PREPARATION OF HARD RIPENED CHEESE FROM GOATS' MILK

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "PREPARATION OF HARD RIPENED CHEESE FROM GOATS' MILK" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Certified that this thesis, entitled "PREPARATION OF HARD RIPENED CHEESE FROM GOATS' MILK" is a record of research work done independently by Sri.A.G. ANILKUMAR under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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DEDICATED TO THE
LOVING MEMORY OF
MY BELOVED MOTHER

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INTRODUCTION

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A great part of the world has goat, water buffalo, sheep and camel as the milking animal rather than the cow. The world areas where these species contribute to the development of dairying include the Mediterranean, South West Asia, India and Eastern Europe (Kosikowski, 1978). Sheep and goats are renowned for their adaptability to thrive in places of scanty vegetation.

According to FAO Production Year Book (1980), cows, buffaloes and goats in India contributed 13.0, 17.0 and 0.93 million metric tonnes of milk respectively.

The goat population in India is increasing at the rate of one million per year, inspite of the lack of much developmental programmes for this species (Taneja, 1979). The tropics contribute about 70.0 per cent (310 million) towards the total world population of about 445 million goats (FAO, 1979). Out of the 71 million goats in India, Kerala alone possesses 1.683 million goats which forms about 31.0 per cent of the total number of livestock in the State.

According to an Integrated survey, the quantity of milk produced by goats was estimated as 0.54 lakh metric tonnes which was about 7.0 per cent of the total milk produced by cattle, buffaloes and goats in the State.

In recent years, the progressive formulation of various developmental activities in our country has laid great importance on the milk production potential of goats. The present trend in this regard is to produce contemporary pure-bred locals and cross-breds with exotic breeds like Saanen and Alpine depending on location and requirements (Shanmugasundaram, 1980).

One of the main objectives of the 'All India Coordinated Research Project on Goats for Milk' is to evolve a breed of goat suitable for the agro-climatic conditions prevalent in Kerala, and capable of producing greater quantities of milk by cross breeding the native Malabari goats of Kerala with exotic breeds such as Alpine and Saanen.

In India goats milk is, in general, considered inferior to cows' or buffaloes' milk, and is used entirely for beverage purposes. On the contrary, the manufacture of products from goats' milk is quite substantial in Europe. In Spain, goats' milk represents 11.0 per cent of the milk used for cheese making and that in Greece nearly 3.0 per cent. In France, out of the total 273.4 million litres of goats' milk that are being produced in an year, about 53.0 per cent is used for cheese and 10.0 per cent for beverages and drying. In the USA where there is no dearth of cows' milk, the milk of goats finds a market due to its superiority in nutritional quality or supposed value as a source of milk for individuals who are allergic to the proteins of cows' milk (Prakash and Jenness, 1968).

Several methods have been developed to preserve milk in one or the other form eg., condensed milk, dried milk, fermented milk and cheese. Among these, cheese is probably the oldest and most popular product manufactured from milk. The word "cheese" has been derived from the Latin word "caseus". Cheese is a product made from the curd obtained from milk by coagulating the casein with the help of rennet or similar enzymes in the presence of lactic acid produced by added or adventitious microorganisms, from which part of the moisture has been removed by cutting, cooking and/or pressing, which has been shaped in a mould and then ripened by holding it for some time at suitable temperature and humidity (Davis, 1965).

The type of cheese produced in European countries showed considerable regional differences. In course of time, certain regions became known for certain varieties of cheese eg., France for Roquefort, Switzerland for Swiss, England for Cheddar and Stilton, Holland for Gouda and Edam etc. Besides these, other varieties like Brick, Camembert, Limburger, Romano, Cream cheese, Neufchatel, cottage, Trappist, Blue vein and whey cheese are also widely known.

Cheese can easily be made on a small scale in the farm and on a larger scale in a plant. It can be made using simple household utensils or by means of automated equipments.

According to De (1980), Cheddar cheese is probably the best known cheese in the world. The bulk of the cheese produced in India is of the cheddar type.

Goats' milk in many ways resembles cows' milk and it usually produces a white cheese. In ripened goats' milk cheese, a different flavour is obtained because of the difference in the composition of fatty acids between cows' and goats' milk. Many varieties of cheese can be manufactured from goats' milk in the home and in the farm, adopting the same procedures as those employed for cows' milk cheese.

For the economic exploitation of the additional quantities of milk that may become available as a result of cross-breeding and improvement in feeding and management practices, it becomes necessary to find out suitable methods of converting milk into products that are easily acceptable for human consumption. Attempts were made at the National Dairy Research Institute, Keranal to manufacture Khoa and Channa, both indigenous products, from goats' milk (Jailkhani and De, 1978).

The technology relating to the manufacture, curing and keeping quality of cheese from goats' milk is relatively scanty in India. The present study has been undertaken to indicate the procedures that are necessary for the production of a hard ripened variety of cheese from goats' milk, the changes that occur during the curing process and the shelf life of the product. Outlining the procedures for cheese making will enable one to make cheese at home or in the farm. Attempts will also be made to compare the goats' milk cheese with that of cows' milk produced in a similar way.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Cheese is a very nutritious and palatable food consisting of casein, fat, insoluble salts, moisture, to a smaller extent whey proteins, lactose, soluble salts and other minor milk constituents. The manufacture of cheese aims at concentrating the essential solids of milk. Although more than 400 varieties of cheese are described under various names, probably there are only about 18 distinct varieties of natural cheese (Sanders, 1953).

Cheese has been classified on the basis of firmness (moisture content) and type of ripening into very hard, hard, semi-soft or soft; ripened by molds/bacteria or unripened varieties.

The milk of several mammals have been used for cheese production, but cows' milk has been most widely used. Sheep milk is used to make Roquefort in France and Brinsen in Hungary. Small amounts of milk are used from goats and buffaloes in different parts of the world (Foster et al.,1957).

The technical procedures employed in the making of numerous varieties of cheese from cows' milk have been described by several workers, but those relating to goats' milk cheese are relatively scanty.

2.1. Composition of goats' milk

Excellent reviews on the topic have been published by Prakash and Jenness (1968) and Jenness (1980).

2.1.1. Milk Fat

Wide variations have been reported in the fat content of goats' milk. In their review, Prakash and Jenness (1968) have reported that the fat content of goats' milk varied from 3.00 per cent to 5.50 per cent.

Nirmalan and Nair (1962) analysed pooled samples of milk collected from Malabari goats and reported a fat percentage of 4.95 whereas, Devendra (1979) got a value of 4.96 for the same breed.

A very high fat percentage of 5.65 was reported by Ueckermann *et al.* (1974) in goats' milk. Mba *et al.* (1975) reported a value of 5.32 per cent in the milk of Saanen goats at mid lactation.

A fat content of 2.81 per cent was reported by French (1970) in the milk of Saanen goats, whereas Mena and Escamilla H (1977) obtained an average fat per cent of 4.26, 4.13 and 4.38 for Saanen, French Alpine and Nubian breeds respectively.

Quereshi *et al.* (1981) working on Jamnapari goats reported an average milk fat content of 4.70 per cent in individual samples and 4.71 per cent in herd samples.

In a lactation study, Baiju (1981) reported an average milk fat content of 6.29 ± 0.18 and 5.64 ± 0.09 per cent in Alpine x Malabari and Saanen x Malabari cross-bred goats respectively.

2.1.2. Milk proteins

Studies by Ueckermann *et al.* (1974) showed that the protein content of Boer goats' milk was 3.05 per cent.

French (1970) obtained a low value of 2.17 per cent protein in the milk of Saanen goats while Chang and Kim (1978) obtained 3.65 per cent in the same breed. Investigating on Australian Saanen goats, Ranawana and Kellaway (1977 a, 1977 b) reported that the milk protein value ranged from 4.01 to 4.61 per cent.

Mena and Escamilla H (1977) reported the average protein content of goats milk to be 3.14, 3.34 and 3.70 per cent for Saanen, French Alpine and Nubian breeds respectively.

Quereshi *et al.* (1979) found that the protein content of individual and herd milk samples in Jamnapari goats was 3.31 and 3.32 per cent respectively.

Investigating on the milk of Malabari goats, Nirmalan and Nair (1962) reported a total protein content of 4.04 per cent while Devendra (1979) found the value to be 3.89 per cent.

The average protein content of the milk of Alpine x Malabari and Saanen x Malabari cross-bred goats was reported by Baiju (1981) to be 4.40 ± 0.03 and 4.40 ± 0.02 per cent respectively.

2.1.3. Lactose

Lactose is the chief carbohydrate of milk and it plays an important role in fermented dairy products.

Ueckermann *et al.* (1974) obtained a lactose content of 6.12 per cent in the milk of Boer goats. Ranawana and Kellaway (1977a, 1977b) studied the lactose content in the milk of Australian Saanen goats and reported a range of 4.85 to 4.93 per cent, whereas French (1970) found a value of 3.50 per cent in the milk of Swiss Saanen goats.

In another study, Chang and Kim (1978) obtained a lactose content of 3.91 per cent in the milk of Saanen goats.

The milk of British Alpine and Anglo-Nubian goats was found to contain 4.83 and 4.05 per cent lactose respectively (Devendra, 1972).

Working on the milk of Jamnapari goats Quereshi *et al.* (1981) reported a value of 3.05 per cent lactose. The average value reported by him was identical for individual as well as herd milk samples.

The milk of Malabari goats was found to contain 5.10 per cent lactose (Nirmalan and Nair, 1962), but Devendra (1979) could obtain a value of 4.11 per cent only in the same breed.

Investigations by Baiju (1981) revealed the average lactose content of the milk of Alpine x Malabari goats to be 4.05 ± 0.08 per cent and Saanen x Malabari goats to be 4.06 ± 0.02 per cent.

2.1.4. Ash

Milk ash is known to contain Potassium, Sodium, Magnesium, Chlorine, Phosphorus and Sulphur in relatively larger amounts. Small amounts of Iron, Copper, Zinc, Aluminium, Manganese, Cobalt and Iodine and traces of Silicon, Boron, Titanium, Vanadium, Rubidium, Lithium and Strontium are also present. Besides other functions, some of them are important in the coagulation of milk by rennin.

The ash content in the milk of Boer goats was found to be 0.69 per cent (Ueckermann et al., 1974).

Devendra (1972) reported a value of 0.78 and 0.79 per cent ash in the milk of British Alpine and Anglo-Nubian goats respectively. Similarly, Chang and Kim (1978) obtained a value of 0.78 per cent in the milk of Saanen goats.

The ash content in the milk of Jamnapari goats was 0.81 per cent (Quereshi et al., 1981). Nirmalan and Nair (1962) studied the ash content of Malabari goats' milk and reported a value of 0.76 per cent while Devendra (1979) reported a value of 0.83 per cent in the same breed.

The average ash content in the milk of Alpine x Malabari and Saanen x Malabari cross-bred goats was 0.776 ± 0.001 and 0.782 ± 0.001 per cent respectively (Baiju, 1981).

2.2. Quality of milk for cheese making

The quality of milk has a profound effect on the quality of the cheese made from it. The quality of milk is assessed in relation to its composition, microbial load, physical properties and organoleptic characteristics. Van Slyke and Price (1952) opined that the quality of milk is visible in its flavour, odour and appearance. Thus, only those batches of milk that conform to high standards are selected for cheese making. It is necessary that raw milk for cheese making has a very low microbial flora in it. Mastitis milk, even if diluted in the factory by normal milk, presents potential danger of pathogens.

Working on Cheddar cheese, Tittsler et al. (1946) found that the bacteriological quality of both raw and pasteurized milk was an important factor affecting the quality of cheese.

Raw milk has been used for the manufacture of cheese in the United Kingdom by some milk producers, in much small-scale in the rest of Europe, and largely in Asia (Chapman and Sharpe, 1981). The same workers opined that many Cheese makers considered untreated milk to produce a more flavourful cheese.

A number of research reports have shown that the flavour quality of milk is reflected in flavour development in cheese (Fyksen and Steinsholt, 1974; Bakkene and Steinsholt, 1975; Bakke et al., 1976); when a strong flavoured milk was processed, it gave stronger flavoured cheese. The intensity of the goaty flavour was highly correlated with the free fatty acids content (Bakkene and Steinsholt, 1975; Bakke et al., 1976).

According to Chapman and Sharpe (1981), the storage of chilled raw milk led to the multiplication of psychrotrophs and consequent production of extra-cellular lipases and proteinases, particularly by Pseudomonads, Achromobacter, Acinetobacter and Aeromonas.

Law et al. (1976) found that efficient pasteurization of milk at 72°C for 15 to 17 seconds greatly reduced the total count of microorganisms and added that the off-flavours produced in cheese made from pasteurized milk could possibly be due to the microbial enzymes that survived pasteurization.

The microbial enzymes had the potential to affect the processing properties of milk adversely and to impair the quality of milk products (Law, 1979).

Lipases caused rancidity in Swiss cheese (Pinheiro et al., 1965); in Dutch variety (Driessen and Stadhouders, 1971); in Cheddar cheese (Law et al., 1976) and in Camembert (Dumount et al., 1977).

Proteinases caused the loss of excessive amounts of nitrogen into the whey of soft cheese made from milk with psychrotrophic counts of 10^6 (Feuillat et al., 1976), whereas with cheddar cheese, the losses of nitrogen into the whey, and therefore the yield of cheese, were not influenced by psychrotrophic counts of 10^7 colony forming units per millilitre (cfu ml^{-1}) in the raw milk (Law et al., 1979).

2.3. Heat treatment of milk

Pasteurization of raw milk has been practiced almost universally, and with nearly all types of cheese. The process helps in destruction of all pathogenic organisms and many harmful or potential spoilage organisms. In addition, this process helps to minimize the variations in the ripened cheese. Foster et al. (1957) pointed out that the cheese made from pasteurized milk ripened more slowly as compared to that from raw milk, presumably due to the destruction of many of the useful organisms and natural enzymes originally present in raw milk.

Outlining a process for the manufacture of a patent variety of cheese, Elias (1972) recommended heating of either fresh or previously boiled or pasteurized milk to a temperature of 85°C.

Pasteurization of milk reduced the numbers of unwanted bacteria and cheese of good quality could be made with milk heat treated within the range of 68 to 74°C with 15 seconds holding time (Langsrud and Reinbold, 1973).

An increase in pasteurization temperature (from 65 to 73°C for 15 seconds) caused an increase in rennet retention (Dulley, 1974).

Double heat treatment at 60 to 65°C and 72°C respectively enabled the milk to be stored for 48 to 72 hours at 5 to 6°C, without marked effects on rennet coagulation, but increasing the temperature of the first treatment to 70°C had adverse effects (Karlikanova, 1974).

Wasserfall et al. (1976) made Edam cheese from milk pasteurized at 62 to 64°C for 30 minutes with the addition of a concentrated suspension of lysozyme prior to the incorporation of rennet.

From a study on Baby-Edam cheese, El-koussy et al. (1977) concluded that heating the cheese milk to 76.6°C to 82.2°C increased both cheese yield and the moisture content. Further, they noted a marked improvement in the quality of low-fat Baby-Edam cheese made from milk heated to 76.6°C.

Minarik and Dolezalek (1977) found that both total solids content and firmness of the coagulum decreased as pasteurization temperature was raised from 63°C to 85°C and heat treatments at 100°C gave excessively soft coagulum of very low total solids.

Karlikanova and Durova (1979) determined the optimal heating conditions for double heat treatment of cheese milk as being 65°C with 20 to 25 seconds holding and 71 to 72°C for 20 - 25 seconds for the first and second treatments respectively.

In the United Kingdom milk for cheese making is given a form of heat treatment sufficient to destroy undesirable bacteria without affecting the physical and chemical properties of milk. The temperature-time combination of 72°C for 15 seconds meet those requirements, and the minimum recommended combination was 68°C for 15 seconds (Chapman and Sharpe, 1981).

Various workers have suggested different temperatures for pasteurization of milk for cheese making. Chapman and Sharpe (1981) suggested 71°C for 15 seconds for Cheddar cheese, 72°C for 15 seconds for Emmenthal and slightly above this for cottage cheese. They have reported that heating above 74°C resulted in defects in body and eye formation and splits in the cheese. These workers have also stated that the milk used in the manufacture of camembert cheese was generally heat treated at 72°C for 15 seconds.

While some varieties of goat milk cheese are made from pasteurized milk (Cargouet, 1971; Elias, 1972), most reports of processing do not include pasteurization (Mocquot and Bejambes, 1960; Efthymiou, 1974; Jaouen, 1974; Bottazi, 1975).

Epidemics of Brucellosis among human population have been traced to the consumption of unpasteurized goat cheese (Escalante and Held, 1969; Street _et al._, 1975).

Kosikowski (1978) recommended the heat treatment of feta cheese milk at 62.8°C for 10 to 15 minutes or pasteurization at 62.8°C for 30 minutes during warm seasons. In the case of sainte Maure cheese, he recommended 62.8°C for 30 minutes while for mold ripened cheese it was advocated as 62.8°C for 30 seconds.

In the manufacture of soft pickled cheese from goats' milk, heat treatment adopted by Dariani _et al._ (1980) was 63°C for 30 minutes.

2.4. Addition of Calcium chloride

The composition of milk is sometimes altered for cheese making by adding certain substances from sources other than milk. Calcium chloride ($CaCl_2$) is added to correct faulty coagulation of milk that may be caused by excessive heat treatments during pasteurization or by milk from abnormal udders, or by milk that is deficient in calcium salts (Van Sly and Price, 1952).

Davis (1965) attributed the slower renneting and weaker curd associated with excessive heat treatment of milk, partly to the precipitation of part of the soluble calcium salts in the milk. He recommended that an approach to normal behaviour could be effected by addition of 0.01 to 0.03 per cent calcium chloride to the milk, or by the addition of whey powder or concentrate.

The coagulation time decreased somewhat and the firmness of coagulum increased significantly with increasing total calcium content of milk. Native ionic calcium had a highly significant positive effect on coagulum firmness, but not on the coagulation time. A substantially greater effect on the coagulum firmness consequent to the addition of calcium chloride was noted in milk of low rather than high titrable acidity (Horian and Kreal, 1974). These workers recommended the addition of 10.0 g calcium chloride per 100 l of milk.

In another study Minarik and Dolezalek (1977) reported that addition of calcium chloride decreased coagulation time and increased firmness of the coagulum.

From a comparative study of the rennet coagulation of goats' and cows' milks, Blattner and Gallmann (1980) concluded that addition of calcium chloride had less effect on goats' than on cows' milk.

In the preparation of Edam and Gouda cheeses, Chapman and Sharpe (1981) recommended addition of calcium chloride upto 0.02 per cent.

Lazarevska and Bauer (1983) adopted the addition of 40 ml of a 50.0 per cent solution of calcium chloride per 100 l milk in the manufacture of soft cheese from cows' milk.

2.5 Starter cultures

Lactic acid fermentation by bacteria is necessary in the production of all kinds of cheese. The important functions of lactic acid are: i) promotes coagulation of milk by rennin; ii) the drainage of whey is prompted as it causes curd to shrink; iii) prevents growth of undesirable microorganisms during making and ripening; iv) promotes fusion of curd into a solid mass; v) controls enzymic changes during ripening in order to obtain desirable characteristics in ripened cheese. These aspects can be efficiently controlled by the kind and amount of starter used and the method of handling the curd (Foster *et al.*, 1957).

According to Singh (1979), the purpose for which starter cultures are to be used may have much to do with the qualities which are most important for the finished dairy products.

Normally, the larger the inoculum the shorter is the lag phase. Davis (1965) opined that the usual quantities of starter varied from 0.5 to 2.0 per cent with an average of about 1.0 per cent.

The heat treatment of the curd is one of the important factors which decides the type of starter culture to be used for cheese making. If the curd is heated only upto 38°C or slightly higher, *Streptococcus lactis* or *Streptococcus cremoris* is used. The culture may consist of single strain, but more often it contains several strains of one or the other species. If all the curd is cooked to higher temperatures like 49°C to 54°C, mixtures of *Streptococcus thermophilus* with a lactobacillus usually *Lactobacillus bulgaricus*.

Lactobacillus helveticus are used (Foster *et al.*, 1957).

Singh (1979) recommended single strain starter of *Streptococcus lactis* or *Streptococcus cremoris* for use in cheddar cheese manufacture.

Sharpe (1979) reported that lactic acid bacteria used in cheese making include streptococci, leuconostocs and Lactobacilli and selected species of these genera could be used as combined cultures or as mixtures of single strain cultures.

According to Chapman and Sharpe (1981), mesophilic starters (Optimum temperature 20 to 30°C) could be used to produce a wide variety of cheese whereas, thermophilic starters (optimum temperature 37 to 45°C) could normally be used in the production of cooked cheese varieties. These authors have stated that in the preparation of very hard varieties of cheese like Grana or Parmesan, a starter comprising of *Streptoccus thermophilus* and *Lactobacillus bulgaricus* could be used at 1.0 per cent level. They recommended a 1.0 to 2.0 per cent inoculum of mesophilic lactic acid streptococci for Cheddar cheese, an inoculum of thermophilic lactic acid bacteria consisting, generally, of 0.03 to 0.10 per cent of *Streptococcus thermophilus* and upto 0.20 per cent of *Lactobacillus helveticus* or *Lactobacillus bulgaricus*, together with 1.0 to 2.5 ml per

1000 l of a culture of propionibacteria for Emmenthal cheese; a 0.50 per cent inoculum of mesophilic lactic acid streptococci for Edam and Gouda varieties and 0.10 to 0.20 per cent of *Streptococcus lactis* or the same amount of a combination of *Streptococcus lactis* and *Streptococcus thermophilus* for Limburger cheese.

Srinivasan (1984) recommended the following types of starters: *Streptococcus lactis*, *Streptococcus cremoris* and Leuconostoc for cottage cheese; *Streptococcus lactis*, *Streptococcus cremoris* and *Streptococcus diacetylactis* for cheddar; *Streptococcus thermophilus*, *Lactobacillus bulgaricus*, *Propionibacterium shermanni* for Swiss and *Streptococcus lactis*, *Streptococcus thermophilus* and *Bacterium linens* for Brick cheese. Use of defective starters is one of the cause for the development of defects in ripened cheese. Thus, Hoglund *et al.* (1972) found that the use of homofermentative instead of heterofermentative starters coupled with certain modifications in the technology of manufacture reduced open texture in Cheddar cheese.

Kratochvil (1978) claimed that an uniform and fully aged flavour developed in American-type cheese by following essentially the same steps used in the manufacture of such cheese, but with some modifications which included the addition of specific pairs of strains of Lactobacillus plantarum and Streptococcus durans over and above the normal starter used.

A starter used in the manufacture of plasticized cheeses comprised mesophilic streptococci (Streptococcus lactis, Streptococcus cremoris) thermophilic streptococci (Streptococcus thermophilus) and lactobacilli (Lactobacillus lactis). The ratio between mesophilic, thermophilic streptococci and lactobacilli was 2:1:1. The use of this starter improved the quality of cheese (Ramazanov et al., 1980).

Richardson et al. (1980) reported an improvement in acid production and cheese quality when undefined commercial blends of lactic cultures were replaced with phage insensitive, single strains propagated either in pairs or in one multiple blend of five or six strains.

According to Chikuma et al. (1979), cheese ripening was hastened and a satisfactory cheesy flavour obtained after 30 days of ripening when a mixed Streptococcus cremoris + Leuconostoc citrovorum culture was used.

From a study on cows' milk cheese JobElias (1981) reported that cheese prepared from mixed starter Streptococcus lactis and Streptococcus faecalis showed the highest proteolytic and lipase activities. Such cheese also showed better body and flavour characters.

Investigating on Cheddar cheese Sukumaran (1982) tried varying combinations and quantities of starter organisms. The organoleptic scores reported by him for cheese ripened at 10°C for 120 days using different combinations were: 1.0 per cent Streptococcus lactis - 90.0; 2.0 per cent Streptococcus lactis - 95.0; and 4.0 per cent Streptococcus lactis - 90.0; 1.0 per cent Streptococcus lactis + Streptococcus thermophilus (1:1) - 92.0; 2.0 per cent Streptococcus lactis + Streptococcus thermophilus (1:1) - 92.0 and 4.0 per cent Streptococcus lactis + Streptococcus thermophilus - 91.0. The scores for a 1:1:1 mixture of Streptococcus lactis, Streptococcus thermophilus and Lactobacillus bulgaricus at 1.0, 2.0 and 4.0 per cent were 91.0, 90.0 and 89.0 respectively. Using a ratio of 1:1:2 of Streptococcus lactis, Streptococcus thermophilus and Lactobacillus bulgaricus, the cheese scored 90.0, 91.0 and 86.0 at 1.0, 2.0 and 3.0 per cent level of inoculum respectively. The organoleptic scores obtained for a combination of Streptococcus lactis, Str. thermophilus and Lactobacillus acidophilus in 1:1:1 ratio at 1.0, 2.0 and 4.0 per cent rate of inoculation were 94.0, 91.0 and 94.0 respectively, but when the ratio of these organisms was changed to 1:1:2 the scores were 95.0, 95.0 and 94.0 at 1.0, 2.0 and 4.0 per cent level of inoculation respectively.

Goat milk cheeses like all other cheeses utilize a variety of microorganisms in manufacture and aging to produce the final body and texture qualities. In many instances cheese is made without culture, relying on the natural flora to develop acid needed to cause protein coagulation (Galal, 1978; Kosikowski, 1978). Wide variations have been reported in the amount and species of organisms used in culturing (Efthymiou, 1974; Elias, 1972; Galal, 1978).

2.6. Renneting

Most varieties of cheese is prepared by using rennet as the coagulating agent. It is a very powerful milk coagulant and its effect in cheese making takes place in three phases (Chapman and Sharpe, 1981). The speed of coagulation and firmness of curd depend on various factors like temperature, quantity of rennet etc.

2.6.1. Types of rennet and other enzymes

Cheeses made with 50/50 mixture of pig pepsin and calf rennet was shown by Dan and Jespersen (1970) to have a quality equal to or better than that obtained by calf rennet alone.

In case of Edam and Emmenthal cheeses made with microbial

Noury (Mucor pusillus) or Suparen (Endothia paracitica) rennets, no difference was observed in the acidity, dry matter, fat, total nitrogen and salt content, but small differences were observed in proteolysis (Kyla-Siruola and Antila, 1970).

In a comparative study of 'Rennilase 46 C' rennet (from Mucor miehei) and calf rennet, Dennien (1977) showed that both rennets produced a satisfactory coagulum in 30 minutes when used at the recommended rates (calf rennet at 112 ml and Rennilase at 56 ml per 455 litre of milk). The cheeses thus produced were also of equal quality.

Minarik and Dolezalek (1977) have made cheese using mikrozym (a Czechoslovak preparation from Bacillus subtilis), Danish Rennilase and Lactochym.

Seven milk clotting preparations (calf rennet, rennet/pepsin, four enzymes from Mucor miehei and one from Mucor pusillus) were used to make Cheddar cheese. No significant difference in the composition of the cheeses could be attributed to the type of clotting enzyme (Wong et al., 1977).

Mulvihill et al. (1979) showed that piglet gastric proteinase was less proteolytic than calf chymosin towards α_{s1} casein at pH 5.8 or 5.2 and opined that the former may be used satisfactorily for making cheese in which the milk-clotting enzyme is not actively proteolytic against major caseins.

The effects of five milk clotting enzymes (including crude and purified enzymes from Bacillus subtilis K-26, calf rennet and 50:50 mixtures of the purified bacterial enzymes and calf rennet or swine pepsin) on the Cheddar cheese ripening and quality were investigated by Rao and Mathur (1979). On the basis of organoleptic evaluation, they found that cheese made with a 50:50 combination of purified bacterial enzyme and calf rennet was as acceptable as control cheese made with calf rennet.

Ogundiwin and Oke (1983) made Wara by using the juice from Sodom apple (Calotropis procera) for coagulating the curd.

2.6.2. Rennet coagulation time

Amer et al. (1974) studied the factors affecting the rennet coagulation time. They inferred that heating cow milk (CM) and buffalo milk (BM) for 10 minutes at 65.5°C to 82.2°C increased the rennet clotting time progressively. This was observed to a lesser extent with cow milk than with buffalo milk. They also found that addition of Calcium chloride at increasing concentrations to heated milk shortened the rennet clotting time.

Herian and Krcal (1974) found that with an increase in the total calcium content of milk, the coagulation time decreased somewhat. Enzymic coagulation occurred even when the calcium concentration exceeded 980 mg/litre, but increasing it to more than 1380 mg/litre did not decrease the coagulation time.

In a study using different microbial rennets, Minarik and Dolezalek (1977) found that with increasing rennet dose, the coagulation time decreased for all rennets by about the same degree. Further, he showed that increasing acidity of the milk to a maximum of 15.0°SH before the addition of the rennets reduced coagulation time particularly with Rennilase.

Rennet clotting time (RCT) was decreased by reduced pH, increased temperature and increased concentrations of rennet or added calcium. Only extremes of concentration or dilution of milk increased the rennet clotting time (Storry and Ford, 1982).

Dalgleish (1983) showed that the coagulation rate at a given temperature in the range of 15 to 40°C increased with the concentration of Ca^{2+}, but at high temperatures the coagulation rate became independent of the concentration of Ca^{2+}.

Storry <u>et al.</u> (1983) found the rennet clotting time to be negatively correlated with β - casein and total calcium.

2.6.3. Quantity of rennet

Dennion (1977) used calf rennet at the rate of 112 ml/455 litre and Rennilase at 56 ml/455 litre to obtain cheese of good quality.

For the preparation of Parmesan and Cheddar varieties, Chapman and Sharpe (1981) recommended a renneting rate of 25 ml per 100 litre and 22 ml per 100 litre of milk respectively.

2.7. Manufacturing Process

2.7.1. Cutting the curd

The purpose of cutting is to permit a large portion of whey to escape from the curd. The curd is ready to be cut when it will break cleanly, without shattering ahead of a thermometer that is inserted at an angle and raised slowly. Cutting too fine was found to increase the fat losses in whey (Tittsler, 1965).

2.7.1.1. Moisture expulsion

Reduction in curd particle size below 1/4" and increasing the time of dry stirring promoted moisture expulsion, but at the same time caused significant increase in fat losses (Feagen *et al.*, 1965). Further, they reported that when the curd cubes were cut into 1/4", 3/8", 1/2" and 3/4" thick and drained for 2½ hour the curd cubes contained 50.0, 53.0, 58.0 and 70.0 per cent moisture respectively.

According to Gilles (1976) decreasing the knife size for cutting the curd is one of the methods available to the cheese-maker for the reduction of the moisture content of Cheddar cheese.

Soulie (1979) recommended to cut the curd into particles the size of maize grains in the preparation of goats' milk chee

2.7.2. Cooking the curd

Most of the workers have stated that moisture expulsion was greater when the temperature of cooking was more. Thus, Mocquot and Bejambes (1960) reported that, in the case of goats' milk cheese, the cut curd was to be heated for 1 hour to 37°C and heating continued for 30 to 60 minutes.

Feagon *et al.* (1965) working on Cheddar cheese used a cooking temperature of 38 to 39°C. They were of opinion that moisture expulsion from the cheese could be increased by raising the cooking temperature and increasing the salt ratio without causing increased fat losses.

Heating hastened the expulsion of whey from the curd, increased elasticity and altered the bacterial flora. In case of Cheddar, Edam and Gouda where lactic acid organisms were used (*Streptococcus lactis*, *Streptococcus cremoris* in Cheddar, *Streptococcus diacetylactis* or Leuconostoc in Edam and Gouda), the cooking temperature was around 38°C (Webb *et al.*, 1974).

In the preparation of stirred curd cheddar or Monterey cheese, Kosikowski (1978) recommended a maximum cooking temperature of 38°C.

According to Chapman and Sharpe (1981), the curd was stirred in the whey and heated to 39 to 40°C over a period of 40 to 45 minutes (0.11 to 0.15 per cent lactic acid).

2.7.3. Cheddaring

The method of treatment of curd during piling or cheddaring varies from place to place but always involves further cutting, turning and piling to a greater height (Davis, 1976).

Gilles (1976) considered variations in cheddaring operation as a good method to control the moisture content of cheese.

Various changes occur in the curd during cheddaring. The starter bacteria continue to multiply and produce lactic acid at the rate of approximately 0.10 per cent every 20 minutes. Whey continues to get drained from the curd which becomes elastic, smooth and silky and eventually exhibits the characteristic 'chicken-breast' texture (0.60 to 0.80 per cent lactic acid) (Chapman and Sharpe, 1981).

2.7.4. Salting

Salt is normally added to cheese

i) to suppress growth of unwanted microorganisms;

ii) to assist physico-chemical changes in the curd;

iii) to slow down the growth of the lactic acid and other types of wanted microorganisms; and

iv) to give the cheese an appetising taste.

Salting may be performed by mixing salt with the broken curd, by rubbing salt on to the surface of the newly formed cheese, or by immersing the fresh cheese in brine (sodium chloride solution of about 20.0 per cent). The salt normally used in cheese making is about 2.0 per cent of the weight of the curd (Davis, 1965).

Gilles and Lawrence (1973) considered it desirable to salt the curd at relatively low titratable acidities (after 5 h at $\leqslant$ 0.65 per cent) if cheese was to be stored for 4 to 6 months or more.

In an experiment on salt distribution in Cheddar cheese, Fox (1974) detected high within-vat variations in the range of spread of salt. Further, he reported better salt distribution in cheeses made with automated salting systems than in cheeses salted using manually operated systems.

Raffaele (1978 publ. 1980) analysed 12 samples of goats' milk cheese aged 2 to 6 months and found a range of 3.61 to 6.69 per cent sodium chloride in it. Such cheeses, it was observed, were sometimes heat treated at 43 to 45°C with brining for 16 h at 8°C.

Kosikowski (1978) recommended addition of ½ lb of table salt per estimated 10 lb curd, shifting the salt over the curds and stirring regularly with spatula for 15 to 20 minutes.

2.7.5. Hooping, Pressing and Paraffining

All hard cheeses are pressed, sometimes under considerable pressure. After salting, the curd is thoroughly mixed, allowed to stand for a short time and filled into cloth-lined hoops or moulds under hand pressure. The cheese is then put to press under gentle pressure which is steadily increased upto about 1000 kg and finally to about 1750 kg in two hours (Davis, 1976).

Chapman and Sharpe (1981) recommended that salted curd should be delivered to cheese moulds and pressed hard (2 to 3 tonnes) for 15 to 18 h.

From an experiment on Cheddar cheese, Hoglund et al. (1972) concluded that vacuum pressing was the major contributory variable in reducing openness. They reported that open texture in Cheddar cheese was reduced by the use of homofermentat starters, non-flow cheddaring and vacuum pressing.

Various types of waxes are used for coating the surface of cheese. Davis (1965) suggested a complex mixture of ordinary paraffin wax and micro-crystalline waxes having a melting point of 52 to 54°C. The method involved immersion of the cheese in the wax for 5 ± 1 seconds at a temperature of 138 ± 3°C.

Similarly, Kosikowski (1978) outlined a procedure involving the immersion of the firm and dry cheese totally for 5 seconds in hot melted food wax. Alternately, he suggested the surfaces of unwaxed green cheese may be smeared with a layer of butter or margarine to seal them and prevent drying and mold invasions.

2.8. Ripening of cheese

According to Van Slyke and Price (1952) the temperatures maintained for cold-curing are usually from 32 to 34°F, ideal being 35°F and that for warm-curing 50 to 60°F.

The most suitable ripening temperature for waxed cheese was 10°C and for holding periods of 3 to 6 months the storage temperature should be 7°C (Davis, 1965).

Butkus *et al.* (1974) obtained best quality Cheddar cheese when the temperature during the first 1½ month was maintained at 12 to 13°C and subsequently reduced to 6 to 7°C for the following 1½ month of ripening. For subsequent storage (not exceeding 5 months) a temperature of 6 to 8°C was the optimum.

In an experiment Park et al. (1975) ripened cheese for 6 months at 10 ± 2°C and 90 ± 5 per cent relative humidity, whereas in a patent method Kratochvil (1978) recommended ripening the cheese for 4 to 10 weeks at 60 to 68°F.

According to Kosikowski (1978), Monterey cheese is cured by holding the buttered or waxed cheese, with occasional turning, on clean board surface in a cool area (4 to 15°C) for 2 to 6 months. If cheese was made from raw milk, it must be held for atleast 2 months above 2°C before consuming.

Sood and Kosikowski (1979) ripened cheddar cheese at 10°C for 3 months using various added microbial enzymes.

Different varieties of cheese have been ripened for different durations and at different conditions. The cheese had to be stacked one on the top of another to maximise utilization of floor space, but it was necessary to hold these cheeses at lower temperatures (6°C) to discourage gas production. This use of low temperature slowed down the ripening process, so these cheeses required a longer time to mature. Thus, a Cheddar cheese ripened at 6°C required 9 months to reach the same degree of maturity as could be reached by a cheese made from the same batch of curd in 6 months with ripening at 13°C (Law *et al.*, 1979).

Comparative studies on the ripening of cheddar cheese at three ripening temperatures namely, 10°, 15° and 18°C showed that ripening above 10°C invariably resulted in off flavour development and undesirable body and texture characteristics of cheese (Sukumaran, 1982).

2.8.1. Humidity

Storage of cheese in a room with high relative humidity was found to minimise evaporation losses from cheese surface. Holding one cheese at 15.5°C in a room in which the air was 75 to 80 per cent saturated with moisture while another identical cheese stored under a bell jar where the air was completely saturated with moisture, the first cheese lost over 11.0 per cent of its weight whereas the other gained almost 2.0 per cent in weight (Van Slyke and Price, 1952).

According to Chapman and Sharpe (1981) Cheddar and related types of cheese are matured on shelves at 15°C and 88.0 per cent relative humidity.

2.9. General changes during ripening

2.9.1. Acidity and pH

The rate and extent of acid development is an important factor influencing the texture and subsequent ripening of cheese.

A pH value between 5.40 and 5.50 at the time of milling the curd is considered desirable for making the best cheese (Wilson et al., 1945). They, further, opined that excessive H-ion concentration of titratable acidity at any given stage during the manufacture of cheese resulted in an inferior quality.

The pH value of cheese decreased to between 4.95 and 5.30, preferably between 5.05 and 5.20 during the first few days and thereafter, it increased slightly for a few months, but finally increased rapidly to approximately 5.30 to 5.50 in one year (Brown and Price, 1934).

The gradual increase in pH during cheese ripening is caused by destruction of the lactic acid, formation of non-acidic decomposition products and weaker or less highly dissociated acids, including acetic and carbonic acids followed by liberation of alkaline products of protein decomposition (Tittsler, 1965).

In an experiment on Edam cheese, Bilgi (1980) found that the values for pH ranged from 5.65 to 5.80 with an average of 5.73 for two days old cheese. By 135 days of ripening, the values ranged from 5.50 to 5.60 with an average of 5.55. The average pH values after 60, 90 and 120 days were 5.36, 5.42 and 5.50 respectively. The lowest pH of 5.26 was recorded after 30 days of ripening.

Analysing 12 samples of goats' milk cheese aged 2 to 6 months, Raffaele (1978, Publ. 1980) reported a wide pH range of 5.09 to 5.65.

From a study on the ripening of Chabichou type cheese during a 30-day period, Wolfschoon and Furtado (1979) reported that pH and lactic acid were increased and decreased respectively from 5.20 to 6.82 and from 0.83 to 0.05 per cent. The minimum and maximum pH values of 14 cheese samples analysed by these investigators between the first and fourth day after production were 5.20 and 5.30 respectively.

2.9.2. Moisture

Moisture content is one of the principal factors influencing the firmness of cheese. The moisture content varies from about 30.0 to 40.0 per cent in hard cheeses stored for a year or more. Semi-soft cheeses contain 39.0 to 50.0 per cent moisture, while soft cheeses have 50.0 to 75.0 per cent moisture, with a maximum limit of 80.0 per cent. Soft types are more perishable than hard ones. Under Federal standards of identity, Cheddar cheese should contain not more than 39.0 per cent moisture, unless suitably labelled as "excess moisture cheese" (Kosikowski, 1978).

The moisture content is most necessary for the activity of biological agents of ripening. Some of the moisture evaporates gradually because of various factors and some of it becomes intimately associated with proteins as ripening progresses (Van Slyke and Price, 1952).

Raffaele (1978, Publ. 1980) reported the moisture and fat content of 2 to 6 months old goats' milk cheese to be 25.78 to 44.25 per cent and 32.87 to 50.54 per cent respectively.

2.9.3. Chemical changes

2.9.3.1. Lipolytic changes

Honor and Tuckey (1951) have shown that agitation of cheese milk increased lipolysis during ripening of cheddar cheese.

Analysis of free fatty acids contents of domestic Edam, Gouda and Cheddar cheese showed that free fatty acids contents of these cheeses varied from 85.5 to 156.3 mg/100 g of cheese. Most of the samples contained acetic, n-butyric, caproic, caprylic and capric acids. Some samples of Gouda and cheddar cheese contained relatively large amounts of n-valeric and iso-valeric acids (Nakanishi et al., 1962).

The lipid fraction of milk is said to contribute more towards the development of flavour of cheese than any other component of milk. Whereas protein and lactose in milk are sources of many flavour precursor for Cheddar cheese, milk fat is perhaps more important as a contributor towards flavour production, since cheese made from skim milk does not develop a typical flavour (Ohren and Tuckey, 1969).

The fat content of cheese affects its ripening. Nakanishi and Hosono (1965) found that the Gouda cheese made from skim milk ripened slowly than the whole milk cheese. However, they noticed no difference in types and amounts of amino acids between the two types of cheese.

Patton (1963) found that acetic acid was the dominant volatile acid in Cheddar cheese and the absence of this compound from the mixture of volatile fatty acids resembled hydrolytic rancidity caused by hydrolysis of milk fat.

Thakur et al. (1975) demonstrated that salt was an important factor determining the changes in fat during ripening. They showed that unsalted cheddar cheese had more fat hydrolysis than controls. During 12 weeks, volatile fatty acids in unsalted cheese increased from 22.9 to 28.9 ml 0.1 N acid/100 g while the controls ranged from 16.7 to 22.6 ml.

Bhat et al. (1978) were of the opinion that free fatty acids as a whole appeared to play some role in Cheddar cheese flavour. They showed that, at the end of 7 months ripening period, the total free fatty acids (TFFA) increased to 3.9 and 2.8 μ mol/g fat and the steam volatile free fatty acids (SVFFA) increased to 0.35 and 0.26 μ mol/g fat in cow and buffalo cheeses respectively.

Decomposition of fat in cheese is not extensive, but some hydrolysis of fat occurs during cheese ripening and the products of greatest importance are volatile lower fatty acids, including butyric, caproic, caprylic and capric (Chapman and Sharpe, 1981).

Babel and Hammer (1945) have shown that rennet is also a source of lipase, rennet paste causing more lipolysis and a better flavour than rennet extract.

From a systematic study on the lipolytic activity of lactic streptococci, Stadhouders and Veringa (1973) concluded that those organisms hydrolysed mono and diglycerides, although their activity against triglycerides was very weak.

In a study on commercial milk, Law *et al.* (1976) observed highest incidence of lipolytic activity among psychrotrophic gram-negative flora in strains of *Pseudomonas fluorescens* and *Ps. fragi*.

Similarly, Singh *et al.* (1976) observed more liberation of butyric and higher fatty acids and formation of larger quantities of volatile fatty acids in experimental Cheddar cheese using *Pseudomonas fragi* P - 80, *Serratia marcescens* SM - 40, *Micrococcus freudenreichi* MF-1 and *Sarcina lutea* SL - 51.

2.9.3.2. Carbohydrate breakdown

It has been observed by Suzuki *et al.* (1910) that lactose disappears from fresh cheese in 3 to 6 days. The lactose present in cheese is converted in part by microorganisms to acetic and propionic acids.

Hiscox *et al.* (1941) found that the acetic acid derived from the lactose constituted the bulk of the volatile acids of the cheese.

The milk sugar in unripened cheese is quickly used by microorganisms present. Lactic acid has been found to be the principal product of this fermentation but smaller amounts of other acids are also formed (Van Slyke and Price, 1952).

2.9.3.3. Proteolysis of cheese

Van Slyke and Hart (1903) and Van Slyke and Price (1952) claimed that proteolysis in cheese begins with addition of rennet to the milk.

Van Slyke and Hart (1903) found that in one year ripening period, the water soluble nitrogen increased to 44.70 per cent, amino nitrogen to 28.40 per cent and ammonia nitrogen to 5.40 per cent of the total nitrogen.

Webb *et al.* (1974) also stated that paracasein and minor proteins are gradually converted to simpler nitrogenous compounds namely, proteoses, peptones, amino acids and ammonia. They have attributed the rate and extent of proteolysis to various factors like

i) increase in ripening temperatures;

ii) quantity of the rennet;

iii) moisture content of the cheese;

iv) salt content of the cheese;

v) larger size of cheese and

vi) acidity of the cheese.

In a study of Cheddar cheese, Park *et al.* (1975) reported the level of water soluble nitrogen to be 28.0, 39.0 and 59.0 per cent of total nitrogen at 4, 12 and 24 weeks of ripening respectively, while the corresponding values for non-protein nitrogen were 9.0, 17.0 and 22.0 per cent.

During a 12 week period, Thakur *et al.* (1975) found that the average soluble nitrogen of unsalted Cheddar cheese increased from 7.0 to 39.0 per cent of the total nitrogen, while the values for control ranged from 5.9 to 22.5 per cent.

Total nitrogen content in cheese immediately after manufacture and in waxed and unwaxed cheeses after 6 months ripening was 22.10, 26.00 and 35.52 per cent respectively. The corresponding contents of water soluble nitrogen as per cent of total nitrogen were 6.78, 27.64 and 16.47 per cent (Park et al., 1978).

According to Mulvihill et al. (1979) piglet gastric proteinase was less proteolytic than calf chymosin towards bovine αS_1- casein at pH 5.8 or 5.2.

Cheddar cheeses treated with microbial enzymes developed higher soluble protein and free volatile fatty acids and displayed better flavour and greater acceptability than control cheeses. Increased rate of proteolysis in enzyme - treated cheese had a direct relation to accelerated ripening (Sood and Kosikowski, 1979).

JobElias (1981) observed a definite correlation between proteolytic activity, ammonia liberation and reduction in total nitrogen and increase in water soluble nitrogen. Further, it was noted that the highest proteolytic and lipolytic activities occurred in cheese prepared from mixed starter *Streptococcus lactis* + *Streptococcus faecalis*.

Wolfschoon and Furtado (1979) analysed 28 samples of

Chabichou - type cheese and reported that soluble nitrogen amounted to 45.0 per cent of total nitrogen after 30 days.

Wolfschoon - Pombo and Furtado (1979) working on Chabichou cheese reported that soluble nitrogen increased from about 10.0 to 45.0 per cent of total nitrogen during the first 30 days of ripening.

2.9.4. Coliform bacteria

Coliforms are considered as "sanitary indicators" and therefore the presence of coliforms in a pasteurized product indicates post-pasteurization contamination. This indirectly points to the degree of sanitation adopted during the manufacture of the product.

Escherichia coli was determined at various stages of cheese making operation after the cheese skim milk was inoculated to give counts of 2.5×10^4 or 4.0×10^5 cells/ml. The numbers of coliform organisms remained constant at the inoculated concentration in the cheese milk upto a cooking temperature of 43°C. At 43°C, when the curd was separated from the whey, the curd (not washed) had coliform counts that were two log cycles greater than the whey (Vecchianocce *et al.*, 1978).

Luck and Dunkeld (1981) analysed 130 samples of 4 to 8 weeks old cheese for faecal <u>Escherichia coli</u> and total coliform counts. They found that <u>E. coli</u> were present in 86.0 per cent of all samples. Their count ranged from less than 1.0 to more than 50 000/g, with 43.0 per cent samples containing less than 100/g. The total coliform count ranged from less than 1.0 to 36×10^6/g, with 40.0 per cent of samples containing less than 100/g.

Nielsen (1976) opined that coliforms normally found in Cheddar cheese present no public health problem. A decreasing trend of coliforms could also be observed during ripening.

Elliot (1978) reported that coliform count decreased quite rapidly with time in most samples, but some samples maintained a substantial population for a considerable time.

Luck and Dunkeld (1981) suggested that the standards for 4 to 8 weeks old cheese should be less than 100/g, less than 1000/g, less than 1500/g and less than 10 000/g for faecal coliforms, total coliforms, Enterobacteriaceae and faecal streptococci respectively.

However, Elliot (1978) concluded that coliform count was not a reliable index for comparing the quality of different lots of cheese, even at the same age.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. Milk

Pooled raw milk from cows and goats were obtained from the University Livestock Farm, Mannuthy and the A.I.C.R.P. on Goats for Milk, Mannuthy respectively.

3.2. Analysis of milk

3.2.1. Collection of milk samples

The samples of milk required for the analysis of milk were collected as per ISI standards (IS : 1479, Part I, 1960).

3.2.2. Chemical analysis of milk samples

The following chemical analyses were carried out.

3.2.2.1. Fat

The fat percentage in milk was determined according to the procedure described in the ISI Standards (IS : 1224, 1958).

3.2.2.2. Protein

Determination of the protein content of milk was carried out by the dye binding method using Amido black (Pearson, 1976)

3.2.2.3. Acidity

The titratable acidity of milk was estimated following the ISI specifications (IS : 1479, Part II, 1961).

3.2.2.4. Lactose

The lactose content of milk was determined using the Benedict's method.

3.2.2.5. Total solids

The Zeal lactometer reading was corrected to 84°F and the total solids derived using the modified method suggested by Mathew and Subrahmanyam (1983).

3.3. Starter cultures

Pure cultures of *Streptococcus lactis* and *Str. thermophilus* were obtained from National Dairy Research Institute, Bangalore.

3.3.1. Maintenance and Propagation of starter cultures

The pure cultures were maintained by propagating them daily in sterilized skimmed litmus milk. The inoculated cultures of *Str. lactis* were incubated at room temperature whereas those of *Str. thermophilus* were incubated at 37°C. The activated cultures were transferred to sterilized skimmed milk at 2.0 per cent level to obtain feeder cultures.

3.4. Preparation of cheese

3.4.1. Materials

The following materials were used for cheese making:

Cheese vat, strainer, cheese knives, wooden hoops, muslin cloth, laddle, stainless steel knife, hot and cold water, BOD incubator and Refrigerator.

3.4.1.1. Cheese vat

A rectangular double jacketed laboratory model cheese vat was used (Fig.1). The size of the vat was 40 x 25 x 18 cm and its capacity was 10.1. This was cleaned thoroughly and sterilized by scalding with hot water before use.

3.4.1.2. Cheese knives

Separate stainless steel cheese knives with vertical and horizontal blades were used to cut the coagulum into 1 cm cubes (Fig.2).

3.4.1.3. Strainer

A clean and sterile stainless steel strainer was used for draining the whey from the cheese vat.

3.4.1.4. Stainless steel knife

Sterilized stainless steel knife was used to mill the curd into pieces of uniform size.

3.4.1.5. Wooden hoops

Cubical wooden hoops which were cleaned and soaked in scalding water for 30 min. were used for hooping and pressing the curd (Fig.2).

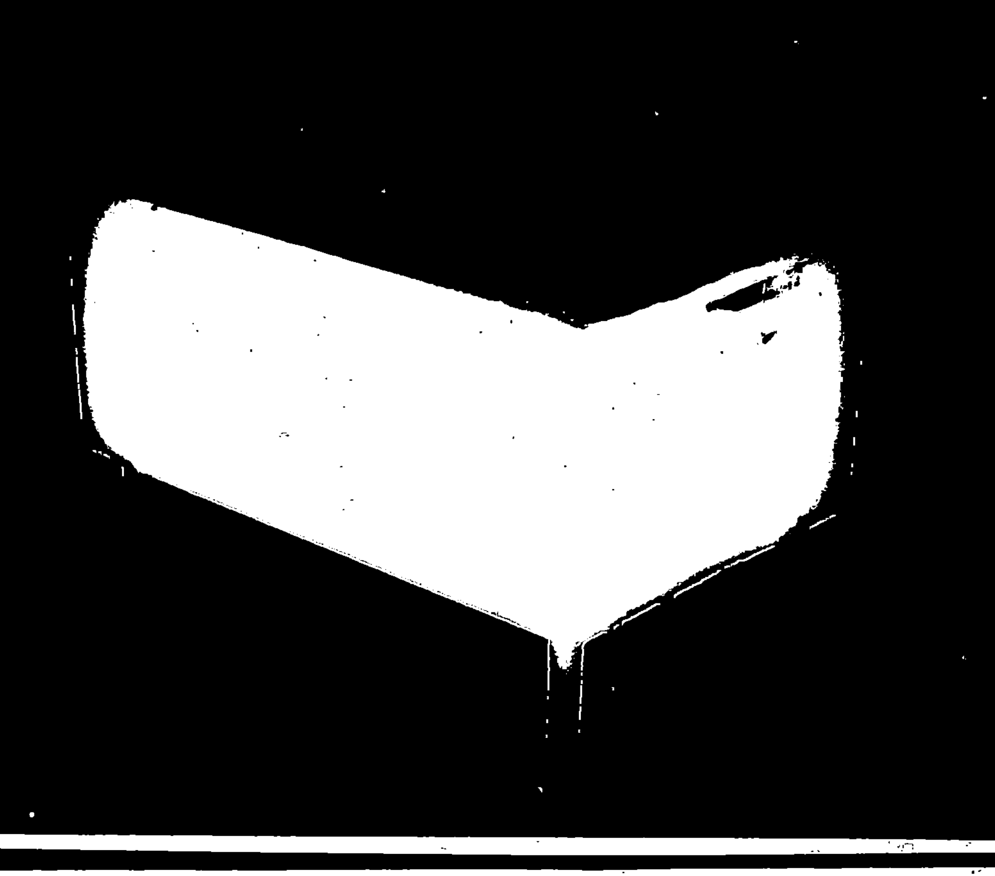
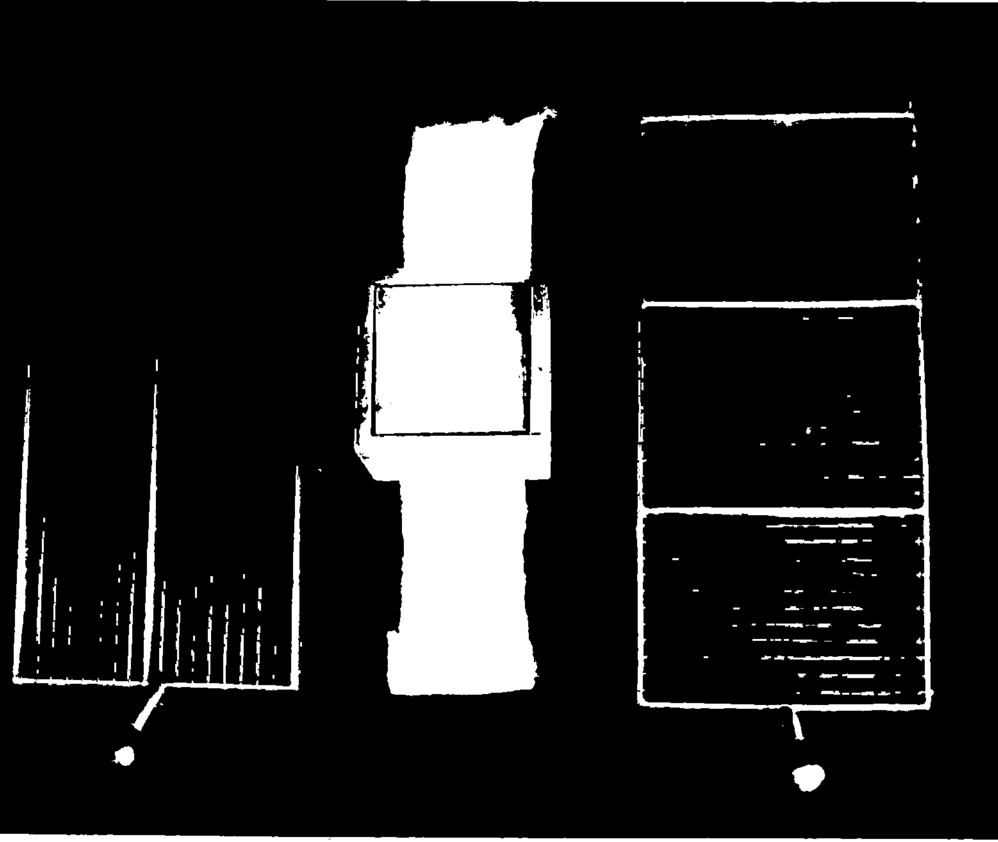


Fig.1. Laboratory Model Cheese Vat.



A B A

Fig.2 A. Cheese knives

B. Cheese hoop

3.4.1.6. Muslin cloth

Clean strips of muslin cloth soaked in scalding water for 30 min and later immersed in salt solution were used as cheese cloth for hooping and pressing.

3.4.1.7. BOD incubator and Refrigerator

These equipments served the purpose of providing desired temperature for curing. The relative humidity in the BOD incubator and refrigerator was maintained at 85.0 per cent.

3.4.2. Methods

Three batches of cheese were made each from cows' and goats' milk by the same procedure (Appendix-I).

3.4.2.1. Setting of milk

The raw milk was strained and pasteurized at 72.6°C for 15 s and cooled to 30°C. This milk was then transferred to the cheese vat. Ten millilitre of a 40.0 per cent solution of calcium chloride was added to 10 litres milk. Then the culture (a mixture of equal parts of *Str. lactis* and *Str. thermophilus*) was added to the cheese milk at 2.0 per cent level. This was mixed well and allowed to stand till the acidity increased by about 0.02 per cent. Then, 0.3 ml of Rennilase diluted to 1:30 with distilled water was added to

10 litres milk. This was mixed well and allowed to set into a firm coagulum.

3.4.2.2. Cutting the curd

The curd was first cut with the horizontal cheese knife along the long axis of the vat and then with the vertical cheese knife both, along the long and short axis of the vat. The curd particles so obtained were left undisturbed for 10 min.

3.4.2.3. Cooking the curd

The curd cubes were cooked in whey. The temperature of the curd was enhanced from 31°C to 38°C at the rate of 1°C for every 5 minutes. Meanwhile, the curd was gently agitated at intervals. The maximum temperature of 38°C was maintained until the acidity of the mass returned to that of the milk used. Following the cooking, the whey was drained off.

3.4.2.4. Draining the whey

The warm whey was drained through the metallic strainer and the curd particles trapped in it were returned to the vat.

3.4.2.5. Cheddaring

The curd in the vat was spread as an even layer and cut into two. The piling, repiling and rolling on longitudinal and horizontal axis were carried out at intervals of fifteen minutes.

3.4.2.6. Milling the curd

The cheddared blocks of curd were hand-milled using a stainless steel knife. The curd pieces were gently agitated in the vat during the progress of this operation.

3.4.2.7. Salting

Dry salting was done to the milled curd at the rate of 2.0 per cent.

3.4.2.8. Hooping and Pressing the curd

The cheese hoop was lined with the moist cloth and filled with curd pieces. A wooden board was placed on the top of hooped curd and pressed overnight, at room temperature, using weights.

3.4.2.9. Curing or ripening

The block of cheese was removed from the hoop on the following day and kept overnight in a cool and dry place for the surfaces to dry. The dried cheese block was cut into two halves and paraffined using food grade paraffin. One of the blocks was placed in a BOD incubator set at 10°C (RH. 85 per cent) and the other in a Refrigerator at 5°C (RH 85 per cent).

3.5. Analysis of cheese

3.5.1. Chemical analysis

3.5.1.1. Sampling

The cheese samples were collected at the beginning of ripening (O-day) and at the end of 13 weeks of ripening as per the methods laid down by ISI (IS : 2785, 1964).

3.5.1.2. Fat

The fat content in cheese was estimated in 5.0 g of cheese by the Gerber's method (Davis and MacDonald, 1953).

3.5.1.3. Moisture

Analysis of cheese for its moisture content was performed following the ISI specifications (IS 2785, 1964).

3.5.1.4. H-ion concentration (pH)

Ten grams of cheese sample was mixed with 10 ml of distilled water until a fine paste was obtained. pH readings of the samples were recorded using a digital pH meter.

3.5.1.5. Salt

Determination of salt content of cheese was made following the procedure laid down by ISI (IS : 2785, 1964).

3.5.1.6. Nitrogen (Protein)

3.5.1.6.1. Total nitrogen (Total Protein)

The total nitrogen content of cheese was determined using an aliquot containing 0.75 g of cheese, according to the method described by Kosikowski (1978).

3.5.1.6.2. Soluble Nitrogen (Soluble Protein)

Aliquots containing 1.5 g cheese was used for the estimation of soluble nitrogen, as per the method Kosikowski (1978).

3.5.1.7. Steam volatile Free Fatty Acids (SVFFA)

Ten grams of cheese fat was steam distilled until 100 ml of the distillate was collected. The distillate was titrated against 0.01 N KOH in Methanol. Results are expressed as μ mol/g fat (Ramamurthy and Narayanan, 1974).

3.5.2. Bacteriological Analysis

The bacteriological analysis of cheese was done to determine the coliform count.

3.5.2.1. Sampling

Cheese samples were collected aseptically at 0-day and after 13 weeks of ripening according to the APHA method (Olson et al., 1978).

3.5.2.2. Coliform count

Appropriate dilutions of the cheese homogenates were plated using violet red bile agar medium. The plates were incubated at 32°C for 24 h for the development of the colonies (Olson et al., 1978), and the results expressed as colony forming units per gram cheese ($cfug^{-1}$).

3.5.3. Sensory evaluation

A panel of judges consisting of three members evaluated the cheese using a score card (Appendix-II) modified slightly from that suggested by Van Slyke and Price (1952). The Marks allotted were:

Flavour	45
Body and texture	40
Finish	15

3.5.4. Estimation of yield of cheese

The weight of green cheese obtained in each batch was recorded using a sensitive balance. Based on the composition of milk used, the yield of cheese was estimated using the following formulae:

1. Formula of Van Slyke and Price
   $Y = 1.63 (C + F)$ where
   Y : Yield of cheese
   C : Casein content of milk
   F : Fat content of milk.

2. Formula of Van Slyke
   $Y = 1.40 (C+F) - 1.04$ where
   Y : Yield of cheese
   C : Casein content of milk
   F : Fat content of milk.

3. Formula of McDowall
   $Y = 1.22 (C+F) + 2.32$ where
   Y : Yield of cheese
   C : Casein content of milk
   F : Fat content of milk.

4. Formula - 1
   $Y = 2.3 F + 1.4$ where
   Y : Yield of cheese
   F : Fat per cent of milk.

5. Formula - 2

$Y = 2.7\ F$ where

Y : Yield of cheese

F : Fat per cent of milk.

3.5.5. Statistical analysis

The experiment was laid out and analysed as a 2^3 factorial with three replications (Snedecor and Cochran, 1967).

The data on Sensory evaluation of ripened cheese were analysed as a 2 x 2 x 3 factorial experiment.

In order to evaluate the efficiency of different formulae to estimate the yield of cheese, a non-parametric test proposed by Friedman (Steel and Torrie, 1960) was used. The modulus of the difference between the actual yield and those obtained using different formulae was used as the observations for the above test.

RESULTS

RESULTS

4.1. Chemical composition of milk

4.1.1. Goats' milk

The composition of goats' milk used in the preparation of cheese is presented in Table 1. The fat content ranged from 4.00 to 5.10 per cent with an average of 4.57 ± 0.32 per cent. The protein content had a range of 3.97 to 4.13 per cent with an average of 4.04 ± 0.05 per cent while the corresponding values for lactose were 4.47 to 5.32 and 4.90 ± 0.25 per cent. The total solids (TS) of goats' milk was distributed in the range of 13.40 to 15.30 per cent with an average value of 14.31 ± 0.55 per cent. The range and average values of solids-not-fat (SNF) of goats' milk were 9.40 to 10.20 and 9.74 ± 0.24 per cent respectively.

4.1.2. Cows' milk

The data presented in Table 2 indicate the composition of the milk of cows. The fat content was found to have a range of 3.80 to 4.70 per cent with an average of 4.33 ± 0.27 per cent while the corresponding values for protein and lactose were 3.41 to 3.86 and 3.68 ± 0.14 per cent and 4.90 to 5.40 and 5.13 ± 0.15 per cent respectively. The total solids content of cows' milk was distributed in the range of 13.18 to 14.58

per cent with an average of 13.86 ± 0.36 per cent while the corresponding values for solids-not-fat were 9.38 to 9.68 and 9.53 ± 0.09 per cent.

4.2. Acid development during cheese making

4.2.1. Goats' milk

Table 3 depicts the titratable acidity of milk or whey at various stages of cheese manufacture. The range of acidity before addition of starter was 0.19 to 0.25 per cent with an average value of 0.217 ± 0.018 per cent while the corresponding values at the time of renneting were 0.24 to 0.27 and 0.25 ± 0.01 per cent lactic acid. After cutting, the acidity ranged from 0.13 to 0.17 with an average of 0.153 ± 0.012 per cent lactic acid while the values after cooking were 0.16 to 0.22 and 0.190 ± 0.017 per cent respectively. The whey showed a range of 0.27 to 0.57 per cent lactic acid with an average of 0.433 ± 0.088 per cent at the end of cheddaring operations.

4.2.2. Cows' milk

The acidity of the milk or whey at various stages of manufacture of cheese is presented in Table 4. The titratable acidity at the time of addition of starter ranged from 0.17 to 0.18 per cent lactic acid with an average of 0.177±0.005 per cent. The average acidity at the time of renneting was

0.213 ± 0.006 per cent lactic acid with a range of 0.20 to 0.22 per cent. After cutting, the acidity decreased to an average value of 0.137 ± 0.003 per cent lactic acid with a range of 0.13 to 0.14 per cent. There was a gradual increase in the acidity during cooking and reached an average value of 0.173 ± 0.003 per cent lactic acid with a range of 0.17 to 0.18 per cent by the end of the process. The cheddaring operations produced a sharp increase in the acidity which, by the end of the process, reached a maximum average value of 0.50 ± 0.025 per cent with a range of 0.47 to 0.55 per cent lactic acid.

4.3. Yield of cheese

4.3.1. Goats' milk cheese

The yield of cheese obtained from goats' milk is presented in Table 1. An average of 1.43 ± 0.08 kg of green cheese was obtained from 10.0 litres of goats' milk and the yield varied from 1.320 to 1.580 kg.

4.3.2. Cows' milk cheese

On an average, cows' milk yielded 1.145 ± 0.060 kg of green cheese per 10.0 litres milk with the yield varying from 1.035 to 1.250 kg (Table 2).

4.3.3. Evaluation of different formulae

The actual yields of green cheese (gravimetric) obtained in the study and those estimated using various formulae are presented in Table 5. The average yield of green cheese estimated from 10.0 litres of goats' milk using the formula of Van Slyke and Price, Van Slyke, McDowall, Formula-1 and Formula-2 was 1.258 ± 0.557, 1.185 ± 0.479, 1.174 ± 0.416, 1.190 ± 0.073 and 1.233 ± 0.035 kg respectively while the ranges for the corresponding formulae were 1.163 to 1.356, 1.103 to 1.269, 1.103 to 1.247, 1.060 to 1.313 and 1.080 to 1.377 kg.

In the case of green cheese from 10.0 litres of cows' milk, the average yield was estimated to be 1.174 ± 0.046, 1.113 ± 0.039, 1.111 ± 0.034, 1.137 ± 0.063 and 1.170 ± 0.074 kg using the formulae of Van Slyke and Price, Van Slyke, McDowall, Formula-1 and Formula-2 respectively while the corresponding ranges estimated were 1.099 to 1.257, 1.049 to 1.184, 1.055 to 1.173, 1.014 to 1.221 and 1.026 to 1.269 kg respectively.

Statistical analyses of the data showed that there was no significant difference between the actual yield obtained and those computed using the five formulae (Tables 6 and 7). However, the formulae have been ranked in the order of their suitability based on the mean of their rank values ($\overline{r}_i$). In case of goats' milk cheese, the best formula was found to be that suggested by Van Slyke and Price which had the lowest

$\bar{F}_i$ value of 1.33. The other formulae in the order of their descending merit were formula-2, Van Slyke's formula, formula-1 and McDowall's formula which had $\bar{F}_i$ values of 2.33, 3.50, 3.67 and 4.17 respectively. In the case of cheese from cows' milk, the formula of Van Slyke and Price showed the least $\bar{F}_i$ value of 2.33 suggesting it to be the best one. The others in the order of their descending merit were formula-2, formula-1, Van Slyke's formula and McDowall's formula which showed $\bar{F}_i$ values of 2.67, 3.00, 3.17 and 3.83 respectively.

4.4. Chemical analysis of cheese

4.4.1. Moisture content of cheese

The moisture content of goats' milk cheese is furnished in Tables 8 and 9. The range of moisture in green cheese was 30.00 to 34.92 per cent with an average of 32.26 ± 1.43 per cent. Cheese ripened at 5°C showed an average value of 26.96 ± 0.32 per cent and had a range of 26.62 to 27.60 per cent while those ripened at 10 °C had an average of 29.45 ± 0.74 per cent and a range of 28.14 to 30.70 per cent.

Green cheese from cows' milk was found to contain 31.38 to 34.86 per cent moisture with an average of 33.05 ± 1.07 per cent (Table 10). The range of moisture in cows' milk cheese ripened at 5°C and 10°C was 26.56 to 30.04 and 27.00 to 30.00 per cent with the average values of 27.83 ± 1.11 and 28.07 ± 0.97 per cent respectively (Table 11).

The analysis of variance indicated a highly significant difference ($P \leq 0.01$) in the moisture content of green and ripened cheese irrespective of the species and temperature of ripening (Table 12).

4.4.2. <u>Fat content of cheese</u>

Tables 8 and 9 illustrate the fat content of green and ripened cheese from goats' milk. Green cheese was found to contain an average of 33.33 ± 1.20 per cent fat while the range was 31.0 to 35.0 per cent. In the case of cheese ripened at 5°C and 10°C, the range and average values were 34.0 to 36.0 and 35.0 ± 0.58 per cent and 35.0 to 36.0 and 35.33 ± 0.33 per cent respectively.

On moisture free basis the green cheese from goats' milk contained 47.63 to 50.0 per cent fat with an average of 49.18 ± 0.77 per cent while the corresponding values for cheese ripened at 5°C and 10°C were 46.33 to 49.72 and 47.92 ± 0.98 per cent and 48.71 to 51.08 and 50.10 ± 0.71 per cent respectively (Table 14).

Data relating to the fat content of cows' milk cheese are represented in Tables 10 and 11. The green cheese was found to contain 34.0 to 35.0 per cent fat with an average of 34.33 ± 0.33 per cent. Ripening of cheese at 5°C increased the fat content to 37.0 to 38.0 per cent with an average of 37.67 ± 0.33 per cent while in cheese ripened at 10°C the range and average values were 37.0 to 39.0 per cent and 38.0 ± 0.58 per cent respectively.

Green cheese from cows' milk was found to contain 50.67 to 52.20 per cent fat on moisture free basis with an average of 51.29 ± 0.46 per cent. The range and average values of fat, on moisture free basis, in cheese ripened at 5°C and 10°C were 50.38 to 54.32 and 52.22 ± 1.14 per cent and 52.05 to 53.70 and 52.87 ± 0.48 per cent respectively.

The analysis of variance of the data, presented in Table 13, revealed that the cheese obtained from cows' milk and goats' milk had highly significant difference in their fat content ($P \leqslant 0.01$). A highly significant difference was noted ($P \leqslant 0.01$) between the fat content of green and ripened cheese irrespective of the temperature of ripening.

4.4.3. Protein content of cheese

4.4.3.1. Total protein

The total protein content of goats' milk cheese is presented in Tables 8 and 9. Green cheese had an average total protein content of 28.35 ± 0.86 per cent with a range of 26.80 to 29.77 per cent. The range and average protein contents of cheese ripened at 5°C and 10°C were 32.24 to 34.38 and 33.30 ± 0.62 per cent and 31.26 to 35.18 and 33.06 ± 1.14 per cent respectively.

On moisture free basis the green cheese from goats' milk was found to contain 41.18 to 42.53 per cent protein with an average value of 41.83 ± 0.39 per cent. The range of protein, on moisture free basis, in cheese cured at 5°C and 10°C was 44.53 to 46.88 and 45.11 to 48.96 per cent while their corresponding average values were 45.59 ± 0.69 and 46.85 ± 1.13 per cent respectively (Table 14).

Tables 10 and 11 illustrate the total protein content of cows' milk cheese. The range of protein content in green cheese was 23.17 to 29.77 per cent, in cheese cured at 5°C 28.26 to 32.22 per cent and in cheese cured at 10°C 29.75 to 32.75 per cent while the corresponding average protein content was 26.58 ± 1.91, 30.58 ± 1.19 and 31.75 ± 1.00 per cent respectively.

Table 14 presents the total protein content of cows' milk cheese on moisture free basis. Green cheese had a protein content of 35.57 to 43.38 per cent on moisture free basis and the average value was 39.63 ± 2.26 per cent. Cheese cured at 5°C had an average protein content of 42.34 ± 1.03 per cent on moisture free basis with a range of 40.39 to 43.87 per cent while the values for cheese cured at 10°C were 44.12 ± 0.81 and 42.50 to 44.99 per cent respectively.

The analysis of variance (Table 15) revealed significant difference in the total protein content of goats' milk cheese and cows' milk cheese ($P < 0.05$). A highly significant difference ($P \leq 0.01$) was observed in the total protein content of green and ripened cheese irrespective of the temperature of ripening.

4.4.3.2. Soluble protein

Data presented in Table 16 indicate the soluble protein content of goats' milk cheese. Green cheese was found to contain 2.98 to 3.72 per cent soluble protein with an average of 3.23 ± 0.25 per cent. All the cheese samples ripened at 5°C showed a soluble protein content 5.96 per cent while the cheese ripened at 10°C had values ranging from 6.70 to 8.93 per cent with an average of 8.19 ± 0.74 per cent.

The soluble protein in green cheese made from cows' milk was found to be distributed in a range of 3.72 to 4.47 per cent with an average of 3.97 ± 0.25 per cent. The cheese cured at 5°C showed an average of 7.69 ± 0.25 per cent soluble protein and a range of 7.44 to 8.19 per cent while the corresponding values for cheese cured at 10°C were 10.92 ± 0.66 and 9.68 to 11.17 per cent respectively (Table 17).

The analysis of variance (Table 18) showed a highly significant difference ($P \leqslant 0.01$) in the soluble protein content of cheese made from goats' and cows' milk. A highly significant difference was also noticed ($P \leqslant 0.01$) between green and ripened cheese in their soluble protein content and also between cheese cured at 5°C and 10°C. The temperature x period of ripening produced a highly significant interaction ($P \leqslant 0.01$) and the species x period of ripening produced significant interaction effects ($P \leqslant 0.05$) in the soluble protein content of cheese.

Based on the critical difference, it was seen that goats' milk cheese and cows' milk cheese were homogenous with regard to soluble protein at the beginning of ripening, but at the end of ripening they differed significantly both among themselves and with their pre-ripening values (Table 27). Comparison of the mean values also showed that the soluble protein content of cheese ripened at 5°C and 10°C differed from each other and from their pre-ripening values (Table 28).

4.4.4. Salt content

Data on the concentration of salt in goats' milk cheese are furnished in Tables 8 and 9. Green cheese was found to contain 1.23 to 1.24 per cent salt with an average of 1.23 ± 0.003, whereas the corresponding values for cheese ripened at 5°C and 10°C were 1.36 to 1.61 and 1.52 ± 0.08 per cent and 1.37 to 1.39 and 1.38 ± 0.006 per cent respectively.

The salt content of green cheese obtained from cows' milk ranged from 0.94 to 1.74 per cent with an average of 1.25 ± 0.25 per cent (Table 10). Cheese ripened at 5°C had an average salt content of 1.49 ± 0.02 per cent with a range of 1.46 to 1.52 per cent while the corresponding figures for cheese ripened at 10°C were 1.41 ± 0.04 and 1.34 to 1.46 per cent respectively (Table 11).

The analysis of variance (Table 19) showed that ripening had a significant effect ($P \leq 0.05$) on the salt content of cheese irrespective of the species.

4.4.5. Steam volatile free fatty acids (SVFFA)

Table 15 illustrates the SVFFA content of goats' milk cheese. Green cheese contained 0.90 to 2.00 μ mol/g fat SVFFA with an average of 1.50 ± 0.32 μ mol/g fat. Cheese cured at 5°C had an average SVFFA content of 4.13 ± 0.23 μ mol/g fat and a range of 3.90 to 4.60 μ mol/g fat while the corresponding figures for cheese cured at 10°C were 9.33 ± 0.97 and 7.40 to 10.40 μ mol/g fat respectively.

In the case of cheese prepared from cows' milk, the range of SVFFA content in green cheese, cheese ripened at 5°C and cheese ripened at 10°C was 1.50 to 1.90, 3.10 to 3.70 and 7.20 to 8.50 μ mol/g fat respectively. The corresponding average values were 1.73 ± 0.12, 3.33 ± 0.19 and 7.77 ± 0.50 μ mol/g fat respectively (Table 17).

Table 20 gives the analysis of variance for the SVFFA content of cheese. The temperature of ripening had highly significant effects at 1.0 per cent confidence level. SVFFA differed highly significantly ($P \leqslant 0.01$) between green and ripened cheese and the temperature x ripening interaction was also highly significant ($P \leqslant 0.01$). A significant effect ($P \leqslant 0.05$) was also found for species x ripening interaction.

On further examination, it was found that the SVFFA content of goats' and cows' milk cheese changed significantly during ripening after which the cheese from the milk of these two species had significant difference in their SVFFA content (Tables 27 and 28).

4.5. Hydrogen-ion concentration (pH)

Data presented in Table 16 represent the pH of goats' milk cheese. Green cheese showed a pH range of 5.0 to 5.19 with an average of 5.11 ± 0.06. The range and average pH values of cheese ripened at 5°C and 10°C were 5.23 to 5.36 and 5.30 ± 0.04 and 5.31 to 5.37 and 5.34 ± 0.02 respectively.

Green cheese from cows' milk had a pH range of 5.15 to 5.37 with an average of 5.23 ± 0.07. Cheese ripened at 5°C were found to be in the pH range of 5.24 to 5.35 with an average of 5.29 ± 0.03 while those ripened at 10°C had a range of 5.29 to 5.37 and an average of 5.33 ± 0.02.

The analysis of variance (Table 21) showed that ripening had a highly significant effect on the pH of cheese ($P \leqslant 0.01$), irrespective of the species.

4.6. Coliform count

Tables 8 and 9 furnish the coliform count of goats' milk cheese. Green cheese had counts ranging from 250 to 550 cfu/g with an average of 386.67 ± 86.86 cfu/g while cheese ripened at 5°C and 10°C did not show any coliforms.

Green cheese from cows' milk had an average load of 210 ± 115.9 cfu/g with a range of 250 to 400 cfu/g while cheese ripened at 5°C and 10°C contained no coliforms (Tables 10 and 11).

4.7. Sensory evaluation of cheese

Data on the sensory evaluation of goats' milk cheese ripened at 5°C and 10°C are presented in Tables 22 and 23. The total score of cheese ripened at 10°C ranged from 77 to 95 with an average of 85.78 ± 1.89. The range and average values for the flavour, body and texture and finish were 35 to 42 and 39.22 ± 0.81, 25 to 39 and 34.33 ± 1.52 and 10 to 14 and 12.22 ± 0.40 respectively. Cheese ripened at 5°C showed a total score in the range of 77 to 92 with an average of 85.22 ± 1.75. The range and average values for the flavour, body and texture and finish of these samples were 37 to 40 and 38.11 ± 1.09, 25 to 38 and 34.56 ± 1.27 and 10 to 15 and 12.56 ± 0.58 respectively.

Tables 24 and 25 represent the sensory evaluation score of cows' milk cheese ripened at different temperatures. Cheese ripened at 10°C scored 90 to 96 with an average of 92.22 ± 0.78. The range and average scores for flavour, body and texture and finish were 40 to 43 and 41.44 ± 0.38, 35 to 38 and 37.56 ± 0.34 and 12 to 15 and 13.22 ± 0.43 respectively. The total score for cheese ripened at 5°C ranged from 76 to 92 with an average of 87.00 ± 1.67. The flavour, body and texture and finish had range and average scores of 30 to 42 and 38.22 ± 1.19, 35 to 38 and 36.33 ± 0.47 and 11 to 14 and 12.44 ± 0.41 respectively.

The analysis of variance (Table 26) showed that significant difference existed in the sensory scores of goats' and cows' milk cheese ($P \leqslant 0.05$).

The defects observed in the flavour, body and texture and finish of cheese from goats' and cows' milk ripened at 5°C and 10°C are presented in Table 29. Cheese prepared from the milk of both species stored at 5°C did not develop the full flavour, whereas the main flavour defect in cheese ripened at 10°C was the development of slight rancidity. The predominant defect in body and texture was 'crumbly' while the main defects in finish were 'cracked' and 'uneven surface'.

TABLES

Table 1. Composition of goats' milk and yield of green cheese.

Trial number	Quantity (litres)	Fat %	Protein %	Lactose %	Total solids %	SNF %	Yield of cheese (kg)
1	10.0	5.10	4.13	5.32	15.30	10.20	1.580
2	10.0	4.00	4.02	4.47	13.40	9.40	1.320
3	10.0	4.60	3.97	4.92	14.23	9.63	1.385
Average	10.0	4.57 ±0.32	4.04 ±0.05	4.90 ±0.25	14.31 ±0.55	9.74 ±0.24	1.430 ±0.030

Table 2. Composition of cows' milk and yield of green cheese.

Trial number	Quantity (litres)	Fat %	Protein %	Lactose %	Total solids %	SNF %	Yield of green cheese (kg)
1	10.0	3.80	3.78	4.90	13.18	9.38	1.035
2	10.0	4.50	3.41	5.40	14.02	9.52	1.150
3	10.0	4.70	3.86	5.08	14.38	9.68	1.250
Average	10.0	4.33 ±0.27	3.68 ±0.14	5.13 ±0.15	13.86 ±0.36	9.53 ±0.09	1.145 ±0.060

Table 3. Development of acidity during cheese making from goats' milk.

Trial number	Acidity (in % lactic acid) at				
	Addition of starter	Addition of rennet	After cutting	After cooking	After cheddaring
1	0.19	0.24	0.13	0.16	0.27
2	0.25	0.27	0.17	0.22	0.57
3	0.21	0.24	0.16	0.19	0.46
Average	0.217 ±0.018	0.250 ±0.010	0.153 ±0.012	0.190 ±0.017	0.433 ±0.088

Table 4. Development of acidity during cheese making from cows' milk.

Trial number	Acidity (in %) lactic acid) at				
	Addition of starter	Addition of rennet	After cutting	After cooking	After cheddaring
1	0.18	0.22	0.14	0.18	0.55
2	0.17	0.20	0.14	0.17	0.47
3	0.18	0.22	0.13	0.17	0.48
Average	0.177 ±0.003	0.213 ±0.006	0.137 ±0.003	0.173 ±0.003	0.500 ±0.025

Table 5. Yield of cheese.

Trial number	Gravimetric (kg)	Formula of Van Slyke & Price (kg)	Formula of Van Slyke (kg)	Formula of McDowall (kg)	Formula-1 (kg)	Formula-2 (kg)
Goats' milk						
1	1.580	1.356 (-14.8%)	1.269 (-19.68%)	1.247 (-21.08%)	1.313 (-16.89%)	1.377 (-12.85%)
2	1.320	1.163 (-11.89%)	1.103 (-16.44%)	1.103 (-16.44%)	1.060 (-19.70%)	1.080 (-18.18%)
3	1.385	1.255 (-9.39%)	1.182 (-14.66%)	1.171 (-15.45%)	1.198 (-13.50%)	1.242 (-10.33%)
Average	1.428 ± 0.078	1.258 ± 0.557	1.185 ± 0.479	1.174 ± 0.416	1.190 ± 0.073	1.233 ± 0.085
Cows' milk						
1	1.035	1.099 (+6.18%)	1.049 (+1.35%)	1.055 (+1.93%)	1.014 (-2.03%)	1.026 (-0.87%)
2	1.150	1.167 (+1.48%)	1.106 (-3.83%)	1.106 (-3.83%)	1.175 (+2.17%)	1.215 (+5.65%)
3	1.250	1.257 (+0.56%)	1.184 (-5.28%)	1.173 (-6.16%)	1.221 (-2.32%)	1.269 (+1.52%)
Average	1.145 ± 0.062	1.174 ± 0.046	1.113 ± 0.039	1.111 ± 0.034	1.137 ± 0.063	1.170 ± 0.074

Note: 1) Figures in parentheses indicate the percentage variation of the estimated value from the observed value.
2) Negative sign indicates that estimated value is less than observed value.
3) A positive sign indicates that estimated value is more than the observed value.

Table 6. Evaluation of different formulae used to estimate the yield of goats' milk cheese.

Batch number	Van Slyke & Price	Van Slyke	McDowall	Formula-1	Formula-2
	Formulae				
1	0.224 (2)	0.311 (4)	0.333(5)	0.267(3)	0.203(1)
2	0.157 (1)	0.217(2.5)	0.217(2.5)	0.260(5)	0.240(4)
3	0.130 (1)	0.203 (4)	0.214(5)	0.187(3)	0.145 (2)
Rating total					
r_i	4	10.5	12.5	11	7
$\bar{r}_i$	1.33	3.50	4.17	3.67	2.33

* Figures in parentheses indicate the ranking

Table 7. Evaluation of different formulae used to estimate the yield of cows' milk cheese.

Batch number	Van Slyke & Price	Van Slyke	McDowall	Formula-1	Formula-2
	Formulae				
1	0.064 (5)	0.014 (2)	0.020 (3)	0.021 (4)	0.009 (1)
2	0.017 (1)	0.044(3.5)	0.044(3.5)	0.025 (2)	0.065 (5)
3	0.007 (1)	0.066 (4)	0.077 (5)	0.029 (3)	0.019 (2)
Rating total					
r_i	7	9.5	11.5	9	8
$\bar{r}_i$	2.33	3.17	3.83	3.00	2.67

* Figures in parentheses indicate the ranking.

Table 8. Composition of green cheese and ripened cheese (cured at 5°C) from goats' milk.

Trial number	Green cheese					Ripened cheese (cured at 5°C)				
	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g
1	30.00	35.00	29.77	1.24	400	26.66	35.00	34.38	1.36	Nil
2	34.92	31.00	26.80	1.23	530	26.62	34.00	33.28	1.59	Nil
3	31.86	34.00	28.47	1.23	230	27.60	36.00	33.24	1.61	Nil
Average	32.26 ±1.43	33.33 ±1.20	28.35 ±0.86	1.23 ±0.003	386.67 ±86.86	26.96 ±0.32	35.00 ±0.58	33.30 ±0.62	1.52 ±0.08	Nil

Table 9. Composition of ripened cheese (Cured at 5°C and 10°C) from goats' milk.

Trial Number	Ripened at 5°C					Ripened at 10°C				
	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g
1	26.66	35.00	34.38	1.36	Nil	28.14	35.00	35.18	1.39	Nil
2	26.62	34.00	33.28	1.59	Nil	30.70	35.00	31.26	1.37	Nil
3	27.60	36.00	32.24	1.61	Nil	29.52	36.00	32.75	1.39	Nil
Average	26.96 ±0.32	35.00 ±0.58	33.30 ±0.62	1.52 ±0.08	Nil	29.45 ±0.74	35.33 ±0.33	33.06 ±1.14	1.38 ±0.006	Nil

Table 10. Composition of green cheese and ripened cheese (Cured at 5°C) from cows' milk.

Trial Number	Green cheese					Ripened cheese (Cured at 5°C)				
	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g	Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g
1	34.86	34.00	23.17	1.74	400	26.56	37.00	32.22	1.46	Nil
2	32.90	34.00	26.80	1.10	Nil	30.04	38.00	28.26	1.52	Nil
3	31.38	35.00	29.77	0.90	230	26.83	38.00	31.26	1.49	Nil
Average	33.05 ±1.01	34.33 ±0.33	26.58 ±1.91	1.25 ±0.25	210 ±115.9	27.85 ±1.11	37.67 ±0.33	30.58 ±1.19	1.49 ±0.02	Nil

Table 11. Composition of ripened cheese (Cured at 5°C and 10°C) from cows' milk.

Trial Number	Ripened at 5°C Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g	Ripened at 10°C Moisture %	Fat %	Protein %	Salt %	Coliforms cfu/g
1	26.56	37.00	32.22	1.46	Nil	27.00	38.00	32.75	1.46	Nil
2	30.04	38.00	28.26	1.52	Nil	30.00	37.00	29.75	1.43	Nil
3	26.88	38.00	31.26	1.49	Nil	27.20	39.00	32.75	1.34	Nil
Average	27.83 ±1.11	37.67 ±0.33	30.58 ±1.19	1.49 ±0.02	Nil	28.07 ±0.97	38.00 ±0.58	31.75 ±1.00	1.41 ±0.04	Nil

Table 12. ANOVA for the moisture content of cheese.

Source	df	SS	MSS	F
Species	1	0.416	0.416	0.127
Temperature	1	2.802	2.802	0.855
Duration (Ripening)	1	125.675	125.675	38.362 **
Species x Temperature	1	1.903	1.903	0.581
Species x Duration (Ripening)	1	1.644	1.644	0.502
Temperature x Duration (Ripening)	1	2.802	2.802	0.855
Error	17	55.690	3.276	
Total	23	190.932		

Table 13. ANOVA for the fat content of cheese.

Source	df	SS	MSS	F
Species	1	20.167	20.167	14.293 **
Temperature	1	0.167	0.167	0.118
Duration (Ripening)	1	42.667	42.667	30.239 **
Species x Temperature	1	0	0	0
Species x Duration (Ripening)	1	4.167	4.167	2.953
Temperature x Duration (Ripening)	1	0.166	0.166	0.118
Error	17	23.99	1.411	
Total	23	91.333		

** $P \leqslant 0.01$.

Table 14. Composition of green cheese and cheese ripened at different temperatures (Moisture free basis).

Trial Number	Green cheese		Cheese cured at 5°C		Cheese cured at 10°C	
	Fat %	Protein %	Fat %	Protein %	Fat %	Protein %
Goats' milk cheese						
1	50.0	42.53	47.72	46.88	48.71	48.96
2	47.63	41.18	46.33	45.35	50.51	45.11
3	49.90	41.78	49.72	44.53	51.08	46.47
Average	49.18 ±0.77	41.83 ±0.39	47.92 ±0.98	45.59 ±0.69	50.10 ±0.71	46.85 ±1.13
Cows' milk cheese						
1	52.20	35.57	50.38	43.87	52.05	44.86
2	50.67	39.94	54.32	40.39	52.86	42.50
3	51.01	43.38	51.97	42.75	53.70	44.99
Average	51.29 ±0.46	39.63 ±2.26	52.22 ±1.14	42.34 ±1.03	52.87 ±0.48	44.12 ±0.81

Table 15. ANOVA for the total protein content of cheese.

Source	df	SS	MSS	F
Species	1	21.470	21.470	4.682 *
Temperature	1	0.327	0.327	0.071
Duration (Ripening)	1	133.105	133.105	29.024 **
Species x Temperature	1	0.742	0.742	0.162
Species x Duration (Ripening)	1	0.094	0.094	0.021
Temperature x Duration (Ripening)	1	0.326	0.326	0.071
Error	17	77.969	4.586	
Total	23	234.033		

** $P \leqslant 0.01$

* $P \leqslant 0.05$

Table 16. Production of soluble protein, steam volatile free fatty acids (SVFFA) and pH in the curing of cheese.

Goats' milk cheese									
Trial number	Green cheese			Cheese cured at 5°C			Cheese cured at 10°C		
	Soluble protein %	SVFFA μ mol/g fat	pH	Soluble protein %	SVFFA μ mol/g fat	pH	Soluble protein %	SVFFA μ mol/g fat	pH
1	2.98	2.00	5.00	5.96	4.60	5.30	6.70	10.49	5.37
2	2.98	1.60	5.15	5.96	3.90	5.25	8.95	10.20	5.33
3	3.72	0.90	5.19	5.96	3.90	5.36	8.93	7.40	5.31
Average	3.23 ±0.25	1.50 ±0.32	5.11 ±0.06	5.96 ±0.00	4.13 ±0.23	5.30 ±0.04	8.19 ±0.74	9.33 ±0.97	5.34 ±0.02

Table 17. Production of soluble protein, steam volatile free fatty acids (SVFFA) and pH in the curing of cheese.

Cows' milk cheese.

Trial Number	Green cheese			Cheese cured at 5°C			Cheese cured at 10°C		
	Soluble protein %	SVFFA μ mol/g fat	pH	Soluble protein %	SVFFA μ mol/g fat	pH	Soluble protein %	SVFFA μ mol/g fat	pH
1	3.72	1.50	5.15	8.19	3.20	5.24	11.91	7.60	5.29
2	4.47	1.80	5.17	7.44	3.70	5.29	9.68	8.50	5.37
3	3.72	1.90	5.37	7.44	3.10	5.35	11.17	7.20	5.33
Average	3.97 ±0.25	1.73 ±0.12	5.23 ±0.07	7.69 ±0.25	3.33 ±0.19	5.29 ±0.03	10.92 ±0.66	7.77 ±0.38	5.33 ±0.02

Table 18. ANOVA for the soluble protein content of cheese.

Source	df	SS	MSS	F
Species	1	13.276	13.276	27.764 **
Temperature	1	11.166	11.166	23.351 **
Duration (Ripening)	1	126.455	126.455	264.455 **
Species x Temperature	1	0.377	0.377	0.788
Species x Duration (Ripening)	1	3.322	3.322	6.947 *
Temperature x Duration (Ripening)	1	11.165	11.165	23.349 **
Error	17	8.129	0.478176	
Total	23	173.890		

* $P \leq 0.05$
** $P \leq 0.01$

Table 19. ANOVA for the salt content of cheese.

Source	df	SS	MSS	F
Species	1	0	0	0
Temperature	1	0.017	0.017	0.354
Duration (Ripening)	1	0.266	0.266	5.541 *
Species x Temperature	1	0.002	0.002	0.042
Species x Duration (Ripening)	1	0.005	0.005	0.104
Temperature x Duration (Ripening)	1	0.018	0.018	0.375
Error	17	0.815	0.048	
Total	23	1.123		

* $P \leq 0.05$

Table 20. ANOVA for steam volatile free fatty acids of cheese.

Source	df	SS	MSS	F
Species	1	1.354	1.354	2.650
Temperature	1	34.800	34.800	68.102 **
Duration (Ripening)	1	122.854	122.854	240.419 **
Species x Temperature	1	0.221	0.221	0.433
Species x Duration (Ripening)	1	3.009	3.009	5.889 *
Temperature x Duration (Ripening)	1	34.801	34.801	68.104 **
Error	17	8.681	0.511	
Total	23	205.7196		

** $P \leqslant 0.01$

* $P \leqslant 0.05$

Table 21. ANOVA for the pH of cheese.

Source	df	SS	MSS	F
Species	1	0.019	0.019	2.714
Temperature	1	0.002	0.002	0.286
Duration (Ripening)	1	0.122	0.122	17.429 **
Species x Temperature	1	0	0	0
Species x Duration (Ripening)	1	0.022	0.022	3.143
Temperature x Duration (Ripening)	1	0.003	0.003	0.429
Error	17	0.118	0.007	
Total	23	0.2863		

** $P \leqslant 0.01$

Table 22. Score card of goats' milk cheese ripened at 10°C.

Trial number	Judges	Flavour (45)	Body and texture (40)	Finish (15)	Total (100)
	A	42	37	12	91
1	B	36	32	12	80
	C	40	25	12	77
	A	40	36	14	90
2	B	35	35	12	82
	C	40	35	10	85
	A	42	39	14	95
3	B	40	35	12	87
	C	38	35	12	85
Average		39.22 ±0. 81	34.33 ±1.32	12.22 ±0.40	85.78 ±1.89

Table 23. Score card of Goats' milk cheese ripened at 5°C.

Trial Number	Judges	Flavour (45)	Body and texture (40)	Finish (15)	Total (100)
	A	40	38	14	92
1	B	40	35	12	87
	C	40	25	12	77
	A	38	35	15	88
2	B	30	35	12	77
	C	40	35	10	85
	A	37	38	15	90
3	B	38	35	11	84
	C	40	35	12	87
Average		38.11 ± 1.09	34.56 ± 1.27	12.56±0.58	85.22 ± 1.75

Table 24. Score card of cows' milk cheese ripened at 10°C.

Trial Number	Judges	Flavour (45)	Body and texture (40)	Finish (15)	Total (100)
1	A	42	38	14	94
	B	42	38	12	92
	C	42	37	15	94
2	A	40	38	12	90
	B	42	38	14	94
	C	40	38	12	90
3	A	42	35	13	90
	B	43	38	15	96
	C	40	38	12	90
Average		41.44 ± 0.38	37.56 ± 0.34	13.22 ± 0.43	92.22 ± 0.78

Table 25. Score card of cows' milk cheese ripened at 5°C.

Trial Number	Judges	Flavour (45)	Body and texture (40)	Finish (15)	Total (100)
1	A	30	35	11	76
	B	42	38	12	92
	C	37	38	14	89
2	A	38	35	12	85
	B	39	35	11	85
	C	42	38	12	92
3	A	40	37	14	91
	B	38	35	14	87
	C	38	36	12	86
Average		38.22 ± 1.19	36.33 ± 0.47	12.44 ± 0.41	87.00 ± 1.67

Table 26. ANOVA for Sensory evaluation of cheese.

Source	df	SS	MSS	F
Species	1	152.11	152.11	7.55 *
Temperature	1	75.11	75.11	3.73
Judge	2	116.05	58.025	2.88
Temperature x species	1	49.00	49.00	2.43
Error	30	604.59	20.153	
Total	35	996.86		

* $P \leqslant 0.05$

Table 27. Comparison of mean values of soluble protein and SVFFA of goats' and cows' milk cheese in relation to ripening.

Species	Ripening	Soluble protein %	SVFFA in µ mol/g fat
Goat	Before (0-day)	3.23[a]	1.50[a]
	After(13 weeks)	7.07[b]	6.70[c]
Cow	Before (0-day)	3.97[a]	1.73[a]
	After (13 weeks)	9.31[c]	5.55[b]

Note : Identical letters indicate no difference.

Table 28. Comparison of mean values of soluble protein and SVFFA of cheese cured at 5°C and 10°C before and after ripening.

Temperature	Ripening	Soluble protein %	SVFFA µ mol/g fat
5°C	Before (0-day)	3.60[a]	1.62[a]
	After (13 weeks)	6.83[b]	3.73[b]
10°C	Before (0-day)	3.60[a]	1.62[a]
	After (13 weeks)	9.55[c]	8.55[c]

Note : Identical letters indicate no difference.

Table 29. Defects observed in cheese.

Type of Cheese	Temperature of ripening	Defects in flavour	Defects in body & texture	Defects in finish
From goats' milk				
1	5°C	Slightly bitter, flat, Acid, very slightly rancid	Crumbly - Spongy	Uneven surface
2	5°C	Flat, goaty	Crumbly	Cracked
3	5°C	Flat	Crumbly	Cracked uneven surface
1	10°C	Slightly rancid	Slightly crumbly	Uneven surface
2	10°C	Slightly rancid	Crumbly	Light spots cracked
3	10°C	Slightly rancid	Crumbly	Cracked
From cows' milk				
1	5°C	Flat	Crumbly Crudy	Scaly paraffin
2	5°C	Flat	Crumbly	Uneven surface
3	5°C	Flat	Crudy	—
1	10°C	Very slightly rancid	Crumbly	—
2	10°C	Very slightly rancid	—	Scaly paraffin Uneven surface
3	10°C	—	Pasty	Slightly mouldy.

DISCUSSION

DISCUSSION

As a result of the use of exotic breeds for intensive cross-breeding in goats, it is expected that a great deal of surplus milk would become available in a few years. One of the methods by which the surplus milk can economically be utilised is to manufacture cheese. Therefore, the present study was undertaken to outline the procedure necessary in the manufacture of a hard ripened variety of cheese from goats' milk and to compare it with that produced in a similar way from cows' milk. The results obtained are discussed in the following paragraphs.

5.1. Chemical composition of milk

Goats' milk used in the present study was found to contain an average of 4.57 per cent fat, 4.04 per cent protein and 4.90 per cent lactose. These values are similar to those reported by Nirmalan and Nair (1962), Prakash and Jenness (1968), Devendra (1979) and Baiju (1981). The values reported by French (1970) for the lactose content of the milk of Swiss Saanen goats was less than that obtained in the present study.

Cows' milk used in the study was found to contain, an average of 4.33 per cent fat, 3.68 per cent protein and 5.13 per cent lactose.

The amount of protein and fat in the milk of goats was found to be more than that in cows' milk. Consequently, a higher cheese yield could be expected from the milk of goats.

5.2. Acid development during cheese making

The acidity of goats' and cows' milk prior to the addition of starter was found to be 0.217 ± 0.018 and 0.177 ± 0.03 per cent lactic acid respectively. Eckles *et al.* (1973) and Rangappa and Achaya (1975) have reported similar values in case of cows' milk. The mean acidity at renneting was 0.250 ± 0.010 and 0.213 ± 0.006 per cent lactic acid in goats' and cows' milk cheese respectively, while after cutting the corresponding values were 0.153 ± 0.012 and 0.137 ± 0.003 per cent lactic acid. The development of acidity prior to the addition of rennet is essential for the optimum activity of the enzyme and helps in the expulsion of whey. Van Slyke and Price (1952) recommended that the acidity after cutting should be 0.130 per cent for cows' milk with 4.50 per cent fat. The acidity during cooking was found to increase to 0.190 ± 0.017 and 0.173 ± 0.003 per cent lactic acid in goats' and cows' milk curd respectively. This has been attributed to the continued activity of the starter organisms. The acidity after cheddaring was found to be 0.433 ± 0.088 and 0.500 ± 0.025 per cent lactic acid in goats' and cows' milk coagulum respectively. These values are close to the values recommended by Van Slyke and Price (1952) and Tittsler (1965) in cows' milk cheese.

5.3. Yield of cheese

An average of 1.43 ± 0.08 kg of green cheese was obtained from 10.0 litres of goats' milk while that obtained from the same quantity of cows' milk was 1.145 ± 0.060 kg. The higher yield of cheese obtained from goats' milk corresponds to the higher total solids content of the milk of goats.

Eckles *et al.* (1973) pointed out that the yield of hard cheese varied from 8.0 to 14.0 per cent. Klyuchyute and Butkus (1978) obtained 9595.9 kg of pressed cheddar cheese from 100 250 kg of milk.

Based on rennet coagulation studies on cows' and goats' milk, Blattner and Gallmann (1980) were of opinion that a lower cheese yield only could be expected from goats' milk because of greater NPN loss in whey and more intensive whey separation.

Eventhough the potential yield of cheese from milk is clearly related to the concentration of casein and fat, the actual yield depends on the efficiency with which these milk components are incorporated into curd. Thus, the higher yield of cheese obtained from goats' milk, in the present study, could only be due to its higher total solids content and better incorporation of the individual components into the curd.

5.4. Chemical analysis of cheese

5.4.1. Moisture content

The moisture content of green cheese from goats' and cows' milk was found to be 32.26 ± 1.43 and 33.05 ± 1.01 per cent respectively. The values after ripening at 5°C and 10°C were 26.96 ± 0.32 and 29.45 ± 0.74 per cent respectively in goats' milk cheese and 27.83 ± 1.11 and 28.07 ± 0.97 per cent respectively in cows milk cheese.

According to Eckles *et al.* (1973) Cheddar cheese contains 30.00 to 36.79 per cent moisture while American Swiss cheese has 30.00 to 34.00 per cent moisture. Raffaele (1978, Publ. 1980) found that samples of goats' milk cheese from Sardinia contained 25.78 to 44.25 per cent moisture, while Wolfschoon and Furtado (1979) and Wolfschoon-Pombo and Furtado (1979) reported moisture content of 51.0 to 53.0 per cent in Chabichou cheese.

The moisture content of cheese can be altered by varying the technological parameters. Thus, cheese of any moisture content can be obtained depending on the manufacturer's requirement and the type of cheese. In the present study, as the aim was to prepare a hard variety of cheese, the moisture content was kept at the minimum.

During ripening, a statistically significant decrease in the moisture content of cheese could be observed which can be attributed to the evaporation of moisture from cheese. Van Slyke and Price (1952), Rao and Mathur (1979), Bilgi (1980), JobElias (1981), Sukumaran (1982) and several other workers have also recorded a similar finding in different varieties of cheese.

5.4.2. <u>Fat content</u>

The fat content of goats' milk cheese before ripening and after ripening at 5°C and 10°C was 33.33 ± 1.20, 35.00 ± 0.58 and 35.33 ± 0.33 per cent respectively, while the corresponding values for cheese from cows' milk were 34.33 ± 0.33, 37.67 ± 0.33 and 38.0 ± 0.58 per cent respectively.

The fat content of goats' milk cheese observed in the present study falls within the range reported by Raffaele (1970, Publ. 1980).

On moisture free basis, the fat content of green cheese from goats' and cows' milk was 49.18 ± 0.77 and 51.29 ± 0.46 per cent respectively. Cheese from goats' milk ripened at 5°C and 10°C had a fat content of 47.92 ± 0.98 and 50.10 ± 0.71

per cent respectively on moisture free basis, while in cows' milk cheese the corresponding values were 52.22 ± 1.14 and 52.87 ± 0.48 per cent respectively.

Statistically, the fat content in goats' and cows' milk cheese was found to differ significantly. Cows' milk cheese showed a higher fat level than goats' milk cheese, in both green and ripened samples.

Ripened cheese made from the milk of both the species was found to contain a significantly higher fat content than in green cheese. This may be due to the loss of moisture during the ripening process.

5.4.3. Protein content of cheese

5.4.3.1. Total protein

Green cheese from goats' milk had an average total protein content of 28.35 ± 0.86 per cent while cheese ripened at 5°C and 10°C had 33.30 ± 0.62 and 33.06 ± 1.14 per cent protein respectively.

The total protein content of green cheese, cheese ripened at 5°C and 10°C from cows' milk was 26.58 ± 1.91, 30.58 ± 1.19 and 31.75 ± 1.00 per cent respectively.

On moisture free basis, the total protein content of goats' and cows' milk cheese in the unripened state and ripened at 5°C and 10°C was 41.83 ± 0.39 and 39.63 ± 2.26, 45.59 ± 0.69 and 42.34 ± 1.03 and 45.85 ± 1.13 and 44.12 ± 0.81 per cent respectively.

Statistical analysis showed that the goats' milk cheese had significantly higher total protein content than cows' milk cheese. This corresponds to the higher protein content in the milk of goats used in the present study.

The total protein content of ripened cheese was significantly higher than that in green cheese. This may be attributed to the loss of moisture due to evaporation during the ripening process.

5.4.3.2. Soluble protein

The amount of soluble protein present in the cheese made from goats' milk before ripening and after ripening at 5°C and 10°C was 3.23 ± 0.25, 5.96 and 8.19 ± 0.74 per cent respectively equivalent to 11.39, 17.90 and 24.77 per cent of the total nitrogen respectively.

These values are similar to those reported by Raffaelo (1978, Publ. 1980), in terms of soluble nitrogen expressed as per cent of total nitrogen, but are lower than those reported by Wolfschoon and Furtado (1979) in Chabichou cheese.

The soluble protein content of cows' milk cheese before ripening and after ripening at 5°C and 10°C was 3.97 ± 0.25, 7.69 ± 0.25 and 10.92 ± 0.66 per cent respectively equivalent to 14.93, 25.15 and 34.39 per cent of the total nitrogen respectively. These values are close to those observed by Thakur et al. (1975) in unsalted Cheddar cheese. Park et al. (1975) reported the water soluble nitrogen to be 39.0 per cent of the total nitrogen in Cheddar cheese ripened at 10 ± 2°C for 12 weeks.

Soluble protein content of goats' milk cheese after ripening was found to be significantly lower than that of cows' milk cheese while in green cheese the content of soluble protein did not differ significantly.

Jailkhani and De (1978) were of the view that goat milk casein during digestion forms a less tough and more friable coagulum than does cow milk casein, so that proteolytic enzymes penetrate and break it down more rapidly. But, the findings of the present study show that the changes taking place during ripening of cheese are not similar to the digestive changes of casein observed by these workers.

The present study also indicated that the temperature of ripening has a significant effect on the formation of soluble nitrogen in cheese. A higher level of soluble nitrogen was observed in cheese cured at 10°C rather than at 5°C.

According to Tittsler (1965), several authors have reported that the rate, nature and extent of protein decomposition during cheese ripening is related to and influenced by the nature and concentration of proteolytic microbial enzymes, increased moisture content, presence of lactic acid, temperature and other factors, such as pH, oxidation-reduction potential and salts, that effect enzyme activity. Therefore, the difference in the soluble protein content of ripened goats' and cows' milk cheese observed in the present study can be attributed to the combined effect of these factors.

5.4.4. Salt content

The salt content of goats' and cows' milk cheese prior to ripening and after ripening at 5°C and 10°C was 1.23 ± 0.005, 1.52 ± 0.08 and 1.38 ± 0.006 per cent and 1.25 ± 0.25, 1.49 ± 0.02 and 1.41 ± 0.04 per cent respectively.

Raffaele (1978, Publ. 1980) reported a range of 3.61 to 6.69 per cent salt in goats' milk cheese in Sardinia, while Wolfschoon and Furtado (1979) reported the salt content in Chabichou type cheese to be 1.4 to 2.2 per cent.

Statistical analysis showed that ripened cheese had significantly higher salt content as compared to green cheese. This increase can be attributed to the decrease in the moisture content of the ripened cheese.

Slight differences noticed in the salt content of cheese between replicates may be due to the variations in moisture content, some manufacturing aspects, dry salting etc. Fox (1974) observed wide variations in the salt content within the vat as well as within the block.

5.4.5. Steam volatile free fatty acids (SVFFA)

Green cheese from goats' milk was found to contain an average SVFFA of 1.50 ± 0.32 μ mol/g fat while in those ripened at 5°C and 10°C, the values were 4.13 ± 0.23 and 9.33 ± 0.97 μ mol/g fat respectively.

In case of cows' milk cheese, the SVFFA content before ripening, after ripening at 5°C and 10°C was 1.73 ± 0.12, 3.33 ± 0.19 and 7.77 ± 0.38 μ mol/g fat respectively.

The analysis of variance showed that the difference of SVFFA content between goats' and cows' milk cheese was not significant.

Nakanishi et al. (1962) reported free fatty acids content ranging from 85.5 to 156.3 mg/100 g cheese in domestic Edam, Gouda and Cheddar cheese.

The SVFFA contents reported by Bhat et al. (1978) in cow and buffalo milk cheddar cheese were 0.35 and 0.26 μ mol/g fat respectively.

The results of the present study show values much higher than those reported by Bhat et al. (1978) and Sukumaran (1982).

The temperature of ripening was found to have significant effect on the SVFFA content of cheese made from goats' and cows' milk. Higher values were observed in cheese ripened at 10°C than that ripened at 5°C. Comparison of critical difference showed that goats' and cows' milk cheese did not differ significantly in the SVFFA content before ripening, but after ripening they differed significantly, with cows' milk cheese showing lower values. This may be due to higher hydrolytic changes taking place in goats' milk cheese. The higher rate of hydrolysis noted in cheese ripened at 10°C may be due to higher activity of the lipolytic enzymes present in cheese.

5.4.6. Hydrogen - ion concentration (pH)

The mean pH of green cheese prepared from goats' milk was found to be 5.11 ± 0.06 while cheese ripened at 5°C and 10°C had mean pH of 5.30 ± 0.04 and 5.34 ± 0.02 respectively.

Cows' milk cheese had an initial mean pH of 5.23 ± 0.07 which increased to 5.29 ± 0.03 and 5.33 ± 0.02 after ripening at 5°C and 10°C respectively.

The analysis of variance showed that the difference in the pH of green and ripened cheese was highly significant. Although not significant, cheese cured at 10°C had higher pH than those cured at 5°C.

Brown and Price (1934) reported that after an initial decrease, the pH of cheese increased subsequently to the range of 5.30 to 5.40 in one year.

Sukumaran (1982) found that the pH of Cheddar cheese decreased to values between 4.93 and 5.38 after 90 days of ripening and between 4.95 and 5.40 after 120 days of ripening. The pH of green cheese reported was in the range of 4.75 to 5.25.

The findings of the present study are, therefore in agreement with those reported by earlier workers.

In case of Edam cheese, Bilgi (1980) reported an average pH of 5.42 for cheese ripened for 90 days. Raffaele (1978, publ. 1980) reported a pH range of 5.09 to 5.65 for goats' milk cheese made in Sardinia. Wolfschoon and Furtado (1979) found that the pH of Chabichou cheese increased from 5.20 to 6.82

during a 30-day period. A similar finding was reported by Wolfschoon-Pombo and Furtado (1979) who found that the pH rose from 5.20 to 6.80 in Chabichou cheese during the first 30 days of ripening.

According to Tittsler (1965) the gradual increase in pH during cheese ripening is caused by the destruction of the lactic acid, the formation of non-acidic decomposition products and weaker or less highly dissociated acids, including acetic and carbonic acids and the liberation of alkaline products of protein decomposition.

5.5. Coliform count

The average coliform load of green cheese from goats' milk was found to be 385.67 ± 36.86 cfu/g, but cheese ripened at 5°C and 10°C did not show any coliform.

In cows' milk cheese, the average coliform load noted in green cheese was 210 ± 115.9 cfu/g cheese ripened at 5°C and 10°C did not show any coliform.

Luck and Dunkeld (1981) reported a total coliform load of less than 1.0 to 36 x 10^6/g in four to eight weeks old cheese samples.

According to Elliot (1978) the coliform count of cheese decreased with advancement of time. The findings of the present study also show the same trend.

5.6. Sensory evaluation of cheese

The total score of goats' milk cheese ripened at 10°C and 5°C was 85.78 ± 1.89 and 85.22 ± 1.75 respectively while the corresponding values for cows' milk cheese were 92.22 ± 0.78 and 87.00 ± 1.67. It could be seen that cheese ripened at 10°C scored higher than those ripened at 5°C. The cows' milk cheese scored higher than the goats' milk cheese. The lower scores for cheese ripened at lower temperature may be due to the comparatively lower rate of ripening changes.

The cheese cured at 5°C had a slightly better body and texture and finish, but the flavour was better in cheese cured at 10°C.

In cows' milk cheese the ripening at 10°C was more beneficial for all the three characters viz. flavour, body and texture and finish.

Significant difference could be observed between the total score of goats' and cows' milk cheese, the latter scoring higher at both the ripening temperatures.

Most of the cheese samples cured at 5°C did not develop the typical cheese flavour completely. Goats' milk cheese ripened at 10°C had slight rancid changes while in cows' milk cheese these changes were very much less. Lipolytic changes are essential in cheese, but the formation of certain fatty acids like butyric, caproic and capric acids in higher quantities can give rise to a slight rancid flavour. This can also occur due to the enzymes present in the rennet/milk or by the enzymes produced by the microorganisms.

Heat-resistant lipases, originating from psychrotrophs such as pseudomonads present in the raw milk, survive in the cheese and, if present at high enough levels, cause rancidity to develop by hydrolysing the milk fat triglycerides to release free fatty acids (FFA), such as butyric, caproic and capric (Chapman and Sharpe, 1981).

The main defect noticed in the body and texture was 'crumbly'. This may be due to the hardness of the cheese resulting from a low moisture content.

Ripening at 5°C was found to result in scaly paraffin in some samples. This could be due to the higher shrinkage taking place at that temperature. According to The Prevention of Food Adulteration Act, 1954 (1982) hard cheese shall contain not more than 43.0 per cent moisture and not less than 42.0 per cent milk fat of the dry matters. In the present study, goats' milk cheese ripened at 5°C, contained an average of 26.96 ± 0.32 per cent moisture and 47.92 ± 0.93 per cent fat in dry matter while the corresponding values for cheese ripened at 10°C were 29.45 ± 0.74 and 50.10 ± 0.71 per cent. The moisture content of cows' milk cheese ripened at 5°C and 10°C was 27.83 ± 1.11 and 28.07 ± 0.97 per cent respectivoly while the fat in dry matter of cheese cured at these temperatures was 52.22 ± 1.14 and 52.87 ± 0.48 per cent respectively. Thus, cheese prepared in the present study conform to the legal specifications of hard cheese.

SUMMARY

SUMMARY

An investigation was carried out to prepare a hard ripened variety of cheese from goats' milk and to compare it with that produced from cows' milk. Pooled raw milk was collected from goats of the All India Coordinated Research Project on Goats for Milk, Mannuthy and the cows of the University Livestock Farm, Mannuthy for preparing cheese from goats' milk and cows' milk respectively. A total of six batches of cheese were prepared.

The milk was pasteurized and inoculated with Str. lactis and Str. thermophilus followed by renneting, cutting, cooking, cheddaring, salting, hooping and pressing. Cheese so prepared was cured for 13 weeks at 5°C and 10°C at 85.0 per cent relative humidity. Samples were collected from both the green and ripened cheeses and analysed for its moisture, fat, total protein, soluble protein, steam volatile free fatty acids (SVFFA), salt and pH. The coliform load in the sample was also determined. The possible influence of temperature, ripening, species and their interactions were also studied.

The average composition of the goats' milk used in the study was fat - 4.57 $\pm$ 0.32 per cent, protein - 4.04 $\pm$ 0.05 per cent and lactose - 4.90 $\pm$ 0.25 per cent while the corresponding figures for cows' milk were 4.33 $\pm$ 0.27, 3.68 $\pm$ 0.14 and

5.13 ± 0.15 per cent. The average yield of green cheese from 10.0 litres of goats' milk was 1.43 ± 0.08 kg whereas from cows' milk it was 1.145 ± 0.06 kg.

The moisture content of green cheese and cheese ripened at 5°C and 10°C from goats' milk was found to be 32.26 ± 1.43, 26.96 ± 0.32 and 29.45 ± 0.74 per cent respectively while in cows' milk cheese the corresponding values were 33.05 ± 1.01, 27.83 ± 1.11 and 28.07 ± 0.97 per cent. The ripened cheese had a significantly lower moisture content as compared to the green cheese.

Goats' milk cheese before ripening had an average of 33.33 ± 1.20 per cent fat while the value in cows' milk cheese was 34.33 ± 0.33 per cent. After ripening at 5°C the fat content of goats' and cows' milk cheese changed to 35.0 ± 0.58 and 37.67 ± 0.33 per cent respectively while the corresponding values in cheese ripened at 10°C were 35.33 ± 0.33 and 38.0 ± 0.58 per cent respectively. Statistical analysis showed the fat content of goats' milk cheese to be significantly lower than that of cows' milk cheese and the ripened cheese to have a significantly higher fat content as compared to the green cheese.

The total protein content of green cheese from goats' and cows' milk was 28.35 ± 0.86 and 26.58 ± 1.91 per cent respectively while in those ripened at 5°C and 10°C the values were 33.30 ± 0.62 and 30.58 ± 1.19 per cent and 33.06 ± 1.14 and 31.75 ± 1.00 per cent respectively. Statistical analysis showed the total protein content of goats' milk cheese to be significantly higher than that of cows' milk cheese. Further, the green cheese was found to have a total protein content significantly lower than that of ripened cheese which may be attributed to the loss of moisture during the ripening process.

The average salt content of goats' milk cheese before ripening and after ripening at 5°C and 10°C was 1.23 ± 0.003, 1.52 ± 0.08 and 1.38 ± 0.006 per cent respectively while the corresponding values for cows' milk cheese was 1.25 ± 0.25, 1.49 ± 0.02 and 1.41 ± 0.04 per cent. Ripened cheese was found to have significantly higher salt content as compared to green cheese.

Green cheese from goats' and cows' milk showed an average soluble protein content of 3.23 ± 0.25 and 3.97 ± 0.25 per cent respectively while the values after ripening at 5°C and 10°C were 5.96 and 7.69 ± 0.25 per cent and 8.19 ± 0.74 and 10.92 ± 0.66 per cent respectively. The species, temperature and ripening were found to have significant direct effects while the species x ripening and temperature x ripening had significant interaction effects on the soluble protein content of cheese.

Goats' milk cheese before ripening was found to contain an average of 1.50 ± 0.32 μ mol/g fat steam volatile free fatty acids (SVFFA) and after ripening at 5°C and 10°C the values increased to 4.13 ± 0.23 and 9.33 ± 0.97 μ mol/g fat while in the case of cows' milk cheese the values were 1.73 ± 0.12, 3.33 ± 0.19 and 7.77 ± 0.38 μ mol/g fat. The temperature of ripening and the ripening process had significant direct effects on the SVFFA content of cheese while the significant interaction effects were that of species x ripening and temperature x ripening.

The mean pH of green cheese from goats' and cows' milk was 5.11 ± 0.06 and 5.25 ± 0.07 respectively while after ripening at 5°C and 10°C the values were 5.30 ± 0.04 and 5.29 ± 0.03 and 5.34 ± 0.02 and 5.33 ± 0.02 respectively. Statistically significant difference was observed in the pH of green and ripened cheese with the former having lower pH values.

The mean coliform load in green cheese from goats' and cows' milk was 386.67 ± 86.86 and 210 ± 115.9 cfu/g respectively, but no coliforms could be detected in the samples of ripened cheese.

The average sensory evaluation scores of goats' milk cheese ripened at 5°C and 10°C were 85.22 ± 1.75 and 85.78 ± 1.39 respectively while the corresponding scores for cows' milk cheese were 87.00 ± 1.67 and 92.22 ± 0.78 respectively. Cheese prepared from goats' milk had a significantly lower score as compared to that made from cows' milk mainly due to the onset of slight rancid changes in the former.

Batches of cheese prepared from both cows' milk and goats' milk were found to conform to the standards laid down in the PFA Act, 1954 (1982) for hard cheese.

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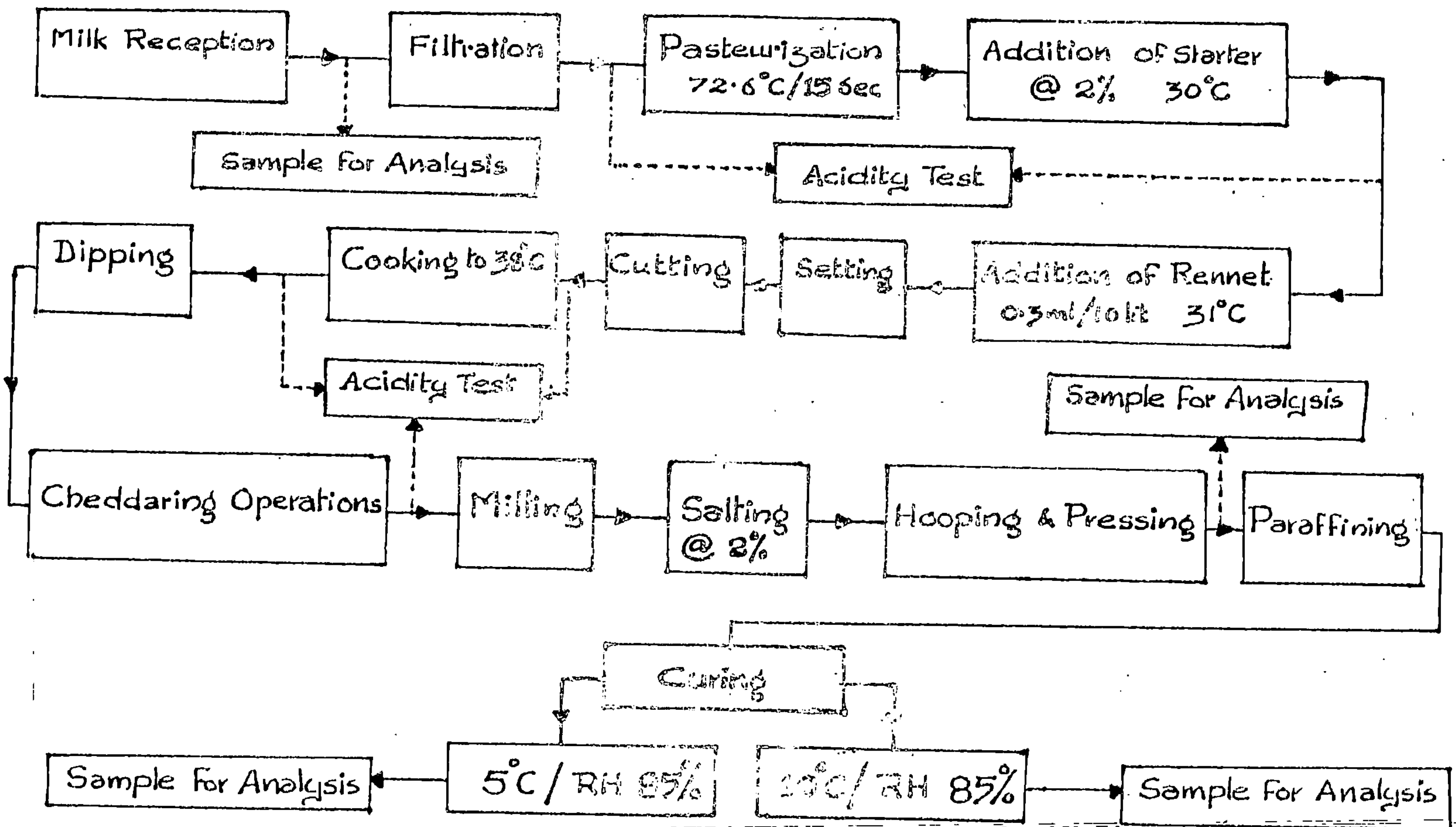
APPENDICES

APPENDIX - I

Flow Diagram for the Preparation of a Hard and Ripened variety of Cheese



APPENDIX II

Score card* for sensory Evaluation of cheese samples

Name of Judge :

Date :

Sample No. :

	Flavour	Body and texture	Finish	Total score	Remarks
Max. Marks :	45	40	15	100	
Marks allotted :					

* Directions for scoring

Deduct from the perfect score proportionately for the defect noticed and give the criticism(s) in remarks column.

Flavour	Body & texture	Finish
Acidity	Crumbly	Cracked
Bitter	Curdy	Light spots
Goaty	Gassy	Mouldy
Fermented	Spongy	Scaly paraffin
Cowy	Pasty	Uneven surface
Flat		
Mouldy		
Heated		
Rancid		
Unclean		

PREPARATION OF HARD RIPENED CHEESE FROM GOATS' MILK

By

A. G. ANIL KUMAR

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirement for the degree

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Faculty of Veterinary and Animal Sciences
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1985

ABSTRACT

An investigation was undertaken to produce a hard ripened variety of cheese from goats' milk and to compare it with that produced from cows' milk. Pooled samples of raw milk collected from the goats of the All India Co-ordinated Research Project on Goats for Milk, Mannuthy and the cows of the University Livestock Farm, Mannuthy were heat treated (72.6°C/15 seconds) and used to prepare six batches of cheese.

Samples of cheese collected prior to and after ripening were subjected to various analyses.

The results of the study indicated that the yield of cheese from goats' milk (1.430 kg from 10.0 litres milk) was higher than that obtained from cows' milk (1.145 kg from 10.0 litres milk).

The moisture content of cheese was found to decrease during ripening. Goats' milk cheese had a lower moisture content prior to and after ripening at 5°C, but after ripening at 10°C cows' milk cheese showed a lower value.

The cheese from cows' milk had a higher level of fat as compared to that from goats' milk. The fat content of cheese was found to increase during the ripening process.

The total protein content was higher in goats' milk cheese both prior to and after ripening, but the level of soluble protein was found to be higher in cows' milk cheese. Ripening at 10°C produced a higher level of soluble protein as compared to ripening at 5°C.

Although ripened cheese contained a higher salt content as compared to green cheese, significant difference could not be observed in its level between goats' and cows' milk cheese.

The level of steam volatile free fatty acids (SVFFA) was slightly higher in cows' milk cheese prior to ripening, but after ripening goats' milk cheese showed higher values. Ripening at 10°C produced a higher level of SVFFA as compared to 5°C.

The pH of cheese made from goats' milk was slightly lower than that made from cows' milk, prior to and after Ripening. The pH was also found to increase during ripening, the change being more marked at 10°C.

Goats' and cows' milk cheese ripened at both the temperatures (5°C and 10°C) showed no coliforms, but the green cheese from goats' milk showed a higher coliform load.

The cows' milk cheese was judged better than goats' milk cheese. Although not significant, samples of cheese ripened at 10°C scored higher than those ripened at 5°C, the difference being more remarkable in cows milk cheese.

Samples of cheese produced in the present study was found to conform to the standards prescribed for hard cheese under the PFA Act (1982).