 1981) who reported that undenatured whey proteins resist proteolysis during ripening. There is a suggestion that the non-starter lactic acid bacteria (NSLAB) in cheese may be able to hydrolyse the undenatured whey proteins (El-Soda et al, 1981; Hickey and Broome, 1984). The NSLAB count in cheese was not, however estimated in the present investigation.

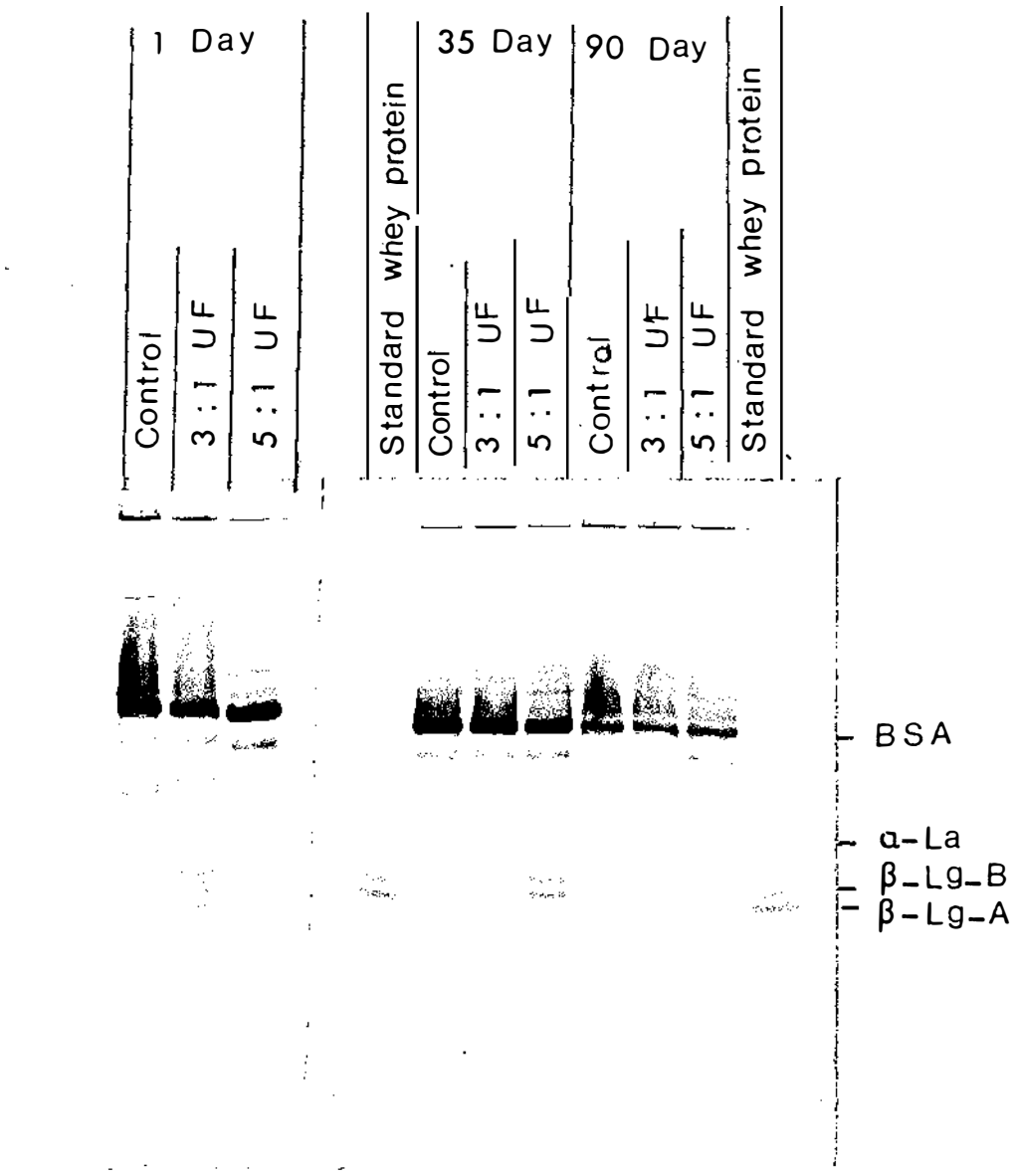


Figure 7.9 Polyacrylamide thick slab gel electrophoresis of cheese showing the proteolysis of whey proteins. The cheeses were made from control milk, 3:1 and 5:1 UF retentates.

The acid-soluble peptide values (Figure 7.10) at 1-day were higher than those reported by Creamer et al (1985) possibly because the cheeses in the present investigation remained longer (about 3 - 4 hours) at ambient temperature (15-25^{o}C). The proportion of acid-soluble peptides increased with the age of the cheese for all treatments although the average values were highest for the control and lowest for the 3:1 UF Cheddar. If the standard deviation of three determinations on the same sample are considered, these differences between treatments were small. These values compared well with the flavour scores for the cheeses but did not appear to be related to the rate of casein breakdown. It is possible that there was a 'dilution' effect because of whey proteins similar to the one described by Koning et al (1981). However, this does not fully explain the lower values of 3:1 as compared with 5:1 Cheddar.

7.5.7 Cheese quality

7.5.7.1 Sensory evaluation: For all the trials, both 3:1 and 5:1 Cheddars were slightly more yellow in colour as compared with the control (Figure 7.5F) The reason for this is uncertain. There were some differences in the grades of cheeses from the three treatments (Table 7.6). After 35 days of maturation, the 5:1 Cheddar had a flavour and texture comparable with that of the control. However, the 3:1 Cheddar had a slightly lower flavour and texture score. It is unlikely that the small differences in FDM between treatments caused the textural differences (Green et al, 1981a; Lelievre and Gilles, 1982).

The differences in the flavour and texture of cheeses between treatments persisted during the maturation period.

These results were largely confirmed by the sensory panel. There were significant differences between treatments in the mean scores for most of the texture attributes and some of the flavour attributes (Table 7.7).

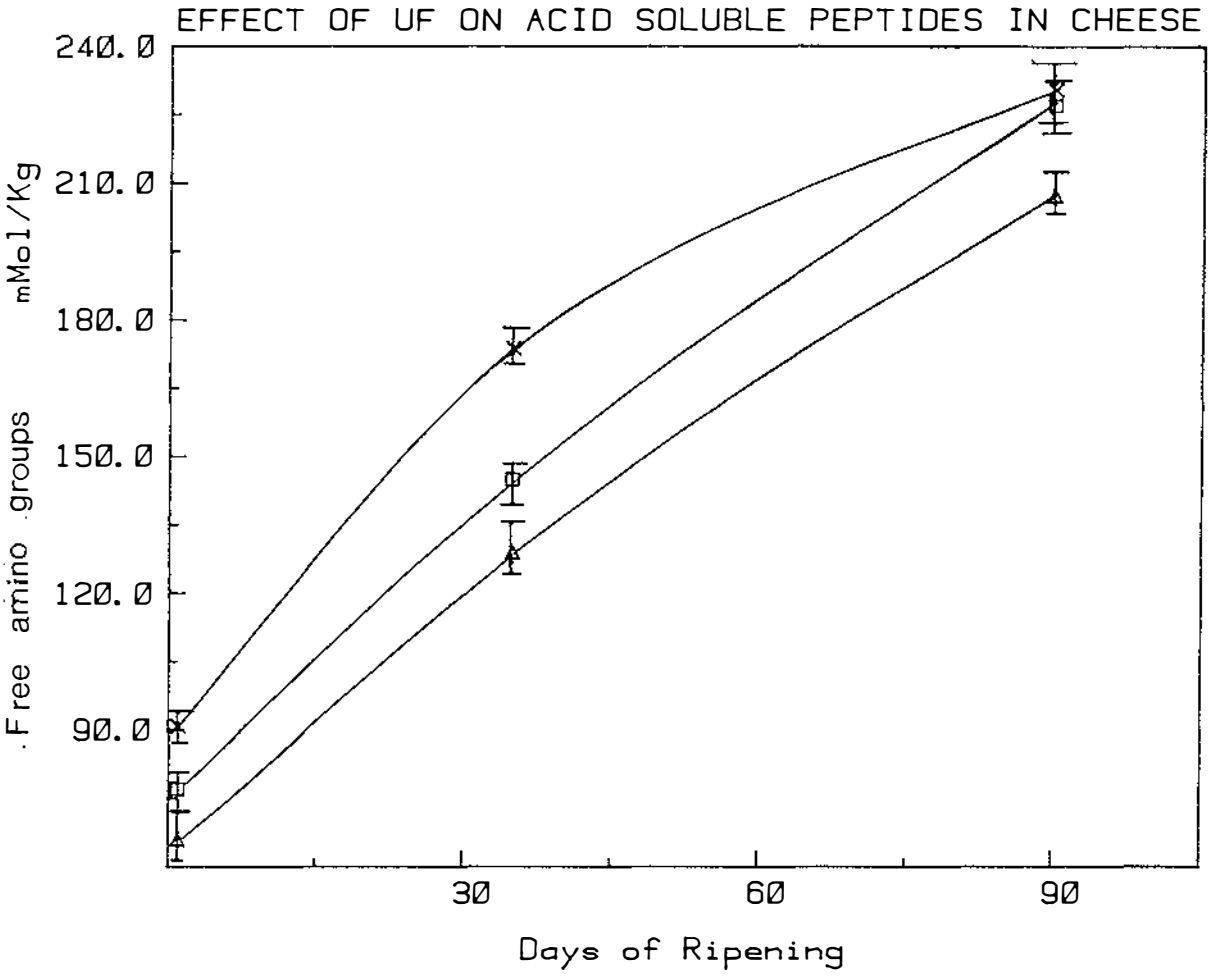


Figure 7.10 Comparison of acid soluble peptides in cheese made from control milk (X —— X), 3:1 UF (Δ —— Δ) and 5:1 UF (□ —— □) retentate at various stages of maturation. The standard deviation of determinations in triplicate is shown by the length of the vertical bars.

Table 7.6 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (6)	Weak (3)	Sl.bitter (6) Sl.sour	Soft (2) Mealy	Normal (6) Sl.sour	Weak (3)
1	3:1	Sl.bland (5)	Loose (2) Sl.rubbery	Sl.sour(5)	Sl.mealy(2) Sl.rubbery	Sl.atypical(5)	Sl.mealy (2) Sl.lumpy
	5:1	Normal (6) Sl.oxidised	Weak (3) Smooth	Sl.sour (6)	Tender (3) Sl.plastic	Sl.oxidised(6)	Tender (3) Sl.plastic
	Control	Normal (6) Sl.sour	Loose (3)	Normal (6) Sl.sour	Floury (3) Mealy	Sl.sour (6)	Sl.mealy (3)
2	3:1	Sl.sour (5)	Firm (2) Crumbly	Sl.bland (5)	Floury (2) Mealy	Sl.bland (5)	Sl.floury (2) Sl.mealy
	5:1	Normal (6) Sl.sour	Firm (2) Sl.crumbly	Sl.sour (6) Sl.oxidised	Tender (3) Plastic	Sl.sour (6)	Tender (3) Sl.plastic
	Control	Normal (7)	Sl.crumbly (3)	Normal (7) Sl.sour	Mealy (3) Smooth	Normal (7) Sl.sour	Smooth (3) Sl.mealy
3	3:1	Sl.sour (6)	Firm (2) Greasy	Sl.sour (6)	Firm (2) Mealy, Curdy	Sl.atypical(6)	Firm (2) Mealy
	5:1	Sl.bitter (6)	Smooth (3)	Sl.sour (6)	Tender (3) Sl.pasty	Normal (6) Sl.sour	Smooth (3) Sl.tender

Note: Figures in brackets refer to grade scores

Table 7.6 Grading of cheese (Continued from previous page)

Trial No	Treat-ment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (5) Sl.sour	Mealy (2) Lumpy	Sl.oxidised(6) Sl.sour	Loose (2) Mealy	Sl.sour (6)	Sl.loose (2) Sl.mealy
4	3:1	Sl.bland (5)	Mealy (2) Lumpy	Sl.sour (5) Sl.bland	Loose (2) Mealy	Sl.sour (6)	Sl.loose (2) Sl.mealy
	5:1	Sl.sour (6)	Smooth (3)	Sl.sour (6) Sl.bland	Mealy (3) Weak	Sl.sour (6) Sl.oxidised	Smooth (2) Sl.tender
	Control	Sl.bitter (6) Sl.oxidized	Lumpy (3) Loose	Sl.sour (6) Sl.astringent	Weak (3) Sl.crumbly	Sl.sour (6) Sl.unclean	Weak (2) Tender
5	3:1	Sl.oxidised(6)	Mealy (2) Rubbery	Sl.fruity (5) Sl.scorched	Loose (3) Rubbery	Sl.oxidised(5) Sl.fruity	Rubbery (2)
	5:1	Sl.oxidised(6) Sl.bland	Sl.tender (3) Mealy	Sl.atypical(6) Sl.astringent	Weak (3) Smooth	Sl.oxidized(6)	Tender (3)
	Control	Sl.sour (5) Sl.oxidized	Sl.tender (3) Sl.mealy	Sl.sour (6) Sl.bitter	Sl.tender (3) Sl.lumpy	Normal (6) Sl.sour	Sl.weak (2) Sl.lumpy
6	3:1	Sl.bland (5)	Sl.mealy (2) Sl.rubbery	Sl.atypical(6)	Mealy (2) Firm	Sl.atypical(5)	Sl.firm (2) Sl.mealy
	5:1	Sl.oxidized(6) Sl.bland	Sl.tender (3) Sl.mealy	Sl.bitter (6) Sl.sour	Sl.tender (3) Smooth	Normal (6) Sl.bitter	Sl.smooth (3) Sl.tender

Note: Figures in brackets refer to grade scores

Table 7.6 Grading of cheese (Continued from previous page)

Trial No.	Treat-ment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Sl.oxidized(5)	Sl.weak (3) Sl.mealy	Sl.sour (6) Sl.bland	Sl.weak (3) Sl.lumpy	Sl.sour (6) Normal	Sl.weak (3) Sl.lumpy
7	3:1	Sl.oxidized(4) Sl.sour	Sl.mealy (2) Sl.rubbery	Sl.bitter (6) Sl.bland	Sl.dry (3) Sl.mealy	Sl.bland (5)	Firm (2) Curdy
	5:1	Sl.oxidized(5) Sl.sour	Sl.pasty (3)	Sl.bitter (6) Sl.sour	Sl.plastic (3) Sl.smooth	Sl.bitter (5) Sl.bland	Sl.tender (3) Sl.smooth
	Control	Normal (6) Sl.sour	Sl.tender (3)	Sl.sour (6) Sl.bitter	Sl.weak (2) Sl.lumpy	Normal (5) Sl.sour	Sl.tender (2)
8	3:1	Sl.bland (5)	Sl.firm (2)	Sl.atypical(5)	Sl.firm (2)	Atypical (4)	Sl.firm (2)
	5:1	Normal (6) Sl.sour	Sl.tender (3) Sl.smooth	Sl.sour (6) Normal	Sl.smooth (3)	Sl.sour (5)	Sl.smooth (3)
	Control	Normal (6) Sl.oxidized	Sl.weak (3)	Sl.sour (5) Sl.bitter	Sl.tender (2) Sl.lumpy	Sl.sour (6)	Sl.tender (2)
9	3:1	Sl.sour (5)	Sl.firm (3)	Sl.atypical(5)	Sl.firm (2) Sl.curdy	Sl.atypical(4)	Sl.firm (2) Sl.curdy
	5:1	Normal (6) Sl.sour	Sl.tender (3)	Sl.sour (6) Sl.oxidised	Sl.tender (3)	Sl.sour (6)	Sl.smooth (3)

Note: Figures in brackets refer to grade scores

Table 7.7 Sensory panel scores

Summary of all treatment means showing significant treatment effects. Samples not significantly different at the 5% level are joined by lines.

A. Mean Texture Scores[+]

Attribute	Treatment and sample means			F ratios
Firmness	5:1 UF	Control	3:1 UF	
	4.2	4.4	5.0	5.05 ns
Rubberiness	Control	5:1 UF	3:1 UF	
	2.0	2.0	3.3	11.74 **
Crumbliness	5:1 UF	Control	3:1 UF	
	3.2	4.2	4.2	5.73 *
Smoothness	3:1 UF	Control	5:1 UF	
	2.9	3.4	4.3	9.97 *
Stickiness	3:1 UF	Control	5:1 UF	
	2.2	3.1	3.8	5.19 *
Mealiness	5:1 UF	Control	3:1 UF	
	2.8	3.7	4.9	15.29 **
Grittiness	5:1 UF	Control	3:1 UF	
	0.2	0.6	0.8	3.22 ns

ns not significant

* significant at 5% level of significance

** significant at 1 % level of significance

*** significant at 0.1% level of significance

[+] scores are means of 4 replicates averaged over 3 and 6 month analysis.

Table 7.7 Sensory panel
B. Mean Flavour Scores[+]

Attribute	Treatment and sample means			F ratio
Acid/sour	3:1 UF	Control	5:1 UF	
	3.9	4.7	4.7	6.58 *
Fruitiness	3:1 UF	5:1 UF	Control	
	2.2	2.9	2.9	3.00 ns
Sulphide	3:1 UF	5:1 UF	Control	
	0.7	0.9	1.1	1.51 ns
Sharpness	3:1 UF	Control	5:1 UF	
	1.0	1.6	1.7	10.98 **
Bitterness	3:1 UF	Control	5:1 UF	
	0.3	0.5	0.6	1.95 ns

ns not significant
* significant at 5% level of significance
** significant at 1 % level of significance
*** significant at 0.1 % level of significance
[+] scores are means of 4 replicates averaged over 3 and 6 month analysis.

A summary of the effect of all variables and interactions is shown in Appendix III C. It is clear that for most of the attributes, 3:1 Cheddar had an inferior score to that of the control and the 5:1 Cheddar. The reason for these differences is uncertain. One possibility is that differences in the residual rennet concentration (Green et al, 1981a; Koning et al, 1981) and level of whey proteins (Koning et al, 1981) influenced these quality attributes. This is consistent with the results of Green (1985) who suggested that intermediate levels of concentration (3:1) yield UF Cheddar of inferior quality. Increased smoothness in 5:1 Cheddar was possibly due to the whey proteins as observed by Boer and Nooy (1980 a, b) for Gouda cheese.

For all treatments, scores for rubberiness, crumbliness and mealiness decreased and those for smoothness and stickiness increased with the age of the cheese. This was expected since proteolysis during maturation influences these textural attributes.

7.6 Conclusion

The results of the present investigation confirm that modification in the method of manufacture is necessary for cheesemaking from 5:1 UF retentate. An alteration in the level of starter addition helps in overcoming some of the problems related to higher pH (Green et al, 1981a) and calcium levels in the UF Cheddar (Sutherland and Jameson, 1981). However, use of conventional starter for UF retentate at levels based on milk quantity prior to UF has the disadvantage of diluting the retentate. This may influence the retention of water soluble components like the whey proteins and therefore the yield (see Chapter 9). For this reason, it is advisable to prepare the starter in the retentate (Mistry and Kosikowski, 1986b).

The present study suggests that the addition of rennet to UF retentate on the basis of milk quantity prior to UF results in UF Cheddar with higher residual rennet concentration as compared with the control. Further research is needed to determine the optimum range of residual rennet concentration in UF Cheddar. It is possible that this range may need to be higher in UF Cheddar as compared with conventional Cheddar to counteract the 'dilution' effect of the whey proteins (Koning et al, 1981). Therefore, substantial savings in rennet for Cheddar cheesemaking from 5:1 UF retentate that might have been anticipated, may not be forthcoming.

CHAPTER 8

EFFECT OF VARIATION IN RENNET ADDITION TO 5:1 RETENTATE ON THE CHARACTERISTICS OF UF CHEDDAR CHEESE

8.1 Introduction

In the previous investigation (Chapter 7), it was shown that the addition of rennet to 5:1 retentate at the normal rennet:casein ratio results in UF Cheddar with a residual rennet concentration that is much higher than that in normal Cheddar. It is generally known that the residual rennet in conventional Cheddar plays a major role in proteolysis (Ledford et al, 1966; Creamer and Richardson, 1974; O'Keefe et al, 1976, 1978) and in establishing cheese quality (Koning et al, 1981). However, information on the optimum level of residual rennet concentration in 5:1 UF Cheddar is lacking. In the present investigation, therefore, an attempt was made to study the effect of residual rennet on the quality of 5:1 UF Cheddar.

8.2 Experimental plan

For all experiments, rennet addition was expressed as rennet:casein ratio (R). This ratio in the control was considered as 1.0 and R values for other treatments were expressed as a fraction of this value.

Four levels of rennet addition to the retentate were chosen corresponding to R values of 0.2, 0.4, 0.6 and 1.0. In other words, 8 ml rennet added to 50 kg control milk was considered as 1.0 R. For the retentate, values of 0.2, 0.4, 0.6 and 1.0 corresponded to the addition of 1.6, 3.2, 4.8 and 8 ml of rennet to 10 kg lots of 5:1 retentate respectively. The choice of 0.2 R was based on literature reports suggesting that rennet additions to UF retentates

may be decreased in proportion to CF. Some of the other levels of rennet addition (0.4 and 0.6 R) were expected to provide UF Cheddars with residual rennet concentration in the vicinity of that in normal Cheddar. This expectation was based on the results of preliminary trials and those of a previous investigation (Chapter 7).

However, cheeses from all four levels of rennet addition and a control could not be made simultaneously due to limitation of number of cheese vats (only three were available) and manpower to make the cheeses. The investigation was therefore done in two series. In the first series, cheeses for the control, 0.2 R and 1.0 R treatments were made. In the second series, cheeses were made for the control, 0.4 R and 0.6 R treatments.

8.3 Experimental

Three trials were done for each of two series during the 1985-86 season.

8.3.1 Milk supply: As described in Chapter 4. About 350 kg milk was needed for each trial.

8.3.2 Ultrafiltration: As detailed in Chapter 4, except that:
(i) 250 - 300 kg milk was subjected to 5:1 UF.
(ii) From the resultant retentate, two lots of 10 kg each were taken for cheesemaking.

8.3.3 Cheesemaking: As detailed in Chapter 7 for the control and 5:1 UF retentate except that:
(i) The 0.2 R, 0.4 R and 0.6 R vats were cut at about 1.2 - 2.2 times RCT. The RCT for the 0.2 R, 0.4 R and 0.6 R retentates was found to be 30 - 35, 15 - 18 and 12 - 15 minutes respectively. The 0.2 R, 0.4 R and 0.6 R retentates were cut at 45 - 50, 25 - 30 and 18 - 24 minutes after rennet addition respectively.

(ii) The cooking of 0.2 R curd was postponed by 30 - 40 minutes because in the initial stages the curd appeared to be slippery and fragile.

8.4 Analytical methods

8.4.1 Chemical analysis of milks, retentates and wheys: The milks, retentates and wheys were analysed for total solids, fat, TN, NCN, NPN, and calcium by the methods described previously (Chapter 4 and Chapter 7).

8.4.2 Chemical analysis of cheeses: The cheeses were analysed for moisture, fat, TN, salt, calcium and pH. The methods for these analyses have been described previously (Chapter 4).

8.4.3 Residual rennet determination: Residual rennet concentration in cheeses was determined by the method outlined in Chapter 7.

8.4.4 Cheese grading: This was done as described in Chapter 4.

8.4.5 Cheese taste panel: The method outlined in Chapter 7 was used for cheeses from some of the treatments (control, 0.4 R and 0.6 R) at three and six months of age.

8.4.6 Polyacrylamide gel electrophoresis: The method described earlier (Chapter 4) was used to assess proteolysis in cheese.

8.5 Results and discussion

For convenience, average results are presented. These are discussed in seven parts:

8.5.1 Milk and retentate composition

8.5.2 Cheese manufacture

8.5.3 Cheese composition
8.5.4 Mass balance
8.5.5 Residual rennet concentration
8.5.6 Cheese proteolysis
8.5.7 Cheese quality

8.5.1 Milk and retentate compositions

The compositions of the milk and 5:1 retentate were similar to those obtained in a previous investigation (Chapter 7).

8.5.2 Cheese manufacture

No major problems were encountered in cheesemaking from the retentates with various levels of rennet addition. Subjective assessment of the curds before cutting suggested that firmness increased with higher levels of rennet addition. At the lowest level of rennet addition (0.2 R), the curd was soft and fragile possibly because of lower casein aggregation and a coarser casein network (Green et al, 1981b). The fragile nature of the curd necessitated delayed cooking of the curd as discussed previously (Chapter 7).

During cheesemaking, the pH of wheys, in all UF treatments at different stages of cheesemaking, were identical and only slightly different from the control. As discussed previously (Chapter 7) the total buffering and the total kg starter added was similar for all treatments. Therefore, it is possible that the small differences in the pH between the control and UF treatments were due to differences in the stimulation of growth and acid production in the retentates (Hickey et al, 1983a, Mistry and Kosikowski, 1985a, b). However, results of a previous investigation (Chapter 4) had suggested that such stimulation may be minimal in the present study for two reasons. Firstly, stimulation in growth could be strain dependent. Secondly, in the absence of diafiltration, such stimulation may be reduced possibly because the process of diafiltration may either remove inhibitory substances from, or release growth

stimulating factors into the milk.

8.5.3 Cheese composition

The composition of UF cheeses from various levels of rennet addition were similar (Table 8.1). However, as compared with the control, UF Cheddar from different treatments had slightly lower FDM suggesting that there may be slightly higher fat losses in the UF wheys. The slightly higher 1-day pH in UF Cheddars as compared with the control was possibly due to differences in buffering capacity (Mistry and Kosikowski, 1985b) and these possibly influenced the calcium values (Creamer et al, 1985).

Table 8.1 Cheese composition

Treatment	Control	0.2 R	0.4 R	0.6 R	1.0 R
FDM %	53.2 ± 1.1	52.4 ± 1.0	52.4 ± 1.0	52.4 ± 1.0	53.1 ± 0.6
MNFS %	53.8 ± 0.9	53.7 ± 0.7	53.9 ± 1.3	54.0 ± 1.3	54.1 ± 0.4
S/M %	5.00 ± 0.12	5.01 ± 0.23	5.08 ± 0.04	4.91 ± 0.04	5.10 ± 0.16
pH 1-day	5.07 ± 0.02	5.15 ± 0.00	5.13 ± 0.01	5.09 ± 0.01	5.12 ± 0.00
TN %	4.04 ± 0.10	4.08 ± 0.07	4.14 ± 0.12	4.13 ± 0.14	4.09 ± 0.06
Ca mM/kg	181.0 ± 1.9	205.0 ± 1.0	208.0 ± 0.5	209.0 ± 3.9	203.0 ± 2.0
Ca/SNFNS	2.48 ± 0.08	2.84 ± 0.06	2.77 ± 0.09	2.79 ± 0.09	2.84 ± 0.02

8.5.4 Mass balance

There were no significant differences in the recovery of various milk constituents in the cheese from different levels of rennet addition (Table 8.2). However, the recovery of fat in all UF Cheddars was slightly lower and TN recovery slightly higher than that in the control. This is consistent with the results of Green (1985). As expected, CN and WPN recovery were similar for all UF treatments.

Table 8.2 Mass balance

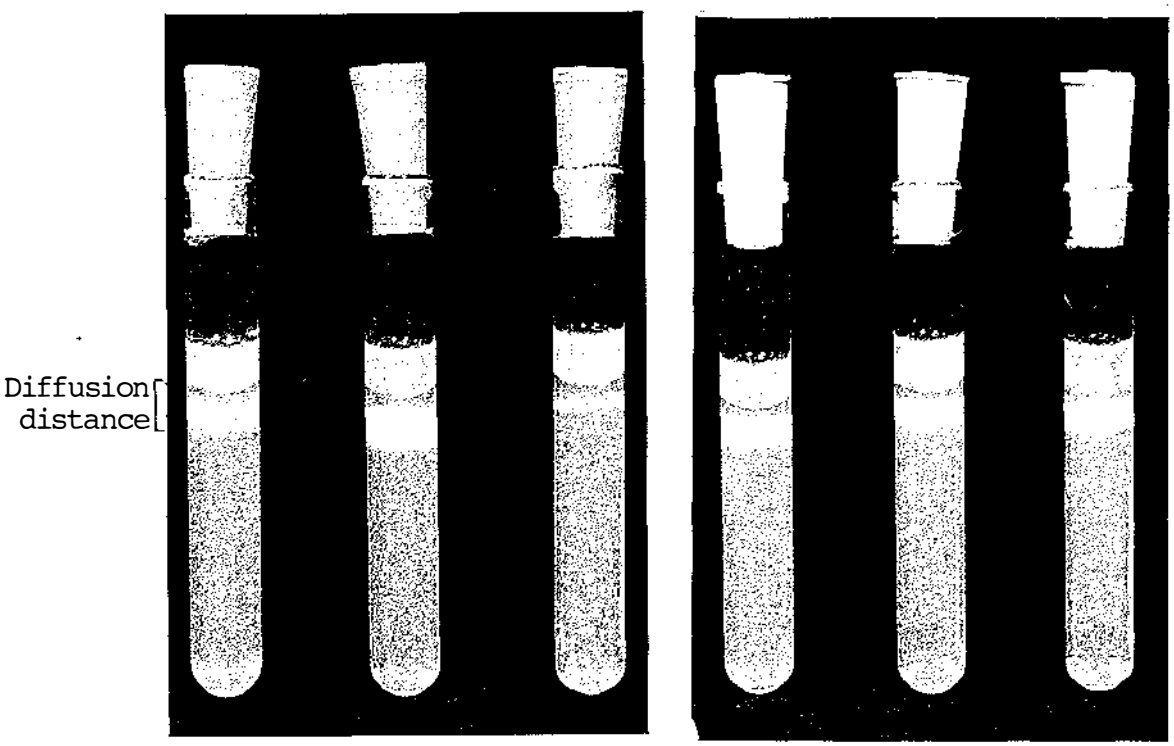
Percentage recovery in cheese

Treatment	Control	0.2 R	0.4 R	0.6 R	1.0 R
Fat	89.5 ± 1.0	86.0 ± 1.2	86.5 ± 0.5	87.2 ± 1.2	87.2 ± 1.0
CN	96.8 ± 0.4	97.0 ± 0.2	97.0 ± 0.1	97.0 ± 0.0	97.0 ± 0.1
WPN	5.4 ± 0.6	34.4 ± 0.3	36.6 ± 1.2	37.0 ± 1.7	34.0 ± 2.5

8.5.5 Residual rennet concentration in cheese

There were large differences in the residual rennet concentration in the cheese (Table 8.3 and Figure 8.1A and 8.1B). Since the pH values at whey drainage for all UF treatments were similar, it followed that differences in residual rennet concentration were primarily due to levels of rennet addition. These results indicated that if rennet additions to 5:1 retentates are decreased in proportion to CF, the resultant UF Cheddar has only one third of the residual rennet as compared with normal Cheddar.

A different picture emerges when the total residual rennet in cheese is expressed as a percentage of that added to the milk or retentate (Table 8.3). There was a proportionate increase in percentage retention of rennet in



(A) (B)

Figure 8.1A and 8.1B Diffusion tubes filled with k-casein agarose gel showing the diffusion of rennet from (A) control, 5:1 UF (1.0 R)* and 5:1 UF (0.2 R)* (series 1) and (B) control, 5:1 UF (0.4 R)* and 5:1 UF (0.6 R)* (series 2) cheese extracts. 100 µl of citrate buffer extracts of cheese samples were applied. The diffusion distance from the extract-gel interface to the bottom of the 'cloud' was measured. [Note that a part of the precipitated k-casein 'cloud' near the extract-gel interface has solubilized possibly due to further proteolysis of para-k-casein]. The diffusion distance was then used to estimate the residual rennet concentration in the cheese samples from the standard curve (Figure 7.3, Chapter 7).

Note: *see Experimental Plan.

UF cheese with increasing level of rennet additions to the retentate. The reason for this trend is uncertain. However, these results show that the addition of rennet to 5:1 retentate at the 0.6 R level yields UF cheese with residual rennet concentration similar to that in normal Cheddar. In other words, in 5:1 UF cheesemaking, if the range of rennet addition is similar to that employed in the present investigation, between 18 and 37% of the rennet added may be retained in the cheese. These results suggest that it is possible to obtain UF Cheddar with required residual rennet concentration by varying the level of addition to the retentate. It must be emphasized that the degree of concentration plays a major role in these retention values (Chapter 7) and that the values reported in the present investigation apply to 5:1 UF retentate with starter added on the basis of milk quantity prior to UF. Higher retentions may be possible with higher degrees of concentration.

Table 8.3 Residual rennet in cheese

Treatment	Control	0.2 R	0.4 R	0.6 R	1.0 R
Residual rennet concentration RU/1000 kg cheese	11.9 ± 0.6	3.4 ± 0.2	8.7 ± 0.2	14.3 ± 0.5	34.7 ± 3.4
pH at whey drainage	6.21	5.98	5.96	5.99	6.00
Rennet retention in cheese (% of that added)	12.1 ± 0.8	18.2 ± 1.1	23.1 ± 0.4	25.1 ± 0.7	37.2 ± 3.5

8.5.6 Proteolysis: Interpretation of the proteolysis was based on the visual examination of the gels since facilities for densitometric analysis were not available. Since the samples were run on different gels and small differences in

the time the gels were run for and sample loading may have occurred, the gels are not completely comparable. Photographs of all the gels are shown in Appendix IV A and IVB. For this discussion, gels from 35 day old samples for various treatments are shown for comparison purposes (Figure 8.2). It appeared that the rate of breakdown of α_{s1}-casein in the control was similar to that in 1.0 R Cheddar (Figure 8.2). This rate was the lowest in 0.2 R and highest in 1.0 R Cheddars. This was expected since α_{s1} breakdown has been shown to be largely dependent on residual rennet concentration in normal Cheddar (Creamer and Richardson, 1974; Gripon et al, 1975; Kleter, 1976; O'Keefe et al, 1976, 1978; Koning et al, 1981). In the present investigation, factors such as cheese composition (Table 8.1) and pH during maturation were similar for the various treatments and therefore unlikely to have a major influence on α_{s1} proteolysis. The 0.6 R Cheddar had slightly higher residual rennet concentration than that in the control and yet the rate of breakdown of α_{s1} casein did not appear to be faster. The reason for this is not certain. One possibility is that the presence of whey proteins in UF Cheddar made the α_{s1} casein less accessible to rennet enzymes.

In contrast, the rate of β-casein breakdown in various treatments did not appear to be grossly different. However, as compared with the control, β-casein proteolysis in 5:1 UF (0.2 R) Cheddar was slightly lower and that in 5:1 UF (1.0 R) Cheddar was slightly higher than the control. As discussed earlier (Chapter 7), it is possible that these differences in β-casein proteolysis were largely due to residual rennet concentration even though rennet enzymes degrade β-casein slowly (Phelan et al, 1973). Moreover, if β-casein proteolysis is primarily due to plasmin as claimed by Creamer (1971, 1974), it should have been identical in all UF treatments unless its activity was inhibited by β-lactoglobulin (Snoeren et al, 1980).

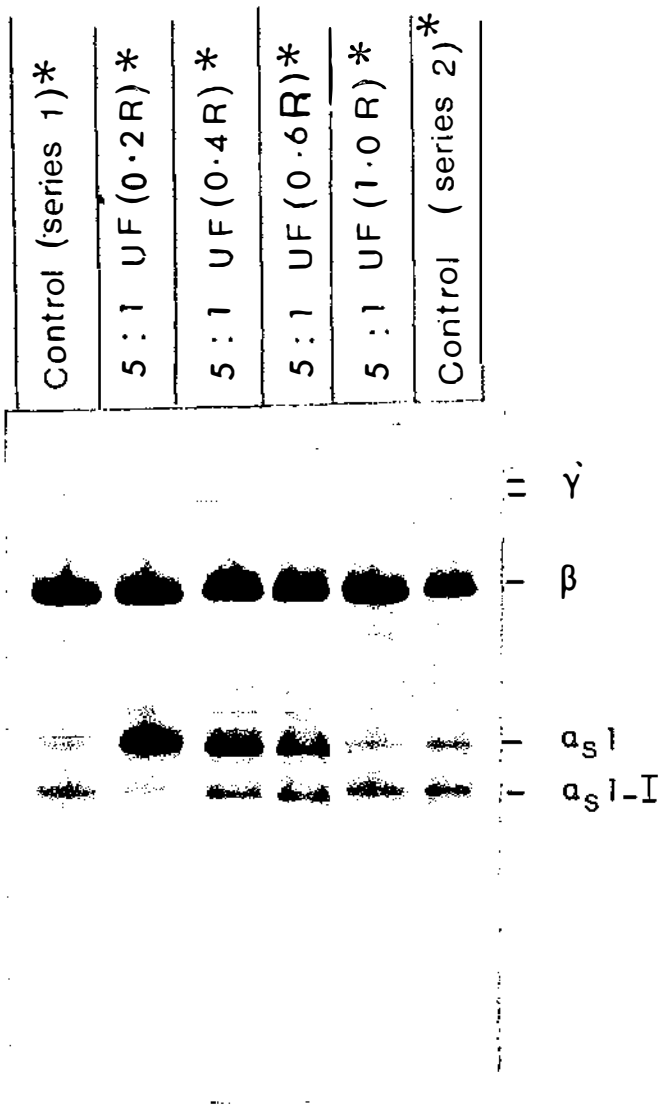


Figure 8.2 Polyacrylamide gel electrophoresis of cheese made from control milk and 5:1 UF retentate with 0.2 R*, 0.4 R*, 0.6 R* and 1.0 R* levels of rennet addition. The age of the cheese is 35 days.

Notes:

1. This photograph has been obtained after combining photographs of gel electrophoresis for samples from series 1* and series 2*. This involved alteration in the magnification of one of the photographs so as to match α_{s1} and β casein bands. Consequently the thickness of some of the bands has been altered. For the original photographs of gels in series 1* and series 2*, see Appendix IVA and IVB respectively.

2. *see Experimental Plan.

8.5.7 Cheese quality

8.5.7.1 Grading

There were some differences in the quality of Cheddars obtained from various treatments (Table 8.4, A and B). The firmer body and atypical flavour of 0.2 R Cheddar was probably due to lack of α_{s1} casein breakdown. The quality of UF Cheddars became progressively closer to that of the control with increasing residual rennet concentration. The 1.0 R Cheddar had a quality comparable to that of the control. In addition, it also had smoother consistency which could be related to the higher whey protein content as observed by Boer and Nooy (1980a, b) in Gouda cheese. This smoothness was least apparent in 0.2 R Cheddar despite the presence of a similar proportion of whey proteins. A possible explanation is that lower α_{s1} casein breakdown in 0.2 R Cheddar made the effect of smoothness less pronounced. The 'bland' flavour observed in some UF Cheddars with lower rennet additions was to some extent possibly a 'dilution' effect due to the whey proteins as suggested by Koning et al (1981). The higher rate of breakdown in 1.0 R Cheddar probably counteracted this 'dilution' effect to give a flavour comparable to that of the control. The results of the present investigation suggest that for UF Cheddar to have a quality comparable to that of normal Cheddar, the residual rennet concentration may need to be much higher than that in conventional Cheddar.

8.5.7.2 Sensory panel

There were some differences in the flavour and the texture attributes of Cheddar cheese obtained from the control, 0.4 R and 0.6 R treatments (Table 8.5). A summary of the effect of all variables and interactions is shown in Appendix IV C. It is clear that 0.6 R Cheddar was relatively closer in texture and flavour to the control. Since the chemical composition of the cheeses from the three treatments was similar, it appears that some of these differences in texture and flavour could be attributed to differences in residual rennet concentration (Green et al,

Table 8.4A (Series 1) Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (6)	Sl.mealy (3)	Sl.sour (6)	Weak (3) Sl.mealy	Sl.fruity (5) Sl.sour	Weak (3) Sl.mealy
1	5:1 UF 1.0 R	Normal (6) Sl.bitter	Sl.tender (3) Smooth	Sl.sour (6) Sl.bitter	Tender (3) Smooth	Sl.oxidized(6) Sl.sour	Tender (3) Smooth
	5:1 UF 0.2 R	Sl.bland (6)	Firm (2) Mealy	Atypical (5)	Firm (2) Crumbly	Atypical (5)	Firm (2) Crumbly
	Control	Normal (6) Sl.sour	Sl.lumpy (2) Sl.mealy	Sl.sour (6) Normal	Sl.tender (3)	Sl.sour (6) Normal	Sl.mealy (3)
2	5:1 UF 1.0 R	Normal (5) Sl.bitter	Sl.mealy (3)	Sl.sour (6) Sl.bitter	Sl.pasty (3) Smooth	Sl.oxidized(6) Normal	Tender (3) Sl.plastic
	5:1 UF 0.2 R	Sl.oxidized(5) Sl.bland	Firm (2) Rubbery	Sl.bland (5) Atypical	Sl.firm (2) Mealy	Atypical (5)	Firm (2) Crumbly
	Control	Normal (6) Sl.sour	Sl.mealy (3)	Sl.sour (6) Normal	Sl.lumpy (3) Sl.loose	Sl.unclean (6) Sl.sour	Sl.mealy (3)
3	5:1 UF 1.0 R	Normal (6) Sl.sharp	Tender (3) Smooth	Sl.sharp (6) Sl.sour	Tender (3) Smooth	Normal (6) Sl.bland	Sl.mealy (3) Smooth
	5:1 UF 0.2 R	Sl.bland (5)	Very firm (2) Rubbery	Sl.bland (5) Sl.sour	Firm (2) Sl.mealy	Atypical (5)	Sl.crumbly (2) Very firm

Note: Figures in brackets refer to grade scores

Table 8.4B (Series 2) Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (6) Sl.sour	Sl.mealy (3) Sl.pasty	Sl.sour (6) Normal	Sl.mealy (3) Smooth	Sl.fruity (6) Sl.sour	Sl.mealy (3)
1	5:1 UF 0.4 R	Atypical (5)	Sl.mealy (2) Sl.firm	Atypical (5) Sl.sour	Sl.mealy (2) Sl.lumpy	Atypical (5) Bland	Sl.firm (2) Sl.curdy
	5:1 UF 0.6 R	Normal (5) Sl.sour	Sl.mealy (3) Sl.pasty	Sl.bland (6) Sl.bitter	Sl.mealy (3) Sl.pasty	Sl.bland (5) Sl.sour	Sl.mealy (3) Sl.firm
	Control	Normal (6) Sl.sour	Sl.tender (3) Sl.mealy	Sl.sour (6) Normal	Sl.mealy (3) Smooth	Sl.sour (6) Sl.fruity	Sl.tender (3)
2	5:1 UF 0.4 R	Atypical (5)	Sl.mealy (3) Sl.firm	Atypical (5)	Sl.curdy (2) Sl.lumpy	Bland (5)	Sl.curdy (2) Sl.firm
	5:1 UF 0.6 R	Normal (6) Sl.bland	Sl.mealy (3) Sl.firm	Normal (6) Sl.bitter	Sl.mealy (2) Sl.pasty	Sl.bland (6) Sl.sour	Sl.firm (2) Sl.smooth
	Control	Normal (6) Sl.bland	Sl.weak (3) Sl.mealy	Normal (6) Sl.sour	Sl.tender (3) Smooth	Sl.sour (6) Normal	Sl.mealy (3)
3	5:1 UF 0.4 R	Atypical (6) Sl.bland	Sl.firm (3) Sl.rubbery	Atypical (6) Sl.sour	Sl.pasty (2) Sl.curdy	Atypical (5) Bland	Sl.firm (2) Sl.curdy
	5:1 UF 0.6 R	Sl.sour (6) Normal	Sl.tender (3) Sl.mealy	Sl.bland (6) Normal	Smooth (2) Sl.tender	Sl.bland (6) Normal	Sl.tender (3) Smooth

Note: Figures in brackets refer to grade scores

Table 8.5 Sensory panel Scores

A. Mean texture scores[+]

Summary of all treatment means showing significant treatment effects. Samples not significantly different at the 5% level are joined by lines.

Attribute	Treatment and sample means			F ratios
Firmness	Control	0.6 Rennet	0.4 Rennet	
	4.6	5.3	5.8	35.75 **
Rubberiness	Control	0.6 Rennet	0.4 Rennet	
	1.7	2.9	3.2	83.86 ***
Crumbliness	0.6 Rennet	0.4 Rennet	Control	
	2.4	2.7	3.3	1.77 ns
Smoothness	0.4 Rennet	Control	0.6 Rennet	
	3.5	4.2	4.4	2.46 ns
Stickiness	0.4 Rennet	0.6 Rennet	Control	
	2.9	3.4	4.0	4.79 *
Mealiness	Control	0.6 Rennet	0.4 Rennet	
	2.9	3.0	3.2	0.15 ns
Grittiness	Control	0.4 Rennet	0.6 Rennet	
	0.0	0.0	0.1	0.92 ns

ns not significant
* significant at 5% level of significance
** significant at 1% level of significance
*** significant at 0.1% level of significance
0.6 Rennet and 0.4 Rennet are the same as 0.6 R and 0.4 R referred to in the text.

Table 8.5 Sensory panel scores

B. Mean flavour scores[+]

Attribute	Treatment and sample means			F ratios
Acid/sour	0.4 Rennet	0.6 Rennet	Control	
	3.3	3.6	4.6	7.35 **
Fruity	0.6 Rennet	0.4 Rennet	Control	
	1.2	1.5	2.8	7.21 **
Sulphide	0.4 Rennet	0.6 Rennet	Control	
	0.2	0.5	0.7	2.37 ns
Sharpness	0.6 Rennet	0.4 Rennet	Control	
	0.6	0.7	1.6	5.89 **
Bitterness	0.6 Rennet	0.4 Rennet	Control	
	0.2	0.2	0.7	2.97 ns

ns not significant

* significant at 5% level

** significant at 1% level

*** significant at 0.1% level

0.6 Rennet and 0.4 Rennet are the same as 0.6 R and 0.4 R referred to in the text.

[+] scores are means of 3 replicates averaged over 3 and 6 months.

1981a). These results are consistent with those of Koning et al (1981) who reported lack of flavour development with lower rennet additions to UF retentates. The results of the taste panel confirmed, to a large extent, the findings from the grading data.

8.6 Conclusion

The results of the present study suggest that residual rennet concentration in UF cheese depends largely on the rate of addition to the retentate and pH at whey drainage. It has been suggested that the residual rennet concentration plays a major role in the proteolysis and quality of UF Cheddar (Koning et al, 1981). Further research is needed to determine the optimum residual rennet concentration in UF Cheddar. It is possible that this optimum value for UF Cheddar will be slightly higher than that for normal Cheddar because of the 'dilution' effect of the whey proteins (Koning et al, 1981). Results also suggest that it may be possible to obtain UF Cheddar with target residual rennet concentration by manipulating the rate of rennet addition to the retentate and also draining the whey at a predetermined pH (Creamer et al, 1985).

CHAPTER 9

YIELD OF UF CHEDDAR CHEESE

9.1 Introduction

The yield of cheese is important since it influences the economics of the cheesemaking process. A number of methods are used to calculate and express cheese yield based on various formulae and assumptions. For the purpose of this discussion, three methods need to be mentioned:

(i) Weight of cheese made from a given quantity of milk, usually kg cheese per 100 kg milk (Lelievre et al, 1983). This method provides useful information for accountants and for purposes of equipment design.

(ii) Weight of cheese from a given quantity of fat in the milk, kg cheese per kg fat. This method is useful when the cheese factory pays for milk on the basis of fat content of the milk.

(iii) Production efficiency. This method involves loss monitoring techniques (Parkin, 1982). It provides a good picture of the losses in the whey and therefore the cheesemaking process.

Each of these methods has its own merits. However, data on the losses in the whey together with an indication of MNFS and FDM value of the cheese possibly provides the best information on evaluation of the yield of cheese.

In commercial manufacture, the losses (and therefore yield) vary from one plant to another depending on the design of the cheesemaking equipment (Phelan, 1981; Barbano and Sherbon, 1984). Literature reports on yield of UF Cheddar are few. One report from Australia suggests that yield of UF Cheddar may be 8 - 10% higher than conventional Cheddar (Jameson, 1984), but the basis of yield calculation

has not been given.

In this laboratory, calculations using the principle of mass balance predict the yield advantage in Cheddar cheese-making from 5:1 UF retentate to be about 6%. The present chapter describes trials carried out to obtain further information about the yield of UF Cheddar.

9.2 Methods by which Ultrafiltration can increase Cheddar cheese yields

A convenient means of evaluating how UF can increase cheese yield from a given supply of milk is to let the weight of cheese manufactured equal the sum of the weights of fat, solids-non-fat and moisture in the product. Yield may now be expressed in terms of retention factors:

kg cheese = [(kg moisture in milk x R1) + (kg fat in milk x R2) + (kg SNF in milk x R3)]

where R1, R2 and R3 are retention factors for moisture, fat and SNF respectively. It is easy to understand, therefore, that measures to increase yield involve increases in these retention factors and hence the production efficiency. Of course, these retention factors cannot be increased beyond certain well defined limits partly because of some inevitable losses and partly because of the effect on quality. For example high MNFS in cheese, while instrumental in increasing yields, may adversely affect quality (Pearce and Gilles, 1979) and grade (Lelievre, 1983a). Therefore, there is generally a trade off between yield and quality.

UF may increase Cheddar yields by influencing the retention of each of the three categories of milk constituents mentioned earlier.

9.2.1 The fat: The weight of fat in the cheese is equal to

the weight of fat in the milk minus the weight lost during manufacture. With a given milk supply, therefore, the only way UF cheesemaking can increase the weight of fat in the cheese is by decreasing fat losses.

In conventional manufacture, fat recovery depends on a number of factors and generally varies from 85 - 94% (Gilles and Lawrence, 1985). The major losses occur when the milk gel formed by rennet action is cut and syneresis takes place. However, losses do take place at all subsequent stages of cheesemaking. Given a code of good manufacturing practice, the extent of losses depend on the design of the cheesemaking unit. It should be possible to design UF cheesemaking plants which provide a decrease in fat losses since, compared with conventional manufacture, whey expulsion is reduced and since less curd surface area needs to be created when the retentate gel is cut. Although the UF whey contains a higher concentration of fat, there is still a potential for overall decreased fat losses in UF cheesemaking. It should be pointed out, however, that most of the fat in the whey can be recovered for further processing and is often as valuable as the fat in the fresh milk. Therefore, decreases in fat losses make a relatively minor contribution to the profitability of modern cheese-making plants.

9.2.2 The **solids-non-fat:** For both UF and conventional cheese the weight of SNF in the cheese depends primarily on the weight of casein in the milk. This is because 80 - 85% of the SNF in cheese is casein. Also, insoluble minerals such as calcium phosphate are associated with the casein and gain entry into the cheese. The losses of casein are also important.

UF cheesemaking has the potential to decrease casein losses in a manner similar to decrease in fat losses discussed earlier. Such reductions in casein losses have great economic significance because extra casein allows the inclusion of extra weight of water.

In conventional manufacture, the water soluble components in milk make a very minor contribution to the weight of SNF in the cheese since the retention of these components is very low. In UF cheesemaking, their retention is increased and a higher proportion of whey proteins, macropeptide from casein, and minerals is present in the product. It must be remembered that, while the inclusion of a higher proportion of water soluble components may increase yield, quality may be affected. For example, the presence of denatured β-lactoglobulin may inhibit plasmin (Snoeren, 1980) which plays a role in development of flavour in the cheese. On the other hand, the inclusion of extra whey proteins has been found to increase smoothness in Gouda cheese (Boer and Nooy, 1980a, b).

9.2.3 The moisture: The weight of moisture in the cheese can be controlled by varying the manufacturing conditions. The moisture to casein ratio (which is related to the ratio of moisture to non-fat substance) influences both the quality (Lawrence and Gilles, 1980) and yield (Gilles and Lawrence, 1985) of Cheddar cheese. While attaining higher MNFS has obvious yield advantages, it is generally recognised that if MNFS is too high, quality is likely to decline (Lelievre and Gilles, 1982). The cheese-maker should aim for the target MNFS that gives the correct trade off between yield and grade (Lelievre, 1983a). It is not known whether UF cheesemaking will permit the proportion of moisture to SNF in the cheese to be altered from the target level for conventional manufacture. There are three possibilities. Firstly, if it is the moisture:casein ratio rather than the MNFS that determines quality as suggested by Lawrence and Gilles (1980), the presence of extra water soluble components will not allow the weight of moisture to increase above the level in the conventional cheese. Therefore the target MNFS will be lower as compared with that in the conventional cheese. Secondly, if it is MNFS that relates directly to quality, the extra SNF in UF cheese will permit the weight of moisture to be increased proportionally. In this case, the target MNFS in UF cheese and conventional

product remains the same. Thirdly, if some components of the extra SNF in UF cheese, such as whey protein or macropeptide are capable of imbibing large quantities of moisture, it may be possible to further increase the weight of water in the cheese without adversely affecting quality. In this case, the target MNFS of UF cheese will be higher than that of conventional cheese.

9.3 Experimental approach

The yield advantages in UF cheesemaking outlined in the foregoing discussion are, in effect, of two types.

Firstly, there are yield increases that are due to the incorporation of extra water-soluble SNF components into the UF cheese. The degree of retention of these components depends on the moisture content of the retentate and that of the final product. Thus, with a given MNFS, a realistic measurement of increase in yield due to inclusion of extra water soluble components can be made. Such measurements were carried out in the present investigation. The extra SNF components may allow the incorporation of additional weight of moisture to be incorporated into the cheese. In the present study this possibility was investigated by checking the relationship between the quality and MNFS of UF Cheddar.

Secondly, reductions in the fat and/or casein losses to levels below those encountered in conventional manufacture may increase cheese yields. Such yield increases are possible if suitable cheesemaking equipment can be designed. In the present study, the levels of fat and casein losses occurring with UF cheesemaking were measured. The effect of some factors influencing these losses was also studied. The factors were:

(i) mode of operation of UF plant i.e. batch or continuous,
(ii) degree of curd handling.

Calculations were then made to predict possible yield advantages with suitable UF cheesemaking equipment.

9.4 Experimental

Three trials were carried out for each of the two experiments during 1984-5 and 1985-6 dairying seasons.

9.4.1 Batch vs continuous operation of UF unit: Pasteurized and standardized milk was divided into two lots. The smaller lot (50 kg) was retained as control.

9.4.1.2 Ultrafiltration: The bigger lot (250 kg) was heated to 51±1°C and placed in the preconditioned UF unit. The plant was run first on the continuous mode and the required amount of retentate (20 kg) was continuously drawn. It was then switched to batch mode and the remaining milk concentrated to a level similar to that of retentate obtained from the continuous mode.* In the continuous mode the degree of UF was controlled manually by regulating the flow of retentate and permeate. At high CF (>3:1), the flow of retentate was very low and difficult to regulate. Therefore, it was not possible to obtain a CF higher than 3:1. On an average, residence time for milk in the UF plant was 10-15 minutes and 40-45 minutes for continuous and batch modes respectively.

9.4.2. Cheesemaking: This was as described in Chapter 7 for control and 3:1 retentate.

9.4.2.1 Control vs 5:1 UF (normal MNFS - 52-55%) vs 5:1 UF (high MNFS - >55%)

This part was as described previously (Chapter 7) for control and 5:1 UF (normal MNFS) except that milk was standardised to casein:fat ratio of 0.57 - 0.6. Preliminary trials had shown that high MNFS levels(~57%) are difficult to attain when milk of normal casein:fat ratio (0.68 - 0.72) is used.

* See Section 4.3.2 for other details of UF.

For 5:1 UF (high MNFS) treatment there was a slight deviation in the method as described below:

(i) Starter was added at a reduced rate of 1.5% w/w (based on milk quantity prior to UF) so that 0.75 kg starter was added to 10 kg 5:1 retentate.

(ii) The retentate was set at 35°C.

(iii) The temperature was maintained at 35°C from starter addition to separation of curds and whey.

(iv) In order to prevent the curd particles from fusing together, the curd particles were gently stirred from time to time. This handling was kept to a minimum.

Mass balance exercises were carried out during all cheesemaking trials as described previously (Chapter 4).

9.5 Analyses

The milks and retentates were analysed for total solids, fat, TN, NCN, NPN and calcium. The cheeses were analysed for moisture, fat, TN, salt, pH and calcium. The cheeses were also graded when 35 days, 3 months and 6 months of age by a panel of 3-4 experienced judges. Some cheese samples were also assessed by a sensory evaluation panel. Methods for all the above analyses have been described previously (Chapter 4).

9.6 Results

Mass balance results of a previous investigation (Chapter 7) for control and 5:1 UF cheeses (Table 9.1) are used in the discussion.

Table 9.1 Mass balance

		Milk/Retentate					whey					cheese				Percentage		Recovery
Trial no.	Treatment	Weight (kg)	Fat %	TN %	NCN %	NPN %	Weight (kg)	Fat %	TN %	NCN %	NPN %	Weight (kg)	Fat %	TN %	Moisture %	Fat %	Casein %	Whey protein %
1	C	51.0	3.86	0.532	0.142	0.032	46.20	0.42	0.168	0.159	0.046	5.15	35.0	3.95	34.22	91.6	97.9	7.0
	5:1	11.0	20.00	2.246	0.512	0.039	5.75	7.95	0.779	0.672	0.096	5.10	32.0	4.01	36.48	74.2	96.8	36.4
2	C	51.0	3.85	0.499	0.124	0.040	46.20	0.33	0.144	0.138	0.040	5.05	35.0	3.85	34.94	89.9	98.5	5.4
	5:1	11.0	18.30	2.094	0.466	0.096	5.80	7.30	0.714	0.606	0.092	4.95	32.0	4.00	35.72	78.7	96.5	35.5
3	C	51.0	4.03	0.519	0.134	0.029	46.60	0.37	0.161	0.155	0.045	4.90	37.0	3.95	34.06	88.2	98.6	4.3
	5:1	11.0	20.40	2.338	0.508	0.033	6.40	5.63	0.712	0.607	0.088	5.20	36.0	4.00	34.63	83.4	96.7	36.5
4	C	51.0	3.50	0.515	0.135	0.029	46.10	0.35	0.166	0.156	0.045	4.70	34.0	3.90	35.70	89.5	97.6	5.4
	5:1	11.0	17.00	2.242	0.502	0.032	6.20	5.40	0.705	0.600	0.090	4.85	32.5	4.12	35.71	83.4	96.6	38.9
5	C	51.0	4.00	0.529	0.139	0.028	46.90	0.39	0.170	0.166	0.052	5.00	36.0	3.75	35.30	88.2	99.0	5.5
	5:1	11.0	19.10	2.383	0.528	0.033	6.10	5.54	0.758	0.663	0.086	5.10	34.8	3.92	35.10	84.5	97.2	35.4
6	C	51.0	3.80	0.540	0.135	0.028	46.20	0.36	0.153	0.142	0.042	5.05	34.0	3.96	35.35	88.6	97.5	3.5
	5:1	11.0	18.30	2.364	0.519	0.029	6.40	4.70	0.741	0.646	0.098	5.10	33.5	4.03	35.24	84.9	97.0	34.9
7	C	51.0	4.00	0.530	0.140	0.027	46.50	0.42	0.172	0.156	0.038	5.00	35.5	3.82	34.80	87.0	96.3	4.7
	5:1	11.0	18.90	2.340	0.535	0.030	6.25	5.25	0.775	0.680	0.085	5.05	34.6	3.95	34.70	84.1	97.0	33.1
8	C	51.0	3.85	0.529	0.129	0.026	46.50	0.39	0.165	0.151	0.042	5.00	34.5	3.81	35.80	87.9	96.8	3.4
	5:1	11.0	18.50	2.300	0.495	0.030	6.30	4.80	0.725	0.615	0.082	5.05	34.1	3.91	35.65	84.6	96.5	34.4
9	C	51.0	3.60	0.529	0.124	0.026	46.70	0.35	0.157	0.141	0.041	4.90	33.5	4.10	34.50	89.7	96.4	6.6
	5:1	11.0	17.95	2.324	0.479	0.029	6.40	4.75	0.688	0.583	0.080	5.00	33.0	4.19	34.75	83.6	96.7	35.0
Mean	C	51.0	3.84	0.524	0.134	0.029	46.43	0.37	0.162	0.152	0.045	4.97	35.0	3.90	35.0	89.0	97.6	5.1
		±0.0	±0.18	±0.012	±0.006	±0.004	±0.26	±0.03	±0.009	±0.009	±0.004	±0.12	±1.0	±0.10	±0.6	±1.3	±0.9	±1.2
	5:1	11.0	18.72	2.292	0.505	0.031	6.18	6.18	0.733	0.630	0.089	5.04	33.6	4.01	35.3	82.4	96.8	35.6
		±0.0	±0.98	±0.085	±0.021	±0.003	±0.24	±1.97	±0.031	±0.033	±0.006	±0.10	±1.30	±0.09	±0.6	±3.4	±0.2	±1.5

Note: 'C' denotes control.

9.6.1 Cheese composition: The average compositions of control and 5:1 UF cheeses were close (Table 9.2) and similar to those reported by other workers making UF cheese (Sutherland and Jameson, 1981; Van Leeuwen et al, 1984; Green, 1985). The compositions are in the range expected for good quality Cheddar made by conventional methods.

Table 9.2 Composition of cheese

Composition characteristic	Control	5:1 UF
FDM %	53.69 ± 1.51	51.96 ± 1.69
MNFS %	53.76 ± 0.91	53.23 ± 0.72
S/M %	4.95 ± 0.10	5.05 ± 0.21
1-day pH	5.07 ± 0.02	5.12 ± 0.02

9.6.2 Weight of SNF in cheese: The weights of SNF in the control and 5:1 UF cheeses can be calculated using mass balance results (Table 9.3). 50 kg control milk plus 1 kg starter was found to yield 1.50 ± 0.06 kg SNF in the control cheese. Similarly, 10 kg of 5:1 retentate plus 1 kg starter was found to give 1.57 ± 0.03 kg SNF in the UF cheese. For both treatments, the variation was probably due to changes in the milk composition.

The increase in SNF in the UF cheese would be expected to be largely made up of protein as confirmed by increase in TN in UF cheese (about 10 g TN or 65 g protein from 51 kg milk plus starter).

From the average whey protein recovery figures for the control and UF cheeses (5.1 ± 1.2% and 35.6 ± 1.5% respectively, Table 9.1) and the average whey protein content of the milk (0.67% w/w), it can be calculated that UF Cheddar has about 0.10 kg more whey protein than the control per 51 kg milk plus starter. However, the increase in weight of SNF in the UF cheese is less than expected from the whey protein figures probably because of higher fines losses in

Table 9.3 Weight of SNF in cheese from 50kg milk + 1kg starter

Trial No.	Control (kg)	5:1 UF (kg)
1	1.585	1.608
2	1.518	1.598
3	1.418	1.527
4	1.424	1.542
5	1.435	1.535
6	1.548	1.594
7	1.485	1.550
8	1.485	1.528
9	1.563	1.613
Mean ± s.d	1.50 ± 0.06	1.57 ± 0.03

UF cheesemaking procedure as compared with the control. This is consistent with the casein recovery figures of 97.6 and 96.7% for control and UF cheeses respectively. These figures can be used to estimate the weight of SNF in the UF cheese if the losses of fines in the UF cheese stay at levels similar to control. In this case, weight of SNF in the UF cheese becomes 1.59 kg (i.e. $1.57 \times \frac{0.98}{0.97}$) from 51 kg milk plus starter. Considering the problems encountered in mass balance trials under pilot-scale conditions, difficulties in sampling retentate and cheese, and the assumptions inherent in proximate analysis, the agreement between the increase in weight of SNF and the increase in the weight of whey protein in UF cheese is of the order expected.

Table 9.8 shows that the whey protein increase, and hence the SNF increase in the UF product is such that the concentration of whey protein in water in the cheese is 1.4 times that in the water of the retentate. This is true of both the 3:1 and 5:1 makes and the factor does not depend on how the curd is handled. Since the factor is constant under

the conditions of the present investigation, yields can be forecast under other conditions as described later (section 9.7.3.1).

9.6.3 Weight of fat in cheese: The weight of fat in the 5:1 UF cheese was less than that in the control cheese (Table 9.4). This was due to relatively high fat losses occurring during UF Cheddar manufacture (fat recovery 82.4% compared with the control fat recovery of 89.0%). These recovery values are similar to those reported by Green (1985) but lower than the values calculated from the data in the patent of Van Leeuwen et al, (1984).

Table 9.4 Weight of fat in cheese from 50kg milk + 1kg starter

Trial No.	Control (kg)	5:1 UF (kg)
1	1.803	1.632
2	1.768	1.584
3	1.813	1.872
4	1.598	1.560
5	1.800	1.775
6	1.717	1.709
7	1.775	1.747
8	1.725	1.722
9	1.650	1.650
Mean ± s.d	1.739 ± 0.07	1.695 ± 0.09

A comparison of fat recovery figures for cheeses made from retentate concentrated by batch and continuous UF showed that the fat recovery was slightly higher in the cheese made from retentate obtained by operating UF plant on continuous mode, than in the product made from retentate obtained by operating UF plant on batch mode (Table 9.5). UF plants cause changes in the milk fat which amounts to 'partial' homogenization (Green et al, 1984). Such changes

may be greater with batch than with continuous operations since the residence time of milk in the former case is greater. A recent report (Jameson, 1984) suggested that such homogenization action should be minimised and results of the present study confirm this to be the case.

Table 9.5 Fat recovery in cheese obtained from retentate concentrated with UF unit operating in batch and continuous mode

Particulars	Control	Batch	Continuous
Fat recovery %	89.5 ± 0.8	75.7 ± 0.8	77.4 ± 0.5

The effect of level of curd handling was also studied. The trials were the same as those used to make high MNFS cheese. The results suggest that fat recovery improved with reduced curd handling (Table 9.6). Clearly, therefore, fat losses occurring in UF cheesemaking can be minimised by appropriate design and operation of UF plant and by suitable design of cheesemaking equipment.

Table 9.6 Effect of curd handling on fat recovery in 5:1 UF Cheddar

Particulars	Control	5:1 UF	
		Normal curd handling	Reduced curd handling
Fat recovery %	89.8 ± 0.6	85.8 ± 0.6	88.0 ± 0.4

9.6.4 Weight of moisture in cheese: In the MNFS range of about 52-55%, the control and UF cheeses were found to have the same quality with similar MNFS. Decreasing MNFS did not improve organoleptic quality of the UF cheese. However,

with an increase in MNFS, grade was found to decline (Table 9.7). This decline may be linked to the manufacturing procedure needed to make the high MNFS product. Thus, results of the present investigation suggest that the extra SNF in UF cheese does permit the inclusion of extra water in the product without undesirable effects on the flavour or texture provided the amount of extra water is such that it does not increase the MNFS in the UF cheese beyond that of conventional Cheddar.

9.7 Discussion

The yield of cheese made by any process from any given milk supply depends on three factors, namely compositions of the milk and the final product and losses occurring during manufacture. UF cheese yield may be influenced by each of these factors and the manner in which this may happen is briefly discussed below.

9.7.1 Composition of the milk

The composition of milk is likely to have a small direct effect on yield increases in UF cheesemaking. The increases in weight of SNF of UF cheese is largely due to the incorporation of the whey proteins. Therefore, the variation in the level of whey proteins in the milk during the dairying season may have a marginal effect on the potential yield increase. The composition of the milk may also influence the potential decreases in fat and fines losses.

9.7.2 The composition of the cheese

The results of the present investigation suggest that the composition desired for good quality UF Cheddar is the same as that for conventional Cheddar. In a typical case, both FDM and MNFS would be about 53.5% for UF Cheddar. Other investigators (Sutherland and Jameson, 1981; Van Leeuwen *et al*, 1984; Green, 1985) have reported a similar composition.

Table 9.7 Cheese quality and grades

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (6) Sl.sour	Sl.mealy (3) Sl.loose	Normal (6)	Sl.mealy (3)	Normal (5) Sl.sour	Sl.mealy (3)
1	5:1 UF Normal MNFS	Normal (6) Sl.sour	Sl.greasy (3) Smooth	Sl.bitter (6) Sl.sour	Sl.greasy (3) Smooth	Normal (6) Sl.oxidized	Smooth (3) Sl.greasy
	5:1 UF High MNFS	Sl.sour (5) Sl.bitter	Floury (2) Crumbly	Sour (4) Bitter	Weak (2) Crumbly	Sour (4) Bitter	Crumbly (2) Floury
	Control	Normal (6) Sl.bland	Sl.mealy (3) Sl.rubbery	Normal (6) Sl.fruity	Sl.tender (3) Smooth	Normal (6) Sl.fruity	Weak (3) Smooth
2	5:1 UF Normal MNFS	Normal (6) Sl.bland	Sl.pasty (3) Smooth	Normal (6) Sl.oxidized	Sl.plastic (3) Smooth	Normal (6) Sl.oxidized	Smooth (3) Sl.greasy
	5:1 UF High MNFS	Sl.sour (5) Unpleasant	Pasty (2) Crumbly	Sl.sour (5) Sl.bitter	Tender (2) Sticky	Sour (5) Bitter	Sticky (2) Crumbly
	Control	Sl.sour (6) Normal	Weak (3) Sl.pasty	Normal (6) Sl.sour	Sl.mealy (3) Smooth	Sl.fruity (5)	Sl.mealy (3)
3	5:1 UF Normal MNFS	Sl.sour (6) Sl.bitter	Tender (3) Smooth	Sl.bland (5) Sl.sour	Smooth (3) Sl.plastic	Sl.sour (5) Sl.oxidized	Smooth (3)
	5:1 UF High MNFS	Sour (5) Bitter	Weak (3) Sticky	Sour (4) Bitter	Sticky (2) Crumbly	Sour (4) Bitter	Sticky (2) Crumbly

9.7.3 The losses occurring during cheese manufacture

In view of the similarities in composition of UF and conventional product, any increases in yield with UF manufacture must be due to increases in recovery of milk solids. These may be conveniently classified into two groups:

(i) Water soluble SNF components

(ii) Fat, casein or fines.

9.7.3.1 Increase in recovery of water soluble SNF components

In the present investigation an increase in the recovery of water soluble components was recorded and potential overall yield increases can be calculated from these results.

Case 1

Assuming that the fat, casein and fines losses are the same in the conventional and UF processes, MNFS is 53.5%, FDM in control cheese is 53.5%, and both cheeses are made from the same milk, 100 kg milk will yield:

(from mass balance trials, Table 9.3)

(a) Control Cheddar

(i) SNF = $1.50 \times \frac{100}{51} = 2.94$ kg

(ii) Moisture = $2.94 \times \frac{53.5}{46.5} = 3.39$ kg

(to keep MNFS at 53.5%)

(iii) Similarly, fat = 3.39 kg

(to keep FDM at 53.5%)

Total conventional Cheddar = 9.72 kg

(b) UF Cheddar (also from mass balance trials reported in Table 9.3)

(i) SNF = $1.57 \times \frac{98}{97} \times \frac{100}{51} = 3.11$ kg

(corrected to fines losses similar to control Cheddar)

(ii) Moisture = $3.11 \times \frac{53.5}{46.5} = 3.58$ kg

(to keep MNFS at 53.5%)

(iii) Fat (as for control Cheddar) = 3.39 kg

Total UF Cheddar = 10.08 kg

This is a yield increase of 3.7%.

Case 2

The UF yield figure in Case 1 could be increased slightly by preparing the starter in the retentate and so avoiding dilution of the retentate. The increase in yield can be estimated on the basis of the reduction in water loss required to make the cheese. Again consider 100 kg milk as starting material. In the trials reported earlier (Chapter 7), an average of 14.2 kg water in the retentate (20 kg retentate of 62% moisture = 12.4 kg; plus 2 kg starter of 90% moisture = 1.8 kg moisture) was reduced to 3.4 kg water in the final cheese. If the starter is prepared in the retentate (i.e. there is no dilution with starter), 12.4 kg water would be reduced to approximately 3.4 kg in the product. In the present investigation, calculations suggest that the concentration of whey proteins in the cheese was 1.4 times that of the whey proteins in the retentate (Table 9.8). On an average 100 kg retentate contains 0.67 kg whey protein. If it is assumed that the concentration of whey protein in the water in the UF cheese is twice that of the whey protein in the retentate, it can be calculated that the yield now will be:

(i) SNF = 3.11 (as in case 1) + $[(0.67 \times 2 \times \frac{3.4}{12.4}) - (0.67 \times 2 \times \frac{3.4}{14.2})]$

= 3.16 kg

(ii) Moisture = $3.16 \times \frac{53.5}{46.5}$ = 3.64 kg

(to keep MNFS at 53.5%)

(iii) Fat = 3.39 kg (as in Case 1)

Total UF Cheddar = 10.19 kg

In this case the yield increase is 4.8% which is an optimistic estimate considering that a factor of 2 (rather than 1.4) was used to calculate the extra whey protein retention in the UF cheese. Therefore this estimate allows for increases in SNF other than those derived from whey protein.

Table 9.8 Whey protein:water ratio in retentates and UF cheeses

Particulars	Mean water kg	Mean whey protein kg	Mean whey protein / water %	No. of trials
3:1 UF				
Retentate 17.7 kg	12.980 ± 0.190	0.346 ± 0.019	2.67 ± 0.160	9
Cheese	1.717 ± 0.064	0.067 ± 0.010	3.92 ± 0.540	
Ratio *			1.47	
5:1 UF				
Retentate 11.0 kg	6.890 ± 0.090	0.331 ± 0.017	4.80 ± 0.250	9
Cheese	1.782 ± 0.040	0.115 ± 0.010	6.45 ± 0.550	
Ratio*			1.34	
5:1 UF				
Retentate 11.0 kg				
Low curd handling	1.876 ± 0.04	0.130 ± 0.005	6.93 ± 0.12	3
Ratio*			1.44	

* whey protein : water in cheese
whey protein : water in retentate

9.7.3.2 Increase in recovery of fat, casein and fines

In conventional manufacture, the fat and the colloidal components of milk (casein, calcium phosphate) are largely recovered in the cheese. UF cheesemaking has the potential to further improve the recovery of these components.

Case 3

If all fines losses are eliminated, then the weight of cheese from 5:1 retentate (from 100 kg milk) with no dilution by starter is calculated as:

(i) SNF = 3.16 x $\frac{100}{98}$ = 3.22 kg
(as in Case 2)

(ii) Moisture = 3.22 x $\frac{53.5}{46.5}$ = 3.70 kg

(to maintain MNFS at 53.5%)

(iii) Fat = 3.39 (as in Case 1 and Case 2, i.e. FDM lower than in case 1 and 2)

Total UF Cheddar = 10.31 kg.

This is a 6.1% yield increase for UF Cheddar with MNFS equal to 53.5% and the weight of fat equal to that in the control.

Case 4

It is also possible to increase the weight of fat in the cheese by decreasing losses. It has been suggested that an increase of 5% in fat recovery is possible (Van Leeuwen et al, 1984) when cheese is made from 5:1 retentate. If this increased fat recovery was considered in the yield calculations, the weight of cheese is calculated as:

(i) SNF = 3.22 kg (as in Case 3)

(ii) Moisture = 3.70 kg (as in Case 3)

(iii) Fat = 3.39 (as in Cases 1-3) + (3.39 x 0.05)
= 3.56 kg

Total UF Cheddar = 10.48 kg

This is a yield increase of 7.8%, which is in close agreement with the average yield increase of 8.4% reported by Van Leeuwen et al (1984).

Commercial Significance

The increase in yield due to incorporation of extra fat of the milk into the cheese would be of relatively small financial advantage to cheese factories that recover fat from the whey for further processing. Furthermore, losses tend to increase when processes are scaled up from pilot plant level to factory level and the same may hold good for UF cheesemaking. Therefore, the sustainable yield increase under commercial conditions is more likely to be of the order of 4% than the 8% reported in the pilot scale work of Van Leeuwen et al (1984).

9.9 Conclusion

The manufacture of Cheddar cheese from milk concentrated to 5:1 level results in the incorporation of water soluble SNF components which allows the inclusion of moisture to keep the MNFS constant. This brings about a yield increase of approximately 4%. If the losses of casein fines can be reduced, the yield advantage may be about 6%. Also, if fat recovery in UF cheese can be improved by 5%, yield can be increased further to about 8%. However, yield advantages accruing from increased fat recovery may be of relatively small financial advantage to modern cheesemaking plants which can efficiently recover fat from the whey.

These yield advantages do not look attractive compared with those reported for soft cheese varieties. Considering that milk contains approximately 0.7% w/w of whey protein and only about one-third of it may be retained in the UF Cheddar made from 5:1 retentate, it is easy to understand that yield advantages from whey protein alone are limited to only about 2.3%. These values double if an equal quantity of moisture is included. Therefore, substantial yield advantages in UF Cheddar from whey protein alone may not be forthcoming. Furthermore, some potential increases in yield in UF cheesemaking plants are possible with conventional manufacture as well. The production efficiency of all plants is the highest when losses are reduced to a minimum and the product composition is targeted to the correct MNFS and FDM. With the current state of UF cheesemaking technology, it is possible that reductions in losses in conventional plants may prove to be a more profitable method of increasing yields than the use of UF cheesemaking methods. However, if there is further advancement in ultrafiltration process, such as concentration of milk to higher solids level, the situation may improve slightly for UF cheesemaking.

CHAPTER 10

MISCELLANEOUS EXPERIMENTS

10.1 Introduction

Investigations on some minor aspects of Cheddar cheesemaking from UF retentate were also carried out. These have been briefly reported in the present chapter. The experiments reported are the following:

10.2 Effect of UF cheesemaking from fresh milk (without overnight storage) on the yield and quality of Cheddar cheese.

10.3 Effect of addition of UF permeate to cheese curd from 5:1 retentate on the quality and yield of Cheddar cheese.

10.4 Effect of addition of whey protein supplemented permeate to cheese curd from 5:1 UF retentate on the quality and yield of Cheddar cheese.

10.2 EFFECT OF UF CHEESEMAKING FROM FRESH MILK (WITHOUT OVERNIGHT STORAGE) ON THE QUALITY AND YIELD OF CHEDDAR CHEESE

10.2.1 Introduction

It has been reported that some release of free fat may occur during overnight storage of milk (Te Whaiti and Fryer, 1976). This may influence fat recovery and quality of UF Cheddar. In the present study, the effect of UF cheesemaking from fresh milk on the cheese quality and yield was investigated.

10.2.2 Experimental

Ideally the experiment should have been designed such that a comparison could be made between UF cheesemaking from milk with storage and that from milk without storage. However, due to practical difficulties this was not done. Instead, UF cheese was made from milk without storage and its quality and yield (for respective treatments) compared with those from another investigation (Chapter 7) wherein milk was stored overnight at 2-4^{o}C.

Three trials were done during the 1985-6 season. These trials were identical to those described earlier (Chapter 7) except that all operations from milk procurement to the pressing of cheese were performed on the same day.

Analytical methods have been described previously (Chapter 4 and Chapter 7).

10.2.3 Results and Discussion

Average results are discussed since they show the main trends and avoid unnecessary detail.

10.2.3.1 Mass balance and yield: The recovery of fat and other milk constituents was slightly different for various treatments (Table 10.1). However these recovery values were identical to those obtained in previous trials (Chapter 7).

Table 10.1 Mass balance

Percentage recovery in cheese

Treatment	Control	3:1 UF	5:1 UF
Fat	88.4 ± 1.1	78.9 ± 0.93	84.2 ± 0.54
CN	96.7 ± 0.57	96.0 ± 0.53	96.9 ± 0.14
WPN	4.93 ± 1.28	17.1 ± 1.84	34.4 ± 0.90

Therefore, it appears that overnight storage of milk does not significantly influence the recovery of fat and other milk constituents. A possible explanation could be that if some free fat was formed during overnight storage (Te Whaiti and Fryer, 1976), it was possibly converted to globular form during UF of milk (Green et al, 1984) thereby minimising the influence of free fat on fat recovery. The yields obtained for various treatments in the present experiment (Table 10.2) were, for practical purposes, identical to those obtained for the same treatments earlier (Chapter 9). This was expected since the retention of various milk constituents was not influenced by overnight storage of milk. Therefore, it appears that overnight storage of milk does not significantly influence fat recovery or cheese yield.

Table 10.2 Yield of cheese

Yield	Control	3:1 UF	5:1 UF
kg cheese per 100 kg milk	9.96 ± 0.12	9.80 ± 0.08	10.10 ± 0.08
kg cheese(adjusted to 36.0% moisture) per 100 kg milk	10.28 ± 0.05	10.12 ± 0.08	10.42 ± 0.05

10.2.3.2 Cheese quality: There were some differences in the grades of cheeses from the three treatments (Table 10.3). These differences in the quality of cheese between treatments were similar to those obtained in a previous investigation (Chapter 7). Therefore, these results suggest that overnight storage of milk does not significantly influence the quality of cheese obtained from UF retentates.

Table 10.3 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (7)	Sl.loose (3)	Normal (6) Sl.sour	Sl.mealy (3)	Sl.sour (6) Sl.aromatic	Sl.mealy (3)
1	3:1 UF	Sl.bland (5)	Sl.firm (2) Sl.crumbly	Sl.bland (5)	Sl.curdy (2)	Sl.bland (5)	Sl.firm (2)
	5:1 UF	Normal (6)	Tender (3) Sl.smooth	Normal (6) Sl.sour	Sl.smooth (3)	Normal (6) Sl.sour	Sl.smooth (3)
	Control	Normal (6) Sl.sour	Sl.lumpy (3)	Sl.sour (5)	Sl.mealy (3)	Sl.sour (6)	Sl.floury (3)
2	3:1 UF	Sl.atypical(5)	Sl.firm (2) Sl.mealy	Sl.atypical(5)	Sl.firm (2)	Sl.atypical(5)	Sl.curdy (2)
	5:1 UF	Normal (6) Sl.sour	Sl.smooth (3)	Normal (5) Sl.sour	Sl.smooth (3)	Sl.aromatic(6)	Sl.smooth (3)
	Control	Sl.sour (6) Sl.bitter	Sl.crumbly (3)	Sl.sour (6)	Sl.floury (3)	Sl.sour (5) Sl.bitter	Sl.mealy (3)
3	3:1 UF	Sl.bland (5)	Sl.firm (2) Sl.mealy	Sl.atypical(4)	Sl.firm (2)	Sl.atypical(5)	Sl.firm (2)
	5:1 UF	Sl.sour (6)	Sl.smooth (3)	Sl.sour (6) Sl.bitter	Sl.smooth (3)	Normal (6) Sl.aromatic	Sl.smooth (3)

Note: Figures in brackets refer to grade scores

10.2.4 Conclusion

The results of the present investigation in conjunction with those of a previous one (Chapter 7) suggest that overnight chilled storage of milk does not significantly influence the recovery of fat or any other milk constituent during UF cheesemaking. Results also suggest that under the conditions of manufacture employed in the present investigation, the effect of such overnight storage on quality of UF Cheddar is minimal.

10.3 EFFECT OF ADDITION OF PERMEATE TO CHEESE CURD FROM 5:1 UF RETENTATE ON THE QUALITY AND YIELD OF CHEDDAR CHEESE

10.3.1 Introduction

One of the problems in Cheddar cheesemaking from UF retentate is related to the handling of the UF curd in the absence of sufficient quantities of whey (Chapter 2). A suitable liquid medium which facilitates UF curd handling without flushing out milk constituents from the curd may be helpful. The UF permeate can perform this function to some extent (Sutherland and Jameson, 1980).

In an earlier experiment (Chapter 4), it was shown that the addition of the permeate to the retentate prior to setting (i.e. rennet addition) resulted in no yield advantages although the quality of the cheese was similar to control. If it can be shown that the addition of permeate to the retentate could be delayed till after the curd is cut, some yield advantages appear possible. Therefore, in the present study, the effect of addition of permeate to the UF cheese curd (after cutting) on the yield and quality was investigated.

10.3.2 Experimental

During the 1984-85 season, two trials were done. Two levels of permeate addition were chosen - 50% and 100% of that removed. The experimental procedure was similar to the one described previously (Chapter 7) except that 20 and 40 kg of UF permeate were added to 5:1 UF curd from 10 kg retentate each (after cutting) in vats 2 and 3 respectively. Vat 1 was the control.

Analytical methods have been described previously (Chapter 4 and 7).

10.3.3 Results and Discussion

For convenience, results have been averaged and discussed under five sections:

10.3.3.1 Milk, retentate and permeate composition.
10.3.3.2 Cheese manufacture.
10.3.3.3 Cheese composition.
10.3.3.4 Mass balance and yield.
10.3.3.5 Cheese quality.

10.3.3.1 Milk, retentate and permeate composition: The compositions of milk and 5:1 retentate were similar to those obtained in a previous investigation (Chapter 7). Average permeate composition is shown in Table 10.4.

Table 10.4 Composition of permeate

Total solids (%)	5.45 ± 0.03
TN (%)	0.034 ± 0.001
NPN (%)	0.033 ± 0.000

10.3.3.2 **Cheese manufacture:** The UF curds were easier to handle in the presence of liquid medium compared with the standard 5:1 make described earlier (Chapter 7).

10.3.3.3 **Cheese composition:** The composition of the cheeses from the three treatments was similar (Table 10.5). The cheeses from permeate added treatments had slightly higher MNFS, possibly because the addition of the permeate interfered with the syneresis of the UF curds.

Table 10.5 Cheese composition

Treatment	Control	50% permeate added	100% permeate added
FDM %	53.0 ± 0.40	52.8 ± 0.40	52.7 ± 0.40
MNFS %	53.7 ± 0.15	53.9 ± 0.25	54.0 ± 0.25
S/M %	4.94 ± 0.05	5.04 ± 0.03	4.91 ± 0.02
pH 1-day	5.09 ± 0.01	5.11 ± 0.01	5.07 ± 0.01
TN %	3.98 ± 0.03	4.03 ± 0.03	4.00 ± 0.00
Ca mM/kg	185 ± 5.0	198 ± 3.0	189 ± 3.0
Ca/SNFNS	2.69 ± 0.02	2.78 ± 0.06	2.64 ± 0.07

10.3.3.4 **Mass balance and yield:** The recovery of fat in both permeate added treatments was only marginally lower than that in the control (Table 10.6). When recovery values obtained in the present investigation are compared with those of a previous study (Chapter 7), it is clear that fat recovery in UF Cheddars can be improved by the addition of permeate to facilitate handling of the curd. However, the addition of the permeate resulted in flushing out of the whey proteins as suggested by the recovery values for WPN (Table 10.6).

Table 10.6 Mass balance

Percentage recovery in cheese

Treatment	Control	50% permeate added	100% permeate added
Fat	90.2 ± 0.4	88.2 ± 0.00	88.4 ± 0.00
CN	98.2 ± 0.5	98.2 ± 0.2	98.4 ± 0.2
WPN	5.1 ± 0.4	8.5 ± 0.4	6.2 ± 0.3

The addition of permeate did help in increasing recovery of CN to levels similar to that in the control. The yield of cheese from the three treatments was similar (Table 10.7). This was expected since the recovery of various milk constituents for the three treatments was alike.

Table 10.7 Yield of cheese

Yield	Control	50% permeate added	100% permeate added
kg cheese/100 kg milk	10.06 ± 0.06	10.08 ± 0.04	10.14 ± 0.04
kg cheese* /100 kg milk	10.26 ± 0.04	10.20 ± 0.04	10.24 ± 0.06

* adjusted to 36.0% moisture

10.3.3.5 Cheese quality: The quality of cheese obtained from the three treatments was similar (Table 10.8). It is possible that the 'dilution' effect due to the whey proteins in 5:1 UF Cheddar suggested by Koning et al (1981) was minimised in permeate added UF Cheddars due to the flushing out of the whey proteins. However, results of an earlier investigation (Chapter 7) suggested that the 'dilution' effect is anyway minimised if residual rennet concentration in 5:1 UF Cheddar is suitably increased. It is possible,

Table 10.8 Grading of cheese

Trial No.	Treatment	35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
1	Control	Normal (6) Sl.sour	Sl.mealy (3)	Sl.sour (6) Sl.bitter	Sl.mealy (2)	Sl.sour (6) Normal	Sl.mealy (2)
	+ 50% permeate*	Sl.sour (6)	Sl.floury (3)	Sl.sour (6)	Sl.mealy (2)	Sl.sour (5) Sl.bland	Sl.mealy (2) Sl.crumbly
	+ 100 % permeate*	Sl.sour (6)	Sl.mealy (3)	Sl.sour (6) Sl.bitter	Sl.floury (2)	Sl.sour (5)	Sl.mealy (2)
2	Control	Normal (6) Sl.sour	Sl.floury (3)	Sl.sour (5) Sl.bitter	Sl.mealy (3)	Normal (5) Sl.sour	Sl.mealy (3)
	+ 50 % permeate*	Sl.sour (6) Sl.bland	Sl.mealy (3)	Sl.sour (5)	Sl.mealy (3)	Sl.sour (5)	Sl.mealy (3) Sl.crumbly
	+ 100 % permeate*	Sl.sour (6) Sl.bland	Sl.mealy (3)	Sl.sour (5)	Sl.mealy (3) Sl.floury	Sl.sour (5)	Sl.mealy (3)

Note: Figures in brackets refer to grade scores

* see experimental

Note: Figures in brackets refer to grade scores

therefore, that the permeate also flushed out a part of the residual rennet in the UF cheese so that any problems expected due to excessive residual rennet in UF cheese were minimised.

10.3.4 Conclusion

The results of the present investigation suggest that the addition of permeate to 5:1 UF curd after cutting helps in handling of the curd and decreasing losses of fat and casein. However, the permeate also flushes out most of the whey proteins from the UF curd thereby decreasing yield advantages. Therefore, measures to facilitate handling of the UF curd should not preferably involve introduction of a liquid medium since this is likely to nullify yield advantages by flushing out the water soluble SNF components, mainly whey proteins.

10.4 EFFECT OF ADDITION OF WHEY PROTEIN SUPPLEMENTED PERMEATE TO THE CHEESE CURD FROM 5:1 UF RETENTATE ON THE QUALITY AND YIELD OF CHEDDAR CHEESE

10.4.1 Introduction

The difficulties associated with handling of 5:1 UF curd and resultant losses of fat and casein fines (Chapter 7) can be partly overcome by the addition of some UF permeate to the UF curd after cutting (Section 10.3). However, in the process, most of the whey proteins get flushed out, thus nullifying yield advantages. The addition of the permeate therefore works against the primary objective of increasing yields through increased retention of whey proteins in the cheese. A possible means of overcoming this difficulty involves blending of whey protein powder in the permeate prior to its addition to the UF curd after cutting. The higher concentration of whey proteins in the permeate surrounding the UF curd particles may miminise the flushing out of the whey proteins. In the present

investigation the effect of addition of whey protein supplemented permeate to the cheese curd from 5:1 retentate on the quality and yield of Cheddar cheese was studied.

10.4.2 Experimental Plan

The level of whey protein supplementation chosen was such that the whey protein:moisture ratio in the permeate was equivalent to that in 5:1 retentate. Calculations suggested (see Appendix VA) that 3 kg whey protein powder (80% protein on dry matter basis) needs to be added to 40 kg permeate to achieve this.

10.4.3 Experimental

Two trials were done during the 1984-5 season. The experimental procedure was similar to that described previously (Section 10.3.2 of this chapter) except that to the experimental vat (Vat 3), 40 kg permeate supplemented with 3 kg whey protein powder, was added to the 5:1 UF curd after cutting. Vat 1 was the control and Vat 2 involved 100% permeate addition without whey protein supplementation. Analytical methods have been described previously (Chapter 4 and Chapter 7).

10.4.4 Results and discussion

For convenience, average results are discussed because these show the main trends. These are discussed in four sections:

10.4.4.1 Composition of the permeate and whey protein supplemented permeate.
10.4.4.2 Cheese composition.
10.4.4.3 Mass balance and yield.
10.4.4.4 Cheese quality.

10.4.4.1 Composition of permeate and whey protein supplemented permeate:

The blending of whey protein powder resulted in a large increase in NCN, TN and total solids content of the permeate (Table 10.9).

Table 10.9 Composition of permeate and whey protein supplemented permeate

	Permeate	Whey protein supplemented permeate
Total solids (%)	5.41 ± 0.05	10.5 ± 0.30
TN (%)	0.037 ± 0.002	0.840 ± 0.010
NCN (%)	——	0.780 ± 0.020
NPN (%)	0.034 ± 0.001	0.039 ± 0.001

10.4.4.2 Cheese composition: The composition of the cheeses from the three treatments was similar (Table 10.10).

Table 10.10 Cheese composition

Treatment	Control	Permeate added	W.P. supplemented permeate added
FDM %	52.6 ± 0.2	52.2 ± 0.1	52.4 ± 0.1
MNFS %	53.4 ± 0.1	53.4 ± 0.1	53.7 ± 0.1
S/M %	5.09 ± 0.05	5.12 ± 0.05	5.17 ± 0.00
pH 1-day	5.09 ± 0.02	5.11 ± 0.01	5.05 ± 0.01
TN %	3.99 ± 0.03	4.03 ± 0.03	4.02 ± 0.04
Ca mM/kg	178 ± 2.0	183 ± 3.0	188 ± 2.0
Ca/SNFNS	2.47 ± 0.03	2.52 ± 0.04	2.61 ± 0.03

10.4.4.3 Mass balance and yield: The recovery of fat and CN was similar for the three treatments (Table 10.11). The calculations for recovery of WPN in control and permeate added Cheddars were done as described previously (Chapter 4). For whey protein supplemented permeate added Cheddars, calculations were done as follows:

% WPN recovery =

$$\frac{\left[\begin{matrix}\text{WPN in}\\ \text{retentate}\end{matrix}\right]+\left[\begin{matrix}\text{WPN in W.P. supple-}\\ \text{mented permeate}\end{matrix}\right]-[\text{WPN in whey}]}{\left[\begin{matrix}\text{WPN in}\\ \text{retentate}\end{matrix}\right]+\left[\begin{matrix}\text{WPN in W.P. supple-}\\ \text{mented permeate}\end{matrix}\right]} \times 100$$

The blending of whey protein in the permeate prior to its addition to the UF curd did not significantly increase the recovery of WPN. The reason for this is uncertain. One possibility is that a portion of the moisture in the UF curd was 'bound' so that the real concentration of the whey proteins in the curd was much higher than that in whey protein supplemented permeate. Consequently, at least in the initial stages, the whey protein supplemented permeate flushed out part of the whey proteins in the curd. One way to check on this possibility is to further increase whey protein:moisture ratio in the permeate and investigate whether this prevents the flushing out of the whey proteins.

Table 10.11 Mass balance

Percentage recovery in cheese

% Recovery	Control	Permeate added	W.P. supplemented permeate added
Fat	89.5 ± 0.4	88.9 ± 0.9	88.3 ± 0.7
CN	97.8 ± 0.1	98.1 ± 0.2	97.6 ± 0.1
WPN*	4.3 ± 0.2	6.2 ± 0.1	9.2 ± 0.9
SNF	34.7 ± 0.2	35.2 ± 0.3	24.2 ± 0.3
			35.5 ± 0.3 **

* see section 10.4.4.3 for definition of WPN recovery

** calculated on the basis of SNF content of milk for comparison purposes.

In the later stages of syneresis, it is possible that the shrinkage of the curd due to cooking and acid development resulted in further loss of moisture and whey protein irrespective of the concentration of whey proteins in the medium surrounding the curd. Obviously this phenomenon may also occur in UF curd from the other treatments with and without permeate addition. The SNF recovery in whey protein supplemented permeate added Cheddar was slightly higher than that in the other two treatments.

The yield of cheese from the three treatments was similar (Table 10.12). This was expected since recovery of various milk constituents was alike for the three treatments.

Table 10.12 Yield of cheese

Yield	Control	Permeate added	WP supplemented permeate added
kg cheese per 100 kg milk	10.06 ± 0.06	10.16 ± 0.06	10.08 ± 0.04
kg cheese* per 100 kg milk	10.28 ± 0.08	10.32 ± 0.08	10.24 ± 0.08

* adjusted to 36.0% moisture

10.4.4.3 Cheese quality: The quality of cheese obtained from the treatment involving whey protein supplemented permeate addition was slightly inferior to that of cheese from the other two treatments (Table 10.13). The reason for this is not known. One possibility is that some off flavours in the cheese originated from the whey protein powder addition. The results of this investigation agree with those of a previous one (Chapter 6) suggesting that the addition of dried whey protein to milk, retentate or permeate leads to flavour problems in the cheese.

Table 10.13 Grading of cheese

Trial No.	Treatment	Stage of cheese maturation: 35 days Flavour	35 days Texture	3 months Flavour	3 months Texture	6 months Flavour	6 months Texture
	Control	Normal (6) Sl.sour	Sl.mealy (3)	Sl.sour (6)	Sl.mealy (3)	Normal (5) Sl.aromatic	Sl.mealy (3)
1	Permeate added	Sl.sour (6)	Sl.floury (3)	Sl.sour (5)	Sl.floury (3)	Sl.sour (5)	Sl.floury (3)
	W.P. supplemented permeate added	Sl.sour (5) Sl.bitter	Sl.crumbly (3)	Sl.sour (5) Sl.unclean	Sl.crumbly (2)	Sour (4) Sl.unclean	Sl.crumbly (2) Sl.mealy
	Control	Normal (6) Sl.bitter	Sl.mealy (3)	Normal (6)	Sl.mealy (2)	Normal (6) Sl.sour	Sl.mealy (3)
2	Permeate added	Sl.sour (6)	Sl.floury (3)	Sl.sour (6)	Sl.floury (2)	Sl.sour (6)	Sl.floury (2)
	W.P. supplemented permeate added	Sl.sour (5) Sl.unclean	Sl.crumbly (2)	Sl.sour (5) Sl.unclean	Sl.crumbly (2)	Sour (4) Sl.unclean	Sl.crumbly (2) Sl.mealy

Note: Figures in brackets refer to grade scores

10.4.5 Conclusion

The results of the present investigation suggest that the presence of extra whey proteins in the liquid medium surrounding the curd particles does not significantly increase the recovery of whey proteins in the cheese. Further work is needed to investigate whether addition of permeate supplemented to higher levels of whey protein to the UF curd will permit increased recovery of whey protein.

CHAPTER 11

OVERALL DISCUSSION

The problems encountered in UF Cheddar are mainly those concerning quality and lack of viable yield increase. In terms of quality, the problems include:

(1) high 1-day pH (Green et al, 1981a)

(2) high calcium in cheese (Sutherland and Jameson, 1981).

(3) atypical flavour and texture, possibly due to lack of proteolysis (Green et al, 1981a, 1985).

Investigators have sought to overcome the first two quality problems by decreasing the pH of the milk prior to UF (Sutherland and Jameson, 1981). Results of the present investigation suggest that another solution is the addition of starter on the basis of milk quantity prior to UF. The starter could preferably be prepared in the concentrated milk (Mistry and Kosikowski, 1986b) to minimise the dilution effect of the starter encountered in the present investigation. The lack of proteolysis reported in UF Cheddar (Green et al, 1981a) may be overcome by the addition of rennet on the basis of milk quantity prior to UF. The resultant UF Cheddar has higher than normal residual rennet which is possibly required to offset the 'dilution' effect of the whey proteins (Koning et al, 1981).

Information on the optimum range of MNFS for UF Cheddar is lacking. Data from the present investigation suggest that a MNFS level similar to that of traditionally made Cheddar can be maintained in cheese made from UF milk provided that not more than about one third of the whey protein in the original milk is retained in the cheese. The ratio of moisture to casein in traditional Cheddar cheese is about 1.4:1 (Gilles and Lawrence, 1985). In the presence of whey proteins either the casein is carrying a higher ratio of moisture or the whey protein is also binding roughly the same proportion of water as the casein.

The conflicting resports in the literature on yield increases in UF Cheddar cheesemaking are not easily compared

because the basis for yield calculation is often different or sometimes not given. There appear to be no yield advantages when Cheddar cheese is made from milk concentrated two-fold (Chapman et al, 1974; Green et al, 1981a) and the present study confirms this finding. Other workers utilizing retentate supplemented milks to give CF of 1.2:1 to 1.9:1 (Kealey and Kosikowski, 1985; Kosikowski et al, 1985) and water reconstituted retentates (Kosikowski, 1980) have however reported increases in yield. Nevertheless, when the data in these three papers are examined in the same way as in the present investigation, no significant increase in yield is obtained. Yield increases as high as 25% for Gouda cheese (Boer and Nooy, 1980a) have been claimed but the basis for yield calculation has not been reported. Such large increases are obviously possible only with:

(a) recovery of all the whey proteins in the milk
(b) the incorporation of extra moisture in the cheese due to the presence of whey proteins as was demonstrated in the present investigation
(c) significantly higher recovery of fat.

Increased fat recovery, while increasing yield, has little benefit on the profitability of the process since modern cheesemaking plants can recover most of the fat from the whey.

One report from Australia suggests that the yield of UF Cheddar from 5:1 retentate may be 8 - 10% higher than conventional Cheddar (Van Leeuwen et al, 1984) although theoretical calculations earlier using the Vanslyke formula estimated this increase to be about 14% (Sutherland and Jameson, 1981). A part of this yield increase was due to increased fat recovery. Results of the present investigation using a similar basis for yield calculation predict the yield advantage to be about 4 - 6% assuming that the fat losses stay at normal levels. It is unlikely that this yield advantage will be considered commercially significant. Further research is needed to investigate the means of attaining increasing yields in UF Cheddar without loss of quality.

APPENDIX I (Chapter 4)

IA - GRADING OF CHEESE

(a) Sensory grading of cheese

Reference N.Z.D.D.M. 54 (1983)

All cheeses should be graded at a temperature of 10^{o} to $13^{o}C$.

(i) Colour and appearance: This assessment is made by visual examination of the plug taken from the cheese.

(ii) Flavour and odour: The odour is assessed by sniffing a sample of cheese taken with the trier. The taste is assessed by placing a small portion in the mouth and tasting to check for undesirable flavours.

(iii) Body and consistency: The assessment of the body and consistency of cheese is made by rubbing a portion of the sample between the thumb and the forefinger.

(iv) Closeness and texture: Closeness and texture are assessed by examination of the cheese plug.

(b) Definition of degree terms

Slight (Sl.) - detectable only on critical examination.
Definite (Def.) - easily detectable.
Pronounced (Pron.) - markedly identifiable and present to a large degree.

(c) Guidelines for grading Cheddar cheese

(i) Colour: The cheese may be natural or coloured but should be uniform. Slight seaminess may be permitted but it must not be mottled or bleached (Table 12.1).

(ii) Flavour: The flavour should be pleasing and the cheese should be free from any feed taints and undesirable flavours and odours.

When assessing Cheddar cheese for flavour it is important to note the age of the cheese because as it matures various flavours develop, some of which may be undesirable. For a cheese to score 7 - 10 points, at 35 days of age, it should have no flavour defects. Cheese scoring 6 points may have slight flavour defects but must still be acceptable to all consumers. Cheese with definite flavour faults would score below 6 points and if unsound, fermented, unclean or sulphide would score less than 5 points, depending upon the intensity of the flavour (Table 12.1).

(iii) Body: The body of a freshly drawn sample should be firm and appear solid, smooth and compact. Cheese scoring 4 or 5 points would not be commented upon. Cheese scoring under 4 points will be downgraded according to seriousness of the defect. When a fault is not serious, the word "slight" is used before describing the defect.

(iv) Texture: Cheddar cheese should have a close texture but may possess a few mechanical holes. The cheese is downgraded according to the seriousness of the defect (Table 12.1).

Table 12.1 Guidelines for grading Cheddar cheese

	Body, texture and colour points			
	5	4	3	2 1
Body (1)				
Chalky		S	D	P
Curdy		S	D	P
Doughy		S	D	P
Floury		S	D	P
Gritty			S	D P
Lacks smoothness		S	D	
Lumpy			D	P
Mealy			D	P
Overfirm		S	D	P
Pasty			S	D P
Tender		S(2)	D	
Weak				D P
Texture				
Fractured			S	D P
Loose			S	D P
Open		S	D	P
Pinny			S	D P
Slitty				D
Ragged				D
Colour				
Bleached				D
Mottled			S	D

S = Slight D = Definite P = Pronounced

Notes:

(1) It is essential that graders take the analysis and the age of the cheese into consideration when making an assessment of the body.

(2) Especially when FDM is high.

Table 12.1 (Continued)

	Flavour points				
	10-8	7	6	5	4	3-1
Astringent			S	D	P	
Bitter			S	D		
Cowy			S	D		
Fermented				S	D	P
Flat		S	D			
Fruity			S	D	P	
Musty			S	D	P	
Off-flavour			S	D	P	
Oxidised				S	D	P
Salty		S	D	P(harsh)		
Sharp		S	D	P		
Sour		S	D	P		
Stale			S	D		
Sulphide			S	D	p	
Uncharacteristic			S	D	P	
Unclean				S	D	P
Unsound					D	P
Weedy			S	D	P	

Note:
The intensity of flavour will vary as the cheese matures. A little sulphide or fruity flavour is acceptable as the cheese ages.

APPENDIX IB

SELECTION AND TRAINING OF PANELISTS

Panelists were selected from staff members of N.Z.D.R.I., based on the method of Zook and Wessman (1977). Each prospective panelist was required to evaluate some fourteen to sixteen triangles of restructured cheese, two triangles being administered at each session. Restructured cheese was used for the screening procedure since dilution techniques could be used to make the differences between samples progressively smaller. Several of the triangles were reversed although these triangles were administered at different sessions, to prevent the panelists discriminating on the way the test was administered rather than on the samples. Panelists were ranked on their ability to discriminate between samples. Prospective panelists who were ranked in the top third went forward into a training programme. This screening procedure was followed by an eight week training programme. During this training programme, four half-hour round table discussion sessions were held each week. Each panelist was expected to participate in at least three sessions per week. During the last week of training, 'half-blind' sessions were held in which panelists made individual judgements in the sensory panel room before joining other panelists for further discussion of the scores and the chance to retaste the samples.

APPENDIX IC

QUESTIONNAIRE USED TO EVALUATE CHEDDAR CHEESE SAMPLES

Name _____ Date _____

CHEDDAR CHEESE PANEL

In front of you are several samples of Cheddar cheese. Please evaluate them for the following characteristics using a 0-10 scale where

0 = Absent
2 = Threshold
4 = Weak
6 = Moderate
8 = Strong
10 = Intense

	Sample Nos.			
	_____	_____	_____	_____
TEXTURE:				
1. Firmness (Soft ——> Firm)	_____	_____	_____	_____
2. Rubberiness (Not rubbery ——> Very rubbery)	_____	_____	_____	_____
3. Crumbliness (Not crumbly ——> Very crumbly)	_____	_____	_____	_____
4. Smoothness (Not smooth ——> Very smooth)	_____	_____	_____	_____
5. Stickiness (Not sticky ——> Very sticky)	_____	_____	_____	_____
6. 'Bittiness' (Not 'bitty' ——> Very 'bitty')	_____	_____	_____	_____
7. Other				
a. _____	_____	_____	_____	_____
b. _____	_____	_____	_____	_____

COMMENTS:

APPENDIX IC (Continued)

FLAVOUR

Name _____ Date _____

	Sample Nos.			
	_____	_____	_____	_____
FLAVOUR:				
1. Acid/sour				
a. _____	_____	_____	_____	_____
b. _____	_____	_____	_____	_____
2. Fruity/Fermented	_____	_____	_____	_____
3. Sulphide	_____	_____	_____	_____
4. Sharpness	_____	_____	_____	_____
5. Bitterness	_____	_____	_____	_____
6. Other				
a. _____	_____	_____	_____	_____
b. _____	_____	_____	_____	_____
c. _____	_____	_____	_____	_____

COMMENTS:

APPENDIX ID

DEFINITION OF TERMS USED BY THE SENSORY PANEL TO EVALUATE THE EXPERIMENTAL CHEESES

TEXTURE

Firmness: The amount of force required to take the first bite of cheese, assessed using the front teeth.

Rubberiness: The degree to which the cheese returns to its initial form after biting, assessed during the first two to three chews.

Crumbliness: The degree to which the cheese structure falls apart and breaks up during the initial two to three chews.

Smoothness: The smoothness of the cheese against the palate as it breaks down during mastication.

Stickiness: The stickiness of the cheese against the palate and around the teeth during mastication.

Bittiness: The degree of 'bittiness' or graininess in the mouth just before swallowing.

APPENDIX ID (Continued)

FLAVOUR

Acid: A 'clean' flavour similar to that of a dilute solution of mineral acid, usually perceived at the back and sides of the tongue.

Sour: A 'dirty' flavour often associated with fermented-type flavours perceived at the back and sides of the tongue but tending to linger in the mouth as an aftertaste.

Fruity/ Fermented: Associated with products that have been fermented. In cheese, this group of characteristic flavours includes flavours described as: yeasty, alcoholic, ethanol, fizzy, efferves -cent, tangy, fruity.

Sulphide: Group of characteristic flavours in cheese which may have the distinctive character of hydrogen sulphide or may variously be described as feedy, weedy, cabbagey, oniony etc. (possessing a note similar to that found in the sulphur-containing vegetables).

Sharpness: A 'peppery' characteristic perceived on the tongue which tends to linger - often associated with the flavour of very mature Cheddar cheese.

Bitterness: One of the four basic tastes perceived at the back of the tongue, tending to linger on as an aftertaste. In cheese this is caused by the presence of bitter peptide compounds and is similar to the bitterness found in UHT milk after prolonged storage.

APPENDIX IE

SUMMARY OF STATISTICAL ANALYSIS OF SENSORY PANEL RESULTS

	Experimental factors			
	Replicate	Treatment	Month	Trt x Month
Attribute:				
Firmness	37.37 *	15.03 ns	0.92 ns	2.47 ns
Rubberiness	1.24 ns	3.93 ns	12.93 *	0.33 ns
Crumbliness	0.77 ns	0.13 ns	0.37 ns	3.99 ns
Smoothness	2.16 ns	1.01 ns	0.08 ns	4.26 ns
Stickiness	17.26 ns	0.04 ns	3.21 ns	3.06 ns
Residual Mouthfeel	10.66 ns	1.42 ns	0.71 ns	0.32 ns
Acid/sour	4.55 ns	0.00 ns	0.09 ns	0.17 ns
Fruity/ Fermented	2.88 ns	1.88 ns	0.16 ns	0.70 ns
Sulphide	0.03 ns	0.69 ns	0.10 ns	1.59 ns
Sharpness	0.84 ns	0.11 ns	0.00 ns	0.15 ns
Bitterness	1.16 ns	0.25 ns	0.21 ns	0.00 ns

ns not significant

* significant at 5% level of significance

APPENDIX II (Chapter 6)
IIA - SLURRY CALCULATIONS

Given: Moisture in cheese = 35.2%
Salt in cheese = 1.75%
Total solids in WPC = 10.0%
Total protein in WPC = 84.0% (DM basis)

Target: Total solids in slurries = 40.00%
Salt in moisture = 4.2%

Calculations

Control slurry

Quantity of cheese in each bottle = 600 g.

Total moisture in 600 g cheese = 600 x 35.2
= 211.2 g.

If x is the amount of water to be added:

$$\frac{\text{Total moisture in 600 g cheese + x}}{\text{Total quantity of cheese + x}} = \frac{60}{100}$$

$$\frac{211.2 + x}{600 + x} = 0.6$$

$$211.2 + x = 0.6(600 + x)$$

$$0.4\,x = 360 - 211.2$$

$$x = \frac{360 - 211.2}{0.4}$$

$$= 372 \text{ g}$$

Therefore, 372 g water needs to be added to 600 g of cheese.

Salt:

Total salt in 600 g cheese = 600 x 1.75
= 10.5 g

Total salt required = (Total moisture in cheese + Total added water) x 4.2
= (211.2 + 372) x 4.2
= 24.4 g

Total salt to be added = 24.4 - 10.5 = 13.9 g

Slurry B (corresponding to 20% retention of undenatured whey protein)

In this slurry, one quarter of the water to be added was replaced by WPC.

$$\text{Quantity of WPC} = \frac{372}{4} = 93.0 \text{ g}$$

Quantity of water = 372 - 93 = 279 g

However, the solids in 93.0 g WPC would increase the solids beyond calculated 40.0%. Therefore, extra water was added to compensate for extra solids in WPC.

Solids in 93.0 g WPC = 9.3 g

$$\text{Extra water to be added} = \frac{9.3}{0.4} = 23.3 \text{ g}$$

Salt

Total salt in 600 g cheese = 10.5 g (as for slurry A).

Total salt required = (Water to be added
+ extra water to be added
+ water in WPC
+ water in 600 g cheese)
x 4.2

= (279 + 23.3 + 83.7 + 211.2)
x 4.2

= 25.1 g

Therefore:

Total salt to be added = 25.1 - 10.5
= 14.6 g

APPENDIX IIB

SCORE CARD FOR TASTE PANEL OF SLURRIES

Date _____ Judge _____

Reference Scale	0 None	2 Slight	4 Moderate	6 Pronounced	8 Very pronounced

Attribute	Sample No.
1. Acid	
2. Bitter	
3. Diacetyl	
4. Fruity	
5. Lipolytic rancidity	
6. Salty	
7. Unclean	
8. Others	
_____	
_____	
9. Overall Score	

APPENDIX IIC - AVERAGE TASTE PANEL SCORES FOR SLURRIES

Day	Treat-ment*	Acid	Bitter	Diacetyl	Flavour Attribute: Fruity/ Fermented	Flavour Attribute: Lipolytic Rancidity	Flavour Attribute: Salty	Flavour Attribute: Unclean	Flavour Attribute: Whey Protein	Overall Score
0	A	2.94	0.67	1.28	1.00	0.11	4.61	0.08	0.44	2.89
	B	3.06	1.33	1.17	1.11	0.33	4.06	0.06	0.61	3.17
	C	3.39	1.00	1.11	0.72	0.78	3.94	0.09	0.22	3.06
	D	3.50	0.61	0.94	0.89	0.39	3.89	0.08	0.11	3.11
	X	3.61	0.94	1.11	0.89	0.11	4.11	0.11	0.44	3.67
	Y	3.22	0.72	1.67	0.72	0.44	3.72	0.22	0.56	3.17
	Z	3.17	0.94	1.50	0.78	0.33	4.06	0.08	0.33	3.22
3	A	2.94	1.22	1.00	1.56	0.61	3.78	0.33	0.50	3.33
	B	3.39	1.44	1.00	1.39	0.44	3.83	0.72	0.61	2.89
	C	3.28	1.61	1.00	1.33	0.89	3.94	0.61	0.78	3.22
	D	3.44	1.44	0.50	1.56	0.94	3.67	0.67	0.56	3.22
	X	3.06	1.67	0.44	1.44	0.83	4.00	0.78	0.33	3.00
	Y	3.28	1.44	1.61	1.11	1.06	3.78	0.56	0.28	3.50
	Z	3.17	1.28	1.00	1.17	0.89	3.83	0.44	0.83	3.61
6	A	3.06	1.56	0.72	1.83	0.89	4.00	0.78	0.39	4.00
	B	3.17	1.72	0.61	1.56	1.06	4.00	0.56	0.44	3.94
	C	3.39	1.39	0.56	1.50	1.06	3.83	0.17	0.78	4.06
	D	3.33	1.50	0.78	1.50	1.11	3.78	0.67	0.83	4.17
	X	3.00	1.39	0.72	0.94	1.00	4.00	0.67	0.33	4.22
	Y	2.94	1.28	1.00	1.28	0.83	3.83	0.39	0.22	4.56
	Z	3.78	1.61	1.00	1.83	1.50	3.94	0.50	0.50	4.44

* see experimental plan (Chapter 6)

APPENDIX IID

CHEMICAL COMPOSITION OF WHEY PROTEIN POWDER (ALACEN 343)* SUPPLIED BY NEW ZEALAND DAIRY BOARD

Constituent	%
Moisture	4.5
Total Protein	80.0
Fat	4.4
Ash	3.3
Lactose	7.8

* from acid casein whey

APPENDIX IIE

CALCULATIONS FOR WHEY PROTEIN ADDITION TO MILK (Chapter 6)

Assume: (i) Whey protein content of milk = 0.7%
(ii) One third of the whey proteins in milk are retained in 5.1 UF cheese.

Given: In conventional method, 5% of the whey proteins in milk are retained in the cheese.

Calculations:

Consider 100 kg milk. Whey protein content = 0.7 kg

Required whey protein content of the cheese = $\frac{0.7}{3}$ kg

= 0.24 kg (approximately)

Now, 5% corresponds to 0.24 kg

100% corresponds to 4.8 kg

Whey protein already present in milk = 0.7 kg

Therefore whey protein to be added = 4.8 - 0.7

= 4.1 kg

If the whey protein powder contains 80% w/w of whey protein,

Quantity of whey protein powder required = $\frac{4.1}{0.8}$

= 5.1 kg.

APPENDIX III (Chapter 7)

APPENDIX IIIA - QUESTIONNAIRE USED TO EVALUATE UF CHEDDAR CHEESE SAMPLES

Name _____ Date _____

CHEDDAR CHEESE PANEL

In front of you are several samples of Cheddar cheese. Please evaluate them for the following characteristics using a 0-10 scale where:

0 = Absent
2 = Threshold
4 = Weak
6 = Moderate
8 = Strong
10 = Intense

	Sample Nos.			
	_____	_____	_____	_____
TEXTURE:				
Firmness (Soft -> Firm)	_____	_____	_____	_____
Rubberiness (Not rubbery -> Very rubbery)	_____	_____	_____	_____
Crumbliness (Not crumbly -> Very crumbly)	_____	_____	_____	_____
Smoothness (Not smooth -> Very smooth)	_____	_____	_____	_____
Stickiness (Not sticky -> Very sticky)	_____	_____	_____	_____
'Bittiness' (Not 'bitty' -> Very 'bitty')				
a. Mealy/Curdy	_____	_____	_____	_____
b. Gritty/Sandy	_____	_____	_____	_____
Other_____	_____	_____	_____	_____

FLAVOUR:

Acid/Sour _____	_____	_____	_____	_____
_____	_____	_____	_____	_____
Fruity/Fermented	_____	_____	_____	_____
Sulphide	_____	_____	_____	_____
Sharpness	_____	_____	_____	_____
Bitterness	_____	_____	_____	_____
Other_____	_____	_____	_____	_____

COMMENTS:

APPENDIX IIIB

DEFINITION OF ADDITIONAL TERMS USED BY THE SENSORY PANEL TO EVALUATE UF CHEDDAR CHEESES

a. Mealiness: The degree of 'mealiness' or graininess in the mouth just before swallowing.

b. Grittiness: The amount of hard, particulate matter perceived during final mastication of the cheese (often caused by the presence of calcium lactate in the cheese).

Note: Definition of other terms used in the questionnaire is shown in Appendix ID.

APPENDIX IIIC

SUMMARY OF STATISTICAL ANALYSIS OF SENSORY PANEL RESULTS

Control vs 3:1 vs 5:1 Cheddar

	F Ratios				
Attribute	Replicate	Treatment	Time	Treatment x Time	Error
A. Texture					
Firmness	1.45 ns	5.05 ns	0.58 ns	0.11 ns	2.39 *
Rubberiness	0.07 ns	11.74***	11.28***	0.16 ns	0.89 ns
Crumbliness	1.34 ns	5.73 *	20.81***	0.08 ns	2.62 **
Smoothness	1.43 ns	9.97 *	18.83***	0.07 ns	0.87 ns
Stickiness	0.59 ns	5.19 *	57.09***	1.23 ns	1.73 ns
Mealiness	0.41 ns	15.29***	35.27***	0.18 ns	0.59 ns
Grittiness	3.35 ns	3.22 ns	0.10	1.65 ns	2.41 *
B. Flavour					
Acid/Sour	4.30 ns	6.58 *	28.90***	0.15 ns	0.83 ns
Fruity/ Fermented	0.12 ns	3.00 ns	27.29***	0.14 ns	0.35 ns
Sulphide	0.71 ns	1.51 ns	16.83***	0.29 ns	0.79 ns
Sharpness	8.57 *	10.98 **	47.17***	0.76 ns	0.39 ns
Bitterness	2.63 ns	1.95 ns	2.67 ns	0.07 ns	0.53 ns

ns not significant
* significant at 5% level
** significant at 1% level
*** significant at 0.1% level

APPENDIX IIID

PREPARATION OF GEL SOLUTION AND REAGENTS FOR POLYACRYLAMIDE THICK SLAB ELECTROPHORESIS

(i) Separating gel (100 ml)

Acrylamide	11.50 g	12% PA
"Bis"	0.50 g	4.2% cross linked
"Tris"	2.90 g	240 mM
Temed	200.0 µl	13.4 mM
HCl 1M	5.0 ml	50 mM
EDTA	0.08 g	2.2 mM
Water	80 ml	pH 8.9

The gel solution was degassed, temperature adjusted to 20°C and 0.1% fine-ground ammonium persulphate (dissolved in a small amount (2 ml) water) was added, quickly swirled and immediately poured.

(ii) Electrode chamber buffer (2 l)

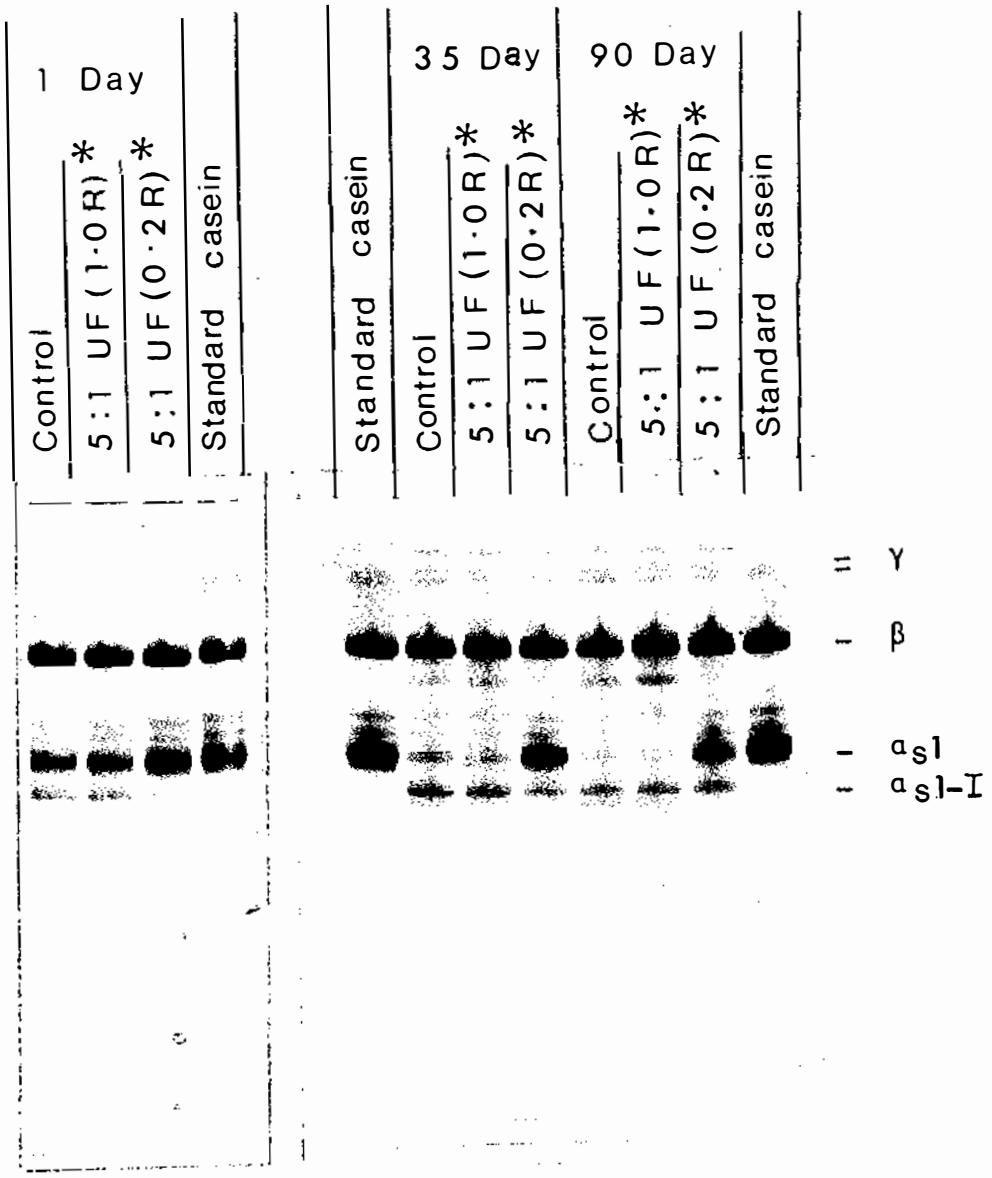
"Tris"	1.0 g	4.1 mM
Glycine	7.5 g	50 mM
Water to	2 l	pH 8.46

(iii) Stacking gel (50 ml)

"Cynaogum"	3.5 g	7% PA
"Temed"	50.0 l	6.7 mM
EDTA	0.07 g	3.6 mM
Electrode chamber buffer	47 ml	pH 8.5

The gel solution was warmed to 20°C, degassed and 0.1% ammonium persulphate (dissolved in a small amount (2 ml) water) was added, quickly swirled and poured.

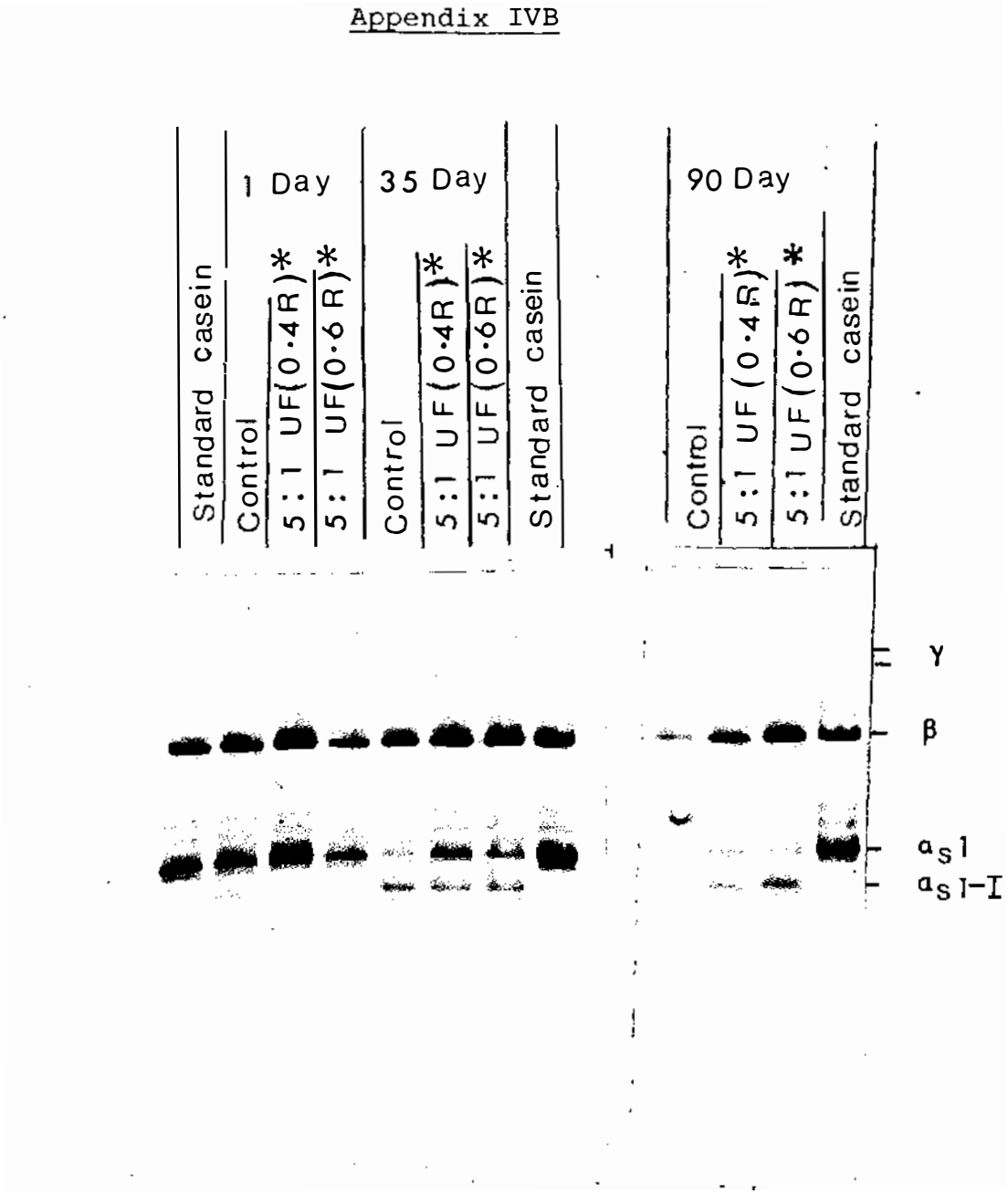
Appendix IVA



Polyacrylamide gel electrophoresis of cheese made from control milk, 5:1 UF (1.0 R*) and 5:1 UF (0.2 R*) at various stages of maturation (series 1*).

*see Experimental Plan (Chapter 8)

Appendix IVB



Polyacrylamide gel electrophoresis of cheese made from control milk, 5:1 UF (0.4 R*) and 5:1 UF (0.6 R*) at various stages of maturation (series 2*).

*see Experimental Plan (Chapter 8)

APPENDIX IVC

SUMMARY OF STATISTICAL ANALYSIS OF SENSORY PANEL RESULTS
Control vs 5:1 UF (0.4 R)[+] vs 5:1 UF (0.6 R)[+]

Attribute	'F' ratios Replicate	Treatment	Time	Treatment x Time
A. TEXTURE				
Firmness	3.24 ns	33.75 **	2.23 ns	0.21 ns
Rubberiness	12.65 *	83.86 ***	66.93 ***	5.13 ns
Crumbliness	0.56 ns	11.45 *	0.03 ns	1.29 ns
Smoothness	2.63 ns	13.79 *	1.62 ns	0.93 ns
Stickiness	3.95 ns	7.78 *	0.17 ns	0.57 ns
Mealiness	2.42 ns	4.52 ns	3.55 ns	0.06 ns
Grittiness	2.07 ns	6.89 ns	8.58 *	11.75 **
B. FLAVOUR				
Acid/sour	13.13 *	29.55 *	19.80 **	1.83 ns
Fruity/ Fermented	54.85 **	234.55***	39.69 ***	0.25 ns
Sulphide	10.50 *	64.80 ***	21.06 **	7.85 *
Sharpness	12.68 *	55.10 **	4.13 ns	1.06 ns
Bitterness	10.22 *	24.73 **	0.52 ns	0.04 ns

ns not significant
* significant at 5% level of significance
** significant at 1% level of significance
*** significant at 0.1% level of significance

[+] see experimental plan

APPENDIX VA (Chapter 10)

CALCULATIONS FOR WHEY PROTEIN SUPPLEMENTATION OF UF PERMEATE

Percentage of W.P. in milk = 0.7 (approximately)

Kg W.P. in 100 kg 5:1 retentate = 3.5 kg

Approximate kg moisture in 5:1 retentate = 62 kg

Ratio of W.P./moisture = 5.64

The objective was to obtain the same W.P./moisture ratio in permeate.

Approximate % moisture in permeate = 95

Therefore W.P. to be added to 100 kg permeate = $\frac{5.64}{0.95}$

= 7.425 kg

Quantity of W.P. powder needed for

40 kg permeate = 7.425 x 0.4

= 2.97 kg

= 3.00 kg (approximately)

Note: W.P. = Whey Protein

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