QUALITY ASPECTS OF FETA CHEESE MANUFACTURED FROM MIXTURES OF COW'S MILK AND GOAT'S MILK

BY

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SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE
M INST AGRAR FOOD PROCESSING

IN THE
DEPARTMENT OF FOOD SCIENCE
FACULTY OF NATURAL, AGRICULTURAL AND
INFORMATION SCIENCES
UNIVERSITY OF PRETORIA

OCTOBER, 1999

DECLARATION

I, the undersigned, hereby declared that this dissertation is my original work and has never been submitted at any university for a degree.

ACKNOWLEDGEMENTS

I wish to extend my sincere gratitude to all those who assisted in conducting this research. Special appreciation is due to:

- Prof. B. H. Bester (Department of Food Science, UP) for offering guidance with his ingenuity in the field of fermented milk products and dairy science and technology.

- The Department of Food Science for financial assistance.

- Mrs R. de Kock (Department of Food Science, UP) for assistance in planning for sensory evaluation and statistical analysis of the results.

- Mr J. Grimbeeck (Department of Statistics and Data Analysis, UP) for guidance in designing the project plan.

- Mr G. Duodu (Department of Food Science, UP) for technical assistance in the laboratory and statistical analysis of the results.

- My family, friends and husband, Abraham, for their love and support.

- God Almighty, for giving me strength and wisdom to cope, the baby girl I got while carrying out this research and for making my dreams a reality.

ABSTRACT

Title:- Quality Aspects of Feta Cheese Manufactured from Mixtures of Cow's Milk and Goat's Milk

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Degree:- M Inst Agrar Food Processing

Pure goat's milk and pure cow's milk were analysed for microbial, physical and chemical quality. The milks were mixed in the proportions of 100% cow's milk (treatment 1), 65% cow's milk + 35% goat's milk (treatment 2), 35% cow's milk + 65% goat's milk (treatment 3) and 100% goat's milk (treatment 4). Feta cheese was made from these milks and the experiment was done three times (three batches in all).

Physical, chemical and microbial analysis were performed on the Feta cheeses on day 2, 7, 14 and 21 after manufacturing. Sensory evaluation of the cheeses was done only on batch 3 after ripening the cheeses for a period of 21 days.

Analysis of the Feta cheeses revealed that the treatments differed significantly ($p < 0.05$), especially in terms of fat content, total solids content, log total plate count (TPC), texture, pH, protein content and free fatty acids (FFA) content. Other quality aspects, namely soluble protein content, NaCl content and sensory evaluation scores did not differ significantly ($p > 0.05$) between treatments. The pH, log TPC, soluble protein content, FFA content, NaCl content and texture changed significantly ($p < 0.05$) during ripening.

The Feta cheeses made from high proportion of goat's milk (treatments 3 and 4) had higher microbial counts, FFA content and soluble protein content than cheeses made from milk with higher proportions of cow's milk. Although treatments 2 and

3 almost overlapped in soluble protein content, the values concerning these three quality aspects generally increased as the proportion of goat's milk used for cheese manufacturing increased (the trend being treatment 1<2<3<4). Conversely, the pH values decreased systematically from treatment 1 to 4.

The mean fat content of the Feta cheeses increased systematically with increase in the proportion of cow's milk, while the mean total protein content followed the reverse pattern. In all the cheeses, the lactose content was almost negligible from the second day after manufacturing. The texture analysis results fluctuated significantly with time and between the treatments and there was no logical trend found.

Despite the difference in composition and other characteristics, the acceptability of all the Feta cheeses was the same as they all received a sensory evaluation score of "like slightly".

UITTREKSEL

Titel: - Kwaliteitsaspekte van Feta-kaas Vervaardig van Mengsels van Beesmelk en Bokmelk

Deur

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Studieleier:- Prof B.H. Bester

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Suiwer bokmelk en suiwer beesmelk is ontleed vir mikrobiologiese, fisiese en chemiese kwaliteit. Die melk is gemeng in die proporsies van 100 % beesmelk (behandeling 1), 65 % beesmelk + 35 % bokmelk (behandeling 2), 35 % beesmelk + 65 % bokmelk (behandeling 3) en 100 % bokmelk. Feta-kaas is gemaak van hierdie melk en die eksperiment is drie keer herhaal (altesaam drie lotte).

Fisiese, chemiese en mikrobiologiese ontledings is gedoen op die Feta-kaas op dag 2, 7, 14 en 21 na vervaardiging. Sensoriese evaluering van slegs lot 3 se kaas is gedoen na rypmaking vir 'n periode van 21 dae.

Analise van die Feta-kaas het getoon dat die behandelings beduidend van mekaar verskil het ($p < 0.05$), veral in terme van vetinhoud, totale vastestowwe-inhoud, log totale plaattelling (TPT), tekstuur, pH, proteïeninhoud en vrye vetsuur-inhoud (VVS). Ander kwaliteitsaspekte, naamlik oplosbare proteïeninhoud, NaCl-inhoud en punte vir sensoriese evaluering het nie beduidend ($p > 0.05$) verskil tussen behandelings nie. Die pH, log TPT, oplosbare proteïeninhoud, VVS-inhoud, NaCl-inhoud en tekstuur het beduidend ($p < 0.05$) verander gedurende rypmaking.

Die Feta-kaas gemaak van melk met 'n hoë proporsie bokmelk (behandelings 3 en 4) het hoër mikrobiologiese tellings, VVS-inhoud en oplosbare proteïeninhoud gehad as kase gemaak van melk met hoër proporsies beesmelk. Al het behandelings 2 en 3 omtrent oorvleul wat oplosbare proteïeninhoud betref, het die waardes vir hierdie drie

kwaliteitsaspekte oor die algemeen toegeneem soos die proporsie bokmelk gebruik in die kaasvervaardiging toegeneem het (die neiging was 1<2<3<4). In teenstelling hiermee het die pH-waardes sistematies verlaag van behandeling 1 na 4.

Die gemiddelde vetinhoud van die Feta-kaas het sistematies toegeneem met 'n toename in die proporsie beesmelk, terwyl die gemiddelde totale proteïeninhoud die omgekeerde patroon gevolg het. Die laktose-inhoud van al die kase was onbeduidend vanaf die tweede dag na vervaardiging. Die resultate van tekstuurmetings het beduidend gewissel met tyd en tussen behandelings, maar geen logiese neiging is gevind nie.

Ten spyte van die verskille in samestelling en ander eienskappe, was die aanvaarbaarheid van al die Feta-kase dieselfde en het almal 'n sensoriese evaluering van "hou effens van" gekry.

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1. INTRODUCTION

Cheesemaking practice is an ancient milk preservation technique, which is believed to have been pioneered in the Eastern Mediterranean countries over 10 000 years ago (Fox, 1987b; Scott, 1986 according to Early, 1992). It was traditionally made on small scale by carrying milk in animal skin sacks, stomachs or bladders. Over centuries, the cheesemaking technique has been modified and finally evolved into a large scale commercial process in which scientific principles are applied (Early, 1992).

Cheesemaking is a form of milk preservation in which the nutrients of milk are selectively concentrated in the form of a palatable food. The concentration of the milk solids is basically achieved by curd production through either acidification, renneting or a combination of the two. The newly formed product, cheese, has a different image and consumption pattern from fresh milk (Early, 1992).

There is a wide variety of cheeses which are manufactured both industrially and on small scale world wide. One of the major reasons for this is the difference in the mammal species used as the source of milk; for instance in Greece, goats and sheep are used as the major if not sole source of milk for the daily human diet as well as for processing to cheese and other milk products (Eekhof-stork, 1976; Barbosa, 1990). In South Africa milk from goats and sheep is scarce and produced in small quantities. For cheesemaking purposes on industrial scale, cow's milk is predominantly used and by far the most commonly produced milk.

Cheese produced from goat's and ewe's milk is typically white in colour, and native to countries like Greece where these milks are produced in large quantities. These include Feta cheese and a variety of other brined or pickled cheeses. According to Barbosa (1990), Feta cheese has gained high popularity and

conquered new markets in many countries other than Eastern Mediterranean countries. As a result, the chemical composition of Feta cheese may vary from one country to another depending on the raw material used and its processability. However, the chemical composition of Feta cheese can be generalised as shown in Table 1.1.

Table 1.1: Chemical composition of Feta cheese (Macrae, Robinson & Sadler, 1993)

Constituents	Percentages
Moisture	48 - 54
Fat in dry matter	48 - 52
Protein	≈25.1
Salt	4 - 5

Apart from the features given in Table 1.1, Feta cheese is known to be soft in texture and has a pH value of about 4.3 to 4.6 (Tzanetakis, Mastrojiannaki & Tzanetaki, 1995).

Feta cheese and other cheeses made from goat's milk or mixtures of goat's and other milk provide a most effective relief from the dull monotony of factory made cow's milk cheese. Blending cow's milk with at least 25% goat's milk has been reported to give cheese a unique but pleasant flavour and texture (Brown, 1981).

1.1 PROBLEM STATEMENT

For the South African market, there are problems related to the manufacturing of Feta cheese of the original Greek type.

(i) The supply and production of ewe's and/or goat's milk is not so well established as that of cow's milk. This implies that collection of sufficient goat's

milk to start processing may take too many days and incur high expenses for storing and transportation of milk over long distances from the producers to the processors. A solution would be to use mixtures of the two types of milk.

(ii) Feta cheese made exclusively from cow's milk loses its familiar properties. It is not as smooth and fragrant as the Greek type, moreover it possess an unusual yellow colour which is misleading and give consumers a wrong perception about the product.

(iii) The properties of milk from a given mammal species may vary considerably due to seasonal, regional and vegetation (used as feed) variations and this can make South African milk different from that used for production of Feta cheese in other countries (Lacroix, Paquin & Verret, 1993; Ozimek & Kennelly, 1993; Potter & Hotchkiss, 1995).

1.2 OBJECTIVES

Despite the complications mentioned in section 1.1, consumers still demand high quality Feta cheese with typical characteristics more especially in terms of flavour, nutritional value, safety and standard composition. Based on these facts, the objective of this project was to study the effect of using mixtures of cow's milk and goat's milk on the composition, physical, chemical and sensory properties of Feta cheese.

2. LITERATURE REVIEW

2.1 BASIC INGREDIENTS USED FOR FETA CHEESE MANUFACTURING

2.1.1 Milk

Milk is the most important basic ingredient used for cheesemaking, and its physical, chemical and microbiological properties affect the chemical composition and organoleptic properties of the cheese. Milk of various mammal species and breeds have been used for manufacturing Feta cheese. Goat's milk and cow's milk (Table 2.1) are among the milks that may be used separately or in combination for making Feta cheese, and the properties of the cheese will depend more or less on the composition of the milk (Fox, 1987b; Potter & Hotchkiss, 1995).

Table 2.1: Proximate composition of goat's milk and cow's milk (Potter & Hotchkiss, 1995)

Constituent	% in cow's milk	% in goat's milk
Fat	3.80	4.24
Protein	3.35	3.70
Lactose	4.75	4.51
Ash	0.70	0.75
Total Solids	12.60	13.18
Water	87.40	86.82

2.1.1.1 Total solids content

According to Harding (1995), the difference between cow's milk and goat's milk composition is not much, moreover the composition also depends on the breed of the dairy animal. However, Table 2.1 shows that goat's milk is higher in total solids content, especially fat and protein. This is advantageous to the cheese processor in terms of yield since a unit volume of goat's milk produces a significantly higher amount of Feta cheese than cow's milk (Anifantakis, 1990).

2.1.1.2 Fat content

Table 2.1 also shows that the average fat content of goat's milk is 4.24% compared with 3.80% for cow's milk. Moreover, goat's milk has a relatively poor creaming ability owing to its small fat globules and the absence of agglutinin, a clustering agent (Macrae *et al,* 1993). Goat milk lipids are higher in short chain fatty acids (C_4 - C_{12}), which are more easily attacked by lipase. As a result, Feta cheese made from goat's milk is richer in free fatty acids and hence the cheese has a rancid but pleasant flavour, while that of cow's milk has rather a dull flavour.

The fact that goat's milk lipids are present as small fat globules compared to cow's milk is an advantage in cheesemaking. Small fat globules are easy to incorporate into the cheese curd, while big ones are more easily pressed out of the curd resulting in high losses of fat and low cheese yield (Scott, 1986). Cheese manufacturers reduce this problem by homogenising milk for manufacturing certain cheese types.

2.1.1.3 Protein content

The proteins in milk fall into two distinct types, whey proteins which exist in solution and casein in colloidal state. Casein constitute a large proportion of total proteins in both goat's and cow's milk, 95% of which is incorporated into the curd, while most of the whey proteins are lost with the water (Early, 1992).

According to Macrae *et al* (1993), goat's milk has more total protein content, but a slightly lower casein content than cow's milk. As a result, goat's milk form a softer and more friable curd than cow's milk, consequently Feta cheese made from the former is softer in texture.

2.1.1.4 Odour and flavour

The fact that goat's milk contains about twice as much of capric, caprylic and caproic acids as does cow's milk has been claimed to be a reason for the characteristic odour and flavour associated with goat's milk (Lampert, 1975). Johnson & Peterson (1974) indicated that the goat flavour is a genetic characteristic, but it can be affected by feed, environmental conditions and the presence of the billy goat while milking.

2.1.1.5 Colour

Goat's milk is almost white in colour as it contains little or no carotene because of the goat's efficiency in converting carotene to vitamin A. As a result, Feta cheese made from goat's milk is typically white in colour, while that of cow's milk has a yellowish tint since it is rich in carotene (Neilsen, Olsen, Lyndon, Sorensen & Skibsted, 1996).

2.1.1.6 Health implications

Goat's milk forms smaller and more flocculent curds which are more easily digested than cow's milk (Ensminger, Ensminger, Kolande & Robinson, 1986). The former also lacks some of the unique proteins present in the latter, which cause asthma, eczema and other allergic reactions in some people. Therefore goat's milk is often recommended for invalids and infants (Brown, 1981).

2.1.2 Starter cultures

According to Tzanetakis, Vafopoulou-Mastrojinnaki & Litopoulou-Tzanetaki (1995), the natural microflora responsible for fermentation in Feta cheese made from raw goat's milk are lactic acid producing bacteria mostly of the genera *Lactobacillus, Lactococcus* (formerly called *Streptococcus*) and *Leuconostocs*. For industrial manufacturing of Feta cheese, a commercial starter culture consisting of one or more of these micro-organisms is commonly used.

The major role of starter cultures in cheesemaking is to convert the milk sugar (lactose) into lactic acid, which in turn causes important and desirable changes necessary in cheesemaking. Such changes include curdling of the milk solids, protein denaturation and development of flavour components. In addition, lactic acid is responsible for the low pH (4.3 to 4.6) which is a characteristic of Feta cheese and it also provides an acidic medium for the activity of proteolytic enzymes. The low pH has a preservation effect by inhibiting and minimising growth of undesired pathogenic and spoilage bacteria (Early, 1992; Pappas, Kondyli, Voutsinas & Mallatou, 1996). For industrial processing of Feta cheese from pasteurised milk, *Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp.*cremoris* are commonly used as starter culture (Varnam & Sutherland, 1994).

Most of the amino acids of the milk proteins exist in a form that cannot be utilised directly by the starter bacteria, but the presence of a proteinase system is advantageous as it converts the proteins into the absorbable form. Proteinase activity plays an important role during cheese ripening, by hydrolysing casein to soluble and absorbable amino acids and peptides (Cogan, Barbosa, Beuvier, Salvadori, Coccincelli, Fernandes, Gomezm Kalantzopoulos, Ledda, Medina, Rea & Rodriquez, 1997).

2.1.3 Rennet

The role of rennet in Feta cheesemaking is to convert the milk to a curd which is more stable and firm than that obtained by acid coagulation alone and also to impart desirable changes during ripening (Fox, 1987a). The ability of rennet to perform these functions is due to the presence of the enzyme chymosin, which is secreted in the abomasum (fourth stomach) of the suckling ruminant. Sometimes rennet may contain a combination of chymosin and pepsin in different ratios. In the ancient cheesemaking practice of carrying milk in animal skin sacks, stomachs

and bladders, the milk absorbed the enzymes from the tissues, and these served the renneting functions (Fox, 1987a: Varnam & Sutherland, 1994).

For large scale manufacturing of Feta cheese in modern dairies, an extract from lamb and kid vells, in combination or separately, are usually used as a source of chymosin (Scott, 1986).

2.1.4 Salt

As indicated in Table 1.1 Feta cheese contains about 4 - 5% of sodium chloride (NaCl), which plays an important role in preservation and improving the organoleptic properties of the cheese. It lowers the water activity of the cheese and hence negatively affects growth of undesired micro-organisms and it also influences cheese ripening. NaCl is responsible for the characteristic saltiness of Feta cheese (Pappas *et al.*, 1996).

2.2 CHEESEMAKING SCIENCE AND TECHNOLOGY

2.2.1 Heat treatment of milk

Pasteurisation is the heat treatment usually applied to milk prior to cheesemaking. The conditions for this heat treatment are 63°C for 30 min or 72°C for 15 s.

2.2.1.1 Microbiological effect

Pasteurisation destroys pathogens and lactic acid bacteria and reduces the load of micro-organisms which would otherwise compete with starter culture bacteria for nutrients (Varnam & Sutherland, 1994). Common milk-borne pathogens like *Campylobacter* and *Salmonella* are among the organisms destroyed. The majority of psychrotrophic spoilage bacteria are also destroyed, but some of the enzymes produced by these bacteria may survive. Their enzymes are partly responsible for the rancid flavour due to lipolytic reactions in Feta cheese produced from

unpasteurised milk and also participate in proteolytic reactions during ripening of the cheese (Fox, 1987a; Early, 1992).

2.2.1.2 *Physico-chemical effects*

Pasteurisation results in increased cheese yield by incorporating denatured whey proteins into the curd (Fox, 1987a; Early, 1992). If a more severe heat treatment is applied, the physico-chemical properties of milk are affected. These include formation of large casein micelles and β-lactoglobulin complexes with k-casein through sulphydryl bonding. The complex inhibits the action of chymosin on casein and hence reduce rennetability of the milk. The latter situation is aggravated by reduced availability of calcium ions in the milk. Poor rennetability of milk can be reversed by addition of calcium chloride at the rate of 0.02% of the milk (Scott, 1986; Fox, 1987a; Early, 1992).

2.2.1.3 *Heating technique*

According to Scott (1986), the equipment used for heat treatment of cheesemilk is very variable. In small volume dairy factories, vats or tanks are jacketed to carry hot water or steam which is used as a heating medium. For large scale factory operation, heat exchangers, tubular or multiple-plate type, are commonly used because of their efficiency in heat transfer and economical use.

At any heat treatment temperature, goat's milk fouls the equipment faster than cow's milk. This makes it difficult to ensure uninterrupted continuous processing of large volumes of goat's milk in a cheese plant since the heat exchangers must be shut down and cleaned very often (Kanstanas, Lewis & Grandison, 1995). In traditional technology, milk in large pans or pots was heated directly over a slow fire or indirectly in a water bath (Kosikowski, 1978).

2.2.2 Fermentation

Lactic acid bacteria (*Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp. *cremoris* in the case of Feta cheese) obtain energy for their metabolic activities anaerobically by catabolic reactions in which lactose is converted to lactic acid and energy (Keeton, 1983; Bohinski, 1987).

2.2.2.1 Advantages of fermentation

Fermentation plays an important role in preservation and providing variety in milk products. Several of the end products enable fermentation to perform these duties, particularly acids and alcohols, which are flavour components, flavour precursors and inhibitory to the growth of pathogenic and spoilage micro-organisms. If the pH of the cheese is maintained below 4.6 through acid production, growth of the toxin producing micro-organism, ***Clostridium botulinum***, is also inhibited (Varnam & Sutherland, 1994; Potter & Hotchkiss, 1995).

Starter micro-organisms involved in fermentation are not only catabolic, but they are anabolic as they synthesise many complex vitamins and other growth factors. The net increase in the level of some vitamins may be off-set by the fact that the micro-organisms use some of these for their own metabolic activities. The level of folic acid and choline may increase by up to 100%, while that of pantothenic acid and biotin may increase only slightly (Varnam & Sutherland, 1994; Potter & Hotchkiss, 1995).

Fermentation is also believed to increase bioavailability of some minerals and trace elements especially phosphorus, however there is still some controversy concerning minerals like calcium, magnesium and zinc (Varnam & Sutherland, 1994).

2.2.2.2 Lactic acid fermentation

a) Homofermentation

Lactose is initially broken down to galactose and glucose by the enzyme β - galactosidase. The process of the biodegradation of this sugar is called glycolysis,

in which pyruvic acid ($C_3H_4O_3$) is an important intermediate. This requires a large number of successive steps, each catalysed by a specific enzyme. When a homofermentative micro-organism like *Lactococcus lactis* ssp. *cremoris* is involved, the sole compound formed is lactic acid, and energy is released for the micro-organism's activities (Bohinski, 1987).

b) Heterofermentation

Lactose is converted to glucose and galactose, and subsequently to pyruvic acid in a similar manner as in homofermentation. However, when a heterofermentative micro-organism is responsible for biodegradation of the intermediate (pyruvic acid), other substances apart from lactic acid are also formed. These include diacetyl, acetoin, 2,3 -butanediol, acetic acid, ethyl alcohol, formic acid and carbon dioxide (Keeton, 1983; Bohinski, 1987; Cogan, 1995). According to Cogan (1995), diacetyl and acetic acid are important in flavour perception and carbon dioxide in the texture of fermented dairy products.

Irrespective of the end product, fermention only releases a very small amount of energy for lactic acid bacteria (LAB) metabolism purposes and hence the end products still contain much of the original energy. Fermentation can be simplified and generalised as indicated in Figure 2.1.

2.2.2.3 Citric acid fermentation

According to Kosikowski (1978), fresh milk contains about 0.2% of naturally occurring citric acid. Some strains of *Leuconostoc* species (*L. cremoris, L. dextranicum* and *L. mensenteroides*) and *Lactococcus lactis* subsp. *diacetylactis* can degrade citric acid, with the formation of an important flavour component called diacetyl. Apart from this, aroma compounds like volatile acids, acetic acid, oxalacetate, acetaldehyde, acetone and butylene glycol are also produced. Citric acid fermentation is also known to be responsible for the pin holes seen in Feta

cheese (Figure 2.2) due to production of high amounts of carbon dioxide (Davis, 1976; Tomkins, 1992).

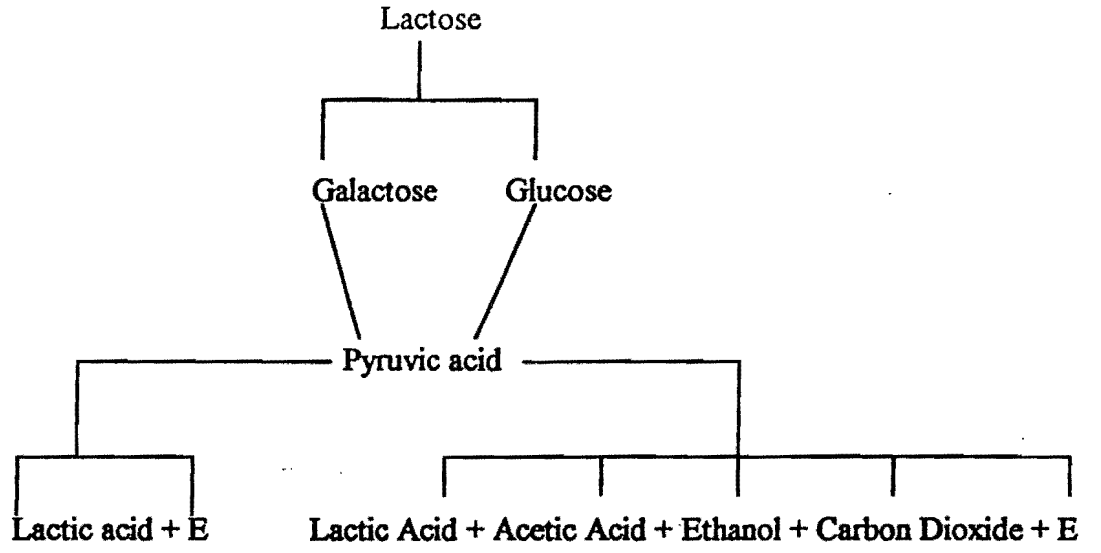

Figure 2.1: Fermentation of Lactose (Modified from Bohinski, 1987).

Depending on the bacterial species involved, citric acid fermentation can lead to formation of various compounds, some as intermediates and others as end products as shown in Figure 2.3 (Fox, 1987a).

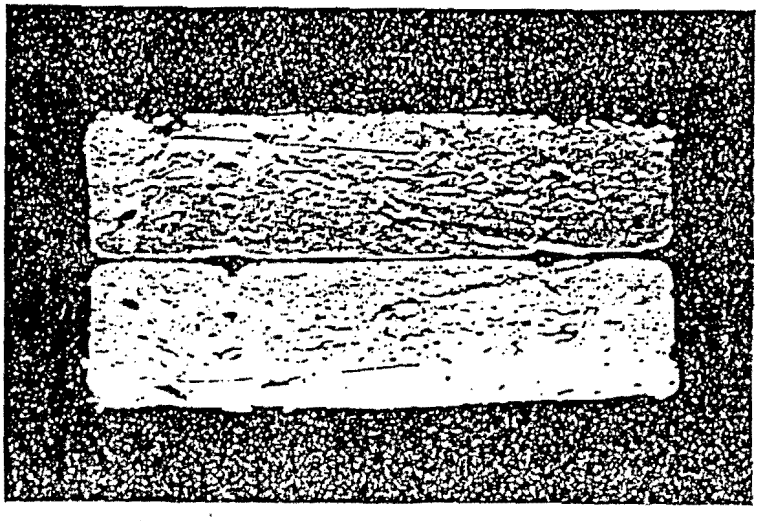

Figure 2.2: Ripe Feta cheese (Davis, 1976).

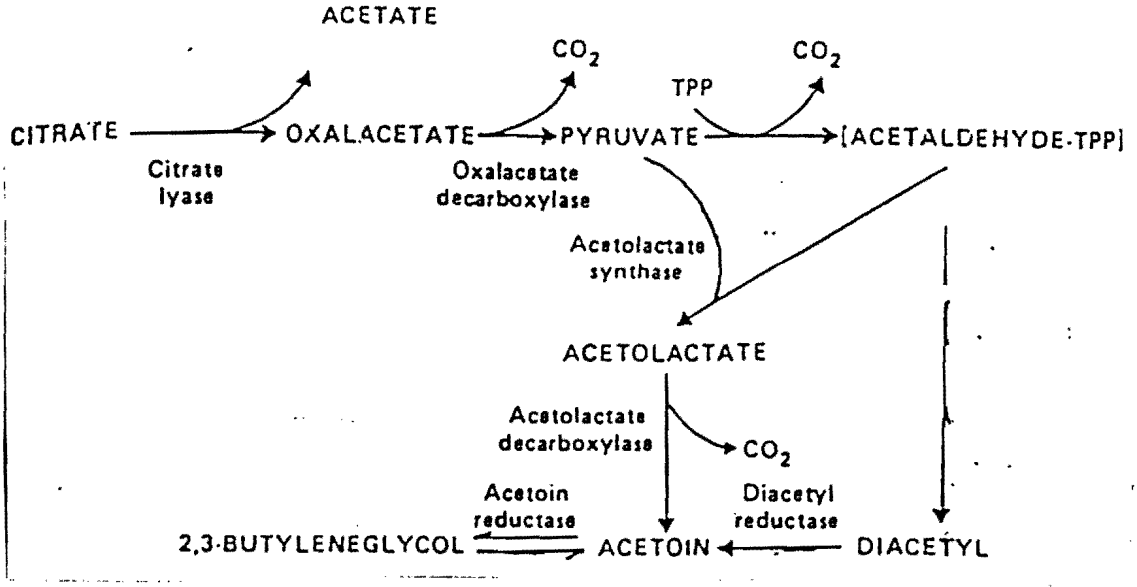

Figure 2.3 Pathway for the metabolism of citrate (Fox, 1987a).

2.2.3 Curd formation

2.2.3.1 Acid curd formation

The normal pH of milk is about 6.6, and as the pH drops due to lactic acid production, casein micelles are destabilised. At the pH of about 4.6, coagulation of the casein occurs. The calcium ions are released and they form a network with casein molecules. This is followed by aggregation of casein, when the positively charged β-casein and the negatively charged α- casein attract each other. The curd is further strengthened by the collapse of the hair-like κ- casein in a manner shown in Figure 2.4 (Varnam & Sutherland, 1994).

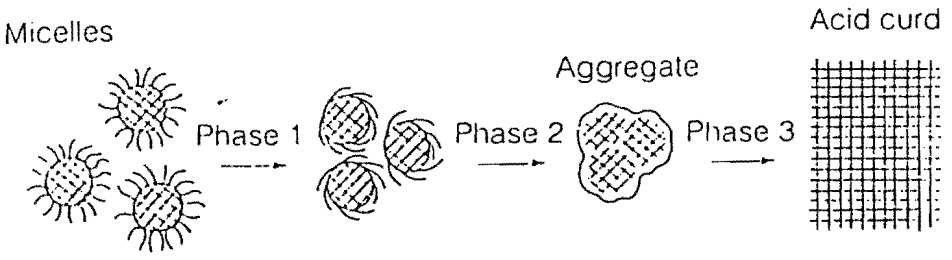

Figure 2.4: Acid curd formation (Varnam & Sutherland, 1994).

The increased acidity, together with moderate heat of about 35°C and some stirring cause the curd to synerese and expel moisture (whey) from the coagulum, and a product with significantly lower moisture content of about 35 to 60% (compared to 87% moisture in milk) is formed (Fox, 1987a).

2.2.3.2 Rennet coagulation

The activity of rennet is caused by:-

(i) Proteolysis by chymosin (or any other proteolytic enzyme present)

(ii) Slight acidification

(iii) Heat application (35°C)

(iv) Increase in calcium ion concentration

At normal pH of milk, casein molecules (submicelles) exist in clusters which are held together by calcium phosphate and aggregate to form casein micelles illustrated in Figure 2.5.

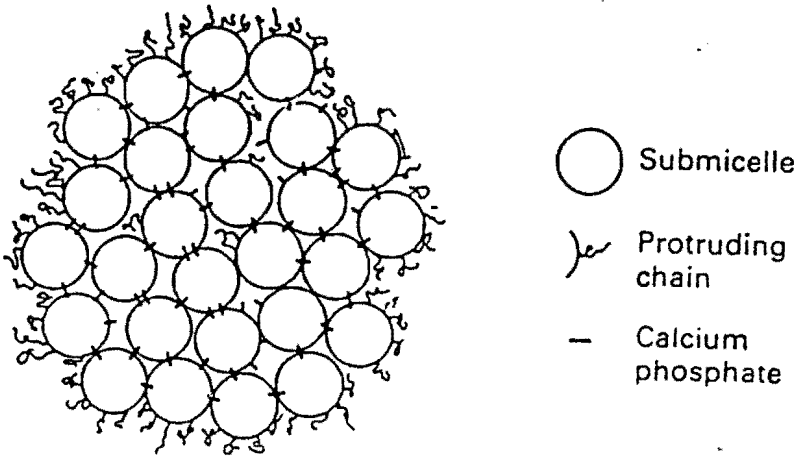

Figure 2.5: Model of casein micelles (Macrae *et al.*, 1993)

On the surface of each micelle chains of the hydrophilic c-terminal (κ-casein) of the submicelles protrude. These make the micelles to be negatively charged on the surface, such that electrostatic repulsion forces keep the micelles apart. Chymosin splits the casein molecules at specific peptide bonds between the 105th and 106th amino acids, resulting in the removal of the highly acidic and hydrophilic c-terminal chains and hence reducing the repulsion forces which kept the molecules apart (Fox, 1987a; Early, 1992; Macrae *et al.*, 1993)

Once the degree of proteolysis of the κ-casein has reached 80%, the micelles of the original acid curd, which is stabilised by the electrostatic forces and hydrophobic effects, cluster as shown in Figure 2.6. The curd network shrinks further and more water is lost by syneresis (Fox, 1987a; Early, 1992).

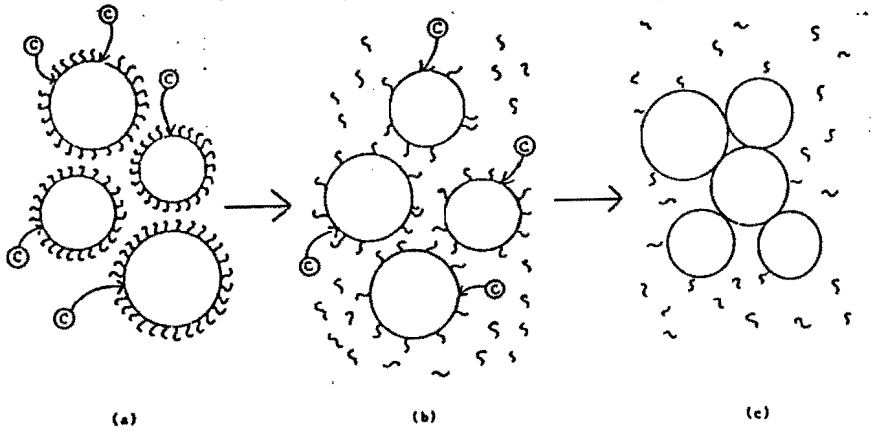

Figure 2.6: Schematic presentation of the attack by chymosin (shown as C) on casein micelles (Fox, 1992).

Three different points in the reaction are illustrated.

(a) The k-casein coat of the micelle is intact, and chymosin has just been added.

(b) Chymosin hydrolyses k-casein, but much of the latter still remain and prevents aggregation.

(c) Almost all of the k-casein have been hydrolysed and micelles aggregate.

2.2.3.3 *Structure of the curd*

According to Brusgaard (1996), a cheese curd contains three major components - casein, fat and water. Casein form an open casing structure in which fat globules are enclosed as shown in Figure 2.7.

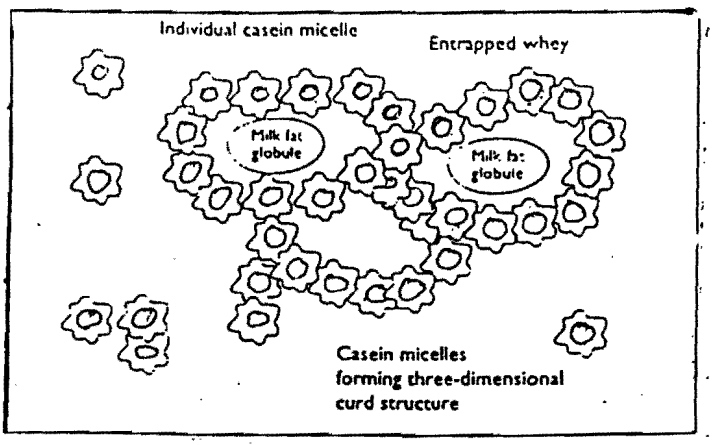

Figure 2.7: Structure of a cheese curd (Brusgaard, 1996).

Water is partly bound to casein, and the remainder fills the spaces between the casein matrix and the fat (Scott, 1986). The size and distribution of the fat globules depend on the fat globules' geometry; cheese made from homogenised milk has a more uniform distribution of the fat globules than that made from unhomogenised milk (Fox, 1987a).

The casein framework is composed of chains which are not linear but somehow with an irregular helical spring structure which imparts some elasticity to the curd. The ratio of fat to casein is important in determining the texture of the cheese. When the ratio is out of balance, the body of the cheese is either too soft or too hard (Scott, 1986) as shown if Figure 2.8.

Although it is not specifically stated that the ratios in the figure are for Feta cheese, a similar pattern of change in texture can be expected when the optimum ratio of fat to casein of Feta cheese milk is altered.

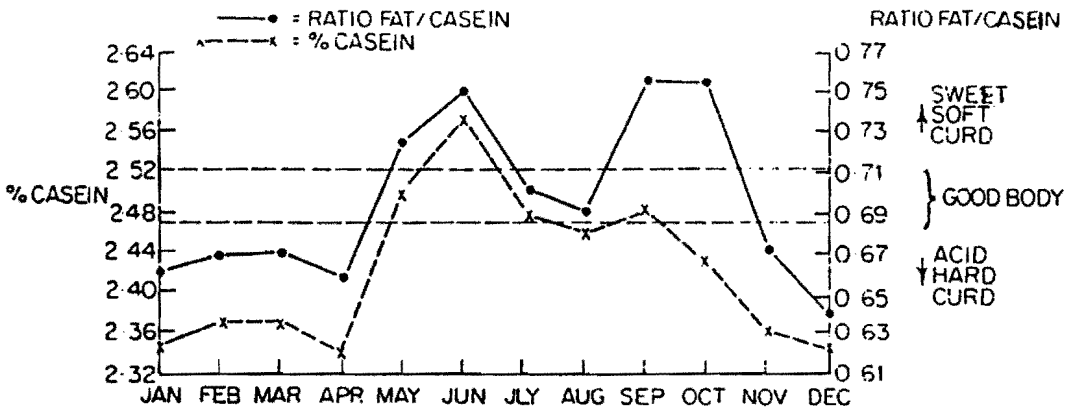

Figure 2.8: Effect of seasonal variation of casein to fat ratio on the texture of cheese (Scott, 1986).

2.2.4 Cutting of the curd

2.2.4.1 Cutting technique

In traditional cheese processing, primitive forms of cutting methods were employed in which long knives, swords, and tree branches were used. Industrially, a pair of cutting knives shown in Figure 2.9, one with horizontal wires and the second one with vertical wires, are used (Kosikowski, 1978).

A knife is carefully inserted into the curd in an upright position, steadily pushed forward from one side of the vat to the opposite. The horizontal wire knife is used first, only in one direction, lengthwise, whereas the vertical wire knife is applied in two directions, the long and the cross cut (Kosikowski, 1978; Scott, 1986).

In highly mechanized cheese factories, round vats are equipped with rotary wire cutters, and rectangular vats have perpendicular knives which require little manual assistance (Kosikowski, 1978).

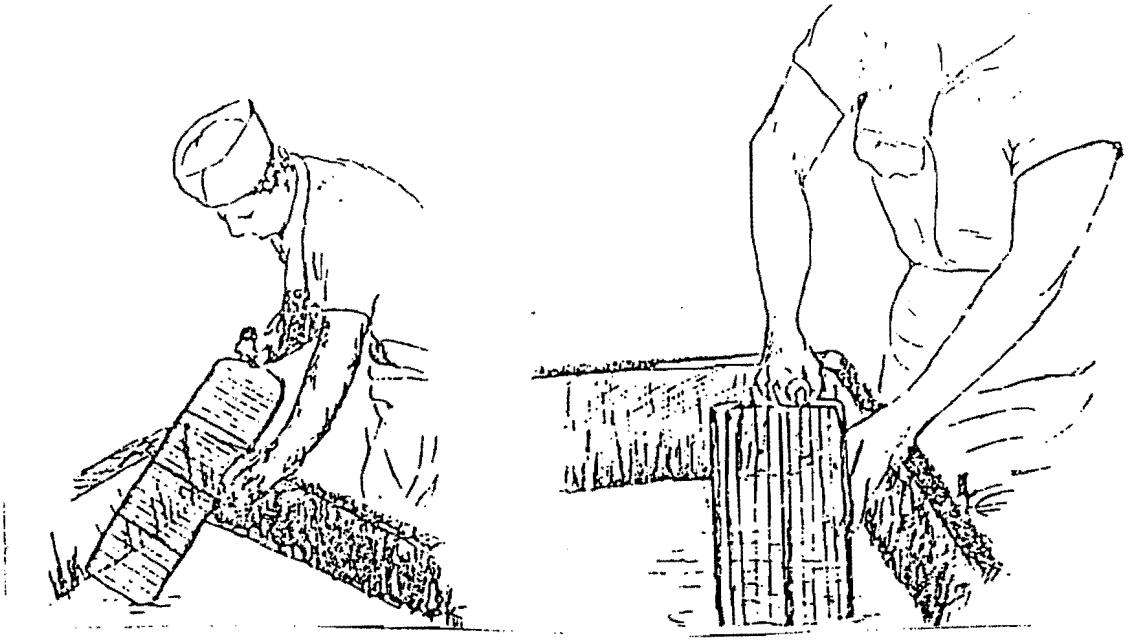

Figure 2.9: Cheese curd cutting operation (Kosikowski, 1978).

2.2.4.2 The impact of cutting

Cutting increases the surface area of the curd and facilitate loss of whey from the curd, allowing the casein matrix to shrink. Gentle uniform cutting keeps the curd from disintegrating into fine particles and thus avoids heavy yield loss (Scott, 1986).

Depending on the distance (spacing) between the wires of the knives, cutting results in breaking the curd into cubes or other uniform shapes. The selection of the specific wire spacing, 1 to 2 cm, determines to an extent, the final moisture level of the cheese. Large cubes give higher moisture cheese than small ones (Scott, 1986).

2.2.5 Salting

In ancient times, traditionally processed Feta cheese was preserved in sea water (Tsotsanis, 1996), while in commercial manufacturing, the curd is dry salted with coarse salt or brine salted. The importance of salt in cheese has been discussed in Section 2.1.4. The salt sprinkled on the surface of the curd dissolves in the

moisture. Through the diffusion process, salt penetrates into the curd and conversely water (whey) migrates outwards. According to Fox (1987a), the rate of salt absorption and the final salt content depends on factors like geometry of the curd, pH, temperature and moisture content (Figure 2.10).

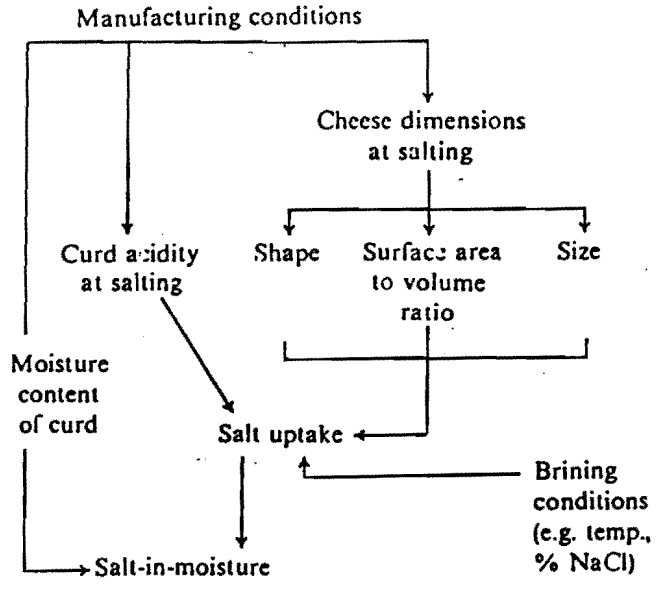

Figure 2.10: - Principal factors that affect salt uptake (Fox, 1987a).

The rate of salt absorption increases with increasing surface area to volume ratio of the cheese. That is, when the curd is cut into smaller pieces, the surface area is relatively larger than in bigger pieces, hence salt absorption occurs fast and time required to attain a desired level is shorter (Fox, 1987a).

When the temperature of the curd is above 32°C, the fat melts and surrounds the surface of the curd and hinders dissolving of the salt in the water, which is a pre-requisite to salt absorption (Fox, 1987a).

Curd pH and moisture content are directly related in this regard. At low pH, the moisture content of the cheese is low as the curd tends to synerese due to acidity, and hence salt absortion is slow and the curd quickly becomes saturated with salt at a low level (Fox, 1987a).

2.2.6 Ripening

During ripening, biochemical reactions occur which enhance the unique flavour, aroma and textural properties of Feta cheese. The primary reactions that occur involve proteolysis and lipolysis (Early, 1992).

2.2.6.1 Lipolysis

a) Lipid hydrolysis and rancidity

In traditional cheese made from unpasteurised milk, native milk lipases and the microbial lipases were responsible for breakdown of fats. In pasteurised milk, the former enzymes are inactivated and the latter are more heat resistant but not always present; hence commercial lipases are commonly added (Efthymiou & Mattick, 1964).

As a result of lipolysis, the concentration of volatile and non-volatile free fatty acids increases. According to Varnam & Sutherland (1994), the resultant total free fatty acids and the short chain fatty acids (C_4 to C_8) content may be about 50 g/kg. These products, together with the naturally occurring short chain fatty acids (refer to subsection 2.1.1.2) in milk, are responsible for the typical pleasant rancid flavour of Feta cheese. According to Efthymiou & Mattick (1964), the pleasant rancid flavour is associated with free fatty acids from C_2 through to C_{10}, while C_{12} and longer fatty acids are responsible for an unpleasant rancidity. The free fatty acids not only function as flavour components in cheese, but are also precursors of other flavour components (Harboe, 1994).

Excessive lipolysis sometimes affect Feta cheese adversely, leading to a rancid flavour defect. This reduces the acceptability of the cheese. It can happen when the cheese milk is spontaneously lipolysed, through processing techniques which induce lipolysis, or addition of too high doses of lipase (Fox, 1983).

b) Lipolytic enzymes specificity

Some of the lipolytic enzymes, specifically pregastric esterases, hydrolyse lipids with preference to the Sn_1 and Sn_3 positions (terminal fatty acids) of the triacylglycerols. These positions are predominantly occupied by short chain fatty acids. The 2-monoacylglycerols are only hydrolysed after their conversion to 1- or 3- isomers (Fox, 1983).

Other lipases, including the microbial lipases, are able to sense the length of the fatty acids and prefer to hydrolyse short chains specifically. For these reasons, lipid hydrolysis products are mostly short chain fatty acids (Harboe, 1994). Since goat milk is richer in short chain fatty acids and more susceptible to lipolysis than cow's milk, Feta cheese made from the former is more often associated with rancid flavour than the latter.

2.2.6.2 Proteolysis

a) Mechanism of proteolysis

In many cheeses a certain portion (about 2 to 6%) of the milk coagulant's proteolytic activity is retained in the cheese curd and the rest of the proteolytic activity is lost with the whey (Brusgaard, 1996). The activity of the enzyme chymosin on the milk proteins continues through the ripening process. Chymosin further breaks down para-casein molecules into peptides and amino acids, but its activity on beta-casein is only limited (Varnam & Sutherland, 1994).

At a certain stage during ripening, the activity of chymosin ceases due to unfavourable conditions like increase in pH and decrease in temperature, and secondary micro-flora originating from the starter culture may take over proteolysis and break down amino acids further, as shown in Figure 2.11 (Fox, 1987a).

In many cheeses, especially those made from goat's milk, the most predominant amino acid at the end of ripening is usually proline, followed by glutamic acid,

valine, leucine, isoleucine, histidine and lysine, which in all make up as much as 60% of the total free amino acids content (Fresno, Tornadijo, Carballo, Bernado & Gonzalez-Preito, 1997)

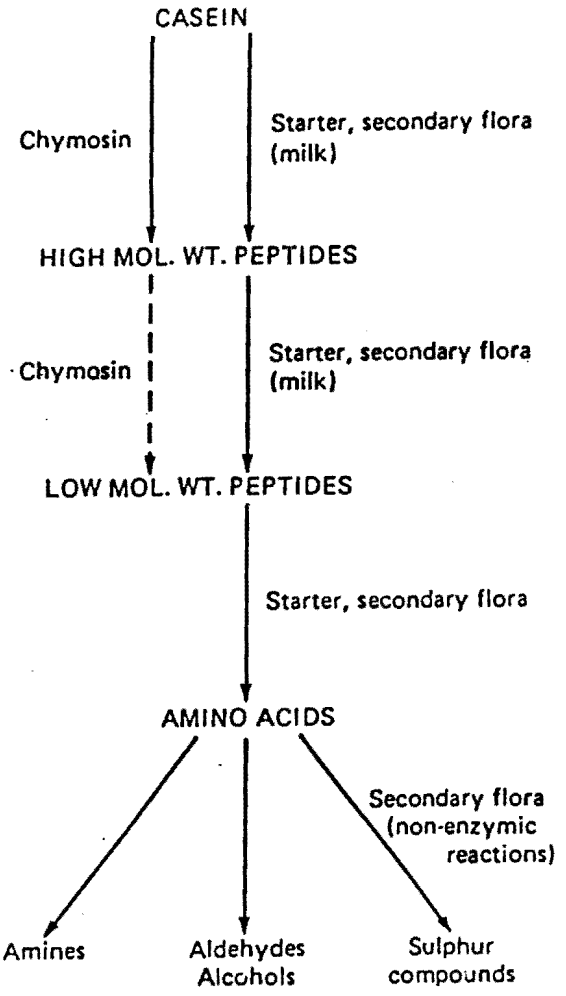

Figure 2.11 - Breakdown of casein during cheese ripening (Fox, 1987a).

This amino acid profile is typical of cheeses in which the starter microflora consists of *Lactococcus* and *Lactobacillus*. These micro-organisms have special peptidases for hydrophobic peptides rich in proline (Fresno *et al.*, 1997). During storage of the cheese, peptides and amino acids dissolve in the whey and decrease with decrease in moisture content of the cheese (Macrae *et al*, 1993).

b) Textural changes

Proteolysis also result in softening of the cheese due to calcium phosphate precipitation which weakens the casein network during ripening. The effect is highly dependent on the pH value, in most cases high pH induce activity of proteinase and further soften the cheese (Varnam & Sutherland, 1994).

According to Fox (1987a), chymosin is to a large extent responsible for the texture development in cheese. Its action is more favoured near the centre of the curd where the salt content is low.

2.2.6.3 Flavour components

Bitter peptides in cheese originate mostly from α - casein and β-casein fractions with high average hydrophobicity (Q). Peptides with a Q- value of < 5.44 kJ/residue tend to be non-bitter, and those with Q > 5.86 are bitter, whereas no predictions can be made about peptides with Q-values ranging between 5.44 and 5.86 kJ/residue (Gomez, Garde, Gaya, Medina & Munez, 1997). According to Scott (1986), phenylalanine is one of the amino acids which cause bitterness when occupying the terminal position of casein fragments.

Rennet produces bitter peptides from both α- and β- casein, whereas starter culture proteinases release bitter peptides mostly from β - casein. Peptidases from some strains of lactic acid bacteria are very effective in degrading bitter peptides and subsequently reducing the bitter flavour in cheese (Gomez *et al.*, 1997).

2.3 DEVELOPMENTS IN FETA CHEESEMAKING

In recent years, several attempts have been made to improve the quality of Feta cheese manufactured from cow's milk, with the intention of making it resemble the traditional version as much as possible. Many developments have been made in the

production of the cheese such as developments in mechanization and manipulation of ingredients.

2.3.1 Ultra filtration and reverse osmosis

Due to higher content in total solids, especially fat and protein, the cheese yield is significantly higher when goat's or sheep's milk is used for Feta cheesemaking than when cow's milk is used (Anifantakis, 1990). This has led to the concentration of milk solids using techniques like ultra-filtration (UF) and reverse osmosis in Feta cheese manufacturing. UF was found to be advantageous in improving the cheese yield by 25 to 30%, the concentrate had better rennetability properties (80% less rennet is used) and fat losses were also reported to be minimal. These improvements occur when the milk was concentrated to the ratio 1 : 4.5 (El-Gazzar & Marth, 1991).

UF Feta cheese had almost the same overall composition as the traditional product except that the former had 3 to 5% more moisture than the latter due to the high water holding capacity of whey proteins retained in UF cheese (El-Gazzar & Marth, 1991). The UF cheese also had a different texture, no mechanical holes and hence a different mouth feel which usually made the cheese less acceptable (Renner & El-Salam, 1977). When UF milk concentrate is used, it is always necessary to make changes in the basic Feta cheesemaking procedure and hence it causes some inconvenience and unusual complications.

2.3.2 Skim Milk Retentate powder

De Block, De Ville & Petit (1996) made a contribution in Feta cheese manufactured by adding skim milk retentate powder to the cheese milk. The cheese produced this way had a higher yield and the production was economical. However, the composition of this cheese did not meet the specifications as it was

found to have a much lower fat content (13%) than the traditional version (reference cheese) which had about 22% (m/m) fat content.

2.3.3 Low heat skim milk powder and anhydrous milk fat

Jana & Thakar (1996) produced Feta cheese using high solid content (37 to 38%) recombined milk prepared by mixing low heat skim milk powder (LHSMP) and anhydrous milk fat (AMF). This was meant to help in regions with low or fluctuating supplies of fresh milk and where there are long distances between the milk production areas and the cheese processing centres. Feta cheese of moderate taste, good colour and good consistency was produced from the high solids recombined milk. However, this was reported to have certain limitations, which include:-

- Fast acid development
- Poor rennetability
- Insufficient firmness of the curd
- Syneresis and drainage problems
- High residual lactose content

Corrective measures were necessary but found to be time consuming as well as uneconomical.

Jana & Thakar (1996) further pointed out that the LHSMP and AMF flavour usually associated with recombined milk was also present in the Feta cheese. Moreover, an alternative technology was required to enable the homogenisation step to be eliminated as it led to fat globule participation in the protein matrix, thereby affecting cheese structure and texture.

2.3.4 Bleaching of the milk fat

2.3.4.1 High temperature bleaching

In an attempt to improve the colour of cow's milk Feta cheese, milk fat from cow's milk was bleached in a bath of silicon oil at temperatures between 180 and 280°C (Neilsen, Olsen, Lyndon, Sorensen & Skibsted, 1996). The bleaching mechanism involved removal of carotenoids, which also act as antioxidants. As a result, increased cholesterol oxidation in the Feta cheese was reported. This was aggravated by increased oxidation of heat-treated milk fat by thermal hydrolysis of lipid hydroperoxides. This oxidation led to development of undesired rancid flavour and accumulation of toxic oxysterol in the cheese.

2.3.4.2 Chemical Bleaching

Treatment of the cream from cow's milk with chlorophyll or 0.00048% of benzoil peroxide resulted in production of Feta cheese with a white colour without adversely affecting the flavour of the cheese (Zerfiridis & Kristoffersen, 1968).

2.3.5 Other non-dairy additives

2.3.5.1 Coagulants and coagulation catalyst

Recombined and reconstituted milks exhibit poor rennetability as a result of irreversible precipitation of the minerals calcium and phosphorus. Even when pasteurised milk is used for cheesemaking, the rate of coagulation is slower and the resultant coagulum is weaker than when unpasteurised (raw) milk is used. Addition of calcium chloride at the rate of 0.02% of the weight of the cheese milk or addition of aqueous extracts of flowers of *Cynara* sp were effective in counteracting rennetability defects (Jana & Thakar, 1996). Ionic calcium plays an important role in forming intermolecular bridges during curd formation (Varnam & Sutherland, 1994).

Extracts from some plants have been tried as milk coagulating agents, although there is no evidence that these can be applied in Feta cheese processing. Examples of such plants are given in Table 2.2.

Table 2.2 Plants giving extracts that will coagulate milk (Tomkins, 1992).

Common name	**Scientific name**
Burdock	*Arctium minus*
Bittersweet	*Solanum dulcamara*
Mallow	*Malva sylvestris*
Thistle	*Cirsium and Carlina spp*
Fig tree	*Ficus carica*
Hogweed	*Heracleum sphondylium*
Knapweeds	*Centaurea spp*
Lady's bedstraw	*Galium verum*
Ragwort	*Senecio jacobaea*
Spearworts	*Ranunculuc spp*
Nettle	*Urtica dioica*
Teasel	*Dipsacus fullonum*
Yarrow	*Achillea millefolium*
Spurge	*Euphorbia lathyrus*

2.3.5.2 Lipolytic agents

Feta cheese manufactured from pasteurised cow's usually lacks the characteristic flavour normally associated with goat's milk cheese. For fullest flavour, a commercial lipase (kid and lamb extract in the ratio 2: 1) was added to the milk at the rate of 7.5 g/500 kg milk (Zerfiridis & Kristoffersen, 1968). Cheese produced with other classes of commercial lipases produced atypical rancid, bitter and unclean flavours, and also developed peppery and soapy flavour defects (Efthymiou & Mattick, 1964).

Despite the positive aspects of using non-dairy additives, there are strict regulations concerning the use of additives in dairy products. In many countries, the regulations are based on the FAO/WHO Food Standards Committee recommendations, but such regulations still vary from country to country (Scott, 1986). This threatens the international market of Feta cheese containing additives.

2.3.6 Low fat version of Feta cheese

World wide, there is an overwhelming demand for reduced fat food products and the food scientists and manufacturers are challenged to satisfy this trend. According to Mann (1996), a Greek research team manufactured Feta cheese from low fat milk using a traditional method. Milk containing 1.5%, 3.0% and 4.5% fat were used and compared with milk with 6.0% fat as control.

Significant increases in protein and moisture content of the cheese with decrease in milk fat content was reported, while the solid-non-fat contents and cheese yield decreased. Apart from these, lipolysis, proteolysis, body, texture and flavour scores of the cheese were adversely affected by reduced fat content. Modifications either in technology or formulations are hence necessary to improve the quality and acceptability of the cheese (Mann, 1996).

Zwaginga (1990) indicated that if the current trend of low fat products is not controlled in cheese formulations, the ultimate product will be a cheese with a rubber-like texture and a bitter taste. To mask these defects, the cheese formulations will have to include mixtures of ingredients that will result in losing the natural image of cheese and the traditional cheesemaking process. Zwaginga (1990) also suggested that if critical limits are approached, manufacturers should stop the adaptation of the process and concentrate on the development of new products based on the availability of raw material and the know-how.

2.3.7 Rennet substitutes

According to Varnam & Sutherland (1994), a shortage and corresponding expense of mammalian rennet has led to the use of proteolytic enzymes from micro-organisms like *Mucor miehei, M. pusillus* and *Endothia parasitica* as substitutes. However, these enzymes are much less specific in hydrolysis (less specific to Phe_{105} - Met_{106} bond) and hence affect the quality of the resultant cheese adversely. This is due to the fact that, unlike the mammalian proteinase which contains a small fraction of pepsin in addition to chymosin, microbial enzyme is purely chymosin (Kandarakis, Anifantakis & Moschopoulou, 1995).

According to Kandarakis *et al.,* (1995), microbial proteinase was successfully used in place of rennet for manufacturing many kinds of cheeses including Feta. Although the Feta cheese had almost the same composition and organoleptic properties as the mammalian rennet cheese, its rate of whey drainage was slightly slower. After slight alterations in the Feta cheesemaking technique were made, the cheese had a higher moisture content.

3. MATERIALS AND METHODS

3.1 MILK

3.1.1 Procurement

Raw full cream cow's milk was collected from the University of Pretoria's experimental farm and pasteurised at 72°C for 15 s, while goat's milk was obtained already pasteurised from the goat herd of the Medical University of South Africa (Medunsa). Since the goat's milk could only be obtained on Friday's, the two batches of milk were stored at 4°C over the week-end prior to cheesemaking.

3.1.2 Sampling

The batches of milk were stirred thoroughly and representative samples of each was collected into sterilised bottles. The chemical and microbiological tests were done in triplicate on each sample.

3.1.3 Fat content

The Gerber method was used to determine the fat content of the milk as outlined by the Food and Agriculture Organization (1986).

3.1.4 Protein content

The protein content of the milk was determined by the Kjeldahl method (Triebold & Aurand, 1963), using a Buchi 430 (digestion equipment), Buchi 322 (distillation unit), Buchi 343 (control unit) and dosimat (Metrohm, Herisau, Switzerland).

3.1.5 pH

The milk samples were shaken thoroughly after which the pH was measured as outlined in Kosikowski (1978) using a "Mettler DL25 titrator" pH meter (Mettler-Toledo, Switzerland)

3.1.6 Titratable acidity

The amount of titratable acidity was determined by titrating 9 ml of the milk with a 0.1M sodium hydroxide solution in presence of phenolphthalein indicator (Richardson, 1985).

3.1.7 Lactose

The lactose content was determined according to the International Dairy Federation (1974).

3.1.8 Total solids/ Moisture content

An oven drying method in which the milk was heated at 100°C until a constant weight was obtained, was used (Triebold & Aurand, 1963).

3.1.9 Total plate count

The standard plate count was carried out according to Marth (1978). The Plates were incubated at 30°C for 72 ± 3 h.

3.2 FETA CHEESE

3.2.1 Starter culture preparation

The starter culture preparation started about 7 days before cheese manufacturing. The culture used was a commercial culture CHN 22 (a mixed culture *of Lactococcus lactis, Lactococcus lactis* ssp. *cremoris, Lactococcus lactis* ssp. *lactis biovar diacytilactis* and *Leaconostoc mesensteroides* ssp. *cremoris*). The stock

cultures were supplied in a freeze-dried form by CHR Hansens Lab (Denmark), and were cultured in sterilized skim milk and incubated at 22°C for about 16 h (Kosikowski, 1978).

3.2.2 Manufacturing of the Feta cheese

Four different proportions of goat's milk and cow's milk were mixed as follows:-

Treatment 1: 100% cow's milk and 0% goat's milk

Treatment 2: 65% cow's milk and 35% goat's milk

Treatment 3: 35% cow's milk and 65% goat's milk

Treatment 4: 0% cow's milk and 100% goat's milk

The milks were processed to Feta cheese as shown in Figure 3.1 (modified from Prinsloo, 1997).

3.2.3 Sampling

Two packaged cheeses were picked randomly from each of the four treatments. The packages were opened, water drained, a sample for microbiological analysis taken from each cheese and excess water blotted from the surface of the remainder of each cheese with a paper towel. The individual cheeses, after removal of the sample for microbiological work, were then ground into paste-like form using a pestle and a mortar. The ground sample was then used for chemical analyses.

On each of the eight samples, representing four treatments, tests were done in duplicate, except for pH measurements. All the tests except sensory evaluation (see section 3.2.14) were done on weekly basis (for three weeks) beginning the second day after the milk was renneted.

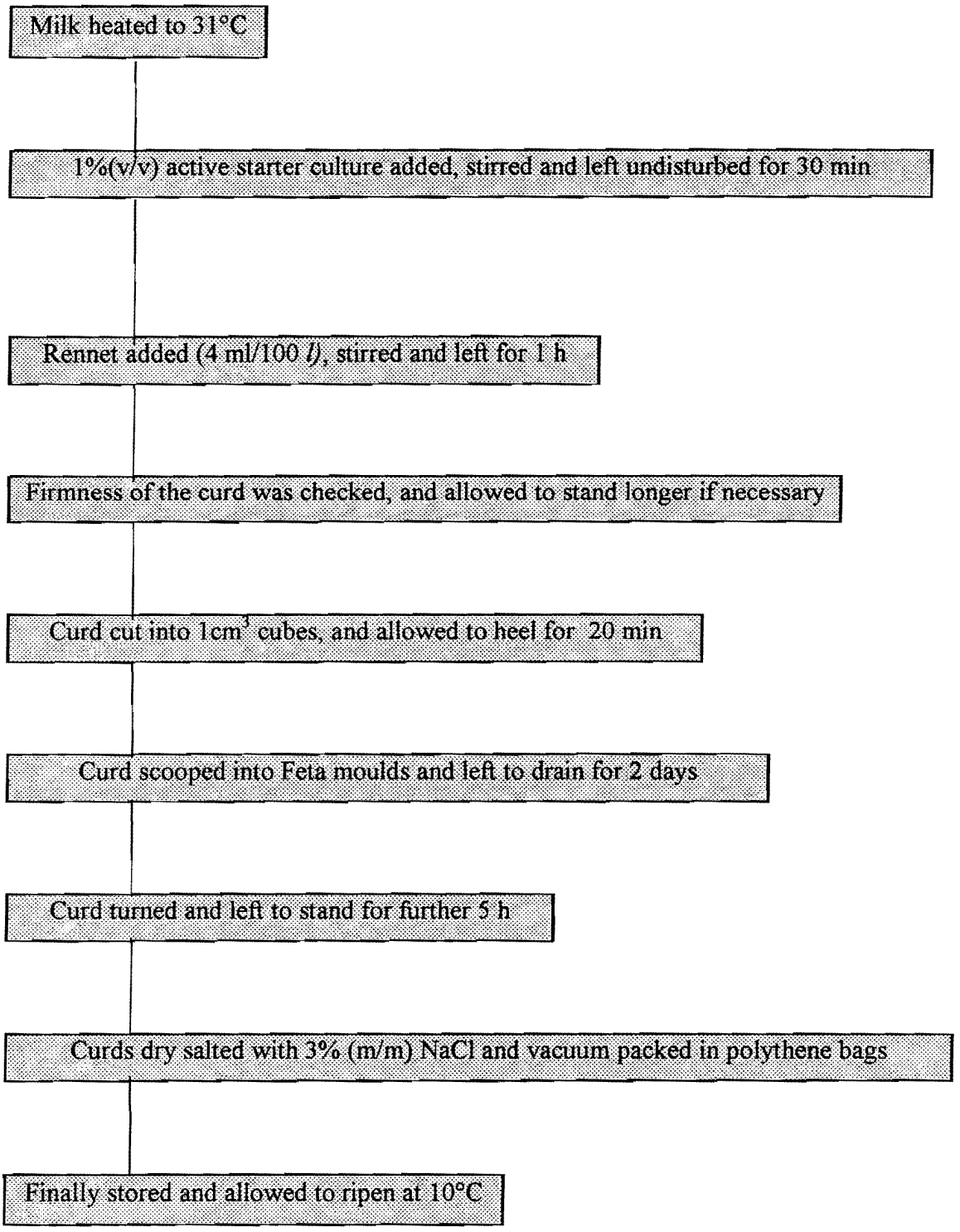

Figure 3.1: Summary of Feta cheesemaking

3.2.4 Fat content

The fat content of the cheeses was determined according to a modified Babcock method (Kosikowski, 1978).

3.2.5 Free fatty acids

Free fatty acids were extracted into a neutralised mixture of benzene-ethanol and titrated with 0.1N sodium hydroxide solution in presence of an indicator (Triebold & Aurand, 1963).

3.2.6 Total Proteins

The Kjeldahl method (Triebold & Aurand, 1963; Kosikowki 1978) was used to determine the protein content of the cheese using the Buchi apparatus (subsection 3.1.4).

3.2.7 Soluble proteins

Soluble proteins were extracted with hot water and subjected to digestion, distillation and titration in a similar manner to total protein in milk and cheese (Kosikowski, 1978).

3.2.8 pH

pH of the cheese samples was measured introducing the pH meter electrode directly into the ground, undiluted cheese samples (Kosikowski, 1978), using a "Mettler DL25 titrator" (Mettler -Toledo, Switzerland).

3.2.9 Moisture content and total solids

The determination of total solids was done by oven drying at 100°C (Kosikowski, 1978).

3.2.10 Salt

Salt (sodium chloride) was extrated into hot water, then titrated with standard solution of 0.171 N silver nitrate according to the Australian Society of Dairy Technology (1966).

3.2.11 Lactose

The lactose in the cheeses was determined according to the International Dairy Federation (1967).

3.2.12 Total Plate Count

The primary dilutions ($^{1}/_{10}$) were made by mixing cheese with sterilised peptone water and macerating in stomacher bags (Art Medical Equipment, Johannesburg). Further dilutions were prepared and plated using the pour plate method (Marth, 1978; International Dairy Federation, 1987).

3.2.13 Texture Analysis

Two representative samples were picked randomly from each of the four cheese treatments and cut into 2 x 2 x 1.5 cm pieces for analysis. An automatic texture analyzer TA-XT2 (Stable Microsystems, England), fitted with a conical probe was used. The machine was programmed to operate using the following settings:-

Mode: Measure force in compression

Option: Return to start

Pre-test speed: 2.0 mm/s

Test speed: 1.0 mm/s

Distance: 10 mm

Trigger type: auto (3 g)

Accessory: P/45 conical probe

3.2.14 Sensory Evaluation

The acceptability of the cheeses was evaluated by 62 panelists 21 days after cheese manufacturing. A Nine-point Hedonic scale evaluation sheet (Figure 3.2) was used to rate the preference of the panelists (Piggott, 1988).

SENSORY EVALUATION OF FETA CHEESE

Date.....

Name.....

Please taste and evaluate 4 samples from left to right, and make a mark (x) in the block that best describes how much you like the specific sample. Drink water between samples.

Degree of Liking	**Codes**			
Like extremely				
Like very much				
Like moderately				
Like slightly				
Neither like nor dislike				
Dislike slightly				
Dislike moderately				
Dislike very much				
Dislike extremely				

Comments

.....

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Figure 3.2: Evaluation sheet used for sensory evaluation

3.3 STATISTICAL ANALYSIS

The whole experiment was repeated three times with batch 1 processed in June, batch 2 in September and batch 3 in November 1998. The results were analysed statistically using Statistica version 5.0 (Statsoft, United States of America) and evaluations were based on a 5% significance level

4. RESULTS

4.1 THE MILK USED IN THE EXPERIMENTS

Table 4.1 shows the composition and properties of cow's milk and goat's milk used for making the Feta cheeses. The cow's milk had higher percentanges of protein, fat, lactose and total solids, and also had better microbiological quality than the goat's milk. The two milks had almost the same pH and titratable acidity.

Statistically, the two milks differed significantly ($p \leq 0.05$) in fat content, total solids content, lactose content and log total plate count; but there was no marked difference in protein content, pH and titratable acidity.

Table 4.1: Composition and properties of cow's milk and goat's milk used for making three batches of Feta cheese

Milk Type	Batch	Proteins (%)	Fats (%)	Total solids (%)	pH	Titratable Acidity (%)	Lactose (%)	Log Total Plate Count
Cow's milk	1	3.44	3.93	14.36	6.74	.0.21	4.53	3.51
	2	3.32	3.77	12.39	6.72	0.14	4.80	2.66
	3	3.39	4.17	13.30	6.72	0.14	4.67	2.49
	*Means	3.38	3.96	13.35	6.73	0.17	4.67	2.89
	**SD.	0.07	0.19	1.01	0.05	0.04	0.12	0.61
Goat's milk	1	2.88	3.40	10.13	6.73	0.19	4.27	2.31
	2	3.57	3.07	11.34	6.66	0.15	4.60	4.86
	3	3.37	3.00	10.77	6.70	0.16	4.37	2.64
	*Means	3.27	3.16	10.75	6.70	0.17	4.41	3.27
	**SD	0.32	0.20	0.54	0.05	0.02	0.15	1.59
	***P-value	0.3397	0.0000	0.0000	0.1764	0.9357	0.0013	0.04911

*Means = Mean values for milk used in June (Batch 1), September (Batch 2) and November (Batch 3).

**SD = Standard deviation

***(P-values) = Differences were significant where $p \leq 0.05$

4.2 FETA CHEESES

4.2.1 Chemical, physical and microbiological aspects of the Feta cheeses

Table 4.2 summarises the degree of difference (p-values) between cheese treatments (cheese made from different proportions of cow's milk and goat's milk) as well as the impact of ripening on the cheeses. The four Feta cheese treatments differed significantly ($p \leq 0.05$) in all aspects except soluble protein content, salt content and sensory properties. Moreover, pH, log total plate count, soluble protein content, free fatty acids, salt content and texture of the cheeses changed significantly during ripening.

Table 4.2 P-values for the Feta cheeses

Variables	Treatment effect*	Day effect**
pH	0.0000	0.0000
Log Total plate count	0.0402	0.0004
Fat content	0.0000	0.3213
Soluble protein content	0.0902	0.0000
Total solids content	0.0000	0.0617
Free fatty acids content	0.0002	0.0000
Protein content	0.0000	0.5527
NaCl content	0.8487	0.0018
Texture	0.0081	0.0000
Sensory score	0.5106	N/A***

Treatment effect * = Effect of using different portions of cow's milk and goat's milk

Day effect** = Changes in the composition of Feta cheese during ripening (10°C for 21 days).

N/A***= Not applicable

4.2.2 Fat content

The fat content of all the treatments (Table 4.2) fluctuated only slightly during ripening, but the fluctuations were not statistically significant ($p = 0.3213$). However, the fat content differed significantly ($p = 0.0000$) between the treatments. This is clearly illustrasted in Figure 4.1, where fat content decreased systematically from treatments 1 through to 4 ($1 > 2 > 3 > 4$). The raw data is given in appendix A.

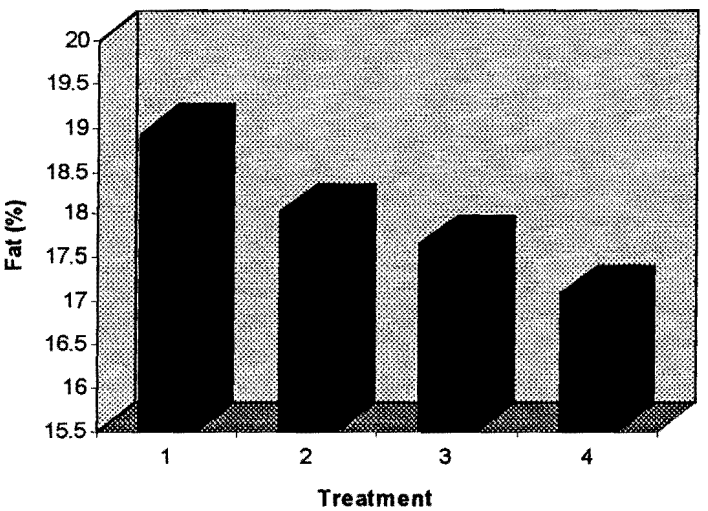

Figure 4.1: The mean fat content of Feta cheese from treatments 1, 2, 3 and 4 (Treatment 1 = 100% cow's milk; Treatment 2 = 65% cow's milk + 35% goat's milk; Treatment 3 = 35% cow's milk + 65% goat's milk; Treatment 4 = 100% goat's milk)

4.2.3 Free fatty acids

The free fatty acids (FFA) content of the Feta cheese from all the four treatments increased significantly ($p = 0.0000$) from day 2 to day 21 of the ripening period (Table 4.2). The values of FFA content also differed significantly ($p = 0.0002$) between the treatments. Treatment 4 had highest values, treatment 1 had the lowest and those for treatment 2 and 3 almost overlapped (Figure 4.2). The raw data is shown in appendix A.

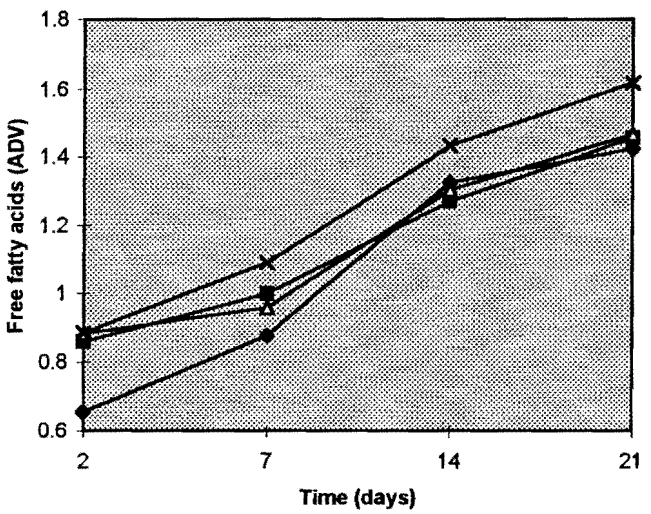

Figure 4.2: Effect on ripening on the free fatty acids content of the Feta cheeses from Treatment 1 (◆:100% cow's milk); Treatment 2 (■:65% cow's milk + 35% goat's milk); Treatment 3 (Δ:35% cow's milk + 65% goat's milk) and Treatment 4 (✖: 100% goat's milk).

4.2.4 Total Proteins

The protein content of the Feta cheeses did not change significantly ($p = 0.5527$) during ripening (Table 4.2), but there was a significant difference ($p = 0.0000$) between treatments. Figure 4.3 indicates that treatment 4 had the highest protein content, followed by treatment 3, whilst treatment 1 and 2 had almost equal values for protein content. The raw data is shown in appendix A.

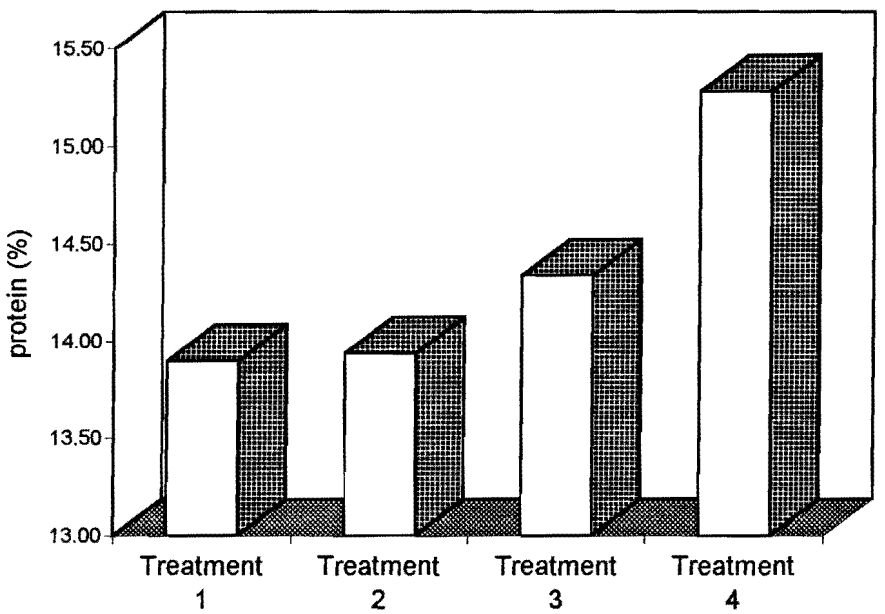

Figure 4.3: The mean protein content of Feta cheeses from treatment 1, 2, 3 and 4 (Treatment 1 = 100% cow's milk; Treatment 2 = 65% cow's milk + 35% goat's milk; Treatment 3 = 35% cow's milk + 65% goat's milk; Treatment 4 = 100% goat's milk)

4.2.5 Soluble proteins

According to Table 4.3 the soluble protein content of the Feta cheeses ranged between 1.50% and 1.85% on day 2, and between 2.89% and 3.08% on day 21. Statistically, there was no significant difference ($p = 0.0907$) between the treatments (Table 4.2), but the values increased significantly ($p = 0.0000$) during ripening (Figure 4.5).

Table 4.3: Soluble protein content of the Feta cheeses during ripening

Treatments*	Day 2	Day 7	Day 14	Day 21
1	1.82% (0.27)**	1.76% (0.48)	2.40% (0.34)	2.94% (0.48)
2	1.73% (0.18)	1.70% (0.21)	2.57% (0.52)	2.98% (0.22)
3	1.85% (0.12)	2.08% (0.46)	2.72% (0.47)	2.89% (0.25)
4	1.50% (0.44)	2.19% (0.47)	2.94% (0.41)	3.08% (0.38)

Treatments*: 1 (100% cow's milk), 2 (65% cow's milk + 35% goat's milk), 3 (35% cow's milk + 65% goat's milk) and 4 (100% goat's milk).

** = Figures in brackets are standard deviations

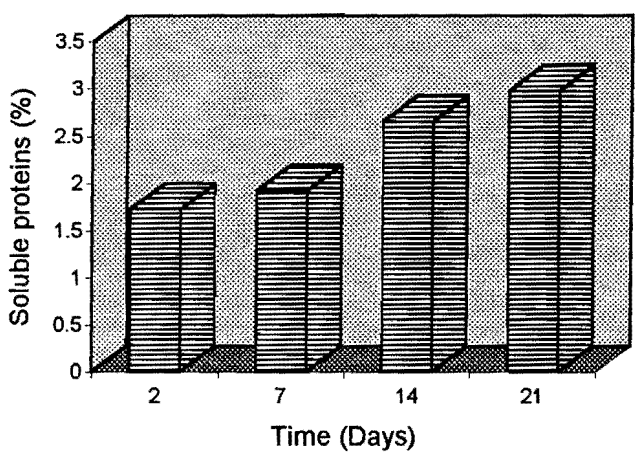

Figure 4.4: Change in soluble protein content of the Feta cheeses during ripening

4.2.6 Total solids

From Table 4.2 it can be seen that the total solids content of the Feta cheeses did not change significantly (p = 0.0617) during ripening. However, there was a significant difference (p = 0000) between the treatments (Figure 4.5). Although the values differed significantly between the treatments, the degree of difference between treatments 1, 3 and 4 was slightly smaller than that between treatment 2 and the other three (raw data is shown in appendix A).

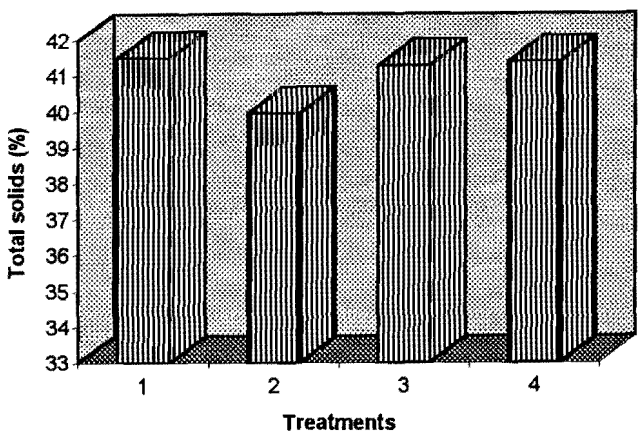

Figure 4.5: The mean total solids content of Feta cheese from treatment 1 (100% cow's milk), treatment 2 (65% cow's milk + 35% goat's milk), treatment 3 (35% cow's milk + 65% goat's milk) and treatment 4 (100% goat's)

4.2.7 Texture

Table 4.4 shows the measure of ease with which the cheese could be penetrated or the force (in N) which the cheese could withstand before breaking. The values ranged between 0.85 N and 1.66 N, and fluctuated with time. According to Figure 4.6, the results did not show any particular trend regarding the different Feta cheese treatments. An example of representative results produced by the texture analyser TA-XT2 is shown in appendix B.

Table 4.4: Texture of the Feta cheese from treatments 1, 2, 3 and 4 during ripening

Treatments*	**Day 2**	**Day 7**	**Day 14**	**Day 21**
1	1.57 N (0.44)**	1.24 N (0.56)	1.66 N (0.41)	1.55 N (0.88)
2	1.40 N (0.51)	1.46 N (0.46)	0.85 N (0.65)	1.22 N (0.43)
3	1.35 N (0.45)	1.48 N (0.87)	0.96 N (0.39)	1.07 N (0.56)
4	1.16 N (0.88)	1.35 N (0.48)	1.24 N (0.43)	0.95 N (0.90)

Treatments*: 1 (100% cow's milk), 2 (65% cow's milk + 35% goat's milk), 3 (35% cow's milk + 65% goat's milk) and 4 (100% goat's milk).

** = Figures in brackets are standard deviations

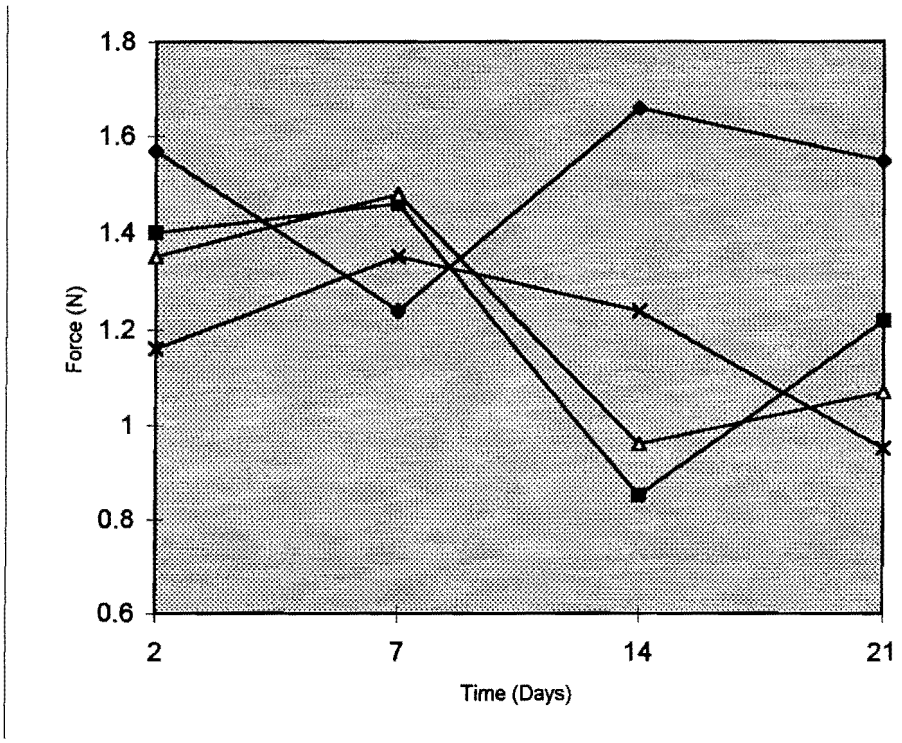

Figure 4.6: Effect of ripening on the texture of Feta cheese from treatment 1 (◆: 100% cow's milk); treatment 2 (■: 65% cow's milk + 35% goat's milk); treatment 3 (△: 35% cow's milk + 65% goat's milk) and treatment 4 (✖: 100% goat's milk)

4.2.8 pH

The pH values of the Feta cheeses are given in Table 4.5. Generally the pH decreased significantly ($p = 0.0000$) from day 2 to day 21 (Table 4.2), although the pattern of change differed with treatments (Figure 4.7). A significant difference ($p = 0.0000$) was observed between the treatments (Table 4.2), where treatment 4 had significantly lower pH values than treatment 1, 2 and 3 (Figure 4.7).

Table 4.5: pH of Feta cheese treatments 1, 2, 3 and 4 during ripening

Treatments*	Day 2	Day 7	Day 14	Day 21
1	4.68 (0.07)**	4.67 (0.08)	4.66 (0.09)	4.62 (0.08)
2	4.64 (0.07)	4.67 (0.08)	4.66 (0.09)	4.58 (0.09)
3	4.67 (0.11)	4.68 (0.09)	4.66 (0.08)	4.61 (0.08)
4	4.62 (0.07)	4.63 (0.06)	4.64 (0.07)	4.63 (0.07)

Treatments*: 1 (100% cow's milk), 2 (65% cow's milk + 35% goat's milk), 3 (35% cow's milk + 65% goat's milk) and 4 (100% goat's milk).

** = Figures in brackets are standard deviations

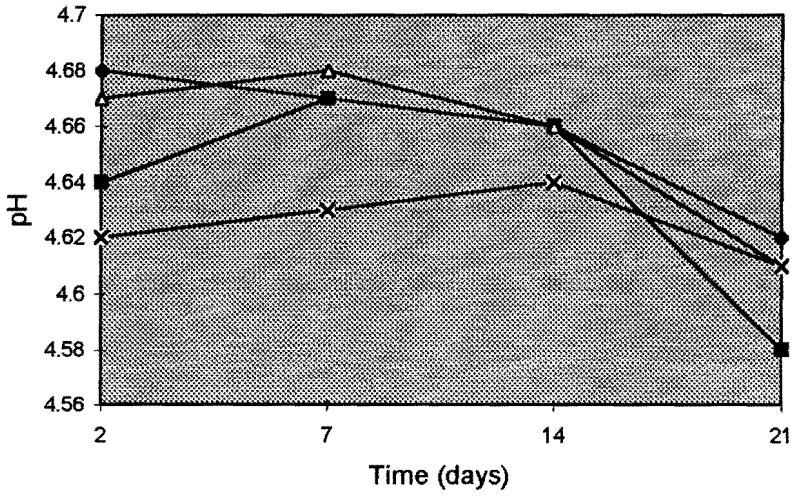

Figure 4.7: Changes in pH of Feta cheese from treatment 1 (◆: 100% cow's milk); treatment 2 (■: 65% cow's milk + 35% goat's milk); treatment 3 (△: 35% cow's milk + 65% goat's milk) and treatment 4 (✖: 100% goat's milk) during ripening

4.2.9 Salt content

The salt content of the Feta cheeses was significantly (p = 0.0018) affected by ripening time (Table 4.2). Generally, the values increased substantially from day 2 to day 14, and remained almost constant between day 14 and day 21. However, the magnitude of change was much greater between day 2 and 7 than between day 7 and 14 (Table 4.6). The p-value of 0.8784 (Table 4.2) indicates that there was no significant difference between the treatments (Figure 4.8). The average salt content ranged between 3.93% and 4. 01%.

Table 4.6: Salt content of Feta cheese from treatment 1, 2, 3 and 4 during ripening

Treatments*	**Day 2**	**Day 7**	**Day 14**	**Day 21**
1	3.88% (0.50)**	4.00% (0.48)	4.09% (0.77)	4.11% (0.40)
2	3.84% (0.87)	3.93% (1.12)	3.96% (1.11)	4.00% (0.29)
3	3.70% (0.85	4.04% (0.34)	4.10% (0.67)	4.08% (0.33)
4	3.71% (1.06)	3.98% (0.43	4.04% (0.52)	4.07% (0.80)

Treatments*: 1 (100% cow's milk), 2 (65% cow's milk + 35% goat's milk), 3 (35% cow's milk + 65% goat's milk) and 4 (100% goat's milk).

** = Figures in brackets are standard deviations.

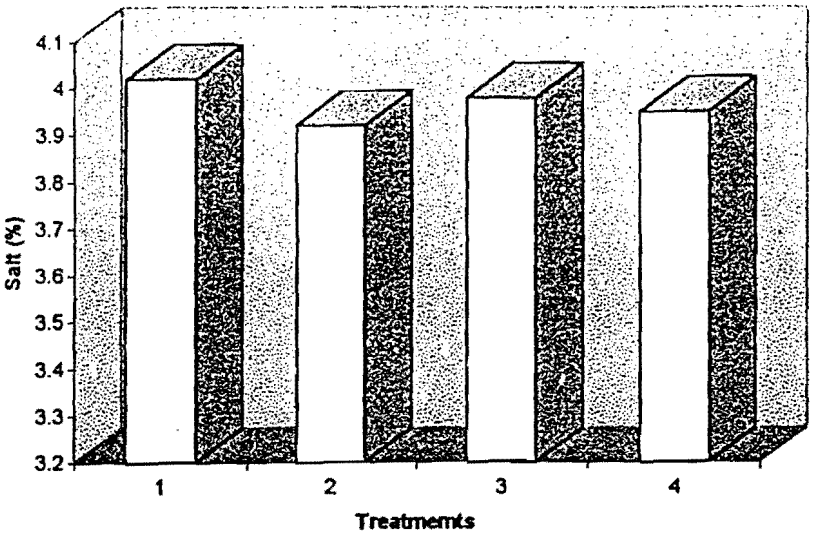

Figure 4.8: The mean salt content of the Feta cheeses from treatment 1 (100% cow milk), treatment 2 (65% cow's milk + 35% goat's milk), treatment 3 (35% cow's milk + 65% goat's milk) and treatment 4 (100% goat's)

4.2.10 Total plate count

The results of the microbial load of the Feta cheeses are given in log total plate count (log TPC). All the cheeses showed a significant ($p = 0.0004$) increase in log TPC values with time. Treatment 4 had the smallest magnitude of change compared to the other three treatments (Figure 4.9). There was also a marked difference ($p = 0.0402$) in log TPC between the treatments, the values having increased systematically from treatment 1 to 4. The raw data is given in appendix A.

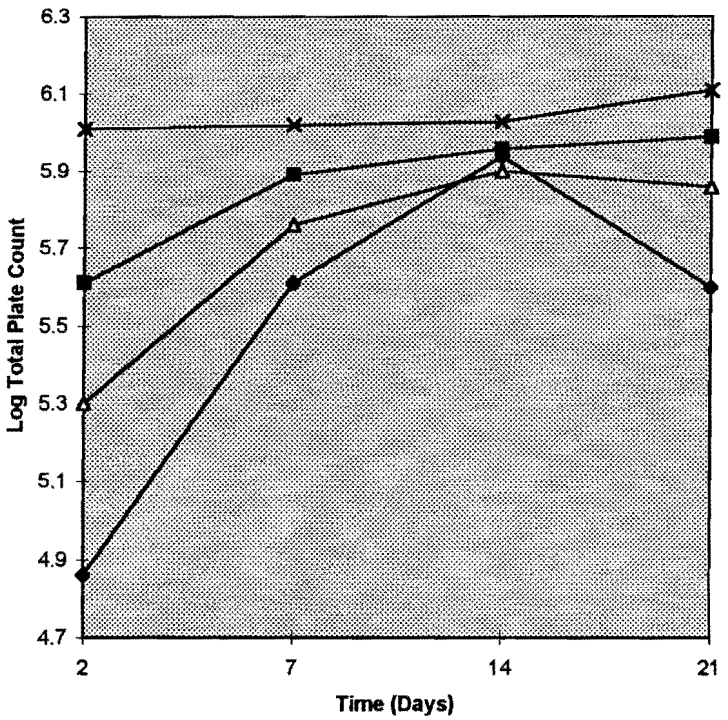

Figure 4.9: Effect of ripening on the microbial load of Feta cheese from Treatment 1 (◆: 100% cow's milk), Treatment 2 (Δ: 65% cow's milk + 35% goat's milk), Treatment 3 (■: 35% cow's milk + 65% goat's milk) and Treatment 4 (×: 100% goat's milk)

4.2.11 Sensory Evaluation

According to Table 4.7, the sensory evaluation score of the four Feta cheeses did not differ significantly as the mean score of all of them corresponded to a Hedonic score of approximately 6 (like slightly).

Table 4.7: Hedonic* score of sensory evaluation of Feta cheeses

Sample	Mean score	Std Deviation
Treatment 1	6.11	1.89
Treatment 2	5.98	1.95
Treatment 3	5.77	2.10
Treatment 4	5.76	2.11

*Hedonic score ranges between 1 and 9, where 1 is the minimum score (dislike extremely) and 9 is the maximum score (like extremely)

4.2.12 Lactose

The lactose content of all the Feta cheeses was found to be almost negligible from the second day after renneting.

5. DISCUSSION

The results of the microbiological, chemical and physical quality analyses of the goat's milk and cow's milk used in these experiments showed that the latter had higher proportions of protein, fat, lactose and total solids in general, and also had better microbiological quality than the former. Statistically, the two milks differed significantly ($p < 0.05$) in all these components except protein content. Apart from this, the goat's milk and cow's milk had no significant difference in pH and titratable acidity.

The main cause of the difference found between the two milks may be the fact that they were produced by two different mammal species (Rosenthal, 1991). Apart from this, the variation could also be due to the fact the milk animals were from two different farms, University of Pretoria experimental farm and Medunsa goat farm, where each species was given a different treatment in terms of milking times and techniques, feeding practices, shelter provided and exposure to different geographical conditions (Lacroix *et al.*, 1993; Ozimek & Kennelly, 1993).

A marked difference in composition of the Feta cheese obtained by the different treatments was noted as early as directly after cheese manufacturing (renneting stage). One difference was in the time taken by the cheese curd to attain the required firmness before cutting. Pure cow's milk (treatment 1) and 65% cow's milk plus 35% goat's milk (treatment 2), attained the desired firmness within roughly one hour, while the curd of 35% cow's milk plus 65% goat's milk (treatment 3) and that of 100% goat's milk (treatment 4) required an extra 30 to 45 minutes (1.5 to 1.75 h after renneting) to achieve the desired firmness. A similar observation was also made by Eleye, Banaon, Ramet & Hardy (1995) on comparing the coagulability of goat's milk and cow's milk.

When pouring the curds into the Feta cheese moulds, problems were experienced with treatments 3 and 4 as their curds were very fragile and slipped through the holes of the moulds and between the bottom of the moulds and the draining mats. According to Adnoy & Abrahamsen (1995), poor rennetability of goat's milk is a common problem in cheesemaking. To a certain extent, the problem is believed to be related to geographical area and season. Adnoy & Abrahamsen (1995) found that poor rennetability was an inherent character and was also associated with low fat content.

According to Fox (1987a), casein content determines the time required for the curd to acquire certain consistency and strength. To clot casein micelles effectively using rennet, the κ-casein component must be split in the region of the Phe_{105}-Met_{106} bond. However, there may be genetic variation in the amino acids between fractions 97 and 129 of the protein. Although the variants may be by only a few amino acids substitution, these differences cause significant changes in renneting and cheesemaking properties (Fox, 1987a). This implies that cow's milk probably contained a higher proportion of κ-casein variants which were susceptible to chymosin attack at the Phe-Met bond than goat's milk.

Analysis of the Feta cheeses revealed that the treatments differed significantly ($p < 0.05$) in terms of fat content, total solids content, log total plate count (TPC), texture, pH, protein content and free fatty acids (FFA) content. Other quality aspects, namely soluble protein, NaCl content and sensory evaluation scores did not differ significantly ($p > 0.05$) between treatments. During ripening, pH, log TPC, soluble protein content, FFA content, NaCl content and texture changed significantly ($p < 0.05$).

The mean salt content of the cheeses ranged between 3.93% and 4.01%, and did not differ significantly ($p > 0.05$) between treatments but it increased significantly during ripening. The magnitude of change was much greater between day 2 and

day 7 than between day 7 and day 21. According to Fox (1987a), the fact that the rate of salt absorption decreased with time may mean that there was a decrease in the NaCl concentration on the surface of the curd.

Since the brine was drained off and the surface of the cheese was blotted dry before sampling, it is likely that more concentrated brine was removed during the early stages of ripening than during later stages and this might have affected the results negatively. Moreover, the salt content may not be regarded very reliable since dry salting was used. According to Fox (1987a), a high error in dry salting is caused by the fact that not all of the salt weighed fall exactly on the surface of the curd and not all of that which fell on the curd is absorbed. Apart from that, the salt uptake is also affected by factors like the dimensions of the cheese, temperature, acidity and curd composition. The high error is verified by the standard deviation which was as high as 1.12.

The trend of fat content of the Feta cheeses indicated that fat content decreased systematically from treatment 1 to 4 and seemed to decrease with decrease in cow's milk proportion in the Feta cheese milk. The reason for this could be the fact that the cow's milk had significantly higher fat content than the goat's milk, and milk fat is one of the major components of cheese (van Boekel, 1993; Varnam & Sutherland, 1994).

Although Scott's (1986) theory stipulated that goat's milk lipids are easy to incorporate into the cheese as they occur in small fat globules and cow's milk usually result in high fat losses, this might not have had significant impact on the final fat content of the cheeses. The expected high fat losses in treatment 1 and 2 cheese might have been offset by the presence of the high amount of fat originating from cow's milk.

The total fat content of the four Feta cheese treatments did not change significantly ($p > 0.05$) during ripening. This may be due to the fact that moisture loss was minimal and the migration of lipolysis products from the curd might have been negligible as it depends on the dimensions of the cheese and level of saturation of the brine into which the products have to dissolve. The lipolysis products, namely long chain free fatty acids, are insoluble in water, hence they remain intact in the cheese curd (Morrison & Boyd, 1987). Although Fox (1987b) stated that a slight increase in fat content may occur due to the continuous losses of soluble degradation products of the solids-non-fat, the increase was negligible.

The mean FFA content of the cheeses differed significantly ($p < 0.05$), where treatment 4 had the highest values, treatment 1 had the lowest and those for treatment 2 and 3 almost overlapped. The trend did not indicate an increase in FFA content with increase in total fat content, but followed the reverse pattern. This may be due to the fact that goat's milk is usually richer in FFA and genetically more susceptible to lipolysis than cow's milk (Fox, 1983). Moreover, the Feta cheeses with high FFA content also had comparatively high microbial load, and hence higher chances of production of lipases. To attain the desired amount of FFA content in pure cow's milk Feta cheese, a commercial lipase is often added in the formulation to increase the degree of lipolysis (Scott, 1986).

Despite the fact that the difference in salt content was not significant between treatment 2 and 3, the higher lipolysis which was expected in the latter due to the presence of higher proportion of goat's milk, might have been slightly retarded by high salt content in this Feta cheese. Miadenov (1973), according to Fox (1987a) reported that fat breakdown increased with decrease in salt content in cheese.

Although the figures did not coincide exactly because of the difference in ripening conditions and age of the cheese, the increase in FFA content correlated with the results obtained by Litopoulou-Tzanataki, Tzanetakis & Vafopoulou-Mastrojiannaki

(1993) and Pappas, Kondyli, Voutsinnas & Mallatou (1996) on Feta cheese. According to the former authors, the amount of FFA ranged between 1.04 acid degree values (ADV) and 1.85 ADV between day 5 and day 20 whilst in the present study, the amounts ranged between 0.65 ADV and 1.62 ADV between day 2 and day 21.

Although the protein content of the goat's milk and the cow's milk did not differ significantly ($p > 0.05$), the four cheeses differed significantly ($p < 0.05$) in protein content. Generally, the values increased systematically from treatment 1 to 4. The research values ranged between 13.90% and 15.28%, and were lower than the literature value of 16.7% quoted by Robinson (1995). However, Robinson (1995) did not state the quality of milk used and age of the cheese.

The fact that the total protein content increased from treatments 1 to 4 may not necessarily imply that the percentage of proteins incorporated into the curd was higher in the cheeses with higher proportions of goat's (treatments 3 and 4) than in the treatment 1 and 2 cheeses. It could be that the amounts of proteins recovered in the latter were offset by its higher proportion of fat content. According to van Boekel (1993), cheese is a product in which the protein and fat of milk constitute the major fraction of the total solids, hence the higher the percentage of one component the lower the percentage of the other.

The total protein content of all the Feta cheeses did not change significantly during ripening and this corresponds with the fact that there was no significant moisture loss. This could be due to the fact that migration of the soluble proteins into the brine was accompanied by loss of water, and hence the net impact was that the total protein and moisture of the cheeses remained the same (Fox, 1987b). However, Renner & El-Salam (1977) stated that up to 15% of the total protein of ripe Feta cheese may be found in the brine, but this depends on the ripening conditions and age of the cheese.

The mean soluble protein content of the Feta cheeses did not vary significantly between the treatments, although they increased as the proportion of goat's milk increased. The soluble protein content seemed to be directly proportional to the mean total protein content in the respective cheeses. This trend may be attributed to the difference in the log TPC, since the soluble protein content values were slightly higher in cheeses with higher microbial load. According to Tsotsanis (1996), the degree of proteolysis of goat's milk and ewe's milk cheese through rennet action is often greater than that of cow's milk cheese during ripening. Despite the trend acknowledged, there is a possibility that the results have been affected by the fact that some of the soluble proteins had dissolved in the brine which was drained off at the beginning of sampling (Renner & El-Salam, 1993).

The mean soluble protein content of the cheeses increased significantly ($p < 0.05$) during ripening. According to Varnam & Sutherland (1994), proteolysis is a major biochemical reaction in the ripening of cheese due to the presence of proteolytic enzymes derived from rennet and both starter and non-starter micro-organisms. The processes may take a few weeks or years depending on the desired quality attributes and ripening conditions, hence its products accumulate with ripening time.

The results of the amount of soluble proteins are difficult to compare with the results of the work done by other authors because of the difference in the methods used. The methods used by several authors (for example Efthymiou & Mattick, 1964; Mallatou *et al.*, 1994; Tzanetakis *et al.*, 1995;) is that of "soluble nitrogen in 12% trichloroacetic acid (TCA-N) as opposed to water soluble nitrogen (WSN) which was used in this research. Kandarakis *et al.* (1995) used both methods, but expressed the amount of soluble proteins as a percentage of total nitrogen and not as a fraction of the whole cheese. For these reasons, values obtained through the latter are lower than the values expressed as percentage of total nitrogen.

Generally, the total solid (TS) content of all the Feta cheeses did not change significantly ($p > 0.05$) during ripening, but the values differed significantly ($p < 0.05$) between the treatments. This correlates with the fact that there was no significant change in fat content and protein content of the Feta cheeses during ripening, as these components constitute the major percentage of TS (Van Boekel, 1993).

The results also indicated that the magnitude of difference in TS content between treatments 1, 3 and 4 was slightly smaller than that between treatment 2 and the other three. Although the mean salt content of the cheeses did not differ significantly, treatment 2 had the lowest salt content which might be responsible for the low TS content in this cheese (Fox, 1987a). However, TS content of treatment 2 cheese might have been most adversely affected by the dry salting method error as this cheese had the highest standard deviation in salt content results.

The mean TS content values were 41.50 %, 39.96%, 41.31% and 41.37% for treatments 1, 2, 3 and 4 respectively. Generally, the TS content correlated with the results of Pappas *et al.* (1996) who found that the moisture level of Feta cheese on day 0 to day 30 ranged between 57% and 63%.

The mean pH of all the Feta cheeses changed significantly ($p < 0.05$) during ripening and the values varied significantly ($p < 0.05$) between cheeses from the different treatments. During the early stages of ripening, the pH of the cheeses was close to 4.70 and dropped to about 4.60 at the end of ripening. A decrease in pH was also reported by Kandarakis *et al.* (1995), who found that pH values changed from 4.78 to 4.43 from day 1 to day 30. The main causes of the difference in pH values found in the present study and those by Kandarakis *et al.* (1995), could be the fact that Kandarakis *et al.* (1995) used ewe's milk, a different

starter culture, different ripening conditions and the age of the cheese also differed.

Compared to the pH of the milks (6.70 and 6.73) the pH of the Feta cheeses was significantly lower. This is attributed to the changes which began during cheesemaking when starter culture was added. The starter and the non-starter lactic acid micro-organisms biodegrade lactose in milk and produce lactic acid, which is responsible for the drop in pH (Bohinski, 1987). In general the main difference between pH values of the Feta cheeses was that cheese from treatment 4 had significantly lower values than that from the other three treatments. This may be attributed to the fact that treatment 4 Feta cheese accumulated more FFA and more amino acids during ripening, and also had higher microbial load than the other cheeses and ultimately its magnitude of change in pH was larger.

The mean log total plate count (TPC) in the cheese from all the treatments changed significantly ($p < 0.05$) with time, and there was a significant ($p < 0.05$) difference between various treatments. The trend for the log TPC showed a significant increase in numbers from day 2 to day 7, but after day 7 the numbers generally leveled-off. This showed that at early stages of ripening, conditions were suitable for the growth of micro-organisms. Later, conditions like high salt content, diminished lactose content and low pH slowed down growth of the micro-organisms (Fox, 1987a).

The log TPC trend verified Scott's (1986) theory that the early stages of the cheesemaking process is concerned with a phase of maximum growth of the bacteria, and that during cheese ripening the retardation phase and death phase become important and their enzymes and other substances are released into the curd. Since the milk was pasteurised, the largest fraction of the micro-organisms must have originated from the starter culture. The rapid growth seen at the beginning of ripening may also be due to the fact that commercial lactic acid

cultures are stimulated by low levels of NaCl but are inhibited by >2.5% (Fox, 1987a).

The difference in mean log TPC between different cheeses seems to be directly related to the original counts of the cheese milk. Since the goat's milk had a significantly higher microbial load than the cow's milk, the cheeses with higher proportions of goat's milk had higher microbial counts.

According to Tzanetakis & Litopoulou-Tzanetaki (1992) low pH (5.19 to 4.56) and salt content below 5.9% favour the growth of lactobacilli, which dorminates over other genera throughout ripening. However, since the types of micro-organisms which were present in the Feta cheeses were not identified in this research, it is not easy to say whether Tzanetakis & Litopoulou-Tzanetaki's (1992) findings applied in the present study. Apart from this, the starter cultures used in the two researches were not the same.

The results of the texture of the Feta cheeses did not show any specific trend during ripening and between the cheeses made from different proportions of goat's milk and cow's milk mixture. The values fluctuated significantly ($p < 0.05$) and ranged between 0.85 N and 1.66 N and the standard deviation was as high as 0.90. According to Fox (1987a), the reproducibility which one may expect when making replicate analysis of one sample, with penetrometer methods used in this study, is limited and the variation may go as high as 30%.

Another cause of fluctuations in the results might be the fact that the replicate samples used for analysis were taken randomly from different parts of the cheeses (some from the surface and others from the center). This might have increased the error since cheese is known to be softer in the center where ripening changes are believed to be more rapid than on the surface (Fox, 1987a; Varnam & Sutherland, 1994).

The lactose content of the Feta cheeses was found to be almost negligible from the second day after renneting of the cheese milk. This supports Cogan's (1995) statement that "generally lactose is undetectable in cheese 24 h after manufacture". This could be caused by the fact that a very high proportion of lactose is lost in the whey during the initial stages of cheesemaking, and the addition of the starter culture resulted in the biodegradation of almost all the residual lactose during the period of about 48 h before the lactose content was first determined (Cogan, 1995).

The sensory evaluation scores of the Feta cheeses which was obtained after ripening the cheeses for a period of three weeks, indicated that there was no significant ($p > 0.05$) difference in acceptability between Feta cheeses made from different proportions of the cow's milk and the goat's milk mixture. The overall score for all the Feta cheeses was "like slightly". Despite the fact that the Feta cheeses differed significantly in some of the chemical and physical quality aspects, there was no specific cheese which was more preferred than others.

6. CONCLUSIONS AND RECOMMENDATIONS

Using mixtures of goat's milk and cow's milk in place of pure goat's milk had the following impact on the quality aspects and manufacturing of Feta cheese:-

- reduced the renneting time
- a firmer and less fragile curd was formed
- Feta cheese maturation process was slowed down
- acid development was slowed down

Despite the difference in the chemical composition, the composition of all the cheeses made in this study met the following literature values specified by Mansfield (1992) (according to Prinsloo, 1997):-

Moisture content = 40.0 to 63.5%
Fat content = 16.0 to 33.9%
Protein content = 12.0 to 20.8%
Sodium chloride = 1.58 to 6.58%
pH = 4.1 to 5.3

The proportions of the milks used determined the quality aspects of the Feta cheese. The higher the proportion of goat's milk in the cheese milk, the more closely the quality aspects of the cheese resembled those of pure goat's milk Feta cheese and *vice versa.*

Since consistency is one of the important factors which have a positive impact on the consumer's perception of taste and quality, and also reduces error in the research, it may be wise to modify processing techniques, like dry salting, which are liable to cause inconsistency.

For research purposes it could be beneficial to standardise the milk for ease of reference as factors like difference in milk chemical composition, breed of animals used as source of milk, age of the cheese and ripening conditions makes it difficult to

find appropriate literature to use. For example, according to Tsotsanis (1996), the fat content of milk used for manufacturing Feta cheese should be 6%.

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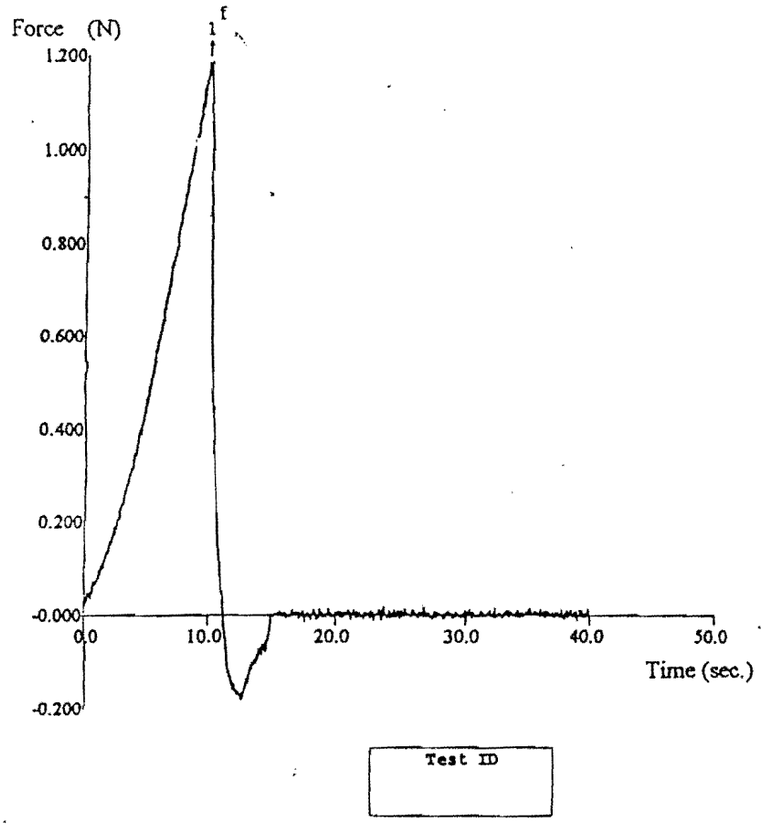
Appendix A: Quality aspects of Feta cheeses made from different proportions of cow's milk and goat's milk

Age (days)	*Treat-ment**	*Total Protein (%)*	*Soluble Protein (%)*	*Fat (%)*	*FFA (ADV)*	*NaCl (%)*	*TS (%)*	*pH*	*Log TPC*	*Texture (N)*
2	1	14.36 (0.74)	1.82 (0.27)**	18.08 (0.86)	0.65 (0.18)	3.88 (0.50)	41.32 (1.16)	4.68 (0.07)	4.86 (0.59)	1.57 (0.44)
	2	14.21 (0.78)	1.73 (0.18)	17.67 (0.65)	0.86 (0.29)	3.84 (0.37)	40.77 (1.36)	4.64 (0.07)	5.61 (0.37)	1.40 (0.51)
	3	14.40 (0.96)	1.85 (0.12)	17.83 (0.76)	0.88 (0.25)	3.70 (0.85)	40.45 (1.02)	4.67 (0.06)	5.30 (0.52)	1.35 (0.45)
	4	15.35 (1.00)	1.50 (0.44)	17.00 (0.85)	0.89 (0.20)	3.79 (1.06)	40.92 (0.96)	4.62 (0.07)	6.01 (0.39)	1.16 (0.88)
7	1	13.37 (0.81)	1.76 (0.48)	19.33 (0.65)	0.88 (0.18)	4.00 (0.48)	41.66 (0.98)	4.67 (0.08)	5.61 (0.52)	1.24 (0.56)
	2	13.76 (0.40)	1.70 (0.21)	18.08 (0.67)	1.00 (0.22)	3.93 (1.12)	39.18 (1.43)	4.67 (0.08)	5.89 (0.55)	1.46 (0.46)
	3	14.42 (0.91)	2.08 (0.46)	17.58 (0.51)	0.96 (0.16)	4.04 (0.34)	40.83 (1.12)	4.68 (0.09)	5.76 (0.48)	1.48 (0.87)
	4	15.11 (0.53)	2.19 (0.47)	17.08 (0.92)	1.09 (0.15)	3.98 (0.43)	41.72 (1.01)	4.63 (0.11)	6.02 (0.06)	1.35 (0.48)
14	1	13.99 (0.46)	2.40 (0.34)	19.06 (0.62)	1.33 (0.16)	4.09 (0.77)	41.84 (0.90)	4.66 (0.09)	5.94 (0.91)	1.66 (0.41)
	2	14.18 (0.38)	2.57 (0.52)	18.31 (0.70)	1.27 (0.19)	3.96 (1.11)	41.19 (1.60)	4.66 (0.09)	5.96 (0.24)	0.85 (0.65)
	3	14.10 (0.89)	2.72 (0.47)	18.00 (0.63)	1.30 (0.25)	4.10 (0.67)	41.04 (1.18)	4.66 (0.08)	5.90 (0.33)	0.96 (0.89)
	4	15.37 (0.88)	2.94 (0.41)	17.63 (0.52)	1.43 (0.18)	4.04 (0.52)	41.93 (1.17)	4.64 (0.07)	6.03 (0.31)	1.24 (0.43)
21	1	13.88 (0.66)	2.94 (0.48)	19.25 (0.58)	1.42 (0.23)	4.11 (0.40)	41.28 (0.95)	4.62 (0.08)	5.60 (0.49)	1.55 (0.88)
	2	13.77 (0.61)	2.98 (0.22)	18.04 (0.40)	1.45 (0.20)	4.00 (0.29)	39.98 (1.21)	4.58 (0.09)	5.99 (0.51)	1.22 (0.43)
	3	14.43 (0.81)	2.89 (0.25)	17.21 (0.40)	1.47 (0.16)	4.08 (0.33)	40.04 (0.87)	4.61 (0.08)	5.86 (0.53)	1.07 (0.56)
	4	15.30 (0.62)	3.08 (0.38)	16.63 (0.71)	1.62 (0.20)	4.07 (0.80)	41.24 (1.00)	4.63 (0.07)	6.11 (0.42)	0.95 (0.90)

Treatment* = 1 (100% cow's milk), 2 (65% cow's milk + 35% goat's milk), 3 (35% cow's milk + 65% goat's milk) and 4 (100% goat's milk)

** = Figures in brackets are standard deviation

Appendix B: An example of rep ed by the texture analyser TA-XT2



FILE NAME	MODE	OPTION	PRE-SPEED	SPEED	POST-SPEED	FORCE	DISTANCE	TIME	COUNT	TRIGGER	PP
SEB0013A.ARC	Force/Comp.	Return to Start	2.0mm/s	1.0mm/s	1.0mm/s	N/A	10.0mm	N/A	N/A	0.03N	20

FILE NAME	PROBE	LOAD CELL	TEMPERATURE	AREA	HEIGHT	WIDTH	LEN
SEB0013A.ARC		25 - 1	0.0 °C	0.000 mm²	0.000 mm	0.000 mm	0.0