TECHNOLOGICAL ASPECTS OF THE MANUFACTURE OF HALLOUMI CHEESE

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Food Technology at Massey University

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STATEMENT OF INTENT

Technological research may be considered to be of three different forms:

1. Fundamental research. The objective is to increase the knowledge base from which industry functions. Application of findings may take more than 10 years.

2. Mission-orientated research. This is research with specific objectives undertaken in specific areas. Application of findings by industry may take between 1 and 10 years.

3. Development research. This entails the application and adaption of existing scientific knowledge. The target for utilizing industry is normally less than 1 year.

In this thesis most of the work described falls into categories 2 and 3. Relatively little attention has been applied to more fundamental research.

ABSTRACT

Halloumi cheese is made in some Middle Eastern countries from sheep's and goat's milk. It is a hard, unripened white cheese that tastes like immature Cheddar, and it has the capacity to melt and stretch when heated.

The present investigation was undertaken to provide information on the manufacture of Halloumi cheese from fresh cow's milk, to define a process for its manufacture from recombined milk, and to examine the application of ultrafiltration procedures to Halloumi manufacture.

The first part of the research programme was conducted in order to determine the optimal manufacturing conditions for making Halloumi from fresh cow's milk, and to establish appropriate methods of measuring physical properties of the cheese (stretchability, meltability and fat loss). It was found that those manufacturing variables which altered the rate and extent of acid development (percentage of starter, priming, cooking temperature and time) had a marked effect on cheese physical properties. These variables could be altered by the cheesemaker to optimize Halloumi properties.

Previous reports indicated that Halloumi with desired properties could not be made from recombined milk. The second part of this thesis describes a study of the manufacture of Halloumi from recombined milk (milk made by recombining skim milk powder with anhydrous milkfat). Two main reasons for this were considered, namely, the effect of homogenization treatment used in the recombining process, and the quality of the powder used.

It was demonstrated that high homogenization pressures resulted in poor stretchability and meltability of the cheese. In contrast low pressure homogenization gave cheese with satisfactory properties. A model based on the viscoelastic behaviour of polymer systems was described in an attempt to explain how the homogenization treatments influence the stretching behaviour of the cheese network, and it was possible to verify the model in suitable experiments.

The preheat temperatures of the skim milk used in the manufacture of skim milk powders were also shown to markedly affect the properties of the cheese. High preheat temperature resulted in reduced stretchability and meltability of the cheese. It was likely that this was due to alteration of the mineral balance and to denaturation of whey proteins. The concentration of total solids prior to spray drying was shown to have no significant effect on the properties of the cheese.

In the final part of the investigation, the application of UF to the manufacture of Halloumi cheese was studied using fresh UF milk, and skim milk powder prepared from UF skim milk. When a 5:1 UF concentrate of fresh milk was used, some modification in the setting time and cutting device was necessary. The quality of UF Halloumi was very similar to that of the control cheese.

In considering the manufacture of Halloumi from recombined milk using UF skim milk powder, the effects on the cheese quality of variations in the ratio of protein to fat, in the solids concentration of the recombined milk, and in the calcium content of the UF skim milk powder were investigated. Best results were obtained when the cheese was manufactured from recombined milk with a low protein-to-fat ratio. The use of low-calcium UF skim milk powder, as opposed to high-calcium powder, resulted in some improvement in the quality of the cheese. Varying the concentration of the recombined milk solids had no significant effect on the cheese properties.

The present investigation has demonstrated that good quality Halloumi cheese having the desirable typical stretchability and meltability can be made not only from fresh cow's milk, but also from recombined and UF milks provided that appropriate materials and manufacturing procedures are used.

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1- A REVIEW OF HALLOUMI CHEESE

1.1 Product Characteristics

Halloumi cheese is an important cheese in Cyprus and some parts of the Middle East. It is a hard, unripened product with a bright white colour and tastes like immature Cheddar cheese. Halloumi should have good stretchability and meltability characteristics.

Halloumi cheese may be consumed directly with bread or may be fried with oil. Sometimes it is used as a material for making a special dessert or sweet known as Kunafa.

1.2 Traditional Manufacture

Traditionally Halloumi cheese is made from sheep's or goat's milk or from a mixture of both. The manufacture of Halloumi cheese from these starting materials has been described by Davis (1976) and Scott (1981). Figure 1 gives an outline of the process described by these authors.

Sheep or goat's milk (6% fat)
Without heat treatment or sometimes with low temperature treatment

↓

Add rennet at 30-34°C. Hold for 40 min.

↓

Cut curd into 2-4 cm cubes. Stir gently and raise temperature to 38-42°C within 20 min.

↓

Allow curd to settle, then press curd by hand to bottom of vat.

↓

Drain off and retain the whey. Heat the whey to 80-90°C to precipitate the whey proteins. Filter.

↓

Cut the curd into 10 kg blocks, place these on large cloths and press. Cut the curd from the press into 10 x 15 x 5 cm blocks. Place the blocks in boiling deproteinated whey for 40-80 min.

↓

Cool the blocks at room temperature for 10-20 min and sprinkle 5% salt onto the curd and hold for 4 h. After that place the curd in containers with 30% brine at room temperature.

Figure 1. Manufacturing scheme for Halloumi cheese from sheep's milk

1.3 Product Composition

Cheesemakers usually use the parameters, moisture in non-fat substance (MNFS), fat in dry matter (FDM) and salt-in-moisture (S/M) for evaluating cheese composition.

There is little data available on the chemical composition of Halloumi cheese. Anifantakis & Kominarides (1983) analysed different samples of Halloumi cheese purchased from Cyprus and also made and analysed some Halloumi from sheep's milk (see Table 1).

These investigators found a very wide range of composition for their samples, especially for the Halloumi from Cyprus. They attributed this variation in chemical composition to a lack of uniformity in milk composition and manufacturing procedure.

They also compared the methods of manufacture of Halloumi from sheep's and cow's milk and the composition of the resultant cheeses. The comparison showed different fat contents in the sheep's and cow's milk but the same ratio of fat to protein was used. There was a different size of curd during cutting, 1 cm for curd made from sheep's milk and 0.5 cm for curd from cow's milk. The sheep's milk was cooked at a lower temperature and for a shorter period of time than the cow's milk.

On comparing the composition of cheese made from sheep's and cow's milk, Antifantakis & Kominarides (1983) found that the pressed curd from sheep's milk had a higher moisture, 51.8% as against 50.4%. The fat content in the whey from cow's milk was higher 0.43% as against 0.34%.

Table 1. Published figures of the composition of Halloumi cheese made from sheep's milk

Components	Halloumi cheese made in pilot-scale studies[1]			Halloumi cheese from Cyprus markets[2]		
	Mean	Values Range	Standard deviation	Mean	Values Range	Standard deviation
Moisture (%)	42.15	39.04-43.84	1.39	42.53	35.46-48.56	3.75
MNFS[3] (%)	58.42	-	-	57.14	-	-
FDM (%)	48.09	46.10-49.99	1.95	44.52	37.95-50.48	3.98
S/M[3] (%)	3.42	-	-	8.32	-	-
Protein (%)	23.71	21.95-25.02	1.02	24.46	20.86-30.45	2.28
Soluble protein (%)	0.76	0.64- 0.89	-	1.15	0.83- 1.55	1.14
pH	5.86	5.30- 6.10	0.22	-	-	-

Data from Anifantakis & Kominarides, 1983 .

[1]13 samples.
[2]17 samples.
[3]Calculated from the data.

2. OBJECTIVE OF THE INVESTIGATION

There is a good market for Halloumi cheese in many countries of the Middle East. The objective of the first part of the present investigation was to produce this cheese type from fresh cow's milk. The New Zealand Dairy Board would then have the variety available for export.

Some countries in the Middle East would prefer to make their own cheese from recombined milk rather than purchase the finished product. The objective of the second and third parts of the study was to develop a procedure for making Halloumi cheese from recombined milk (milk powder + anhydrous milkfat + water) based on experience gained from the first section of the investigation.

A satisfactory product cannot be made from conventional skim milk powder. This is because the cheese so made lacks the desired stretchability and meltability characteristics (Gilles, private communication; O'Keeffe & Phelan, 1983).

PART A

HALLOUMI CHEESE FROM COW'S MILK*

*Part of this work has been published in the New Zealand Journal of Dairy Science and Technology, 22, 181-189 (1987).

A-1 INTRODUCTION

Halloumi cheese is traditionally made from sheep's or goat's milk, whereas the objective of the present work is to make the product from cow's milk. There is relatively little information describing the manufacture of Halloumi from cow's milk. Anifantakis & Kominarides (1983) briefly described the conditions for making such Halloumi. Also Kristensen (1986) described a manufacturing scheme using cow's milk to which ovine lipase, 1-2% yoghurt culture and rennet were added. To date, a detailed study of Halloumi manufacture from cow's milk has not been reported and there is no information on how the process should be optimized.

In the past, methods have been developed to make from cow's milk a number of varieties of cheese traditionally produced from sheep's or goat's milk. For example, Feta cheese can now be made from cow's milk. The main problems lie with the colour and flavour of the product rather than with the manufacturing procedure.

Given the experience in New Zealand in manufacturing a range of cheese types, the information available on Halloumi and the importance of the variety, it was decided to investigate the manufacture of Halloumi from cow's milk under New Zealand conditions.

A-2 EXPERIMENTAL APPROACH

This study was confined to finding ways of manufacturing and of improving the composition and quality of Halloumi cheese. The following experimental plan was adopted.

Development of a preliminary procedure for making cheese from cow's milk under New Zealand conditions.

Development of procedures for testing the stretchability, meltability and fat loss characteristics of the cheese.

Investigation of how variations in manufacturing procedures influence the quality of the final product (organoleptic, chemical composition and physical properties).

A-3 DEVELOPMENT OF PRELIMINARY PROCEDURE FOR MAKING HALLOUMI CHEESE FROM COW'S MILK UNDER NEW ZEALAND CONDITIONS

A-3.1 Introduction

The objective of this study was to start with cow's milk and make Halloumi that possessed the main characteristics of the cheese variety using a manufacturing scheme based on that shown in Fig. 1. In some of the trials, attempts were made to use brine salting rather than dry salting as the former process is much simpler on a commercial scale. Experience at the New Zealand Dairy Research Institute suggests dry salting is not essential.

The main characteristics of Halloumi are that it should stretch and melt on heating. Traditionally the folding test is used to assess the stretchability of the cheese after heating.

Composition is also important. The target adopted here was that the product lay within the specification reported in Table 1.

A-3.2 Experimental

Twenty-four vats of Halloumi cheese were manufactured in this section of the study (22 vats with starter and two without starter).

A-3.2.1 Milk supply

Whole milk was obtained from the Manawatu Co-operative Dairy Company. The milk (about 50-100 l, depending on the trial) was then pasteurized at 72°C/15 s (Alfa-Laval plate heat exchanger with capacity of 2500 kg/h) and standardized to the required casein to fat ratio using pasteurized skim milk. The resultant standardized milk was cooled to 33-34°C.

A-3.2.2 Cheesemaking

The method used for manufacturing Halloumi was a manual procedure based on that described in Fig. 1, except for the differences mentioned below.

1. Standardized cow's milk was used for cheesemaking.

2. After coagulation, curd was cut into 0.5 cm cubes.

3. In some of the trials the curd was dry stirred.

4. Small hoops (about 10 kg cheese) were used.

5. For pressing, a vertical pneumatic press was used.

6. The curd was pressed for one hour (15 min at 70 kPa, 15 min at 140 kPa and 30 min at 210 kPa).

7. The curd from the press was cut into 10 x 15 x 3 cm blocks.

8. Attempts were made to use brine salting rather than dry salting in some of the trials.

9. The cheeses were packed in polythene bags and stored at 8°C.

A-3.3 Analytical Procedures

A-3.3.1 Sample preparation

A block of cheese (0.4-0.8 kg) of at least two weeks of age was finely grated, mixed thoroughly to secure a representative sample and stored in screw-cap polyethylene bottles in a refrigerator at 4°C.

A-3.3.2 Chemical analyses

The cheese samples were analysed for moisture content, fat content and pH. Details of the methods are given in Table A.5.

A-3.3.3 Physical properties

A-3.3.3.1 Folding test. Folding the curd is an important step of Halloumi cheesemaking. A curd piece of normal size is folded manually after heating in hot whey. If the curd stretches properly it should have a smooth fibrous, unbroken surface. If stretching is inadequate the resultant cheese will be cracked after folding.

A-3.4 Results and Discussion

A-3.4.1 Manufacture without starter

In the first trial (data is not reported), cheese was made without starter. Pasteurized milk was set with rennet at the rate of 16 ml/100 l of milk at 33°C. After 60 min the curd was cut with 0.5 cm knives and the vat contents then heated to 37°C for 20 min. The pH of the curd during processing was high and stretchability of the curd was poor. Clearly, the low bacterial count in pasteurized milk is not sufficient to bring about the correct ripening of the curd. Therefore in future trials starter was added.

A-3.4.2 Manufacture with starter

Data for all these trials are summarized in two tables: manufacturing data are presented in Table A.1 and the chemical composition of cheese in Table A.2.

In trial 1, 2% starter was used (*Streptococcus cremoris* 584 and 134), the casein to fat ratio was 1.2 and the resultant cheese was salted by soaking in brine (20%) for 24 h at 8°C. This cheese was found to be very hard. The hardness suggested excessive moisture loss and hence in future trials the concentration of salt in the brine was reduced to 10%.

In trials 2-8 a single strain starter (*Streptococcus cremoris* 584) was used in an attempt to reduce the final pH of the cheese. The percentage starter added was varied. These trials showed that the pH of the cheese could be altered by changing the percentage starter added to milk. Provided the casein to fat ratio was adjusted to an appropriate value the FDM was in a suitable range (should be about 40-50% according to Antifantakis & Kominarides, 1983). However, the MNFS of all these cheeses were too high.

In trials 9 and 10 a multi-strain starter (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) was used; this did not help to reduce any of the manufacturing problems.

Trials 11 to 16, a larger addition of the starter than had been tried before (trial 1) was used. This gave the pH in the correct range but the MNFS was still high.

Table A.1. Manufacturing data for 22 trials of Halloumi cheese made from cow's milk

Manufacturing steps	Trials																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Amount of milk (kg)	80	80	80	80	80	80	55	55	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Casein to fat ratio (C/F)	1.2	0.8	1.0	0.8	0.8	0.7	1.7	1.0	1.3	1.0	1.1	0.9	1.1	0.9	1.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8
Amount of starter (kg)	2.0	1.0	2.0	1.0	0.5	0.75	0.9	0.9	0.9	0.9	2.2	2.2	1.6	2.2	3.3	3.3	3.3	3.1	3.1	3.1	3.1	3.1
Type of starter	*	**	**	**	**	**	**	**	***	***	*	*	*	*	*	*	*	*	*	*	*	*
Amount of rennet added (ml)	13	13	13	13	13	13	9	9	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Time of setting (min)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	40	40	40	40	40	40
Temperature of cooking (°C)	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	40	37	37	37	37	37
Dry stirring	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No
Dry salting	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes
Time of salting	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	3	3
Percentage of salt in brine (%)	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

*, S. cremoris 584, 134.
**, S. cremoris 584;
***, L. bulgaricus + S. thermophilus

Table A.2. Composition and folding of cheese made from fresh cow's milk

Composition	Trials																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
MNFS (%)	–	–	66.1	69.5	62.5	71.3	65.2	68.3	69.1	71.4	70.1	70.1	64.6	70.2	68.3	70.1	68.3	67.0	68.8	65.2	55.3	57.9
FDM	–	–	45.4	52.2	41.5	50.9	30.7	41.2	36.5	40.6	38.2	44.9	39.2	45.5	38.1	41.8	46.5	44.8	50.4	48.5	47.2	48.8
pH	–	–	5.2	5.5	5.8	5.7	5.7	5.8	6.2	6.1	5.4	5.7	5.7	5.6	5.3	5.3	5.9	5.3	5.5	5.4	5.8	5.7
Folding	–	–	Yes	Yes	Yes	Yes	Yes	Yes	Cracked	Cracked	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

In trial 17 the time between cutting and setting was reduced to 40 min in an attempt to encourage moisture expulsion. The temperature of cooking was raised to 40°C. However, this cook temperature inhibited the starter and hence the pH was high (pH 5.9).

In trials 18-19 the 40 min between setting and cutting was retained but the cook temperature was reduced to 37°C. This gave the appropriate pH but the MNFS was still too high.

Trial 20 was carried out using the same procedure as in trial 19 but dry stirring was used during processing to reduce the MNFS. The dry stirring reduced the MNFS by about three percentage points but further moisture expulsion methods were required since the MNFS value was still unacceptable.

In the last trials, i.e. 21-22, dry salting for 16-18 h was used and the time of soaking in brine reduced to 3 h. Using this procedure the final MNFS of the cheese was 55.29% in trial 21 and 57.89% in trial 22.

In total, these trials demonstrated a procedure for making Halloumi with a composition in the middle of the range reported by Anifantakis & Kominarides (1983).

A more detailed study of the physical characteristics of the cheeses was not attempted because the trials were only of a preliminary nature.

A-3.5 Conclusion

Halloumi cheese was made from cow's milk under New Zealand conditions. Trials were made in which different factors (casein to fat ratio, percentage starter, type of starter, time of setting, cooking temperature, dry stirring, dry salting and different percent of salt in brine) were altered to reach the desirable properties of the cheese.

Most of the cheeses from the trial were high in MNFS but when the cheese was made with dry stirring and dry salting during processing, the correct MNFS was obtained.

A-4 DEVELOPMENT OF STRETCHABILITY, MELTABILITY AND FAT LOSS TESTS

A-4.1 Introduction

Various physical properties play an important role in determining the quality of cheese. One such physical property is texture. However, textural measurements of cheese are complicated. To determine texture the finished product is usually evaluated subjectively.

Textural properties depend on the procedure used to make the cheese and differ from variety to variety. Different criteria are used to evaluate different cheeses. For example, hardness, chewiness and adhesiveness for Cheddar cheese, melting and stretching for Mozzarella cheese and melting alone for processed cheese. As far as Halloumi cheese is concerned, it is the stretchability, meltability and fat loss characteristics that are important, especially when the product is incorporated into a more complicated food system such as a Kunafa.

A-4.1.1 Stretching

Stretching characteristics have been measured in different types of cheese. All the early workers studying the stretching properties of cheese used subjective methods. Kosikowski & Silverman (1951), and Kosikowski (1951), evaluated the stretching of processed Mozzarella and traditional Mozzarella cheeses by using cubes of cheese and placing them in a water bath at 74°C for 5 min. After that the cubes were moulded together between the fingers into an amalgamated mass and stretched. A similar technique for determining stretching properties was used when Covacevich (1975), tested the stretching of Mozzarella cheese made from ultrafiltered milk.

Gupta (1971) determined the elastic properties of Cheddar and Gouda cheese by measuring the length of melted cheese which is wrapped around a steel rod.

Yang & Taranto (1982) used the Weissenberg test for determining the stretchability of Mozzarella cheese analogues made from soy protein products. In this test, a rod is placed in a sample of melted cheese (heated to 80°C in a water bath) and then turned a fixed number of revolutions. The final height reached by the melted cheese on the rod is a measure of stretchability.

A-4.1.2 Melting

A large variety of methods are available for the evaluation of melting properties in cheese. Arnott et al. (1957) determined the melting quality of processed cheese by using a standard cylinder of cheese and heating it to 100°C for 15 min, allowing it to stand at room temperature for 15 min and then placing it in a refrigerator at 7.5°C. Melting was expressed as a percentage decrease in cylinder height after this heat treatment.

Olsen & Price (1958) used a different method to determine the melting properties of pasteurized processed cheese. The sample was placed in a pyrex glass tube, one end of which was closed. The tube was placed in an oven at 110°C for 8 min and the distance the melted cheese had flowed along the tube was measured.

Gupta et al. (1984) used a similar technique to determine the melting characteristics of commercial and experimental processed cheeses, but used a water bath held at 92°C for heating. Another method for determining the melting properties of Cheddar cheese is that of Weik et al. (1958). A cylinder of cheese was placed in a test tube and heated in a water bath at 80°C. The time required for the sample to melt was recorded. Harvey et al. (1982) described another melting method for processed Cheddar cheese. A piece of cheese (known dimensions) was heated in a petri dish for 6 min in an electric oven at 139°C. The melting value was calculated as the difference between the average area before and after melting of the cheese.

Gupta (1971) used a different method to determine the melting properties of Cheddar and Gouda cheeses. A slice of cheese was placed in an aluminium dish and heated for 4 min over boiling water. The meltability was calculated as the percentage increase in the area of the sample after heating.

A-4.1.3 Fat loss

A study of the fat leakage of pizza cheese during baking was made by Breene et al. (1964). A slice of cheese was placed on filter paper and held for 5 min in an air-circulation oven at 110°C. The total area covered by melted fat was measured.

In another study, Fernandez & Kosikowski (1986) used a similar technique to measure the fat leakage properties of low moisture Mozzarella cheese from ultrafiltered milk, but used 10 min time for heating.

A-4.2 Testing Procedures Selected

The objective methods developed for measuring stretching and melting in a number of cheese types may not be applicable to Halloumi since the texture and the ingredients of Halloumi are different. For example, a product with good flowability during heating is needed in the Weissenberg test. The flowability of Halloumi cheese would be expected to be insufficient to allow the use of this test. This is because Halloumi has a higher solids content and is more rigid.

Dry heating is used for determining the melting properties of processed cheese. However, this procedure is not applicable for use with cheeses like Halloumi as surface drying of the sample occurs during heating.

The filter paper method for measuring the fat loss appears to be the only method in the literature. As far as Halloumi is concerned, fat loss is probably easier to measure accurately and objectively by determining the fat loss during the melting test by standard analytical methods.

The details of the methods developed are as follows.

A-4.2.1 Stretchability test

The method was based on the testing of dough stretchability in bakery products (Faridi, 1985). The stretchability measurements were done by an Instron Food Testing Instrument (Instron Limited, High Wycombe Bucks HP 1235Y Model 1140). The Instron was fitted with 5 kg load cell and was operated with a cross head speed of 20 cm/min and chart speed of 20 cm/min.

Cheese was cut into pieces with dimensions 10 x 2 x 1.5 cm and placed in a plastic bag to prevent any losses of moisture. A special plastic plate (10 x 10 x 1 cm) was made for the test, two clips and four needles were used to fix the cheese over a 4 x 4 cm opening in the plate during testing. A stainless steel hook of 6 cm length was fixed in the cross head to pull the heated cheese (see Fig. A.1). A piece of cheese was placed on the plate and heated at 85°C for 4.5 min using a water bath. After heating, 1 min was allowed to fix the plate on the Instron machine. The stretchability was calculated as the total length in centimetres of the sample before breaking. The Instron measurements were carried out with an ambient temperature of 20°C.

A-4.2.2 Meltability test

The method was based on the procedure of Gupta (1971). A cubic sample of Halloumi cheese (2 x 2 x 2 cm) was placed in an aluminium dish. The dish was covered with cellophane and a lid to ensure a saturated atmosphere in the dish during heating. The dish was held in a boiling water bath for 25 min. After cooling, the melted cheese was lifted from the dish and placed on graph paper. The area of the melted cheese was traced with a pencil. Meltability was reported as the percentage increase in area after heating.

A-4.2.3 Fat loss test

The fat leaking from a known weight of cheese during melting was dissolved in hexane and transferred to a separation flask to wash the solution with distilled water and remove any particles from the solvent.

The solvent was decanted into the preweighed flask, then evaporated in a water bath and the flask was heated in the oven for 1 h at 105°C. The fat loss was expressed as grams of fat per 100 gram of cheese.

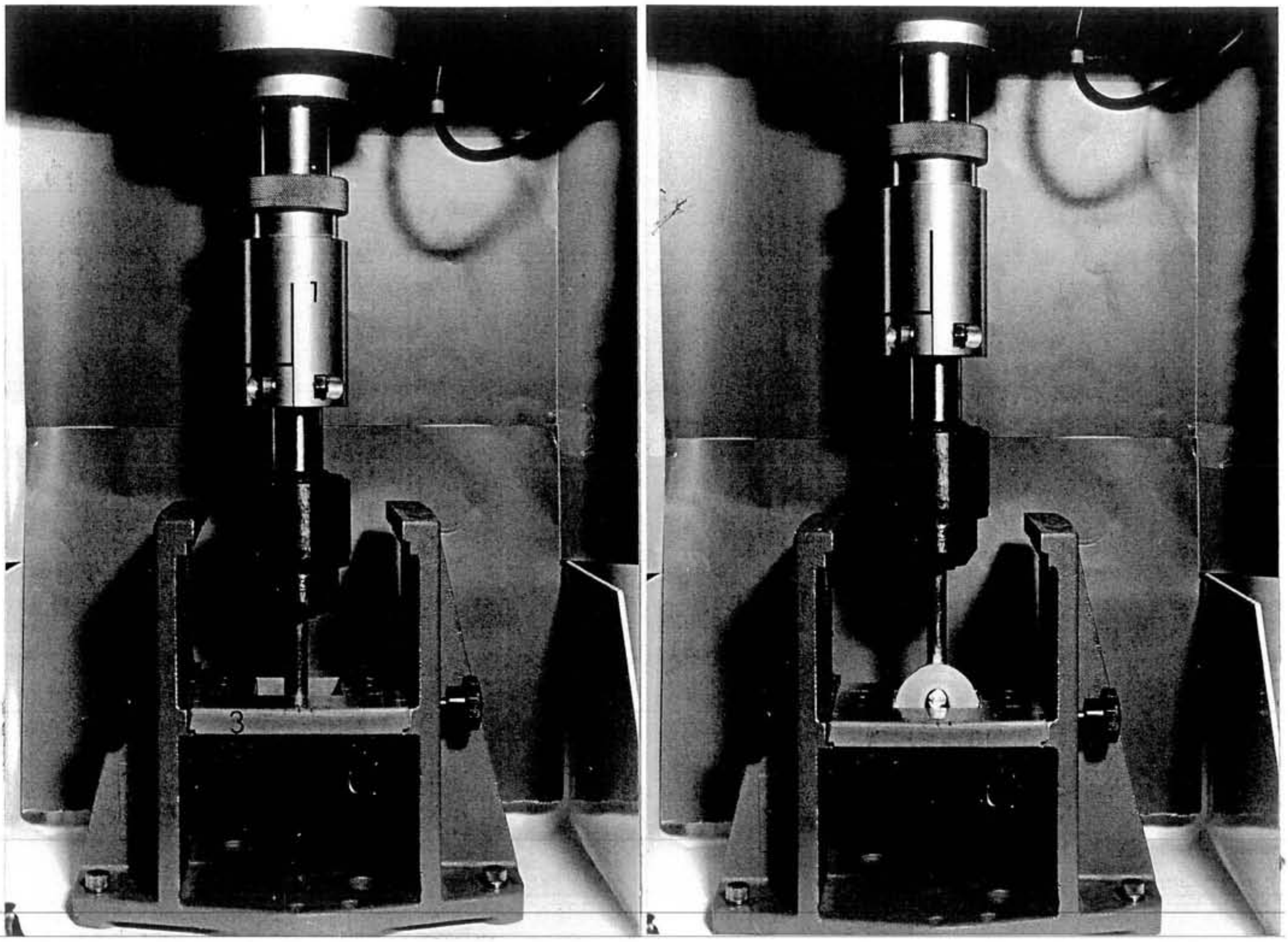

Figure A.1. Instron Food Testing Instrument for stretchability test.

1. Cross head
2. Stainless steel hook
3. Plastic plate
4. Clips

A-5 THE EFFECT OF VARIATIONS IN MANUFACTURING PROCEDURES ON THE COMPOSITION AND QUALITY OF HALLOUMI CHEESE

A-5.1 Introduction

In the previous section of this investigation, a procedure for making Halloumi with most of the desired product characteristics was devised. However, the influence that the various manufacturing steps have on the composition, physical properties and sensory characteristics of the product is incompletely understood.

Many manufacturing variables are known to influence cheese quality. Some of these factors provide a suitable means of controlling certain characteristics of the product (van Slyke & Price, 1979) since they may be altered relatively simply in commercial situations.

In the present study, the influence of such manufacturing variables on properties of Halloumi cheese was investigated. The relationship between the chemical composition and cheese quality was also studied.

A-5.2 Experimental Plan

There are a number of variables that may be modified relatively simply to alter cheese properties. These variables were studied at two levels in 12 trials carried out in random order using a Plackett and Burman design (Isaacson, 1970) (Table A.3 shows the details). The composition, physical characteristics and sensory properties of the cheeses were then measured.

A-5.3 Experimental

Twelve vats of Halloumi cheese were manufactured during the 1984/85 dairying season.

Table A.3. Plackett-Burman Design Matrix for 12 experiments of manufacturing Halloumi cheese

Runs	C/F	Starter (%)	Priming (min)	Cooking temperature (°C)	Cooking time (min)	Dry stirring	Pressing time (min)	Heating temperature (°C)	Heating time (min)	Dummy* K	Dummy* L
1	0.7	2.5	60	39	0	None	60	95	20	1	1
2	0.7	1.5	0	37	0	None	60	85	20	0	0
3	0.9	1.5	60	39	20	None	60	85	40	0	1
4	0.9	1.5	60	39	0	Yes	90	95	20	0	0
5	0.9	1.5	0	37	20	None	90	95	20	1	1
6	0.7	2.5	60	37	20	Yes	90	85	20	0	1
7	0.7	1.5	60	37	20	Yes	60	95	40	1	0
8	0.7	2.5	0	39	20	None	90	95	40	0	0
9	0.9	2.5	60	37	0	None	90	85	40	1	0
10	0.7	1.5	0	39	0	Yes	90	85	40	1	1
11	0.9	2.5	0	39	20	Yes	60	85	20	1	0
12	0.9	2.5	0	37	0	Yes	60	95	40	0	1

*Dummy factor to complete the design.

A-5.3.1 Milk supply

The milk was obtained the same as described in A-3.3.

A-5.3.2 Cheesemaking

Cheese was made from 50-60 l of standardized milk in 100 l vats. The manufacturing procedures were in accordance with commercial practice and the conditions were kept as constant as possible. The same type of starter was used in all the trials (*S. cremoris* 584 and 134 in 1:1 ratio). The manufacturing procedure used is shown in Fig. A.2.

A-5.4 Analytical Procedures

A-5.4.1 Chemical analysis of milk. The milk was analysed for total solids, fat, total nitrogen, casein, calcium and phosphate. Details of all these methods are given in Table A.4.

A-5.4.2 Chemical analysis of cheese. Samples of cheese were prepared in the same manner as described in A-3.3.1. The cheese was analysed for moisture, fat, total nitrogen, salt, pH, calcium and phosphate. Details of all these methods are given in Table A.5.

Pasteurize milk and cool to 33°C

Standardize milk

Inoculate milk with starter*

Prime if required*

Add rennet

Cut curd (0.5 cm^3) 40 min after rennet addition

Increase temperature up to target temperature* within 20 min and stir for another 20 min* at target temperature if required

Drain whey and transfer the curd to the hoops

Dry stirring if required

Press the curd for target time* (15 min at 70 kPa, 15 min at 140 kPa and the remainder at 210 kPa)

Cut the pressed curd into pieces of 10 x 15 x 3 cm

Transfer the curd pieces to heated deproteinated whey at target temperature*

Heat the whey to 85-95°C

Remove precipitated whey protein by filtration through cheese cloth

Cook the curd pieces in deproteinated whey for required time*

Fold the curd pieces lengthwise and hold for one hour at ambient temperature

Add salt and keep the curd pieces overnight at 4-8°C

Next day, put in brine (10%) for 3 h at 8°C
Drain for one hour

Pack in plastic bags and store at 4-8°C for two weeks

*See Table A.3 for the levels studied.

Figure A.2. Manufacturing scheme for Halloumi cheese from cow's milk

Table A.4. Chemical methods for anlaysis of milk

Particulars	Method	Reference	Principle of method
Total solids	NZDDM 1.12a	FIL-IDF 21-1962	Sample is dried in oven for 5 h at 103°C
Fat	NZDDM Babcock		
Total nitrogen	NZDDM 1.11a Kjeldhal	FIL-IDF 20-1962	A weighedsample 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
Calcium	NZDDM 1.2.1a	Pearce (1977)	A sodium hydroxide/EDTA solution of the sample is back titrated with standard calcium solution using Patton and Reeder's indicator (pH greater than 13.1)
Phosphate	Phosphomolybdate	Chen *et al.* (1956)	Phosphate and ammonium molybdate react in acid solution to form phosphomolybdate complex, which is reduced to intensify blue complex by acid. Maximum absorbance at 660 nm is proportional to amount of phosphate present.

Table A.5. Chemical methods for anlaysis of cheese

Particulars	Method	Reference	Principle of method
Moisture	NZDDM 4.4.3.0 Gravimetric		Sample is dried in oven at 105°C for 16 h
Fat	NZDDM 4.1.1a Schmidt-Bonzynski Ratzlaff	FIL-IDF 5A-1969 BS.770-1976	Fat is extracted from an HCl digest of the sample with ethyl ether and petroleum ether. The solvents evaporated and the residue weighed
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.
Total nitrogen	NZDDM 1.11.19 Semi-micro Kjeldahl	FIL-IDF 20-1962	Method is same as for milk.

Table A.5 (cont)

Particulars	Method	Reference	Principle of method
pH	NZDDM 4.5.1a		Direct reading utilizing the EMF between a glass electrode and a reference electrode using a pH meter.
Calcium	NZDDM 4.4.8.1	Pearce (1977)	Sample is dissolved in HCl and diluted with water. NaOH is added and titrated against EDTA using Patton and Reeder's indicator.
Phosphate	Phosphomolybdate		Method is same as for milk.

A-5.4.3 Physical measurements

Stretchability, meltability and fat loss measurements were carried out as described previously (A-4).

A-5.4.4 Sensory evaluation

A sensory panel was used. The cheeses were carefully graded by five judges experienced in dairy products assessment. Scores were given for appearance, texture and flavour by using the scoring system in Fig. A.3.

Each panelist was required to score:

1. A block of uncooked cheese for colour, surface appearance, texture of cut surface, elasticity (assessed) and flavour (sourness, saltiness and clean flavour).

2. A cube of cooked cheese* (2 cm length) for tenderness by mouthfeel.

3. A block of cooked cheese* (2 x 1.5 x 10 cm) for stretchiness (assessed).

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*Samples of cheese were cooked by heating at 85°C for 4.5 min in a water bath.

HALLOUMI CHEESE TASTE PANEL

Please objectively judge the appearance, texture and flavour by circling the appropriate score.

Sample No.

Uncooked Cheese

Appearance

	White	1	2	3	4	5	Yellow
	Dull	1	2	3	4	5	Very glossy
Texture							
	Close	1	2	3	4	5	Open
	Not elastic	1	2	3	4	5	Very elastic
Flavour							
	Not sour	1	2	3	4	5	Very sour
	Not salty	1	2	3	4	5	Very salty
	No unclean flavour	1	2	3	4	5	Strong unclean flavour

Cooked Cheese

Texture

	Very tough	1	2	3	4	5	Very tender
	No stretch	1	2	3	4	5	Great stretch

COMMENTS

Figure A.3. Questionnaire used to evaluate Halloumi cheese samples

A-5.5 Results and Discussion

A-5.5.1 Milk composition and cheesemaking

The composition of the milk used in the 12 trials was typical of that for milk produced during the major part of the dairy season (see Table A.6).

As expected, when the fat content of the milk was decreased during standardization, the total solids of the milk was also decreased while the casein to fat ratio was increased.

The details of cheesemaking are presented in Table A.7. This table shows how the rate and extent of acid development varied in the different trials. On average, the titratable acidity of the whey after cutting the gel was 0.12% with priming, while it was 0.10% without priming. The average of titratable acidity after draining the whey was 0.13% with priming and 0.11% without priming. The moisture content of the dry stirred curd before press was about 42% and about 50% at the manufacturing stage with no dry stirring. The moisture content of all the cheeses after heating in the whey, but before salting, was in the region of 40%. The heating operation expelled the additional moisture in the curd that was not dry stirred.

Table A.6. Composition for 12 runs of fresh cow's milk

Composition	Trials											
	1	2	3	4	5	6	7	8	9	10	11	12
TS (%)	11.9	12.0	11.3	11.5	11.1	11.5	12.0	11.7	11.6	11.8	11.2	11.4
Casein (%)	2.5	2.5	2.6	2.6	2.6	2.5	2.5	2.5	2.7	2.7	2.6	2.7
Fat (%)	3.4	3.4	2.7	2.8	2.7	3.4	3.4	3.0	3.3	2.8	2.9	
Calcium (mM/kg)	32.1	31.6	31.1	31.3	30.0	31.0	30.6	30.4	29.8	27.2	29.5	31.3
Phosphate (mM/kg)	19.8	19.6	20.0	19.6	18.7	19.0	19.5	19.9	20.4	20.8	20.2	20.9

Table A.7. Manufacturing data for 12 trials of Halloumi cheese made from fresh cow's milk

Manufacturing Steps	Trials											
	1	2	3	4	5	6	7	8	9	10	11	12
Amount of milk (l)	50	50	50	50	50	55.6	55	55	55	58	55	55
Acidity of milk (%)	0.14	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Amount of starter (kg)	1.25	0.75	0.75	0.75	0.75	1.39	0.83	1.38	1.38	0.87	1.38	1.38
Acidity of starter (%)	0.74	0.63	0.74	0.64	0.67	0.75	0.64	0.69	0.65	0.67	0.71	0.65
Time of starter added	10.20	10.10	10.05	10.35	9.35	9.30	10.20	10.05	9.40	9.45	9.40	9.40
Amount of rennet (ml)	9	9	9	9	9	10	9.9	9.9	9.9	10.5	9.9	9.9
Time of rennet added	11.20	10.10	11.05	11.35	9.35	10.30	11.20	10.05	10.40	9.45	9.40	9.40
Acidity of milk before adding rennet(%)	0.17	0.15	0.16	0.16	0.15	0.18	0.16	0.15	0.17	0.15	0.17	0.15
Time curd cut	12.00	10.50	11.45	12.15	10.15	11.10	12.00	10.45	11.20	10.25	10.20	10.20
Acidity of whey after cutting (%)	0.125	0.105	0.110	0.115	0.10	0.13	0.115	0.110	0.125	0.095	0.110	0.105
Time of cooking started	12.05	10.55	11.50	12.20	10.20	11.15	12.05	10.50	11.25	10.30	10.25	10.25
Time of cooking finished	12.25	11.15	12.30	12.40	11.00	11.55	12.45	11.30	11.45	10.50	11.05	10.45
Cooking temperature (°C)	39	37	39	39	37	37	37	39	37	39	39	37
Time of drained whey	12.35	11.25	12.40	12.50	11.10	12.05	12.55	11.40	11.55	11.00	11.15	10.55
Dry stirring	None	None	None	Yes	None	Yes	Yes	None	None	Yes	Yes	Yes
Acidity of whey at draining (%)	0.130	0.110	0.120	0.120	0.110	0.16	0.117	0.115	0.14	0.105	0.125	0.112
Time of pressing started	12.50	11.40	12.55	13.05	11.25	12.20	13.10	11.55	12.10	11.15	11.30	11.10
Time of pressing finished	13.50	12.40	13.55	14.35	12.55	13.50	14.10	13.25	13.40	12.45	12.30	12.10

Table A.7 (contd)

Manufacturing Steps	Trials											
	1	2	3	4	5	6	7	8	9	10	11	12
Weight of cheese before pressing (kg)	8.60	9.60	8.10	6.10	8.00	7.40	7.70	9.00	9.50	7.95	6.8	7.8
Weight of cheese after pressing (kg)	5.65	6.25	5.15	4.809	5.34	5.65	5.92	6.16	6.26	6.025	5.22	5.95
Percent of whey lost during pressing (%)	34.3	34.9	36.4	21.3	33.3	23.6	23.12	31.56	34.11	24.21	23.24	23.72
Time of heating started	13.55	12.45	14.00	14.40	13.00	13.55	14.15	13.30	13.45	12.50	12.35	12.15
Time of heating finished	14.15	13.05	14.40	15.00	13.20	14.15	14.55	14.10	14.25	13.30	12.55	12.55
Temperature of whey (°C)	95	85	85	95	95	85	95	95	85	85	85	95

A-5.5.2 Effect of the selected manufacturing variables on the chemical composition of the cheese

To evaluate the effect of treatment level on the chemical composition of Halloumi cheese, the mean values of the experimental results for each level were calculated as shown in Table A.8. The t-value was calculated to indicate whether there was a significant correlation between treatment and response (chemical composition). The data from the latter analysis are presented in Table A.9.

The effect of manufacturing variables on each components parameter was considered as follows.

A-5.5.2.1 The moisture in the non-fat substance (MNFS). Table A.9 shows three variables significantly affected the MNFS level in the cheese, namely the casein to fat ratio (C/F), priming and the whey heating temperature.

The increase in MNFS with decrease in C/F ratio and vice versa would be expected on the basis of experience with other cheese variables. As the C/F ratio is decreased, more fat is present in the curd.

The presence of fat in the cheese appears to limit the protein-protein interactions that are responsible for syneresis. Hence with a fixed manufacturing regime, as the FDM increases so does the MNFS (Lelievre, 1983).

The MNFS was found to increase significantly when priming was used. This agrees with the observation of Creamer et al., 1985, in their investigation of Cheddar cheesemaking. The mechanism by which priming or acidification influences the MNFS is uncertain. The hydration of the casein micelles in renneted milk increases until the pH reaches about 5.2 and then decreases (Creamer, 1985). The same effect could possibly occur in Halloumi cheese and would explain the observed results.

Table A.8 shows that as the whey heating temperature increased so did the MNFS content in cheese. Heat is generally associated with the removal of water from cheese at lower temperatures. Moreover, the

Table A.8. Mean values of the composition of Halloumi cheese (responses) for the different manufacturing treatments (variables)

Manufacturing treatment	Level	MNFS (%)	FDM (%)	S/M (%)	Calcium (mM/kg)	Calcium/SNFNS (g/100 g)	Phosphate (mM/kg)	Phosphate/SNFS (g/100 g)	pH
C/F	0.7	54.9	46.5	7.2	226	2.83	95	3.13	5.6
	0.9	52.8	41.2	6.2	228	2.85	102	2.98	5.6
Starter (%)	1.5	53.7	44.2	6.2	229	2.91	104	3.14	5.8
	2.5	54.1	43.5	7.2	215	2.77	97	2.96	5.5
Priming time (min)	0	53.0	43.3	6.7	232	2.91	108	3.20	5.8
	60	54.8	44.3	6.7	212	2.77	93	2/90	5.4
Cooking temperature (°C)	37	54.4	44.8	7.1	208	2.74	96	2.95	5.6
	39	53.4	42.8	6.4	235	2.95	105	3.10	5.7
Cooking time (min)	0	54.0	44.2	6.9	222	2.84	101	3.08	5.7
	20	53.8	43.5	6.5	224	2.84	101	3.03	5.6
Dry stirring	without	54.1	44.4	7.1	215	2.79	96	2.94	5.6
	with	53.8	43.3	6.4	229	2.89	106	3.16	5.6
Pressing time (min)	60	53.8	44.0	6.8	224	2.86	100	3.02	5.7
	90	54.0	43.0	6.7	221	2.82	102	3.09	5.5
Whey heating temperature (°C)	85	53.4	43.6	6.8	219	2.76	102	3.06	5.6
	95	54.5	44.1	6.7	225	2.92	99	3.04	5.6
Heating time (min)	20	53.8	43.7	6.7	217	2.76	96	2.90	5.6
	40	54.0	44.0	6.8	227	2.92	106	3.21	5.6

Table A.9. Relationship between the composition of Halloumi cheese and the manufacturing treatment (t-value)

Manufacturing treatment	MNFS	FDM	S/M	Ca++	Ca/SNFNS	Phosphate	P/SNFNS	pH
C/F	-10.26***	-9.09**	-2.55	18.11**	0.59	-0.49	1.10	1.55
Starter	0.83	-2.01	2.25	-7.89**	-4.36**	-1.19	-6.09**	-6.52**
Priming	6.86**	0.53	-0.24	-11.44***	-3.98**	0.20	-4.79**	-8.71**
Cooking temperature	-3.52	-2.09	-1.46	16.11***	6.04**	1.43	4.32**	1.12
Cooking time	-1.31	-1.42	-1.14	2.70	-0.25	0.95	0.98	-2.18
Dry stirring	-1.63	-1.95	-1.96	10.38***	3.12*	-0.32	2.79	-0.57
Pressing time	0.12	-1.30	-0.39	-0.62	-1.11	1.03	-0.61	-4.08*
Whey heating temperature	5.15**	0.83	-0.27	4.42**	4.89**	-0.96	-2.54	-1.00
Heating time	0.96	0.62	-0.24	7.72**	5.01**	-0.36	8.86**	-1.00

*P < 0.1; ** P < 0.05; *** P < 0.01.

cheese formed with a higher whey heating temperature had a high calcium/solids non-fat non-salt ratio Ca/SNFNS and this would be expected to reduce rather than increase the hydration as found here. These factors suggest heating caused a marked change in the curd structure and consequently in the curd hydration.

A-5.5.2.2 Fat in dry matter FDM. The C/F ratio was found to be the only variable that influenced the FDM percentage in cheese. As would be expected from mass balance consideration, the FDM content in cheese increased as the C/F ratio deceased.

A-5.5.2.3 Salt-in-moisture ratio (S/M). None of the variables showed any effect on the S/M, this would be expected because the dry salting and brining processes were kept constant.

A-5.5.2.4 Calcium. There are three forms in which calcium is present in milk at normal pH. About 9% of the total occurs as free calcium ions, the remainder is associated with casein and colloidal calcium phosphate. All three forms are in equilibrium with each other (Pyne, 1962; Parry, 1974).

As Tables A.8 and A.9 show, all the variables studied affected the calcium content of Halloumi except the cooking time and the pressing time.

Increasing the C/F ratio caused a higher calcium percentage in cheese. Gupta (1971) found the same trend in the calcium content of Cheddar and Gouda cheeses made from milk at high and low C/F ratio. The influence of C/F ratio on Ca/SNFNS was calculated. It was found that C/F ratio did not show any effect on the ratio. Thus the apparent effect of C/F ratio on calcium level resulted from changes in the weight of fat and moisture in the cheese rather than from differences in the amount of calcium present in each gram of protein. The fat and protein contents of cheese made from low C/F ratio contained 49.1% fat and 42.5% protein, while the cheese made from high C/F ratio contained 42.6% fat and 48.2% protein.

The percentage of starter added to milk was found to have an effect on the calcium content in cheese. As the level of starter added was increased, a significant decrease in the calcium content in cheese was found. The level of Ca/SNFNS also followed the same trend. A higher amount of starter produces acid more rapidly in the initial stages of cheesemaking, hence greater solubilization of calcium occurs early in the process. This soluble calcium is lost in the whey expelled from the curd. If the acid is produced later in the process, although the calcium is solubilized, the bulk of whey expulsion has already occurred and hence more calcium remains in curd or can only diffuse down its concentration gradient.

A negative correlation was found between priming and the calcium content of the cheese. Creamer et al. (1985), used acidified milk for making Cheddar cheese. They found that the calcium content in cheese was less than in the cheese made from normal milk. This is in agreement with the present study. As far as Halloumi is concerned, priming influences cheese calcium levels in a manner similar to the effect of greater starter addition.

Cooking temperature is an important factor influencing both the water removal from the curd and the acid development. The results showed that with the lower cooking temperature effect the calcium content in the cheese was lower. The cooking temperature also showed a significant effect on the Ca/SNFNS ratio. The starter used in the trials was sensitive to cooking temperature. At 37°C, the starter had a high rate of acid production and therefore the calcium was solubilized. However, at 39°C, the starter was inhibited to some extent and the rate of acid development was slowed.

The time of cooking the curd did not show any effect on the calcium content, presumably because this did not affect the acid production significantly.

It was found that the cheese made from dry stirred curd contained more calcium than the cheese made from curd which was not dry stirred. The Ca/SNFNS ratio was also affected by dry stirring at the level $p < 0.1$.

A further trial was carried out in an attempt to understand why dry stirring influenced the calcium levels. The curd after draining the whey was divided into two parts, the first part was dry stirred and the other part was not. The chemical compositions of the curds were determined before and after heating. The resultant cheeses were also analysed. The results were tabulated in Table A.10.

Table A.10 shows that dry stirring promoted the expulsion of moisture early in the cheesemaking process at which relatively small amounts of calcium had been solubilized. In contrast, when dry stirring was not used more fluid was expelled at later stages of manufacture at which time more calcium had been solubilized by the acid produced.

The pressing time did not show any significant effect on the calcium content in cheese. If pressing was carried out for a long time (i.e. several hours) a difference would be expected. However, the pressing times of 60 and 90 min used in this study showed no significant difference.

It was found that calcium content and Ca/SNFNS ratio in the cheese increased as the heating temperature increased and as the heating period increased. This would be expected since calcium phosphate precipitates in milk, cheese and whey as the temperature is increased. Jabolonka & Munro (1985) studied the effect of different heating temperatures on the calcium content of acid casein. They found that more calcium was precipitated at 55°C than at 45°C, showing the same trend as found here.

A-5.5.2.5 Phosphate. Generally the phosphate levels showed the same kind of change with treatment as the calcium levels. However, the results were not significant in as many cases. The mechanism by which phosphate and calcium levels changed would be expected to be the same, namely solubilization by acid and precipitation by heating.

A-5.5.2.6 pH of the cheese. The results showed that more priming and more starter lowered the pH as would be expected. Increases in the pressing time would also be expected to decrease the pH as shown because the extra time would allow the continued conversion of lactose to lactic acid before the starter was inhibited by heating.

Table A.10. Composition of curd during processing and the resultant cheese

Chemical Composition	Unstirred curd			Stirred curd		
	Before heating	After heating	Cheese	Before heating	After heating	Cheese
MNFS (%)	67.1	57.4	56.1	57.1	56.8	56.1
S/M (%)	-	-	8.4	-	-	7.8
Ca (mM/kg)	164	187	173	183	195	180
Ca/SNFNS (g/100 g)	-	-	2.5	-	-	2.7
pH	5.7	-	5.7	5.7	-	5.7

A-5.5.3 Effect of the selected manufacturing variables on the physical properties of the cheese and the relationship of these properties to the product composition

The effect of the manufacturing variables on the physical properties (stretchability, meltability and fat loss) of Halloumi cheese were statistically analysed. The data are presented in Tables A.11 and A.12.

A-5.5.3.1 Stretchability. As far as the stretchability properties of the cheese are concerned, results given in Tables A.11 and A.12 showed that all the manufacturing variables apart from the C/F ratio affected the stretchability of Halloumi cheese. In general, the ability of any cheese to stretch appears to depend on the pH and the Ca/Dry Matt ratio of the product (Keller et al. 1973). The results in Table A.13 indicated that Halloumi conformed to this pattern, in the range tested decreases in the Ca/SNFNS ratio and decreases in the pH increased the tendency of the cheese to stretch.

The mechanism by which changes in pH and Ca/SNFNS values alter stretch is uncertain, though it is clear they would alter cheese structure. Presumably the influence of all the manufacturing variables on stretch is via their influence on the pH and Ca/SNFNS values.

A-5.5.3.2 Meltability. Data presented in Tables A.11 and A.12 showed that manufacturing variables which tended to influence acid development generally influence product meltability. The association between meltability and both Ca/DM= and pH given in Table A.13 are consistent with this pattern. Similar trends have been reported for other cheese varieties (Arnott et al., 1957; Weik et al., 1958; Thomas, 1970, and Keller et al., 1973).

A-5.5.3.3 Fat loss. C/F ratio was the only manufacturing variable that influenced the percentage fat loss from the cheese on melting (see Table A.11). The significant correlation between fat loss and FDM would be expected (Table A.13). These results are similar to those found by Breene et al. (1964).

The MNFS, pH and S/M also had a relatively large influence on the fat loss (Table A.13), suggesting that the structure of the curd may be important in this respect.

=Dry Matter

Table A.11. Mean values of the physical properties of Halloumi cheese (responses) for different manufacturing treatment (variables)

Manufacturing treatment	Level	Physical property		
		Stretchability (cm)	Meltability (%)	Fat loss (%)
C/F	0.7	31.2	260	4.3
	0.9	29.8	249	2.2
Starter (%)	1.5	25.5	217	3.0
	2.5	35.6	291	3.5
Priming time (min)	0	26.1	203	2.5
	60	34.9	305	4.0
Cooking temperature (°C)	37	32.3	286	3.4
	39	28.7	222	3.2
Cooking time (min)	0	27.6	245	3.1
	20	33.5	263	3.5
Dry stirring	without	26.1	240	3.4
	with	35.0	268	3.1
Pressing time (min)	60	27.6	226	2.9
	90	33.4	282	3.6
Whey heating temperature (°C)	85	32.3	284	2.9
	95	28.8	224	3.6
Heating time (°C)	20	31.4	259	3.1
	40	29.6	249	3.4

Table A.12. Relationship between the physical properties of Halloumi cheese and the manufacturing treatments (t-value)

Manufacturing treatment	Phyiscal property		
	Stretchability	Meltability	Fat loss
C/F	-5.0	-1.1	-4.0*
Starter (%)	35.0***	6.7*	0.7
Priming time (min)	30.3**	9.2*	2.4
Cooking temperature (°C)	-11.9**	-5.7*	0.2
Cooking time (min)	20.5**	1.7	0.7
Dry stirring	31.1**	2.6	0.8
Pressing time (min)	19.9**	5.2*	1.0
Whey heating temperature (°C)	-12.5**	-5.6*	1.2
Heating temperature (min)	- 6.2*	-0.9	0.6

* P < 0.05; ** P < 0.01; *** P < 0.001.

Table A.13. Correlation coefficients between the composition and physical properties of Halloumi cheese

Physical property	Correlation coefficient							
	MNFS	FDM	S/M	pH	Ca	Ca/SNFNS	Phosphate	P/SNFNS
Stretchability	0.31	-0.01	0.14	-0.81**	-0.39	-0.50*	-0.18	-0.38
Meltability	0.43	0.15	0.31	-0.83**	-0.64*	-0.74*	-0.41	-0.48
Fat loss	0.87**	0.69*	0.57*	-0.69*	-0.67*	-0.27	-0.44	-0.21

* $P < 0.05$; ** $P < 0.01$.

A-5.5.4 Effect of the selected manufacturing variables on the sensory properties of the cheese and the relationship of these properties to the chemical and physical characteristics of the product

The appearance, flavour and texture of uncooked cheese and the texture of cooked cheese, were the factors evaluated by the panelists. In Table A.14 is listed the effect of manufacturing variables on the organoleptic properties of Halloumi cheese.

The t-values were calculated to indicate whether there was a significant relationship between the manufacturing variables and the sensory parameters. The data from the latter analysis are presented in Table A.15.

None of the manufacturing variables significantly affected the sensory parameters of uncooked cheese (Table A.15).

As far as the cooked cheese is concerned, the tenderness of the product was the only parameter affected. None of the manufacturing variables had a significant influence on the taste panel assessment of the stretchiness of the cheese. A possible explanation for this is the panel experienced some difficulty in distinguishing between cheeses with high stretch characteristics. However, the panel measurements of stretchiness are correlated with the instrumental reading of stretchability (Table A.16).

In addition, the relationship between the taste panel assessment of cooked and uncooked cheeses and its chemical and physical properties is given in Table A.16.

Considering the uncooked cheese, the sensory panel saltiness increased as the MNFS increased. This is because the S/M content of the cheese was fairly constant and hence with a higher MNFS the product has a greater salt content.

The sourness of the cheese would be expected to increase as the pH decreased. This trend was not statistically significant in the present case. The results given in Table A.16 showed that the greater the

Table A.14. Mean values of the sensory parameters of Halloumi cheese (responses) for different manufacturing treatments (variables)

Manufacturing treatment	Level	Sensory parameter								
		Colour	Appearance	Texture	Elasticity	Sourness	Saltiness	Clean flavour	Tenderness	Stretchiness
C/F	0.7	2.8	3.4	2.1	3.1	1.9	2.8	1.3	3.3	3.2
	0.9	3.3	3.7	2.0	3.9	1.8	2.6	1.2	2.5	3.4
Starter (%)	1.5	3.1	3.7	2.1	3.6	1.8	2.8	1.2	3.8	3.0
	2.5	3.0	3.4	2.0	3.4	1.9	2.7	1.3	2.9	3.8
Priming time (min)	0	3.0	3.6	2.3	3.5	1.7	2.7	1.2	3.9	3.1
	60	3.1	3.5	1.8	3.6	2.0	2.7	1.3	2.8	3.7
Cooking temperature (°C)	37	3.1	3.4	1.8	3.5	2.1	2.9	1.2	3.2	3.1
	39	3.0	3.7	2.3	3.6	1.6	2.5	1.3	3.5	3.6
Cooking time (min)	0	2.7	3.8	2.1	3.6	1.8	2.8	1.4	3.4	3.3
	20	3.4	3.4	2.0	3.4	1.8	2.6	1.1	3.3	3.4
Dry stirring	without	2.9	3.6	1.9	3.5	1.9	2.8	1.4	3.2	2.9
	with	3.2	3.6	2.2	3.5	1.8	2.7	1.1	3.5	3.8
Pressing time (min)	60	2.9	3.4	2.2	3.4	1.7	2.7	1.3	3.4	3.0
	90	3.2	3.7	2.0	3.7	1.9	2.7	1.2	3.3	3.7
Whey heating temperature (°C)	85	3.1	3.6	1.9	3.6	1.9	2.5	1.3	3.1	3.6
	95	3.0	3.5	2.2	3.4	1.7	2.9	1.2	3.6	3.1
Heating time (min)	20	3.1	3.5	2.0	3.5	1.9	2.6	1.3	3.3	3.8
	40	3.0	3.6	2.2	3.5	1.8	2.9	1.2	3.4	2.9

Table A.15. Relationship between the sensory parameters of Halloumi cheese and the manufacturing treatments (t-value)

Manufacturing treatment	Sensory parameter								
	Colour	Appearance	Texture	Elasticity	Sourness	Saltiness	Clean flavour	Tenderness	Stretchiness
C/F	1.83	5.74*	-0.29	3.99	-0.33	-0.65	-0.88	15.00**	0.52
Starter	0.13	-5.18*	-0.38	-0.78	0.16	-0.25	-0.41	-18.15**	2.86
Priming	0.40	-1.60	-2.82	1.19	0.94	-0.08	0.21	-25.65**	2.16
Cooking temperature	-0.56	3.78	2.47	0.14	-1.52	-0.98	0.44	6.49*	1.79
Cooking time	1.30	-6.84*	-0.36	-1.59	-0.01	-0.56	0.30	-3.65	0.25
Dry stirring	0.70	0.12	1.39	-0.16	-0.20	-0.37	-2.26	5.84*	2.62
Pressing time	0.81	5.09*	-1.07	2.46	0.56	-0.05	-1.03	-1.15	2.62
Heating temperature	-0.18	-2.32	1.40	-1.67	-0.59	1.09	-0.32	10.28**	-1.65
Heating time	-0.30	2.32	1.05	0.24	-0.40	0.72	-0.967	2.37	-3.06

* $P < 0.05$; ** $P < 0.01$.

Table A.16. Correlation coefficient between the sensory parameters and composition, and physical properties of Halloumi cheese

Sensory parameter	Correlation coefficient										
	MNFS	FDM	S/M	pH	Ca	Ca/SNFNS	Phosphate	P/SNFNS	Stretchability	Meltability	Fat loss
Colour	-0.39	0.42	0.34	-0.16	0.32	-0.06	0.21	-0.14	0.32	-0.27	-0.42
Appearance	-0.44	-0.43	-0.48	0.44	0.48	0.42	0.37	0.43	-0.45	0.35	-0.53*
Texture	-0.37	0.23	-0.29	0.07	0.49	0.40	0.34	0.47	-0.45	-0.35	-0.27
Elasticity	-0.51*	-0.60*	-0.53*	-0.07	0.39	-0.02	0.28	0.05	0.08	0.71*	-0.55*
Sourness	0.43	0.28	0.43	-0.50*	0.71*	-0.76*	-0.45	0.45	0.43*	0.67*	0.45
Saltiness	0.50*	0.42	0.48	-0.10	-0.34	-0.01	-0.13	-0.01	-0.2	-0.09	0.46
Tenderness	0.67*	0.44	0.59*	-0.83**	-0.82**	-0.74*	-0.76*	-0.52*	0.69*	0.84**	0.71*
Stretchiness	-0.04	-0.32	-0.13	-0.53*	-0.07	-0.34	-0.07	-0.40	-0.73*	0.58*	0.13

* $P < 0.05$; ** $P < 0.01$.

sourness ranking of the product the lower the value of the Ca/SNFNS ratio. This may reflect that Ca/SNFNS and pH values increased and decreased concomitantly in the cheeses studied. However, the possibility that calcium ions may also be having a direct effect on the perception of sourness cannot be excluded.

Considering the cooked Halloumi, the cheeses with high tenderness ranking had high MNFS values and vice versa (Table A.16). The relationship between tenderness and FDM suggested a similar trend but this was not statistically significant. Toughness was associated with high Ca/SNFNS and high pH values. This may be because cheeses with these compositions did not stretch or flow readily when a stress was applied and did not have a high meltability when cooked. The sensory tenderness was found to have a significant correlation with meltability.

The only factor that showed a statistically significant correlation with the sensory stretchiness was the pH, stretchability and meltability. Greater stretchiness would be expected as calcium was removed from the cheese. However, in the present case the relationship between calcium and stretchiness was not statistically significant.

A-5.6 Conclusion

The results of the present study show that Halloumi cheese can be manufactured from cow's milk by adapting the manufacturing schedule that is traditionally used for sheep's milk. Manufacturing variables that alter the rate and extent of acid development have a marked influence on the characteristics of the cheese.

PART B

HALLOUMI CHEESE FROM RECOMBINED MILK

B-1 INTRODUCTION

Worldwide demand for milk products is increasing. In developing countries local milk supplies are usually unable to cope with the growing demand. Therefore dairy products made from recombined milk play a large part in these countries (Andersen, 1985).

Fermented milk products and some types of fresh cheeses can be manufactured without problem from recombined milk but it is more difficult to produce hard and semi-hard cheeses.

The present view discusses the manufacture of various types of cheese from recombined milk by considering the raw materials used, the conversion of these raw materials to recombined milk and finally the production of the cheese.

B-1.1 Raw Materials

In the manufacture of recombined milk for cheesemaking, the main dairy materials are skim milk powder (SMP) and milkfat. Whole milk powder may be used but it is not recommended because of potential coagulation problems and flavour deterioration which may occur in the powder on prolonged storage.

B-1.1.1 Skim milk powder

The most important factor in the manufacture of recombined milk products is the quality of the SMP used. The preheat treatment given to the skim milk during the manufacture of SMP varies depending on the products for which the powder will be used. Powder used for cheese-making should be of the low heat type. Normally low heat MPs are classified as those having a whey protein nitrogen index[1] greater than 6 mg/g. Gilles & Lawrence (1980) pointed out that a low heating temperature is necessary to maintain good rennetability of the

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[1]Whey protein nitrogen index (WPNI). The amount of undenatured whey protein in the milk powder.

reconstituted milk. The heat treatment is associated with whey protein denaturation during processing the SMP. Denaturation of whey protein is not significant until milk temperatures exceed 65°C (Davis & White, 1959) and above this temperature the extent of denaturation is related to the time of heating and the temperature of the milk (Harland et al., 1952). Also the heat treatment has a large effect on the ionic calcium which is essential for coagulation (Kannan & Jenness, 1961). In general, low heat SMPs contain a large concentration of ionic calcium, and result in recombined milks with higher curd tensions than would be the case if high heat SMP were used (Muldoon & Liska, 1972).

Another important variable in the manufacture of SMP is the concentration of milk prior to drying. The chief effect of concentration is on the viscosity of the milk, which in turn influences the physical characteristics of SMP (Muir, 1980). Increasing the milk total solids leads to a higher viscosity in the concentrate and a higher solubility index (SI)[1] of SMP (Baldwin et al., 1980). Usually the increase of viscosity with concentration is not linear, especially when the concentration of milk solids exceeds 45% and this can affect the powder quality (Muir, 1980).

In industrial practice, it is desirable to maximize the milk total solids because it is more economical to remove water in the evaporator than in the spray drier. There is no information on the effect of the concentration of milk solids before drying on the recombined cheese products.

B-1.1.2 Milkfat

Milkfat is used as a fat source where recombined milk products are manufactured. The most commonly used is anhydrous milkfat (AMF). Anhydrous milkfat when used in the manufacture of recombined cheese presents no special problems, provided it meets an appropriate minimum quality standard (Sanderson, 1979). When fat is dispersed in a casein-water matrix, the physical properties of the AMF have no effect on the quality of the recombined milk (Gilles & Lawrence, 1980).

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[1]Solubility index (SI). The amount of sediment remaining after the milk powder has been dissolved in water.

B-1.2 Preparation of Recombined Milk

The methods of preparing recombined milk, which is subsequently used to produce different dairy products are similar. All the methods involve reconstitution, homogenization and finally heat treatment.

B-1.2.1 Reconstitution

Reconstitution involves mixing the SMP with water. The temperature of the water used appears to be unimportant. Poulsen & Mondorf (1964) suggest a temperature of 8-10°C, assuming that reconstituted milk is allowed to hydrate for no less than 4 h. According to Newstead et al. (1979), a temperature of 40-50°C would require a hydration time of only 15 min. Gilles & Lawrence (1980) found it convenient to reconstitute the powder for cheesemaking at 28-30°C so that the addition of recombined cream at 50°C would bring the final mixture to the setting temperature required. Normally the reconstitution temperature is 45-55°C which is suitable for blending the fat into the reconstituted skim milk.

B-1.2.2 Homogenization

Homogenization is necessary for reforming the fat emulsion and therefore is one of the essential steps in processing the recombined milk. Recombined milk is an oil-in-water emulsion with the fat globules (i.e. oil) dispersed in reconstituted skim milk. The properties of the recombined milk are different from those of natural milk. The differences concern the state of dispersion of the fat (Oortwijn & Walstra, 1982). When milkfat is emulsified into skim milk, most of the materials of the natural fat globule membrane are absent, and the composition of the new membrane is completely different from that of the natural membrane (Mulder & Walstra, 1974). Skim milk protein is the main material of the newly-formed membrane, while phospholipids are absent (Wiese & Palmer, 1932). The amount of adsorbed material is influenced by the conditions of homogenization such as pressure which affects both the fat globule size and the membrane composition. When homogenization is used to produce recombined milk for cheesemaking, a homogenization pressure 800-1000 psi is used to minimize damage to the protein structure (Sanderson, 1970; George, 1972). For most varieties of cheese, it is generally undesirable to use high homogenization pressures because the properties of the resultant recombined milk adversely affect curd firmness and the characteristics of the resultant cheese. Nevertheless, in some varieties of cheese such as Feta, high homogenization pressures will actually improve the cheese texture.

B-1.2.3 Heat treatment

A heat treatment at 72°C for 15 s after homogenization is recommended to ensure satisfactory bacteriological quality of the recombined milk (Gilles & Lawrence, 1980).

B-1.3 Manufacture of Cheese

The manufacturing procedure for producing cheese from recombined milk is essentially the same as that for fresh milk. Gilles & Lawrence (1980) demonstrated that the cheesemaking properties of recombined milk are somewhat different from those of the original milk from which the powder is manufactured. For example, the rate of coagulation is slower, the gel strength is reduced and the rate of syneresis of the curd during manufacture is slightly decreased. To compensate for these differences minor modifications to the cheese manufacturing procedures are required.

The possibility of manufacturing different types of cheese from recombined milk gained much attention several years ago. Some reports show that the use of recombined milk for cheesemaking changed cheese characteristics such as texture and flavour. Czulak & Hammond (1974) found that Cheddar cheese made from skim milk powder and butter oil did not develop the typical flavour and had a different texture. Another study (Gilles & Lawrence, 1980) showed that recombined milk is not acceptable for fresh white cheese production due to the anhydrous milkfat flavour.

Cheese varieties like Mozzarella and Halloumi are characterized by their special properties of stretching and melting when made traditionally from fresh milk. Gilles & Lawrence (1980) concluded that they cannot be made successfully from recombined milk as these properties are largely lost. It is nevertheless possible to produce

Mozzarella cheese from low heat skim milk powder and fresh cream according to other workers (Flanagan et al., 1978; Thompson, 1978; Demott, 1983). The physical properties of the cheese are good and similar to those of Mozzarella made from fresh milk. This suggests the difference between fresh cream and recombined cream is of critical importance.

After examining a number of commercial low heat skim milk powders, O'Keefe & Phelan (1982) concluded that they were not suitable for use in the manufacture of Halloumi cheese. These experiments on Halloumi were carried out using AMF rather than fresh cream to prepare the recombined milk.

B-2 EXPERIMENTAL APPROACH

There are a number of factors that may affect the quality of Halloumi cheese from recombined milk as opposed to fresh milk. These factors are listed as follows.

The separation of whole milk into cream and skim milk. The treatment is an essential step in the manufacture of SMP.

The suitability of powder for making cheese from recombined milk appears to be affected by the preheat treatment of the milk, and the total solids of the concentrate before drying.

Homogenization is used to prepare recombined milk. Thus the particle size distribution of fat and the membrane of the fat globules are different in recombined and fresh milk. There are suggestions in the literature that homogenization alters the stretchability and meltability behaviour of Mozzarella cheese.

The approach adopted herein is to first check the influence of separation, homogenization and replacement of cream with AMF. Any problems that these factors present to Halloumi manufacture from recombined milk need to be solved before the question of powder quality is addressed.

B-3 PRELIMINARY STUDY ON THE EFFECT OF SEPARATION, HOMOGENIZATION AND REPLACEMENT OF CREAM WITH AMF ON CHEESE QUALITY

B-3.1 Introduction

In the previous part of this study, it was demonstrated that Halloumi cheese can be made from fresh cow's milk and that manufacturing conditions can be varied to optimize product quality.

In this section, preliminary trials were conducted to assess the effect of separation, homogenization and replacement of cream by AMF on the quality of cheese.

B-3.2 Experimental Plan

The investigation was conducted in three stages. The first stage considered the effect of separation, the second looked at the effect of homogenization and the third studied the effect of replacement of cream with AMF and subsequent homogenization.

Standardized milk was split in half. Half was kept as control and the other half was subjected to separation. On completion of separation, the skim milk and cream were remixed. Halloumi was then made from the remixed milk and control milk.

Standardized milk was split into two lots. One lot was kept as control. The other lot was homogenized. Cheese was made from the homogenized milk and control milk.

Standardized milk was split into two lots. One lot was kept as control. The other lot was separated and the skim milk was collected and homogenized with AMF. Cheese was made from recombined milk and control milk.

B-3.3 Experimental

The cheeses were made during the 1984/85 season. The trials involving homogenization were carried out in duplicate.

B-3.3.1 Milk supply

The milk was pasteurized and standardized as described in A-3.3. About 200 l milk was needed for each of the trials.

B-3.3.2 Separation

Skim milk was prepared by separation (Alfa Laval Separator Type 3181 M) after warming the milk to 50°C.

B-3.3.3 Homogenization

Milk was homogenized with a Manton-Gaulin homogenizer (Model K3, AVP Ltd, UK), equipped with a poppet valve and operated with one stage.

Fresh milk was heated to 55°C in a double jacketed vat and homogenized at 13 000 kPa, then cooled to 32°C.

A recombined cream was made by homogenizing skim milk with AMF at 10 000 kPa at 55°C (3:1 ratio). Then the recombined cream was mixed with the rest of the skim milk and cooled to 32°C.

B-3.3.4 Cheesemaking

The detailed experimental conditions for the manufacture of Halloumi cheese are presented in Fig. B.1.

B-3.4 Analytical Procedures

All the methods for chemical analysis, physical measurements and sensory evaluation were followed as outlined in A-5.4.

B-3.5 Results and Discussion

B-3.5.1 Separation treatment

B-3.5.1.1 Milk composition and cheesemaking. The composition of the control milk and remixed milk were similar (Table B.1). During cheesemaking no differences were observed in the gels obtained and the acid development in the two systems.

B-3.5.1.2 Cheese composition. The compositions of the cheeses from the two treatments were quite similar (Table B.2). This was expected since there was no major difference in the milk composition and the two treatments had similar manufacturing conditions.

Pasteurize milk at 72/15 and cool to 32°C

↓

Standardize milk

↓

Inoculate milk with 2% starter

↓

Prime for 60 min

↓

Add rennet

↓

Cut curd (0.5 cm length) 40 min after rennet addition

↓

Increase temperature up to 37°C within 20 min and stir for another 20 min

↓

Drain whey, dry stirr and allow the curd to knit for 10 min. Transfer to the hoops.

↓ (whey branch) Heat the whey to 95°C. ↓ Remove precipitated whey protein by filtration through cheese cloth ↓ (to heated deproteinated whey)

↓

Press the curd for 1 h (15 min at 70 kPa, 15 min at 140 kPa and 30 min at 210 kPa)

↓

Cut the pressed curd in pieces of 10 x 15 x 3 cm

↓

Transfer the curd pieces to heated deproteinated whey at 95°C. Cook for 40 min.

↓

Fold the curd pieces lengthwise and hold for 1 h at ambient temperature

↓

Add salt and keep the curd pieces overnight at 4-8°C

↓

Next day, put in brine (10%) for 3 h at 8°C. Drain for 1 h.

↓

Pack in plastic bags and store at 4-8°C for 2 weeks

Figure B.1. Manufacturing scheme for Halloumi cheese.

Table B.1. Composition of control and remixed milks

Composition	Milk	
	Control	Remixed
TS (%)	12.4	12.9
Casein (%)	2.8	2.8
Fat (%)	4.5	4.6
C/F	0.62	0.60
Calcium (mM/kg)	33	31
Phosphate (mM/kg)	20	19

Table B.2. Composition and physical properties of cheeses made from control and remixed milks

Composition and physical property	Cheese	
	Control milk	Remixed milk
MNFS (%)	58.5	57.1
FDM (%)	49.6	52.3
S/M	8.4	9.3
Calcium (mM/kg)	186	171
Ca/SNFNS (g/100g)	2.87	2.68
Phosphate (mM/kg)	86	93
Phosphate/SNFNS (g/100 g)	3.15	3.46
pH	5.3	5.4
Stretchability (cm)	30.2	27.5
Meltability (%)	459	425
Fat loss (%)	6.2	6.2

B-3.5.1.3 Cheese physical properties. The stretchability, meltability and fat loss properties of cheese from the two treatments were quite alike (Table B.2).

B-3.5.1.4 Conclusion. The above results suggest that separation has little influence on Halloumi characteristics. This would be expected from a consideration of first principles and also from the fact that separation is a part of standardization. Only one trial was carried out. However, it is clear from this trial that the cheese from fresh milk that had been separated and reformed by blending had fully acceptable stretch and melt characteristics. Clearly the problems associated with making Halloumi from SMP do not arise from separation.

B-3.5.2 Homogenization treatment

For convenience, the results of homogenization treatment and replacement of cream with AMF are discussed together since these show the same trends.

B-3.5.2.1 Milk composition and cheesemaking. There were no major differences between the composition of the homogenized fresh milk and the control milk (Table B.3). Furthermore, the homogenized recombined milk and the control milk had similar compositions (Table B.4).

During cheese manufacture, acid development in both the homogenized milks was the same as in the controls. With homogenized milk, the gel obtained before cutting appeared to be softer than the control gel as judged by subjective methods. This was attributed to an increase in the number of weak points in the homogenized milk gel (Mulder & Walstra, 1974). Also after cutting the homogenized milk gel, the curd particles were found to be smaller and to adhere to each other poorly after draining off the whey.

B-3.5.2.2 Cheese composition. The composition of the cheeses made from homogenized milks was different from that of the cheeses made from control milks (Tables B.5 and B.6). MNFS and S/M values of the control cheese were higher than the cheese made from homogenized milk. The pH and Ca/SNFNS values were also different.

Table B.3. Composition of control and homogenized milks+

Particulars	Milk	
	Control	Homogenized at 13 000 kPa
TS (%)	12.9	12.9
Casein (%)	2.8	2.8
Fat (%)	4.0	4.0
C/F	0.7	0.7
Calcium (mM/kg)	33.6	33.6
Phosphate (mM/kg)	19.0	19.0

+ Mean of two trials

Table B.4. Composition of control and recombined milks+

Composition	Milk	
	Control	Recombined*
TS (%)	11.6	11.9
Casein (%)	2.7	2.7
Fat (%)	3.3	3.4
C/F	0.82	0.8
Calcium (mM/kg)	29.8	31.6
Phosphate (mM/kg)	17.2	17.9

+Mean of two trials

*Fresh skim milk with AMF were homogenized at 10 000 kPa.

Table B.5. Composition and physical properties of cheeses made from control and homogenized milks[+]

Composition and physical property	Cheese	
	Control milk	Homogenized milk (13 000 kPa)
MNFS (%)	59.6	53.9
FDM (%)	49.1	50.5
S/M (%)	7.2	4.9
Calcium (mM/kg)	202	212
Ca/SNFNS (g/100 g)	3.11	2.87
Phosphate (mM/kg)	94	97
Phosphate/SNFNS (g/100 g)	3.43	3.12
pH	5.6	5.8
Stretchability (cm)	47.3	No stretching
Meltability (%)	339	264
Fat loss (%)	1.4	0.8

+Mean of two trials

Table B.6. Composition and physical properties of cheeses made from control and recombined milks +

Composition and physical property	Cheese	
	Control milk	Recombined milk*
MNFS (%)	60.5	53.4
FDM (%)	48.1	48.5
S/M	8.6	5.9
Calcium (mM/kg)	208	214
Ca/SNFS (g/100 g)	3.32	2.74
Phosphate (mM/kg)	93	100
Phosphate/SNFNS (g/100 g)	3.52	3.04
pH	5.4	5.9
Stretchability (cm)	27.8	8.2
Meltability (%)	212	120
Fat loss (%)	4.3	0.1

+Mean of two trials

*Fresh skim milk with AMF were homogenized at 10 000 kPa.

B-3.5.2.3 Cheese physical properties. The results in Tables B.5 and B.6 demonstrate that homogenization treatment had a great effect on the cheese properties. It was found that stretch properties were impaired, meltability was decreased and fat loss reduced when homogenization was used.

B-3.5.4 Conclusion

The results of the present study suggest that homogenization treatments have a great influence on the stretch and melt properties of Halloumi. The preliminary trials also show the composition of the cheeses is altered.

The results indicate that further study on the effects of homogenization is needed since this process is one of the essential steps for preparing recombined milk for cheesemaking.

Because of the dominant effect of homogenization, it is not clear at this stage whether replacement of cream by AMF also influences Halloumi characteristics.

B-4 MANUFACTURE OF HALLOUMI CHEESE FROM HOMOGENIZED FRESH MILK

B-4.1 Introduction

In the previous investigation (B-3), it was demonstrated that Halloumi cheese with the desired physical properties cannot be made from homogenized milk.

Mulder & Walstra (1974), suggest that the homogenization process creates small fat globules, thus increasing the surface area which needs to be covered by a surface active agent like protein. However, the adsorption of a protein by this enlarged surface area may change the properties of the fat globules in the milk.

The effect of homogenization on the globule size and surface area is influenced by homogenizing pressure, liquid flowrate, temperature of the liquid and fat content (Phipps, 1985). The most important of these factors is the homogenizing pressure in that only a relatively small change in homogenizing efficiency occurs when the temperature, flowrate and fat content of the liquid are altered.

One factor which could possibly contribute to the problems of cheese quality and could be simply varied is the homogenization pressure. In the literature, it is suggested that high homogenization pressures are not suitable for cheesemaking since they adversely affect the resultant cheese properties. According to Kosikowski (1975) when Mozzarella is made from milk homogenized at 3300-6700 kPa, the resultant cheese lacks stretch and melt characteristics. Therefore, it would be seen relevant to study the effect of homogenization pressures on the quality of Halloumi cheese.

B-4.2 Experimental Plan

Homogenization pressures of 400, 3300 and 6700 kPa were chosen for this study since results of previous experiments suggested that high pressures contributed to the problems associated with the physical properties of Halloumi cheese.

Standardized milk was homogenized at the three pressures mentioned. Cheese was made from control and homogenized milks. The composition, physical characteristics, and sensory parameters of the cheeses were then measured.

B-4.3 Experimental

The experiment was carried out in duplicate. Eight vats (i.e. 2 x 4) of Halloumi cheese were manufactured during the 1985/86 dairying season.

B-4.3.1 Milk supply

The milk was pasteurized and standardized as described in A-3.3. About 50 l milk was needed for each of the trials.

B-4.3.2 Homogenization

Milk was heated to 55°C in a double jacketed vat, homogenized and then cooled to 32°C.

For milk homogenized at pressures of 3300 and 6700 kPa, a Manton-Gaulin homogenizer (described in B-3.3.3) was used.

For milks homogenized at pressure of 400 kPa a simple pump homogenizer (NZDRI) was used.

B-4.4 Analytical Procedures

All the methods for chemical analysis, physical measurements and sensory evaluation were followed as outlined in A-5.4.

B-4.5 Results and Discussion

B-4.5.1 Milk composition and cheesemaking

As expected, the compositions of the control milk and homogenized milks were similar (Table B.7). During cheesemaking, differences were observed in curd particles after cutting and the curd structure after whey drainage. After the gels were cut with the same cheese knives, curd particles made from control milk and from milks homogenized at 400 and 3300 kPa were quite similar, whereas the curd particles made from

Table B.7. Composition of control and homogenized fresh milks +

Composition	Milk				F-ratio
	Control	Homogenized at 400 kPa	Homogenized at 3300 kPa	Homogenized at 6700 kPa	
TS (%)	12.4	12.4	12.6	12.6	0.46
Casein (%)	2.5	2.5	2.6	2.6	0.96
Fat (%)	3.5	3.5	3.6	3.6	0.91
C/F	0.71	0.71	0.73	0.73	-
Calcium (mM/kg)	31	31	31	31	0.07
Phosphate (mM/kg)	20	20	21	21	0.04

+Mean of two trials

milk homogenized at 6700 kPa were small and fragile. After the whey was drained and following dry stirring, the curd was allowed to knit for a short time. In the control milk, and milks homogenized at 400 and 3300 kPa, the curd properties were satisfactory while in milk homogenized at 6700 kPa curd properties were poor. Homogenizing the milk at high pressure resulted in a decrease of the elasticity and matting properties of curd during cooking. This is in agreement with previous work (Peters, 1956).

B-4.5.2 Cheese composition

The chemical composition of the cheeses made from control milk and milks homogenized at pressures of 400, 3300 and 6700 kPa are given in Table B.8.

Analysis of the compositional data shows that the calcium content and the Ca/SNFNS ratio of the cheese made from control milk are significantly less than those of cheeses made from homogenized milks. The effect of homogenization treatment on calcium values may be explained in terms of salt content. During processing, sodium tends to exchange for calcium in the cheese, thus decreasing the calcium content. With homogenization the number of fat globules in the cheese is increased. This leads to a slower diffusion rate of salt into the cheese because the ions have to move around the fat globules (Geurts, 1972). Consequently homogenization results in a decrease in salt content in the cheese and hence an increase in calcium content.

B-4.5.3 Cheese physical properties

The results of the physical properties (stretchability, meltability and fat loss) of cheese made from control and homogenized milks are given in Table B.9.

The results show that the stretchability of cheeses decreased as the homogenization pressure increased (Fig. B.2). The results are in accordance with the earlier observation that milk homogenized at higher pressure (6700 kPa) gave a curd with poor elastic properties (Peters, 1956). It is possible that homogenization influences the properties of the casein micelles, thereby affecting the curd characteristics.

Table B. 8. Composition of cheeses made from control and homogenized fresh milks+

Composition	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
MNFS (%)	56.3^{a}	54.4	56.9^{b}	54.3^{ab}	6.33
FDM (%)	46.5	46.4	46.7	47.7	2.73
S/M	8.1^{a}	7.3	7.0	5.7^{a}	4.47
Calcium (mM/kg)	162	182	181	179	7.02*
Ca/SNFNS (g/100 g)	2.34^{ab}	2.52^{a}	2.63^{bc}	2.41^{c}	7.99*
Phosphate (mM/kg)	113	125	115	123	3.61
Phosphate/ SNFNS (g/100 g)	3.39	3.62	3.49	3.58	0.37
pH	5.30	5.34	5.28	5.34	0.56

+Mean of two trials

* $P < 0.05$.

The supercripts a-d indicate differences between means significant at the 0.05.

Table B.9. Physical properties of cheeses made from control and homogenized fresh milks[+]

Physical property	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
Stretchability (cm)	25.2[e]	20.7[a]	18.6	11.5[ea]	9.1*
Meltability (%)	342[e]	274[a]	237	145[ea]	9.3*
Fat loss (%)	4.8[ei]	3.5[af]	1.8[abe]	0.1[bfi]	27.5**

+Mean of two trials
* P < 0.05; ** P < 0.01.
The supercripts a-d;e-h;i-l indicate differeces between means significat at the 0.05,0.01 and 0.001 levels respectively.

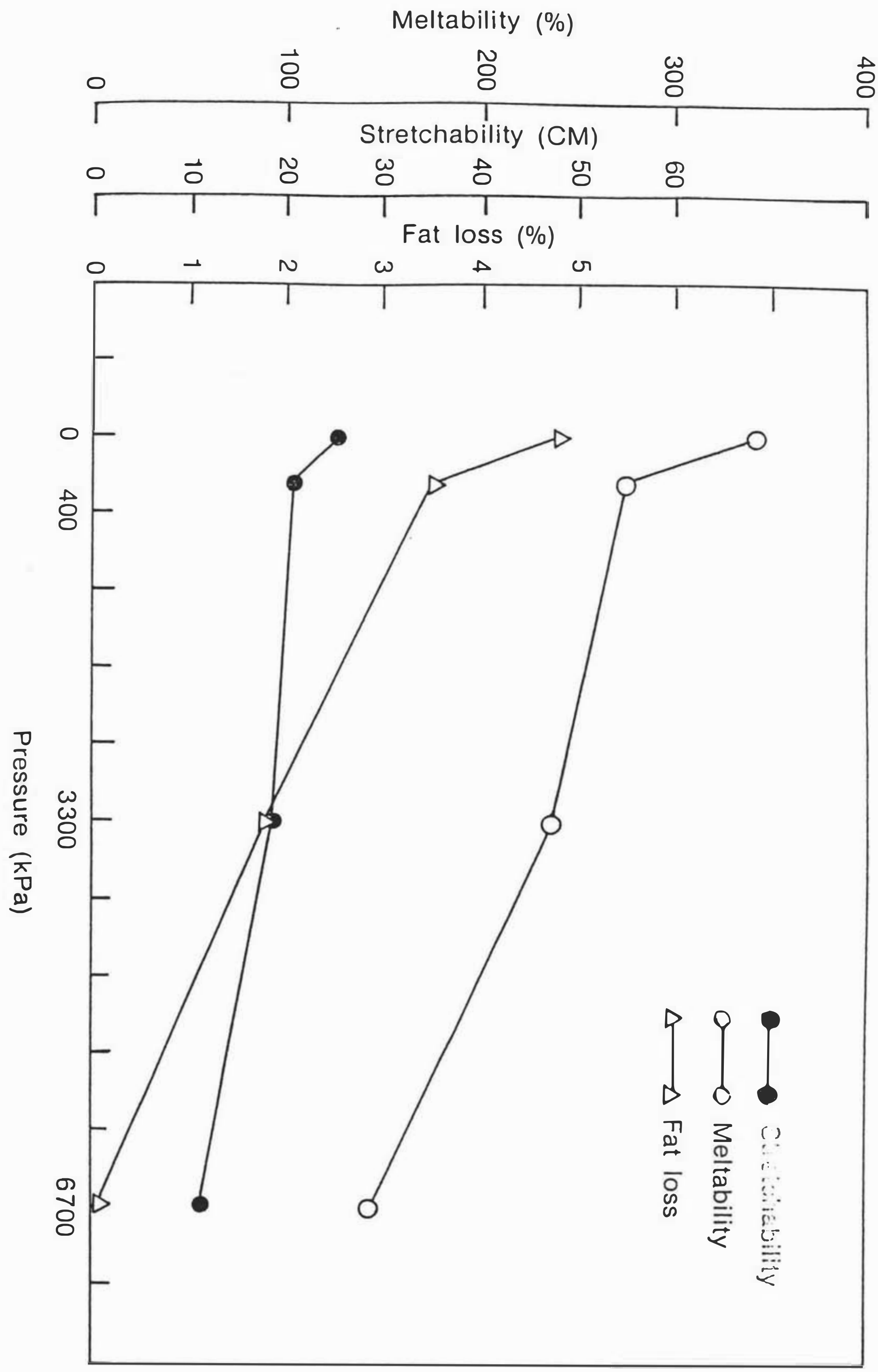


Figure B.2. Effect of homogenization pressures on the physical properties of Halloumi made from homogenized fresh milk.

Table B.10. Mean scores of sensory parameters of cheeses made from control and homogenized fresh milks +

Sensory parameter	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
Colour	2.4	2.1	1.9	1.9	1.18
Appearance	3.2^{a}	3.3^{e}	2.1^{ae}	2.8	9.76*
Texture	2.7^{a}	2.5	2.2^{a}	2.3^{a}	5.48
Elasticity	3.1	2.9	3.1	2.6	0.83
Sourness	2.4	2.5	1.9	2.3	1.20
Saltiness	3.4	3.6	3.4	3.2	0.31
Clean flavour	1.5	1.4	1.4	1.3	0.18
Stretchiness	4.7^{ae}	3.6^{b}	3.4^{a}	2.2^{be}	10.55*
Tenderness	4.3^{abc}	3.6^{a}	3.3^{b}	3.6^{c}	5.85

+Mean of two trials

* P < 0.05.

The supercripts a-d and e-h indicate differeces between means at the 0.05 and o.01 levels respectively.

Table B.11. Correlation coefficients between the sensory parameters and physical properties of cheeses made from control and homogenized fresh milks

Sensory parameters	Correlation coefficient		
	Stretchability	Meltability	Fat loss
Colour	0.5*	0.7*	0.6*
Appearance	0.6*	0.3	0.5*
Texture	0.7*	0.8**	0.8*
Elasticity	0.6*	0.5*	0.4
Sourness	0.0	0.0	0.2
Saltiness	0.3	0.3	0.4
Flavour	0.2	0.2	0.4
Stretchiness	0.9**	0.8**	0.9**
Tenderness	0.4	0.4	0.5*

* $P < 0.05$; ** $P < 0.01$.

The results for meltability of cheese followed the same trend as those for stretchability when homogenization pressures were varied (Fig. B.2).

Progressive increases in homogenizing pressure resulted in corresponding decreases in cheese fat loss (Fig. B.2). This trend may be due to the size of fat globules and the composition of fat globule membrane, which are both influenced by homogenization (Mulder & Walstra, 1974). Also high homogenization creates a more uniform distribution of fat globules throughout the curd (Peters, 1964).

B-4.5.4 Sensory evaluation

The results of the sensory panel (Table B.10) indicated that homogenization had a significant effect on the appearance and the stretchiness of cheese. The other sensory parameters did not show any significant variation.

The sensory parameters were correlated with the physical properties of cheese (Table B.11). Some high correlations were found. For example, the elasticity and stretchiness parameters correlated well with the stretchability and meltability.

B-4.6 Conclusion

The results of this section suggest that when milk, homogenized at a pressure of 6700 kPa, is used for making Halloumi cheese, there are unfavourable effects on the quality of the resultant cheese. However, when a low homogenization pressure is used (e.g. 400 kPa) these effects are almost negligible.

B-5 MANUFACTURE OF HALLOUMI CHEESE FROM FRESH SKIM MILK AND MILKFAT

B-5.1 Introduction

It was shown earlier (B-4) that homogenization of milk at high pressure leads to problems with the quality of Halloumi cheese. It was also shown that some of the problems with the physical properties of the cheese can be overcome by using low pressure homogenization. However, these findings apply to the homogenization of fresh milk but may not apply when the milk system is changed.

The objective of the present investigation is to study the effect of homogenization treatment on the quality of Halloumi made from skim milk and AMF.

B-5.2 Experimental Plan

Homogenized milks were prepared by initially homogenizing fresh skim milk with AMF (ratio 3:1) and then adding the recombined cream to skim milk. Cheese was made from control and homogenized milks. The composition, physical characteristics and sensory parameters of the cheeses were then measured.

B-5.3 Experimental

The experiment was carried out in duplicate. Eight vats (i.e. 2 x 4) of Halloumi cheese were manufactured during the 1985/86 dairying season.

B-5.3.1 Preparation of recombined milk

B-5.3.1.1 Skim milk. Skim milk was prepared by separating the whole milk, pasteurizing at 72°C/15 s and cooling to 45°C.

B-5.3.1.2 Milkfat. Anhydrous milkfat (AMF) was supplied by the New Zealand Dairy Board.

B-5.3.1.3 Homogenization. Recombined cream was made by homogenizing skim milk with AMF (ratio 3:1) at 55°C. Then recombined cream was mixed with the rest of skim milk and cooled to 33°C.

For recombined creams, homogenized at pressures of 3300 and 6700 kPa, a Manton-Gaulin homogenizer (described in B-4.3.2) was used.

For recombined creams homogenized at pressure of 400 kPa a simple pump homogenizer (NZDRI) was used.

B-5.3.4 Cheesemaking

The detailed experimental conditions for the manufacture of cheese are given in Fig. B.1.

B-5.4 Analytical Procedures

All the methods for chemical analysis, physical measurements and sensory evaluation were followed as outlined in A-5.4.

B-5.5 Results and Discussion

B-5.5.1 Milk composition and cheesemaking

The compositions of the control milk and homogenized milks were similar (Table B.12). During cheesemaking, no differences were observed in manufacturing steps, apart from the particle size of the curd after cutting and the curd properties after whey drainage, as discussed previously (B-4.5.1).

B-5.5.2 Cheese composition

The average compositions of the four cheeses are given in Table B.13. Statistical analysis of the data showed that no significant differences were noted in any of the cheese compositions, except for the salt in moisture (S/M) values. The S/M value of the cheese made from control milk is significantly greater than the S/M values for cheeses made from homogenized milks. The higher level S/M of the control cheese was attributed to the greater diffusion of salt as discussed in B-4.5.2.

B-5.5.3 Cheese physical properties

The physical properties of the cheeses are listed in Table B.14. The data followed the same trend as in the results for cheeses made from homogenized fresh milks (B-4).

The stretchability properties of cheeses decreased as the homogenization pressures increased (Fig. B.3). Comparing the

Table B.12. Composition of control and homogenized milks+

Composition	Milk				F-ratio
	Control	Homogenized at 400 kPa	Homogenized at 3300 kPa	Homogenized at 6700 kPa	
TS (%)	11.5	11.5	11.7	11.7	1.30
Casein (%)	2.55	2.55	2.51	2.51	0.24
Fat (%)	3.6	3.7	3.6	3.6	0.44
C/F	0.71	0.70	0.70	0.70	-
Calcium (mM/kg)	29	30	29	29	0.05
Phosphate (mM/kg)	20	20	21	20	0.25

+Mean of two trials

Table B.13. Composition of cheeses made from control and homogenized milks+

Composition	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
MNFS (%)	54.8	54.5	55.1	53.1	2.03
FDM (%)	45.0	45.1	45.7	45.8	0.99
S/M	8.1^{efg}	6.8^{e}	6.3^{f}	6.1^{g}	25.8*
Calcium (mM/kg)	186	188	192	191	0.09
Ca/SNFNS (g/100 g)	2.59	2.47	2.55	2.46	0.25
Phosphate (mM/kg)	129	126	129	127	0.02
Phosphate/SNFNS (g/100 g)	3.74	3.60	3.75	3.61	0.26
pH	5.4	5.5	5.5	5.5	0.02

+Mean of two trials

* $P < 0.05$.

The superscripts a-d; e-h; i-l indicate diferences between means significant at 0.05, 0.01, 0.001 levels respectively.

Table B.14. Physical properties of cheeses made from control and homogenized milks +

Physical property	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
Stretchability (cm)	27.5^{a}	23.4^{b}	14	6.4^{ab}	6.30
Meltability (%)	229	225	221	153	0.83
Fat loss (%)	4.8^{efg}	0.5^{e}	0.4^{f}	0.2^{g}	26.46**

+Mean of two trials
* $P < 0.05$; ** $P < 0.01$.
The superscripts a-d indicate differences between means significant at 0.05 level.
e-h at 0.01 level.

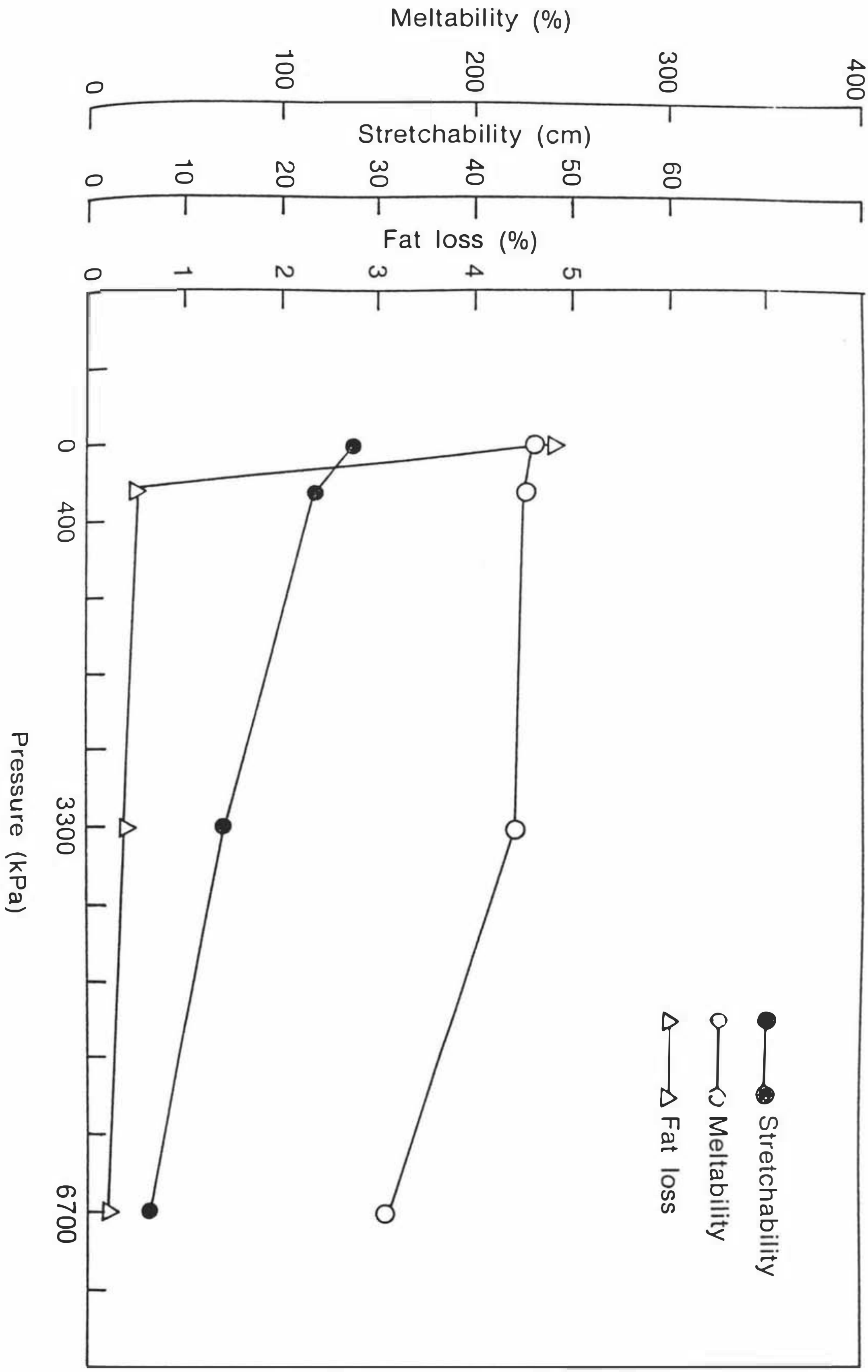


Figure B.3. Effect of homogenization pressures on the physical properties of Halloumi made from control and homogenized milks

Table B.15. Mean scores of sensory parameters of cheeses made from control and homogenized milks +

Sensory parameter	Cheese				F-ratio
	Control milk	Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	
Colour	3.3[ae]	3.0[f]	2.6[ab]	2.0[bef]	17.74*
Appearnce	2.5	2.8	2.70	3.0	0.67
Texture	2.0	1.8	2.1	1.9	0.44
Elasticity	2.1	1.0	2.5	2.2	0.30
Sourness	1.9	1.8	1.8	1.70	0.44
Saltiness	3.3[abc]	2.5[a]	2.5[b]	2.5[c]	4.72
Clean flavour	1.2	1.5	1.3	1.1	0.61
Stretchiness	5.1[a]	4.6	3.4	1.6[a]	3.52
Tenderness	4.7[a]	4.3[b]	3.5	2.7[ab]	4.99

+Mean of two trials

* $P < 0.05$.

The superscripts a-d; e-h indicate differences between means significant at 0.05 and o.o1 levels respectively.

Table B.16. Correlation coefficient between the sensory parameters and physical properties of cheeses made from control and homogenized milks

Sensory Attrbiutes	Correlation coefficient		
	Stretchability	Meltability	Fat loss
Colour	0.79*	0.46	0.70*
Appearance	-0.49	-0.20	-0.37
Texture	-0.19	-0.04	0.25
Elasticity	-0.15	0.50*	-0.21
Sourness	-0.55*	0.20	0.47
Saltiness	0.59*	0.43	0.94**
Flavour	0.44	0.74*	-0.12
Stretchiness	0.97**	0.79*	0.58*
Tenderness	0.97**	0.70*	0.61*

P < 0.05; ** P < 0.01.

stretchability of control cheese with that produced by other treatments, a slight decrease was noted in cheese made from milk homogenized at 400 kPa, while a greater decrease was observed in the cheeses made from milk homogenized at 3300 and 6700 kPa. The reason for this decrease could be attributed to the homogenization pressure changing the structure of the milk casein by facilitating its adsorption on the new surface area of the fat globules (Mulder & Walstra, 1974).

There was no significant difference in the meltability of the cheeses. However, the results showed the same trend as the stretchability results (Fig. B.3).

The fat loss in cheese made from control milk was found to be significantly greater than the fat loss in cheeses made from homogenized milks (Table B.14 and Fig. B.3).

B-5.5.4 Sensory evaluation

The results of the sensory panel (Table B.15) indicated that homogenization had a significant effect on the colour parameter of cheese. The other sensory attributes did not show any significant difference.

The correlation coefficients between sensory parameters and physical characteristics of the cheese are shown in Table B.16. Some high correlations were observed, for example the stretchiness and tenderness parameters correlated significantly with the stretchability, meltability and fat loss.

B-5.6 Conclusion

The results of the present study show that the physical properties of the cheese are affected by the homogenization pressure used in the preparation of the milk. When high homogenization pressure is used a cheese of unsatisfactory quality is produced, while low pressure homogenization gives cheese with satisfactory physical properties. These results confirm the previous results (B-4).

B-6 MANUFACTURE OF HALLOUMI CHEESE FROM RECOMBINED MILK

B-6.1 Introduction

It has been reported that hard and semi-hard cheese can be manufactured from recombined milk using homogenization pressure 5100-6700 kPa (Sanderson, 1970). However, experiments carried out in Sections B-4 and B-5 suggest that it is unlikely Halloumi cheese can be manufactured from recombined milk which has been homogenized at pressures of 5000-6700 kPa. Consequently the effect of homogenization treatment on the quality of Halloumi made from recombined milk was investigated in the present study.

B-6.2 Experimental Plan

Recombined milks were prepared by initially homogenizing reconstituted skim milk with AMF (ratio 3:1) and then adding the recombined cream to the skim milk. Cheese was made from the recombined milks. The composition, physical characteristics and sensory parameters of the cheeses were then measured.

B-6.3 Experimental

The experiment was carried out in duplicate. Six vats (i.e. 2 x 3) of Halloumi cheese were manufactured.

B-6.3.1 Preparation of recombined milk

B-6.3.1.1 Reconstitution of skim milk. Reconstituted skim milk was prepared by mixing 11.9 kg of low heat skim milk powder (manufactured at NZDRI with a preheat treatment of 72°C/15 s), with 122.5 kg of water at 40°C using a powder liquid circulation pump. (The system is particularly suitable for reconstituting the powder rapidly.) The skim milk was kept circulating for 15 min to ensure that all the powder was dissolved.

B-6.3.1.2 Milkfat. AMF was used.

B-6.3.1.3 Homogenization. The homogenization process was the same as that given in B-5.3.1.3.

B-6.3.2 Cheesemaking

The detailed experimental conditions for the manufacture of cheese are given in Fig. B.1.

B-6.4 Analytical Procedures

All the methods for chemical analysis, physical measurements and sensory evaluation were followed as outlined in A-5.4.

B-6.5 Results and Discussion

B-6.5.1 Milk composition and cheesemaking

The compositions of recombined milks were similar (Table B.17). During cheesemaking, no differences were observed in manufacturing steps, apart from the particle size of the curd after cutting and the curd properties after whey drainage, as discussed previously (B-4.4.1).

B-6.5.2 Cheese composition

The average compositions of the three cheeses are given in Table B.18. Statistical analysis of the data showed that there were no significant differences in the cheese compositions.

B-6.5.3 Cheese physical properties

The physical properties of the cheeses are given in Table B.19. The data showed significant variation in the stretchability and meltability properties of the cheeses from the three treatments (Fig. B.4). Fat loss properties did not show any significant difference but followed the same trend as for stretchability.

B-6.5.4 Sensory evaluation

The results of the sensory evaluation (Table B.20) indicated that homogenization had a significant effect on the stretchiness and tenderness of cheese. The other sensory parameters did not show any significant variation. The significant results from the sensory panel confirmed, to a large extent, the findings of the physical properties data.

The sensory parameters were correlated with the physical properties of cheese (Table B.21). A significant positive correlation was observed

Table B.17. Composition of recombined milks[+]

Composition	Recombined milk			F-ratio
	Homogenized at 400 kPa	Homogenized at 3300 kPa	Homogenized at 6700 kPa	
TS (%)	11.7	11.7	11.8	0.45
Casein (%)	2.65	2.60	2.65	2.11
Fat (%)	3.9	3.8	3.9	3.04
C/F	0.69	0.68	0.68	0.59
Calcium (mM/kg)	31	30	32	0.42
Phosphate (mM/kg)	17	17	18	1.13

+Mean of two trials

Table B.18. Composition of cheeses made from recombined milks+

Composition	Cheese: Recombined milk homogenized at 400 kPa	Recombined milk homogenized at 3300 kPa	Recombined milk homogenized at 6700 kPa	F-ratio
MNFS (%)	54.1	55.1	54.0	7.5
FDM (%)	48.7	48.5	48.3	3.9
S/M (%)	5.3	5.5	6.0	0.26
Calcium (mM/kg)	190	185	191	1.30
Ca/SNFNS (g/100 g)	2.46	2.44	2.56	1.1
Phosphate (mM/kg)	101	98	104	1.2
Phosphate/ SNFNS (g/100 g)	2.95	2.95	2.98	1.0
pH	5.6	5.6	5.6	0.8

+Mean of two trials

Table B.19. Physical properties of cheeses made from recombined milks+

Physical property	Cheese: Recombined milk homogenized at 400 kPa	Recombined milk homogenized at 3300 kPa	Recombined milk homogenized at 6700 kPa	F-ratio
Stretchability (cm)	54[ae]	35.5[ab]	6.7[be]	84.9**
Meltability (%)	276[a]	243	133[a]	11.2
Fat loss (%)	0.6	0.6	0.1	1.0

+Mean of two trials
* $P < 0.05$; ** $P < 0.01$.

The superscripts a-d;e-h indicate differences between means significant at 0.05 and 0.01 levels respectively.

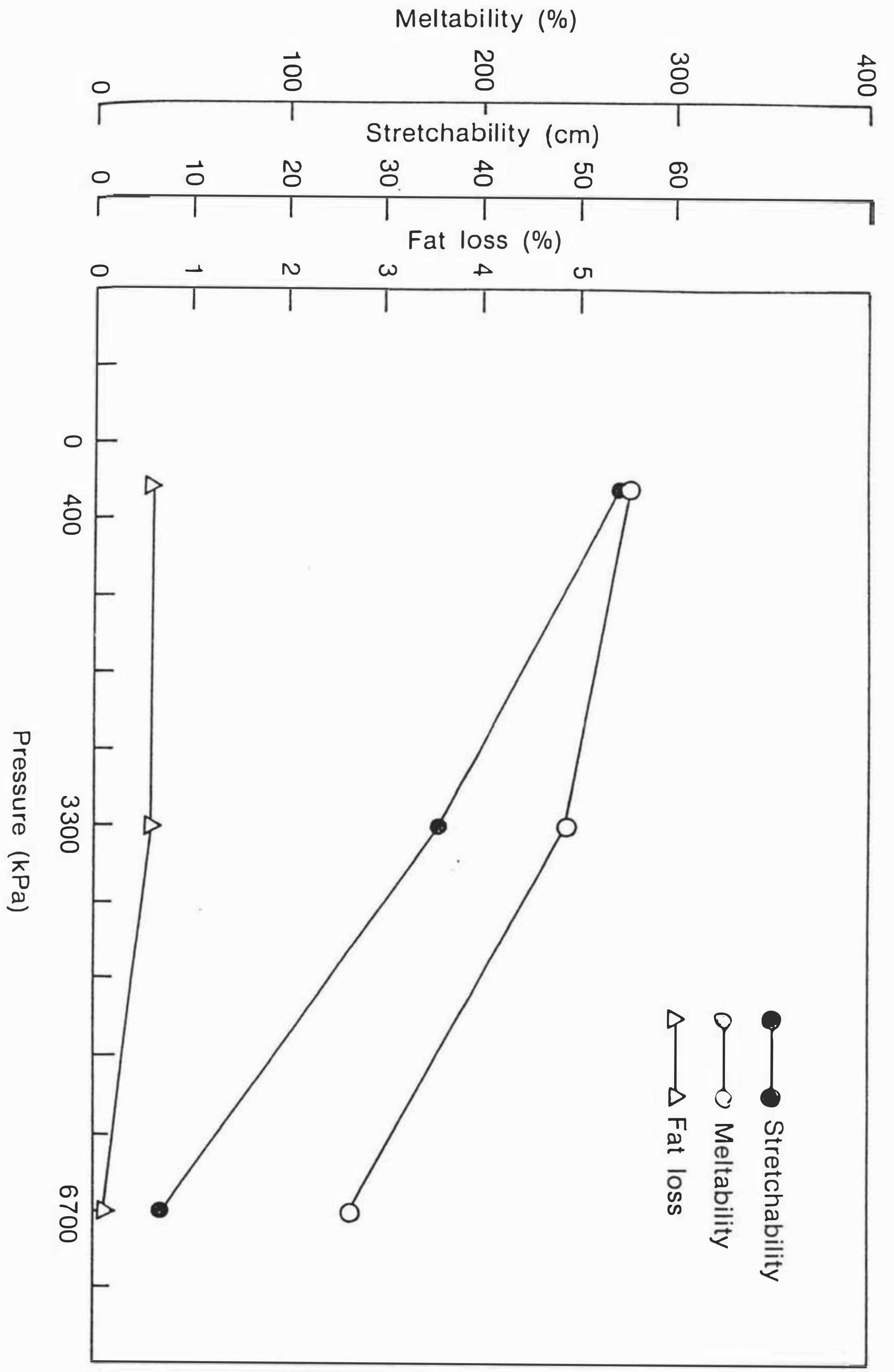


Figure B.4. Effect of homogenization pressures on the physical properties of Halloumi made from recombined milks.

Table B.20. Mean scores of sensory parameters of cheeses made from recombined milks +

Sensory parameter	Cheese: Recombined milk homogenized at 400 kPa	Recombined milk homogenized at 3300 kPa	Recombined milk homogenized at 6700 kPa	F-ratio
Colour	3.6	3.2	1.9	3.06
Appearance	3.2	2.9	3.0	0.31
Texture	2.4	2.5	2.6	0.08
Elasticity	2.4	2.1	2.0	0.41
Sourness	1.8	1.8	2.6	4.38
Saltiness	2.8	2.8	3.6	2.67
Clean flavour	1.4	1.3	1.8	8.12
Stretchiness	5.3^{e}	4.2^{a}	1.2^{ae}	53.87*
Tenderness	4.1	4.1	3.4	9.8

+Mean of two trials
* P < 0.05; ** P < 0.01.
The superscripts a-d; e-h indicate differences between means significant at the 0.05and 0.01 levels respectively.

Table B.21. Correlation coefficients between the sensory parameters and physical properties of cheeses made from recombined milks

Sensory parameters	Correlation coefficient		
	Stretchability	Meltability	Fat loss
Colour	0.80**	0.78*	0.75*
Appearance	0.14	-0.04	0.05
Texture	-0.22	-0.35	-0.10
Elasticity	0.44	0.46	0.73*
Sourness	-0.13	-0.39	-0.35
Saltiness	-0.32	-0.36	-0.40
Flavour	-0.40	-0.44	-0.35
Stretchiness	0.96**	0.94**	0.72*
Tenderness	0.80**	0.85**	0.77

* $P < 0.05$; ** $P < 0.01$.

between stretchiness and stretchability, meltability and fat loss characteristics. Tenderness gave similar positive correlations.

B-6.6 Conclusion

The results of the present study show that the stretchability and meltability properties of the cheese were affected by high homogenization pressure. The result gives further evidence to support the hypothesis that there is a relationship between homogenization treatment and the properties of the resultant cheese.

However, the results also show that it is possible to manufacture a cheese with satisfactory properties from milk reconstituted from SMP and AMF using low homogenization pressures.

B-6.7 Overall Conclusion of the Effect of Homogenization on the Physical Properties of Halloumi Cheese

In the preceding Sections (B-4, B-5 and B-6), studies were carried out to determine the effect of homogenization pressure on the physical properties of Halloumi cheese when made from different types of milk. The results of these studies are given in Tables B.9, B.14 and B.19, while the averaged data for the three set of experiments are shown in Table B.22. The results show that for fresh milk, milk made from fresh skim milk and AMF, and milk produced from SMP and AMF, homogenization treatment had a significant effect on the physical properties of cheese. For each type of milk, stretchability, meltability and fat loss decreased as homogenization pressure increased from 400 to 6700 kPa. Cheeses produced from milks homogenized at pressure of 400 kPa were considered to have satisfactory physical properties.

Further investigations have been undertaken to determine why homogenization treatment affects the physical properties of Halloumi cheese. These studies are reported later (B-9).

Table B.22. Mean scores of physical properties of cheeses made at different homogenization pressures

Physical property	Cheese: Milk homogenized at 400 kPa	Milk homogenized at 3300 kPa	Milk homogenized at 6700 kPa	F-ratio
Stretchability (cm)	32.7^{ei}	22.7^{ej}	8.2^{ij}	38.9***
Meltability (%)	258^{e}	234^{a}	144^{ae}	7.66*
Fat loss (%)	1.5^{ai}	0.9^{ab}	0.1^{bi}	16.1**

* $P < 0.05$; ** $P < 0.01$.

The superscripts a-d; e-h; i-l indicate differences between means significant at the 0.05, 0.01 and0.001 levels respectively

B-7 MANUFACTURE OF HALLOUMI CHEESE FROM DIFFERENT TYPES OF SKIM MILK POWDER

B-7.1 Introduction

In the previous investigation (B-4, B-5 and B-6) it was demonstrated that homogenization of milk at high pressures (about 6700 kPa) had a detrimental effect on the stretching and melting properties of Halloumi, while low pressures (400 kPa) caused a minimal change to cheese properties. Therefore when making Halloumi from recombined milk, low pressure hmogenization must always be used. While homogenization has an important influence on the quality of Halloumi cheese made from recombined milk, the nature of the skim milk powder used may also be significant.

The production of a powder suitable for cheesemaking depends on the process variables. In commercial practice, two process parameters can be altered to change the powder quality, namely (i) preheat treatment of milk, and (ii) solids concentration prior to drying.

The preheat treatment is important, both in terms of the quality of the powder (Baucke & Sanderson, 1970) and of the resultant cheese (Gilles & Lawrence, 1980). Furthermore, Flanagan et al. (1978) suggested that when part of the low heat milk powder is replaced by high heat powder for Mozzarella cheese manufacture, the stretching and melting properties are impaired.

Concentration of total solids prior to drying is another variable that can affect the powder quality (de Vilder et al., 1979; Muir, 1980), and may also affect recombined cheese quality (Gilles, personal communication, 1985).

The objective of the present study was to investigate the effect of preheat treatment of the milk and the total solids concentration prior to drying on the quality of recombined Halloumi cheese.

B-7.2 Experimental Plan

Skim milk was divided into two portions, which were preheated at different temperatures. Each of these portions was subdivided into two lots and concentrated to different levels. The four lots were dried. The composition, physical characteristics and sensory parameters of the cheeses were then measured.

B-7.3 Experimental

The four different types of SMP were manufactured twice in March 1985 and twice in November 1985.

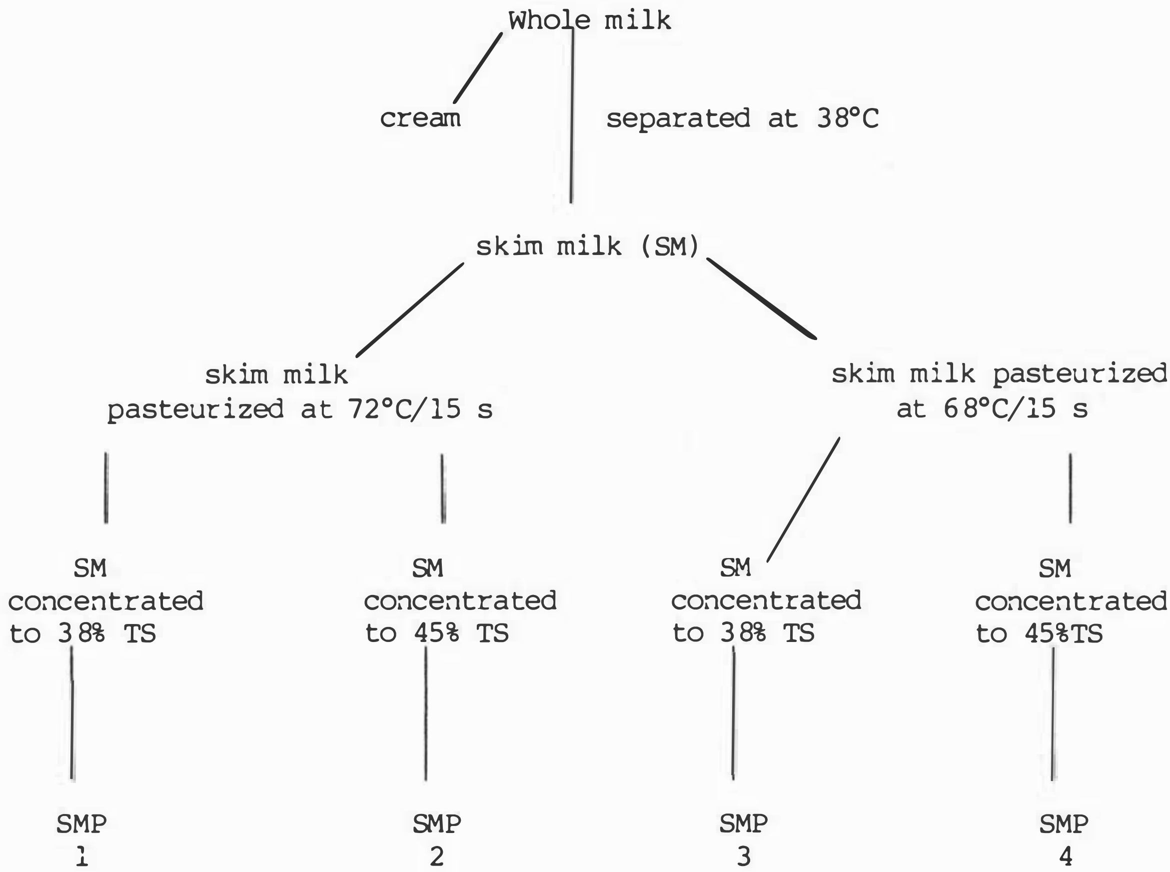
Sixteen vats (i.e. 4 x 4) of Halloumi cheese were manufactured from the SMP made in March 1985 and eight vats (i.e. 4 x 2) from the SMP made in November 1985.

B-7.3.1 Manufacture of skim milk powder
The manufacturing procedure for SMP is shown in Fig. B.5.

B-7.3.1.1 Milk supply. On the day of processing, bulk whole milk was obtained from the Manawatu Co-operative Dairy Company. Skim milk was prepared by separation of whole milk after warming the milk to 38°C. The skim milk was divided into two portions, and pasteurized at 68°C/15 s and 72°C/15 s respectively in a plate heat exchanger.

B-7.3.1.2 Preparation of concentrate. Each portion of skim milk, which had been subjected to preheat treatment, was subdivided into two lots. These lots were concentrated conventionally in a pilot-scale triple effect falling film evaporator (Wiegand, Karlsruhe, GmbH, West Germany) to 38% and 45% total solids. During evaporation, milk temperatures were maintained in the range 35-37°C.

B-7.3.1.3 Spray drying. The concentrated skim milk was dried using a de Laval TCD configuration spray drier (Sweden). Typical drying conditions were:



SMP 1 - preheated to 72°C/15 s, concentrated to 38% TS
SMP 2 - preheated to 72°C/15 s, concentrated to 45% TS
SMP 3 - preheated to 68°C/15 s, concentrated to 38% TS
SMP 4 - preheated to 68°C/15 s, concentrated to 45% TS

Figure B.5. Manufacturing procedure for skim milk powder (SMP).

inlet temperature	200°C
outlet temperature	97-101°C
feed atomization pressure	170-180 bar

B-7.3.2 Preparation of recombined milk

B-7.3.2.1 Reconstitution of skim milk. Reconstituted skim milk was prepared as described in B-6.3.1.1.

B-7.3.2.2 Milkfat. Anhydrous milkfat (AMF) was used.

B-7.3.2.3 Homogenization. Recombined cream was made by homogenizing reconstituted skim milk and AMF at a pressure of 400 kPa. Details of the procedure are given in B-5.3.1.3.

B-7.3.3 Cheesemaking

The detailed experimental conditions for the manufacture of cheese are given in Fig. B.1.

B-7.4 Analytical Procedures

B-7.4.1 Chemical and physical methods for skim milk powder

The skim milk powders were analysed for moisture, total nitrogen, ash, lactose, calcium, phosphate, whey protein nitrogen index and solubility index. Standard methods as detailed in the New Zealand Dairy Division Manual (NZDDM) were followed (Table B.23).

B-7.4.2 Analytical methods for milk and cheese

All the methods for chemical analysis, physical measurements and sensory evaluation were followed as outlined in A-5.4.

B-7.5 Results and Discussion

The results obtained for the two sets of experiments (i.e. SMPs made in March and November) are discussed below.

B-7.5.1 Powder composition and physical properties

Within each set of experiments there were no major differences between the four different types of powders (Table B.24 and B.25). However the protein contents of the powders made late in the dairying season (March) were higher than those of powders made at the peak of the

Table B.23. Chemical and physical methods for analysis of skim milk powder

Particulars	Method	Reference	Principle of method
Moisture	NZDDM 2.9.1a	American Dry Milk Institute (ADMI) 1965	The sample is heated with toluene to extract water vapour as an azeotropic mixture with toluene vapour. Following condensation the water separates and is collected as the more dense layer in a Dean-Stark trap.
Total nitrogen	NZDDM 1-11a Kjeldhal	FIL-IDF 20-1962	Method is described in Table B.5.
Ash	NZDDM 2.3.1a	British Standard 1743:1968	After all the organic material has been burnt off the residue is weighed.
Lactose	NZDDM 2.5.1a		The fat and protein are removed from a reconstituted sample by precipitation and filtration. The optical rotation of the filtrate is measured to give the percentage lactose present.
Calcium	NZDDM	Pearce (1977)	Method is described in Table B.5
Phosphate	NZDDM 2.15.1a	AOAC 2.019	The sample is wet oxidized using nitric and perchloric acids and reacted with a molybdovanadate reagent for colorimetric determination.
Whey protein nitrogen index (WPNI)	NZDDM 2.16.2a	Sanderson (1970)	Casein protein and denatured whey protein are precipitated from the reconstituted milk powder using sodium chloride. Undenatured whey protein is precipitated using amido black dye, and the excess dye determined spectrophotometrically.
Solubility Index (SI)	NZDDM 2.17.1a	ADMI 1965	Under standard conditions the reconstituted milk powder is centrifuged in a graduated tube, and the volume of insoluble material noted.

Table B.24. Composition and physical properties of skim milk powders manufactured from milk subjected to different heat treatments and concentrations (March 1985)

Composition	Skim milk powder			
	Milk heated to 68°C and concentrated to 38%	Milk heated to 68°C and concentrated to 45%	Milk heated to 72°C and concentrated to 38%	Milk heated to 72°C and concentrated to 45%
Moisture (%)	3.7	3.6	3.4	3.8
Protein (%)	39.6	39.8	40.1	39.2
Lactose (%)	46.8	46.9	46.8	46.3
Ash (%)	8.1	8.0	8.0	8.0
Calcium (mM/kg)	351	327	337	343
Phosphate (mM/kg)	210	199	200	215
WPNI	9.6	8.5	8.5	9.4
SI	0.1	0.7	0.2	0.5

Table B.25. Composition and physical properties of skim milk powders manufactured from milk subjected to different heat treatments and concentrations (November 1985)

Composition	Skim milk powder			
	Milk heated to 68°C and concentrated to 38%	Milk heated to 68°C and concentrated to 45%	Milk heated to 72°C and concentrated to 38%	Milk heated to 72°C and concentrated to 45%
Moisture (%)	3.4	3.4	3.4	2.8
Protein (%)	36.5	36.5	36.9	37.4
Lactose (%)	51.1	51.1	51.6	48.6
Ash (%)	8.1	8.0	8.1	8.1
Calcium (mM/kg)	356	352	334	343
Phosphate (mM/kg)	246	240	225	232
WPNI	796	8.0	8.0	7.9
SI	0.1	0.8	0.1	0.5

season (November). This marked increase was probably due to the combined effects of cows approaching the end of lactation (Newstead, 1973) and changes in pasture growth (Bloor, 1981). Solubility index (SI) was affected by the concentration factor. The increase in total solids of the concentrate resulted in an increase in solubility index of the powder. These results were in agreement with data of Baldwin et al., 1980.

B-7.5.2 Milk composition and cheesemaking

As expected, within each set of experiments, the compositions of recombined milks were similar (Tables B-26 and B-27). During cheesemaking, no differences were observed in the curd firmness, and the acid production at different stages of processing also followed a similar pattern.

B-7.5.3 Effect of preheat treatment

The mean values for the compositions of cheeses made from SMPs subjected to different heat treatments are shown in Tables B-28 and B-29.

Within each set of experiments, statistical analysis of the compositional data showed that the preheat treatment temperature did not significantly affect cheese composition. This was expected since the milk compositions were similar and the milks behaved in a similar way during cheesemaking.

The influence of preheat treatment on stretchability, meltability and fat loss properties is demonstrated in Tables B.30 and B.31. The preheat temperature had a significant effect on the stretchability and meltability of cheese. For each set of experiments, these properties decreased appreciably as the temperature increased (Figs B.6 and B.7). There are two possible reasons why the reduction occurred.

Firstly, the effect of preheat temperature could be attributed to the denat– ation of whey protein and the formation of whey protein-casein complexes (Sanderson, 1970; Gilles & Lawrence, 1980), and the subsequent effect on cheese properties. This effect has been observed for Mozzarella cheeses. When high heat powder was used in its manufacture, the

Table B.26. Composition of milks prepared from skim milk powders manufactured at different heat treatments and concentrations (March 1985) +

Composition	Milk				F-ratio
	SMP (68°C-38%)	SMP (68°C-45%)	SMP (72°C-38%)	SMP (72°C-38%)	
TS (%)	11.6	11.6	11.7	11.5	0.80
Fat (%)	4.0	3.9	3.9	4.0	1.25
TN (%)	0.57	0.56	0.56	0.58	1.05
Calcium (mM/kg)	30	29	32	31	1.75
Phosphate (mM/kg)	19	18	18	19	1.30

+Mean of four trials

Table B.27. Composition of milks prepared from skim milk powders manufactured at different heat treatments and concentrations (November 1985)+

Composition	Milk				F-ratio
	SMP (68°C-38%)	SMP (68°C-45%)	SMP (72°C-38%)	SMP (72°C-38%)	
TS (%)	11.8	11.8	11.3	11.7	1.80
Fat (%)	4.0	4.0	3.9	4.0	0.67
TN (%)	0.53	0.53	0.52	0.53	1.47
Calcium (mM/kg)	28	28	28	28	0.28
Phosphate (mM/kg)	20	20	20	22	1.23

+Mean of two trials

Table B.28. Composition of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments (March 1985)+

Composition	Cheese: SMP manufactured from milk heated to 68°C	Cheese: SMP manufactured from milk heated to 72°C	F-ratio
MNFS (%)	51.7	51.8	0.07
FDM (%)	47.6	47.4	1.88
Protein (%) (as dry matter)	42.1	42.2	0.01
S/M (%)	4.0	4.2	1.13
Calcium (mM/kg)	186	189	0.01
Ca/SNFNS (g/100 g)	2.3	2.4	0.19
Phosphate (mM/kg)	93	92	0.21
Phosphate/SNFNS (g/100 g)	2.8	2.7	0.17
pH	5.5	5.4	0.11

+Mean of four trials

Table B.29. Composition of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments (November 1985) +

Composition	Cheese: SMP manufactured from milk heated to 68°C	Cheese: SMP manufactured from milk heated to 72°C	F-ratio
MNFS (%)	52.2	53.3	1.57
FDM (%)	49.7	50.1	3.85
Protein (%) (as dry matter)	39.7	39.9	0.43
S/M (%)	4.7	4.5	0.13
Calcium (mM/kg)	188	184	0.36
Ca/SNFNS (g/100 g)	2.4	2.4	0.01
Phosphate (mM/kg)	93	92	0.01
Phosphate/SNFNS (g/100 g)	2.9	2.9	0.22
pH	5.6	5.6	0.11

+Mean of two trials

Table B.30. Physical properties of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments (March 1985)+

Physical property	Cheese: SMP manufactured from milk heated to 68°C	Cheese: SMP manufactured from milk heated to 72°C	F-ratio
Stretchability (cm)	54.9	50.6	9.14*
Meltability (%)	354	300	5.68*
Fat loss (%)	2.0	1.6	1.05

+Mean of four trials
* $P < 0.05$.

Table B.31. Physical properties of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments (November 1985)+

Physical property	Cheese		F-ratio
	SMP manufactured from milk heated to 68°C	SMP manufactured from milk heated to 72°C	
Stretchability (cm)	32.2	24.1	7.40*
Meltability (%)	217	191	16.04*
Fat loss (%)	1.9	1.5	1.84

+Mean of two trials

* $P < 0.05$.

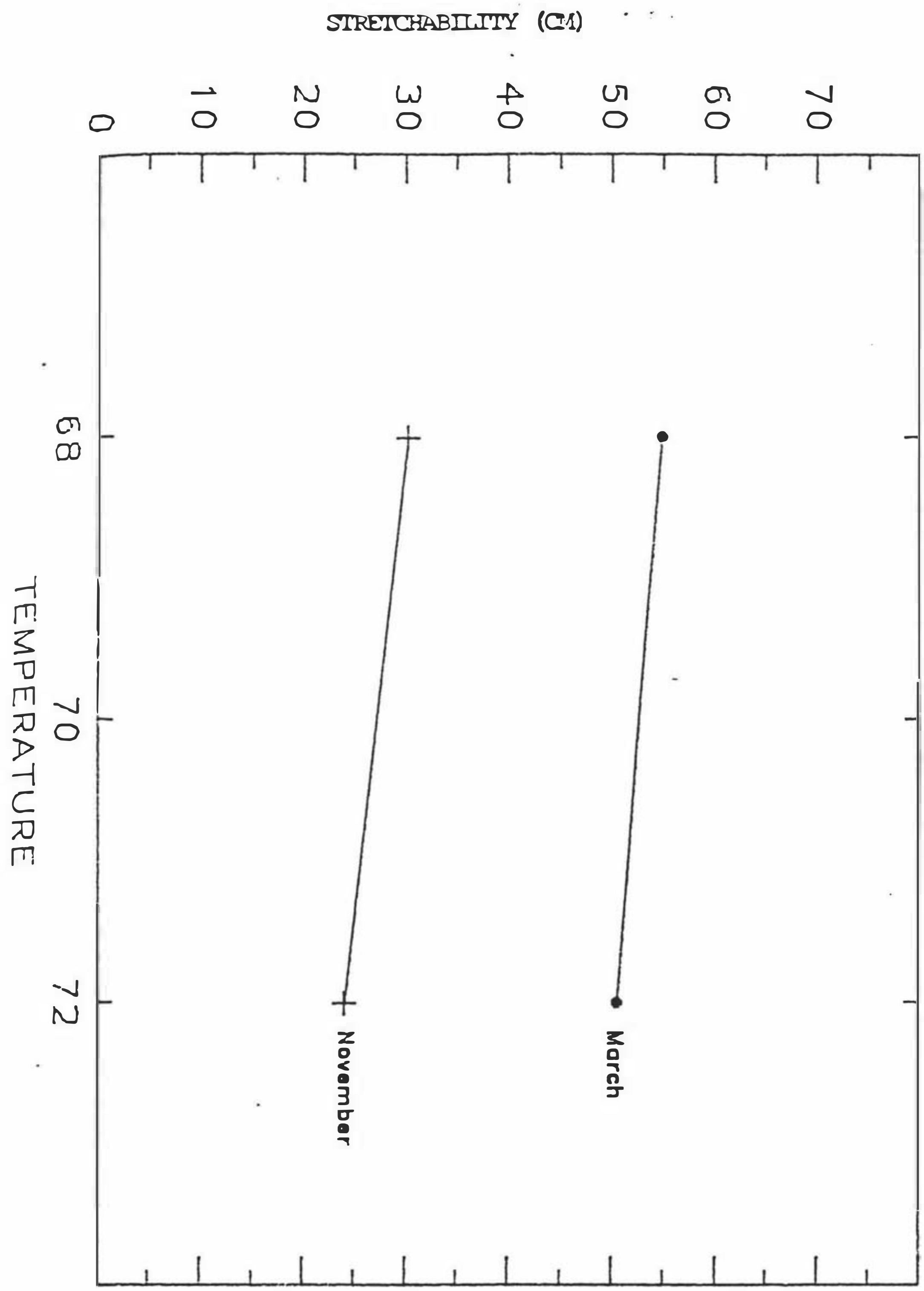


Figure B.6. Effect of heat treatments on the stretchability of cheese made from recombined milks

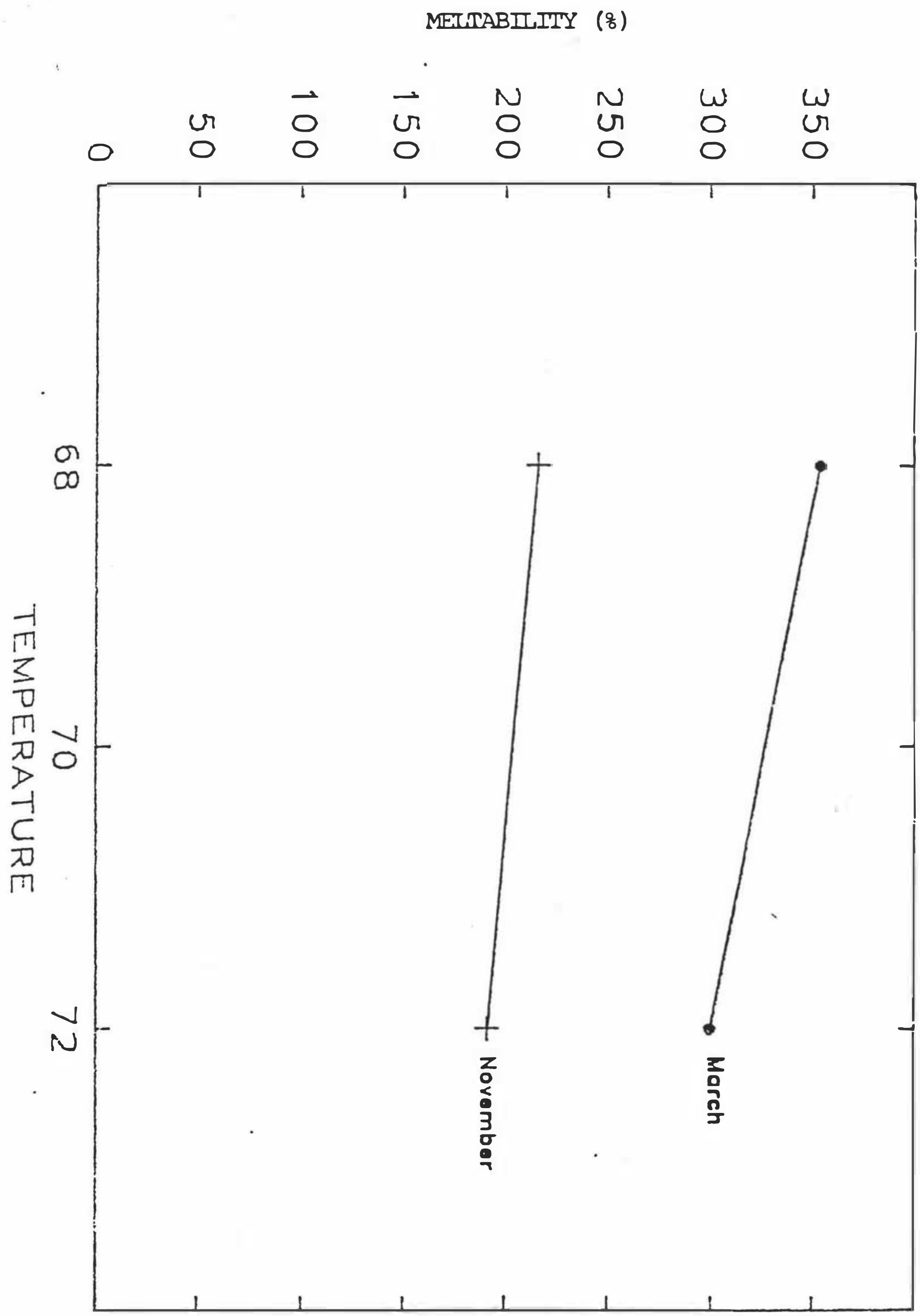


Figure B.7. Effect of heat treatments on the meltability of cheese made from recombined milks resultant cheese had poor physical properties (Flanagan et al., 1978). Secondly, the effect of preheat treatment on the distribution of calcium in milk (Kannan & Jenness, 1961). It is generally recognized that low heat powder contains more ionic calcium than high heat powder (Muldoon & Iiska, 1972) and this may affect the resultant curd and cheese properties. These results suggest that the increase of preheat treatment temperature of milk, even by a few degrees, adversely affects the stretching and melting properties of Halloumi cheese.

B-7.5.4 Effect of concentration of total solids

The compositions of the cheeses made from SMPs, which were manufactured from milk concentrates with different total solids are given in Tables B.32 and B.33. Within each set of experiments, the compositions did not show any significant differences.

The physical properties of these cheeses are shown in Tables B.34 and B.35. Within each set of experiments statistical analysis of the data showed that the total solids of the concentrate did not significantly affect the stretchability, meltability and fat loss of the cheeses.

B-7.5.5 Sensory evaluation

The mean scores of the sensory parameters are presented in Tables B.36 and B.37. For each set of experiments, the results showed that the sensory assessment of stretchiness was the only parameter significantly affected by the two treatment factors studied. Further statistical analysis has shown that the preheat treatment had a significant effect on sensory stretchiness, while the concentration of total solids had no significant effect. These results confirmed the findings of the instrumental measurements of stretchability.

The correlation between the sensory parameters and the physical properties of the cheeses are given in Tables B.38 and B.39. For each set of experiments a significant positive correlation was found between sensory stretchiness, and the stretchability and meltability properties of the cheeses. In contrast, sensory tenderness gave different results for cheeses produced from March and November powders. In the case of cheeses made from November powders, a significant correlation was

Table B.32. Composition of cheeses made from skim milk powders manufactured from milks subjected to different concentrations (March 1985)+

Composition	Cheese: SMP manufactured from milk concentrated to 38%	Cheese: SMP manufactured from milk concentrated to 45%	F-ratio
MNFS (%)	51.8	51.6	0.15
FDM (%)	47.4	47.5	0.34
Protein (%) (as dry matter)	42.2	42.1	0.33
S/M (%)	4.2	4.1	0.09
Calcium (mM/kg)	190	185	0.43
Ca/SNFNS (g/100 g)	2.38	2.29	0.62
Phosphate (mM/kg)	96.9	88.1	3.07
Phosphate/SNFNS (g/100 g)	2.88	2.68	2.19
pH	5.56	5.46	1.0

+Mean of four trials

Table B.33. Composition of cheeses made from skim milk powders manufactured from milks subjected to different concentrations (November 1985)+

Composition	Cheese: SMP manufactured from milk concentrated to 38%	Cheese: SMP manufactured from milk concentrated to 45%	F-ratio
MNFS (%)	52.4	53.0	0.46
FDM (%)	49.8	49.9	0.75
Protein (%) (as dry matter)	39.7	39.8	0.18
S/M (%)	4.5	4.7	0.04
Calcium (mM/kg)	188	185	0.17
Ca/SNFNS (g/100 g)	2.44	2.44	0.00
Phosphate (mM/kg)	92.8	93.0	0.00
Phosphate/SNFNS (g/100 g)	2.88	2.92	0.09
pH	5.6	5.6	0.00

+Mean of two trials

Table B.34. Physical properties of cheeses made from skim milk powders manufactured from milks subjected to different concentrations (March 1985)+

Physical property	Cheese: SMP manufactured from milk concentrated to 38%	Cheese: SMP manufactured from milk concentrated to 45%	F-ratio
Stretchability (cm)	54.4	51.0	2.98
Meltability (%)	337	316	0.88
Fat loss (%)	1.9	1.7	0.09

+Mean of four trials

Table B.35. Physical properties of cheeses made from skim milk powders manufactured from milks subjected to different concentrations (November 1985) +

Physical property	Cheese: SMP manufactured from milk concentrated to 38%	Cheese: SMP manufactured from milk concentrated to 45%	F-ratio
Stretchability (cm)	33.8	28.5	2.43
Meltability (%)	213	196	0.30
Fat loss (%)	1.3	1.0	0.25

+Mean of two trials

Table B.36. Mean scores of sensory parameters of cheese made from different treatment powders (March 1985) +

Sensory parameter	Cheese				F-ratio
	SMP manufactured from milk heated to 68°C and concentrated to 38%	SMP manufactured from milk heated to 68°C and concentrated to 45%	SMP manufactured from milk heated to 72°C and concentrated to 38%	SMP manufactured from milk heated to 72°C and concentrated to 45%	
Colour	3.6	3.5	3.3	3.5	0.52
Appearance	3.1	3.3	3.2	3.1	0.71
Texture	2.0	2.6	2.1	2.3	2.94
Elasticity	3.1	2.7	2.7	2.8	0.68
Sourness	1.5	1.4	1.3	1.7	0.68
Saltiness	1.6	1.7	1.9	2.0	1.32
Clean flavour	1.5	1.6	2.1	1.5	2.82
Stretchiness	4.9	4.5	4.3	3.9	17.34*
Tenderness	4.0	4.2	3.7	3.8	1.08

+ Mean of four trials
* $P < 0.05$.

Table B.37. Mean scores of sensory parameters of cheese made from different treatment powders (November 1985)+

Sensory parameter	Cheese				F-ratio
	SMP manufactured from milk heated to 68°C and concentrated to 38%	SMP manufactured from milk heated to 68°C and concentrated to 45%	SMP manufactured from milk heated to 72°C and concentrated to 38%	SMP manufactured from milk heated to 72°C and concentrated to 45%	
Colour	3.6	3.1	3.5	3.8	2.85
Appearance	2.9	2.9	2.9	3.0	0.33
Texture	1.9	2.2	1.9	2.2	2.0
Elasticity	2.9	2.8	2.8	2.9	0.13
Sourness	1.4	1.6	1.7	1.3	1.33
Saltiness	1.3	1.6	1.6	1.2	3.40
Clean flavour	1.4	1.6	1.3	1.4	0.25
Stretchiness	4.1	3.9	3.2	3.9	8.90*
Tenderness	4.0	4.0	3.4	3.9	2.10

+Mean of two trials

* $P < 0.05$.

Table B.38. Correlation coefficients between the sensory parameters and physical properties of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments and concentrations (March 1985)

Sensory parameters	Correlation coefficient		
	Stretchability	Meltability	Fat loss
Colour	0.09	0.07	-0.06
Appearance	-0.34	-0.30	-0.09
Texture	-0.18	0.13	0.08
Elasticity	0.36	0.27	0.10
Sourness	0.09	-0.19	-0.18
Saltiness	-0.34	-0.28	-0.20
Stretchiness	0.86**	0.58*	0.33
Tenderness	-0.25	0.20	0.24

* P < 0.05; ** P < 0.01.

Table B.39. Correlation coefficients between the sensory parameters and physical properties of cheeses made from skim milk powders manufactured from milks subjected to different heat treatments and concentrations (November 1985)

Sensory parameters	Correlation coefficient		
	Stretchability	Meltability	Fat loss
Colour	-0.33	0.04	-0.11
Appearance	-0.04	-0.24	0.02
Texture	0.07	-0.31	-0.30
Elasticity	0.22	0.29	-0.13
Sourness	-0.62*	-0.46	-0.20
Saltiness	-0.25	-0.29	-0.43
Flavour	0.01	-0.12	0.10
Stretchiness	0.95**	0.67*	0.68*
Tenderness	-0.85**	-0.53*	-0.67*

* $P < 0.05$; ** $P < 0.01$.

Table B.40. Composition of cheeses made from skim milk powders manufactured at different time of dairying season

Composition	Cheese: SMP manufactured in March	SMP manufactured in November	F-ratio
MNFS (%)	51.7	52.7	3.98
FDM (%)	47.5	49.9	371.97*
Protein (%) (as dry matter)	42.2	39.8	135.81*
S/M (%)	4.1	4.6	2.63
Calcium (mM/kg)	187.4	186.4	0.03
Calcium/SNFNS (%)	2.3	2.4	1.48
Phosphate (mM/kg)	92.3	92.9	0.04
Phosphate/SNFNS (g/100 g)	2.7	2.9	2.89
pH	5.4	5.6	4.44

* $P < 0.01$.

Table B.41. Physical properties of cheeses made from skim milk powders manufactured at different time of dairying season

Physical property	Cheese: SMP manufactured in March	SMP manufactured in November	F-ratio
Stretchability (cm)	52.7	27.1	404.23*
Meltability (%)	326	285	51.65**
Fat loss (%)	1.8	1.7	2.81

* P < 0.05; **, P < 0.01.

observed between tenderness and stretchability, meltability and fat loss. However, in the case of cheese made from March powders, tenderness did not show any significant correlation with physical properties. This later result was not expected.

B-7.5.6 Effect of stage of dairying season

Cheeses made from powder manufactured late in the dairying season (March) had a lower FDM and higher protein content than cheese made from powder manufactured at the peak of the season (November). This was expected since the two types of powders had different protein contents (see Tables B.24 and B.25). The cheese with higher FDM had higher MNFS suggesting that these two composition characteristics are interlinked (Lelievre, 1983). However, differences in MNFS between the two stages were too small to be significant. Other compositional data did not show any significant differences.

The physical properties of cheeses made at the two stages of the dairying season were different (Table B.41). Cheese made from powder manufactured late in the dairying season (March) had higher stretchability and meltability values than the cheese made from early season powder (November). The reason for these differences could be attributed to the different functional properties of protein at different stages of the dairying season or different protein contents of cheeses.

B-7.6 Conclusion

The results of the present investigation show that higher preheat treatment contributes to the problems associated with the stretchability and meltability properties of Halloumi cheese made from recombined milk. It is well known that the physical properties of the powder and the resultant cheese are extremely sensitive to variation in salt balance and denatured whey protein, and both are essentially affected by preheat treatment of milk (Baldwin et al., 1980; Gilles & Lawrence, 1980).

The total solids concentration of milk prior to spray drying does not show any significant effect on the cheese quality.

The stage of the dairying season at which milk powder was manufactured influences the physical properties of cheese made from recombined milk.

B-8 MANUFACTURE OF MOZZARELLA CHEESE FROM RECOMBINED MILK

B-8.1 Introduction

Mozzarella is an unripened cheese. It is characterized by its bland flavour and the ability to melt and stretch when cooked. These physical characteristics are similar to those of Halloumi cheese. It is generally known that the stretching and melting properties of Mozzarella cheese are reduced when homogenized milk is used (Breene *et al.*, 1964; Kosikowski, 1975). It has also been reported (Gilles & Lawrence, 1980) that the stretching characteristics of Mozzarella cheese are diminished when recombined milk is used for manufacture, although the reason is not known.

In the present investigation, an attempt was made to study the manufacture of Mozzarella cheese from recombined milk using the principles established for Halloumi production.

B-8.2 Experimental Plan

Recombined milks were prepared by initially homogenizing reconstituted skim milk with AMF (ratio 3:1) and then adding the recombined cream to the skim milk. Cheese was made from the recombined milks. Also cheese was made from standardized milk as a control. The composition, physical characteristics and sensory parameters of the cheeses were then measured.

B-8.3 Experimental

The experiment was carried out in duplicate. Six vats (i.e. 3 x 2) of Mozzarella cheese were manufactured

B-8.3.1 Preparation of recombined milk

B-8.3.1.1 Reconstitution of skim milk. Reconstituted ski milk was prepared as described in B.6.2.1.1.

B-8.3.1.2 Milkfat. Anhydrous milkfat was used.