PARTICIPATORY DEVELOPMENT OF AN INDIGENOUS GOAT CHEESE PRODUCT: MONITORING OF THE CHEMICAL, NUTRITIONAL AND MICROBIOLOGICAL QUALITY FROM MILK TO CHEESE

by

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Dedicated to my family

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LIST OF ABBREVIATIONS

(0)	Fresh cheese
ARC	Agricultural Research Center
ASFC	Aerobic spore former count
A_w	Water activity
BART	*Brucella abortus* ring test
CC	Coliform count
CN	Casein protein nitrogen
EC	*Escherichia coli* count
FFA	Free fatty acids
FFDM	Free fat in dry mater
IDF	International Dairy Federation
LBC	Lactobacilli count
LMP	*Listeria monocytogenes* presence
LSLC	Lactic acid streptococci and lactococci count
M	Mpumalanga
MNFS	Moisture in non-fat substance
NW	North West Province
ND	Not detected
(R)	Ripened cheese
S	Saanen
SAC	*Staphylococcus aureus* count
SCC	Somatic cell count
TBA	Thiobarbituric acid
TBC	Total aerobic bacterial count
WISN	Water-insoluble nitrogen
WSN	Water-soluble nitrogen
YMC	Yeast and Mould count

CHAPTER 1

GENERAL INTRODUCTION

As the population of South Africa continues to grow, the need for a source of high quality food, which reduces malnutrition, increases proportionally. Rural areas, in particular, experience a multitude of difficulties in either producing or obtaining food products which satisfy the nutritional needs of the local population. Milk is, however, an apparent possibility because of its nutritional properties that satisfy a large portion of the human body's daily requirements, its ease of consumption, its suitability for virtually all age groups and its availability. Being able to draw fresh milk from livestock daily overcomes the difficulties of storage and preparation often faced by rural settlements (Harding, 1995).

Milk and milk products have become a major part of the human diet in many countries around the world. Milk provides nutrients of high quality and its moderate inclusion in the diet of all age groups is recommended. Milk contains all the essential amino acids. It also provides calcium (in available form) that is essential to prevent osteoporosis in older women and insures normal bone and tooth development in children. Milk provides the best source of riboflavin, which is essential for assimilation of protein, fat, and carbohydrates by the body, while milk fat constitutes a high-energy source for young children and adults (Central Bureau Report, 1998).

In many countries goat's milk is marketed as a healthy food with many advantages over the milk from other animals (Egwu et al., 1995). There is evidence that a significant proportion of consumers that are unable to use cow's milk, show no detrimental effects when they consume goat's milk. Haenlein (1980) highlighted certain biochemical differences, which provide some metabolic advantages over cow's milk. Some of these advantages are easier digestion, antiallergenic reaction, assistance to individuals with

lactose intolerance problems and it is effective against bronchial asthma (Chandan et al., 1992).

Milk goats are milk producing animals which have a better feed to milk conversion ratio than cattle. The highest milk production is recorded mostly during the second and third lactations. During this period they produce an average of four to five liters per day with exceptional individual goats yielding as much as eight liters per day (Swart, 1998). Goat milk yield, however, depends on various factors such as breed, nutritional quality, age, stage of lactation, genetic make up, health status of the doe, season, frequency of milking and hormonal stimulation. (Donkin, 1993).

The high demand for goats and their products can be attributed to their hardiness and their ability to survive and produce in harsh environments with low rainfalls and with minimal nutritional supplementation. Under these conditions, goats can selectively utilize a wide variety of coarse feeds, grass, leaves and twigs, which are often unpalatable to other livestock. With their unique feeding habits, goats spend up to 60 % of their feeding time browsing. Goats are also able to increase their dietary protein intake during drought and dry periods (Louca et al., 1975). Boer and indigenous feral goats can be regarded as very adaptable, thriving in all climatic regions of South Africa including tropical and subtropical bush, semi desert regions of the Karoo and the greater Kalahari.

At first glance, the dairy cow would appear to be an easier and more practical source of milk. However, dairy cows pose a whole new set of problems for small-scale farmers. The capital lay-out for cows is high, they require large amounts of feed and they have longer generation intervals.

In contrast, goats are uniquely suited to exploit the prevailing circumstances in less developed areas (Steele, 1996; Slippers, 1998) for the following reasons:

- Low initial, replacement and maintenance cost.
- Can be easily handled by women and children.

- Readily available for meat and milk, which is produced in manageable quantities for household consumption.
- Short generation intervals and produce more progeny.
- Wide environmental adaptation range.
- Use of marginal lands and crop residues.
- Reproducing in harsh environments where cattle and sheep find it difficult to survive.
- Biological control of bush encroachment.
- Provide manure to maintain soil fertility and improve crop production.
- Higher biological efficiency than cattle.
- Produce fibre and skin that can sustain cottage industries.
- Create cash flow and job opportunities.
- Requires low external input (like purchased supplements).
- Reduce economic risks.
- Have a wide cultural and regional acceptance.
- Widely used in cultural ceremonies.
- Can be easily liquidated to improve cash-flow when needed.

Casey and Van Niekerk (1988) stated that in the rural areas of South Africa, the local unselected Boer goats and indigenous feral goats are milked for home consumption but it may be considered as a small industry.

1.1. PROBLEM IDENTIFICATION AND MOTIVATION FOR THE STUDY

In South Africa, there are a variety of indigenous goats, which are primarily owned by rural inhabitants. These goats are, however, still a commercially under-utilized resource. The milk of these goats may be used to develop products in order to expand commercial markets, to create jobs, provide high quality food and increase income in rural areas (USAID-SA, 1998b).

A recent market survey performed by the USAID-SA (United State Agency for International Development-South Africa, 1998b) in cooperation with the ARC-Animal Nutrition and Products Institute, indicated an increasing potential for goat milk and meat products. According to this survey, after the consumers were given a chance to taste the products, the intention to purchase them, increased for each product. The increase for meat and cheese was higher (25%) than other products (leather and cashmere) indicating that these products would probably have better market penetration. This survey thus demonstrated a potential market for products from goats. However, quality characteristics play an important role in consumer acceptance of a product.

The quality of dairy products primarily depends on the quality of milk from which the products are made. There is, however, little public knowledge of the quality of goat's milk milked by hand in a rural setting in South Africa (Central Bureau Report, 1998). Before any milk product can be produced and / or marketed, it is necessary to determine its hygiene and chemical characteristics (Harding, 1995).

If commercialisation of goat milk products is to occur, quality characteristics among others need to be investigated. Other factors which require investigation include improved farming methods, increased productive efficiency, business planning, product development, rural financing and improved access to markets by the rural poor.

1.2. OBJECTIVES

Using commercial machine-milked Saanen goat milk as a control, the main objectives of this study were to:

- Determine the chemical, microbiological and nutritional qualities of indigenous goat's milk from the North West and Mpumalanga provinces in South Africa.
- Develop a cheese product from the goat milk of each of the two provinces.
- Conduct chemical, microbiological, nutritional and sensory analysis on the ripened cheeses.
- Determine the shelf-life of the cheeses using microbial analysis

This study forms part of a national programme of "Commercialisation of Indigenous Goats" managed by the Animal Nutrition and Products Institute of the Agricultural Research Council and will provide information regarding microbiological and nutritional quality, product development guidelines and producer and consumer awareness and acceptance. This information will be used to inform the process of small-scale farmer goat commercialisation and small business development of goat dairies and small goat milk value-adding operations in the rural areas of South Africa.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Of the total world production of milk, cows produce about 90.8 %, sheep 1.7 %, goats 1.5 % and buffaloes 6%. Milk from other species such as camels are also creating interest (Harding, 1995). Goats have been used as a source of milk for thousands of years, especially in some areas where climatic conditions prevent cattle from being kept. Goats occur in almost all climatic zones (Gall, 1981). In Africa, the distribution of goats is more concentrated in dry areas. Particularly in the areas of tropical Africa, goats are the most important suppliers of biological nutrients such as essential proteins, minerals, fat and vitamins. Goats can be easily handled and their products, particularly meat and milk, are consumed by many communities (Mowlem, 1992).

Goat's milk has the same composition to that of cow's milk except that goat's milk has a higher proportion of smaller sized fat globules. Knight and Garcia (1997) reported that the average fat globule size of goat's milk (3.5μm) is significantly smaller than that of cow's milk (4.5 μm) while goat's milk has a higher percentage of fat globules. For this reason goat's milk is recommended for babies and other people who may experience difficulties in digesting cow's milk (ARFC, 1998).

Milk and milk product quality is usually determined by composition and hygiene. The compositional quality is mainly influenced by feeding, management system, breed, lactation stage, age, season, health state of the doe and other factors (Heeschen, 1996). Hygienic parameters are very important for quality and safety. The main criteria for milk and milk products of high hygienic value are low numbers of saprophytic microorganisms, absence or very low numbers of pathogenic microorganisms and absence or minimum quantity of residues (Heeschen, 1996).

2.2. HISTORY OF GOATS

Goats have helped people to survive and thrive for countless generations. The goat (*Capra hircus*) is thought to have been the first animal to be domesticated by humans. Evidence suggests that domestication took place about 7000 B.C. in South West Asia, on the border of present day Iraq. From that area, goats spread to all other climatic zones (Peacock, 1996). After domestication, physical differentiation in breeds and types began. Early physical changes affected ears, horns, colour and hair types. These changes arose from nature, nutrition and selection by the goat keepers. Early goat keepers selected goat characteristics that were appropriate to their needs. There is a huge range of colour, size, hair type and other characteristics among the modern breeds.

Goats have shown to be extremely adaptable animals and are found almost in every climatic zone throughout the world. There are now estimated to be about 592-million goats in the world (Peacock, 1996). The majority of goats (> 90%) are found in the developing countries of Asia, Africa and South America (Table 2.1). In Africa, goats are found throughout the continent, particularly in the extensive Savannah and subtropical areas, where the people are dependent on their goats (Mba et al., 1975). In many African countries, goats are traditionally owned by small farmers, peasants and landless agricultural laborers (Akinsoyinu et al., 1977).

In South Africa, the first people to land at the Southern point of South Africa, found only cattle and sheep. They encountered goats only after making contact with Namaqua-Hottentots around 1661. Over the course of time, the indigenous goats were improved by breeding and selecting, especially with a view to increased meat production (Hofmeyr, 1969). As early as 1838, Angora goats were shipped from Turkey to South Africa to serve as the foundation for the mohair industry. On the other hand, milk goats were imported from Europe only around the end of the nineteenth century. These animals were of Swiss origin, the habitat of the known milk goat breed (Saanen). As the popularity of milk goats grew, further importations took place from other European

countries, e.g. the British Alpine and the Toggenburg from the United Kingdom (Hofmeyr, 1969).

Table 2.1. Estimated world goat population (Peacock, 1996).

AREA	POPULATION (MILLIONS)	PERCENTAGE OF POPULATION
Africa	172	73.8
South America	23	9.9
Europe	14	6.0
North America	16	6.9
Former Soviet Union	7	3.0
Oceanic	1	0.4
Total		100

2.3. GOATS IN SOUTH AFRICA

2.3.1. BREEDS

According to Hofmeyr (1969) and USAID-SA and ARC (1998b), the various South African goat breeds may be classified as shown below.

2.3.1.1. INDIGENOUS BREEDS

2.3.1.1.1. Ordinary Boer goats

These goats are short-haired goats which have fairly good conformation and characteristics. These types of goats can still be improved with regard to conformation, growth rate and uniformity.

2.3.1.1.2. Long-haired goats

These goats are less desirable. They are relatively bigger and heavier than other goats. Their meat is coarse and their skin is worthless due to their long hair.

2.3.1.1.3. Polled Boer goats

They are short-haired goats without horns and have a less desirable conformation. They originated from cross breeding of ordinary Boer goats with milk goat types.

2.3.1.1.4. Native goats

These goats are mainly found with black farmers in the developing agricultural sectors of South Africa. They are high on their legs and mostly weak in conformation. Their colour varies according to the interest of the different tribes (Fig. 2.1)

Figure 2.1. Typical South African indigenous goats (Cronje, 1998).

2.3.1.2. MILK GOAT BREEDS

Milk goats do well in all environments. Neither extreme cold nor heat affects them adversely. According to the USAID-SA and ARC (1998b) report, the following milk goat types are currently registered in South Africa:

2.3.1.2.1 Saanen

This breed originated in Switzerland. They are white goats with short hair. They are usually polled. Their face is straight or slightly concave with erected forward pointing ears.

2.3.1.2.2 British Alpine

This breed originated from the United Kingdom around 1920. They have attractive glossy black hair with white markings. The British Alpine and the Saanen have approximately the same size.

2.3.1.2.3 Toggenburg

This breed originated from the province of Ober-Toggenburg, in Switzerland. It was exported to South Africa early in the twentieth century. They have a fawn coloured coat with white markings on the face, ears, legs, tail and thighs. They are smaller in size than the Saanen and British alpine.

2.3.2. POPULATION

The South African agricultural sector is characterized by the developed and developing sectors. The former include the commercial farming sector while the latter mainly include the subsistence farming sector. The majority of the South African goat population is found in the developing agricultural sectors. Unfortunately, limited statistical data are available for these areas. Figures are available only on provincial level

(USAID-SA and ARC, 1998a). The total South African goat population including Angora goats was estimated at 6.7 million with an annual growth rate of 2.1 % for the period of 1994 to 1996. Of the 6.7 million goats, 4.3 million were estimated to be indigenous goats (Table 2.2; USAID-SA and ARC, 1998b).

Table 2.2. Total goat population, including Angora goats, in South Africa (USAID-SA and ARC, 1998b).

PROVINCE	1994	1995	1996	Average annual growth (%)
	Numbers (x 1000)			
Eastern Cape	3156	3218	3221	1.0
Northern Cape	448	432	447	0.1
Western Cape	251	262	258	1.4
Kwazulu-Natal	823	824	833	0.6
North-West	585	615	728	11.5
Free State	76	71	75	0.8
Northern Prov.	960	940	1017	2.9
Mpumalanga	93	81	82	6.5
Gauteng	11	13	14	1.5
TOTAL	6.404	6457	6674	2.1

According to the statistical data shown in Table 2.2, approximately 50 % of the total goat population of South Africa is found in the Eastern Cape, followed by 15 % in the Northern Province, 12 % in Kwazulu-Natal and 11 % in the North-West Province.

2.3.3. MILK PRODUCTION

As yet, official statistical data for the total goat milk production in South Africa is not available, however, the total goat milk production for the estimated 15 000 milking does in South Africa was projected at 230 000 liters per annum (USAID-SA and ARC, 1998b).

Regarding goat milk yield and production, Rubino et al. (1995) stated that goats can improve their milk production when supplied with energy or protein supplements, but the response is limited by the milk producing potential of the breed. Similarly, Gipson and Grossman (1990) reported significant differences between different breeds when comparing the yield, time of peak yield and persistence. Comparing the milk yield of Saanen and other breeds in South Africa, Donkin (1993) pointed out that in the first lactation period, Saanen goats produce two to three liters per day with a total amount of 600 liters per lactation while the cross breeds (Saanen x Tswana doe) produce one to two liters per day and 300 liters per lactation. Regarding the Boer goat breeds in South Africa, Casey and Van Niekerk (1988) reported 1.5 to 2.5 liters per day as an average.

Most goats are seasonal breeders. Iloeje et al., (1980); Kinnedy et al., (1981) and Mourad (1992) reported that the month of kidding had a large influence on the milk yield. Based upon age of individuals, Kritzinger (1994) found that much younger or older does produce less amounts of milk than adult does (3-5 years). Swart (1998), as the South African Goat Milch Breeders Society representative, stated that the highest milk productions are recorded during the second and third lactation periods. During these periods the does produce an average of four to five liters per day with some exceptional individuals yielding as much as eight liters per day.

2.3.4. GOAT MILK PRODUCTS

Figure 2.2 illustrates, in general, how goat milk may be broken down into its components and converted into various products.

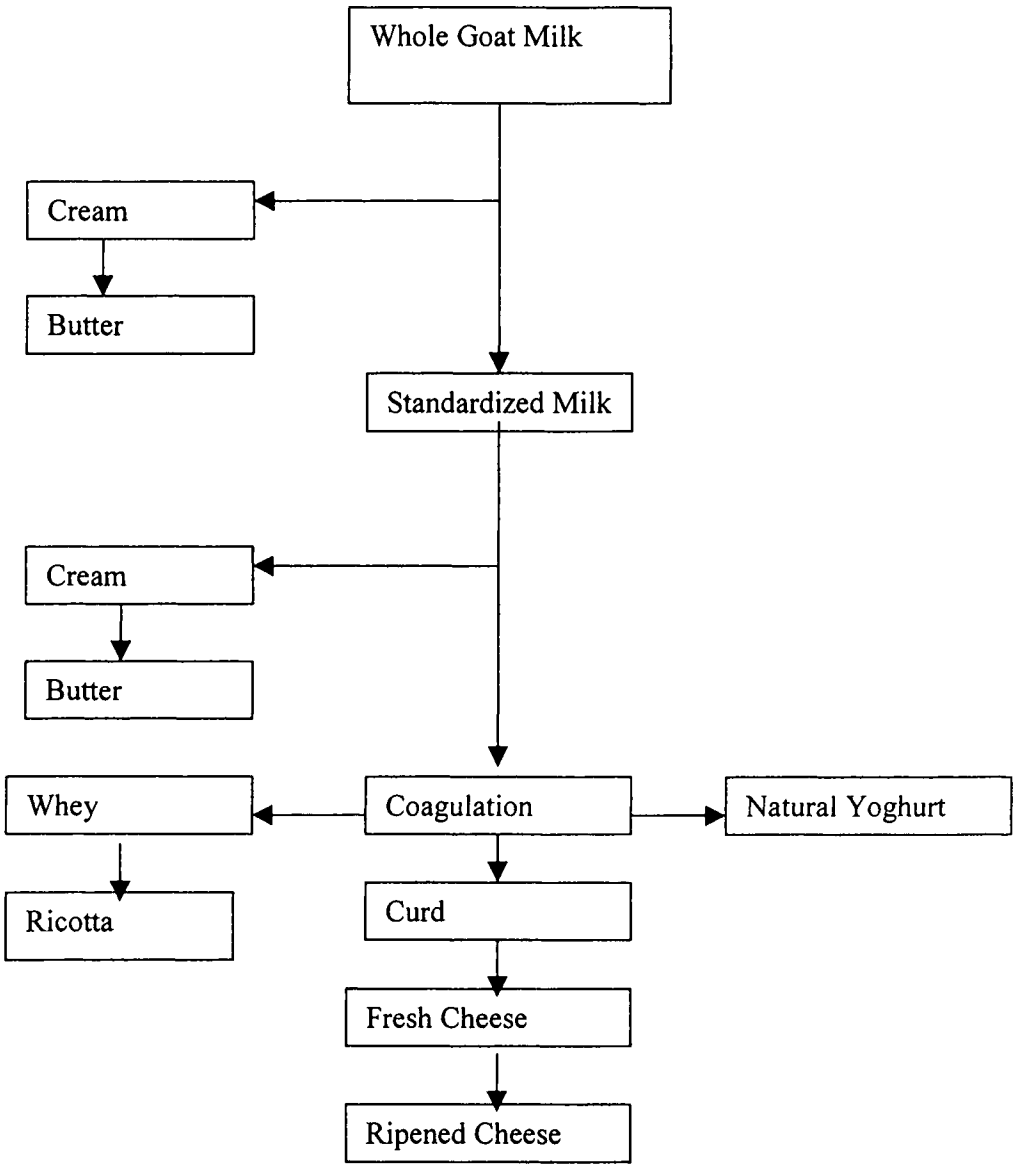

Figure 2.2. Conversion of goat milk into its products (Peacock, 1996).

In South Africa the following products can be produced from goat milk:

2.3.4.1. CHEESE

Soft, fresh style goat cheese (Camembert, Brie, Cottage cheese, Mozzarella); soft mould goat cheese; herbed soft mould goat cheese; chive-and-garlic sliced goat milk cheese; mild and strong feta cheese; Monterey; coldyby; Cheddar; Ricotta and others (Hofmeyr, 1969).

Fairview is the most widely known goat cheese producer in South Africa, with an estimated total production of 40 000 kg per annum. About 70 % of the cheese produced are Gotina and Robiola while 30 % is Hevin and Camembert. There are also other smaller goat cheese producers.

2.3.4.2. YOGHURT

Plain flavoured and frozen yogurt are the yogurt types most commonly produced in South Africa.

2.3.4.3. OTHER PRODUCTS

Dips, ice cream, sorbet, pudding, pie filling, soup and other related products can be produced from goat's milk (USAID-SA and ARC, 1998b).

2.3.5. MILK AND MILK PRODUCTS CONSUMPTION

Normal goat milk corresponds in taste to cow's milk and it can be used for the same purpose as cow's milk. To test the awareness and acceptance for goat milk by the local South African population, a survey was conducted by USAID-SA and ARC (1998b). According to the results obtained, milk was the best known commodity of goats

followed by cheese, yogurt and spreads. Creams and deserts were considered to be luxuries.

Lack of familiarity with goat milk and its products and the poor public image of goat milk and milk products in general, tend to limit the consumption of goat milk. There is limited knowledge and appreciation of the unique qualities of goat milk (Central Bureau Report, 1998). Goat milk currently is used for babies with allergic conditions or other health reasons. In general, the consumption of liquid goat milk is low. Its consumption is mainly based on doctor's directions or for therapeutic conditions (Central Bureau Report, 1998).

The producers goat milk price varies from R2.50 to R3.30 per liter, which is a relatively higher price compared to the approximately R1.30 for cow's milk.

Goat milk cheese also has a higher value compared to that of cow's milk. It is, however, not a general consumer's commodity. In South Africa, most cheese consumers are found in the higher income groups. For this reason, cheese products are mainly available in chain stores within higher income areas. Consumers with high cholesterol and allergic problems are also other key purchasers of goat cheese (USAID-SA and ARC, 1998a).

During a market survey conducted by the USAID-SA and ARC (1998b) in South Africa, the producer's price for goat cheese was estimated for Feta at R33.00 per kg, Rabiola R28.50 per kg and Flavoured cheese R30.50 per kg. The price for similar cheese products in the retailer's store (Faerie Glenn, Pretoria) was remarkably higher (Table 2.3).

Retailers and producers also sell small quantities of goat milk yogurt at approximately R5.25 per liter. Sales are generally targeted at consumers with allergic conditions.

Table 2.3. Retail price of cow and goat cheese, at Pick-N-Pay, Faerie Glenn, Pretoria (27-06-98) (USAID-SA and ARC, 1998a).

Products	Rand per kg
COW CHEESE	
Cheddar	29.00
Gouda	27.95
Processed	27.99
GOAT CHEESE	
Chevin	71.92
Rabiola	85.49

2.4. GOAT MILK COMPOSITION

2.4.1. MICROBIOLOGICAL COMPOSITION

Bacteria are by far the most important microorganisms present in milk. Unfortunately, milk is an ideal medium for the growth of these bacteria. Spoilage may be detrimental to human health, but many microorganisms are considered to be part of the normal flora of the milk (Zottola and Smith, 1993). Prevention of the growth of unwanted opportunists is very important in the production, handling, transportation and processing of good quality milk and milk products (Jervis, 1986; Heeschen, 1996). Production of milk under hygienic conditions and subsequent storage at low temperatures ($\leq$4°C) restricts proliferation of microorganisms (Tirard-Collet et al., 1991).

Many researchers have concerned themselves with the numbers and types of microorganisms found in goat milk (Kapur and Singh, 1978; Dulin et al., 1982; Poutrel and Lerondelle, 1983; Chubb et al., 1985). Microorganisms that may be found in goat milk belong to the following genera and groups of microorganisms: staphylococci,

Bacillus, coliforms, *Micrococcus*, *Streptococcus*, *Corynebacterium* and *Pseudomonas* (Kalogridou-Vassiliadou, 1991). Improper goat housing and management leads to exposure of teat ends to environmental microorganisms (Bramley and Dodd, 1984). In the absence of proper hygiene measures, particularly teat disinfection, bacteria multiply on the teat surface and in the teat duct which often leads to intra mammary infection or mastitis (Devries, 1979).

According to Kalogridou-Vassiliadou (1991), out of 1350 goat milk samples examined, 65 % were infected with pathogenic microorganisms. Raw and improperly handled milk and milk products have been implicated in a number of diseases outbreaks (Doust et al., 1985). *Listeria monocytogenes*, *Salmonella* spp., *Escherichia coli, Staphylococcus aureus* and *Campylobacter* species are recognized as important agents of food borne–illness associated with the consumption of raw milk and milk products (Steele et al., 1997).

Bacteria may find their way into cheese as a result of environmental contamination during manufacturing. The growth of undesirable microorganisms that occur during the ripening of cheese may cause spoilage (cracking, splitting of the cheese and bitterness) and result in poor quality cheese. These spoilage organisms may produce enzymes that are released during the manufacturing and the ripening period (Zottola and Smith, 1993). The number of these organisms may be reduced during curd formation and ripening. These steps have, however, not yet proven to effectively eliminate all the pathogens (Flower et al., 1992). Milk that is used for cheese-making should, therefore, be pasteurized or treated in such a way that will destroy the pathogenic and or toxin-producing organisms present in the milk.

2.4.2. CHEMICAL COMPOSITION

The gross composition of goat milk is similar to that of cow's milk (Table 2.4; Harding, 1995). As with cow milk, however, the composition of goat milk varies within and between breeds, species, stage of lactation, age (Mittal, 1979), feeding (Singhal and

Mudgal, 1985), health state, season (Agrawa and Brattacharyya, 1978; Kala and Prakash, 1990) and other related factors.

The biggest variation between sheep and goat milk lies in the fat content (Table 2.4). Goat milk has, however, almost the same fat composition as cow's milk. The fatty acid composition, however, differs slightly between cow's and goat's milk. Goat milk is richer in short-chained fatty acids (C_4: 0 to C_{10}: 0) which represents 15% of all fatty acids as compared to 9% in cow milk (Morand-Fehr and Sauvand, 1980; Ramos and Juarez, 1981). Goat milk has a relatively high percentage (28%) of small fat globules while cow milk has only 10% small fat globules of sizes less than 1.5 μm. This high percentage of small sized fat globules in goat milk contributes to the easier digestibility of its products (LeJaouen, 1981; Abderkadir, et al., 1998).

Table 2.4. Typical chemical composition of cow, goat and sheep milk (Harding, 1995).

BREED	FAT (%)	PROTEIN (%)	LACTOSE (%)	ASH (%)	TOTAL SOLIDS (%)
COW	3.9	3.2	4.6	0.72	12.6
SHEEP	7.1	5.7	4.6	0.93	18.2
GOAT	3.6	3.3	4.6	0.80	12.1

Milk proteins are the most valuable components of milk in terms of their importance in human nutrition and their influence on the properties of milk products which in turn affects the product quality (Harding, 1995). Protein content of goat milk varies much less than fat content and seems much more dependent on the genetic make up than other environmental factors. In most cases, the protein content of individual goat milk increases at the end of lactation (Mahaut and Korolkzuk, 1993). In relation to cow milk, the non-nitrogen protein of goat's milk is higher. The casein content is, however, slightly lower than in cow milk with a very low proportion or absence of αS1 casein and a high proportion of β-casein (Ramos and Juarez, 1981).

2.4.3. NUTRITIONAL COMPOSITION

In order to stay mentally and physically healthy, our body needs at least 30 identified vitamins and minerals but the amounts of particular vitamins or minerals needed varies with the individual's physical and mental state, age, sex, and, of course, the diet itself (Fredish, 1998).

Beyond meeting daily nutrient requirements, it is of special interest that goat milk has unique properties which distinguish them from cow milk and make them a valuable alternative, not only for infants but also for adults, especially nursing mothers (Baldo, 1984). The Central Bureau Report (1998) also stated that goat milk is as high as, or higher, than cow milk in protein, minerals and vitamins. Goat milk is often medically recommended in situations such as allergic reactions to cow's milk and milk products which might be manifested in both children and adults.

2.4.3.1. MINERALS

The mineral composition of goat milk has been given attention by many researchers (Haenlein, 1980; Akinsoyinu, 1981; Storry et al., 1983). The concentration of the different elements present in the milk depends on the breed, lactation stage, milk yield, season, diet, etc. (Juarez and Ramos, 1986). One of the biggest contributions of goat milk to human nutrition is the calcium (1.2 g/l) and phosphorus (1 g/l) that it supplies (Jenness, 1980). These concentrations are similar to those in cow milk, whereas human milk contains much less of these minerals with only one-fourth as much as calcium and one-sixth of phosphorus. Table 2.5 shows the concentration of some of the main minerals of different species.

Goat milk is richer in iron than human, cow and sheep milk (0.12mg/100g versus 0.07, 0.05 and 0.03 mg/100g respectively) (Alichanidi and Polychroniadou, 1995). As with cow milk, the main elements present in goat milk

undergo substantial fluctuations during lactation (Juarez and Ramos, 1986). Martin-Harmadez and Juarez (1989) examined three groups of goats during the first seven weeks of lactation and from the results they noticed a significant decrease in the concentrations of calcium, phosphorus, sodium and magnesium.

Table 2.5. The average concentration of minerals (mg/100g) found in the milk of ewes, goats, cows and humans (Jenness, 1980).

Major minerals	**Ewe**	**Goat**	**Cow**	**Human**
Calcium (Ca)	193	134	119	32
Magnesium (Mg)	18	14	13	3
Phosphorus (P)	158	111	93	14
Potassium (K)	136	204	152	51
Sodium (Na)	44	50	49	17

Concentrations of phosphorus, calcium, sodium and chloride vary among and within varieties of cheese while concentrations of sulfur and magnesium do not vary much (Park, 1990). The mineral composition of cheese depends on the conditions of manufacture, coagulation, wheying and salting (Martin-Harmandez and Juarez, 1989). Rapid acidification by lactic fermentation followed by efficient wheying favors curd demineralization, whereas rapid coagulation, avoiding or retarding acidification, retains the mineral elements of milk cheese (Martin-Harmandez and Juarez, 1989). Some of the main minerals found in goat milk cheese are shown in Table 2.6.

Table 2.6. Concentration (mg/100g) of major minerals in selected varieties of goat cheeses (Park, 1990).

Cheese varieties	P	K	Mg	Ca	Na	Cl	S
Fresh plain cheese	275	25.8	14.6	172	16	293	3.54
Ripened natural cheese	303	30.3	23.6	101	429	397	6.03

2.4.3.2. VITAMINS

Some of the major vitamins that occur in goat milk are depicted in Table 2.7. Vitamin A is essential for normal growth, reproduction, vision and the development and proper functioning of skin and mucus membranes (Waysek, 1993). Fredish (1998) also indicated that vitamin A protects the lining of the digestive system, urinary and respiratory tract from infection, and in addition to that, is a powerful anti-oxidant. Jenness (1980) reported that goat milk is adequate for the human infant in concentrations of vitamin A and niacin and supplies generous quantities of thiamin, riboflavin and pantothenate, however, it is deficient in vitamin C, D, B_{12}, pyridoxin and folate. Goat milk contains the same amount of water-soluble vitamins (B-complex and C) as cow milk (Jenness, 1980).

Vitamin E is essential for a number of physiological functions and it serves as an anti-oxidant that can inhibit free radical chain reactions in tissue membranes, which in turn inhibits the formation of mutagens. It also plays an important role in the prevention of neuromuscular deficiencies, in maintaining proper blood cell life-spans, and in the prevention of abnormal platelet activities (Waysek, 1993).

Table 2.7. Vitamin content (mg/100g) of cow, sheep, goat and human milk (Alichanidi and Polychroniadou, 1995).

Vitamin	Cow	Sheep	Goat	Human
Vitamin A (retinol)	52	83	44	58
Carotine	21	-	-	24
Vitamin D	0.03	0.18	0.11	0.04
Vitamin E	0.09	0.11	0.03	0.34
Thiamin	40	80	40	20
Riboflavin	0.17	0.32	0.13	0.03
Niacin	0.08	0.41	0.31	0.22
Vitamin B_6	60	80	60	10
Pantothenate	0.35	0.45	0.41	0.25
Vitamin B_{12}	0.4	0.6	0.1	0.01
Folate	6	5	1	5
Biotin	1.9	2.5	3	0.7
Vitamin C	1	5	1	4

2.5. GOAT CHEESE

2.5.1. PRODUCTION

Cheese is the fresh or matured product obtained by the drainage of liquid after the coagulation of milk, cream, butter or a combination thereof (Gordon, 1993). Like cow milk, goat milk also contains fat, protein, lactose, minerals, vitamins, pigments and water. During the cheese making process, these components are divided disproportionately into two phases, liquid whey and the dry matter curd. The curd becomes the cheese while the

whey is further processed to yield different cheeses or it can be used for animal feed or simply discarded (Ricki and Croll, 1993).

The first principle of cheese making is separation of the milk into whey and curd-fractions. Curd can be formed by increasing the acidity of the milk to the point that the milk protein casein can be coagulated and precipitated as a visible solid state. During that process fat is simultaneously taken into the curd. Cheese curd can also be produced by the use of the enzyme rennet, which is able to coagulate the casein (Angela et al., 1993). In actual practice a combination of rennet and added acid or acid produced by starter culture is normally used to form the curd. The second principle of cheese making is the controlled use of bacteria and moulds to produce the desired characteristics of flavour, odor, texture and appearance of the cheese during the ripening period (Ricki and Croll, 1993). The cheese making process may vary among the different cheese types. In general terms, however, cheese making requires the following steps:

a) Preparation of the milk by heat treatment (if it is a pasteurized type)
b) Formation of curd, using acid, enzyme or both
c) Curd cutting
d) Curd cooking
e) Separation of curd from whey
f) Curd processing or working
g) Curd molding or shaping and pressing
h) Curd dressing and waxing
i) Curd ripening or storage time
j) Packaging

By applying certain modifications with respect to time, heat, curd working, molding, changing of the starter culture and other related aspects, the range of produced cheese types can be diverse (Gordon, 1993). Using the common cheese making practice, the curd will contain almost all the original milk fat, about three fourths of the original proteins and about half of the minerals. Virtually all the lactose and the water-soluble

vitamins remain in the whey fraction. The water or moisture content of finished cheese varies with the type of cheese, storage conditions, length of aging period and other factors (Lawrence and Gilles, 1986). Goat milk cheese yield is higher per kilogram when its moisture content is higher. For instance, a hard cheese requires about ten kilograms of goat milk to produce one kilogram of finished cheese product. Soft cheese (wet), on the other hand, requires less than ten kilograms of goat milk to yield one kilogram of cheese (Ricki and Croll, 1993).

2.5.2. STARTER CULTURES

The term 'starter culture' in cheese making refers to the selected microorganisms which are added to milk, cream, or a mixture of milk and cream for initiation and carrying out of the desired fermentation that in turn controls the appearance, body, texture and flavour characteristics of cheese. Besides the primary function of acid production, cheese starters are also responsible for flavour production in cheese (Yadav et al., 1993).

Yadav et al. (1993) classified cheese starter cultures as described below.

2.5.2.1.Classification based on culture function

Depending on their ability of acid production, cheese starter cultures can be lactic or non lactic acid types. The lactic starters are mainly group N-streptococci, *Streptococcus thermophilus* and homofermentative lactobacilli. The non-lactic starters include propionibacteria in Swiss cheese, *Leuconostoc* in Gouda and Dutch cheeses, *Brevibacterium linens* in Brick type cheeses and moulds in certain mould ripened cheeses.

2.5.2.2. Classification based on optimum growth temperature

Depending on their optimum growth temperature, lactic acid producing bacteria (*Lactococcus, Streptococcus, Leuconostoc* and *Lactobacillus*) can be grouped into:

a) Mesophilic starters with optimum growth temperatures at 20 to 30°C. These cultures are commonly used in the production of a wide range of cheese types, for example *Lactococcus lactis* subsp. *lactis, Lactococcus lactis* subsp. *cremoris, Lactococcus lactis* subsp. *diacetylactis* and *Leuconostoc* species.

b) Thermophilic cheese starters with optimum growth temperatures at 37 to 45°C are used for the cooked type cheeses. Some examples are *Streptococcus salivarius* subsp. *thermophilus, Lactobacillus helveticus, Lactobacillus delbrueckii* subsp. *lactis* and *Lactobacillus delbrueckii* subsp. *bulgaricus.*

2.5.2.3. Classification based on starter composition

Usually, a combination of starter cultures is used during production of a cheese type and the combination and proportion of the cultures depends on the type of cheese to be produced. Table 2.8 illustrates the starter culture composition of some types of cheese.

2.5.2.4. Others

Other criteria for selecting starter strains are also based on temperature sensitivity, rate of acid production, potential for better flavour and phage sensitivity (Yadav et al., 1993).

Table 2.8. Cheese types and composition of starter cultures (Cogan and Hill, 1993).

CHEESE TYPE	COMPOSITION OF STARTER CULTURES
Cheddar	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris, Lc. lactis* subsp. *diacetylactis*
Gouda	*Lc.lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris, Lc. lactis* subsp. *diacetylactis, Leuconostoc* spp.
Cottage	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris, Leuconostoc* spp.
Swiss	*S. salivarius* subsp. *thermophilus, Lb. helveticus, Propionibacterium shermanii*
Brick	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris, S. salivarius* subsp. *thermophilus, Brevibacterium linens.*
Mozzarella	*S. salivarius* subsp. *thermophilus* or *S. faecalis* and *Lb. delbrueckii* subsp. *bulgaricus.*
Blue Roquefort	*Lc. lactis* subsp. *lactis, Penicillium roqueforti*
Camembert	*Lc. lactis* subsp. *lactis, Penicillium camemberti*

2.5.3. DETERMINATION OF QUALITY

2.5.3.1. MOISTURE

Moisture content is a very important parameter in controling the yield and quality of cheese. A difference of 1% in moisture content is equivalent to a difference of 1.8% in yield (Emmons, 1993). Moisture and salt contents both must be within a certain range for the production of optimum quality cheese (Lawrence et al., 1984). In cheese, the moisture content is known to vary within blocks, between blocks, within vats, within days and between days (Loikema, 1993).

Based on the moisture content, Fox (1993) categorized cheeses into five different groups namely dried cheese (<40%), grated cheese (40 to 49,9%), hard cheese (50 to 59.9%), soft cheese (60 to 60.9%) and fresh cheese (70 to 82%). In young cheddar cheese, the S/M (amount of salt in moisture) ratio has a great influence on the water activity of the cheese that in turn determines the ratio of microbial growth rate and

enzymatic activities in the cheese. Especially the proteolytic activity of chymosin, plasmin and starter proteinases can be affected (Fox and Walley, 1971; Richardson and Pearce, 1981). If the S/M value is low enough (<4.5), then the number of starter organisms will reach a higher level in the cheese and the chance of off-flavour production due to the starter culture can be increased accordingly (Berhny et al., 1975).

2.5.3.2. FAT/LIPIDS

Fat (lipids) in cheese exists as physically distinct globules dispersed in the aqueous protein matrix (Lawrence and Gilles, 1987). Generally, consumers prefer cheese with a high fat content, due to the fact that high fat content contributes a significant flavour to cheese (Renner, 1993). The typical aroma of some types of cheeses such as Cheddar develops only when the FFDM (% free fat in dry matter) is at least 40 to 50%, since the aroma in a cheese mainly develops due to the breakdown of the fat during the ripening period (Stanton, 1984; Jameson, 1990).

Commercial cheese with a high FFDM usually has a high MNFS (moisture in non-fat substance). In turn, this causes a decrease in firmness of the product (Lawrence and Gilles, 1980). In general, if the fat content in a cheese is increased, the cheese becomes softer. In other words, the volume of the fraction of protein molecules decreases whereas the moisture content increases (Kimber et al., 1974).

Fat or lipids are a group of substances whose members are often physically or chemically unrelated but are classified together because of their solubility in non-polar solvents. This group of naturally occurring compounds are not soluble in water but are soluble in organic solvents such as chloroform, benzene, ether and alcohol. The classification of total lipids refers to the sum of monoglycerides, diglycerides, triglycerides, free fatty acids, phospholipids, glycolipids, terpens, sterols, waxes and other ether soluble compounds (Carpenter et al., 1993).

The lipid fraction of goat milk and cream contains 97.99% free lipids (petroleum ether extractable) and 1 to 3 % bounded lipids (chloroform-methanol extractable). The major lipid fractions of goat's milk fat are shown in Table 2.9 (Juarez and Ramos, 1986). The composition and distribution of lipids in goat milk is similar to that of cow milk except that goat milk fat has almost twice the C_8:0, C_{10}:0 and C_{12}:0 fatty acid content than that of cow milk (Juarez and Ramos, 1986).

Table 2.9. Distribution of lipids in free and bounded fractions of goat milk (Juarez and Ramos, 1986).

Free Lipids (97.99%)	- Glycerides (96.8%)		
	- Diglycerides (2.2%)		
	- Monoglycerides (0.9%)		
Bonded Lipids (1-3%)	- Neutral Lipids (46.8%)-	Triglycerides (56.7%)	
		- Diglycerides	33.3%
		- Cholesterol	
		- Free fatty acids	
		- Monoglycerides (10%)	
	- Glycerides (8.5%)		
	- Phospholipids (44.7%)	- Phosphatidyl ethanolamine (35%)	
		- Phosphatidyl serine(3.25%)	
		- Phosphatidyl inositol (4.0%)	
		- Phosphadidyl choline (28.2%)	
		- Sphingomyelin (28.2%)	

The proportional distribution of fatty acids in milk fat triglycerides of cow and goat milk differs slightly, but the fatty acids are not incorporated randomly in the glycerides in either species. Thus, their triglyceride molecules do not contain more than one butyric group (Dimic, 1965).

The neutral lipid fraction of goat milk has been found to contain minor, but significant components (<1% of the total neutral lipids). Using gas liquid chromatography (GLC) analysis, it was found that goat milk contained the following major fatty acids in the neutral lipid fraction: C_{10}:0, C_{12}:0, C_{14}:0, C_{16}:0, C_{18}:0 and C_{18}:1 (Cerebulis et al., 1984). According to Marai et al. (1969), goat milk fat trigylcerides with a broad range of molecular weight and an even number of acyl carbons are found predominately.

In goat's milk, in proportions similar to that of cow's milk, ISO and anti ISO acids are predominant in the branched chain fatty acids. A range of other monomethyl branched components, mostly with methyl substitutions on carbon 4 and 6 are present in goat's milk fat. However, these are virtually absent in cow's milk (Massart-Leen et al., 1981).

Polar lipids make up approximately 1.6% of the total lipids in goat milk. Of the polar lipid fraction, glycolipids make up 16% in goat milk compared to 6% reported for cow milk (Cerebulis et al., 1984).

2.5.3.2.1. Free fatty acids (FFA) and rancidity

Fatty acids are organic acids composed of hydrocarbon chains with a carboxyl group (-OOH) at one end. These compounds can be short-chain, long-chain, saturated or unsaturated (Atheron and Newlander, 1981; Harmon, 1995). The fatty acid content of cow and goat milk is shown in Table 2.10.

Boros (1985) has also assessed individual fatty acids of goat milk in various lactation periods. Based on the results obtained, he concluded that:

a) Capric acid (C_{10}:0) increased with advancing lactation period.
b) No substantial change was seen in the content of lauric acid (C_{12}:0) throughout the lactation period.

c) Palmitic acid (C_{16}:0) was at its lowest concentration in the spring with a slight increase in summer.

d) Components of stearic acid (C_{18}:0) and oleic acid (C_{18}:1) decreased slightly with advance in lactation.

e) With respect to the unsaturated fatty acid content, minimum amounts of oleic acids were found in the summer season.

Table 2.10. Comparison of the fatty acid content (%) of goat and cow milk (Boros, 1985).

FAT	C_4	C_6	C_8	C_{10}	C_{12}	C_{14}	C_{16}	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Cow	4.21	2.42	2.32	8.45	3.11	2.26	26.6	16.9	24.3	1.34	1.04
Goat	5.04	2.82	1.69	3.57	3.88	14.7	26.4	11.8	21.7	2.34	1.13

Milk contains a very potent lipase which normally never reaches its potential in milk. This indigenous milk lipase causes lipolysis in raw milk cheese and probably makes some contribution in pasteurized milk cheese, especially if the milk is heated at sub-pasteurization temperatures (Olivecrona et al., 1992). A potentially very important source of potent lipase in milk and cheese are psychrotrophic microorganisms which dominate the microflora of refrigerated milk. These lipases can be absorbed on the surface of fat globules and cause cheese spoilage and rancidity (Fox et al., 1993; Harmon, 1995). The problem of rancid flavour will be most apparent in high fat products (Harmon, 1995).

Milk lipase is highly selective for fatty acids on the Sn_3 position. Since the butyric acid in milk fat is esterified at the Sn_3 position, this specificity probably explains the disproportionate concentration of free butyric acid in cheese (Driessen, 1989). Fat found in goat milk, unlike that of the cow, correlates closely to spontaneous lipolysis and can play a major role in flavour impairment even at a low storage temperature (Harding, 1995). It was also found that mainly volatile

fatty acids with short chains up to C_{10}:0 had a prominent flavour and high correlation of lipase activity (Trodaht et al., 1981). Cheese fat from goat milk cheese has a higher content of volatile fatty acids than cheese made from mixed cow and goat milk.

Lipolysis and production of free fatty acids differs in different cheese products. Free fatty acids account for less than 3% of the lypolysis in many bacterially ripened varieties of cheeses (Gouda, Cheddar, Gruyere, etc.), 3 to 10% in mould ripened cheese (Brine and Camembert cheese), 10 to 15% in the internal mould ripened cheeses (Roquefort), 15 to 20% in Blue cheese (Danablu and Cabrales) and over 20% in other lipid rich cheeses (Marcos, 1993).

A high level of free fatty acids may contribute to inhibit the growth of starter cultures which are used in cheese making which in turn affects the quality of a cheese (Harmon, 1995).

2.5.3.3. PROTEIN

Basically, cheese consists of an aggregation of water, fat, protein (mainly casein) in roughly equal amounts by weight plus small amounts of NaCl and lactic acid. Out of these, the protein matrix gives rise to the rigidity of the cheese. Any modification of the nature or amount of the protein present in cheese can modify its texture (Fox et al., 1993).

Factors such as climate, nutrition, stage of lactation, parity, breed, bacterial proteolysis and other related factors can bring differences in protein content. Apparently, it is difficult to determine the influence of each factor becuase other conditions such as sampling and production are involved (De Peters and Cant, 1992).

A common factor in all proteins is the presence of nitrogen (N) in reasonably constant proportions. This can be determined using the Kjeldahl method (Harding, 1995). In cheese, the total protein content can be defined as Kjeldahl N x 6.38. The result

obtained can then be divided into three broad fractions, casein protein N, whey protein N and non-protein N (Cerebulis and Farrell, 1975). The protein content is the raw material for cheese processing and its content determines the cheese yield and quality.

Compared to cow milk, goat milk has much higher non-protein N (8.7% compared to 5.2%) and lower proportions of coagulable proteins (70.9% compared to 73.0%). Quito et al. (1986) found an average value of 34.1% total protein content in a fresh cheese (24 hours old) made from traditionally farmed goat milk. The protein fractions of goat milk seem to be slightly different from those of cow milk (Table 2.11).

Table 2.11. Protein fractions of goat and cow milk (Storry et al., 1983).

PROTEIN	GOAT (%)	COW (%)
Total Casein	2.14-3.18	2.28-3.27
α_S-Casein	0.34-1.12	0.99-1.56
β-Casein	1.15-2.12	0.61-1.41
K-Casein	0.42-0.59	0.27-0.61
Total Whey Protein	0.37-0.70	0.88-1.49
Lactoglobulin	0.18-0.28	0.23-0.49
α-Lactalbumin	0.06-0.11	0.08-0.12
Serum Albumin	0.01-0.11	0.02-0.04

The casein protein content of milk is an essential variable for cheese quality and yield. Therefore, most cheese quality and yield predicting formulas are dependent on milk protein, especially casein protein (Emmons et al., 1990).

Based upon composition, amino acid sequence and genotype, casein proteins are classified into four groups as described below.

2.5.3.3.1. α_{S1}-Casein

The α_{S1} group (99 amino acid residues) is a mixture of α_{S0} and α_{S1}. Rennet cleaves α_{S1} casein during the initial stage of cheese ripening yielding products of higher electrophoretic motility (Grapping et al., 1985). According to DeJong (1978) there are negligible differences in α_{S1} casein breakdown between soft cheese and cheese with low moisture content. Usually the α_{S1} content of goat milk is less than in cow milk (Kehagias, 1986).

2.5.3.3.2. α_{S2}-Casein

The α_{S2} group (207 amino acid residues) consists of five proteins (α_{S2}, α_{S3}, α_{S4}, α_{S5} and α_{S6}). Schmidt (1980) claimed that α_{S2} casein at pH 7.8 can be completely degraded by plasmin with concomitant appearance of faint bands of high electrophoretic mobility and diffused bands in the negative direction. The α_{S2} content of goats is higher than in cows (Kehagias, 1986).

2.5.3.3.3. β-Casein

The β-casein (209 amino acid residues) contains 5-PO_4 residues. Under the action of protease, especially plasmin, it yields three components namely γ_1, γ_2 and γ_3 (Rank et al., 1985). The overall breakdown of β-casein in cheese is affected by the salt concentration. Thomas and Pearce (1981) found that up to 50% of β-casein was degraded after one month of ripening in a zone with a 4% salt concentration, however only 10% was hydrolyzed when 8% salt concentration was reached. Kehagias and Galles (1984) reported that β-casein content of goat milk is slightly higher compared to cow milk.

2.5.3.3.4. K-Casein

According to their glycoside content, K-casein (169 amino acid residues) exists as seven different parts (from K1 to K7) (Snoven and Van Riel, 1979). After the primary action of chymosin, which cleaves the Phe(105)-Met(106) bond, only the hydrophobic fragment (1 to 105) of k-casein called paracapa casein remains in the curd (Rank et al., 1985). Green and Foster (1974) pointed out that paracapa casein migrates toward the cathode in alkaline gel electrophoresis. Unlike all other proteins and peptides in cheese, K-casein is not degraded during cheese ripening (Nath and Ledford, 1973).

Cheese undergoes a series of complex sequential changes during ripening that are caused by proteinases from milk, milk clotting enzymes, lactic starter cultures and other microorganisms that are adventitious or added (Grapping et al., 1985). The rate, extent and nature of proteolysis during cheese ripening as well as the amount and nature of degradation of a product varies according to the enzyme involved, the type of cheese made and the environmental conditions of ripening (Aleandri et al., 1990).

Primary proteolysis in cheese may be defined as those changes in α-, β- and γ-casein peptides and other minor peptides that may be detected by polyacrylamide gel electrophoresis (PAGE). Secondary proteolysis products could include those peptides, proteins and amino acids soluble in the aqueous phase of cheese and are extractable as a water-soluble fraction (Rank et al., 1985). Polyacrylamide gel electrophoresis has remained a very useful technique to study cheese ripening (Grapping et al., 1985).

2.5.3.4. SALT

In the majority of cheese varieties, salt is added and it plays a major role in regulating and controlling cheese quality (Ricki and Croll, 1993).

According to Yadav et al., (1993), salt is used in the production of cheese to:

a.) Control the microbial growth and activity.

b.) Control various enzymatic activities.

c.) Reduce the moisture content and water activity.

d.) Help in the syneresis of the curd resulting in whey expulsion.

e.) Bring about physical change in cheese protein which influences cheese texture, protein solubility and protein conformation.

According to Pearce and Gilles (1979) the lowest percentage of downgraded cheese can be expected in the range of 1.6 to 1.8 % salt. Salt levels of more than 4.9% are necessary to prevent development of a bitter taste in cheese.

Proteolysis in cheese ripening is considerably more extensive in unsalted than in salted cheese. For the same reason, the body of unsalted cheeses is less firm than that of salted cheeses (Schroder et al., 1988). The proteolytic activity of chymosin, pepsin and rennet are stimulated by increasing the NaCl concentration to an optimum of about 6%, whereas αS_1 can be actively hydrolyzed up to 20% NaCl concentration. In contrast, the hydrolysis of β-casein by chymosin and pepsin can be inhibited completely at a concentration of 10% NaCl (Fox and Walley, 1971).

Commercial lactic acid cultures of cheese are stimulated by low levels of NaCl, but are very strongly inhibited above 2.5% NaCl. Thus, the activity of starter and its activity to ferment residual lactose are strongly dependent on the S/M level in the curd (Irvine and Price, 1961).

2.5.3.5. WATER ACTIVITY (A_W)

The essential parameters in relation to the stability of food are temperature, water activity, relative humidity, pH and redox potential (Fox, 1993). According to Van den Berg (1986), water activity is the second most critical parameter in relation to food microbiology. The water activity spectrum ranges between 0 and 1 but microbial

metabolism is restricted to the upper half (from above 0.6 where there is use of full unbounded water, to very near 1 where enough nutrient solutes are available for most of the microorganisms to develop and survive). The minimum water activity value for growth and toxin production is the most relevant parameter for prevention technology and public health protection (Fox, 1993).

In general, water activity of cheese ranges from 0.70 to 1.0, although most cheese varieties have water activities above 0.90. As stated by Fox (1993) cheese manufacture is essentially a dehydration process that may continue over a long ripening period. If milk is concentrated four fold of its original concentration, then its initial water activity (0.995) drops to about 0.990 which is equivalent to the addition of 25g of salt per liter of milk, thus, part of the overall moisture content is bounded to casein as non-solvent water. The loss of solvent water from cheese upon salting is the single most significant process that accounts for the increase in solute concentration and concomitant decrease in water activity in the majority of cheese varieties, particularly in bacterially long ripened hard cheese types (Marcos, 1993).

2.5.3.6. SENSORY EVALUATION

The comparison of the taste qualities of similar food products has become an indispensable tool to food technologists (Basker, 1988). Depending on the cooking temperature used during manufacture and moisture content, fresh rennet cheeses are more or less "rubbery" and are essentially flavourless. Although they may be consumed in this state, this is not usually done. Instead, they are matured (ripened) for periods ranging from about three weeks (e.g. Mozzarella) to two to three years, depending on the moisture content of the cheese and the intensity of flavour desired (Fox et al., 1993). The basic composition and structure of cheeses are determined by the curd manufacturing operations, but it is during ripening that the individual and unique characteristics of each cheese variety develop, as influenced by the composition of the curd and other factors, e.g. the microflora established during manufacture (Bothma, 2000).

There are three primary events that occur during cheese ripening, i.e. glycolsis, proteolysis and lipolysis (Fox et al., 1993). These primary reactions are mainly responsible for the basic texture changes that occur in the cheese curd during ripening and are also largely responsible for the basic flavour of cheese. However, numerous secondary changes occur concomitantly and it is these secondary transformations that are mainly responsible for the finer aspects of cheese flavour and the modification of cheese texture.

McGugan et al., (1979) stated that the secondary proteolytic action of the coagulant influences flavour in three ways:

1. Some rennet-produced peptides are small enough to influence flavour. Unfortunately, some of these peptides are bitter due to excessive proteolysis (too much proteolytic rennet or unsuitable environmental conditions), too much moisture or too little salt.

2. Rennet-produced peptides serve as a substrate for microbial proteinases and peptidases, which produce small peptides and amino acids. These contribute at least to background flavour, and perhaps unfortunately to bitterness if the activity of such enzymes is a chemical mechanism, leading to a range of sapid compounds (amines, acids and NH_3) which are major contributors to characteristic cheese flavour.

3. Alterations in cheese texture appear to influence the release of flavourful and aromatic compounds, arising from proteolysis, lipolysis, glycolysis and secondary metabolic changes of cheese during mastication.

2.6. CONCLUSION

Milk and milk products form a major part of the human diet. In various rural areas of South Africa, indigenous goats are kept for various reasons, but may be seen as an

under-utilized source of good quality food. The products of these goats may even be seen as a way to develop entrepreneurial skills and help the rural people to provide for their families and even the community.

In the first part of the literature survey, a broad overview is given about the history of goats and goats in South Africa. Special mention is made of the breeds, population demographics, milk and milk production figures and consumption of these products. Although only a small amount of people use goat milk and goat milk products, a survey showed that the likelihood of consuming these products increases as soon as the people were given a chance to taste the products (USAID-SA and ARC, 1998b).

The second part of the literature survey focuses on goat milk composition. The chemical composition, with special reference to the nutritional (minerals and vitamins) value, is discussed and compared to cow's milk. The microbial aspects of goat milk are also discussed in this part.

In the last part of the survey, goat cheese is discussed in detail. The production of cheese and the different types of starter cultures are discussed. The quality of cheese may be determined by different parameters such as moisture, lipid fractions, protein fractions, salt content and by sensory evaluation. Each of these parameters is discussed.

CHAPTER 3

MATERIALS AND METHODS

This study was conducted as follows:

- Determination of microbiological, chemical and nutritional quality of indigenous (Mpumalanga and North West Provinces) and Saanen (imported) goat milk.
- Production of a Gouda type cheese of each of the two provinces' goat milk as well as from the Saanen goat milk.
- Determination of the microbiological, chemical, nutritional and sensory quality of the cheeses

The microbiological and chemical analysis of the milk and cheese and the sensory evaluation of the cheeses were performed by the Department of Food Science, Faculty of Natural and Agricultural Science, UFS, Bloemfontein (SA). The nutritional analysis of the milk and manufacturing of the cheese was done at the Irene Animal Nutrition and Products Institute of the Agricultural Research Council, Irene (SA).

3.1. SAMPLING

3.1.1. Participatory technology development and transfer

Although the main objective of this project was concerned with the microbiological, chemical and nutritional analysis of indigenous goat's milk from Mpumalanga and the North West Province as compared to the milk from exotic Saanen goats, to some extent it was also concerned with the participation of the ultimate beneficiaries of the knowledge collected from the study. Before the commercialisation of any product from the rural or small-scale farmer is deemed feasible, the hygiene and quality standards of their produce is often questioned. This study would thus serve to

determine if milk of adequate quality could be produced by small-scale farmers, with limited technology, very basic equipment, and using indigenous goats.

Extension officers of the Mpumalanga and North West Province Departments of Agriculture were approached to assist in the facilitation of participation of small-scale indigenous goat owners in their areas. The objectives of the project were explained to the extension officers and their recommendations regarding the process to be followed was included in the methodology of beneficiary participation. In Mpumalanga, the village of Hogoholle near Marble Hall, which is located about 167m from the Irene campus, was used as a sampling site, and in the North West Province, the rural areas around Brits, specifically Tebets, which is located about 135km from the Irene campus was used.

Goat owners in both of these areas possess between 2 and 15 goats each (Figures 3.1 and 3.2). These goats are not usually milked and are mainly used for traditional purposes or as a means of quick cash flow. In most cases 3 to 5 does were walking with kids. These animals are penned near to the homesteads in the evening and are allowed to free range communally between 11:00 a.m. and 18:00 p.m. every day.

Figure 3.1 Indigenous goats from the Mpumalanga province used in this study.

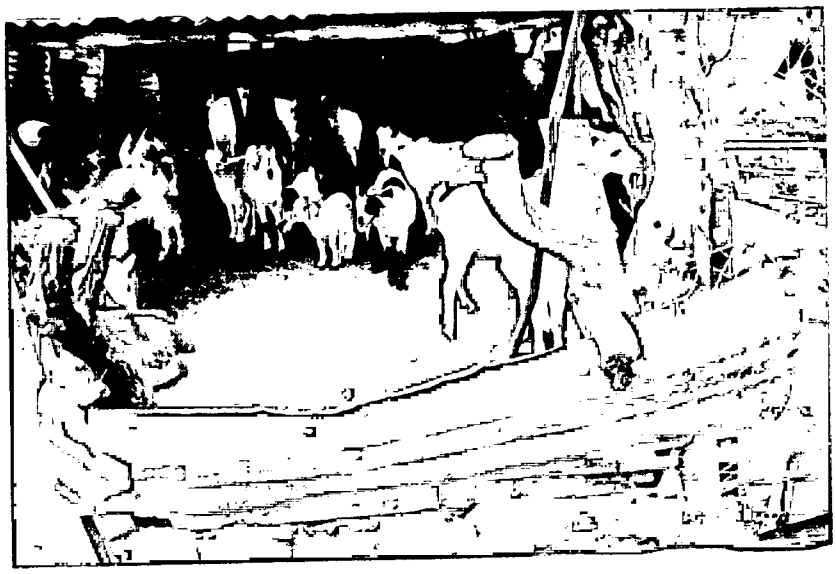

Figure 3.2 Indigenous goats from the North West Province used in this study.

To start the study, small demonstrations were held to explain the potential role of indigenous goats in job-creation and small business development. Goat owners were then allowed free choice to participate in the study. In studies of this nature, it is often the case that samples are collected from the animals of rural owners without the exercise being of any benefit to them. It was thus decided that a technology transfer process should be followed whereby milking skills could be imparted to the goat owners and to leave the sampling process completely in the hands of the goat owners themselves (the aim of the study was to determine the impact of the rural situation on the quality of the milk and cheese product produced therefrom).

Attention had to be given in two areas:

a) The milker. Owners were given an understanding of good hygiene practice. Emphasis was placed on the washing and drying of hands before milking and that minor wounds and skin abrasions should be covered. Also, it was explained that a

regular milking routine should be followed, including udder cleaning and fore milk removal.

b) The animal and environment. In hand milking situations, faecal contamination is common. Thus it was explained that milking should take place away from animal housing. Animals to be milked should be washed and brushed regularly to avoid dirt and hairs falling into the milk. It was shown how udders should be washed with clean water and dried with clean towels. If no towels were available, the udder could be rubbed dry by hand.

Once goat owners had expressed their willingness to participate in the study, a price for their milk was decided on. R 3.50 was paid for each litre of milk collected. This should not be seen as an incentive to participate in the study, but to demonstrate to the small-scale farmers that the milk is a valuable commodity that could be sold.

To improve the collection and storage logistics of the two Provinces, gas was provided to dysfunctional refrigerators in the possession of the extension officers. The milking of the animals were then left up to the farmers themselves, and the collection and storage of the milk was the responsibility of the extension officers. Milk was collected and paid for by staff of the FSRE & SMME Development Programme of the Animal Nutrition and Products Institute of the Agricultural Research Council of Irene on a weekly basis.

During the course of the collection period (which lasted 72 days) several management recommendations had to be made in order for the small-farmers to understand the implications of goat milking. The most important of these was the separation of kids from does the night before milk collection. Under the communal herding system of Mpumalanga and North West Province, this proved rather a difficult exercise. However, several farmers made great pains to assist with the sample collection.

Saanen milk was obtained from a commercial dairy goat farm (Heloma) located 34 km from the Irene campus. The milk from 26 goats was pooled for sample analysis. The goats in this dairy are in excellent condition and produce, on average, 4.5 litres per day. The price paid per litre was R 3.50 (as for the indigenous goat milk).

3.1.2. Milk

All samples were collected and handled according to IDF Standard 50C (1995). All the samples were collected aseptically into sterile containers early in the lactation period (during June and July). The samples were transported and kept at 0–4^{0}C and microbiological and chemical (fat, protein, lactose) analysis were performed within 12 to 24 hours after collection.

For the microbiological and chemical analysis of the milk, six groups (consisting of six to eleven individuals) of indigenous goats were milked by hand in each of the two provinces. Each of the 12 samples contained 250 ml milk. As a control, six samples (250 ml each) were also collected from Saanen goats machine milked at a small commercial dairy.

For the production of cheese, ± 30 litres of milk from each of the three sampling sites were collected over a period of ± 2 months and kept frozen until cheese production.

3.1.3. Cheese

For the microbial and chemical analysis of the cheese, samples were taken from each of the two blocks (duplicate samples) of the three types of cheeses. The rest of the cheeses were again vacuum-packed and stored in the ripening room as described under 3.2 until the next sampling time.

3.2. CHEESE PRODUCTION

The ± 30 litres of goat milk from each of the three groups were processed into Gouda types of cheeses in the following way:

The goat milk was heated to 35°C and a starter culture consisting of *L. lactis* subsp. *lactis* and *L. lactis* subsp. *cremoris* (FRC 60) was added. Commercial calf rennet (Irene Dairy Industry Center) was added in the ratio of 20-25 ml per 100 liters of milk. Then the milk was left to coagulate for 30- 45 min. The curd was cut into small cubes (1 cm) and the whey was drained. The curd was placed in two moulds (14 cm diameter and 10 cm high) and pressed at 1.5 psi / kg of cheese for two hours. Salting was carried out in a brine bath, the cheeses were left to dry-off and then vacuum packed. Ripening was carried out in a controlled atmosphere at a temperature between 11 and 13 °C with a relative humidity between 70 % and 80 % for 60 days.

3.3. MICROBIAL QUALITY

3.3.1. Goat milk

All the goat milk samples were subjected to somatic cell counts (SCC) using a Fossomatic® apparatus (Model 15600).

Ten ml of each milk sample was diluted in 90 ml sterile phosphate buffer solution. Appropriate serial decimal dilutions were made using sterile phosphate solution. Inoculation and incubation was done according to the following procedures:

a) Total bacteria count (TBC) on Standard Plate Count agar (Oxoid CM463) with 0.1% skim milk powder. Plates were incubated for 48 hours at 32°C (IDF Standard 100B: 1991).

b) Coliforms (CC) and *E.coli* count (EC) on Violet Red Bile Agar (VRB) with 4-methyl-umbellifery-B-D-Glucose (MUG) (Oxoid CM107) and plates were incubated for 24 hours at 37°C (Oxoid Manual, 1995).

c) *Staphylococcus aureus* count (SAC) was surface plated on Baird Parker agar (Oxoid CM275) plus egg yolk-tellurite emulsion (Oxoid SR54). Plates were incubated for 24 hours at 37°C (IDF Standard 145A: 1997).

d) Yeasts and Moulds count (YMC) was surface plated on Chloramphenicol agar. Plates were incubated for 5 days at 25°C (IDF Standard 94B: 1990).

e) *Listeria monocytogenes* presence (LMP): A 25ml milk sample was added to 225ml buffered Listeria enrichment broth (Oxoid CM897) plus Listeria selective enrichment supplement (Oxoid SR141) and incubated at 30 °C for 24 hours. Then a loop full of the enriched culture was streaked onto Listeria selective agar (Oxoid CM856) plus Listeria selective supplement (Oxoid SR140). Presence of *Listeria monocytogenes* were checked after incubation at 35 °C for 2 days (IDF Standard 143: 1990).

f) Aerobic spore former count (ASFC): A 20 ml sample was heat treated at 80 °C for 12 min and a serial dilution prepared. Then, 1ml of each of the serial dilutions were inoculated on Standard Plate Count agar (Oxoid CM463) with 0.1% soluble starch. Plates were incubated at 32°C for 48 hours (Frank et al., 1992).

3.3.2. Goat cheese

The microbiological analysis of the three cheeses was done at the following four stages:

1. Immediately after manufacture (one day after manufacture = Day 1)
2. Halfway through ripening (28 days after manufacture)

3. End of ripening (60 days after manufacture)
4. At the end of shelf life (167 days after manufacture)

Ten grams of each cheese sample was blended in 90 ml sterile phosphate buffer solution for one minute (IDF Standard 122B: 1992). The preparation, inoculation and incubation of samples were done according to the following procedures:

a) Lactic acid streptococci and lactococci (LSLC): 1ml of each dilution was plated on M17 agar (Oxoid CM785) and plates were incubated for 48 hours at 32 °C (Oxoid Manual, 1995).

b) Coliform (CC) and *E. coli* count (EC); see microbiological analysis of milk.

c) *Staphylococcus aureus* count (SAC); see microbiological analysis of milk.

d) Yeast and mould count (YMC); see microbiological analysis of milk.

e) *Lactobacilli* count (LBC): 1ml of each dilution was plated on MRS agar (Oxoid CM361). Plates were overlaid with MRS agar and incubated for 24 hours at 32° C (Oxoid Manual, 1995).

3.4. CHEMICAL QUALITY

3.4.1. Goat milk

The fat, protein and lactose contents of each milk sample were determined with a Milkoscan®.

3.4.2. Goat cheese

3.4.2.1 Moisture and total solid contents

Moisture and total solids content of the cheese were determined according to IDF Standard 4A (1982).

3.4.2.2 Ash content

Ash content was determined according to IDF Standard 27 (1964).

3.4.2.3 Water activity

Water activity was determined with a Novasina water activity meter (TH 200 Model).

3.4.2.4 Salt content

Salt content was determined according to IDF Standard 17A (1972).

3.4.2.5 Lipid analysis

3.4.2.5.1 Fat extraction and fat free dry matter

After weighing six grams of each cheese sample into a 250 ml round bottom flask, 45 ml chloroform-methanol (2:1 v/v) was added and the sample was macerated with an ultra-Turrax for 1 min. The sample was refrigerated at 4 °C overnight and filtrated into a fat-separating funnel using Whatman no. 1 filter paper. After all the filtration processes had been done, the non-fat (water) content of the sample was removed by evaporation under vacuum in a rotary evaporator at 60 °C for 20 min. The sample (fat) was transferred into pre-weighed polytop glass containers by washing the flask with 6 x 5 ml diethyl ether. The diethyl ether was then removed by evaporation under a stream of nitrogen on a heating block at 60 °C for 20 min. The filter paper and polytop were dried overnight in a vacuum dry oven at 50 °C. The next morning, the percentage of fat free dry

mater (FFDM) was calculated from the differences of pre-weighed and dried filter paper (Folch et al., 1957).

3.4.2.5.2 Fat content

Fat content was determined according to IDF Standard 5B (1986).

3.4.2.5.3 Free fatty acids

From the extracted fat, a one gram sample was weighed into a 250 ml flask and solvent (mixture of 20 ml methanol [95%], 20 ml diethyl ether and 1 ml phenolphthalein indicator) was added. After thorough mixing, the mixture was titrated with 0.1 N NaOH until a pink colour persisted for 15 seconds. The percentage of FFA (as oleic acid) was calculated as follows:

$$\% \text{ FFA} = \frac{V \times 0.0282 \times 100}{W}$$

Where: V = ml of 0.1 N NaOH, W = weight of sample taken and the number 0.0282 taken as the correction factor.

3.4.2.5.4 TBA value (rancidity)

Thiobarbituric acid reactive substances (TBARS) were determined according to the method of Raharjo (1992). Five grams of the cheese sample was dissolved in 20 ml of 5% TCA (Trichloroacetic acid)), macerated with an ultra-turrax for 1 min. and centrifuged at 10000g for 5 min at 4 °C. The sample was filtrated into a 25 ml volumetric flask and 55 ml TCA was added to fill it up to the mark. Four milliliters of TBA (2-Thiobarbituric acid) was added to a 4 ml sample and mixed thoroughly with a vortex. The sample was heated in a waterbath at 94±1°C for 5 min and cooled down to room temperature. The sample was then measured at 532 nm after zeroing the

spectrophotometer against the blank. The final concentration of the sample was read from the standard curve calculated as follows:

$$\text{mg malonaldehyde/ 1000g of cheese} = \frac{\text{concentration (Um) x MW x end volume x 100}}{\text{Sample mass (g) x 1000 x R}}$$

Where: concentration (Um) = read from standard curve

MW = – 72.063 (molecular weight of malonaldehyde)

R = Average recovery percentage of all standards after reading the value from the standard curve.

$$\text{End volume} = \frac{\text{Mass (g) x \% moisture + 20}}{100}$$

3.4.2.5.5 Fatty acid composition

Following the extraction and methylation procedures, fatty acids were quantified using a Varian GX 3400 flame ionization gas chromatographer, with a fused silica capillary column (Chrompack CPSIL 88, 100 m length, 0.25 μm ID, 0.2 μm film thickness). The column temperature was 40-230 °C (hold 2 min; 4 °C/ min; hold 10 min). Fatty acid methyl esters in hexane (1μl) were injected into the column using a Varian 8200 CX auto-sampler with a split ratio of 100: 1. The injection port and detector were both maintained at 250° C. Hydrogen was used as the carrier gas at 45 psi and nitrogen was the makeup gas. Chromatograms were recorded with Varian Star Chromatography software. Identification of sample fatty acids was made by comparing the relative retention time of fatty acid methyl ester peaks from samples with those of standards obtained from Sigma (Sigma 189-19).

3.4.2.6 Protein analysis

3.4.2.6.1 ***Protein content***

The protein content was determined according to IDF Standard 25 (1964).

3.4.2.6.2 ***Proteolysis of the cheese***

Samples for electrophoresis were prepared as described by Shalabi and Fox (1987). The samples were dispersed in sample buffer (pH 7.6; Shalabi and Fox, 1987) and aliquots of 5-20 µl were used for alkaline urea–polyacrylamide gel electrophoresis. The gels consisted of resolving gel (12.5% T and 4% C, pH 8.8) and stacking gel (12.5% T and 4 % C, pH 8.4) according to Andrews (1983).

Electrophoresis was done on a Mighty Small miniature slab gel electrophoresis unit (SE 260; Hoefer Scientific Instruments) using a power supply (Model PS 500X DC, Hoefer Scientific Instruments) set at 210 volts (constant) for two gels running simultaneously.

Staining of the peptide bands was done according to Blakesley and Boezi (1977) with Coomassie Blue G250 (Fluka) as staining medium. No destaining was necessary and the gels were stored in distilled water where the protein bands became more intense. The electrophoretograms were photographed.

3.5 NUTRITIONAL ANALYSIS OF GOAT MILK AND CHEESE

The nutritional value (minerals [sodium, potassium, magnesium, calcium, fluorine, chloride, nitrate, phosphorus and sulphate], vitamin A and vitamin E) of all the milk and ripened cheese samples were determined by the ARC-Irene Analytical Services.

3.6. SENSORY EVALUATION OF CHEESE

One hundred and thirty panelists (16 to 85 years of age) were recruited from the Mpumalanga and North West provinces (75 females and 55 males) to sensorily evaluate the three ripened goat milk cheeses (North West, Mpumalanga and Saanen). Evaluation was performed at room temperature using the Smiley Face scale, in combination with preference ranking (Basker, 1988).

The cheeses were cut into cubes of 10 mm x 10 mm and presented on white paper plates for evaluation. Samples were coded using three digit numbers picked from a table of random numbers. Panelists assigned ranks by using separate Smiley Face scales for each sample and were allowed to choose a specific facial expression only once. For result interpretation, the following ranks were allocated to the different facial expressions: Like a lot/ like a little = 1; neither like nor dislike = 2; dislike a little/ dislike a lot = 3. Tap water at room temperature was provided for rinsing between samples during taste sessions.

3.7. STATISTICAL ANALSIS

Statistical analysis was performed on the microbial and chemical quality of the milk and on the lipid quality of the cheese, since these were the critical areas in this study. Differences in parameters between different groups of samples were determined using a one-way analysis of variance (ANOVA) procedure (NCSS, 2000). The Newman-Keuls multiple comparison test (α = 0.05) was used to identify differences between treatment means.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. GOAT MILK

4.1.1 MICROBIAL QUALITY

The presence of pathogens, somatic cell count, saprophytic and spoilage organisms, microbial toxins and sensory properties are all important aspects that should be well analyzed when studying the microbiological and hygienic quality of raw milk (Gonzalo, 1995).

The microbial quality of milk generally depends on a variety of factors. In rural areas, however, a number of other factors may also play a role which can have an effect on the microbial load of the goat milk. The factors are: relatively small flocks, low yield per animal, rudimentary shelters, poor milking facilities, primitive goat rearing style, poor water supply, dirty teats and udders, hand milking and consequently longer milking times (Emaldi, 1995).

In this study, milk was sampled in two rural areas (Mpumalanga and North West provinces) from the goats owned by rural people who had been trained how to milk goats in an hygienic manner. Saanen goat milk was obtained from a dairy where commercial hygienic principles applied. The microbial quality of these milk samples will now be discussed under spoilage parameters and the pathogenic content of the milk.

4.1.1.1 SPOILAGE PARAMETERS

The growth of microorganisms in milk affects the quality of milk and milk products by bringing about milk spoilage. The rate at which the milk spoilage occurs depends upon not only the initial microbial load, but also on conditions under which milk is stored and the length of time that it is stored (Yadav et al., 1993).

The microbial counts of hand-milked indigenous goat milk of two provinces, Mpumalanga and North West, were compared with machine-milked Saanen goat milk and are depicted in Table 4.1.

Table 4.1. Microbial counts (log10 cfu/ml) and somatic cell counts (x1000) of Mpumalanga (M) and North West (N) indigenous raw goat milk compared to Saanen (S) raw goat milk.

Sample	TBC	ASFC	CC	YMC	SCC
M	3.28±0.77[a]	ND	1.12±0.95	2.07±1.13	560.5±60.77
N	3.75±0.33[a]	0.36±0.89	0.69±0.51	2.06±0.36	732.7±91.33
S	5.65±0.12[b]	ND	1.64±0.14	1.87±0.08	1231.3±31.80

Different superscripts in the same column differ significantly ($p < 0.05$).

M= Mpumalanga indigenous goat raw milk

N= North West indigenous goat raw milk

S= Saanen goat raw milk

TBC = Total aerobic bacterial count

ASFC = Aerobic spore former count

CC = Coliform count

YMC = Yeast and mould count

SCC = Somatic cell counts

ND = Not detected

According to Yadav et al. (1993), very good quality milk will have a total bacteria count of less than 5.30 log10 cfu/ml. The two indigenous goat milk samples (Mpumalanga, 3.28 log10 cfu/ml and North West 3.75 log 10 cfu/ml) both fell within this limit (Table 4.1) and did not differ significantly from each other. The TBC of the Saanen goat milk (5.65 log 10 cfu/ml) fell just outside this limit, but could still be regarded as fairly good (Yadav et al., 1993). The TBC of the Saanen milk differed significantly from the two indigenous goat milks (Table 4.1). The reason for the higher count in the Saanen milk could be ascribed to the fact that the Saanen goats were milked by a machine, while the indigenous goats were hand milked. The milking machine may contribute to higher microbial loads.

Aerobic spore formers were absent in the Mpumalanga and Saanen goat milk (Table 4.1), but a very small amount (0.36 log 10 cfu/ml) was present in the North West indigenous goat milk. There were no significant differences between the samples (Table 4.1). The presence of aerobic spore formers, especially the species of *Bacillus*, is of great importance in the production of milk products (Varnam and Sutherland, 1994). These organisms can survive pasteurization and heating conditions during processing of milk and can multiply and produce sweet curdling (Yadav et al., 1993).

The term coliform bacteria in milk denotes the aerobic and facultative anaerobic gram negative, non-spore forming, rod shaped bacteria which ferment milk sugar (lactose) into acid and gas at 32 °C within 48 hours. The typical genera included under this group are *Escherichia, Enterobacter* (*Aerobacter*) and *Klebsiella,* although some lactose-fermenting species of other genera may also be included. The presence or absence of this group of organisms is indicative of the hygienic quality of the milk (Yadav et al., 1993).

In this study, the highest amount of coliforms were found in the Saanen milk (1.64 log 10 cfu/ml), followed by the Mpumalanga milk (1.12 log 10 cfu/ml) and lastly the North West goat milk (0.69 log 10 cfu/ml) with no significant differences (Table 4.1). According to Tirard-Collet et al. (1991) the upper limit for good quality raw goat milk is

3 log 10 cfu/ml. Not one of the goat milks in this study reached this value which is representative of good quality milk.

The count of yeast and mould colonies ranged (in a decreasing order) from 2.07 log 10 cfu /ml (Mpumalanga), 2.06 log 10 cfu/ml (North West) to 1.87 log 10 cfu/ml (Saanen) (Table 4.1). No significant differences between the samples were found. The reason for the lower YMC in the Saanen milk could again be attributed to the enclosed milking system used where there was minimal contact to air and dust which are the major sources of yeasts and moulds. The yeast and mould count of the milk in this study was, however, much lower than those reported by Barbosa and Miranda (1986) who conducted a similar study on goat milk.

Somatic cell count in milk is widely used to evaluate the status of intra-mammary infection in dairy animals, and provides information for a mastitis control program (Krzyezewiski et al., 1995). The somatic cell count threshold, which provides a reliable discrimination between infected and non-infected ewe and goat species suggested by several reporters, ranges between 200 and 400 x 10^3 (Reneus, 1986; Cruz et al., 1994; Gonzalo, 1995). It does, however, not mean that an animal with a SCC of 400 x 10^3 SCC/ml definitely has mastitis, but the probability increases as this value remains high over period of sampling or as the magnitude of a single cell increases (Reneus, 1986). Zeng and Escobar (1995) also suggested that elevated somatic cell count in goat milk might not affect cheese yield at a significant level, as long as the milk does not come from mastitic udders.

The most common agents causing mastitis are classified as minor (coagulase-negative staphylococci, micrococci and corynebacteria) and major (coagulase-positive staphylococci (especially, *Staphylococcus aureus*), streptococci, enterobacteria, *Pseudomonas* and mycoplasmas) pathogens according to the degree of damage they produce in the mammary gland (Gonzalo, 1995).

The somatic cell count (SCC) of the Mpumalanga, North West and Saanen goat milk are shown in Table 4.1. No significant differences were found. All the milk samples had higher SCC than the upper limit of 400 x 10^3 SCC/ml. An explanation for these high counts may lie in the following facts: goat milk has higher SCC than cow milk, because goat milk contains larger numbers of epithelial cells, and these cells are counted as somatic cells (Park and Humphey, 1986). Therefore, the number of leukocytes has to be counted specifically if goat milk is tested for mastitis conditions, because, relatively low leukocytes are actually present in goat milk with high somatic cell count (Sheldrakeet et al., 1981). In addition to the high concentration of epithelial cells, goat milk also contains considerable numbers of cytoplasmic particles which are similar in size to milk leukocytes (Dulin et al., 1982).

Despite the above mentioned common constraints which are encountered in most goat production areas, the overall microbial quality of the milk was very good and acceptable for human consumption and cheese production.

4.1.1.2 PATHOGENIC ORGANISMS

Before the widespread use of pasteurization in the 1930's, milk products were a major vehicle for transmission of human diseases such as thyphoid fever, diphtheria, septic sore throat, tuberculosis and brucellosis. However, after the enforcement of the pasteurized milk ordinance, the number of such outbreaks that were associated with dairy products, declined dramatically (Flower et al., 1992).

The pathogenic content of Mpumalanga, North West Province and Saanen raw goat milk, are given in Table 4.2.

The teat duct, especially the region adjacent to the orifice, can be colonized by organisms such as *Staphylococcus aureus,* which can persist for many weeks, shedding constantly into the outgoing milk (Varnam and Sutherland, 1994). *Staphylococcus aureus* is a gram–positive bacterium that produces a heat stable enterotoxin that, when ingested,

causes nausea, vomiting and diarrhea. Although pasteurization is capable of destroying *S. aureus*, preformed enterotoxin will not be destroyed by this process (Flower et al., 1992). According to the microbiological standard suggested by Yadav et al. (1993), the upper threshold for consumption in liquid raw milk is < 2.0 log 10 cfu/ml.

All three the milk samples in this study had lower amounts of *S. aureus* than the upper threshold suggested by Yadav et al. (1993), with North West Province the highest (1.05 log 10 cfu/ml), followed by Saanen milk (0.99 log 10 cfu/ml) and the lowest levels found in the Mpumalanga milk (0.4 log 10 cfu/ml) (Table 4.2). No significant differences were present. The low counts suggested that good hygienic practices were followed.

Table 4.2. Mean values and standard deviations of pathogenic microorganisms of raw goat milk from Mpumalanga (M), North West (N) and Saanen (S).

Sample	SAC	EC	LMP	BART
M	0.4±0.72	ND	ND	ND
N	1.05±0.96	0.13±0.22	ND	ND
S	0.99±0.11	0.65±0.10	ND	ND

Different superscripts in the same column differ significantly.

SAC = *Staphylococcus aureus* count

EC = *Escherichia coli* count

LMP = *Listeria monocytogenes* presence

BART = *Brucella abortus* ring test

Escherichia coli was not present in the Mpumalanga milk, but low amounts were found in the North West (0.13 log 10 cfu/ml) and Saanen (0.65 log 10 cfu/ml) milk. These values were, however, lower than the 2.0 log 10 cfu/ml cut off point for raw goat milk suggested by Tirard-Collet et al. (1991) and did not differ significantly from each other. The milk had, therefore, a very good hygienic quality.

The presence of *E.coli* in raw milk is not an indication of direct faecal contamination (unlike than in the case of water supplies) as they may also come from other sources like improper cleaning/sanitizing of milking equipment (moisture and milk residues allow the rapid building up of coliforms by multiplication) (Yadav, et al., 1993).

As indicated in Table 4.2, no *L. monocytogenes* were present in the goat milk of Mpumalanga, North West or Saanen. *Listeria monocytogenes* is ubiquitous in nature (present in feces of animals, in raw milk and leafy vegetables) (Flower et al., 1992). The ingestion of *L. monocytogenes* through milk and milk products may cause a disease called listeriosis, which may be lethal (Flower et al., 1992; Yadav et al., 1993).

As illustrated in Table 4.2, *Brucella* was not detected in any one of the goat milk samples. *Brucella abortus* is one of the most important species of the *Brucella* genus which are pathogenic for various species of animals and man (Yadav et al., 1993). This organism is the causative agent of undulant fever. Infection includes a bacteremic phase followed by localization in the reproductive and reticuloendothelial systems (Flower et al., 1992). It can localize in the uteri of pregnant females and in the mammary glands of lactating females, enabling the organism to be shed into the milk for many years. In the USA, during 1971 through 1978, approximately 10% of brucellosis cases were attributable to consumption of milk and dairy products and foreign raw milk goat cheese was often implicated as a vehicle for infection in these outbreaks. *Brucella abortus* display resistance to environmental stress, including freezing, and can survive in frozen products for several years (Flower et al., 1992).

In conclusion it can be said that the microbiological quality of the raw milk of the two hand-milked indigenous goat milk samples (Mpumalanga and North West) was very good. The quality of the machine-milked Saanen goat milk was slightly lower than the two hand-milked indigenous goat milk groups, but still of a good standard.

4.1.2. CHEMICAL QUALITY

Since the purpose of milk secretion is to feed the neonatal, its composition reflects the particular nutritional needs of the young, the natural habitat and nursing habit of the species. Consequently, composition of the milk of various species and even within the same species differs slightly qualitatively and quantitatively. Although all milk contains the same major constituents (i.e. water, protein, fat, lactose and minerals), the composition of milk within any particular breed of each species of animal differs from day to day depending on various factors such as: feed, breed, stage of lactation, age, health of the animal, climatic conditions and milking intervals (Haenlein, 1996). In turn, the composition of milk determines its nutritive value and its suitability as a raw material for the making of dairy and other products. Therefore, these parameters determine the acceptability and preference of products by consumers (Haenlein, 1996).

The fat, protein and lactose contents of Mpumalanga, North West Province and Saanen goat milk are compared in Table 4.3.

Table 4.3. Mean values and standard deviations of the fat, protein and lactose contents of Mpumalanga (M), North West (N) and Saanen raw goat milk.

Sample	Fat (%)	Protein (%)	Lactose (%)
Mpumalanga	4.96±1.90	4.23±0.34^{b}	4.91±0.17^{b}
North West	4.95±2.08	4.18±0.09^{b}	5.00±0.30^{b}
Saanen	3.14±0.10	2.75±0.01^{a}	4.20±0.01^{a}

Different superscripts in the same column differ significantly ($p < 0.05$).

The fat content of the two indigenous goat milks was higher than the Saanen milk (about 4.95 % for Mpumalanga and North West versus 3.14% for Saanen milk) but it did not differ significantly. According to McCance and Widdowsons (1992) the average fat standard for goat milk is 3.5%. The indigenous goat milk is therefore, higher, and the Saanen milk, lower, than this value. The main factors that are responsible for this variation, could be as a result of differences in feed, breed, climate, stage of lactation and health state.

McCance and Widdowsons (1992) reported that, on average, goat milk contains about 3.1% protein. The indigenous goat milk again had higher values (4.23% for Mpumalanga and 4.18% for North West), while the Saanen milk was lower 2.75% than this standard. The protein content of the two indigenous goat milks did not differ significantly from each other, but did differ significantly from the Saanen milk (Table 4.3).

Lactose is the major solid constituent of milk. In general, the concentration varies between 4.2 and 5.0%. The lactose content usually is the lowest in late lactation milk or in milk from animals suffering from udder diseases (Varnam and Sutherland, 1994). McCance and Widdowsons (1992) reported that 4.4% is an ideal value to be considered as an average of lactose content for goat milk. The lactose content of the two indigenous goat milks was slightly higher (4.91% for Mpumalanga and 5.0% for North West Province goat milk) (Table 4.3). The Saanen milk had a lactose content of 4.20%, which is slightly lower than the standard. No significant differences were present between the two indigenous goat milks, but the lactose content of the Saanen milk differed significantly from the indigenous milk (Table 4.3).

In general, the fat, protein and lactose content of the two indigenous goat milks did not differ significantly from each other. These values were also higher than the Saanen milk, which differed significantly from the indigenous goat milk. The reason for these differences can be ascribed to several factors such as breed, age, health status and nutrition (Jenness, 1980).

4.1.3 NUTRITIONAL QUALITY

In order to sell goat milk and milk products for human consumption, it is of considerable market advantage to know the factors that cause milk consumption to vary and to what extent. The information will be even more important in the future, when it becomes better known how to change milk composition by manipulating, for example, the feeding of goats in order to satisfy the needs of diet conscious and disease afflicted consumers and their children (Haenlein, 1996).

The mineral and fat-soluble vitamin composition of Mpumalanga, North West Province and Saanen goat milk are given in Table 4.4.

Table 4.4. Mineral (mg/100g) and fat-soluble vitamin (μg/100mg) content of Mpumalanga, North West and Saanen raw goat milk.

Minerals and Vitamins	Mpumalanga	North West	Saanen	Standard*
Sodium (Na)	37.75	37.85	39.25	42
Potassium (K)	148.75	168.2	197.45	170
Magnesium (Mg)	15.37	12.75	14.35	13
Calcium (Ca)	149.05	155.3	112.3	100
Chloride (Cl)	126.7	142.55	159.7	150
Phosphorus (P)	392.6	299.85	267.75	90
Nitrate (NO_3)	7.5	7.85	6.1	-
Sulphur (S)	35.85	26.15	16.7	-
Vitamin A	33	25	34	44
Vitamin E	56	65	128	30

*McCance and Widdowsons (1992).

The mineral content of goat milk has been reported by many researchers (Haenlein, 1980; Akinsoyinu, 1981; Storry et al., 1983). In this study, the sodium concentration of all three milk samples was lower than the standard given although the Saanen milk had a slightly higher value than the indigenous milk (Table 4.4). The potassium concentration of the two indigenous goat milk differed from each other, but were still lower than the standard, while the Saanen milk was much higher than the standard (Table 4.4). The magnesium content of the goat milks in this study was in the same order and corresponded well with literature (Table 4.4).

Milk is one of the main sources of calcium and phosphorus, which are the crucial elements for the body to function properly (Jenness, 1980). The calcium content was much higher for the two indigenous goat milks than the standard, while the Saanen milk had a value slightly higher than the standard (Table 4.4). The phosphorous concentration of all three goat milks were three to four times higher than the standard given, with Mpumalanga milk the highest and Saanen milk with the lowest concentration (Table 4.4). The indigenous goat milk, therefore, seems to be of a very high quality concerning these two minerals.

Except for the Mpumalanga milk, which had a low chloride content, North West and Saanen milks had chloride concentrations in the same order as the standard (Table 4.4). The nitrate content of the two indigenous goat milks (Mpumalanga and North West) were nearly the same while the Saanen milk had a slightly lower content. The sulphur concentration varied much between the three goat milks with Mpumalanga having the highest and Saanen the lowest concentration. No standard values for these two minerals could be obtained from the literature (Table 4.4).

Goat milk contains adequate amounts of vitamin A for human infants (Jenness, 1980). The vitamin A content of the three goat milks in this study were, however, lower than the standard with North West having the lowest content (Table 4.4). Vitamin E content of the Saanen milk was much higher (128 μg/100 mg) than the standard (30 μg/100 mg). The two indigenous goat milks also had higher vitamin E contents than the

standard but not as high as the Saanen milk (Table 4.4). These large concentrations of vitamin E are an advantage since vitamin E is a good antioxidant and may help in preventing breakdown of fat and thus rancidity in the product.

The differences in mineral and vitamin content can be ascribed to one or a combination of factors, such as breed, nutrition, stage of lactation, season and climate variation (Juarez and Ramos, 1986).

4.2. GOAT CHEESE

A good manufactured cheese should have a smooth, homogeneous structure, a uniform colour and be free from excessive openings due to the formation of gases. Various factors can cause physico-chemical or microbial defects. The most important factors are: the use of poor quality or contaminated milk, poor protein and fat content, improper protein/fat ratio, incorrect pH value and moisture content, inadequate processing (e.g. unsuitable time-temperature regiments, inadequate agitation, improper cooling) or unsuitable storage. The first step, therefore, towards producing good quality cheese, is to monitor all these factors (Caric and Kalab, 1987).

Three primary events occur during cheese ripening namely glycolysis, proteolysis and lipolysis. These primary reactions are mainly responsible for the basic texture changes that occur in cheese curd during ripening and are also largely responsible for the basic flavour of the cheese (Fox et al., 1993). The rate, extent and the nature of protein and fat degradation during cheese aging has been extensively reviewed by Fox (1989).

4.2.1 CHEESE PRODUCTION

About 30 litres of the goat milk from Mpumalanga (M), 30 litres from North West Province (N) and 40 litres of Saanen milk were used to produce a Gouda type of cheese as described in Chapter 3.

The North West goat milk, when defrosted, had a higher titratable acidity value (0.27) than the upper limit for normal milk (0.18). The reason was that the milk was kept at 15°C for about 32 hours whereas the other two milks were kept at 5°C after milking. During cheese processing, however, the acidity of the curd was normalized.

The yields of these three cheeses on the day after processing were 3.68 kg for Mpumalanga, 3.30 kg for North West Province and 3.24 kg for the Saanen cheese (Fig. 4.1). In whole milk cheese, such as Cheddar and Gouda, the sum of the protein and fat content is the principle factor affecting the yield (Varnam and Sutherland, 1994).

The Saanen cheese was slightly whiter and softer than the two indigenous cheeses (Fig. 4.1). The reason for the higher yields, texture and colour differences of the indigenous goat milk will be explained by the results of the chemical analysis (Section 4.2.3). The North West Province cheese were slightly harder than the Mpumalanga cheese because of the higher acidity level during processing which brought about a higher whey expulsion and thus a drier cheese.

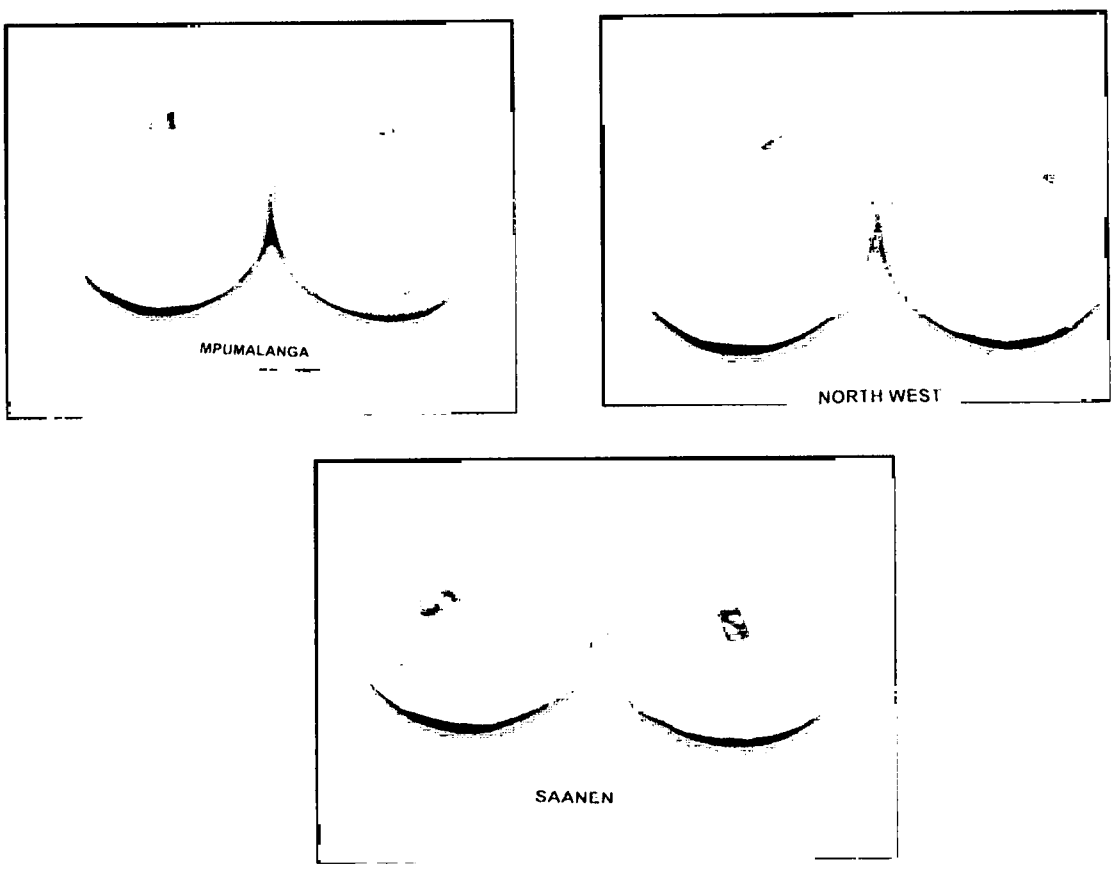

Figure 4.1. Cheeses produced from Mpumalanga and North West indigenous goat milk and Saanen goat milk.

4.2.2. MICROBIAL QUALITY

The results of the microbial analysis of the Mpumalanga, North West and Saanen cheeses directly after processing and during ripening, are depicted in Table 4.5.

Table 4.5. Average value of duplicate samples of the microbial count (log10 cfu/g) performed on Day one, middle-ripening (28 days), ripened (60 days) and at the end of shelf life (167 days) of the Mpumalanga (M), North West (N) and Saanen (S) cheeses.

	Day one			**Mid of ripening**			**Ripened**			**End of shelf life**		
	M	**N**	**S**	**M**	**N**	**S**	**M**	**N**	**S**	**M**	**N**	**S**
LBC	8.83	8.71	8.77	7.98	7.43	8.49	7.49	6.72	7.92	5.44	6.11	7.21
LSLC	8.93	8.59	8.97	7.83	7.65	8.69	7.54	6.92	7.93	4.83	5.69	6.94
SAC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
EC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
YMC	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.15	1.97	2.45

LBC = Lactobacilli count

LSLC = Lactic acid streptococci and lactococci count

SAC = *Staphylococcus aureus* count

CC = Coliform count

EC = *E. coli* count

YMC = Yeast and mould count

ND = Not detected

The high lactobacilli (LBC) and lactic acid streptococci and lactococci counts (LSLC) for all three the cheeses at Day one (Table 4.5) were as expected because these organisms are added as starter culture organisms. The LBC and the LSLC of all three the cheeses declined during the ripening period as the conditions became more unfavourable (food resources declining, atmosphere, etc.). The LBC and LSLC of the Mpumalanga

cheese were, however, the highest at Day one (8.83 log10 cfu/g and 8.93 log10 cfu/g respectively) but declined the quickest and gave the lowest values of all three the cheeses at the end of shelf life (5.44 log10 cfu/g and 4.83 log10 cfu/g respectively). The North West cheese had the lowest LBC and LSLC (8.71 and 8.59 log10 cfu/g respectively) at Day one. The Saanen cheese gave intermediate values between Mpumalanga and North West from Day one until the end of shelf life (Table 4.5).

No yeasts and moulds were detected during the ripening period of all three the cheeses (Table 4.5). At the end of shelf life, however, yeasts and moulds were detected in all three the cheeses. This was, however, not a problem, since the cheeses were already past its shelf life and would not pose a problem to consumers when consumed before the shelf life expires. According to Varnam and Sutherland (1994), moulds are a sporadic problem caused by growth (possibly in association with yeasts) in folds and wrinkles of plastic packaging. The amount of colonies in all three the cheeses were, nevertheless, not a high risk for toxin production because only 20 % of the common spoilage moulds (*Penicillium* and *Aspergillus*), at much higher concentrations, can potentially produce toxic metabolites (Varnam and Sutherland, 1994).

Although small numbers of coliforms, *E. coli* and *S. aureus* were present in the goat milk (Tables 4.1 and 4.2), these organisms did not survive the pasteurization process and were not detected from Day one until the end of shelf life of all three the cheeses (Table 4.5). This is a good indication of the good hygienic quality of these cheeses and that no post-pasteurization contamination took place. The overall hygienic quality of the cheese making process depends on the presence of microorganisms in the milk, curd and the cheese itself. The bacteriological quality of goat milk is the most variable factor in a dairy industry and the most critical point in a modern hygienic dairy quality chain (Emaldi, 1995).

In cheese and fermented milk products, lactic acid fermentation, salt concentration and moisture content have an inhibitory effect on pathogenic bacteria and food poisoning microorganisms (Morris and Tatini, 1986; Emaldi, 1995). Lactic acid has

a natural tendency to accumulate in milk and curd, thus enhancing the stability and safety of cheese (Emaldi, 1995). Although cheese is generally considered to be a low-risk food, both hard and soft cheese types have been associated with significant outbreaks of food-borne diseases (Varnam and Sutherland, 1994). The presence of *Listeria monocytogenes* in the three cheeses was not tested since these organisms were not present in the goat milk. According to Varnam and Sutherland (1994), *Listeria monocytogenes* and some types of *Escherichia coli* can, however, grow in some soft cheeses, but not in semi-hard or hard varieties. The use of unpasteurized milk, insufficient growth of starter microorganisms and post-production contamination are the major risk factors in cheese production (Varnam and Sutherland, 1994). The bacteriological results of this study indicate, however, that good manufacturing practices were applied and that there was sufficient growth of the starter organisms.

4.2.3 CHEMICAL QUALITY

The chemical composition of the milk affects the nature of the final cheese (Varnam and Sutherland, 1994). The results of the chemical analysis will now be discussed in detail.

4.2.3.1 MOISTURE CONTENT

The majority of ripened cheeses are categorized as hard with a moisture content of 30-40%, semi-hard with a moisture content of 40-50% and soft with a moisture content of 50-75% (Park, 1990). According to this categorization, all three the ripened cheeses in this study fell in the hard cheese group (Fig. 4.2).

Based on moisture content, Fox (1993), however, classified cheese into five groups, namely: dry cheese (<40%), grated cheese (40-49.9%), hard-cheese (50-59.9%),

soft cheese (60-69.9%) and fresh cheese (70-82%). According to this classification, all three the goat milk cheeses will fall in the dry class.

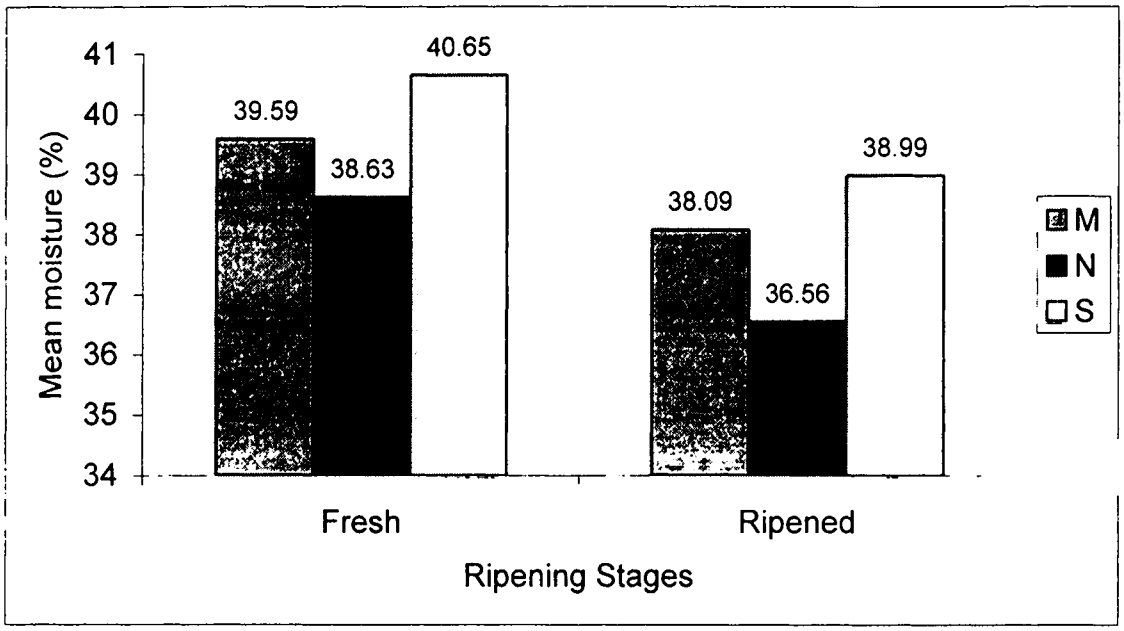

Figure 4.2. Moisture content (%) of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

The vast majority of goat cheese is usually of the soft type and almost all goat cheese types are of the natural drainage type associated with slow coagulation, which apparently leaves more moisture within the product (LeJaouen, 1981). The cheeses in this study were, however, of the Gouda type, explaining the reason for the lower amount of moisture.

In both sampling stages (fresh and ripened), the moisture content was the highest for the Saanen cheese followed by the Mpumalanga cheese and then the North West cheese (Fig. 4.2).

The moisture content of all three cheeses decreased during the ripening period as moisture was lost to the atmosphere (Fig. 4.2). In other words, the mean percentage of

total solids increased as the moisture content decreased (Figures 4.2 and 4.3). Khatoon et al. (1990) also observed a similar trend of decrease of moisture percentage with increase of the total solid content in a goat cheese in which the moisture content decreased from 38.5 % to 35.0% within six months of the ripening period.

4.2.3.2 TOTAL SOLIDS CONTENT

The mean values of the total solids content of the three cheeses are shown in Figure 4.3. As maturation of the cheese took place, the total solids content increased as the moisture content decreased. The extent and trend of increase were similar to that reported by Carballo et al. (1994). The Saanen cheese had the lowest amount of total solids because of its higher moisture content (Fig. 4.2) while the North West cheese had the highest amount of total solids because of the lower moisture content (Fig. 4.2). The Mpumalanga cheese gave intermediate values between Saanen and North West cheeses (Fig. 4.3).

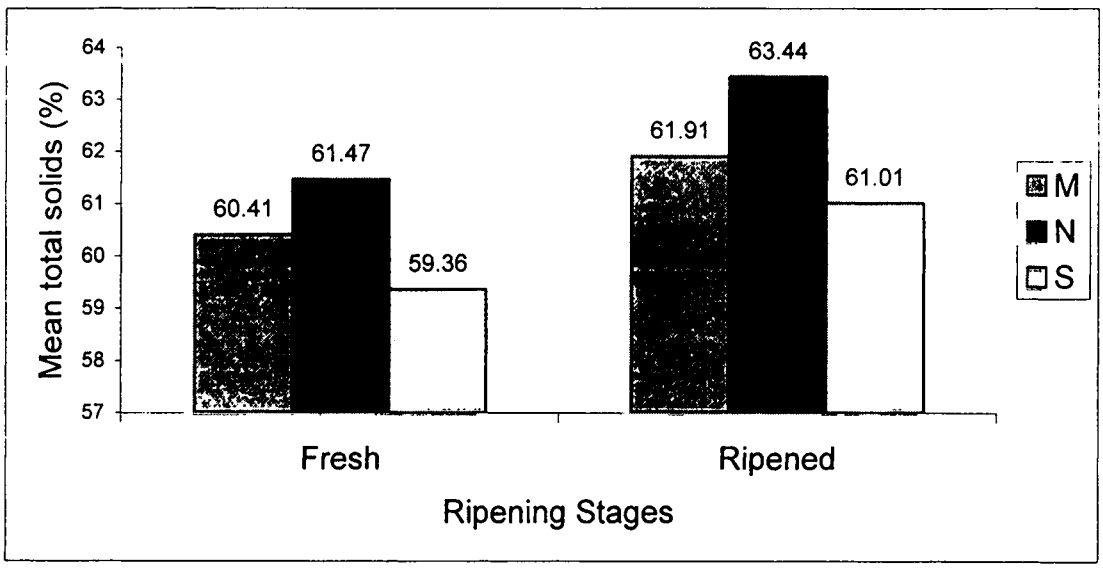

Figure 4.3. Total solids content of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

4.2.3.3 ASH CONTENT

The ash content of the three cheeses is given in Figure 4.4. The average ash content of all three cheeses gradually increased during ripening. The Mpumalanga cheese had the highest ash content followed by the Saanen cheese while the North West cheese had the lowest ash content. This suggested that the total mineral content (including trace elements) of the Mpumalanga cheese was relatively higher.

Compared to the average value (4.4%) reported by Carballo et al. (1994), all the values in this experiment were slightly lower. These differences might be ascribed to one or many factors including differences in breed, nutrition, environment, climate and season (Jenness, 1980).

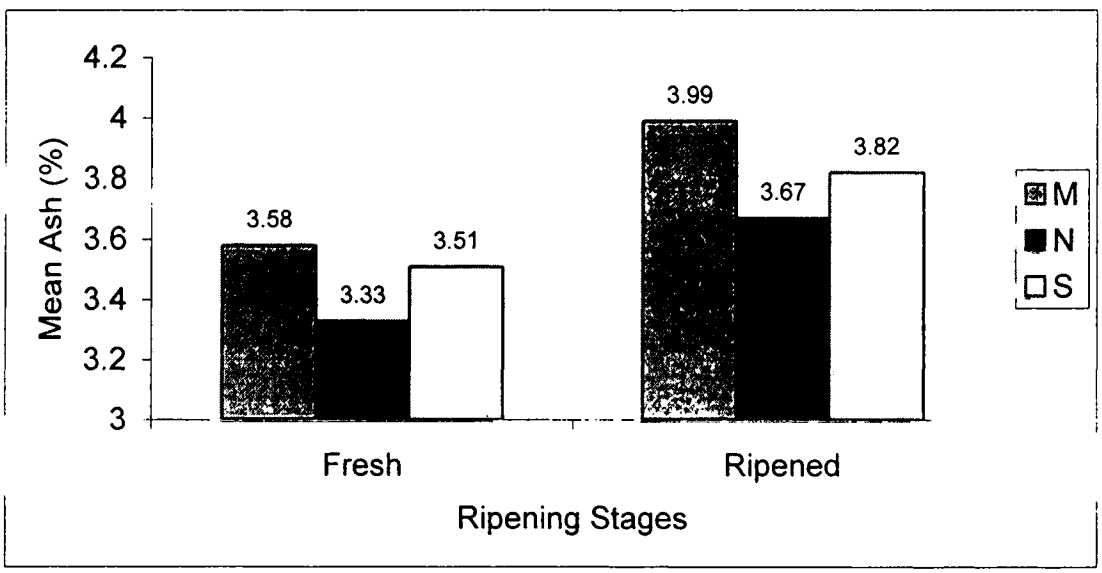

Figure 4.4. Ash content of the Mpumalanga (M), N.W. Province (N) indigenous and Saanen (S) goat milk cheese at the fresh and ripened stages.

4.2.3.4 WATER ACTIVITY (A_w)

The water activity (A_w) spectrum ranges between 0 and 1, however, microbial growth is restricted below 0.6. Values nearer to 1.0 are an indication that there is enough water to dissolve nutrients, enabling most of the organisms to develop and survive (Fox, 1993).

Cheese manufacture is essentially a dehydration process that may continue over a long ripening period. The minimum water activity value for microbial growth and toxin production is the most relevant parameter for prevention technology and public health protection (Van den Berg, 1986). According to Fox (1993), water activity of cheese in general ranges from 0.7 to 1.0.

The water activity of the three cheeses taken at both stages of ripening, are depicted in Figure 4.5. The Saanen cheese had the highest water activity values through ripening while the North West cheese had the lowest values (Fig. 4.5). The A_w values of all three the cheeses declined as ripening of the cheeses took place indicating the moisture loss during ripening.

Varnam and Sutherland (1994) stated that the water activity in cheese varies from 0.97 to 0.94 in a high moisture cheese such as Gouda and to 0.90 or below in a very fully aged cheddar cheese. Aged cheese of some very hard varieties may have a water activity below 0.85. The values of the three ripened goat milk cheeses in this study ranged between 0.917 and 0.922 and were in agreement with the results of Carballo et al. (1994).

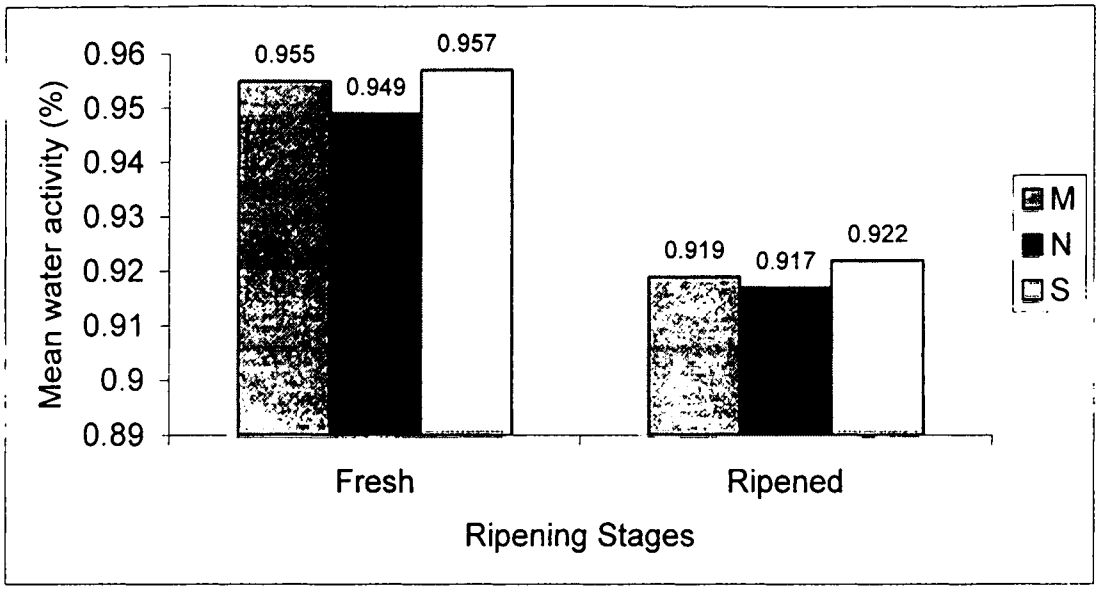

Figure 4.5. Water activity values of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

4.2.3.5 SALT CONTENT

In the majority of cheese types, salt is added and plays an important role in regulating and controlling the cheese quality. It controls the microbial growth and enzyme activity, reducing moisture content and water activity and enhances whey expulsion (Yadav, et al., 1993).

The average salt concentration of the Mpumalanga, North West and Saanen cheeses during the ripening period are depicted in Figure 4.6. The salt concentration of all the cheeses slightly increased throughout the ripening period because of moisture loss and thus concentration. This was in agreement with studies by Carballo et al. (1994). The salt content of the North West cheese was slightly higher than the other two cheeses, but at the end of ripening, all three the cheeses had the same salt concentration.

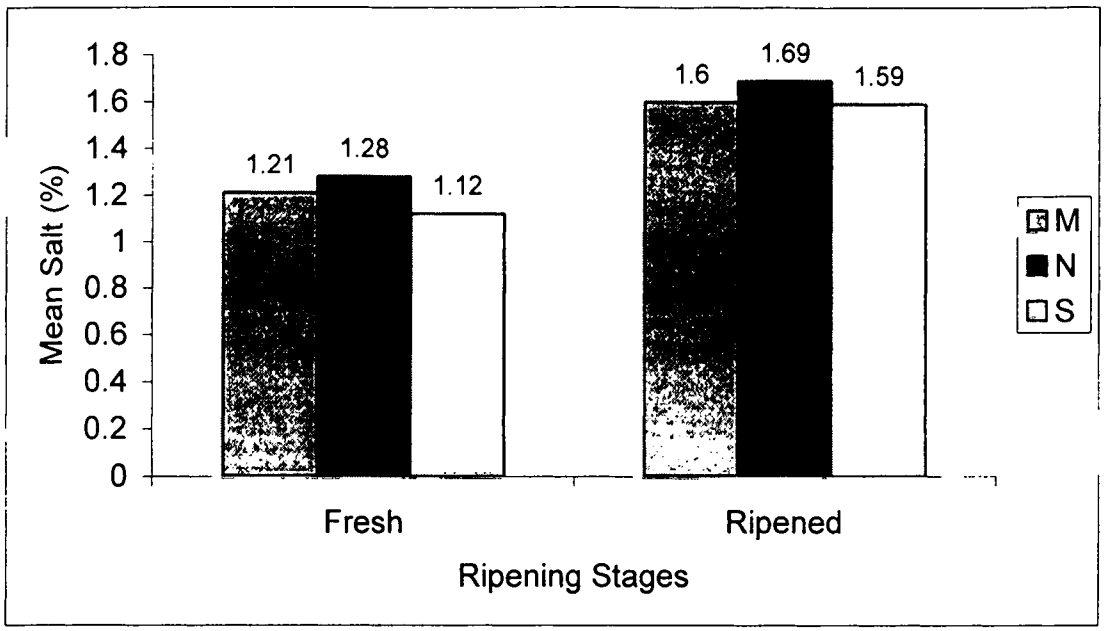

Figure 4.6. Average salt content of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

4.2.3.6 LIPID ANALYSIS

The development of flavour intensity in cheese is directly related to the butyric acid content but it is also influenced by the relative proportions of the various free fatty acids (FFA). Thus, analysis of the lipolytic activity is required to provide both the lipolysis level (with techniques such as free fat in dry matter and TBA values) and the complete fatty acid composition (Corrodini and Neviani, 1994).

4.2.3.6.1 FAT CONTENT

Generally, consumers prefer cheese with a high fat content due to the fact that high fat content contributes to a better flavour in cheese (Renner, 1993). If the fat content

of a cheese increases, the cheese becomes softer, in other words the volume fraction of protein molecules decreases whereas the moisture content increases (Kimber et al., 1974).

The average fat content of the three cheeses over the ripening period is illustrated in Figure 4.7 and is a reflection of the fat content of the goat milks. The fat content of all three the cheeses increased slightly during ripening due to moisture loss. In general, fresh cheese may have a fat content as low as 12%, while ripened cheese may contain between 20 and 30% fat (Renner, 1993). The fat content of the ripened cheeses in this study varied between 27.08% (Saanen) and 29.41% (North West) (Fig. 4.7). The North West cheese had the highest fat content and Saanen the lowest fat content during the ripening stages (Fig. 4.7) which is also a reflection of the fat content of the milk (Table 4.3).

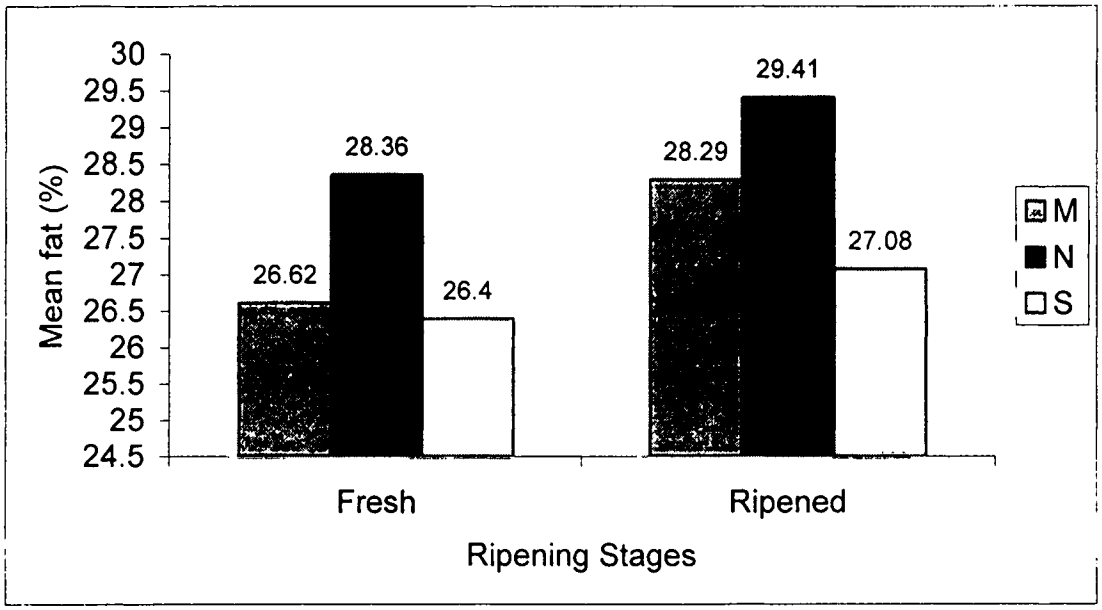

Figure 4.7. Average fat content of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

4.2.3.6.2 FREE FAT IN DRY MATER (FFDM)

The typical aroma of some cheeses, such as Cheddar, develops only when the fat in dry matter content is at least 40 - 50 %, since the aroma in a cheese mainly develops

due to the breakdown of the fat during the ripening period (Stanton, 1984; Jameson, 1990). Commercial cheese with a high free fat in dry mater (FFDM), usually has a high moisture in non-fat substance (MNFS). In turn, this causes a decrease in firmness of the product (Lawrence and Gilles, 1980).

The average FFDM of the Mpumalanga (M), North West (N) and Saanen (S) cheese are depicted in Figure 4.8. The FFDM of the indigenous goat milk cheeses were higher (about 33%) than the Saanen goat cheese (about 29%). This is a reflection of the fat content of the milk (Table 4.3). In the fresh cheese samples, the two indigenous goat cheeses had very similar concentrations of FFDM. However, when ripened, the FFDM of North West and the Saanen goat cheese were slightly increased, while the Mpumalanga ripened cheese decreased significantly and could not be explained. These values were lower than those given by Stanton (1984) and Jameson (1990) for Cheddar cheese, because the cheeses in this study were of the Gouda type.

The Saanen fresh cheese had a significantly lower FFDM content than the two indigenous fresh cheese samples but the two indigenous fresh cheeses did not differ significantly ($P < 0.01$) from each other. All three the ripened cheeses did, however differ significantly from each other ($p < 0.05$). There were also significant differences between the Mpumalanga indigenous fresh and ripened cheeses. However, there were no significant differences between the North West indigenous and the Saanen goat fresh and their respected ripened cheeses (Fig. 4.8).

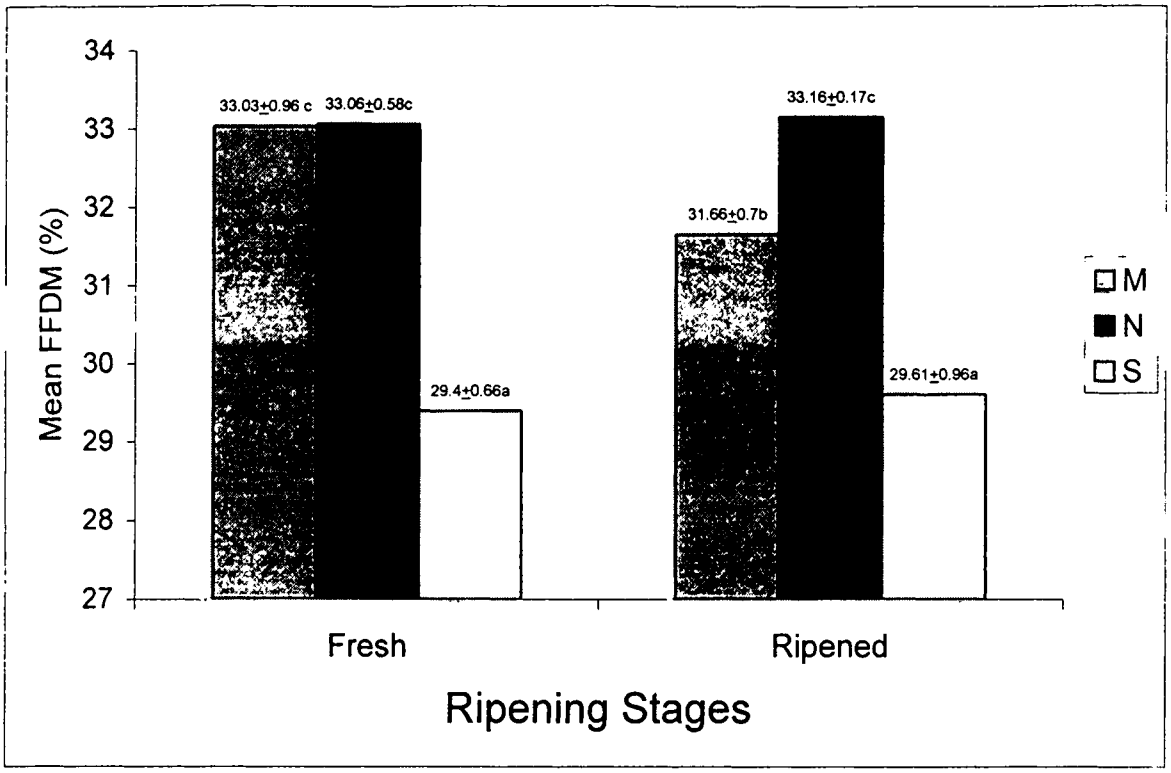

Figure 4.8. Average free fat in dry mater (FFDM) content of Mpumalanga (M), North West (N) and Saanen fresh (one day old) and ripened cheese. Different superscripts differ significantly ($p < 0.05$).

4.2.3.6.3 FREE FATTY ACIDS (FFA)

The free fatty acids in cheese can contribute directly to its flavour (Siezen and Van den Berg, 1994). Non-ripened cheese normally shows a low content of free fatty acids. In cheese made from pasteurized milk this value increases only slightly during ripening, because milk lipase has been practically inactivated and starter bacteria posses hardly any lipase activity (Siezen and Van den Berg, 1994).

Trodaht et al. (1981) stated that cheese fat from goat milk had a higher content of volatile fatty acids. The main volatile fatty acids with short chains had a prominent

flavour and high correlation with lipase activity. According to Harding (1995) this plays a major role in flavour impairment, even at low storage temperatures.

The free fatty acid (FFA) content of the Mpumalanga, North West and Saanen cheeses are depicted in Figure 4.9. There were no significant differences among all three the fresh cheese samples as well as between the Mpumalanga and Saanen ripened cheeses. In the ripened cheeses, however, the North West ripened cheese differed significantly from the Mpumalanga and the Saanen ripened cheeses. Significant differences were also detected between the North West fresh cheese and the ripened one. This implies that the North West cheese fat was rapidly degraded by lipases. As a result of this high development of FFA, a goaty smell developed in the North West ripened cheese. The allowed FFA percentage for human consumption is equal or less than 3% (Kershaw, 1986). All three the cheeses in this study conformed to this standard.

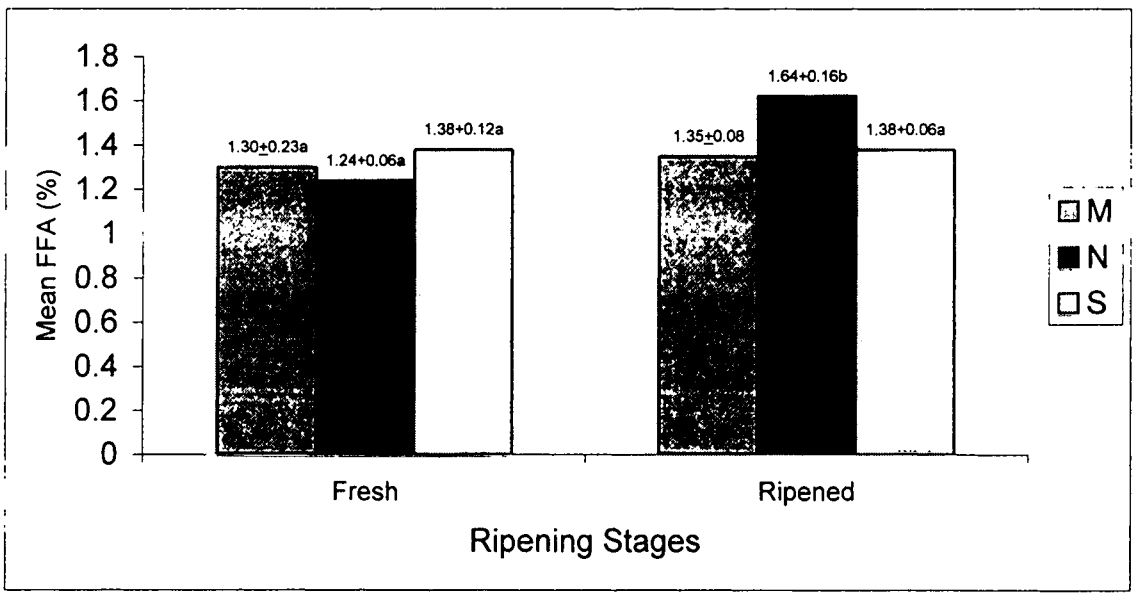

Figure 4.9. Average free fatty acid (FFA) content of Mpumalanga (M), North West (N) and Saanen (S) of fresh (one day old) and ripened cheese. Different superscripts differ significantly ($p < 0.05$).

4.2.3.6.4 TBA VALUE

Lipolysis during cheese ripening is caused primarily by microbial lipases, because the native lipase in milk is largely inactivated by pasteurization. As a result of lipolysis, in a number of cheese varieties, there is a close link between the content of free volatile fatty acids and their flavour (Renner, 1993).

The TBA value (mg malonaldehyde/kg of cheese) of the three cheeses in this study is given in Figure 4.10.

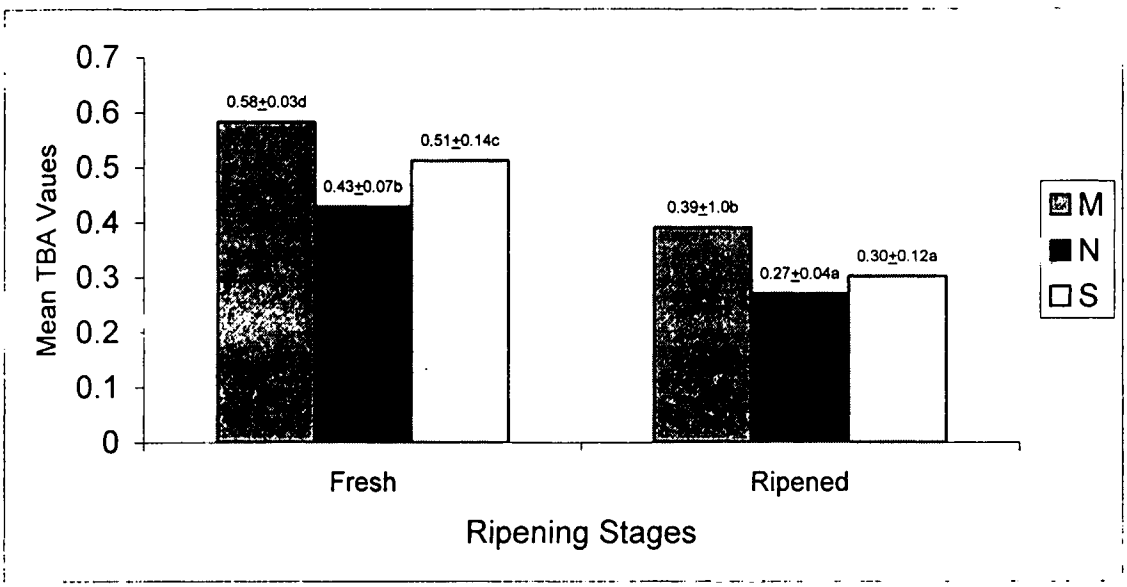

Figure 4.10. TBA values of Mpumalanga (M), North West (N) and Saanen (S) of fresh (one day old) and ripened cheese. Different superscripts differ significantly ($p < 0.05$).

Significant differences were present in all three the fresh cheeses with Mpumalanga giving the highest value and North West the lowest value. The Mpumalanga and Saanen ripened cheeses did not differ significantly from each other, but did differ significantly from the North West ripened cheese. The TBA value decreased during ripening. Fresno et al. (1997), however, reported an increasing pattern while

Carballo et al. (1994), found that the TBA value remained constant throughout the entire ripening period. It is speculated that the decreasing TBA-value in this study is due to the fact that TBA-values were only determined on Day 1 and then on Day 60. If TBA-values were also taken in between these periods, a possible increase may have been witnessed before the decrease.

4.2.3.6.5 FATTY ACID COMPOSITION

The fatty acid composition of the Mpumalanga, North West and Saanen fresh and ripened cheeses is given in Table 4.6.

Table 4.6 Mean fatty acid composition of fresh and ripened cheese of Mpumalanga (M), North West (N) and Saanen (S) cheeses.

	M(0)	N(0)	S(0)	M(R)	N(R)	S(R)
C4:0	0.68±0.08	0.63±0.16	0.72±0.07	0.74±0.13	0.61±0.06	0.69±0.13
C6:0	1.58±0.06^{d}	1.40±0.22^{b}	1.32±0.14^{a}	1.70±0.15^{e}	1.49±0.07^{c}	1.39±0.12^{b}
C8:0	2.59±0.06^{e}	2.30±0.16^{c}	1.76±0.08^{a}	2.66±0.11^{e}	2.43±0.09^{d}	1.90±0.05^{b}
C10:0	9.76±0.19^{d}	8.43±0.09^{c}	6.10±0.14^{a}	10.11±0.47^{e}	8.58±0.16^{c}	6.53±0.18^{b}
C12:0	4.05±0.05^{b}	3.93±0.14^{b}	2.76±0.04^{a}	4.17±0.24^{b}	4.21±0.41^{b}	2.88±0.05^{a}
C14:0	8.97±0.13^{b}	7.99±0.15^{a}	8.04±0.08^{a}	9.15±0.31^{b}	8.03±0.11^{a}	8.19±0.10^{a}
C16:0	28.44±0.24^{c}	23.76±0.17^{a}	25.16±0.16^{b}	28.63±0.54^{c}	23.99±0.31^{a}	25.47±0.30^{b}
C18:0	11.96±0.22^{a}	13.37±0.07^{b}	16.12±0.05^{d}	11.91±0.06^{a}	13.46±021^{b}	15.69±0.36^{c}
C18:1c9	20.75±0.16^{b}	22.21±0.13^{c}	27.03±0.18^{e}	20.47±0.22^{a}	22.12±0.29c	26.68±0.22^{d}
C18: 2c912	1.66±0.05^{a}	2.07±0.10^{b}	2.94±0.06^{c}	1.64±0.11^{a}	2.13±0.09^{b}	2.86±0.07^{c}

Different superscripts in the same row differ significantly ($P < 0.05$).

(0) = Fresh cheese sample

(R) = Ripened cheese sample

In both of the two indigenous goat cheeses, palmitic acid (C16:0) had the highest concentration which accounted for 28.44 and 28.64% for the Mpumalanga fresh (one day

old) and ripened cheeses, respectively, and, 23.76 and 23.99% for the North West fresh and ripened cheeses versus 25.16 and 25.47 % of the Saanen fresh and ripened cheeses, respectively. However, unlike the two indigenous goat cheeses, Saanen cheese had the highest C18:1c9 (oleic acid) content (27.03 and 26.68% of the fresh and ripened cheeses respectively).

Stearic acid (C18:0) had the third highest concentration in all the fresh and ripened cheeses. Following the above mentioned three principal fatty acids, C14:0 (myristic), C10:0 (capric), C12:0 (lauric), C8:0 (caprylic), C18:2c9,12 (linoleic), C6:0 (caproid) and C4:0 (butyric) acid contents were recorded in descending order from the highest to the lowest concentration. Cerebulis et al. (1984) reported the highest value of C18:1c9 which is similar to that of the Saanen cheese.

4.2.3.7 PROTEIN ANALYSIS

4.2.3.7.1 PROTEIN CONTENT

The nutritional importance of cheese arises from its high content of biologically valuable proteins. The average protein content of the Mpumalanga, North West and Saanen cheeses at three stages of ripening, is illustrated in Figure 4.11. There was a slight increase in the protein content of all three the cheeses during ripening.

In general, the protein content of different varieties of cheese varies between 20 and 35% (Renner, 1993). All three the cheeses in this study did not conform to the lowest limit of 20% protein. The North West cheese had the highest protein content (19.45%), the Mpumalanga cheese had 18.36% and the Saanen cheese had the lowest protein content of 15.42%. Several factors could have played a role, namely nutrition, breed and stage of lactation (De Peters and Cant, 1992).

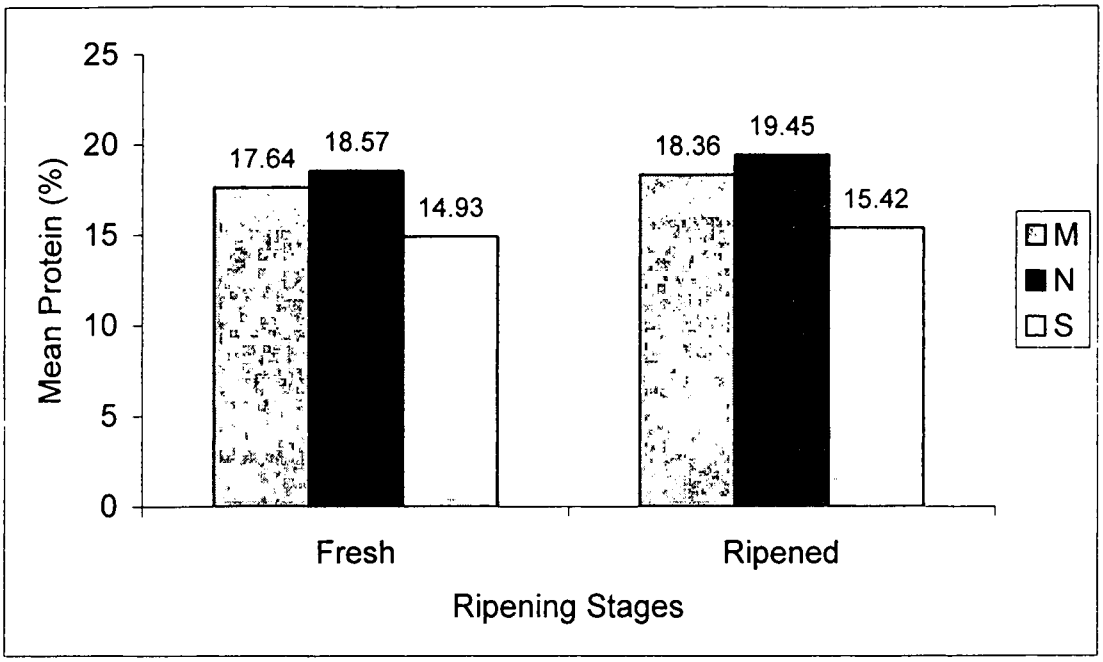

Figure 4.11. Average protein content of the Mpumalanga (M), North West (N) and Saanen (S) goat milk cheeses taken at the fresh and ripened stage.

4.2.3.7.2 PROTEOLYSIS OF THE CHEESE

Proteolysis is a major event in the ripening process of most cheeses. Measurement of protein breakdown products of a cheese has been used as a primary indicator of cheese maturation because the extent of degradation is associated with the development of flavour and texture characteristics of most varieties (Jin and Park, 1996).

Protein degradation during cheese maturation is influenced by several factors including plasmin, chymosin, protease from starter and non-starter bacteria, pH of the curd, storage temperature and time of maturation, salt-to-moisture ratio and humidity (Creamer and Richardson, 1974). Compounds such as peptides and amino acids, resulting from proteolysis of casein by indigenous proteases in milk products, are important constituents that affect cheese quality (Igoshi et al., 1986). Proteolysis of commercial cow milk has been studied extensively with different analytical techniques. However, few

have been reported on the characterization of proteolytic patterns of protein moieties in goat milk cheese products (Jin and Park, 1996).

In this study, the extent of the protein degradation of the three goat milk cheeses was tested using the Urea-PAGE method. Samples of the three different cheeses were taken at two stages, at day one after processing (fresh) and when ripened (60 days). Analysis was done on the water-insoluble nitrogen fraction (WISN; primary proteolysis) and the water-soluble nitrogen fraction (WSN; secondary proteolysis).

4.2.3.7.2.1 WATER-INSOLUBLE NITROGEN FRACTION (WISN)

For each group of caseins (especially α, β and γ caseins), the differences in mobility may occur as influenced by the phosphate content and genetic variants of the different groups of caseins (Grapping et al., 1985). Primary proteolysis in cheese result from the action of chymosin and plasmin (Fox et al., 1994). Both rennet and alkaline protease are mainly responsible for the breakdown of casein into large peptides which are then hydrolyzed primarily by starter enzymes to smaller peptides and amino acids (Marcos et al., 1979).

The protein breakdown of the major water-insoluble casein fractions and the development of the relatively large peptides in the three different cheeses taken at day one and after ripening are shown in Figure 4.12. The main peptides were identified according to Marcos et al. (1979) and Jin and Park (1996).

The β-CN is degraded by plasmin to form the γ-peptides. The γ_2-CN and γ_3-CN peptides were the first bands to be seen in all the samples at the top position of the respective lanes. The intensity of these proteins was slightly fainter in the fresh cheese compared to the ripened cheese (lanes 2, 4 and 6 versus 3, 5 and 7, respectively). The intensity of these peptides was very weak especially in the Mpumalanga and Saanen fresh cheese.

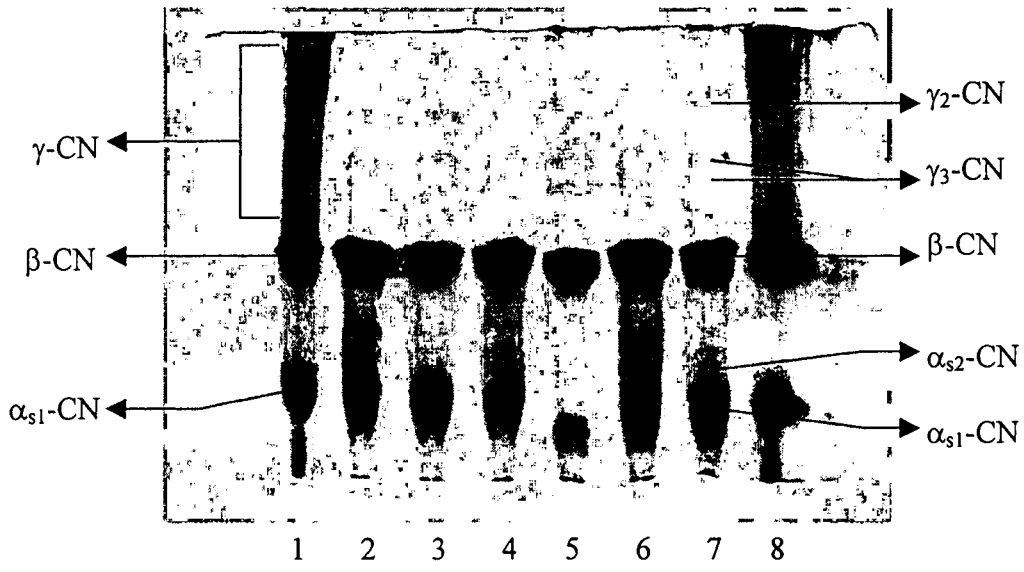

Figure 4.12. Urea-PAGE of the water insoluble nitrogen fractions (WISN) of the Mpumalanga, Saanen and North West goat fresh and ripened cheeses. Lanes 1 and 8: marker (sodium caseinate). Lanes 2 and 3: fresh and ripened Mpumalanga cheese. Lanes 4 and 5: fresh and ripened Saanen cheese. Lanes 6 and 7: fresh and ripened North West cheese.

The degradation of the β-CN by chymosin (rennet) from the N-terminal is indicated by the presence of the β-CN bands with a higher electrophoretic mobility than γ-CN. The intensity of the bands of β-CN was higher in all the fresh cheeses compared to the ripened cheeses. This indicates that β-CN was further degraded by the rennet during the maturation period.

In the β-casein region, there is a major central band of β-casein between two minor bands, usually masked by the major ones. The minor band that migrates slightly

faster than the major β-CN probably represents a degraded product named β-I (Marcos et al., 1979). However, this protein was not distinctively identified in this study. Between the β-CN and α-CN bands, there are a number of bands that could not be identified. They are probably the larger peptides from β-CN.

Creamer and Richardson (1974) indicated that rennet plays the major role in the initial breakdown of α_{s1}-CN. Interestingly, the α_{s1}-CN band of the Saanen cheese sample migrated further downwards than the two indigenous cheeses. In all the lanes a faint to clear band of α_{s2}-CN was observed. This was as expected, because, α_{s2}-CN is one of the main goat milk casein proteins which differentiate it from cow's milk (Jin and Park, 1996). The intensity of the α_{s2}-CN was, however, greatly reduced in the Saanen fresh and ripened cheese. In all three the cheeses, the intensity of the α_{s1}-CN and α_{s2}-CN were slightly higher in the ripened samples than the respected fresh cheeses.

4.2.3.7.2.2 WATER-SOLUBLE NITROGEN (WSN)

The water-soluble nitrogen fraction patterns of the Mpumalanga, North West and Saanen goat milk fresh and ripened cheeses are shown in Figure 4.13.

Unlike the WISN results, no bands are visible in the γ-CN region of the WSN of all three the samples (Fig. 4.13). This is because they are present in the WISN fraction (Fig. 4.12)

Compared to the WISN results (Fig. 4.12), a very faint β-CN band appeared for all three the cheeses. Opposite to the pattern in the WISN, the β-CN intensity of all three the cheeses was slightly higher in the ripened cheese. A possible explanation may be that during maturation, β-casein (insoluble in water) may be degraded to form water-soluble β-CN peptides (and vice versa).

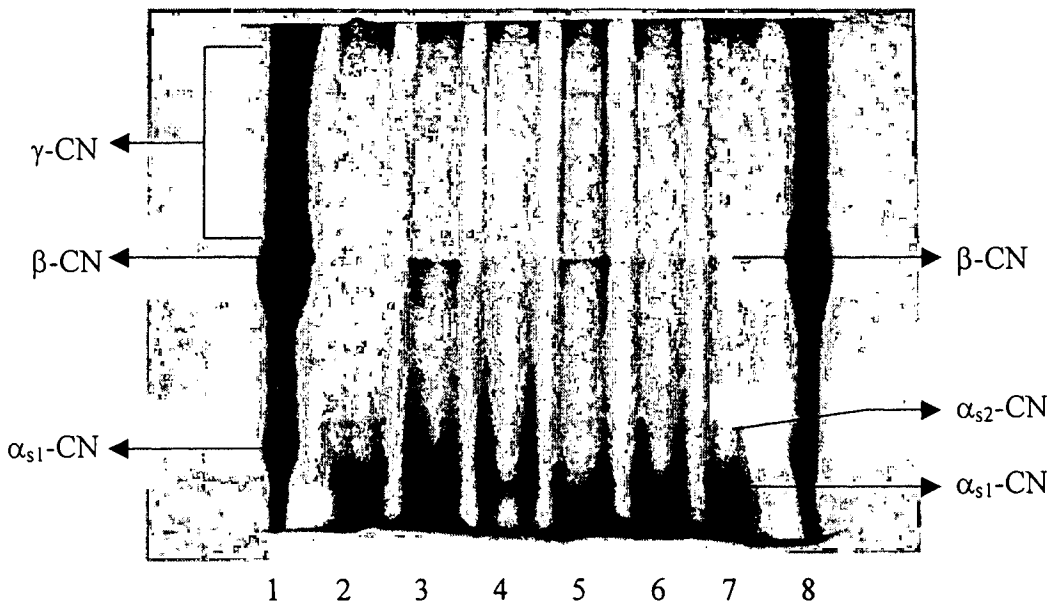

Figure 4.13 Urea-PAGE of the water-soluble nitrogen fractions (WSN) of the Mpumalanga, Saanen and North West goat fresh and ripened cheeses. Lane 1: marker (sodium caseinate). Lane 2 and lane 3: fresh and ripened cheese of Mpumalanga. Lane 4 and lane 5: fresh and ripened cheese of Saanen. Lane 6 and lane 7: fresh and ripened cheese of North West.

The α_{s2} and α_{s1} bands were clearly formed in all three the cheeses. The intensities of the α_{s1} bands of the fresh cheeses were higher than the ripened cheeses bands. A number of densely packed undifferentiated bands developed after the α_{s1} band in the ripened cheeses. This indicates that the well-degraded proteins and peptides of small molecular size accumulated at the bottom of each lane as an indication of the maturation of the cheese. Compared to the indigenous cheeses, the Saanen fresh cheese had a very faint α_{s2} band.

Possible reasons for the differences in both water-soluble and water-insoluble nitrogen fractions between the three cheeses could be ascribed to nutrition, breed, stage

of lactation and bacterial proteolysis. Definite changes also occurred in the casein content during ripening (Fig. 4.12 and Fig. 4.13).

4.2.4 NUTRITIONAL QUALITY

The concentration of calcium, phosphorus as well as other minerals varies between cheese types (Renner, 1993). Park (1990) also stated that mineral composition of cheese depends on coagulation, wheying and salting during cheese processing.

The mineral and fat-soluble vitamin contents of the three cheeses are compared in Table 4.7. The concentrations of magnesium, calcium, nitrate and phosphorus between the three cheeses were almost similar (Table 4.7). The calcium and phosphorus content of cheese are as important as those of milk, since 100g of soft cheese will supply 30–40 % of the daily calcium requirement and 12–20 % of the daily phosphorus requirement (Renner, 1993). The concentration of sodium, potassium, chloride and sulphur was slightly, to much higher in the Saanen cheese than in the two indigenous cheeses. The reason for these differences is probably because of genetic differences between the Saanen and indigenous goats.

With the exception of potassium, the concentrations of the minerals and vitamins were much higher in the cheese than in the milk (Table 4.4). The reason for this is because the production of cheese is a concentration process. The concentration of vitamins A and E were slightly higher in the North West cheese, followed by the Mpumalanga and then the Saanen cheese (Table 4.7).

The concentration of all the minerals and vitamins were much higher than those found in the literature except for sodium (Table 4.7). The reason is because of the various factors that were mentioned earlier (breed, nutrition, etc.) as well as the fact that the cheese in this study was of the Gouda type, which is a much harder (drier) cheese type than the soft cheese used in the literature (Park, 1990; McCance and Widdowsons, 1992).

The minerals and vitamins are therefore, much more concentrated in cheese produced in this study.

Table 4.7. Mineral and fat-soluble vitamin content (mg/100g) of the Mpumalanga (M), North West (N) and Saanen (S) ripened cheese.

Minerals	**Mpumalanga**	**North West**	**Saanen**	**Literature values**
Sodium (Na)	203.1	198.4	286.6	429 (a)
Potassium (K)	55.6	33.8	154.5	30.3 (a)
Magnesium (Mg)	39.1	40	44.7	23.6 (a)
Calcium (Ca)	785.7	818.4	795.8	101 (a)
Chloride (Cl)	972.4	834.3	1051.5	397 (a)
Phosphorus (P)	513.4	516.6	508.7	303 (a)
Sulphur (S)	21	24.3	37.7	6.03 (a)
Nitrate (NO_3)	7.8	8.5	8.7	-
Fluorine (F)	435.4	371.3	379.7	-
Vitamin A	1.82	3.35	1.56	0.25 (b)
Vitamin E	1.56	2.98	2.91	0.53 (b)

(a) Park (1990), (b) McCance and Widdowsons (1992).

4.2.5 SENSORY QUALITY

The three different goat milk cheeses were ranked by the panel of 130 assessors and the results are given in Table 4.8.

From Table 1 (Basker, 1988) the P = 0.05 significance level is attainable when the rank sum differences are greater than or equal to 36.3 and from Table 2 (Basker, 1988)

the P = 0.01 significance level is attained when the rank sum differences are greater than or equal to 45.1. In Table 4.9 the products are arranged in decreasing order of preferences i.e. increasing order rank sums; then Greek letters are used to indicate products whose rank sums do not differ significantly.

Table 4.8. Preference differences between the three products.

Product	**A (North West)**	**B (Mpumalanga)**	**C (Saanen)**
Rank sum	302	228	250
Differences vs A		74	52
B			22

Table 4.9. Differences between the Mpumalanga, North West and Saanen cheeses.

Significance level	**P = 0.05**	**P = 0.01**
Critical difference	36.3	45.1
Product B (M)	α	α
Product C (S)	αβ	αβ
Product A (N)	β	β

From Tables 4.8 and 4.9 it became clear that Product B (Mpumalanga) was significantly preferred over Product A (North West), but not over product C (Saanen). An overlapping range of preference between product B and C was identified. Possible reasons for the North West goat cheese being less preferred, were its slightly harder texture and goaty smell because of the acidity that developed during milk storage (15°C for 32 hours) before cheese production.

The significantly lower preference of the North West cheese by the panel could be ascribed to the significantly higher free fatty acid content of this cheese (see section 4.2.3.6.3). According to Rage and Lunder (1995), goat flavour is difficult to interpret, because this flavour is correlated not only with the high level of free fatty acids, but also with the type of fatty acid and/or other components.

CHAPTER 5

CONCLUSIONS

In South Africa, there are a variety of indigenous goats, which are primarily owned by rural inhabitants. These goats are, however, still a commercially underutilized resource. The milk of these goats may be used to develop products in order to expand commercial markets, to create jobs, provide nutritional quality food and increase income in rural areas.

The quality of milk and dairy products primarily depends on the quality of the milk from which they are made. Thus, the aim of this experimental study was to determine the microbiological, chemical and nutritional quality of the indigenous goat milk of two provinces (Mpumalanga and North West) and compare it to Saanen milk. Another aim was to produce a cheese from each of the three goat milks and determine the microbial, chemical, nutritional and sensory quality of these cheeses.

The microbial quality of the goat milk is reflected in a number of microbial counts. The total bacterial count of the two indigenous goat milks were lower than the limit (5.30 log 10 cfu/ml) for very good quality milk (Yadav et al., 1993). The Saanen milk fell just outside this limit and differed significantly from the indigenous goat milk. A small amount of aerobic spore formers were present in the North West indigenous milk which could produce spoilage of the milk if not properly handled and stored.

A relatively small number of coliforms were present in all three the goat milks, but not one reached the upper limit of 3 log 10 cfu/ml which would have negatively affected the milk (Tirard-Collet et al., 1991). This is an indication of good hygienic practices. The Saanen milk had a higher count for coliforms than the indigenous milk. The reason for this may be the fact that the indigenous goats were milked by hand while

the Saanen goats were machine milked. Improper cleaning of the milking equipment may contribute to the higher count.

The reason for the low number of yeast and moulds present in all three the goat milks, is because these organisms are present in dust and in the air which can contaminate the product. The lower amount of the YMC in the Saanen milk can again be contributed to the fact that the Saanen goats were milked by machine, which is an enclosed system with minimal contact to air and dust.

All three the goat milks in this study had very high somatic cell counts. The SCC of goats is, however, higher than cow's milk because goat milk contains large numbers of epithelial cells, which are counted as somatic cells.

Very small numbers of *S. aureus* were present in the three goat milk samples. All were, however, lower than the limit of less than 2.0 log 10 cfu/ml (Yadav et al., 1993). The North West goat milk had the highest count, but the overall low counts suggested that good hygienic practices were followed.

The absence of *E. coli* in the Mpumalanga goat milk, is an indication of good hygiene. The low amounts present in the North West and Saanen milk are cumbersome since some of these *E. coli* may cause illness and pose a health hazard for young children and the elderly. The absence of *Listeria monocytogenes* and *Brucella abortus* in all three the goat milks are necessary since these organisms may cause illness in humans.

The overall microbial quality of the two indigenous goat milks was better than the Saanen milk. Of the two indigenous milks, Mpumalanga goat milk had a better quality because of the absence of *E. coli*.

The chemical quality of the three goat milks is reflected in the fat, protein and lactose concentrations. In all three these parameters, the two indigenous goat milks had almost the same values which were significantly (protein and lactose) higher than the

Saanen milk. This variation is ascribed to a variety of factors, namely feed, breed, lactation stage, age and health status.

The nutritional quality of the three goat milks was good in terms of sodium, potassium, magnesium and chloride, but was extremely good (especially the indigenous goat milk) in terms of calcium and phosphorous which are the crucial elements for the body to function properly (Jenness, 1980). Although vitamin A content was very low in the North West goat milk, the vitamin E content was double than the standard. The Mpumalanga goat milk also had a higher vitamin E content than the standard, but Saanen had the highest content which is an indication of good anti-oxidant properties.

At the beginning of cheese processing, the North West milk had a much higher acidity than the Mpumalanga and Saanen milks. This was due to improper storage and handling of the milk prior to processing. During processing, the acidity was normalized, but the North West cheese still yielded a much harder and drier cheese, because of higher whey expulsion, than the other two cheeses. The two indigenous cheeses had higher yields than the Saanen. This could be ascribed to the higher fat and protein contents of the indigenous goat milks.

The lactobacilli and lactic acid streptococci and lactococci counts were a reflection of the bacterial starter culture that was used to produce the cheese. The counts declined during ripening as the conditions became more unfavorable for the bacteria (depletion of nutrient, unfavorable atmosphere, etc.). The microbial quality of all three the cheeses were high since no *S. aureus*, coliforms or *E. coli* could be detected during all the stages of ripening until the end of the shelf life. No yeasts and moulds were present in all three the cheeses during ripening, but at the end of shelf life, small amounts were present on all three cheeses.

The moisture content of all three cheeses decreased during ripening as a result of moisture loss to the atmosphere. The Saanen cheese had the highest moisture content

followed by the Mpumalanga cheese. The North West cheese was the driest because of higher whey expulsion.

As maturation of the cheese took place, the total solids content increased as the moisture content decreased. The Saanen goat cheese had the lowest total solids because of its higher moisture content, while the North West cheese had the highest amount of total solids because of the lower moisture content.

The Mpumalanga cheese had the highest ash content followed by the Saanen cheese. This suggests that the total mineral content (including trace elements) of the Mpumalanga cheese was relatively higher.

The A_w values of all three the cheeses declined as ripening of the cheese took place indicating the moisture loss during ripening. The Saanen cheese had the highest A_w values at the fresh and ripened stages as a result of higher moisture content, while the North West cheese had the lowest values.

The salt concentration of all the cheeses slightly increased during ripening because of the concentration process during moisture loss. The salt concentration of the North West cheese was initially slightly higher than the other two. However, at the end of ripening, all three cheeses had the same concentration of salt.

The fat content of all three cheeses increased during ripening as loss of moisture continued. The North West cheese, followed by the Mpumalanga cheese, had higher contents as a result of the higher fat content of the indigenous goat milks.

Both the indigenous fresh cheeses had the same FFDM which was significantly higher than the Saanen cheese. During ripening, however, the FFDM of the North West and Saanen cheeses increased slightly. For an unknown reason, FFDM levels of the Mpumalanga cheese decreased significantly.

The fresh North West cheese had the lowest FFA content, while it had a significantly larger concentration in the ripened cheese compared to the other two cheeses. This implies that the North West cheese fat was rapidly degraded by lipases. As a result of this high development of FFA, a goaty smell developed in the North West ripened cheese.

In all three the cheeses, the TBA values decreased in the ripened cheeses. This was in contrast to literature. A possible explanation may be that TBA-values were only determined on Day 1 and then on Day 60. If TBA-values were also taken in between these periods, a possible increase may have been witnessed before the decrease. The Mpumalanga cheese gave the highest TBA values indicating that it may be more prone to rancidity development in the end product.

In both the indigenous goat cheeses, the palmitic acid (C16:0) had the highest concentration in the fresh and ripened cheeses, while the Saanen cheese had oleic acid (C18:1c9) in the highest concentration. The other fatty acids in all three the cheeses were recorded, in descending concentration, as follows: C14:0, C10:0, C12:0, C8:0, C18:2c9,12, C6:0 and C4:0.

The protein content of all three cheeses increased during ripening. The two indigenous goat cheeses had much higher protein contents than the Saanen cheese and reflected the protein content of the goat milks in this study.

When the proteins were further analysed by Urea-PAGE, it was found that the γ_2-CN and γ_3-CN bands were the first two peptides recorded in the WISN in all three the cheeses. The β–CN was the next band and was the major peptide present in all three the cheeses. The α_{s1}-CN was the smallest peptide present in all three the cheeses. This peptide of the Saanen goats, however, migrated further downwards on the gel than the two indigenous goat's α_{s1}-CN.

The WSN did not contain any γ_2-CN and γ_3-CN bands in all three the cheeses. The intensity of the β–CN bands in all three the cheeses were, however, much higher in the WSN than in the WISN. The α_{s1}-CN bands were similar in the WSN and WISN.

The nutritional quality of the cheeses was very good when compared to literature values. The concentration of Mg, Ca, and P in the three cheeses were almost similar. The concentrations of Na, K, Cl, and S was slightly to much higher in the Saanen cheese than in the two indigenous cheeses. This difference could be ascribed to genetic make-up between the Saanen and indigenous goats.

The concentration of vitamin A and E were slightly higher in the North West cheeses followed by the Mpumalanga and then the Saanen cheeses. The N.W. grazing area was probably richer in Vitamin A and E than the other two.

The Mpumalanga cheese was significantly preferred over the North West cheese but not over the Saanen cheese. The reason could be because of the higher acidity of the North West goat milk which was used to make the cheese. The Saanen and the Mpumalanga cheese had the same degree of preference by the consumers.

From the above, the final conclusion can be drawn that both the indigenous goat milks were of a very high microbiological, chemical and nutritional quality when compared to Saanen milk. The cheese products of the Mpumalanga and Saanen milks were also of a very high microbiological, chemical and nutritional quality and were preferred by the consumers. The high acidity level of the North West goat milk used for cheese production had, however, a negative effect on most of the above mentioned parameters.

The milk of the indigenous goats are, therefore, an excellent way to provide a nutritional quality food, expand commercial markets, create jobs and increase income in rural areas.

CHAPTER 6

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CHAPTER 7

SUMMARY

The milk of indigenous goats has great potential in providing a nutritional food for poverty stricken communities. The aim of this study was to investigate the microbiological (spoilage and pathogenic), chemical (fat, protein and lactose) and nutritional (minerals, vitamins A and E) quality of indigenous goat milk from Mpumalanga and North West and compare it to Saanen goat milk. In almost all the quality parameters, the milk of the indigenous goats had a higher quality than the Saanen milk. The differences of most of the quality parameters between the indigenous and Saanen goat milk were ascribed to feed, breed, lactation stage, age, health status and the fact that the Saanen goats were machine-milked, while the indigenous goats were milked by hand.

Another aim was to produce a Gouda-type cheese from each of the three goat milks. The microbiological (spoilage and pathogenic), chemical (moisture, total solids, ash, water activity, salt, fat content, free fat in dry matter, total free fatty acids, rancidity [TBA-value], fatty acid composition, protein content and proteolysis), nutritional (minerals and vitamins A and E) and sensory quality of the cheeses were then determined. The milk of the North West indigenous goats was acidic at the start of cheese production, but was normalized during production. The acidic nature of the cheese had, however, a negative effect on most of the quality parameters and resulted in a harder cheese with a goaty smell. The Mpumalanga and Saanen cheeses compared well in all the quality parameters and the sensory analysis suggested that no significant difference were present between these two cheeses.

The conclusion was drawn that the milk of indigenous goats are an excellent way to provide a nutritional quality food, expand commercial markets, create jobs and increase income in rural areas.

Key words: Indigenous goats, Saanen goats, milk, cheese, quality (microbiological, chemical, nutritional, sensory).

OPSOMMING

Die melk van inheemse bokke het groot potensiaal vir die voorsiening van 'n voedsame voedsel vir arm gemeenskappe. Die doel van hierdie studie was om die mikrobiologiese (bederf en patogene), chemiese (vet, proteïen en laktose) en voedingswaarde (minerale, vitamiene A en D) kwaliteit van inheemse bokmelk vanaf Mpumalanga en Noord-Wes te ondersoek en dit met Saanen bokmelk te vergelyk. Die inheemse bokmelk het amper in al die kwaliteitsparameters 'n hoër kwaliteit as die Saanen melk gehad. Die verskille tussen die inheemse en Saanen bokmelk is toegeskryf aan faktore soos voedsel, ras, laktasie stadium, ouderdom, gesondheidstatus en die feit dat die Saanen bokke met melktoerusting gemelk is terwyl die inheemse bokke met die hand gemelk is.

'n Ander doelwit was om 'n Gouda-tipe kaas van elk van die drie bokmelke te vervaardig. Die mikrobiologiese (bederf en patogene), chemiese (vog, totale vastestowwe, as, wateraktiwiteit, sout, vetinhoud, vry vet in droë massa, totale vrye vetsure, galsterigheid [TBA-waarde], vetsuur samestelling, proteïen inhoud en proteolise), voedingswaarde (minerale, vitamiene A en D) en sensoriese kwaliteit van die kase is daarna bepaal. Die melk van die Noord-Wes inheemse bokke was suur aan die begin van kaasvervaardiging, maar die suurheid is gedurende vervaardiging genormaliseer. Die suur aard van die kaas het egter 'n negatiewe effek op meeste van die kwaliteits parameters gehad en het 'n harder kaas met 'n bokagtige reuk tot gevolg gehad. Die Mpumalanga en Saanen kase het goed ooreengekom in al die kwaliteits parameters en die sensoriese analiese het aangedui dat geen beduidende verskil tussen die twee kase teenwoordig was nie.

Die gevolgtrekking is gemaak dat melk van inheemse bokke 'n uitstekende produk is om 'n voedsel te voorsien wat hoë voedingswaarde het, wat gebruik kan word om kommersiële markte uit te brei, werk te verskaf en inkomste in landelike areas te verhoog.

Sleutelwoorde: Inheemse bokke, Saanen bokke, melk, kaas, kwaliteit (mikrobiologies, chemies, voedingswaarde, sensories).