CHEDDAR CHEESE MANUFACTURE WITH AN ADMIXTURE OF BUFFALO, COW AND GOAT MILKS

. THESIS
SUBMITTED TO THE KURUKSHETRA UNIVERSITY
FOR THE DEGREE OF
DOCTOR OF PHYLOSOPHY
IN THE FACULTY OF DAIRYING, ANIMAL HUSBANDARY
AND AGRICULTURE

BY
MAN SINGH RATHORE

DIVITION OF DAIRY TECHNOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
(I. C. A. R.)
KARNAL (HARYANA) INDIA
1983

Regn. No. 80.UD.PH.D.6

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Dated 21st May, 1983

I certify that the work reported in the thesis entitled, "Cheddar cheese manufacture with an admixture of buffalo, cow and goat milks" was carried out by Shri Man Singh Rathore, under my guidance as requirement for the degree of DOCTOR OF PHILOSOPHY, in the faculty of Dairying, Animal Husbandry and Agriculture, Kurukshetra University, Kurukshetra.

Bijoy Kr. Chakraborty

(BIJOY KUMAR CHAKRABORTY)

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I will consider myself amply rewarded if poor goat farmer of the parched arid lands is respectfully brought into the orbit of commercialism of milk product manufacturing in the country. Herewith, I present this work with all the faults I possess.

(Man Singh Rathore)

DEDICATION

Father's	:	Late Major Chhotu Singh Ji for his uncompromisable principles of life.
Mother's	:	Smt. Antar Kunwar for her blessings.
Wife's	:	Mrs. Supyar Kanwar for her lost week ends.
Daughters	:	Suman, Santosh and Manju
		and
Sons	:	Mahipal and Ajaypal for their lost attention.

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INTRODUCTION

INTRODUCTION

Cheese may have been one of the first manufactured foods consumed by man. History records its usage more than 4000 years ago (Kosikowski, 1966). Amongst many varieties of cheese, the cheddar, a medium hard cheese, is the most important variety in the world today. More cheddar is made than any other named variety primarily due to its keeping quality, transportability, and consumer acceptance (Davis, 1981). It is popular in India due to its mild flavour.

Although cheddar cheese is usually made from cow milk, its manufacture from buffalo milk has been developed in India due to the prevalence of buffalo milk in this country. The state of progress in this regard can be realised from the fact that currently Amul Dairy has been utilizing considerable quantity of buffalo milk for cheddar cheese manufacture.

Manufacturing steps recommended for buffalo milk in cheddar cheese (Czulak, 1964; Burde and Srinivasan, 1967) differ from those for cow milk cheddar in important details such as quantity of starter culture, time and temperature of cooking, etc. These differences in manufacturing steps have been necessary due to the inherent difference between cow and buffalo milk systems in terms of compositional, physico-chemical and biochemical properties. It appears that the cheddar cheese manufacturing procedure developed for one milk system is not applicable to the other. The successful cheddar cheese making enterprise, at the present state of technology must, therefore, use milk of single species without any intermixing of cow, buffalo or goat milk.

For several reasons, collection of milk of a single species is faced with difficulties under existing conditions of dairying in India. Indian farmer keeps cow, buffalo and goat for the purpose of obtaining bullock power, milk, and meat. In general, minor quantities of milk of a particular species is mixed with the major portion of the milk collected in the dairy project area. Consequently many dairy plants in India receive varying amounts of cow, buffalo or goat milk. Separate arrangements for receiving and

processing small quantities of cow or goat milk may not be always convenient for a dairy plant handling large amount of buffalo milk. There is, therefore, a natural concern as to the effect of mixing cow or goat milk with the bulk of buffalo milk on the manufacture of cheddar type cheese. Should there be any problem, modifications in the processing technology would be necessary to counteract such a problem.

At the present time researches on the use of mixed species milk for cheddar cheese making appears to be very limited. There is a need to study the effect of incorporating varying amounts of cow and goat milk into buffalo milk on the manufacturing process and quality of cheddar cheese. Such a study is essential to the development of technology suitable for utilizing mixed milk for manufacturing cheddar type cheese.

CHAPTER 2.

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REVIEW OF LITERATURE

REVIEW OF LITERATURE

Cheddar is a hard, close-textured and bacteria ripened variety of cheese. The characteristics of a particular type of cheese depends upon the physico-chemical and biochemical changes and the microbial ecology of the coagulum occurring during manufacture and curing. These changes are mainly influenced by the type of milk, the starter microflora, and the coagulants used for cheese making. Cow milk has been used for the manufacture of almost all varieties of cheese. The technology of cheddar cheese manufacture from cow milk has been known for quite some time (Davis, 1965; Kosikowski, 1966). Very little published work is available on cheddar cheese manufacture from buffalo milk (El-Sokkary and Hasan, 1952; Nezim, 1959; Godbersen, 1964; Czulak, 1964; Burde and Srinivasan , 1967). Goat milk has been utilized for the manufacture

of some hard and soft varieties of cheese (Wilster,1959). However, no published report is available on the manufacture of cheddar type cheese from goat milk.

This review is primarily concerned with compositional differences in buffalo, cow and goat milks, their curd forming properties, the technology of cheddar cheese making with pure milk systems and the use of milk mixtures in cheddar cheese making.

2.1 COMPOSITION OF COW, BUFFALO AND GOAT MILK SYSTEMS

Biologically, milk is tailored to the growth needs of young ones. As the need of young ones of different mammalian species varies, the nature of milk secreted by various mammals also varies. These differences are reflected not only in gross composition but also in detailed physico-chemical and biochemical properties. Amongst the several domesticated mammals, cow, buffalo and goat are of major importance to India's dairy industry. While the literature on cow milk composition is voluminous (Webb et al.,1978) the reviews related to buffalo and goat milk have been rather limited (Ganguli, 1974a; Laxminarayana and Dastur, 1968, on buffalo milk; Jenness, 1980; Parkash and Jenness, 1968, on goat milk).

The difference in these 3 milks are being reviewed in terms of gross composition, protein and lipid systems with particular reference to cheese making technology.

2.1.1 GROSS COMPOSITION

Gross composition of milk is generally considered in terms of TS, fat, SNF, carbohydrates and ash. These constituents vary in all species with factors such as breed, feed, season, stage of lactation, individuality, etc. (Webb et al.,1978). Although, the degree and extent of variation may differ from species to species there is certain commonality in these trends. However, in pooled milk as received by dairies individual variations are minimized and show a gradual change alongwith the season and associated changes in climate and feed factors.

Fat is considered to be the most important of all the constituents of milk. Fat level has been given maximum attention due to its variability and commercial importance. In comparison to the high yielding western breeds of cattle, pure bred zebu cattle are known to have a higher level of fat. While a 3.5 to 4.5 per cent fat level has been generally recognised for cow milk in the west, in India 4 to 5 per cent fat level is usually expected in cow milk (De, 1982). As against these fat levels of cow milk water buffaloes in India are known to yield milk in range of 6.0 to 13.0 per cent fat (Laxminarayana and Dastur, 1969), 6.5 to 7.0 per cent being more usual under normal conditions. The fat levels in goat milks however, are similar to cow milk (Devendra, 1980).

In comparison to cow milk, both buffalo and goat milks are characterised by higher TS, protein, lactose and ash content (Ganguli, 1974[a]; Devendra, 1980). In buffalo milk these levels are much higher than in goat milk. Typical values for cow, buffalo and goat milks are 13.5%, 18.7%, 13.9% for TS, 2.8%, 3.7%, 3.7% for protein, 8.1%, 9.7%, 9.1% for SNF and 0.74%, 0.86%, and 0.85% for ash, respectively (Devendra, 1980).

Related to these compositional differences, these milk systems also exhibit different values for pH, titrable acidity, buffering index, viscosity and heat stability (Ganguli, 1974[a]; Laxminarayana and Dastur, 1968; Parkash and Jenness, 1968) bringing characteristic changes in product made from these milks.

2.1.2 PROTEIN SYSTEM

Milk proteins assume importance by virtue of their role in various processes. They impart colour and body and texture properties to the dairy products. In cheese making, besides their role in body and texture characteristics of cheese, they help in entrapping the fat into coagulated protein matrix.

According to the fourth report of the committee of American Dairy Science Association for protein nomenclature (Whitney et al., 1976), cow milk proteins have been classified into casein (precipitated from

skim milk by acid at pH 4.6) and non casein proteins. Whey proteins are included in the category of non casein proteins. Similar to the cow milk system, buffalo and goat milk proteins also consists of casein and non casein protein (Ganguli, 1974[b] for buffalo and Parkash and Jenness, 1968 for goat milk).

The percentage of total casein and non casein proteins in cow milk ranges between 76 to 86% and 14 to 24 %, respectively (Webb et al., 1978). The average values for these fractions in buffalo and goat milks are to the extent of 76% and 24%, 74% and 26%, respectively (Ganguli, 1974[b]; Parkash and Jenness, 1968; Jenness, 1980).

The caseins have been separated into various fractions such as α, β and γ caseins (McKenzie, 1967; Laxminarayana and Dastur, 1968; Parkash and Jenness, 1968; Ganguli, 1974[b]). These exist in the concentration of 55.5%, 44.5% and 40% α-casein, 39.1%, 52.4% and 60% β-casein of the total caseins for cow, buffalo and goat milks, respectively (Ganguli, 1974[b]). The γ-casein in cow and buffalo milk occurs upto the extent of 6.4% and 3.1% of the total casein. However, goat casein system lacks this fraction (Ganguli, 1974[b]).

The buffalo milk casein has the lower proportion of α_s-casein and higher proportion of β-casein in comparison to the corresponding fractions in cow milk and both have lower electrophoretic mobility than their cow milk counterparts (Singh and Ganguli, 1976). The amino acid pattern of α_{s1}-casein of buffalo milk has been reported to be distinct from that of cow milk (Abd El-Salam, 1975). The α_{s1} fraction of buffalo milk is free of carbohydrate, cystine and cystein. The β-casein fraction of buffalo milk possesses end groups identical to those of cow β-casein. These are N-terminal arginine and C-terminal sequence of Ile-Ile-val. However, the amino acid composition and the tryptic peptide patterns of buffalo and cow β-casein are not similar (Abd El-Salam and El-Shibiny, 1975).

The fastest electrophoretic component of goat milk casein (in alkaline system) represents a much smaller proportion of the total casein in comparison to cow milk (Parkash and Jenness, 1968). Richardson and Creamer (1975) isolated this component of goat milk casein and found that compositionally it is similar to the minor bovine casein designated as α_{s2}-casein. Due to the absence of the α_{s1} fraction in goat milk, the addition of as little as 1 per cent of cow milk to goat milk can be detected by gel-electrophoresis

(Aschaffenburg and Dance, 1968). The β-casein of goat milk has two components called β_1 and β_2-casein (Richardson and Creamer, 1974).

Like the cow milk κ-casein, buffalo milk κ-casein has both κ-A and κ-B fractions. However, its α_s stabilizing ability is lower in comparison to cow milk κ-casein (Ganguli, 1979). The goat κ-casein has different amino acid sequence than that of cow milk (Dayhoff, 1979). It has 171 residues in comparison to 169 in cow milk systems. However, its phe-met residues are at position 105 and 106.

The major whey protein or serum protein of milk are known to be α-lactalbumin and β-lactoglobulin. The concentration of β-lactoglobulin and α-lactalbumin in cow milk has been reported to be 0.30 and 0.10 g per 100 ml (Brunner et al., 1960). For buffalo milk Ismail et al. (1970) have reported the values 0.37 and 0.14 g per 100 ml milk, for β-lactoglobulin and α-lactalbumin, respectively.

Cow milk has β-lactoglobulin A, B and C variants (McKenzie, 1967). Buffalo and goat milk have been reported to have only one genetic form of β-lactoglobulin (Sen and Sinha, 1961; Phillips and Jenness, 1965). It has been established that buffalo

milk β-lactoglobulin is identical to cow milk β-lactoglobulin B variant (Mawal et al., 1965). Similarly, goat milk also does not have the genetic variant for β-lactoglobulin (Phillips and Jenness, 1965).

The α-lactalbumin of cow milk has been reported to contain two components viz., α-lactalbumin A and α-lactalbumin B (Bell and McKenzie, 1967). No such variants have been reported for the buffalo and goat milks.

2.1.2.1 Protein-Protein Interactions

The various protein fractions exist in the milk system in complex colloidal form and partly in solution. Complex formation between milk proteins is very critical for understanding the physico-chemical changes undergone by milk during manufacturing, particularly in case of fermented milk products like cheese. In the native state, the most important protein-protein interaction phenomenon can be found in casein micelles.

Micelles are sub-microscopic spherical aggregates that are found in cow milk within the range of 90 to 100 nm. The structure and constituents of casein micelles have been the subject of many excellent reviews (Rose, 1969; Slattery and Evard, 1973; Webb et al., 1978). The micelles are known to be composed

of smaller subunit micelles of 10 nm size. The major compositional units of micelles are α, β and κ -caseins. The complex association of the individual caseins in micelles is aided by calcium. Formation of micelles impart better stability of multi-electrolytes and environmental changes in milk brought about by shift in pH or processing effects of heat and other related agents.

In the milk systems, casein exists in an equilibrium between soluble and micellar forms (Sabarwal and Ganguli, 1970; Jenness, 1980). The soluble casein, as found in cow and goat milks is virtually absent from the buffalo milk. Buffalo milk casein micelles are larger (135 nm) in size than those of cow milk (90 nm) and contain higher level of calcium and lower level of sialic acid and hexose in comparison to cow milk casein micelles (Sabarwal and Ganguli,1970). Buffalo milk casein micelles have more opacity and lower voluminosity (solvation) than the cow milk casein micelles (Ganguli, 1973, 1974b).

The goat milk micelles also differ markedly in several respects from those of cow milk. The difference is attributed to the probable absence of α_{s1}-casein in goat milk (Jenness, 1980). The proportion

of small micelles is more in goat milk than in the cow milk. A few of the micelles have been reported to be about 200 nm in diameter and the majority below 80 nm in diameter (Parkash and Jenness, 1968; Richardson, et al., 1974). Their solvation (1.60 g H_2O/g pellet) is also low in comparison to cow milk micelles with 1.90 g H_2O/g pellet solvation (Thompson et al., 1969). Goat casein micelles contain higher calcium than the cow milk micelles (O'Connor and Fox, 1977).

2.1.2.2 Heat Induced Interactions

The interactions between various protein fractions at normal temperatures have not been reported so far. However, when milk is heated, denaturation and interaction of whey protein and casein components of skim milk have been reported by several workers (Hartman and Swanson, 1965; Hunzikar and Tarassuk,1965; McKenzie, 1967; Purkayastha et al., 1967; Tessier et al., 1967; Morr and Josephson, 1968). At temperatures over 80°C the serum proteins denature. This process is accompanied by extensive breaking and randomisation of the stabilizing disulphide bonds. The process is especially marked in β-lactoglobulin having one free sulphydryl group which initiates autocatalytic disulphide exchange reactions (Webb et al., 1978). The interaction

between β-lactoglobulin and κ-casein has been reported in detail by McKenzie (1967). This reaction occurs when more than 50% of the whey proteins have been denatured by heat. It is also a time dependent reaction (Morr and Josephson, 1968). At 100°C, interaction between β-lactoglobulin and κ-casein occurs, although the κ-casein remains fixed to the micelle. This interaction alters the nature of the micelle surface affecting the stability of micelles to heat and to enzyme action.

The interaction of β-lactoglobulin with κ-casein improves the yield of cottage cheese (Harper and Hall, 1976). Attempts have been made to incorporate the serum proteins into cheese by heating the milk, prior to renneting, to induce complex formation with κ-casein. This has been found to inhibit aggregation, presumably because the bound serum protein stabilizes the para-casein micelle (IDF, 1979).

2.1.3 LIPID SYSTEM

Lipid phase essentially entrapped in the protein matrix undergoes lipolytic changes during curing and thus contributes to the flavour and textural properties of cheese. In comparison to other natural fats, milk fat is generally characterized by larger

proportion of short chain fatty acids like butyric, caproic, capric, etc. (Jenness and Patton, 1959). In addition to the total fat level in milk, relative proportion of constituting fatty acids and their distribution throughout the triglyceride structure vary in different milk systems (Jensen and Sampugna, 1966; Parkash and Jenness, 1968; Ramamurthy and Narayanan, 1971, 1972 and 1973; Jenness, 1980). These are further influenced by environmental factors such as nature of fat present in the feed (Jenness and Patton, 1959). All even number straight chain fatty acids (C_4 to C_{18}), present in cow milk fat, are also present in buffalo and goat milk fats. Cow milk has a higher content of C_{16}:0, C_{18}:0, C_{18}:1 and C_{18}:2 and the goat milk fat is rich in C_6:0, C_8:0, C_{10}:0, C_{12}:0 and C_{14}:0 (Glass et al., 1969) and the buffalo milk fat contains higher amounts of C_4:0, C_{16}:0 but is low in C_{18}:1 (Cucurachi and Lotito, 1968). The saturated fatty acids in goat milk fat are upto the extent of 67 per cent of the total weight of fatty acids.

Ramamurthy and Narayanan (1971) have also reported differences in fatty acid composition of cow and buffalo milk fats. These authors (1972) further reported that dienoic and trienoic fatty acids are higher in cow milk fat whereas, tetra and pentaenoic

acids are more in buffalo milk fat. The major part of these fatty acids was in non-conjugated form. The conjugated pentaenoic acid was found absent in cow milk fat.

The triglycerides of cow and goat milk fats are much alike (Devendra, 1980). Similar report was also published earlier by Mills et al.(1976). Ramamurthy and Narayanan (1973) reported the triglyceride pattern of buffalo milk fat to be different than the cow milk fat triglycerides. The buffalo fat contains higher amounts of higher melting triglycerides in comparison to cow milk fat. This results in earlier crystallization of buffalo fat than the cow milk fat.

The relative composition of triglycerides and the fatty acid distribution in triglyceride influences the melting point and crystallization behaviour of the resultant fat. Due to presence of mixed triglycerides butter fat of all the three milks exhibit a range of melting or softening points instead of a sharp one. Buffalo milk fat exhibits higher melting point ranges and goat milk fat lower than those by cow milk butter fat system (deMan , 1961; Jensen and Sampugna, 1966; Raghuveer and Havhmond, 1967; Parkash and Jenness, 1968; Ramamurthy and Narayanan, 1973).

Butter fat in native milk exists as an emulsion protected by a fat globule membrane, which is composed of protein-phospholipid complex. Structure of fat globule system in milk has been the subject of excellent reviews (King, 1955; Mulder and Walstra,1974). Fahmi et al.(1956) observed significant differences in diameter of milk fat globules of different species. For goat and cow, the size has been reported to be between 1 to 10 μm diameter. Goat milk fat contains larger number of smaller size globules. The percentage distribution of smaller globules upto 4.5 μm diameter for cow, buffalo and goat milk fats was observed to be 40.9, 65.4 and 82.8 per cent, respectively. This influences the curd forming properties of milk by imparting homogenization like effect when the globules are smaller. Milks with larger size fat globules produce a firm curd.

The creaming properties (agglutination) of goat milk are poor as compared to cow milk because of the lack of agglutinin in this systems (Jenness,1980).

2.2. CURD FORMING PROPERTIES OF COW, BUFFALO AND GOAT MILK SYSTEMS

Formation of curd represents the conversion of colloidal casein micelle system into a semisolid three dimensional gel matrix in contrast to amorphous precipitates often experienced during the preparation of acid caseins. The formation of curd, the strength

of the gel matrix, its moisture holding as well as releasing properties are important to the progressive development of cheddar cheese during the subsequent stages of cutting, cooking, cheddaring, milling, hooping and curing. The nature of curd formed due to the enzymatic action of rennet is quite different from that formed as a result of a grdual decrease in pH brought in due to slow increase in acidity by lactic fermentation or other method (such as hydrolysis of lactose).

In addition to the properties of curd strength for acid and rennet curd, clotting time becomes an additional parameter requiring consideration in the formation of rennet curd systems.

Due to inherent differences in the nature of cow, buffalo and goat milks, their curd forming properties differ considerably.

2.2.1 RENNET AND ACID CURDS

The coagulum obtained by rennet action on milk has considerable elasticity. It undergoes shrinkage during scalding, thereby expelling moisture (whey). Shrinkage increases with the increase in the temperature and acidity. In comparison, the acid curds are not elastic but gelatinous and fragile, and shatter more

and contract less than the rennet curds (Webb et al., 1978). Rennet curds enclose the fat and insoluble salts of the milk, while the insoluble salts in case of acid curds rendered soluble and lost in the whey. Sixty to Sixty five per cent calcium and 50 to 60 per cent phosphorus has been reported to be retained in cheddar cheese by Dolby and McDoWall (1935) and Mattick (1938). However, McCammon et al. (1933) reported the values as 80 and 38 per cent, respectively. Similar data on goat and buffalo milk systems are not available.

2.2.2 RENNET COAGULATION OF COW, BUFFALO AND GOAT MILK SYSTEMS

When milk is treated with enzyme rennin, a visible clot is formed. This does not bring any change in the gross composition of milk system (Wright, 1924). It is formed by the caseinate system of the milk entrapping the whey and fat by mechanical entrapment. Coagulation of milk occurs in two phases (i) a primary enzymatic phase in which rennin attacks phenylalanine-methionine peptide bond of κ-casein releasing glycomacropeptide (Waugh and Von Hippal, 1956; Nitschmann et al., 1957; Jolles et al., 1968). and (ii) a secondary non enzymatic phase in which the paracasein system clots in presence of calcium ions (Fox, 1970).

Milk clotting mechanism that follows rennet action is not fully understood. However, electron microscopic studies by Hostettler and Imhoff (1955) have revealed that initially short thread like structure appears to join the micelles and then these form into large fibrils. The caseinate particles tend to agglomerate and eventually change into a crosslinked net-work of fibrous structure. The authors described the final coagulum as an irregularly arranged structure of paracaseinate particles in a three dimensional thread like net-work. The milk fat and whey are trapped within the paracasein structure. Knoop (1976) suggested that the aggregation of the casein micelles is due to the loss of highly charged macropeptide into the whey. This causes a reduction in the charge associated with casein micelles. This may allow Vanderwall's attractive forces between the particles to be dominent causing aggregation or the hydrophobic forces on the enzymatically modified areas might interact. Knoop (1978) reported that rennet coagulation appears to proceed by formation of chains of casein micelles followed by cross linking to produce a three dimensional net-work of about 10μm mesh enclosing the entire liquid mass.

Recently Storry and Ford (1982) have stated that initially the κ-casein moiety of casein micelle is hydrolysed by chymosin according to Michaelis-Menten kinetics. Hydrolysis of 80 to 90 per cent κ-casein results in destabilization of micelles which aggregate by diffusion according to Von Smoluchowski principle. The authors have further stated that coagulation occurs after the addition of rennet at a time which depends on the prevailing rates of κ-casein hydrolysis and micelle diffusion. A period of coagulum firming then follows to give a final structure whose properties depend on the particular type of cheese being made.

The rennet coagulation is faster in buffalo milk due to the much faster rate of secondary reaction with high calcium (Puri and Parkash, 1965; Laxminarayan and Dastur, 1968; Ganguli and Menon, 1971) eventhough the primary reaction is much slower (Gupta and Ganguli, 1965; Ganguli, 1973). The rate of coagulation can be controlled either by adding less rennet or citrate/ phosphate to the milk to slow down the secondary reaction by trapping calcium. Sharma (1962) and Sharma and Bhalerao (1964) reported that rennet coagulation increases by diluting buffalo milk, although the increase was appreciable only at dilutions more than 100 per cent.

Ibrahim and El-Abd (1976) observed that buffalo milk requires less time than cow milk to reach the same level of firmness when curdled with animal rennet. Ooman and Ganguli (1977) showed that release of macropeptides was greater from cow milk micelles than buffalo milk micelles.

The action of rennet on goat milk caseins is much similar to that on cow milk caseins. However, in certain aspects differences have been noticed (Parkash and Jenness, 1968). During rennet action glycopeptides are released both from cow and goat milk caseins. The amino acid composition was similar, but not identical. No N-terminal amino acid has been detected. The C-terminal amino acids for the caseinoglycopeptides of cow are alanine and valine whereas, these are glutamic acid and valine for goat milk (Alais and Jolles, 1961). Heating milk to 95°C for 15 minutes increased coagulation time in cow milk, but had little effect in goat milk (Oosthuizen, 1962). The release of NPN after renneting was however, not greatly affected by such heating in either case. The rennet clotting of goat milk is much faster than cow milk (Frahn, 1926; Puri and Parkash, 1962).

2.2.2.1 Rennet clotting time of cow, buffalo and goat milk systems

The rennet clotting time of milk (RCT) is generally observed visually with the formation of a clot, or rather the sudden fracture of a film of milk on the wall of a test tube, Apparatus for measuring RCT have been described by Berridge (1952) and Bakker et al.(1968). The composition of milk, incorporation of certain additives in milk and the conditions such as acidity, pH and temperature of milk may increase or decrease the formation of visible clot.

The chemical composition of milk has got a greater influence on the rennet clotting time (RCT). White and Davies(1958) observed that the RCT of pooled cow milks varied from 3.2 to 5.4 min., whereas, the individual samples varied from 1.4 to 12.9 min. These authors reported that in general, quick coagulating milk gave a firm curd, while the slow coagulating milks gave a softer curd. It was concluded that in early lactation, renneting times were short and as lactation advanced there was a progressive increase in renneting time.

Puri and Parkash (1962) examined the remneting times of a number of samples of cow, buffalo and goat milks at 15 to 30°C temperatures and remnet concentrations of 10 to 50 mg/100 ml milk and observed individual variations in milk of each species. The

values for cow milk were considerably higher than those for buffalo and goat milks. The last two varieties did not differ so much from each other. The authors found negligible effect of skimming on RCT for all the samples. However, small effect of dilution was noticed for all the milks.

Wahba et al.(1973) observed that milk from individual buffalo coagulates in shorter time than that of individual cow milk by rennin.

Blattner and Gallman (1980) observed that goat milk and its mixture with cow milk coagulated slightly more rapidly than pure cow milk. Addition of calcium chloride and temperature increase had less effect on goat milk than on cow milk.

Sharma (1962) reported that RCT steadily increased with the dilution of cow milk. Buffalo milk registered a minimum around 5 per cent dilution and after that the value never differed upto twice dilution, by more than 10 per cent (on either side) from the value for undiluted milk. Puri and Parkash (1962) however, recorded very small effect of dilution.

Sharma and Bhalerao (1964) reported that with the increasing dilution with distilled water the RCT for cow milk increased upto 500 per cent dilution, whereas buffalo milk remained almost the same upto 100 per cent dilution and showed a steady increase after 150 per cent dilution.

El-Shibiny and El-Salam (1980) diluted the cow, buffalo and goat milks at varying degrees with water and reported that their RCT increased rapidly when diluted higher than 40 per cent for cow and 60 per cent in case of buffalo and goat milk. The rapid increase in RCT was attributed to the level of colloidal calcium.

Dalgleish (1980) reported that after dilution, milks showed a large increase in RCT. Conversely, concentrated milks showed RCT similar to unconcentrated milk.

Wahba et al.(1973) concluded that the RCT increases in both cow and buffalo individual milk by heating raw milk at 85°C for 30 minutes and this increase was more in cow milk than in buffalo milk. Similar observations were recorded by Dolezaleck and Helclova (1964) and Dimov and Georgiev (1965).

Marshall et al.(1978) reported that the heat treatment of milk denatures whey proteins and leads to chemical linkage of β-lactoglobulin to κ-casein, but the heated milk coagulates more slowly with rennet.

Stephen and Ganguli (1976) carried out the studies on the heat induced changes on buffalo milk proteins and reported a prolongation of RCT by heating buffalo milk at 60°C to 100°C for 10 minutes. Heat treated buffalo milk also clotted faster than cow milk under indentical conditions.

Dilanyan and Gabrielyan (1949) observed that the addition of 0.1 - 0.7 ml of 22.2 per cent $CaCl_2$ solution to 10 ml of milk at 35°C decreased the coagulation time, which was shortest when 0.2 ml of the solution was used. Vedyashkin et al.(1958) reported that enrichment of milk with calcium ions improved its coagulation by rennet.

Niki et al.(1958) concluded that addition of $CaCl_2$ to heated milk can restore its RCT. Wahba et al. (1975) observed that heating skim milk or dialysed skim milk at 90°C for 30 minutes prevented their coagulation by rennin. Higher retardation was obserged for cow milk than for buffalo skim milk. The coagulation time, however, decreased in both cow and buffalo skim milk with increasing concentration of calcium.

Castelao et al.(1977) studied the coagulation in milk with varying amounts of $CaCl_2$. It was found that flocculation time decreased with increasing amounts of $CaCl_2$ upto 800 mg/L milk. Similarly Kowalchyk and Olson (1979) observed reduced clotting time with addition of

calcium. However, Aleshko (1979) concluded that not more than 10-15 g $CaCl_2$ should be added per 100 L milk.

Kosikowski and Mocquot (1958) in their review indicated that $CaCl_2$ addition to heated milk reduces the RCT. However, there are limitations to the use of $CaCl_2$. A larger quantity than recommended gives a bitter flavour to the cheese. Also this compound becomes less and less effective as temperature for heating milk continued to rise above minimum pasteurization standards.

Storry and Ford (1982b) concluded that the reduced pH and increased temperature of milk reduces the RCT of the system. Similarly the increased concentration of rennet and added calcium was reported to decrease the RCT of milk. Only extremes of concentration or dilution of milk increased the RCT.

Laila et al.(1981) investigated RCT of goat, buffalo and cow milk and reported that addition of H_2O_2 or formaldehyde increased the RCT of all the milks. Addition of sodium carbonate to the level of 0.2% inhibited milk coagulation. Noticeable increase in RCT was recorded when salt content was increased upto 7.5 $\simeq$ 10%. Cow milk showed more sensitivity towards calcium chloride in lowering RCT.

Fahmi and Sharara (1950) reported that the addition of salt to milk increased its clotting time. The possible explainations for delayed clotting in salted milk given by the authors are that (1) considering rennin as an acid protein of the globulin type, it (like other proteins) may be salted out of solution by sodium chloride, and thus its action is retarded by increased amounts of salt, resulting in a longer time of coagulation, (2) on the principle of base exchange, the addition of sodium chloride to calcium caseinate causes the replacement of the calcium ions by sodium ions with the formation of sodium caseinate or sodium-calcium caseinate complex and calcium chloride as is believed to occur in preparation of soft curd milk by zeolite treatment or addition of sodium citrate or phosphate, (3) both the foregoing factors may operate together.

Sharara (1958) observed that addition of salt to cow and buffalo milks increased the RCT of both the milks. Ramanauskas (1978) reported that bonding of sodium chloride with the para-casein complex of milk influences its physico-chemical properties.

2.2.2.2. Rennet curd strength of cow, buffalo and goat milk systems

The factors affecting RCT also influences the firmness of the curd, but the effects are not always parallel.

Kelley et al.(1951) studied that relationship of RCT and rennet curd tension (RT) and reported that only a general, relationship exists between the RCT and RT. In general, factors which affect one also affect the other, although not neccesarily to the same extent. Both tests are markedly affected by composition of milk, heat treatment, cool-aging, casein content, calcium and acid additions, and seasonal variations in the milk supply. However, homogenization and fat content have a much greater effect on curd tension than on RCT. It was concluded that rapidly formed curd tends to be firm and vice-versa.

Sirry and Shipe (1958) reported that the curd tension increase with rennet coagulation time but decrease with increasing salt concentration. Addition of sodium chloride reduced the curd tension of milk for each coagulation period. Similar observations were recorded by Tracy and Corbett (1940) also.

Miyabe (1960) obtained high RT values when Ca:P ratio (in combination with casein) was low.

Ismail and Salam (1971) standardized cow and buffalo milk to 3:8.5 fat to SNF ratio, pasteurized and renneted at 40°C and allowed to coagulate for 150 minutes. The authors observed that the curd strength of buffalo milk increased with increasing milk solids contents upto 17 per cent, remained unchanged with further increase upto 20 per cent. For cow milk RT increased upto 14 per cent milk solids and decreased with increasing milk solids upto 20 per cent using a lower concentration of rennet. It remained nearly constant when higher concentrations of rennet were used. Buffalo milk curd was always firmer and stronger than that of cow milk of the same solids content.

Ashworth and Nebe (1960) observed that when the pH of the milk is lowered either by the slow addition of acid or by starter development, there is a marked increase in RT alongwith a rise in the calcium content of the whey. After reaching the maximum value of the RT decreases with further acidity development, although the soluble calcium concentration continues to rise.

Bailey and Cardwell (1978) reported higher values of RT with addition of $CaCl_2$ at the rate of 0.10 and 0.15 g per 100 ml milk. Temperature, time and rennet levels also affected RT similarly.

Hofi et al.(1979) observed that curd tension tended to decrease as the temperature of pasteurization of buffalo milk increased. Homogenization reduced the RT of whole milk, but did not affect that of skim milk. Increasing coagulation temperature, setting time and amount of rennet increased the curd tension.

Storry and Ford (1982) observed an increased RT at one hour after RCT by reduction in pH and increase in concentration of added calcium. Increased temperatures decreased coagulum strength whereas, increased rennet concentration had little effect. A curvilinear relationship between total casein concentration and coagulum strength was observed for Friesian and Jersey milks,

2.3 TECHNOLOGY OF CHEDDAR CHEESE MAKING

Basic aim of cheddar cheese making is the controlled expulsion of moisture and development of acidity in the rennet curd. This helps creating suitable physico-chemical and biochemical conditions for microflora that would act in a phased manner to bring about desirable organoleptic and body and texture changes in the curd.

Starting with the standardization of milk the cheddar cheese manufacture proceeds in the following sequential steps, viz. ripening of milk, setting of milk with rennet, cutting the curd, cooking, drainage of whey, cheddaring, milling, salting, pressing, rind formation, paraffining, and curing. Due to the advent of large scale mechanization and automation in the cheese industry, many of these steps have undergone modifications. Thus, cheddar cheese today is made from cow milk using no single orthodox method but by various processes which ultimately result in the same end product.

This review is concerned with the basic technology of cheddar cheese making that is still applicable in small to medium scale batch processes carried out in cheese vats, giving particular attention to the studies reported on cow and buffalo milk systems. Although cheddar cheese from cow milk has been subject of many excellent reviews (Van Slyke and Price, 1949; Wilster, 1959; Davis, 1965; Kosikowski, 1966). Similar information for buffalo milk has been rather limited (Godbersen, 1964; Czulak, 1964; Burde and Srinivasan, 1967; Nejim and Alusi, 1970).

2.3.1 STANDARDIZATION OF MILK

Basic aim of standardization is the maximum retention of fat within the coagulated protein matrix. Fat helps in the retention of moisture in the curd (Whitehead, 1948) and contributes to body and texture and flavour (Ohren and Tuckey, 1969). During the cutting of curd, cooking, and subsequent stages of cheese making, a portion of fat is lost in the whey. This loss can be minimized effecting an overall economy in the total solids recovery in cheese, by standardizing milk in terms of casein to fat ratio. This is due to the fact that retention of fat in cheese is essentially dependent on the amount of casein available in the system for the formation of rennet curd.

A casein:fat ratio (C:F) of 0.7 in cow milk was found most suitable for cheddar cheese (Price and German, 1931). High fat contents of milk results a soft young cheese while higher SNF gives a firm tough cheese (Baron, 1947). Wilster *et al.*(1948) used skim milk powder to adjust fat:SNF ratio to 1:2.35 and reported that fat contents over 4.7% in standardized milk results in brittle and crumbly cheese. Unsweetened condensed milk was used by Hanrehan *et al.*(1959) to

standardize cheese milk to a desired fat:SNF ratio. Chapman et al.(1974) obtained good quality cheddar cheese from milk standardized to fat:SNF ratio of 0.35 - 0.46.

In cheddar cheese manufacture from buffalo milk, a casein:fat ratio of 0.68 to 0.7 was also found suitable (Czulak, 1964; Burde and Srinivasan, 1967). Addition of skim milk powder for adjusting C:F ratio in lieu of skimming the excess fat from buffalo milk was suggested by Nejim and Alusi (1970). Nofal et al. (1977) adjusted the TS of buffalo milk in between 11.5 to 19% and fat:SNF ratio within 3:8.5 for making cheddar cheese with minimum fat losses.

2.3.2 MILK TREATMENTS

In the early years raw cow milk without any treatment has been used for cheese making. However, with the advancement of cheese making technology, treatments like pasteurization, addition of H_2O_2, homogenization, and addition of certain salts have been introduced.

Pasteurization of milk for cheese making has been generally preferred due to better predictability in the manufacturing schedule, the quality of finished product, earlier availability of cheese for sale due

to destruction of pathogens, and slightly increased yield (Davis, 1965). Time temperature combination of 65.5°C for 6 minutes or 72°C for 15 seconds was found suitable for making good quality cheddar from cow milk (Price, 1927; Sherwood, 1936; Wilson et al.,1945; Walter et al.,1959).

Similar heat treatments of buffalo milk for cheese making were suggested by Abd El-Salam et al. (1974), Burde and Srinivasan (1967), and Czulak (1964).

The cheese from pasteurized milk ripens slowly and is milder in flavour than the raw milk cheese. This was attributed to the inactivation of natural enzymes and destruction of beneficial organisms by pasteurization (Law and Hammer, 1935; Roundy, 1958). Addition of 5-25% high quality raw milk to the pasteurized milk improves the flavour of the finished product (Davis, 1965).

Pasteurization also causes prolonged remeting time, higher moisture retention in curd and reduces the curd strength (Dolezalek and Helclova, 1964; Szabo and Balatoni, 1965; Davis, 1965; Chandrashekhara et al.,1957). These defects could be corrected by the addition of some acids (Sammis and Bruhn, 1912), calcium chloride (Price, 1927; Bailey and Cardwell, 1978), a

little more rennet at a slightly higher temperature, and cutting the coagulum slightly later (Davis, 1965).

Abd-El-Salam et al.(1974) suggested addition of phosphate and citrate to reduce the curd strength of buffalo milk. The addition of either sodium pyrophosphate or sodium citrate (0.1 M) improved the quality of cheddar cheese from buffalo milk (El-Safty et al.,1976).

Addition of sodium chloride to cow milk above 0.6 per cent prolonged the coagulation time (Hamdy and Edelsten, 1970). However,at levels below this reduced the coagulation time. Maze (1940) found that sodium chloride above 1 per cent level in milk prolonged coagulation time.

Fahmi and Sharara (1950) have suggested addition of sodium chloride to buffalo milk to reduce curd strength and to produce soft curd.

Amongst ather treatments given to milk which requires modifications in cheese making procedure, homogenization of cow milk for cheese making was reviewed by Peters (1964). The advantages of this treatment are reported to be reduced fat losses in whey, higher yields, lower shrinkages during ripening, and reduced fat leakage at higher temperature. However, this treatment gives weak curd and increases the cost of cheese making.

Neogi and Jude (1978) made cheddar cheese from buffalo milk with homogenization at low pressure and observed that this treatment produced higher moisture content, fat retention and proteolysis, and lower fat and protein content in the cheese.

Addition of H_2O_2 @ 0.02 - 0.5 per cent in cow milk heated to 50°C for 25 seconds followed by catalase treatment has been found to yield satisfactory cheese eliminating the defects of raw or pasteurized milk (Tapty et al., 1958; Roundy, 1958). Kristoffersen and Cole (1960) made cheese from raw, pasteurized and peroxide treated milk and observed that raw milk cheese tended to obtain higher scores for typical cheddar flavour than the other two. Certain flavour defects such as "utensil" and "metallic" were observed in cheese from peroxide treated milk.

Fox (1964) observed faster rennin action on H_2O_2 treated casein. It was, however, observed that H_2O_2 treated α-casein did not produce a gel with rennin either in presence or absence of Ca^{++}.

Gritsenko (1972) reported that small amounts of H_2O_2 raised the NPN content of the milk and increased its sensitivity to rennet. Milk treated with 0.015 per cent H_2O_2 at 47-49°C for 30 minutes coagulated as

rapidly as untreated milk and yielded a firmer curd with 30 per cent less rennet than normally required. Cheese prepared from H_2O_2 treated milk possessed 13-14 per cent more soluble total nitrogen and soluble NPN and a better consistency and texture than cheese from untreated milk.

El-Safty *et al.*(1977) reported that use of H_2O_2 in buffalo milk cheddar cheese restricted the cheese acidity. However, it increased the soluble nitrogen and NPN contents of cheese. It also improved the sensory quality of cheese.

2.3.3 USE OF STARTER CULTURES

The addition of starter culture in cheese milk is necessary for proper rennet action. Suppression of growth of undesirable organisms, expulsion of moisture and ripening of cheese by providing desirable microflora (Vanslyke and Price, 1952). The importance of the acidity produced by starter cultures on the texture and flavour of cheese has been extensively studied (Lowrie *et al.*,1973; Belousva *et al.*,1976; Hoglund *et al.*, 1976). Control of the development of acidity has more influence on the quality of the cheese than any other factor (Wilson, 1942).

Pimblett (1962) reported that increased rate of acid development due to excess starter inocula (upto 5 per cent), influences the quality of cheese, The development of acidity can however, be controlled by using pasteurized milk, by varying the proportion of starter, and by permitting the milk to ripen for 1 hour after addition of starter (Wilson, et al.,1945). The quality of cheddar cheese is closely related to the acid development during the cheese making process (Brown and Price, 1934). These authors reported that the higher acidity results in inferior quality of cheese.

Hansen et al.(1933) observed that starter culture comprising of Str.lactis, Str.cremoris, Str.citrovorus and Str.paracitrovorus was suitable for proper development of acidity in cheese milk and resulted in cheese with satisfactory flavour, body and texture with either raw or pasteurized milk. Szabo and Balatoni (1962) used the following bacteria to choose the best starter for cheddar cheese manufacture using different inocula percentage : 1. Str.lactis, Str.cremoris - 2%. 2. Cheddar starter - 2% 3. Str.therophilus - 2% 4. Str.lactis, Str.cremoris-2% 5. Str.lactis, Str.cremoris-2% 6. Str.lactis, Str.thermophilus-1%, 7. Lb.lactis, Str.thermophilus 0.1-0.3%. It has been reported that the development

of acidity was almost identical with cultures 1, 2 and 6. Culture No.3 had the samllest acidifying effect. Cultures 4,5 and 7 gave the highest acid values.

Cow cheese curd made with a slow starter results in weak and poor textured cheese (Davis, 1965). However, Lawrence et al.(1972) observed that cheese with "slower" starter was of good flavour irrespective of the time of season and large variations in the bacteriological quality of raw milk. They also observed that "faster" starter had a marked tendency to give bitter cheese.

An increase of 0.02 per cent acidity above the initial acidity of milk is necessary for milk coagulation and curd characteristics (Vanslyke and Price, 1952). Chapman and Harrison (1963) however, observed that use of unripened milk (rennet added 15 minutes after starter) had greater control over acid development and moisture expulsion.

For buffalo milk cheddar cheese, no specific attempts have been made so far to isolate and use starter cultures on the basis of their cheese making performance. Essentially, the starters used for cow milk systems have been tried also for buffalo milk.

Acid development in buffalo milk is at a slow rate due to its higher buffering action and needs preincubation with starter culture for a longer time to attain proper acidity (El-Rafey, 1962).

Thomas et al.(1966) reported greater rate of acid production, slightly faster rate of growth and slow proteolytic activity of starter organisms in buffalo milk than in cow milk. However, under cheese making conditions in raw or slightly heat treated milk, slow growth rate of organisms was observed which might be a probable cause of slow rate of ripening of cheese.

Godbersen (1964), Czulak (1964), Burde and Srinivasan (1967) and Nejim and Alusi (1970) also observed a slow rate of acid development in buffalo milk used for cheddar cheese manufacture. Czulak (1964) suggested a higher rate (1.5 per cent) of starter for buffalo milk. Burde and Srinivasan (1967) suggested starter addition at the rate of 2.5 per cent.

2.3.4 RENNETING

The ideal coagulant used for cheddar cheese manufacture is calf-rennet. Rennin, the major component of rennet brings about coagulation of milk as has already been reviewed in sec. 2.2.2. It also causes slow proteolysis of casein during ripening (Alais et al., 1955; Lawrence et al.,1972; Phelan et al.,1973; Green and Foster, 1974).

The quantity of rennet and the coagulation temperature affects the coagulation time. The curd firmness and the properties of coagulum are also influenced by the amount of rennet. Halving the amount of rennet reduces the curd strength and the yield of cheese (Ernstrom, 1956). Incubation of milk with small quantity of enzyme prior to addition of larger amount of enzyme has been suggested by Szadkowska et al. (1978) to reduce the actual quantity of enzyme required.

Kelley et al.(1951) during studies relating to rennet coagulation time and rennet curd tension used, a rennet dilution corresponding to 3 oz of rennet/1000 lbs of milk. Puri and Parkash (1962) used rennet concentrations varying from 10 to 50 mg/100 ml milk for similar studies.

Ernstrom (1956) reported that reduction of rennet to half the normal amount gives a reduced curd strength at the cutting stage, and reduces the yield of cheese solids. It also causes a relatively small decrease in soluble nitrogen when compared to the total percentage present in cured cheese.

Yamamoto et al.(1968) made cheddar cheese with twice the normal proportion of rennet, and found that it increased soluble nitrogen, improved the texture, but did not promote flavour development.

Melachouris and Tuckey (1964) observed that the effect of the amount of rennet used in cheddar cheese making was most noticeable on body and texture only during the very early stages of curing.

Castelao et al.(1977) reported decreased flocculation time with increased amounts of rennet upto 10μl/20 ml milk, but above these levels there was little further decrease. The casein losses in whey were reported to be reduced by addition of rennet upto 3.5μl/20 ml milk.

For cheddar cheese making from cow milk, generally the rennet addition is done as per instructions of the manufacturers. The basic purpose is to get the curd setting in about 30 min. time. For buffalo milk also the curd setting is to be accomplished in 30 min. time. Although buffalo milk clots faster, same amount (as for cow milk) of rennet is added to it.

2.3.5 CUTTING, COOKING AND DRAINING

Moisture retention in curd to a desirable level can be regulated through cutting, cooking and whey drainage. The curd should not be too soft at the time of cutting as it leads to more fat and casein losses, hard curd tends to delay moisture expulsion

(Davis, 1965). Firmness of the curd at cutting influences the elasticity of cheese i.e. curd cut soft results in cheese of high elasticity (Baron, 1947).

Size of the curd cubes influence the surface area exposed for whey expulsion and uniform heating. Gilles (1976) observed that increasing knife size from 6 to 12 mm increases the moisture in cheese by about 1.5 per cent. Reduction in curd cube size below ¼" increases moisture expulsion and fat losses (Feagon et al., 1965).

Gradual increase in cooking temperature to 102°F has been suggested by Price (1944) for cow milk cheddar cheese. Rise in cooking temperatures causes moisture expulsion but affects the starter activity (Gilles, 1976). The cooking of cow milk curd requires about 1 to 1½ hour during which whey temperature reaches 102°F and whey acidity increases by 0.015 per cent. Dolby et al.(1940) has suggested draining of whey at 0.02 to 0.04 per cent more acidity than that at the time of cutting. Higher acidity causes more mineral losses in whey which adversely affect the body of the cheese.

Casein micelles of buffalo milk are larger in size (Sabarwal and Ganguli, 1971; Ganguli, 1973) and retain less water during rennet action. The higher calcium and phosphate and lower citrate content of buffalo milk causes excessive moisture expulsion by curd (Anantakrishnan et al., 1943). The voluminosity of casein micelles of buffalo milk is less than cow milk micelles and it decreases rapidly between a temperature range of 35 to 45°C (Sood et al., 1974) which results in lower moisture retention.

Czulak (1964) suggested cutting of the buffalo milk curd with 3/8 inch knives to obtain firm curd. He recommended stirring and cooking of curd 5 minutes after cutting and continuing for about 50 minutes with a whey temperature of about 99°F. As soon as the titrable acidity of the whey rise by 0.015 per cent above that at cutting the stirring should be stopped and half of the whey should be drained off. Stirring should then be resumed and about 1.5 to 2 per cent salt W/V of the remaining vat contents should be added to the whey and stirring at 99°F for about 20 minutes until the curd cubes are firm. Whey should be than drained off. The addition of salt (NaCl) has been suggested in order to exchange some of the calcium in

the curd for sodium ions and thus reducing the synresis. Similarly, Burde and Srinivasan (1967) suggested early cutting and larger size of knife for cutting the buffalo milk curd, using lower cooking temperature (37.8°C) and draining the whey earlier i.e. shortening the cooking period.

2.3.6 CHEDDARING

Structural changes in the body and texture of the cheese curd takes place during cheddaring. As the curd blocks are piled and repiled, their structure flattens, and the holes or eyes which might be originally present lose their identity in the deformed curd (Kosikowski, 1966). Cheddaring leads to fusion of casein matrix and coalescence of fat globules with progressive elimination of the interstatial spaces (Brooker, 1979). Piling and development of chicken breast structure during cheddaring encourage moisture retention in cow milk cheddar cheese (Gilles, 1976). Chapman (1974) while studying the effects of alternatives to traditional cheddaring on the properties of cheddar cheese observed that elimination of curd turning and restriction of curd flow during cheddaring did not significantly affect the composition and flavour of cheese. The cheese made from dry stirred curd had

firmer texture but poor flavour than the cheese made with traditionally cheddared curd.

Buffalo milk curd poses difficulty in obtaining the desired characteristics during cheddaring. Higher piling during cheddaring has been suggested by Burde and Srinivasan (1967) to obtain good texture in buffalo cheese.

2.3.7 MILLING, SALTING, HOOPING AND PRESSING

At the end of cheddaring, the curd is cut into smaller pieces with the help of a curd mill. Milling the curd over 0.4 per cent acidity or a pH of 5.4 to 5.5 for further removal of whey was suggested by Price and Vanslyke (1952). Milling helps in escape of undesirable flavour and the curd to cool. Acidity at milling affects the elasticity of the cheese (Baron, 1947). High acidity produces soft cheese with less springiness. Yamamoto et al.(1956) reported that higher acidities at milling results in low moisture content in the cheese. Although, these authors could observe no significant differences in the quality of cheese milled between 0.45 and 0.55 per cent acidity. Variations in the time interval from whey removal to milling of the curd do not affect the body scores but have a significant effect on the texture and total scores (O'Connor, 1974).

Salt addition to the milled curd affects the moisture expulsion and controls the growth of undesirable organisms in the cheese curd (Gilles, 1976). Sharp and Mcinerney (1936) reported that the peptizing action of sodium chloride on para-casein in the pH range of 5.0 to 6.0 improves the texture of the cheese.

Lawrance and Gilles (1969) found that the bitterness in cheese depends on the ratio of salt to moisture and pH at 17 days. It is likely to occur if the salt on moisture basis was less than 4.3 per cent, 4.2 to 5.2 per cent salt to moisture values have been reported to be optimum for cheese at 14 days by Pearce and Gilles (1979). Maintaining high pH and high salt concentration has also been suggested by Jago (1974). According to Fox (1975) cheeses with high moisture, low salt and high pH develops a weak body and off-flavours. Cheese with low moisture and salt tends to have a curdy body with little tendency to develop off-flavour.

Knox (1978) reported that grade I cheese can be obtained with salt contents of 1.2 per cent to 1.8 per cent and salt in moisture contents of 3 per cent to 5.2 per cent. Similar observations were recorded by O'Connor (1974). To achieve the salt levels between

4 to 6 per cent in the moisture, Gilles (1976) has suggested addition of salt at the rate of more than 2.5 per cent (W/W).

Czulak (1964) suggested the addition of salt at about 2 per cent W/W of estimated yield of cheddar cheese from buffalo milk.

Hooping and pressing aids to lowering the moisture in the curd and fusion of the curd takes place in first 2-3 hours (Dixon et al., 1975). According to these authors the pressing operation aids the forming of cheese into desired shapes and sizes. Curd fusion takes place by removing occluded air.

2.3.8 CHEESE RIPENING

Cheese blocks after paraffinning are placed in curing room at temperature 6°C - 13°C and humidity 75-80 per cent (RH) for a period ranging from 3 months to one year or more. During this period the rubbery, mild flavoured "green" cheese attains a typical body and texture and flavour characteristics. Ripening of cheddar cheese takes place as number of physico-chemical and biochemical changes are brought about by milk clotting enzymes, starter organisms and the organisms native to milk, and the enzyme secreted by these organisms.

The ripening results in the degradation of lactose, fat and proteins resulting in the gradual change in the pH. Protein degradation is responsible mainly for the softening of body and texture, while the fat degradation contributes to the flavour of the cheese. Lactose degradation is associated with the change in the pH. All these changes are responsible for the final characteristics of cheddar cheese (Harper and Kristoffersen, 1956; Schormuller, 1968).

Sherwood (1936) observed that pasteurized cow milk cheddar cheese ripens somewhat slowly than the raw milk cheese. This happens because of the inactivation of natural enzymes of milk and destruction of beneficial microorganisms.

The pH and acidity change during ripening. The pH values in the initial period decreases to 5.0 to 5.2 and then increases to 5.3 to 5.5. The acidity also increases from the initial value of 0.7 per cent to 1.0 to 1.25 per cent in one year. Decrease in pH has been attributed to lactose degradation in the initial period of ripening (Umomoto and Sato, 1975) and the increase in pH is caused by formation of non-acidic decomposition products and liberation of alkaline products of protein degradation (Webb et al.,1978).

The moisture decrease during the ripening period. This is influenced by curing temperature, humidity, size and shape of the block and type and method of paraffinning. Moisture loss ranging from 2 to 8.7 per cent during ripening has been reported by several workers (Hansen, 1946; Davis, 1965; Kikuchi *et al*, 1968; Sannabhadti and Srinivasan, 1976; Rao and Mathur, 1979).

Increase in the soluble, amino, and ammonia nitrogen was observed by Vanslyke *et al*.(1903) during one year ripening period. Dulley (1974) concluded that proteolysis was mainly due to starter enzymes and it proceeds at a constant rate. Studies on proteolysis by O'keeffe *et al*.(1978) revealed that the coagulant is mainly responsible for the formation of large peptides by the break-down of caseins. While small peptides and free amino acids are produced principally by starter organisms, possibly from coagulant produced peptides.

Fat degradation contributes the most to the flavour of the cheese than any other component (Mabbit and Zielinska, 1956). Ohren and Tuckey (1965) observed that the flavour of cheese increased with the increase in fat content of milk. Cheese made from skimmed milk

does not develop a typical flavour. Hydrolytic and oxidative changes in cheese fat have been responsible for the flavour. Hydrolytic changes are brought about by microorganisms, milk lipases and even rennet (Lane and Hammer, 1939; Harper and Gould, 1952; Bachman, 1959; Stadhouders and Mulder, 1960 and Peterson and Johnson, 1949).

Bitterness in cheese develops due to certain starter culture (Czulak, 1959; Lawrence et al.,1972), type and amount of rennet (Windlan and Kosikowski, 1956; Lawrence et al., 1972), and changes in the manufacturing process like low cooking temperature (Barton, 1957; Lawrence et al., 1972). Pasteurization of milk at higher temperature (Moir, 1930), low salt content, higher moisture and acidity also promote bitterness in cow milk cheese (Phillips, 1935; Tuckey and Ruche, 1940; Czulak, 1959). Lawrie and Lawrence (1972) concluded that starter strains are directly responsible for the formation of bitter flavoured compounds. All starters are capable of producing bitter and non bitter cheese. The authors observed that the response of the selected manufacturing conditions, rather than any single difference between particular starter strain, determined the likelyhood of bitterness development.

Manning (1978) observed that most of the flavour producing compounds increase in concentration during ripening but ethanol and butanone vary in concentration in an unsystematic way.

Buffalo milk cheddar cheese after ripening lacks in typical cheddar cheese qualities in terms of flavour, body and texture. This suggest that neither fat nor protein breaks down as readily as in cheddar cheese from cow milk.

The lipid fraction contributes more to the development of flavour in cheese (Ohren and Tuckey,1969). The slower hydrolysis of buffalo milk fat during cheese ripening may be due to the difference in fatty acid make up between buffalo and cow milk fat (Ramamurthy and Narayanan, 1971). This may result in poor flavour development in buffalo milk cheese (Godbersen, 1964). Garg and Verma (1966) observed progressive decrease in RM and Polenske value during ripening of buffalo cheese. Ramamurthy (1967) however, did not find any change in these values upto 120 days.

Al-Fayadh (1980) reported that the hard consistency of buffalo milk cheese was due to its low moisture content when processed in the conventional manner. The higher heat treatment of the milk has been

suggested as the solution. It increased the moisture content and allowed normal syneresis of the curd. The salt-in-moisture lowered and promoted normal acid development and proteolysis. The flavour development also improved by higher heat treatment of the milk.

Singh and Ganguli (1972) observed that changes in peptide, free amino acids and NPN levels were somewhat higher for buffalo than cow milk cheese during 7 month ripening. Peptide release was similar in both the cheeses during 60-120 days period and differing somewhat thereafter reaching steady maxima in 140 days. NPN liberation increased regularly throughout.

Mathur and Bhalerao (1969) reported no significant differences in changes in TN or nitrogen fractions during ripening of cow milk and buffalo milk cheddar cheese. In buffalo milk cheese made with buffalo's rennet, amino acid content showed downward trend after 150 days, probably due to further break-down of amino acids into NH_3 and other products.

Low moisture, total nitrogen, soluble nitrogen, NPN, salt and acidity and high fat content was observed in buffalo milk cheese than cow milk cheese by El-Sokkary and Hasan (1952). Tambat (1975) also recorded tha similar observations. Hofi *et al.* (1975) observed that

the changes in VFA, total carbonyls, soluble tyrosine and ripening indices were slower in pasteurized buffalo milk cheese than in raw milk cheese.

Singh et al.(1976) found that cheddar cheese prepared from sterilized buffalo milk with the lipolytic culture in the absence of Str.lactis had higher pH values during ripening than those prepared with lipolytic culture plus Str.lactis.

Ramamurthy (1976) stated that hydrolysis of fat is desirable in cheese to acquire typical flavour. The physical state of milk fat is an important factor which influences the fat hydrolysis. A fat in liquid state hydrolyses much faster than the solid fat. At a given temperature the proportion of solid fat is higher in buffalo fat than in cow fat. This results in slower hydrolysis of buffalo fat finally resulting in slow development of flavour in the cheese. Slow hydrolysis of fat and slower flavour development in buffalo milk cheddar cheese have also been reported by Bhat et al.(1978).

Dawood and Al-Shabibi (1978) reported that buffalo and cow milk treated with H_2O_2 yielded higher amount of cheddar cheese than the pasteurized milk (61.6°C/30 min.). Fat breakdown was faster in cow milk

cheese than in buffalo milk cheese which required a longer ripening period also. Cheese made with H_2O_2 treated buffalo milk assumed a metallic flavour. However, for both the species, method of cheese manufacture had no effect on total amount of fatty acids liberated.

Ultrafiltration and Sephadex G-25 gel filtration of the cheese peptides from cow and buffalo milk cheddar cheese indicated that no marked changes occur in the concentration of high molecular weight peptides during ripening in all the cheeses, while concentration of low molecular weight peptides was less in buffalo milk cheese (Alawad and Toma, 1978).

2.4 CHEESE MAKING WITH GOAT MILK

Goat milk, in general is considered inferior to cow's or buffalo's milk in our country. However, in European countries and in some countries of the Middle East, cheese making from goat milk is of national economic importance. In France for instance, more than 75 per cent of the total goat milk production is used for cheese making. Of this, 50 per cent is utilized for manufacturing farm house cheese (Cargouet, 1971). This is true in case of other countries also. The manufacture of goat milk cheese, therefore, can be

most accurately categorised as a "Cottage industry" rather than a large scale commerical enterprise. This situation has led to the development of numerous varieties of cheese from goat milk.

Goat milk has been utilized for manufacture of, usually small and soft varieties in Western countries (Davis, 1976). All these varieties develop a peculiar "tang" because of the chemical nature of the goat milk fat, as is evident from the compositional characteristics of goat milk fat. It contains higher proportions of shorter chain fatty acids C_6 to C_{10}. These fatty acids when liberated during ripening are markedly more "peppery" or "biting" in flavour than the very short (C_2 to C_4) or longer (C_{12} to C_{18}) chain fatty acids (Davis, 1965). Pelissier and Manchon (1976) studied the bitter taste of enzymic hydrolysates from cow, ewe and goat caseins and reported that peptides formed from goat casein by proteases were less bitter than those from cow casein. It was suggested that the lower bitterness in goat cheeses than in bovine cheeses is due to the absence of α_{s1}-casein in the goat milk system.

Over 400 varieties of cheese under 800 different names have been described by Sanders (1953) in his book "Cheese varieties and description". A great

number of these are, or can be, made from goat milk or from combination of goat milk with milk of other species (Morrison et al., 1980).

Portman et al.(1968) have outlined a procedure for making cylindrical Sainte-Maure cheese. Cargouet (1971) has described a method for production of types such as Sainte-Maure, Chabichou, Pyramide and Selle-sur-cher. It involves pasteurizing milk, ripening with 4-5 per cent starter, renneting, draining in filter units, salting (1.5 per cent) and machine moulding. Ripening is done at 10-12°C temperature and 90-92 per cent RH. It takes about 12-15 days for complete ripening.

Rakshy and Hassan (1971) demonstrated the suitability of goat milk for manufacturing a cheese variety similar to Domiati cheese. Average composition of fresh cheese was 60 per cent moisture, 18.5 per cent fat, 2.9 per cent salt, 16.7 per cent total protein and 0.53 per cent soluble protein.

Bottazi (1975) in his article "Peculiarities of the principal Italian cheeses" has given the characteristics of the varieties Caprini and Robiolini freschi. These are small cheeses of 50 to 70 grams in weight, with a short ripening time and without rind.

Lame and Hekmati (1975) made Iranian "Khikki cheese" from mixed goat and ewe milk using natural rennet, ripened and stored in brine in sheep skin or goat skin bags.

Delforno (1977) has described the Piedmontese alps cheeses like Caprino di Rimella, Paglierina and Raschira made from goat milk or goat milk mixed with cows milk.

A description of strauss specialty cheese "Eezit" from goat's milk produced in Israel has been given (Anomymous, 1977).

Kosikowaski (1966) has described the Norwegian cheeses like Gjetost, Mysost, Primost and Gubdrandsdal-sost which are made from goat milk.

Fredriken and Steinsholt (1978) produced a spreadable processed cheese from goat milk with about 45 per cent DM and 47 per cent fat in DM.

A hard goat cheese similar to cow's milk "Tome" is made in Switzerland (Mocquot and Bajambes,1960).

Potts and Simmons (1955) have described the technique for processing a hard cheese from goat milk. It is obtained by renneting the milk at 31°C, coagulation takes place in 30 minutes, curd is cut and cooked at 37°C

for 30-60 minutes, drained in cloth and salted after 14 hours. The curd, however, is not cheddared, milled and pressed. The curing is also for a relatively short period of 10 days.

Romano and Granular cheese has also been made from goat milk (Wilster, 1959). Liquid rennet is diluted 1 to 40 in water and sufficient amount is added to milk at 88 to 90°F to give firm curd in 30 minutes. Curd is cut in cubes of 1/4-1/2" size, heated slowly to 100°F for one hour. After firming, whey and curd cooled to 86°F. Whey is drawn off. Curd is stirred at intervals to keep it in granular form. After 15 to 30 minutes when curd is sufficiently dry, coarse salt is added @ 3 per cent by weight for Granular cheese and 2 per cent for Romano. Curd is then placed in hoops and pressed for several hours. Then it is taken out from the press. Romano cheese is rubbed on the surface with dry salt every third day until it contains about 6 per cent of salt by weight. This takes about three weeks. Granular cheese is paraffined and cured for 2-3 months at 60°F in moderately moist curing room with air circulation.

Romano cheese is rubbed with a mixture of cotton seed oil and black pepper. It is then cured for 6 to 12 months at 50°F to 60°F in cellars or cool

building without refrigeration. The application of oil and pepper is continued at intervals to minimize mold growth and prevent the cheese from drying out.

Some other hard varieties of cheeses from goat milk are also manufactured (Morrison et al.,1980) but no published report is available on the manufacture of cheddar cheese from this milk.

2.5 CHEESE MAKING WITH MIXED MILKS

The milk systems of different species being varied in composition and properties, mixing of these milks with each other might influence the composition and quality of the finished cheeses. However, literature on this is scanty.

Akhundov (1959) obtained good Edam cheese from buffalo milk mixed with skimmed cow milk (1:1). The mixture contained 2.81 per cent fat and 3.02 per cent casein. The yield of cheese was 9.4 per cent with a moisture content of 39.45 per cent, and a dry matter content of 60.55 per cent. The rind and body colour was similar to that for cow milk. The cheese had the characteristic taste, aroma and texture of the cheeses of Edam type.

Nejim (1959) made cheddar cheese by standard methods from equal amounts of whole cow and buffalo milk or ewes and cows milk. The fat content of the mixtures ranged between 3.5 and 7.8 per cent and that of the ripened cheese from 27 per cent to 40 per cent. The cheeses with higher fat content obtained higher scores. Most of the other cheeses were also of fairly good quality.

Cheddar and Edam type cheeses of satisfactory quality and composition were manufactured from buffalo milk standardized to a C:F ratio of 0.7 by addition of reconstituted dried cows skim milk (Nejim and Alusi, 1970). Analytical results of the experimental cheddar cheese gave moisture contents of 35.4, 34.6 and 36.9 per cent against 38.00 per cent for the control. Fat on dry matter basis figures were 43.6 per cent and 47.4 per cent against 48.4 per cent in control. The grade points for experimental samples were 85 and 90 with 95 for the control. The authors had claimed this procedure to be more profitable than the skimming of fat from milk.

Nofal et al.(1977) made cheddar cheese from buffalo milk mixed with cow milk in a ratio of 1:1. The total solids in cheese milk were standardized within 11.5, 15.0 or 19.0 per cent. Increasing total

solids increased the moisture, titrable acidity, fat acidity, and the rate of protein breakdown in cheese during ripening. Mixing of buffalo milk with cow milk slightly improved the quality of cheese compared to cheese from buffalo milk.

Alawad and Toma (1978) made cheddar cheese from 1:1 mixture of cow and buffalo milk and reported that the concentration of low molecular weight peptides increased during ripening and the values were in between those observed for pure cow and buffalo milk cheeses.

Mixed cow and buffalo milk, raw or pasteurized containing 4 ± 1 per cent fat was used for manufacture of Domiati cheese by Zaki *et al.*(1974).

Hofi *et al.*(1975) successfully manufactured good quality Domiati cheese from a mixture of buffalo and cow milk in the ratio of 1:1.

Recently, Waghmare and Gupta (1980) tried 5 combinations ranging from 10 to 50 per cent solids of cow skim solids (SMP) to standardize the buffalo milk to C:F ratio of 0.68 to 0.70. Sensory evaluation of the 5 batches of cheese showed that 90 parts of buffalo milk solids (fresh milk) with 10 parts of cow skim milk solids produced desirable quality cheese followed by

80:20 combination upto 6 months of age. The cheese was prepared by the method of Czulak (1964). The authors observed that except 100 per cent buffalo milk solids (fresh milk) combination, all other combinations had coarse body and poor texture. Decrease in moisture content was observed in all the samples during ripening. However, the decrease in moisture content was more with the increased proportion of SMP in the cheese milk. Sensory evaluation of crude and purified peptides indicated that 50:50 combination was more bitter in comparison to other combinations. No good quality cheese was obtained by incorporating cow skim milk powder. The replacement of SMP by fresh cow skim milk resulted in a better quality cheese. Ofall the combinations 50:50 combination i.e. 50 per cent buffalo milk solids (fresh) and 50 per cent cow milk solids (fresh cow skim milk) gave the best quality cheddar cheese both on physico-chemical and sensory charqcteristics.

El-Gazzar et al.(1982) prepared blends of cow milk containing 0, 25, 50 and 75 per cent buffalo milk and adjusted them to 0.25 per cent total acidity with YH culture and used to manufacture Ras cheese. These were compared to a traditionally produced version composed of a 50:50 cow, buffalo milk blend. On the

basis of physico-chemical and organoleptic evaluation during ripening, cheeses were ranked in descending order of buffalo milk content. The cheese prepared in the traditional manner was ranked lower of all.

Cheese varieties such as Saint-Marcellin are made from mixture of cow and goat milk. The proportion, however, depends upon the availability of goat milk (Mocquot and Bejambes, 1960).

Montemurro (1951) has reported use of cow and goat milk mixture in the manufacture of Provolone cheese. His findings indicated that incorporation of 8.14, 11.25 and 14.32 per cent goat milk in cow milk reduced the yield to 9.11, 9.70 and 8.59 per cent, respectively as compared to the yield 9.89 to 10.10 per cent when pure cow milk was used. Moreover, greater ripening losses and more defects occurred in cheese made from mixed milk.

Steinsholt (1972) used various combinations of cow and goat milk in preparing Gudbrans-dasost cheese.

Funder et al.(1944) reported that best quality Roquefort cheese is made from goat milk when it is mixed with 2.5 to 10 per cent cow milk.

Acceptable quality of cheddar cheese has been made from mixed milk as reported in the limited number of work cited above. It is, however, to be appreciated that there is little information concerning the critical evaluation of the effect of mixing cow and buffalo milk on the product quality and typical characteristics of the mixed milk systems. Naturally then, there is virtual absence of knowledge about various steps involved in cheddar cheese making operations. It is also not clear as to what would be the effect of mixture containing varying proportions of cow and buffalo milks on the cheese quality. No work is available on the manufacture of cheddar cheese from goat milk and/ or the effect of mixing goat milk with buffalo milk on the cheddar cheese quality. It is, therefore, necessary to undertake systematic studies on using mixed milks containing varying proportions of cow, buffalo and goat milks on the quality of cheddar type cheese.

CHAPTER 3.

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SCOPE AND PLAN OF WORK

SCOPE AND PLAN OF WORK

With the basic aim of utilizing various types of mixed milk for cheddar cheese, this investigation centered around two main objectives :

1. To evaluate the effect of mixing different proportions of cow and goat milk with buffalo milk on several technological parameters important to the manufacture of cheddar type cheese, and

2. to develop manufacturing technique for cheddar type cheese from selected mixtures of buffalo milk with cow and goat milk.

Within this scope of investigation, the study was conducted in three phases. Initially, the curd forming properties of milk mixtures were studied. In this, the behaviour of buffalo milk admixed with various amounts of cow and goat milk separately were compared to that of pure buffalo, cow and goat milks

in terms of clotting time, curd strength and true protein in whey.

In the second phase, buffalo milk admixtures with cow and goat milks were used for cheddar type cheese manufacture with conventional methods. Modifications of cheddar cheese making procedures, were attempted in order to gain better control on cheese quality and elimination of defects that were observed with cheeses prepared earlier with conventional methods.

In the third phase, the curing behaviour of mixed milk cheeses prepared by standardized methods were studied and compared with buffalo, cow and goat milk cheese as control.

Limited trials on processed cheese making were also undertaken with mixed milk cheeses.

CHAPTER 4.

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EXPERIMENTAL

EXPERIMENTAL

4.0 This section deals with the methods and materials used in the manufacture of cheddar cheese (control and experimental) together with standard analytical procedures.

4.1 SELECTION OF RAW MATERIALS

4.1.1 MILK

Buffalo, cow and goat milks used in this study, were procured from the Dairy herds maintained at the National Dairy Research Institute (N.D.R.I.) Karnal. The buffalo milk was from a herd of Murrah buffaloes. The cow milk was from a herd of crossbred and Indian purebred cows. The goat milk was fetched from a flock of Beetal, Alpine and Saanen goats and their crosses.

4.1.2 STANDARDISED MILK

Buffalo and cow milks were individually standardized to a 0.7:1.0 casein:fat (C/F) ratio. Goat milk was standardized to 0.65 and 0.7 C/F ratio. The

standardized milks were then mixed in different proportions to form the mixed milk system for various experiments.

4.1.3 STARTER CULTURE

Mother culture of LF-40 (mixed culture of Str.lactis, St.cremoris and St.diacetilactis) was obtained from the Dairy Bacteriology Division of the Institute. Bulk starter culture was prepared from buffalo, cow and mixed skim milks autoclaved at 15 psi for 10 minutes and cooled at 22°C. The skimmed milk was inoculated with 1.0 per cent of mother culture and incubated at 22° ±1°C for 16 hours.

The goat milk systems either pure or mixed in different proportions with buffalo milk coagulated during the autoclaving treatment. Hence, for studies with goat milk containing systems, starters propogated in either cow or buffalo skim milk were used.

4.1.4 SALT

Commercial grade fine grain salt was obtained from M/s Tata Chemicals, Bombay.

4.1.5 CHEESE COLOUR

Annatto (Bixa Orellana) cheese colour from Ch.Hansen's Laboratory, Denmark was used.

4.1.6 CALCIUM CHLORIDE (DIHYDRATE)

Calcium chloride of GR grade from Sarabhai M. Chemicals, Baroda was used.

4.1.7 RENNET POWDER

Hansen's rennet powder was obtained from the Christen Hensen's Laboratory, Denmark.

4.1.8 TRI-SODIUM CITRATE

I.P. grade tri-sodium citrate was procured from M/s Sarabhai Chemicals, Baroda for processed cheese trials.

4.1.9 CHEMICALS

A.R. grade chemicals were used for chemical analyses.

4.1.10 MEDIA

The ready made HI-media of Hindustan Dehydrated Media, Bombay was used for bacteriological analyses.

4.2 CLOTTING TIME WITH STANDARDISED MILK

The standardized buffalo, cow and goat milks and their mixtures were pasteurized at 63°C for 30 minutes and cooled to 30°C. At this temperature, 10 ml of milk was pipetted out in a test tube (18x150 mm) and to it 1 ml of enzyme solution (1% aquous solution w/v) was added, mixed thoroughly within 2-3 seconds.

The test tube was then rotated between the fingers and the time interval from the addition to visible flakes was recorded as clotting time in seconds. On the basis of this clotting time, the quantity of enzyme solution required to clot 50 ml of milk at 30°C in 30 minutes was calculated for determination of curd strength.

4.3 CURD STRENGTH

The curd strength of the various milk systems was determined by the method of Chandrashekhara et al. (1957) with following modifications.

The temperature of milk was adjusted to 30°C in a water-bath. From this 50 ml portions were taken in 100 ml beakers (50 x 72 mm) into which calculated quantity of enzyme solution (sec. 4.2) was added, mixed thoroughly and incubated in the waterbath for 30 minutes. The curd strength was then measured and expressed in grams (g).

4.4 MANUFACTURE OF CONTROL CHEESE

Control cheddar cheese from buffalo and cow milk was prepared by the procedure as recommended by Czulak (1964) for buffalo milk, Kosikowski (1966) for cow and goat milk. The typical schedule for these is presented in Appendix III and VI

4.5 ANALYTICAL METHODS

4.5.1 RAW MILK

4.5.1.1 Acidity

As per IS:1479 (part I) 1960.

4.5.1.2 Fat

As per IS:1224 (part I) 1977.

4.5.1.3 Casein

As per IS:1479 (part I) 1961.

4.5.2 STANDARDIZED MILK

4.5.2.1 Fat and Casein

As per 4.5.1.2 and 4.5.1.3

4.5.2.2 Total solids (TS)

As per IS:1479 (part II) 1961.

4.5.3 STARTER

4.5.3.1 Acidity

As per laboratory manual (Milk Industry Foundation, 1959).

4.5.4 WHEY

4.5.4.1 Acidity

As per 4.5.1.1

4.5.4.2 Fat

As per 4.5.1.2

4.5.4.3 Total solids

As per 4.5.2.2

4.5.4.4 Total nitrogen

As per the method of Menefee and Overman(1940).

4.5.5 CHEESE

4.5.5.1 Sampling

A 250 gm portion of cheese blocks was cut from surface to middle of the block with the help of a sharp knife. The outer half inch layer was discarded and the cheese was minced in a manual mincer and kept in screw capped plastic sample bottles and kept in refrigerator till used for analysis. Representative samples were then taken from these for different chemical analyses.

4.5.5.2 Moisture in cheese

As per method described in 'Laboratory Manual' methods analysis of milk and milk products: Milk Industry Foundation, 1959.

4.5.5.3 Fat

As per IS : 2758-1964.

4.5.5.4 pH

The pH of the cheese was determined as per IS:1479 (Part II) 1961 with a combined glass electrode (CK-61) Elico pH meter, Model-Li-15.

4.5.5.5 Salt

As per IS:2785-1964.

4.5.5.6 Nitrogen fractions

The nitrogen fractions namely, total nitrogen (TN), water soluble nitrogen (SN), non protein nitrogen (NPN) were determined as per method of El-Sokkary & Hasan (1952) following semi-micro Kjeldahl method of Menefee and Overman (1940).

4.5.5.6.1 Total Nitrogen

About 7 grams of the cheese sample was weighed accurately and digested in 300 ml Kjeldahl flask by the Kjeldahl method. The distillation of the digested mass was carried out as per the method of Menefee and Overman (1940).

4.5.5.6.2 Water soluble nitrogen

Five grams of cheese sample, weighed accurately was ground in a mortar with pestle and 25-30 ml of distilled water (50°C) added, mixed thoroughly. The mixture was allowed to stand for 30 minutes and decanted into a 100 ml volumetric flask through Whatman No.1 filter paper. Similarly, two other extractions were carried out and the volume was made upto the mark, with distilled water. A 20 ml

portion of the filtrate was digested and the nitrogen content was determined as per 4.5.5.6.1.

4.5.5.6.3 Non-protein nitrogen

Two grams cheese was thoroughly mixed in a mortar with pestle and transferred into a 100 ml beaker with 40 ml distilled water and 10 ml of 20 per cent trichloro acetic acid (TCA). The contents were heated at 70°C for 10 minutes with continuous stirring, cooled to room temperature and filtered into 100 ml volumetric flask through Whatman No.42 filter paper. The precipitates on the filter paper were washed with one per cent TCA till the volume was made upto the mark. A 20 ml portion of the filtrate was digested and nitrogen content was determined.

4.5.5.6.4 Amino acid nitrogen

The amino acid nitrogen was determined by the method described by O'Keeffe et al.(1976).

A 6 per cent cheese homogenate in water was prepared and heated to 75°C for 5 minutes with continuous stirring. The mixture was cooled to room temperature and filtered into a 150 ml conical flask through Whatman No.1 filter paper. A 50 ml portion of the filtrate was made with 12 per cent TCA and filtered through Whatman No.42 filter paper. into a

conical flask. The filtrate was washed 3-4 times with solvent either to make it free from TCA. The nitrogen content of 20 ml of the filtrate was determined.

4.5.5.8 Fatty acid fractions

4.5.5.8.1 Total free fatty acids (TFFA)

The cheese fat was extracted as per method of Ramamurthy and Narayanan (1974). The cheese was minced by a mechanical mincer, ground in a mortar with pestle and packed tightly into 50 ml centrifuge tubes. These were placed in water-bath maintained at 50-55°C for an hour. The tubes were centrifuged (1500 x g) for 5 minutes and the fat decanted. The TFFA of cheese fat was determined by the method of Lowry and Tinsley (1976).

A 0.2-0.5 g of the fat sample was weighed into a screw capped culture tube in duplicate. 5 ml of benzene solution was added to it and mixed thoroughly. After adding 1 ml of cupric-acetate pyridine solution, the biphasic system was shaken for 2 minutes. The contents were centrifuged at 2000 rpm for 5 minutes. The upper layer was read at 700 nm in spectrocol model CL-23 and absorbance was recorded.

The standard curve was prepared by dissolving 6.34 ml of 99.7 per cent pure oleic acid in benzene and the volume made to 100 ml, out of this, 1 ml was made to 100 ml with benzene which is equivalent to 2000 μm. Hence, one ml contains 20μM. A series of dilutions were prepared from the stock solution and the development of colour was read in the same manner as described for the test sample. Standard curve was drawn by plotting the absorbance values against the oleic acid concentration and was used for determining the TFFA of the sample.

4.5.5.8.2 Total volatile fatty acids (TVFA)

The TVFA contents were determined as per method of Kosikowski (1966) from 10 g of well minced cheese sample and the value expressed as ml of 0.01 N NaOH per 10 g of cheese.

4.5.5.9 Microbiological analysis

The microbiological analysis was carried out as per the methods described in "Laboratory Manual"- Methods of analysis of milk and milk products (MIF, 1959).

4.5.5.9.1 Preparation of dilution blank

The dilution blank consisted of 2 per cent sodium citrate solution in 99 ml and 9 ml portions in screw capped dilution bottles and culture tubes, respectively. These were autoclaved at 121°C for 20 minutes. The dilution blanks were warmed to 45°C before use for preparation of samples.

4.5.5.9.2 Sampling of cheese

With sterile cheese trier, 2-3 plugs of 2 inch size were removed from the cheese block and ½ inch portion from the surface was discarded by cutting with sterile knife. The remaining portion of the plug was cut into small pieces and 11 g of cheese was asceptically weighed and transferred to mortar. To this, about ½ tea spoonful of sterile sand was added and the sample was thoroughly mixed. This was then transferred to 99 ml dilution blank. Further dilutions were made with 9 ml dilution blanks.

4.5.5.9.3 Total count

Total count was taken using autoclaved (121°C for 20 min.) Tryptone-glucose extract agar (TGEA) media which was cooled at 45°C before use. The plates were incubated at 37°C for 48 ± 3 hrs before the counts were taken.

4.5.5.9.4 Proteolytic count

For proteolytic counts, TGEA was used as in 4.5.5.9.3. To this, 5 per cent sterilized skim milk was added asceptically just before plating, mixed thoroughly, and poured in the plates. The plates were incubated at 37°C for 4 days. The colonies having a digested zone surrounding each colony, represented proteolytic one.

4.5.5.9.5 Lactic count

Lactic count was taken by using tomato juice agar media, autoclaved at 121°C for 20 min. and cooled to 45°C before plating. The plates were incubated at 37°C for 3 days and then the counts were taken.

4.5.5.9.6 Lipolytic count

For lipolytic count, trybutyrin agar without tributyrin was used. To this, one per cent tributyrin was added, thoroughly mixed and autoclaved at 121°C for 20 min. At the time of plating, the temperature of the media was brought to 45°C. After three days of incubation at 30°C the colonies were counted.

4.5.5.10 Organoleptic evaluation

After 4 months of ripening, the organoleptic evaluation of the cheese samples was done at regular intervals upto 12 months of age of the cheese. The panel consisted of 5 expert judges. The score card used for judging is presented in Fig.1.

4.6 PROCESSED CHEESE

At the end of 12 months ripening, the different cheeses were melted at 75°C for 5 min.and processed by adding 2.5 per cent trisodium citrate as emulsifier. These were then packed in pre-sterilized 240 g tin containers and stored at 5 ± 1°C.

4.6.1 ORGANOLEPTIC EVALUATION OF PROCESSED CHEESE

Processed cheese was evaluated on the score card as given in Fig.2 only for flavour, body and texture, and colour.

SENSORY EVALUATION OF CHEESE

Date_____ Time_____ Name_____

Instructions: The samples are to be judged for
a. Defects by score card method, and
b. flavour intensity by a 9 point scale.

Characteristics	Ideal score	Sample No. 1	2	3	4
Flavour	45				
Body and texture	30				
Colour	10				

Remarks:

Intensity scale for flavour development

Intensity scale	Score	Sample No. 1	2	3	4
No development	0				
Slight development	0.5-2				
Moderate development	2.5-4				
Definite development	4.5-6				
Very definite development	6.5-7				
Pronounced development	7.5-8				
Very pronounced development	8.5-9				

SIGNATURE

FIG.1 SCORE CARD FOR SENSORY EVALUATION OF CHEESE.

SENSORY EVALUATION OF PROCESSED CHEESE

Date _____ Time _____ Name _____

Instruction : The samples are to be judged as per the score card given below :

Attribute	Ideal score	Sample No. 1	2	3	4
Flavour	45				
Body and texture	30				
Colour	10				

Criticism :

(SIGNATURE)

FIG.2 . SCORE CARD FOR SENSORY EVALUATION OF PROCESSED CHEESE.

CHAPTER 5.

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RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Manufacturing of cheddar cheese from buffalo milk containing different proportion of cow or goat milk was studied in three phases. In the first phase, the effect of mixing cow or goat milk on the curd forming properties of the milk systems was studied. In the next stage, priliminary cheese making trials with various milk systems were undertaken leading to the standardization of cheese making technique for these milks. The third phase was concerned with characterizing the curing behaviour of cheese prepared from different milk mixtures and pure milk systems. Finally, the suitability of various cheeses prepared from the mixed milk system for the manufacture of processed cheese was studied. Accordingly, the results of these studies are presented in this order.

5.1 FAT AND CASEIN LEVELS OF VARIOUS MILK SYSTEMS

In all these studies, the pure buffalo, cow and goat milks standardized to a predetermined C/F ratio served as controls. Various quantities of C/F adjusted buffalo, cow and goat milks were added to obtain desired mixed milks. Mixing of cow or goat milk with buffalo milk was to the extent of 10, 25, 50, 75 and 90 per cent. Such a plan provided pure milks, their equal proportion mixture (50:50) and two intermediate stages (10:90 and 25:75). The total solid, fat and casein levels of these C/F adjusted milks is presented in Appendix-I.

Data summarised in Table-1 revealed that for a given C/F ratio, the final level of fat and casein differed in various milks and their mixtures. The value for fat ranged from 4.20 to 3.45 per cent for buffalo, cow milks and their mixtures. In case of buffalo and goat milksystems these values ranged between 4.20 and 3.44 per cent, respectively. The variations in gross composition are of course, related to the levels of fat and casein originally present in the pure milk system. The pure buffalo milk system had the highest fat level of 4.2 per cent. The fat level of the mixed milks, decreased alongwith a

decreasing proportion of buffalo milk in mixture. A mixture of milks with different C/F ratios (as was done with buffalo milk of 0.70 C/F and goat milk of 0.65 C/F) resulted in samples that also had different C/F ratios alongwith differences in fat and casein levels.

Table-1 : Effect of mixing various amount of cow or goat milk with buffalo milk on the resultant fat and C/F.

Proportion of buffalo milk of C/F 0.7 (%)	Mixture with cow milk of C/F 0.7		Mixture with goat milk of C/F 0.7		Mixture with goat milk of C/F 0.65	
	C/F	Fat %	C/F	Fat %	C/F	Fat %
100	0.70	4.20	0.70	4.20	0.70	4.20
90	0.70	4.10	0.70	4.13	0.69	4.20
75	0.70	4.00	0.70	4.01	0.68	4.10
50	0.70	3.80	0.70	3.83	0.67	4.00
25	0.70	3.80	0.70	3.64	0.67	3.80
10	0.70	3.70	0,70	3.51	0.65	3.78
0	0.70	3.45	0,70	3.44	0.65	3.70

The common practice of adjusting the C/F ratios of milk for cheddar cheese making has been in terms of adding calculated amount of cream or serum to the milk. While this enables the adjustment of C/F ratio of various milks, it does so at a different levels of

total fat and casein depending on the milk systems. These differences in TS, fat and casein would have their influences in the preparation of cheese as well as its final quality.

5.2 CURD FORMING PROPERTIES OF PURE MILKS AND THEIR MIXTURES

For cheese milk, the quality of curd formed is generally determined in terms of clotting time, curd strength and loss of protein in whey. These properties are influenced by the complex mechanism of coagulum formation of the casein systems in milk and factors that affect this, such as heat treatment, level of calcium ions, etc. Since the formation of optimal coagulum is essential to good quality cheese, the rennet curd forming properties of buffalo, cow and goat milks and their mixtures were studied.

5.2.1 CURD FORMING PROPERTIES OF PURE MILK SYSTEM

The effect of pasteurization (63°C/30,min.) and subsequent addition of calcium chloride (8.0 g per 100 L) on the rennet clotting time, rennet curd strength and protein loss in whey was studied with buffalo, cow and goat milk systems, adjusted to C/F of 0.7.

Data presented in Table-2 indicated that the raw cow milk had the highest clotting time followed by buffalo and goat milks. The fastest rennet clotting time of goat milk might be associated with the higher concentration of calcium in the casein micelles of goat milk in comparison to bovine milk micelles (Jenness, 1980). Puri and Parkash (1962) also observed a faster rennet clotting time for goat milk in comparison to cow milk.

The pasteurization treatment increased the clotting time of all the milk systems. However, the increase was most pronounced in case of cow milk. Addition of calcium chloride to the pasteurized cow and goat milks reduced the clotting time to a level less than those of the raw milk systems. The addition of calcium chloride to pasteurized buffalo milk was not attempted, as this is not generally practiced with buffalo milk cheeses due to its higher level of Ca^{++}.

The data on the strength of rennet curd set at 30°C revealed that the buffalo milk had the strongest curd consistent with its high level of calcium ions. The weakest coagulum formed with goat milk might be due to the presence of a larger number

Table-2 : Curd forming properties of buffalo, cow and goat milks.

(Average of 3 trials)

Attribute	Milk treatment	Milk system at C/F 0.7		
		Buffalo (4.2%fat)	Cow (3.45%fat)	Goat (3.44%fat)
Clotting time(sec)	Raw	41.00 (40.00-42.00)	75.00 (74.00-76.00)	38.00 (37.00-39.00)
	Pasteurized	46.66 (46.00-47.00)	95.00 (94.00-96.00)	41.00 (40.00-42.00)
	Pasteurized + $CaCl_2$	-	56.00 (55.00-57.00)	31.00 (30.00-32.00)
Curd strength (g)	Raw	24.84 (24.23-25.26)	18.39 (18.05-19.08)	16.68 (15.99-17.02)
	Pasteurized	22.80 (22.14-23.57)	16.67 (15.99-17.02)	14.62 (13.93-14.96)
	Pasteurized + $CaCl_2$	-	21.83 (21.14-22.17)	18.05 (17.02-19.08)
Protein loss in whey(%)	Raw	1.08 (1.07-1.09)	0.64 (0.63-0.65)	0.86 ((0.85-0.87)
	Pasteurized	1.09 (1.06-1.12)	0.66 (0.65-0.67)	0.88 (0.87-0.89)
	Pasteurized + $CaCl_2$	-	0.64 (0.63-0.65)	0.87 (0.86-0.88)

of small size fat globules (Devendra, 1980), bringing a homogenization type of effect on curd tension. In all these milk systems, pasteurization resulted in decreasing the curd strength which could be restored by the addition of calcium chloride prior to renneting.

Differences in the protein contents of rennet whey obtained from the pure milk systems do not correlate directly with curd strength. For example, strongest curd forming buffalo milk system also exhibited highest loss of protein in whey. This is also related to the level of whey proteins (i.e. β-lactoglobulin and α-lactalbumin, etc.) in these milks. Pasteurization and addition of calcium chloride did not have any appreciable effect on the protein loss in whey in any of the milk system, indicating the formation of satisfactory rennet curd with all the three milks.

5.2.2 CURD FORMING PROPERTIES OF MIXED MILKS

To observe the effect of mixing, pasteurized cow or goat milk to pasteurized buffalo milk on the curd forming properties of the mixture was studied.

From the results depicted in fig.3 (compiled from data in Appendix-II) it is evident that clotting time (fig.3A) of buffalo and cow milk

mixtures increased with an increasing proportion of cow milk. The reverse trends were observed for the buffalo and goat milk mixtures. Buffalo milk mixture containing increasing proportions of cow or goat milk exhibited a decreasing curd strength (fig.3B). Mixing of cow and goat milks into buffalo milk decreased the protein loss in whey (fig.3C).

In general, the curd forming properties of the mixtures were somewhat intermediate between the pure systems. However, the changes in the curd forming properties did not appear to be linear in relation to the compositional changes of the mixture. The effect of mixing different milks on the curd forming properties can not be explained in terms of simple additive effects.

5.3 DEVELOPMENT OF CHEESE MAKING TECHNIQUE

Studies on the curd forming properties of pure milk systems and their mixtures indicated that the properties of rennet curd prepared from mixed milks for cheese making may vary depending upon the extent of the presence of one milk system in the other. At this stage, it was decided to study the effect of mixing milks on the cheddar cheese manufacturing steps and the quality of cured cheese

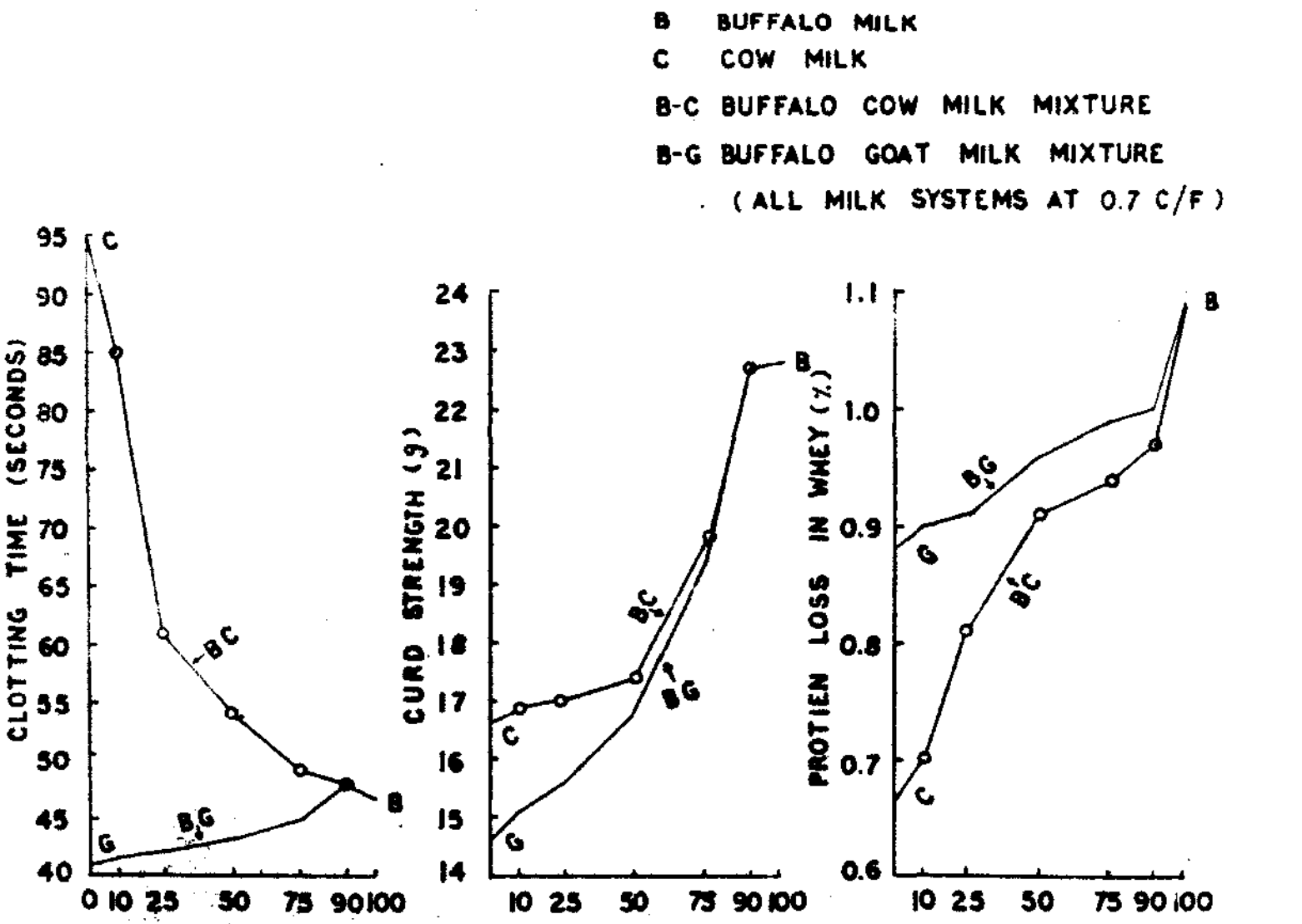


FIG: 3 EFFECT OF MIXING VARYING PROPORTION OF COW AND GOAT MILK WITH BUFFALO MILK ON THE CURD FORMING PROPERTIES.

with the ultimate aim of establishing suitable manufacturing techniques for different milk mixtures. For the initial cheese making trials it was realised that although the method of Kosikowski (1966) could be used for cow milk and the procedure of Czulak (1964) could be followed for buffalo milk, no particular technique was available at hand for cheddar cheese making with pure goat milk. Preliminary cheese making trials with goat milk were, therefore, taken up at this point.

5.3.1 INITIAL CHEESE MAKING TRIALS WITH GOAT MILK

Since, no prior information was available on the manufacture of cheddar cheese from goat milk it was arbitrarily decided to manufacture cheese from goat milk by Kosikowski (1966) method on the basis of the compositional proximity of this milk towards the cow milk.

The cheese was manufactured using 110 kg lots of goat milk standardized to 0.7 C/F ratio and pasteurized at 63°C for 30 min. Starter culture, LF-40 was used @ 1.0 per cent. The manufacturing details of the two batches prepared are presented in Appendix-III.

The important observations during cheese manufacture are summarized in Table-3 where typical data of cow milk cheese are also included for comparison.

Table-3 : Rate of acidity development during manufacture of cheddar type cheese from cow and goat milk.

Stage	Cow milk		Goat milk	
	Time (min.)	Acidity (% LA)	Time (min.)	Acidity (% LA)
Initial	-	.162	-	.135
Ripening	45	.180	70	.153
Cutting	30	.108	30	.090
Draining	60	.126	60	.108
Milling	180	.490	210	.470

During the cheese making it was observed that the acidity development in the goat milk system was rather slow. This was apparent during preripening and cheddaring process. It took 70 min. preripening time to attain 0.02 per cent increase in the acidity as against a normal 45 min. period for cow milk. The cutting and the draining acidities, however, were

within the expected normal range. During cheddaring goat cheese could reach 0.47 per cent LA in 210 min. as against 0.49 per cent LA in 180 min. in the case of cow milk cheese.

The cheddaring behaviour of the cheese was quite comparable to that in the cow milk cheese. The fat loss in goat milk whey (0.2%) was lower than that in cow milk whey (0.3%). The yield of goat cheeses was 9.7 kg as compared to 9.3 kg cheese obtained from cow milk.

Chemical analysis of zero day cheese blocks (Table-4) indicated that goat milk cheese had

Table-4 : Chemical analysis of cheddar type cheese from cow and goat milk.

Attribute	Age of cheese			
	0 day		180 days	
	Cow	Goat	Cow	Goat
pH	5.00	5.20	5.50	5.40
Moisture %	39.12	36.68	33.97	31.85
FDM %	50.12	50.23	49.98	50.18
S/M %	3.42	3.98	4.96	5.40
TN %	3.29	3.24	3.51	3.49
RI %	4.50	4.35	23.63	22.68

slightly lower moisture (36.68%) in comparison to cow milk cheese containing 39.12 per cent. The pH of the cheese was, however, within the desirable range. The salt on moisture basis (S/M) was slightly higher in comparison to cow milk cheese. Fat in dry matter (FDM), and ripening index (RI) values were within the normal range.

The cheeses were cured under conditions similar for cow milk cheese (at 10°C and 75 per cent relative humidity) and the chemical analysis and sensory evaluation was done at the end of the 180 days of ripening.

At the end of 180 days ripening an increase in the pH from initial value of 5.3 to 5.67 was registered (Table-4). A loss in moisture content by 4.83 per cent during curing is within the normal experience with cow cheese. There was a corresponding increase in salt on moisture, total nitrogen (TN) and ripening index of the cheese.

The organoleptic evaluation in Table-5 indicated that this cheese had clean and desirable pronounced flavour. Although it lacked the cheddar

flavour characteristic of cow milk, it attained a general acceptance of the trained judges. Some dryness in the body and texture was also observed.

Table-5 : Organoleptic quality of 180 days old cheddar type cheese from cow and goat milk.

Attribute	Cow	Goat
Flavour	Desirable ccf	pleasant, lacks ccf
Body and texture	Smooth, firm and waxy	Dry
Colour	Normal	Normal (white)

ccf : Characteristic cheddar flavour.

5.3.2 MODIFICATIONS IN CHEESE MAKING PROCESS FROM GOAT MILK

The initial trials indicated that although an acceptable cheddar type cheese can be manufactured from goat milk by Kosikowski (1966) method, there was sufficient scope for improvement in the quality of the cheese. The major constraints observed during the manufacture and curing were slow rate of acid development, lower moisture retention and somewhat dry body and texture. Additional trials with goat milk were, therefore, contempleted with the following modifications in cheese making procedure :

(a) C/F ratio lowered from 0.7 to 0.65 to improve body and texture.

(b) eliminating calcium chloride addition and reducing the cooking temperature to 38°C to attain slightly higher moisture level and

(c) increasing amount of inoculum from 1 per cent to 1.25 per cent to accelerate rate of acid development.

The manufacturing details of two batches of cheese prepared from goat milk with above modifications are given in Appendix-III. Cheese colour was added to goat milk at the rate of about 50 ml per 100 litre.

It is evident from Table-6 that the increased rate of starter addition certainly had its desirable effect on the rate of acid development. Goat milk, control as well as experimental had the same initial acidity. However, it took about 70 min. for 0.02 per cent LA increase in case of the control samples against only 45 min. time for the experimental milk. The acidity of whey at cutting and draining stages was also higher in experimental batches. The cheddaring behaviour of both the cheeses was almost

similar. However, the acidity developed in the experimental cheeses at a faster rate (0.495 per cent LA in about 180 min.).

Table-6 : Rate of acidity development during manufacture of cheddar type cheese from goat milk.

Stage	Goat control		Goat experimental	
	Time (min.)	Acidity (% LA)	Time (min.)	Acidity (% LA)
Initial	-	0.135	-	0.135
Ripening	70	0.153	45	0.153
Cutting	30	0.090	30	0.100
Draining	60	0.108	60	0.126
Milling	210	0.470	180	0.495

The zero day analysis (Table-7) of the cheeses indicated a normal pH value of 5.2 and 5.1 for the control and the experimental samples, respectively. The data also indicated that the experimental cheese had a higher moisture level (38.85%) than in control cheese (36.68%). Associated with the higher moisture content the salt on moisture was also lower in experimental cheese. It was only

3.50 per cent as compared to 3.98 per cent in the control samples. The FDM of the experimental cheeses was slightly higher than those of control samples. This may be associated with the lowered C/F ratio resulting in an increased fat percentage in the milk. The total nitrogen (TN) and RI values were almost similar.

Table-7 : Chemical analysis of cheddar type cheese from goat milk

Attribute	Age of goat cheese			
	0 day		180 days	
	Control	Experimental	Control	Experimental
pH	5.20	5.10	5.40	5.40
Moisture %	36.68	38.85	31.85	34.21
FDM %	50.23	52.85	50.18	53.01
S/M %	3.98	3.50	5.40	4.39
TN %	3.24	3.20	3.49	3.42
RI %	4.35	4.45	22.68	23.50

At the end of 180 days curing, the pH of the cheeses increased from the initial values of 5.2 and 5.1 to a value of 5.4 for both control as

well as the experimental. There was a proportionate decrease in the moisture content of all the cheese samples. Corresponding increase in S/M, TN and RI were also recorded.

Organoleptic analysis of the cheeses (Table-8) revealed a definite improvement in the body and texture characteristics of the experimental cheese. It had a firm, waxy and mellow body and texture as compared to the control samples which had dry and crumbly body texture. The experimental samples had a pleasant characteristic flavour of cheddar type cheese.

Table-8 : Organoleptic quality of 180 days old cheddar type cheese from goat milk.

Attribute	Goat cheese	
	Control	Experimental
Flavour	Pleasant,lack of ccf	Pleasant
Body and texture	Dry, crumbly	Waxy, firm, mellow
Colour	Normal(White)	Normal

ccf : Characteristic cheddar flavour.

It is thus evident from the above that the cheddar cheese quality improved significantly by the process modifications with goat milk. On the basis of these trials, this modified cheddar cheese manufacture schedule was used in subsequent experiments with pure goat milk systems.

5.3.3 CHEESE MAKING TRIALS WITH MIXED MILKS

In order to study the effect of mixing pure buffalo, cow and goat milks in various proportions on the quality of cured cheese it was necessary to determine first the applicability of cheese making practices as per Kosikowski (1966), Czulak (1964) or the one developed for goat milk (see 5.3.2) on various mixed milks. It was, therefore, decided to use standard cow milk cheese making procedure of Kosikowski (1966) for cow milk containing systems and the procedure developed in sec. 5.3.2 for goat milk containing systems.

5.3.3.1 Cheese making with mixed milks containing upto 50 per cent buffalo milk

To test the feasibility of using Kosikowski (1966) and modified Kosikowski method (sec.5.3.2) to the cow and goat milk containing mixtures, respectively it was decided to study the effect of adding buffalo milk, initially upto the level of 50 per cent.

5.3.3.1.1 Cow milk containing systems

The manufacturing details of cheese making trials with cow milk containing systems are appendixed in IV. The observations during cheese making with 4 such milk systems are summarized in Table 9.

Table-9 : Manufacturing behaviour of cheddar type cheese made with buffalo and cow milk mixtures.*

Attribute	Proportion of cow milk in the mixture(%)			
	100	90	75	50
1 Initial acidity of milk(%LA)	0.162	0.153	0.162	0.153
2 Acidity at renneting(%LA)	0.180	0.170	0.180	0.170
3 Ripening time (min.)	45	45	45	70
4 Acidity at cutting(%LA)	0.108	0.108	0.117	0.117
5 Acidity at draining(%LA)	0.126	0.126	0.135	0.135
6 Acidity at milling(%LA)	0.490	0.500	0.495	0.470
7 Fat loss in whey(%)	0.25	0.25	0.25	0.30
8 Total cheddaring time(min.)	180	180	180	210
9 Cheddaring behaviour	Normal	Normal	Normal	Poor development of "chicken breast" texture

* Kosikowski (1966) method.

In comparison to the pure cow milk system, mixed milks containing 10 per cent and 25 per cent buffalo milk did not show much variation in the vat in terms of development of acidity, cheddaring behaviour, and other related parameters. However, the equal proportion mixture of cow and buffalo milk showed a prolonged ripening time (70 min. as against a normal 45 min.), poor cheddaring behaviour, delayed milling acidity (0.47 per cent LA after 220 min. instead of about 0.5 per cent LA after 180 min.) and higher fat loss in whey (0.3 per cent as against 0.25 per cent with others).

The zero day analytical data (Table-10) revealed that with the increased proportion of buffalo milk there was an increase in the pH values. Gradual decrease of moisture from 38.5 per cent to 35.1 per cent alongwith an increase in the proportion of buffalo milk in the mixture from 10 per cent to 50 per cent was also observed. The equal proportion mixture of cow and buffalo milk exhibited a low value for FDM and RI and a high value for TN and S/M.

At the end of 180 days curing period all the cheese samples exhibited further moisture loss ranging from 3.5 to 5.1 per cent. The pH increase, however, did not show a difinite trend. There was a gradual lowering

of RI from 23.63 to 16.52 alongwith an increasing proportion of buffalo milk.

Table 10 : Chemical analysis of cheddar type cheeses made with buffalo and cow milk mixtures.

Attribute	Proportion of cow milk in the mixture(%)			
	100	90	75	50
	0 day			
pH	5.0	5.0	5.10	5.2
Moisture %	39.12	38.50	37.32	35.10
FDM %	50.12	54.73	53.02	49.48
S/M %	3.42	3.12	3.41	4.27
TN %	3.29	3.26	3.35	3.53
RI %	4.50	4.50	4.58	3.55
	180 days			
pH	5.55	5.45	5.40	5.62
Moisture %	33.97	34.12	33.79	30.18
FDM %	49.98	54.68	52.86	49.37
S/M %	4.96	4.18	4.54	5.98
TN %	3.51	3.45	3.52	3.71
RI %	23.63	21.37	18.06	16.59

On the basis of organoleptic evaluation (Table-11) the equal proportion mixture of cow and buffalo milk resulted in a cheese with lowest degree of characteristic flavour, body and texture development.

The mixed milks containing upto 25 per cent buffalo milk possessed sensory properties very similar to the control cheese prepared from cow milk.

Table 11 : Organoleptic quality of 180 days old cheddar type cheese made with buffalo and cow milk mixtures.

Attribute	Proportion of cow milk in the mixture(%)			
	100	70	75	50
Flavour	Desirable ccf	Desirable ccf	Desirable ccf	Mild
Body and texture	Smooth, waxy firm	Smooth, waxy, firm	Smooth, firm	Tough
Colour	Normal	Normal	Normal	Normal

ccf : Characteristic cheddar flavour.

The study indicated the applicability of Kosikowski (1966) technique for cow milk systems containing buffalo milk upto a level of 25 per cent. On the basis of cheese prepared with equal proportion mixture of cow and buffalo milk it was apparent that the standard cow milk cheddar cheese manufacturing technique was not likely to yield satisfactory results with mixtures containing 50 per cent or more buffalo milk.

5.3.3.1.2 Goat milk containing systems

The manufacturing details of cheese making trials with goat milk containing mixtures of buffalo milk are presented at Appendix-V. The important observations during processing and the chemical and organoleptic evaluation data are summarized in Tables 12, 13 and 14.

As can be seen from Table 12, the effect of increasing the proportion of buffalo milk in the goat milk system was very similar to that experienced in case of cow milk containing mixture. Upto the level of 25 per cent buffalo milk addition, goat milk cheeses prepared according to the method developed in sec. 5.3.2 exhibited little difference in the cheese vat in comparison to the pure goat milk system. However, at the 50 per cent level of buffalo milk addition, the cheese making process was characterized by slow preripening, poor cheddaring behaviour, delayed milling acidity and increased fat loss in whey in a fashion very similar to the 50 per cent cow-buffalo milk system (Table-9)

Table 12 : Manufacturing behaviour of cheddar type cheeses made with buffalo and goat milk mixtures.*

Attribute	Proportion of goat milk in the mixture(%)			
	100	90	75	50
Initial acidity of milk(%LA)	0.135	0.135	0.144	0.153
Acidity at renneting(%LA)	0.153	0.153	0.162	0.170
Ripening time (min.)	45	45	45	70
Acidity at cutting(%LA)	0.100	0.100	0.100	0.117
Acidity at draining(%LA)	0.126	0.126	0.126	0.135
Acidity at milling(%LA)	0.495	0.495	0.495	0.470
Fat loss in whey(%)	0.20	0.20	0.20	0.30
Total cheddaring time(min.)	180	180	180	210
Cheddaring behaviour	Normal	Normal	Normal	Poor development of "chicken breast texture

* As per method developed in sec. 5.3.2

The chemical analysis at zero day (Table-13) indicated a lower moisture level in cheeses alongwith increasing level of buffalo milk. The pH values for the mixed milk cheeses were almost similar although

these were slightly higher than that observed for pure goat milk cheese. The FDM values for the mixed milk cheeses were slightly lower than the control. Equal proportion mixture of goat and buffalo milk had a high S/M value of 4.31 and low ripening index value of 3.24.

Table 13 : Chemical analysis of cheddar type cheeses made with buffalo and goat milk mixtures.

Attribute	Proportion of goat milk in the mixture(%)			
	100	90	75	50
	0 day			
pH	5.1	5.2	5.2	5.20
Moisture %	38.85	37.18	37.14	34.48
FDM %	52.85	49.92	48.96	48.60
S/M %	3.50	3.30	3.17	4.31
TN %	3.20	3.27	3.32	3.55
RI %	4.45	4.11	3.28	3.24
	180 days			
pH	5.40	5.45	5.60	5.60
Moisture %	34.21	32.81	32.93	30.02
FDM %	53.01	49.90	48.91	48.55
S/M %	4.39	4.27	4.26	5.86
TN %	3.42	3.46	3.51	3.70
RI %	23.50	22.19	16.29	15.75

At the end of six months curing period all the cheeses experienced loss in moisture ranging from 4.1 to 4.5 per cent, which was within the normal level. Increase in pH values was observed with increased proportion of buffalo milk in goat milk. The RI showed a decreasing value alongwith an increasing proportion of buffalo milk.

On the basis of organoleptic evaluation (Table-14), 50 per cent buffalo milk containing samples were found to possess least satisfactory flavour, body and textural properties. Upto 25 per cent level of mixing of buffalo milk, goat milk cheeses had organoleptic properties very similar to those of pure goat milk cheese.

Table 14 : Organoleptic quality of 180 days old cheddar type cheese made with buffalo and goat milk mixtures.

Attribute	Proportion of goat milk in the mixture(%)			
	100	90	75	50
Flavour	Pleasant	Pleasant	Pleasant	Mild
Body and texture	Waxy, firm, mellow	Waxy, firm, mellow	Waxy, firm, mellow	Tough
Colour	Normal	Normal	Normal	Normal

Studies with cow and goat milk system containing buffalo milk to the extent of 50 per cent revealed that the cheese manufacturing technique used for the pure cow and goat milk systems could be satisfactory applied to mixed milks containing less than 50 per cent buffalo milk. As the proportion of buffalo milk becomes 50 per cent or more, the systems acquire increasingly the characteristics of pure buffalo milk rendering the cow and goat milk cheese making procedures less applicable.

5.3.3.2 Cheese making with mixed milks containing 50 per cent or more buffalo milk

Mixtures containing 50 per cent or more buffalo milk appears to behave more like pure buffalo milk system, as these milks exhibit during cheese making slow development of acidity, a lower level of moisture retention, poor development of "chicken breast" texture during cheddaring, and delayed curing. Czulak (1964) attempted to correct many of these defects by increasing the size of inoculum, and using a salt dilution treatment to reduce the level of calcium ions. The treatment resulted in higher moisture level in cheese and a overall improvement in its quality after curing. The applicability of this approach of preparing cheddar cheese was, therefore, studied with buffalo milk systems containing not more than 50 per cent cow or goat milk.

5.3.3.2.1 Cow milk containing systems

The manufacturing details on cheese making trials with Czulak (1964) method are appendixed at VI. The manufacturing behaviour summarized in Table-15 indicated little difference in the vat behaviour of pure buffalo milk and systems containing 50, 25 and 10 per cent cow milk. All these systems were characterized by a much slower rate of acidity development during

Table 15 : Manufacturing behaviour of cheddar type cheeses made with buffalo and cow milk mixtures.

Attribute	Proportion of cow milk in the mixture(%)			
	50	25	10	0
Acidity at renneting(%LA)	0.153	0.162	0.162	0.160
Acidity at cutting(%LA)	0.108	0.108	0.117	0.108
Acidity at draining(%LA)	0.126	0.126	0.137	0.126
Acidity at milling(%LA)	0.470	0.470	0.470	0.470
Fat loss in whey (%)	0.30	0.30	0.30	0.30
Total cheddaring time (min.)	220	220	230	240
Cheddaring[2] behaviour	Slightly improved	Poor	Poor	Poor

1 Czulak (1964) method.

2 Development of "Chicken breast" texture .

cheddaring resulting in a milling acidity of 0.47 per cent LA at the end of about 4 hours cheddaring. The cheddaring time in these cheeses increased from 220 to 240 min. alongwith an increase in the proportion of buffalo milk. The curd fusion properties of the mixed milk systems were much inferior to those observed in mixed milks containing upto 25 per cent buffalo milk.

The zero day analysis of the cheeses (Table-16) indicated a slightly higher moisture level associated with a higher proportion of cow milk in the mixtures. The FDM values did not show much variation among these cheeses. However, slightly lower pH values with increased proportion of cow milk in the mixtures were recorded. A lower S/M value and higher RI were also associated with an increased cow milk content in the mixture.

At the end of 180 days curing at 10°C and 75 per cent RH the moisture losses were within the range of 5.3 to 3.7 per cent from the zero day values. S/M values registered a corresponding increase. Normal increase in pH values was recorded for all the cheeses. RI indicated a drastic difference between the mixture and pure milk system. RI values exhibited a marked

Table 16 : Chemical analysis of cheddar type cheeses made with buffalo and cow milk mixtures.

Attribute	Proportion of cow milk in the mixture(%)			
	50	25	10	0
	0 day			
pH	5.20	5.25	5.25	5.30
Moisture %	36.57	35.72	35.50	35.15
FDM %	49.38	49.12	48.65	48.70
S/M %	4.11	4.25	4.28	4.36
TN %	3.55	3.70	3.85	4.25
RI %	3.59	3.45	3.05	2.25
	180 days			
pH	5.62	5.55	5.54	5.55
Moisture %	31.23	30.98	31.52	31.43
FDM %	49.27	49.10	48.35	48.65
S/M %	5.27	5.39	5.44	5.49
TN %	3.72	3.85	4.06	4.45
RI %	18.35	13.25	10.07	6.97

increase from 6.97 for pure buffalo milk to about 10 to 18 alongwith an increasing proportion of cow milk in the mixtures. This indicated a potentially beneficial effect of even a small portion of cow milk (10 per cent) on the ripening behaviour of buffalo milk cheeses. With the cheeses prepared from equal proportion of cow and buffalo milks, Czulak (1964) method resulted in a higher ripening index of 18.35 than the value of 16.59 (Table-10) observed with the Kosikowski (1966) method.

Consistent with the ripening behaviour of these cheeses, organoleptic evaluation presented in Table-17 indicated the mildest flavour development in the pure buffalo milk system which was comparatively richer in samples containing higher proportion of cow milk. Body and texture properties changed from slight tough to hard rubbery as the proportion of cow milk decreased. In comparison to the cheese containing less than 50 per cent buffalo milk, sensory evaluation of the cheeses containing 50 per cent or more buffalo milk indicated relatively less progress in ripening at the end of six months period. However, such a slow rate of curing has been normally experienced in buffalo milk cheeses which usually take about 270 days or more for attaining a desirable body, texture and flavour.

Table : 17 Organoleptic quality of 180 days old cheddar type cheese made with buffalo and cow milk mixtures.

Attribute	Proportion of cow milk in the mixture(%)			
	50	25	10	0
Flavour	Mild	Slightly mild	Very mild	Very mild
Body and texture	Slightly tough	Slightly hard and rubbery	Hard rubbery	Hard rubbery
Colour	Normal	Normal	Normal	Normal

5.3.3.2.2 Goat milk containing systems

Manufacturing details of cheeses prepared with buffalo milk systems containing goat milk upto 50 per cent level are presented in Appendix-VII.

Data summarized in Table-18 indicate that the goat milk containing systems behaved very similarly like the cow milk containing systems during the cheese making trials with the Czulak (1964) method. There was little difference between mixtures containing

Table 18 : Manufacturing behaviour of cheddar type cheeses made with buffalo and goat milk mixtures.[1]

Attribute	Proportion of goat milk in the mixture(%)			
	50	25	10	0
Acidity at renneting(%LA)	0.153	0.162	0.162	0.160
Acidity at cutting(%LA)	0.108	0.108	0.117	0.108
Acidity at draining(%LA)	0.126	0.126	0.137	0.126
Acidity at milling(%LA)	0.47	0.47	0.47	0.47
Fat loss in whey(%)	0.30	0.30	0.30	0.30
Total cheddaring time(min.)	220	220	230	240
Cheddaring[2] behaviour	Slightly improved	poor	poor	poor

1 Czulak (1964) method.

2.Development of "Chicken breast" texture .

various proportions of goat milk in terms of acidity development, cooking behaviour and fat loss in whey. The cheddaring was characteristically slower as was observed with the pure buffalo milk system. A milling acidity of 0.47 per cent LA was attained at the end of 220 min. to 240 min. as the proportion of goat milk decreased in the mixture from 50 per cent to zero per cent. The curd fusion properties during cheddaring deteriorated as the goat milk content decreased.

The zero day analysis of moisture (Table-19) indicated values ranging from 35.85 per cent to 35.15 per cent as the proportion of goat milk decreased. There was a corresponding increase in the salt content on moisture basis and decrease in RI. The pH and FDM values for all the cheeses were more or less similar.

At the end of six months ripening period a loss of moisture from 4.6 per cent to 3.7 per cent was observed alongwith an increase in S/M values. The increase in pH followed a normal trend for all the samples. The lowest ripening index of 6.97 observed with the pure buffalo milk, showed a considerable increase ranging from 9.97 to 17.85 as the proportion of goat milk increased from 10 per cent to 50 per cent. Relatively beneficial effect of Czulak (1964) method

Table 19 : Chemical analysis of cheddar type cheeses made with buffalo and goat milk mixtures.

Attribute	Proportion of goat milk in the mixture(%)			
	50	25	10	0
	0 day			
pH	5.25	5.25	5.30	5.30
Moisture %	35.85	35.24	35.25	35.15
FDM %	48.57	48.89	48.37	48.70
S/M %	4.02	4.22	4.29	4.36
TN %	3.50	3.62	3.83	4.25
RI %	3.16	3.05	2.79	2.25
	180 days			
pH	5.60	5.53	5.58	5.55
Moisture %	31.18	31.27	31.45	31.43
FDM %	48.55	48.79	48.17	48.65
S/M %	5.25	5.34	5.41	5.49
TN %	3.70	3.81	4.01	4.45
RI %	17.85	14.12	9.97	6.97

was also observed in cheeses prepared with equal proportion mixture of goat and buffalo milks in terms of higher RI of 17.85 as against 15.75 (Table-13) obtained with the Kosikowski (1966) method.

Organoleptic evaluation (Table-20) of cheeses indicated a progressive development of flavour, body and texture characteristics alongwith an increasing value of RI associated with an increasing

proportion of goat milk. At the end of six months period pure buffalo milk cheese had the lowest development of flavour, body and texture.

Table 20 : Organoleptic quality of 180 days old cheddar type cheese made with buffalo and goat milk mixtures.

Attribute	Proportion of goat milk in the mixture(%)			
	50	25	10	0
Flavour	Mild	Slightly mild	Very mild	Very mild
Body and texture	Slightly tough	Slightly hard and rubbery	Hard, rubbery	Hard rubbery
Colour	Normal	Normal	Normal	Normal

Application of Czulak (1964) method for milks containing 50 per cent or more buffalo milk has in general, proven to be more useful than might have been anticipated with the Kosikowski (1966) method. This can be inferred from buffalo milk systems containing 50 per cent cow or goat milk in terms of relatively higher moisture level, lower S/M, higher RI and a faster rate of ripening. With the Czulak (1964) method presence of cow or goat milks even to the extent of 10 per cent has given a product somewhat

better than that obtained from pure buffalo milk. However, overall quality of cheeses obtained from mixtures containing 50 per cent or more buffalo milk was somewhat inferior to those obtained from the mixtures containing less than 50 per cent buffalo milk using Kosikowski (1966) method. Since Kosikowski (1966) method was found to be less satisfactory with mixtures containing 50 per cent or more buffalo milk, modifications of Czulak (1964) method had to be attempted at this stage to improve the quality of cheeses prepared from these mixtures.

5.3.3.3 Modifications in cheese making process for buffalo milk systems containing 50 per cent and more buffalo milk

The chesses prepared from milks containing 50 per cent or more buffalo milk had in general, a higher pH and lower moisture level that might have been responsible for slow rate of curing. Following modifications of Czulak (1964) method were, therefore, attempted to promote a further rise in acidity development and moisture retention :-

(a) In order to improve moisture retention property, milk systems were pasteurized at a higher temperature of 65°C/30 min.(Al-Fayadh, 1980).

(b) Addition of 1 per cent salt in the milk prior to inoculating with starter culture.

(c) The rate of inoculum was increased from 1.5 per cent to 2.5 per cent level as per Burde and Srinivasan (1967).

(d) A setting temperature of 28°C.

(e) A shorter cooking period of 50 min. were also attempted to aid moisture retention in curd.

Since salt was to be added prior to renneting, the Czułak (1964) procedure of draining part of the whey during cooking and adding salt to the remaining cooking whey was eliminated.

The manufacturing details of these trials are presented in Appendix VIII and IX and summarized in Table-21. The analytical results are presented in Table-22 and 23.

During the cheese making trials conducted with the modified procedure, no adverse effects were observed. As can be seen from Table-21, Whey acidity after cutting was 0.126 per cent LA in the mixed milk systems as against 0.108 per cent LA observed for the buffalo milk control prepared by Czulak (1964) method. The trend of higher acidity development was maintained in the vat through the subsequent stages of draining (after only 50 min. cooking time) and milling (0.50 per cent LA or more at the end of 3 hours cheddaring).

Table 21 : Manufacturing behaviour of cheddar type cheeses made from buffalo milk systems containing 50 per cent and more buffalo milk.

Attribute	Proportion of buffalo milk in the mixture(%)						
	Buffalo cow milk mixtures				Buffalo goat milk mixtures		
	100[1]	90[2]	75[2]	50[2]	90[2]	75[2]	50[2]
Initial acidity of milk(%LA)	0.160	0.153	0.162	0.153	0.170	0.170	0.162
Acidity at cutting(%LA)	0.108	0.126	0.126	0.126	0.126	0.126	0.126
Acidity at draining (%LA)	0.126	0.144	0.144	0.144	0.144	0.144	0.144
Acidity at milling (%LA)	0.470	0.500	0.500	0.500	0.504	0.504	0.504
Fat loss in whey(%)	0.30	0.50	0.50	0.50	0.50	0.50	0.50
Total cheddaring time(min.)	240	180	180	180	180	180	180
Cheddaring[3] behaviour	Poor	Slig- htly impr- oved	Impr- oved	Bett- er	Sligh- tly impr- oved	Impro- ved	Better

1 : Czulak (1964) method.

2.: Modified method (sec. 5.3.3.3).

3 : Development of "Chicken breast" texture.

In addition to the use of a higher rate of inoculum, the incorporation of salt prior to adding starter culture might have exerted a stimulating effect on the starter microorganisms (Mcdowall and Whelan, 1934) resulting in an accelerated rate of acid development. Incorporating salt in the liquid milk instead of in the whey during cooking might have also resulted in a more effective exchange of Ca^{++} with Na^{+} promoting a higher moisture retention (Fahmi and Sharara, 1950) as can be seen from the zero day analysis presented in Table-22. Moisture level in fresh cheeses prepared from the mixed milks were within the range of 37 to 38 per cent as against a level of 35 per cent moisture in buffalo milk control. This indicated that higher pasteurization temperature and shorter cooking time were also effective in promoting higher moisture retention. In general, a slight decrease in the moisture content of fresh cheese was associated with an increasing proportion of buffalo milk in the mixture. Barring the cheese from buffalo milk mixture with 10 per cent cow milk all other experimental cheeses had somewhat lower pH values than the control cheese on zero day. The cheese prepared from the mixed milk systems had a lower S/M value and higher RI. The FDM values for experimental cheeses were higher than those for the buffalo milk control eventhough the fat loss in whey for these cheeses were to the tune of 0.5 per cent. This indicated a higher handling loss of fat in the control cheese.

At the end of 180 days curing period, all the cheeses attained a pH value around 5.5. Moisture level decreased in all the samples, the buffalo milk control having the lowest value of 31.39 per cent. There was

Table 22 : Chemical analysis of cheddar type cheese made from buffalo milk system containing 50 per cent and more buffalo milk.

Attribute	Proportion of buffalo milk in the mixture(%)						
	Buffalo cow milk mixtures				Buffalo goat milk mixtures		
	100	90	75	50	90	75	50
	0 day						
pH	5.20	5.25	5.15	5.10	5.15	5.17	4.93
Moisture (%)	35.15	37.93	38.22	38.35	37.16	38.12	38.53
FDM %	45.27	46.95	48.14	49.59	47.53	47.23	47.74
S/M %	3.95	3.45	3.25	3.39	3.42	3.54	3.31
TN %	4.18	3.78	3.60	3.52	3.82	3.60	3.50
RI %	2.27	2.42	3.52	3.12	2.41	2.08	2.62
	180 days						
pH	5.50	5.50	5.55	5.45	5.55	5.50	5.50
Moisture (%)	31.39	34.29	34.79	34.25	32.99	33.86	33.93
FDM %	45.19	46.89	48.00	49.59	47.51	47.18	47.73
S/M %	5.01	4.49	4.34	4.64	4.45	4.42	4.47
TN %	4.39	3.97	3.77	3.75	4.02	3.85	3.73
RI %	6.68	9.90	13.03	15.36	10.03	14.00	16.22

generally an increase in the S/M and TN values. The FDM value remained more or less constant. The RI values of the experimental samples were much more than those for the control samples. In general, cheeses with increased proportion of cow or goat milk had higher RI values.

The organoleptic evaluation (Table-23) revealed that the control cheese and the one with 90 per cent buffalo milk had a flat flavour after six months ripening. The flavour quality, however, improved with the increased proportion of cow or goat milk in buffalo milk. Improvement in the body and texture attributes were also noticed with the increased proportion of cow or goat milk in buffalo milk.

Table 23 : Organoleptic quality of 180 days old cheddar type cheeses made from buffalo milk systems.

Attribute	Proportion of buffalo milk in the mixture(%)						
	Buffalo cow milk mixtures				Buffalo goat milk mixtures		
	100	90	75	50	90	75	50
Flavour	Flat	Flat	Very mild	Mild	Flat	Very mild	Mild
Body and texture	Tough	Slightly better	Better	Smooth mellow	Slightly better	Better	Smooth mellow
Colour	Normal	Normal	Normal	Normal	Normal	Normal	Normal

The modified cheese making procedure was thus effective in producing better quality cheddar type cheeses from milk mixtures containing 50 per cent or more buffalo milk. The procedure was equally effective in the presence of cow or goat milk in the mixtures.

5.4 CURING BEHAVIOUR OF CHEESES MADE FROM COW, BUFFALO AND GOAT MILKS AND THEIR MIXTURES

Although specific techniques were developed for improving the manufacturing of cheddar type cheeses from different milk systems, the quality of some of these cheeses was not considered identical to those prepared from cow milk control. Since the final quality of cheese is determined by the changes taking place during ripening, the curing behaviour of cheeses prepared from different milk systems was studied at this stage.

The milk system used for these trials were buffalo, cow and goat milks and their mixtures as indicated in sec.5.1. In these studies cow and buffalo milks were adjusted to a C/F ratio of 0.7 and goat milk to a C/F ratio of 0.65. Kosikowski (1966) method was used to prepare cheeses from cow milk systems containing upto 25 per cent buffalo milk. Czulak (1964)

method was used for control buffalo milk cheese. Cheeses made with goat milk systems containing upto 25 per cent buffalo milk were by the method developed in sec.5.3.2. The modified Czulak method developed in sec.5.3.3.3 was used for cheese making with mixed milk systems containing 50 per cent or more buffalo milk.

Cheese blocks (10-12 kg size rectangular blocks) were paraffined after 4-5 days of rind formation and stored at 10°C and 70-75 R.H. for ripening upto 12 months period. Samples were taken from these blocks on zero day, at regular monthly intervals upto 4 months, and 2 month intervals for the remaining 8 months period for chemical analysis. Microbiological analysis and organoleptic evaluation of samples were commenced from 4th month onwards. The results of these studies are presented in this section.

5.4.1 CURING BEHAVIOUR OF PURE MILK CHEESES

In order to study the effect of mixing different milks on the quality of cheese, it is necessary to understand the inherent differences amongst the cheeses prepared from pure milk systems, that served as controls in the mixed milk cheese making studies. Three separate batches of cheeses were prepared from buffalo, cow and goat milk using 90 to 110 kg batches per trial.

5.4.1.1 Organoleptic changes during ripening

During the initial trials of cheese making it was observed that the proper body and texture and flavour development does not take place before 4 months of age. Therefore, organoleptic evaluation of cheeses was initiated after the 4 months curing and at subsequent 2 months interval upto a perod of 12 months. Data on organoleptic evaluation are detailed in Appendix-X.

The cheese samples were scored for flavour (45 points), body and texture (30 points), and colour (10 points). The development of flavour intensity was scored on a 9 point scale.

Fig.4 presents the average values on flavour and body and texture scores of cow, buffalo and goat cheeses. Consistent increase in the organoleptic scores for all the cheeses indicated a continuing improvement of their flavour, body and texture properties throughout the ripening period. However, the buffalo cheeses scored the least at all ages. The flavour scores for cow and goat milk cheeses (Fig.4A) were very similar. Although, the goat milk cheese samples were criticised for lack of typical "cow milk cheddar" cheese flavour, it was liked very much by the taste

panel. The slight differences in the flavours of goat and cow milk cheeses might be associated with their inherent compositional differences. The buffalo cheeses at 12 months age could attain only the scores similar to cow and goat cheeses at 4 months age. This indicates a very slow ripening behaviour of this cheese, reported earlier (Godbersen, 1964; Czulak, 1964; Burde and Srinivasan, 1967).

The development of flavour intensity of the three pure milk cheeses followed a pattern similar to that of flavour scores during ripening (Fig.4B). While the cow and goat milk cheeses were very similar, the buffalo milk cheeses were very slow in development.

Body and texture scores for these cheeses (Fig.4C) also registered a consistent increase throughout the ripening period. In this aspect also the buffalo milk cheeses scored much lower throughout. These were criticized for dry, hard and tough body and texture at all ages. The goat milk cheese was particularly recognised for its smooth, waxy and mellow body and texture. However, when left at room temperature for some time, goat milk cheese samples developed a typical oily appearance on the surface.

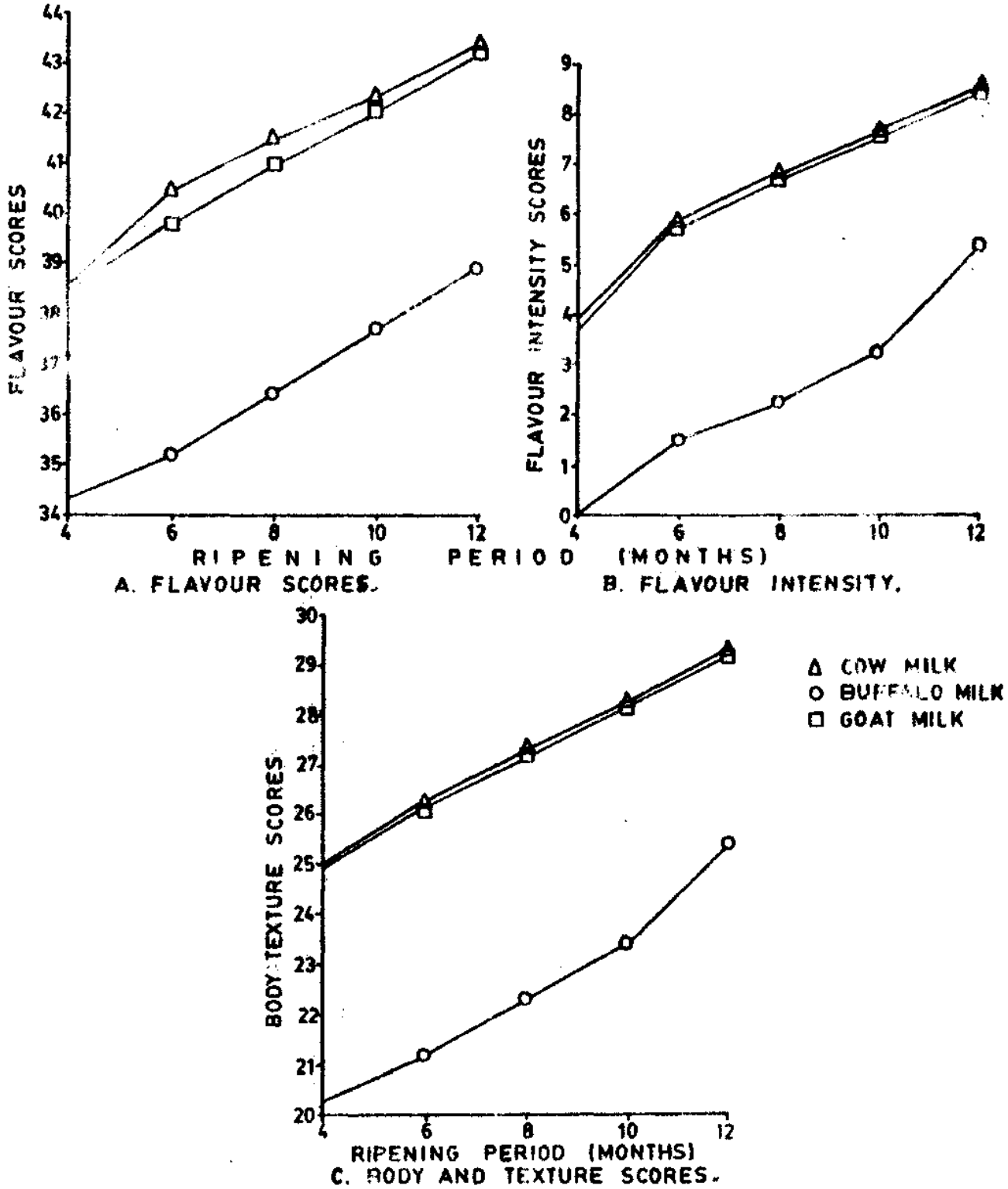


FIG.4 CHANGES IN FLAVOUR, FLAVOUR INTENSITY AND BODY AND TEXTURE OF CHEESE DURING RIPENING.

This is possibly due to the formation of numerous liquid fat droplets at room temperature, since goat milk fat has a lower melting point (Parkash and Jenness, 1968).

The colour scores (Appendix-Xd) for cow and goat milk cheeses were identical. The buffalo milk cheeses scored slightly less on this count also. No adverse criticisms however, were received for this attribute throughout the ripening period. The colour scores for all the cheeses remained constant throughout the ripening period.

5.4.1.2 Changes in pH, moisture and salt content

The pH, moisture and salt on moisture basis (S/M) are considered to be the important factors influencing the curing characteristics of cheese, since these factors influence the biochemical aspects of cheese ripening. The microbial ecology, mainly responsible for ripening in turn is influenced by the biochemical changes occurring in the cheese mass during ripening. The results for these parameters and microbiological analysis in terms of total viable counts and lactic counts are presented in Appendix- XI, XII, XIII and XIV. The average values obtained for these parameters are presented in Fig.5.

The initial (zero day) pH values (Fig.5A) for all the three cheeses were within the normal range of 5.02 to 5.2. The buffalo cheeses had the highest pH value of 5.2 in comparison to cow and goat milk cheeses having 5.02 and 5.10 pH. Consistent increase in pH was observed throughout the ripening period. For buffalo milk cheeses, the pH increased upto 6.0 at 10th month and then dropped to 5.7 at 12th month of age. The increase in pH during ripening may be imputed to the release of the basic amino acids.

The cow and goat milk cheeses had more or less the same moisture (Fig.5B) content on zero day. However, the buffalo milk cheeses contained 3.5 per cent less moisture than that observed in case of cow milk cheeses. Thereafter a gradual decrease in moisture level of all the cheeses was recorded. At the end of 12 months ripening cow and buffalo milk cheeses lost about 6 per cent moisture. The goat milk cheeses on the other hand lost about 7 per cent moisture.

The S/M values (Fig.5C) of the cheeses differed considerably. The buffalo milk cheeses had the highest S/M value throughout the ripening period. At the zero day the cow milk cheeses had the lowest value. Gradual increase in these values was observed

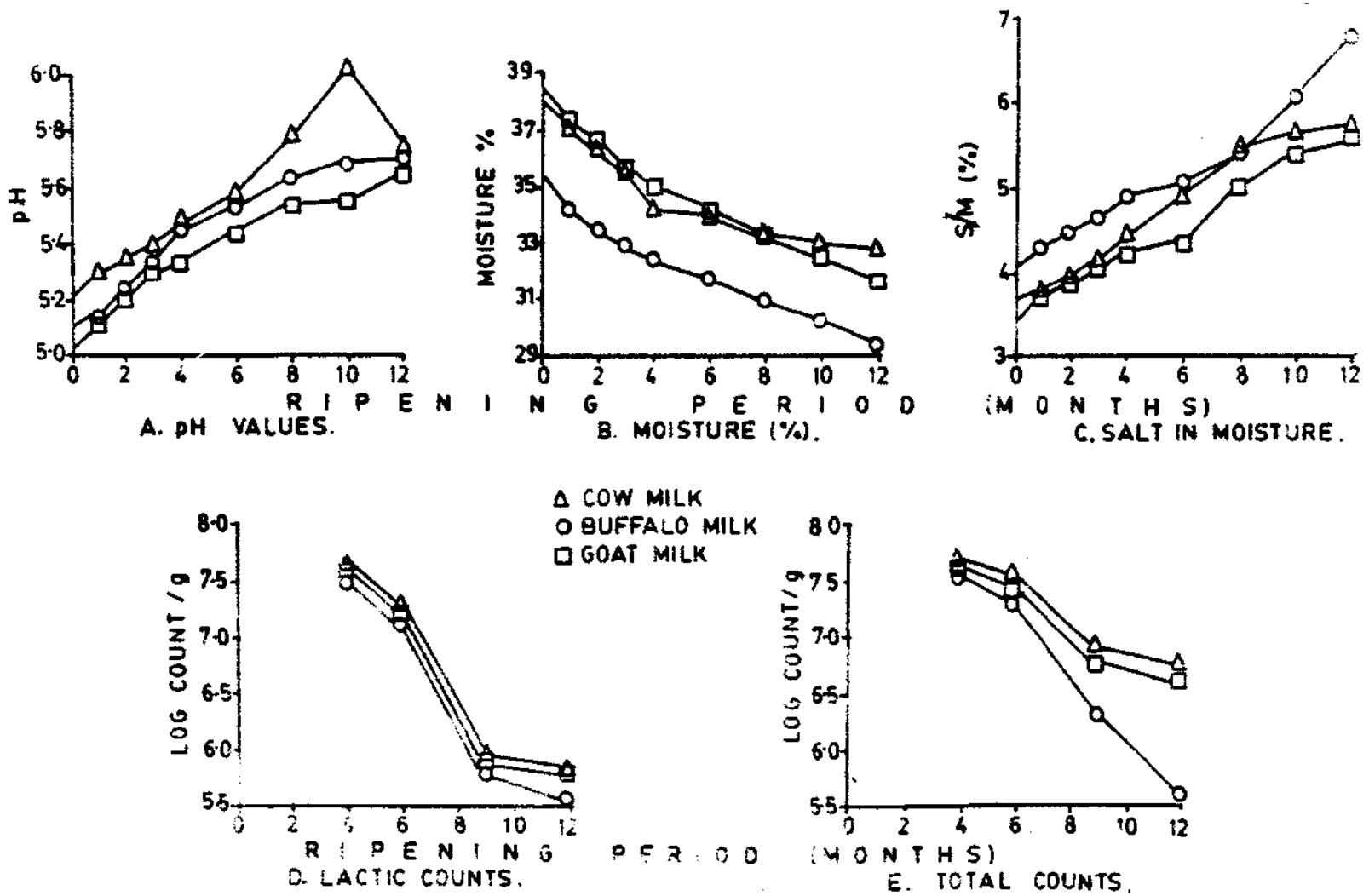


FIG. 5 CHANGES IN pH, MOISTURE, S/M, AND LACTIC AND TOTAL COUNTS OF CHEESE DURING RIPENING.

throughout the ripening period related to the moisture loss trends. The higher S/M values of buffalo milk cheese might have influenced a slow development of flavour, body and texture during the curing of cheeses.

While changes in S/M values are due to the moisture loss during the ripening of cheese blocks, pH changes are associated with changes in microbiological activities. Total viable counts and lactic counts of the cheeses at the end of 4, 6, 9 and 12 months age are presented in Fig.5D and E.

At the end of 12 months curing, total viable counts gradually decreased from an initial level of about 10 million/g to its one tenth value for cow and goat milk cheeses. In the buffalo milk cheeses the decline in count was about 100 fold. However, not much difference was observed between these three systems in a gradual decline of lactic counts to about one hundredth level at the end of one year curing.

5.4.1.3 Proteolytic changes

Primarily, the state of protein breakdwon determines the body and texture qualities of the cheese. It also influences the flavour characteristics of cheese. The proteolysis in terms of SN, NPN and

amino nitrogen was determined for all the 3 cheeses. The proteolytic count (Appendix-XI) at 4, 6, 9 and 12 months age was also recorded for these cheeses. The details of TN, SN, NPN and amino nitrogen values during ripening are appendixed in XV, XVI, XVII and XVIII, and the average values are depicted in Fig.6 and 7.

It is evident from Fig.6A, that the buffalo milk cheese had the highest value for TN. These values for cow and goat milk cheeses were almost similar. An increasing trend for these values was observed throughout the ripening period. This might be associated with decrease in moisture contents of the cheeses. Higher TN values for buffalo cheeses might be because of the higher protein content in this milk.

Protein breakdwon was associated with an increase in the values of SN,NPN and AN expressed as per cent of TN. In case of buffalo milk cheeses the rate of increase in the values of ripening index (RI i.e. SN/TN) was much slower than that for cow and goat milk cheeses (Fig.6B), which exhibited similar trends. The data indicated that the buffalo cheese reached the RI value of only 14.04 per cent at 12 months of age while the cow and goat milk cheeses attained a value of 38.09 and 35.60 per cent, respectively. The slow rate of

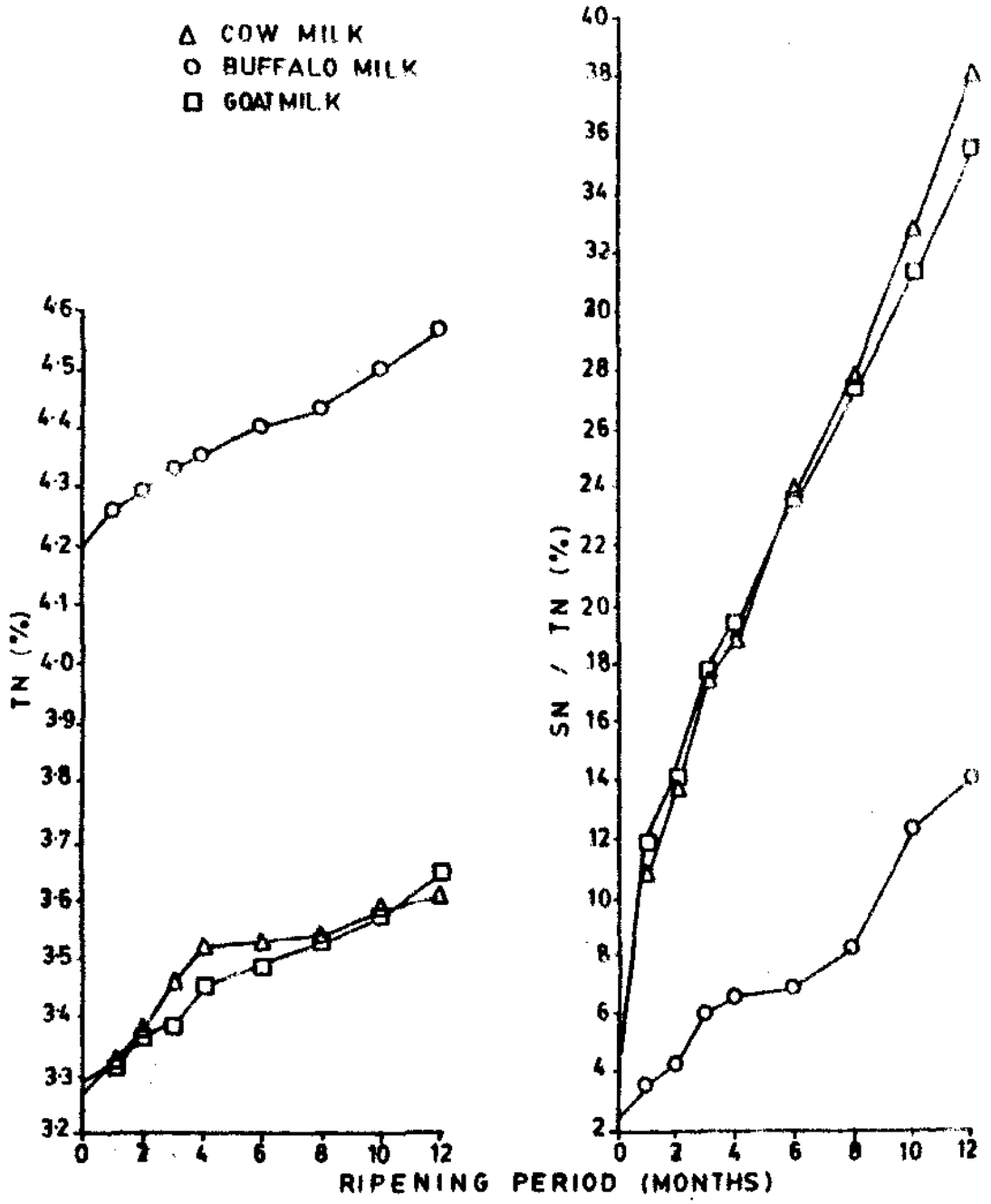


FIG. 6 CHANGES IN TN AND RI (SN / TN) OF CHEESE DURING RIPENING

changes in RI for buffalo cheese is consistent with the slow development of body and texture and flavour during curing as observed in sec. 5.4.1.1.

Cow and goat milk cheeses exhibited very similar proteolytic trends in terms of NPN and AN values (Fig.7), and the rates were much faster than that observed for buffalo milk system.

The proteolytic count of the cheeses (Fig.7C) decreased in a phased manner during ripening. After a decrease in count between 4 and 6 months ripening, a more or less stationary period was observed until 9 months, after which counts began to decline again. The buffalo cheeses had the lowest proteolytic counts. These counts for cow and goat milk cheeses were almost similar.

Differences in the nature of proteolysis of the cheeses made from cow, buffalo and goat milks were also reported by Reddy (1982). On the basis of PAGE study, a delayed breakdown of β-casein component and a slower breakdown of α-casein was observed in buffalo milk cheeses. In comparison to the cow milk system, goat milk systems also exhibited a slightly slower proteolytic rate. These observations are in general agreement with our determinations of proteolytic acitivities of these three systems.

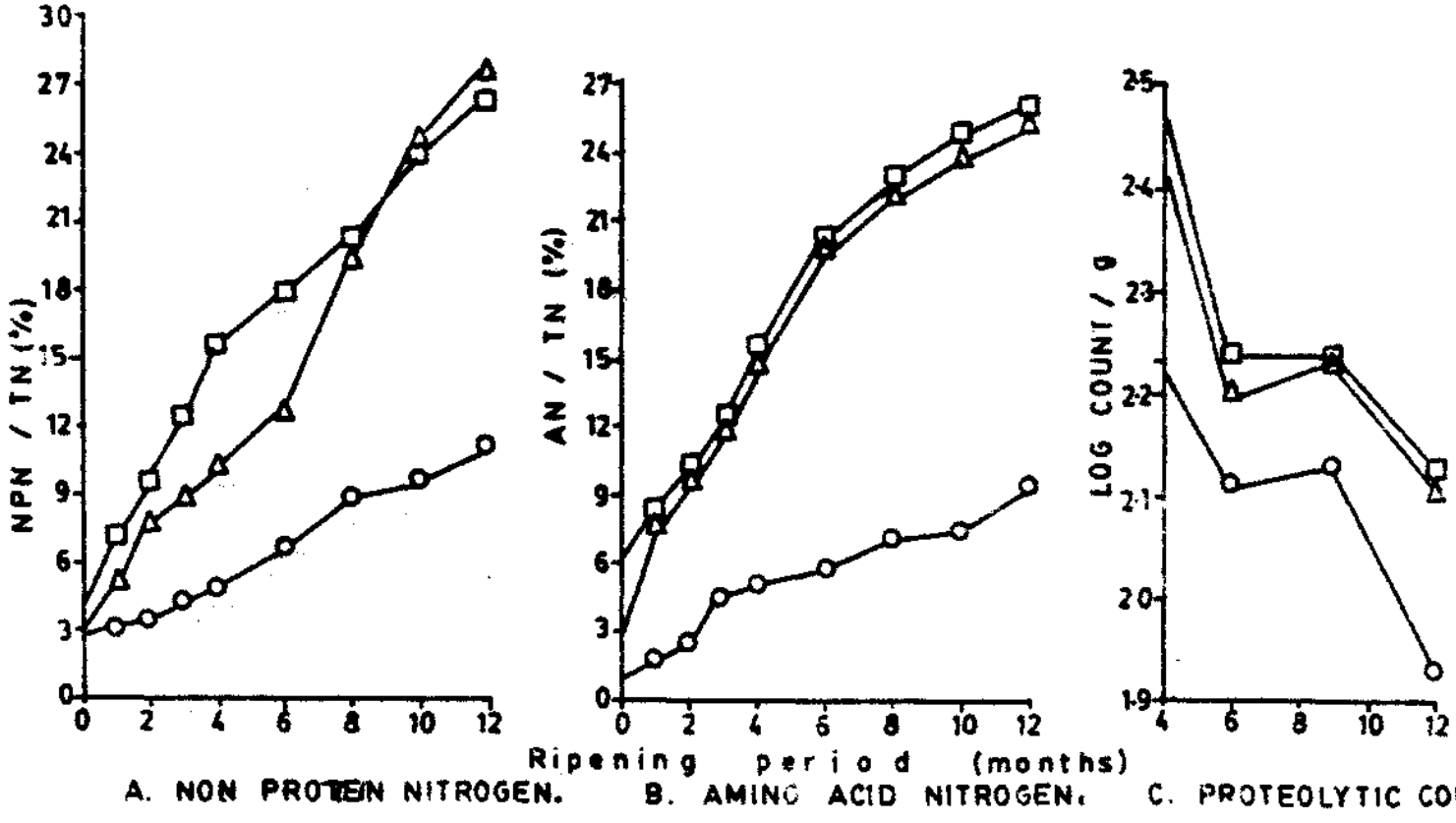


FIG. 7 CHANGES IN NPN, AN, AND PROTEOLYTIC COUNT OF CHEESE DURING RIPENING.

△ COW MILK
○ BUFFALO MILK
□ GOAT MILK

5.4.1.4 Lipolytic changes

Flavour characteristics of cheese are largely influenced by lipolysis. The lipolytic behaviour of cheeses during ripening was studied in terms of lipolytic count as well as the level of total volatile fatty acid (TVFA) and total free fatty acids (FFA). The data for these values are presented in Appendix XI, XIX, XXI and XXII. The average values are plotted in Fig.8. The fat per cent of the cheese sample (Fig.8A) increased from 33.03 to 36.19, 29.49 to 32.28 and 32.93 to 36.64 during ripening for cow, buffalo and goat milk cheeses, respectively. The FDM (Appendix XX) however, remained constant throughout the ripening period. The increase in fat per cent could, therefore, be ascribed to a decrease in the moisture content of the cheeses during ripening. The goat milk cheeses had the highest FDM value followed by cow and buffalo cheeses.

The lipolytic counts at 4 months age (Fig.8B) were in the range of 400 to 600/g for these cheeses. However, cow milk system had the highest level of counts. The goat milk system exhibited trends similar to those of the buffalo milk systems. The counts gradually decreased during the subsequent period of ripening.

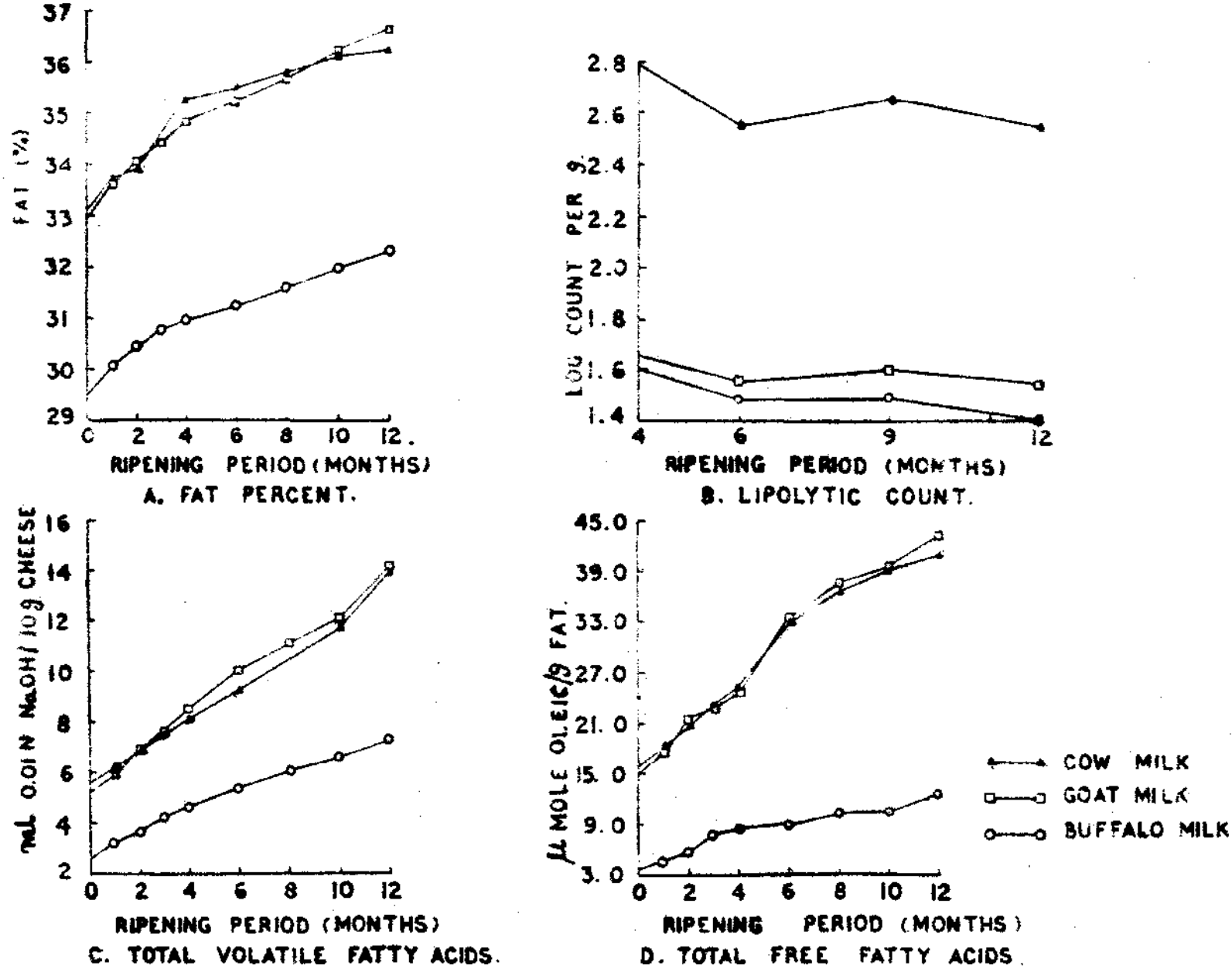


FIG 8 CHANGES IN FAT FRACTIONS AND LIPOLYTIC COUNT OF CHEESE DURING RIPENING.

A steady increase in the level of TVFA and FFA was noticed during the ripening period in all the cheeses. This rate, however, was fastest in goat milk cheeses, follwed very closely by cow milk cheeses. The TVFA VALUE(Fig.8C) for buffalo milk cheese at 12 months was only 7.30 in comparison to 14.17 and 14.14 for goat and cow milk cheeses, respectively. Similarly, the lowest value of 12.37 for FFA (Fig.8B) at 12 months was observed for buffalo cheeses as against 43.36 and 41.24 for goat and cow milk cheese, respectively. It is interesting to note that even though the lipolytic count of goat milk cheese was as low as that exhibited by the buffalo milk system, lipolytic activity measured in terms of TVFA and FFA was as high as that observed in cow milk system. This may probably be due to the presence of a large number small diameter globules of fat which has a lower melting point in goat milk system.

5.4.1.5 Curing characteristics of cow, buffalo and goat milk cheeses

Sensory, chemical and microbiological evaluations revealed that cheeses prepared from the pure milk systems have certain distinct characteristic features.

In general, as curing progressed there was an increasing development of desirable flavour and body and texture characteristics in all the cheese systems. Ripening of cheeses is generally characterised by a

gradual rise in pH, S/M, Fat, TN, RI, NPN, AN, FFA and TVFA values and a decrease in moisture content, total viable, lactic, proteolytic and lipolytic counts.

However, in terms of rate of changes of various parameters measured during the 12 month ripening period, goat milk systems closely resembled the developments in cow milk systems with the exception of lipolytic counts which were similar to those of the buffalo milk systems. Eventhough, the flavour of goat milk cheeses were not exactly identical to that of cow milk cheddar, it was mild, pleasant and well accepted by the taste panel.

In terms of all indicators of cheese ripening, buffalo milk system exhibited slowest rate of changes during curing. The slow curing of buffalo cheese was associated with a much lew moisture level, a high S/M value, and a generally low level microbiological activities.

5.4.2 CURING BEHAVIOUR OF CHEESES FROM BUFFALO-COW MILK MIXTURES

To study the effect of mixing different proportions of cow milk to the buffalo milk on the curing characteristics of cheddar type cheese, batches of cheese containing different proportions of buffalo and cow milk (sec. 5.1) were prepared in triplicate. The curing behaviour of these cheeses is now presented in the following section :

5.4.2.1 Organoleptic changes during ripening

Data on organoleptic evaluation detailed in Appendix X and the average values depicted in Fig.9 indicated a consistent increase in the values of all the organoleptic attributes for all the cheeses throughout the ripening period. The flavour scores (Fig.9A) increased with the increased proportion of the cow milk in the system. The system containing lowest proportion of cow milk (10 per cent) scored the least in comparison to the systems with higher proportion of cow milk. However, even 10 per cent proportion of cow milk in the system gave higher values of flavour development as compared to the pure buffalo milk cheeses. Although, the mixed milk cheeses with major proportion of cow milk (90 and 75 per cent) scored slightly less than the pure cow milk cheeses, these were not criticised for any major difference in the flavour characteristics in comparison to the pure cow milk cheeses. The minor differences in the flavour characteristics could be ascribed to the presence of buffalo milk in the system.

The flavour intensity (Fig.9B) of the mixed milk cheeses showed a pattern similar to that of the flavour. The cheeses with higher proportion of cow

milk were very similar to the pure cow milk. The presence of cow milk in the buffalo milk system improved the flavour intensity scores as compared to the pure buffalo milk system with lowest scores.

Body and texture qualities of the cheeses (Fig.9C) also improved consistently during the ripening period. The presence of even 10 per cent cow milk improved the body and texture characteristics of the cheeses as compared to the cheeses from pure buffalo milk. However, the improvement in these attributes were more discernible when the proportion of cow milk in the system was 50 per cent and more.

The colour scores at zero day (Appendix Xd) for all the cheeses were similar. The control buffalo milk cheeses prepared by Czulak (1964) method scored slightly less. This could be because of the fact that colour was added in all the mixed milk systems and not in the control. These colour scores remained constant throughout the ripening period.

5.4.2.2 Changes in pH, moisture and salt content

The results for the pH, moisture, salt content and the total viable counts and lactic counts are appendixed at XI., XII, XIII and XIV. The average values recorded for these parameters are presented in Fig.10.

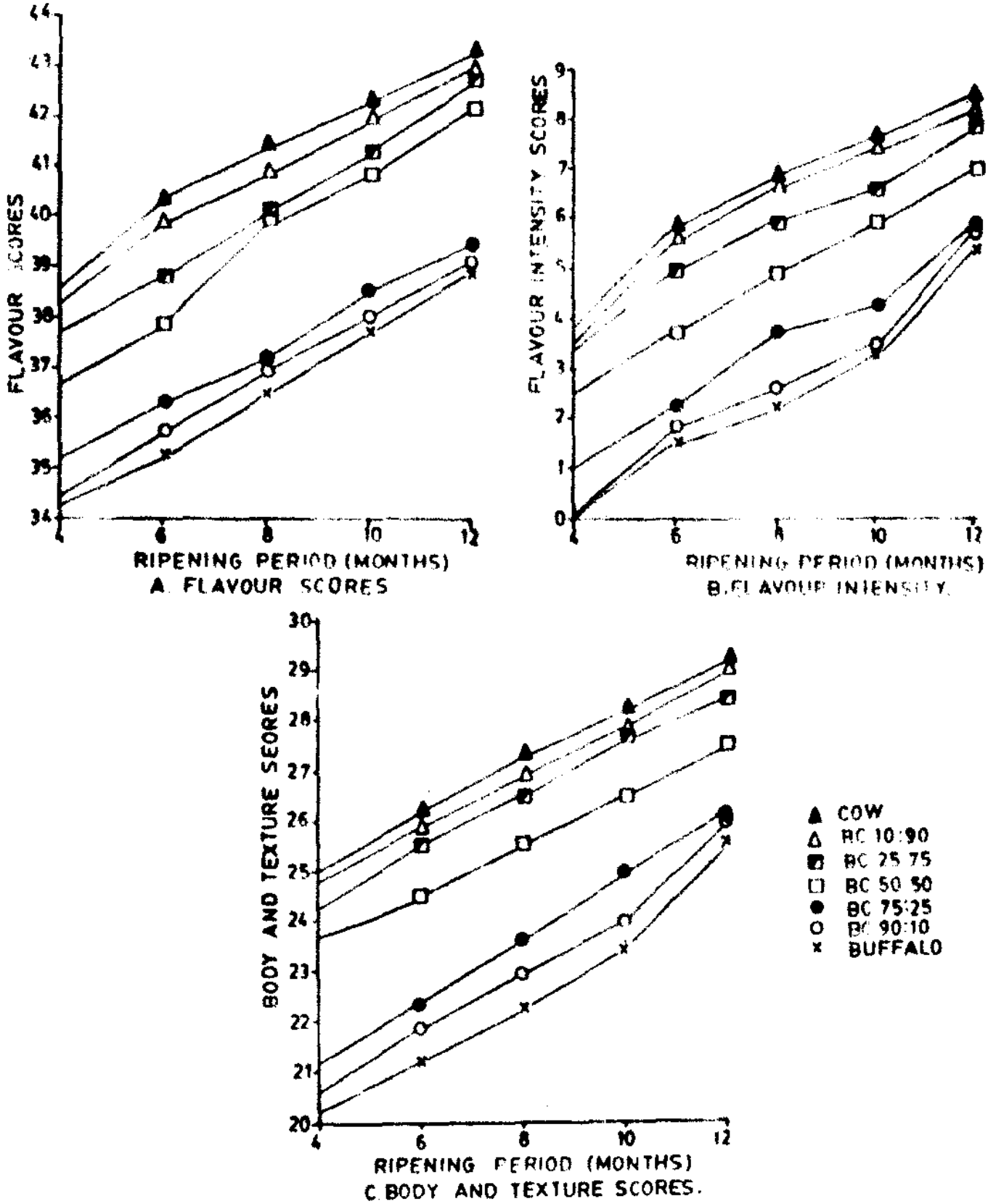


FIG.9 CHANGES IN FLAVOUR, FLAVOUR INTENSITY AND BODY AND TEXTURE OF CHEESE DURING RIPENING.

The zero day pH values (Fig.10A) for all the mixed buffalo-cow milk cheeses were within the range of 5.03 to 5.25. The system containing only 10 per cent cow milk had the highest pH value of 5.25. This ofcourse, was slightly higher than that of the pure buffalo milk system with an average value of 5.2. The pH values increased throughout the ripening period. The increase in these values with milk systems with 50 per cent and more buffalo milk was recorded only upto the 10th month of the age. Thereafter, an abrupt fall in the pH values was observed. This was similar to the trend for pure buffalo milk cheeses. This indicates that the milk systems with higher proportion of buffalo milk behave more or less similar to the pure buffalo milk system.

The moisture content (Fig.10B) of all the buffalo-cow mixed milk cheeses was more or less same on the zero day with the exception of the system containing 75 per cent cow and 25 per cent buffalo milk. These had a slightly low (37.58 per cent) moisture content in comparison to the other cheeses. The moisture content of the other systems was very near to that of cow milk cheeses and much higher as compared to pure buffalo milk cheeses. This implies that the modified procedure for milk systems containing 50 per cent and

more buffalo milk certainly improved the moisture level of the cheeses. A gradual decrease in the moisture level was observed for all the cheeses during the ripening period. All the cheeses lost about 6 per cent moisture in 12 months ripening period. This was similar to the moisture loss for the pure cow and buffalo milk cheeses.

Slight differences in the S/M values (Fig.10C) were observed for all the mixed milk cheeses. In general, the S/M values increased alongwith an increasing proportion of buffalo milk in the system. However, the cheeses with 25:75 blend of buffalo-cow milk had slightly higher S/M value than the cheeses with 50:50 and 75:25 buffalo-cow milks. This could be ascribed to the differences in the manufacturing procedures. The S/M values increased gradually with the advancement of the ripening period. This was related to the moisture loss trends. The S/M values of these cheeses were lower than those observed for the pure buffalo milk cheeses and comparable to those for the cow milk cheeses.

Not much variations in the total counts and lactic counts (Fig. 10D and E) were observed within the different cheese systems. The mixed milk

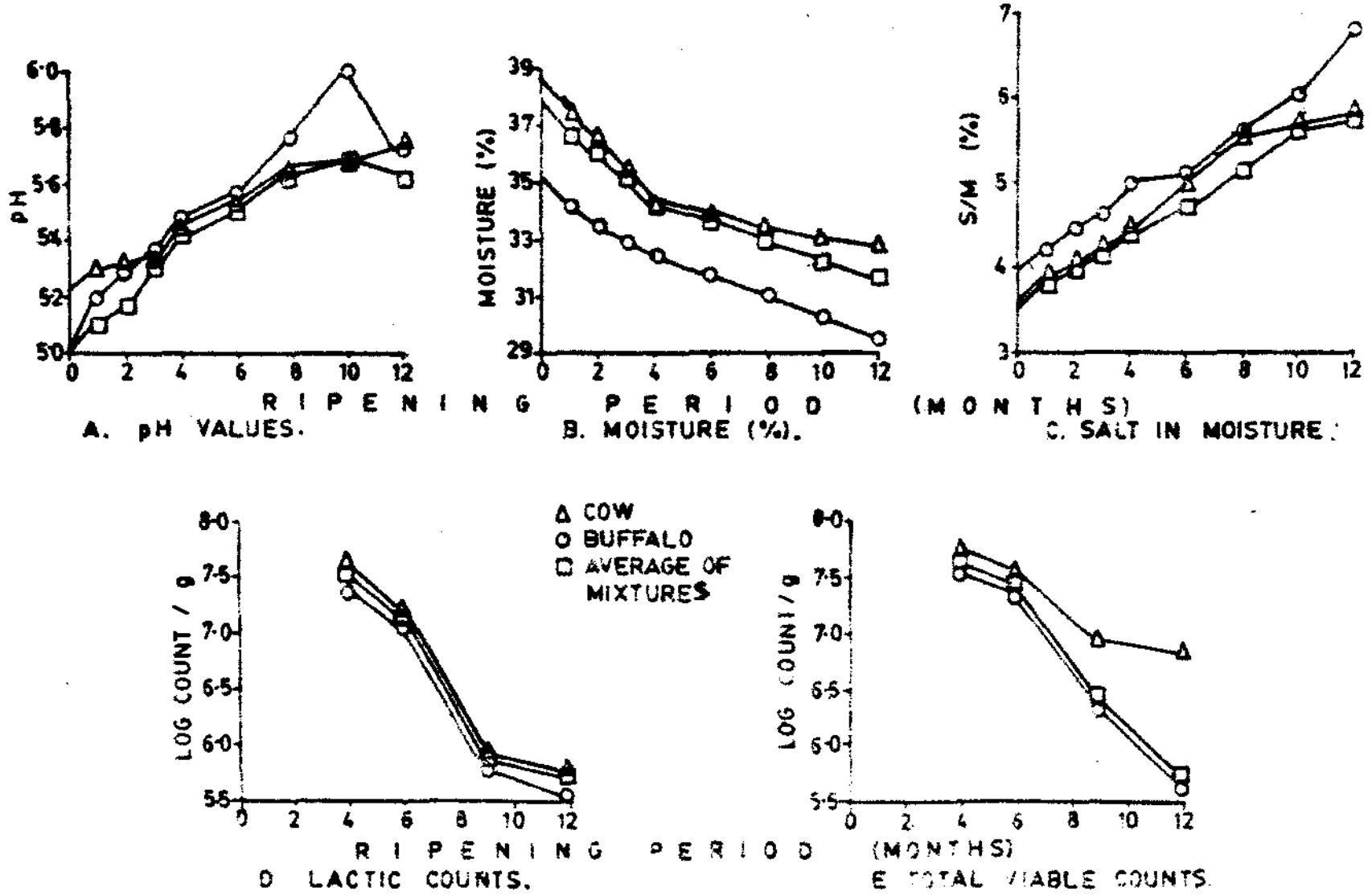


FIG. 10 CHANGES IN pH, MOISTURE, S/M, AND LACTIC AND TOTAL COUNTS OF CHEESE DURING RIPENING.

(buffalo-cow) cheeses had more or less the same number of organisms per gram of cheese in the initial stage (4 months).However, the counts were slightly less than those observed for the pure cow milk cheeses with an exception of cheeses made with 90:10 proportion of cow-buffalo milks. These cheeses had a slightly higher number of total counts. The counts gradually declined with the ripening period and reached about one hundredth level at the end of 12 months age.

5.4.2.3 Proteolytic changes

The proteolytic changes determined in terms of SN, NPN, and AN and the proteolytic counts at different ages are appendixed at XI, XVI, XVII and XVIII. The average values for these attributes are presented in Fig.11 and 12. It is evident from the data that the TN values (Fig.11A) of the cheeses increased with the increased proportion of buffalo milk in the system. The mixture containing highest proportion of buffalo milk had the highest TN percentage (3.81) at the beginning, which, ofcourse, was less than that observed for the pure buffalo milk. The increase in the TN values with the increased proportion of buffalo milk is quite natural because

of the higher concentration of proteins in this milk as compared to the cow milk system. TN values increased throughout the ripening period as the moisture content decreased.

Increase in the SN, NPN, and AN was observed in case of all the cheeses indicating the progress of proteolysis during the curing of cheese systems. The rate of changes in the RI values increased alongwith an increasing portion of cow milk in the system. Cheeses with higher proportion of buffalo milk had the lowest RI value in the beginning of ripening. A gradual increase in these values (Fig.11B) was recorded throughout the ripening period. Cheeses with higher proportion of buffalo milk had slightly higher RI values in comparison to pure buffalo milk cheese. Proportionate increase in these values with increased proportion of cow milk in the system was observed throughout the curing period.

Buffalo-cow mixed milk cheeses exhibited similar pattern in respect to NPN and AN values (Fig.12 A and B). Although, the NPN values for milk systems containing 50 per cent and more cow milk were higher than of pure cow milk upto the 6 months age, these were surpassed by cow milk system towards the end of 12 months age. Mixtures containing less than 50 per cent

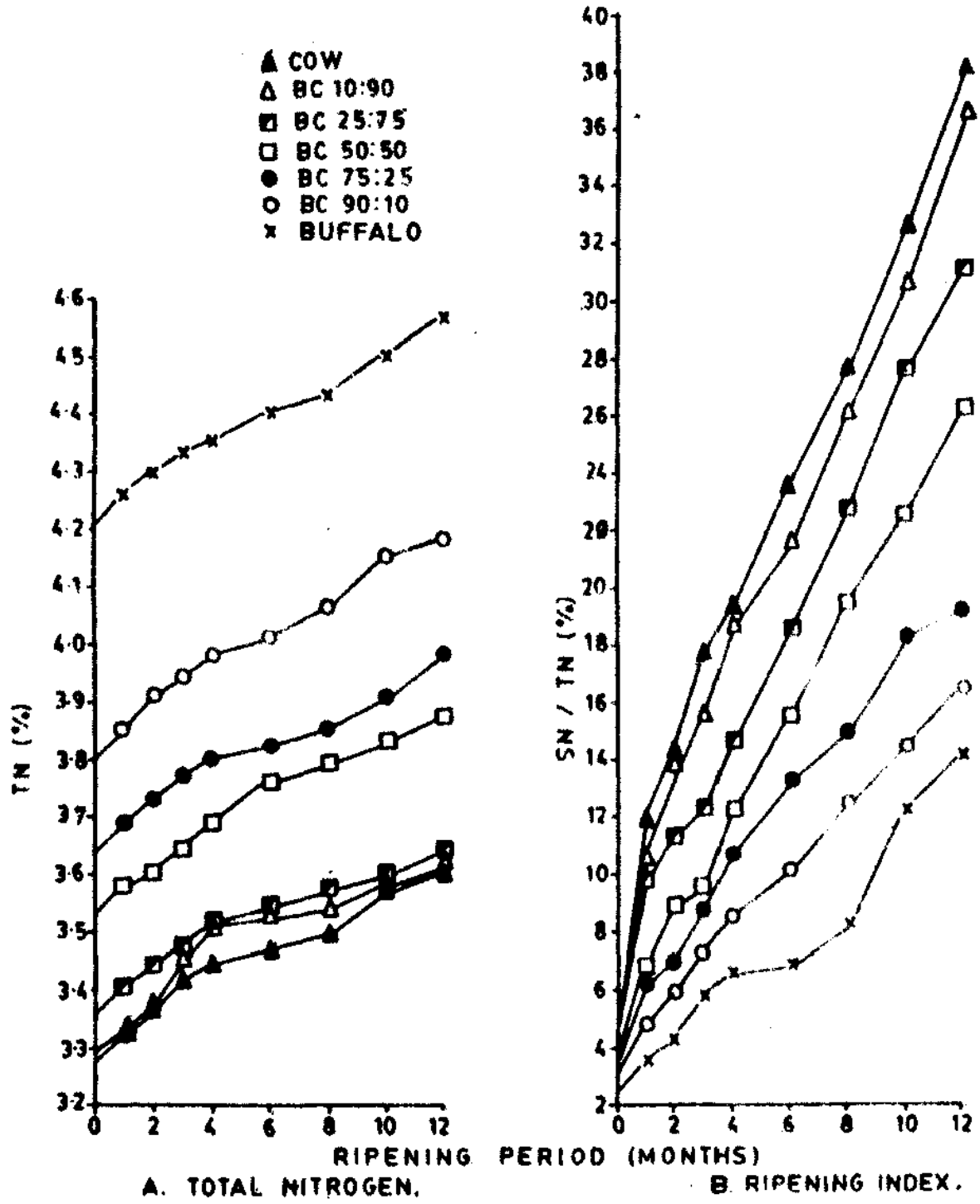


FIG.11 CHANGES IN TN AND RI (SN / TN) OF CHEESE DURING RIPENING

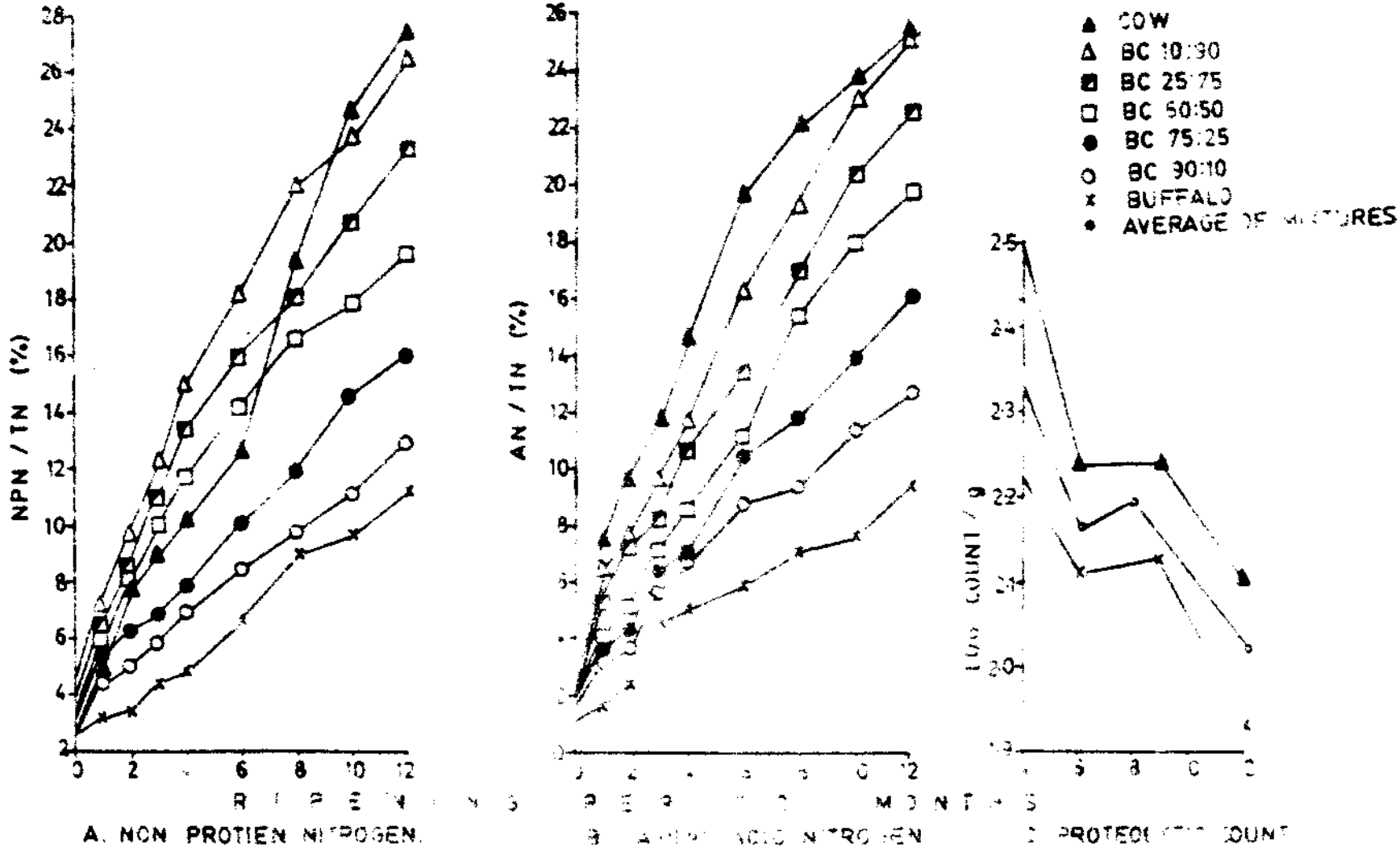


FIG.12 CHANGES IN NPN AN AND PROTEOLYTIC [illegible] OF CHEESE DURING RIPENING

cow milk had lower NPN values than the pure cow milk cheeses, but still these values were higher than those for the pure buffalo milk system. AN values for the buffalo-cow mixed milk systems were proportionate to the increased proportion of cow milk in the system.

The proteolytic count of the cheese (Fig.12 C) also followed a similar sort of pattern. At four months age although, the mixed milk cheeses had a lower proteolytic count, the number decreased with corresponding increase in the proportion of buffalo milk. The count remained almost static at 6 and 9 months of age with the exception of cheese systems containing 90 and 75 per cent of cow milk where it showed a slight increase at 9 months age. The number of proteolytic organisms decreased at 12 months age.

5.4.2.4 Lipolytic changes

The data for fat per cent, TVFA and FFA for mixed buffalo-cow milk cheeses are presented in Appendix XIX, XXI and XXII. The average values detailed in Appendix XIX indicated a gradual increase in the fat percentage of the cheeses with the increased proportion of cow milk in the system. Barring 90:10 mixture of buffalo-cow milk all other cheeses had a higher fat percentage than the pure buffalo milk

cheeses at zero day age. It gradually increased throughout the ripening period with decrease in the moisture content of the cheeses. However, the FDM values indicated a proportionate pattern with the proportionate increase in these values with increasing percentage of cow milk in the system. Eventhough, the fat losses in whey for cheeses made by modified method were much higher than those recorded for pure buffalo milk cheeses, the FDM values (Appendix-XX) for these were higher than it.

The lypolytic counts (Fig. 13C) for the buffalo-cow mixed milk cheeses were lower than those recorded for pure cow and buffalo milk cheese. The counts were more or less equal for all the cheeses and did not indicate any pattern in this regard. Slight gradual decrease in the counts was observed during the subsequent period of curing.

A consistent increase in the concentration of TVFA and FFA (Fig. 13A and B) was recorded for all the cheeses. The increase was proportionate to the increase in the amount of cow milk in the mixed milk system.

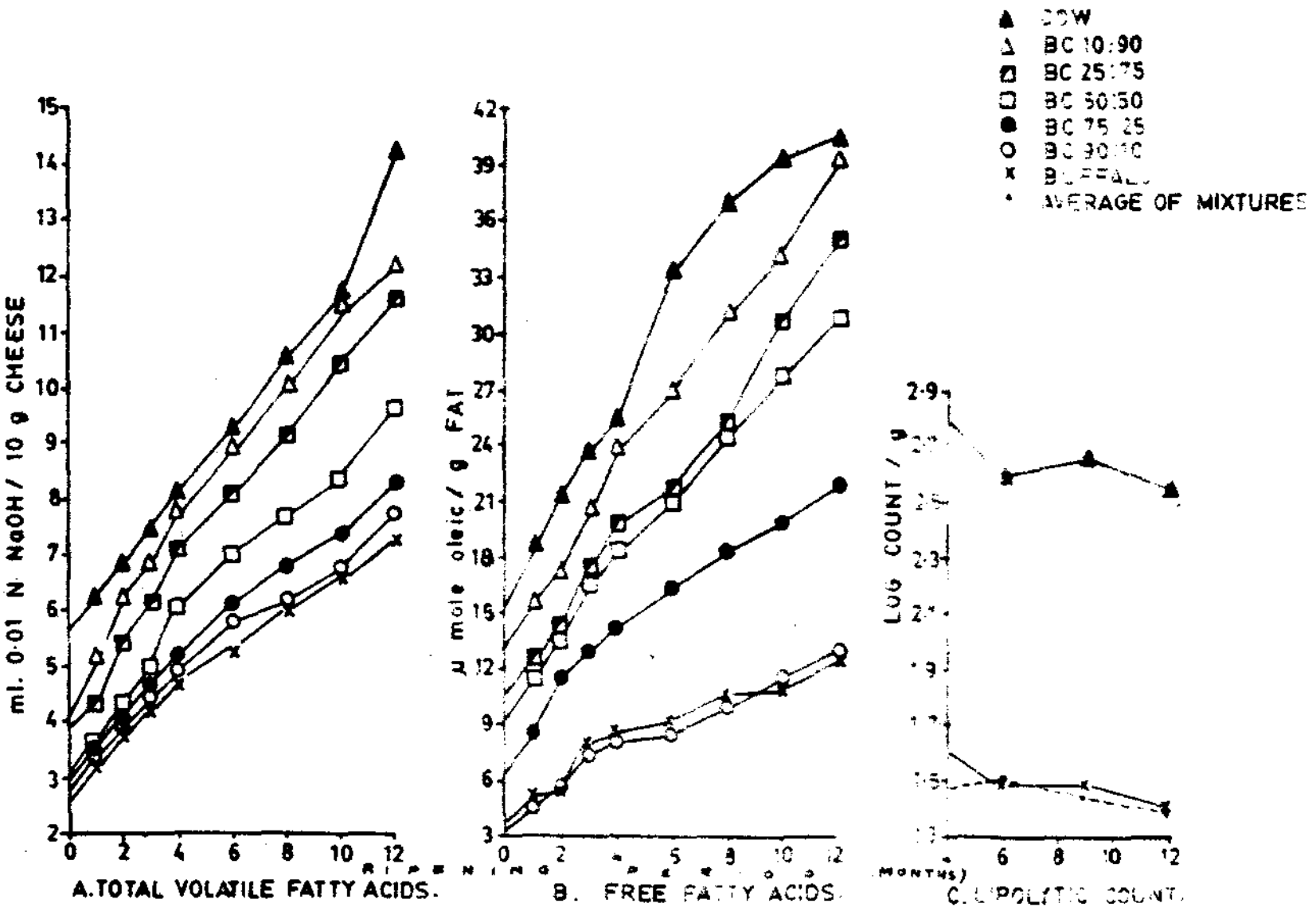


FIG. 13 CHANGES IN TVFA, FFA AND LIPOLYTIC COUNT OF CHEESE DURING RIPENING.

5.4.3 CURING BEHAVIOUR OF CHEESES FROM BUFFALO GOAT MILK MIXTURES

To study the effect of mixing different proportions of goat milk to the buffalo milk on the curing characteristics of cheddar type cheeses, batches of cheese were prepared from the milk systems as outlined in Sec.5.1. The curing behaviour of these cheeses is presented in this section.

5.4.3.1 Organoleptic changes during ripening

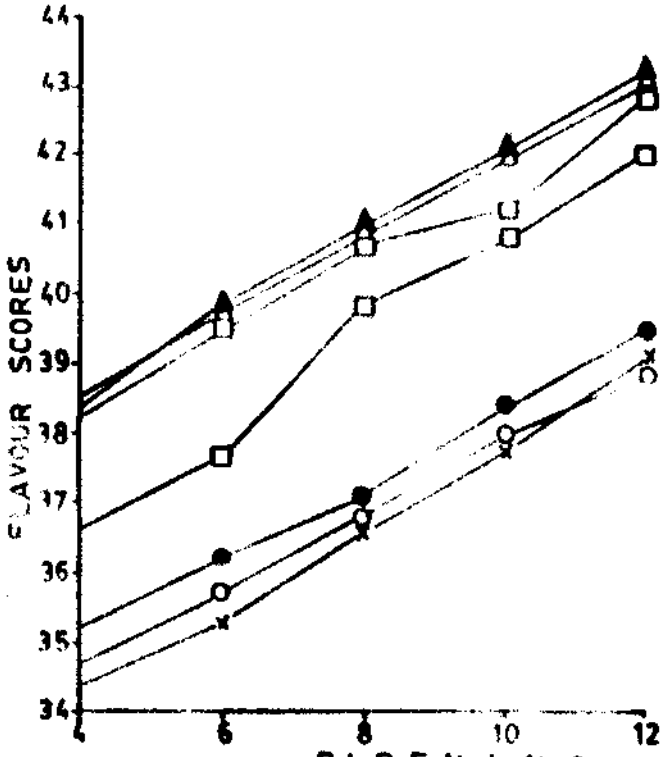
Data on organoleptic evaluation are appendixed at X and the average values are presented in Fig. 14.

The average flavour scores (Fig.14A) indicated a continual increase in these values from 4 months age to the end of curing period for all the cheeses prepared from mixture of buffalo and goat milks. The flavour scores indicated a proportionate increase with the increased amount of goat milk in the milk system. Cheeses containing more than 50 per cent goat milk were very much similar to the pure goat milk cheeses in the flavour characteristics. Mixed milk cheeses scored higher than the pure buffalo milk cheeses at all ages. The data indicated that even a small proportion (10 per cent) of goat milk improved

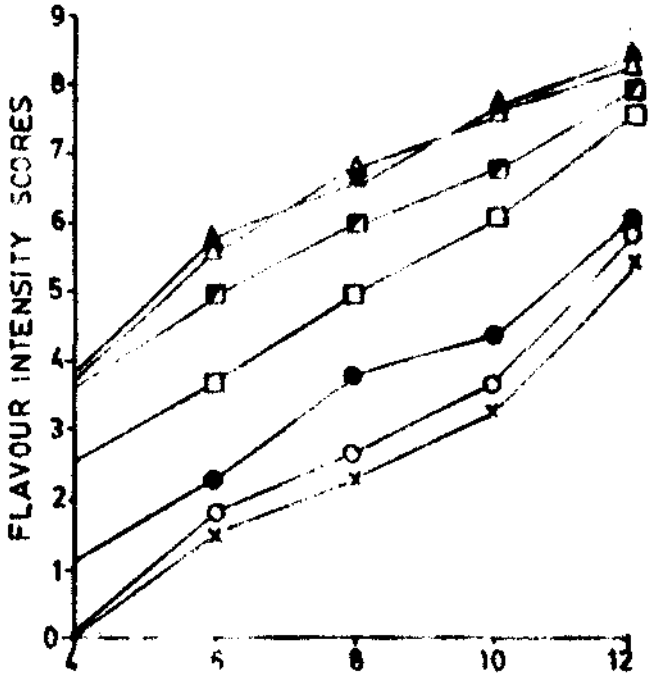
the flavour characteristics of the cheeses. The improvement in this attribute progressed somewhat with the increased amount of goat milk in the buffalo milk system.

The flavour intensity scores of the mixed milk cheese followed a similar pattern to that of flavour scores during ripening (Fig.14B). The cheeses containing 10 per cent goat and 90 per cent buffalo milk were very similar to pure buffalo milk cheeses. The other mixed milk cheeses scored more than the pure buffalo milk cheeses for the flavour intensity depending upon the extent of goat milk in the system.

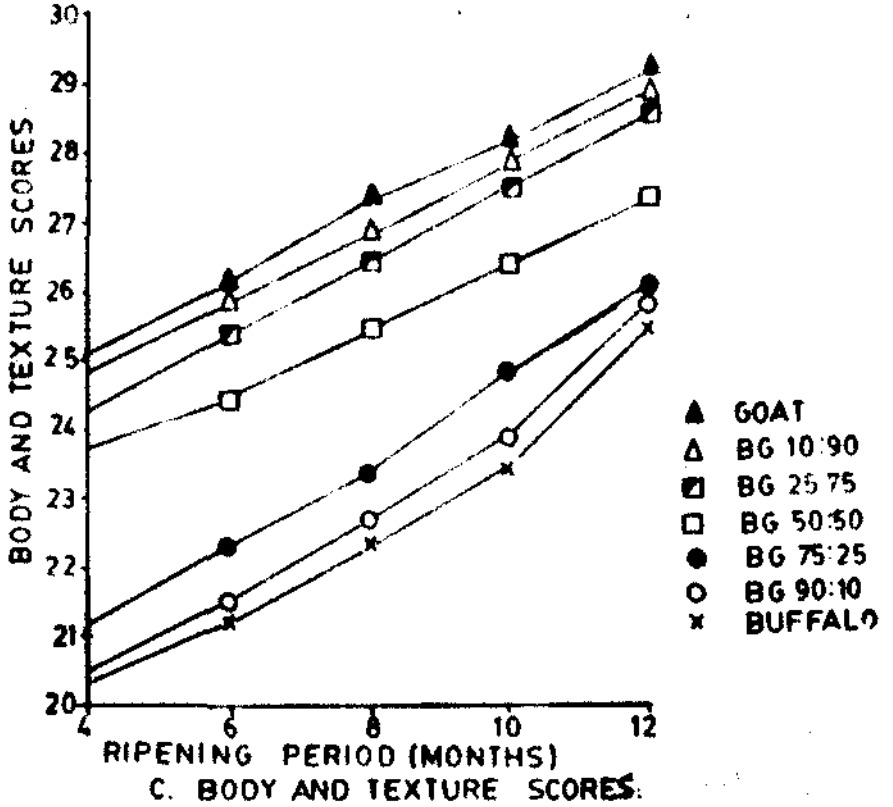
Consistent increase in the body and texture scores (Fig.14C) was noticed for all cheeses throughout the ripening period. The cheeses with higher proportion of buffalo milk scored the least and were criticised for hard and tough body and texture. Appreciable improvement in the body and texture was noticed when the proportion of goat milk in the mixture was 50 per cent or more. These proportions yielded the cheeses with smooth, waxy and mellow body and texture. The appearance of fat droplets on the surface of the cheese as observed in pure goat milk cheese was not noticed in these samples except the ones with 90 per cent proportion of goat milk.



A. FLAVOUR SCORES.



B. FLAVOUR INTENSITY.



C. BODY AND TEXTURE SCORES.

FIG. 14 CHANGES IN FLAVOUR, FLAVOUR INTENSITY AND BODY AND TEXTURE OF CHEESE DURING RIPENING

The colour scores (Appendix Xd) for all the mixed milk cheeses were identical and remained constant throughout the ripening period. These cheeses scored slightly more than that by pure buffalo cheeses. This ofcourse, could be due to the fact that colour was added in the mixed milk systems.

5.4.1.2 Changes in pH, moisture and salt content

The observations recorded for pH, moisture and salt and the microbiological analysis in terms of total viable counts and lactic counts are presented in Appendix XI, XII, XIII and XIV. The average values obtained for these parametes are plotted in Fig.15.

The zero day pH values (Fig.15A) for all the mixed (buffalo-goat) milk cheeses were within the range of 4.93 to 5.2. The cheeses with 90:10 and 75:25 mixture of goat and buffalo milk had the highest pH values of 5.2 which was similar to that observed for pure buffalo milk. The 50:50 milk mixture cheeses had the average pH value of 4.93. Gradual increase in the pH values was observed upto the 10th month of ripening for all the cheeses. The increase was upto the level of 5.70 to 5.78 pH. After this sudden decrease in the pH at 12 months age was

observed for all the mixed milk cheeses except the one containing 90:10 mixture of goat and buffalo milk. The pH increase was slightly less than that observed for pure buffalo milk cheeses but the drop followed more or less the similar pattern indicated by the pure buffalo milk cheese.

The initial moisture content of the cheeses (Fig.15B) was higher in comparison to buffalo milk cheeses. However, the cheeses with higher proportion of goat milk in the mixture had slightly low moisture content than the other cheeses. This might be associated with the difference in the manufacturing procedure for these systems and also the increasing proportion of buffalo milk in the mixture. A gradual decrease in the moisture content of all the cheeses was observed during the subsequent period of ripening. At 12 months age, the cheeses lost about 6-7 per cent moisture. This was quite similar to their counterparts made either from pure buffalo or pure goat milk.

The S/M values (Fig.15C) for the mixed goat and buffalo milk cheeses were within the range of 3.31 to 3.58 per cent at zero day. These values did not follow any pattern in relation to the proportion of two milks in the mixture. However, the values were much lower than those observed for pure buffalo milk

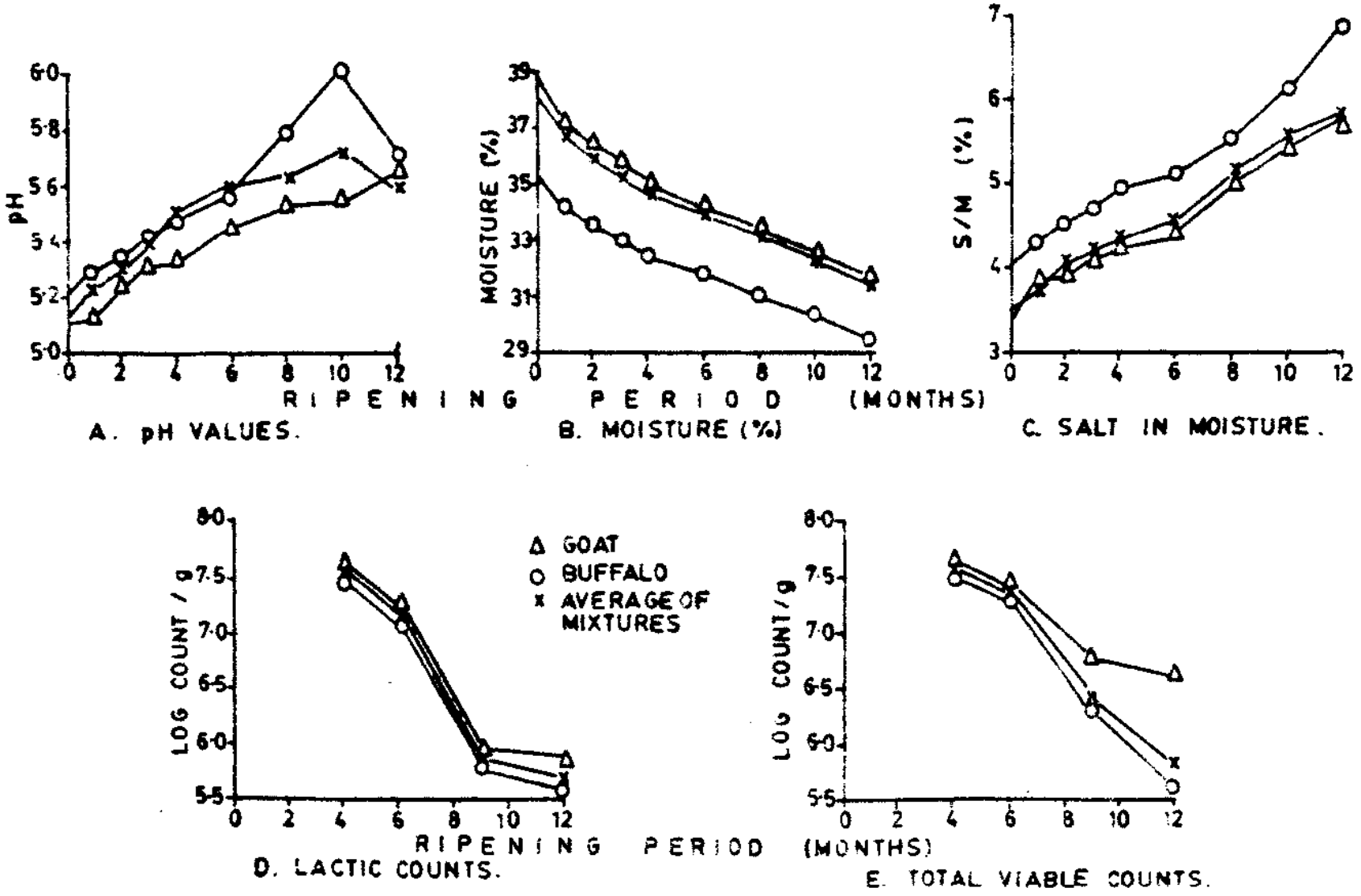


FIG. 15 CHANGES IN pH, MOISTURE, S/M AND LACTIC AND TOTAL COUNTS OF CHEESE DURING RIPENING.

cheeses which had the highest S/M values throughout the ripening period. This was related to the moisture loss trends. Slightly higher S/M values for cheeses with higher proportion of buffalo milk might be responsible for a slow development of flavour characteristics in these cheeses.

Total viable counts and lactic counts of the cheeses at 4, 6, 9 and 12 months age are plotted in Fig. 15D and E.

The initial total counts for the cheeses were more or less similar. The values were slightly less than those observed for pure goat milk cheeses. The presence of either more goat or more buffalo milk in the system had no pronounced effect on the total counts. The number decreased as the ripening period advanced and finally came down to about one hundreth of the initial level in all the cheeses. The cheeses did not vary much in the lactic counts at the 4 months age. The decrease in these counts during ripening was more or less similar for all the cheeses.

5.4.3.3 Proteolytic changes

The proteolytic breakdown in terms of SN, NPN, and AN and the proteolytic count at 4, 6, 9, and 12 months age were determined for all the mixed buffalo goat milk cheeses. The details of these values are

appendixed at XI, XVI, XVII and XVIII. The average values are presented in Fig.16 and 17.

It is clear from Fig.16A that the mixed milk cheese containing higher proportion of buffalo milk had the higher TN values(Appendix-XV). The cheeses with only 10 per cent buffalo milk had the TN values similar to those obtained for pure goat milk cheeses. These values for all the samples increased during ripening. This increase was associated with the decrease in the moisture content with the advancement of the curing period.

Protein breakdown was determined in terms of SN, NPN, and AN and expressed as per cent of TN. The initial RI (Fig.16B) values for the cheeses differed cosiderably. These were higher in comparison to the pure buffalo milk cheeses but slightly lower than the pure goat cheeses. Systems containing higher proportion of buffalo milk had lower RI values and vice-versa. The increase in the RI for all the cheeses during the ripening period was in a more or less linear fashion. However, the minimum increase was observed where the buffalo milk proportion was maximum. The 90:10 buffalo goat mixed milk cheeses at 12 months could attain the RI value of only 16.82 in comparison to 10:90 buffalo goat milk which attained the value of 34.64 at the

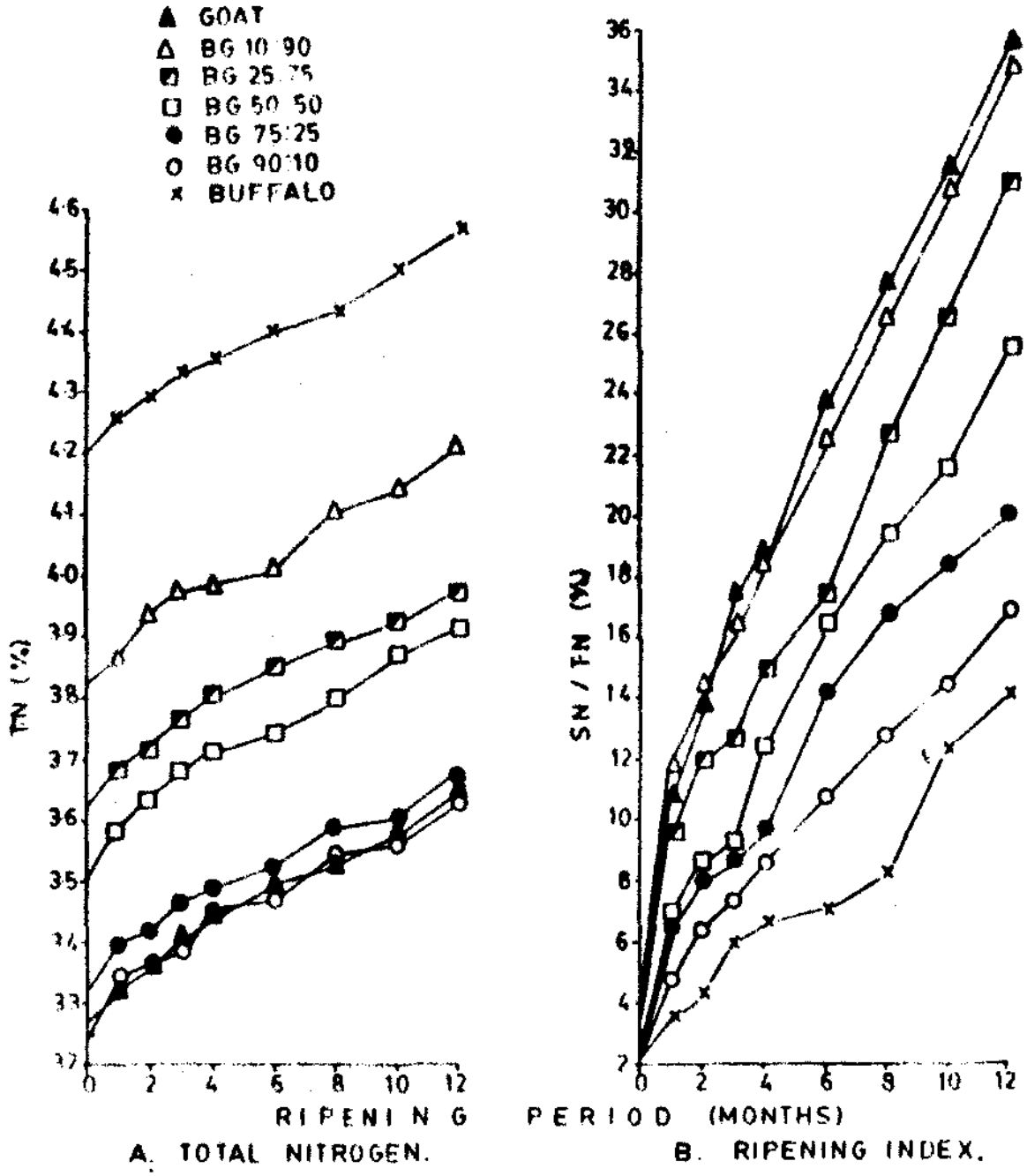


FIG 16 CHANGES IN TN AND RI (SN / TN) OF CHEESE DURING RIPENING.

same age. This slow rate of increase in the RI was also reflected by the slow development of body and texture characteristics of these cheeses.

The NPN and AN values (Fig.17) also indicated the similar pattern as observed in case of RI. The initial values did not indicate any pattern based on the higher proportion of either goat or buffalo milk but the later increase in these values were related to the proportion of goat milk in the mixture. The presence of even 10 per cent goat milk in the system gave higher values of NPN and AN in comparison to the values for pure buffalo milk.

The proteolytic counts (Fig.17C) of the cheeses varied slightly depending upon the milk system. The count for all the cheeses was slightly more than that was observed for pure buffalo milk cheeses. However, it was less than that recorded for the pure goat milk cheeses. The number decreased at 6 months age in all the samples. It remained more or less constant at 9 months age and then declined at 12 months age. The counts for 90:10 goat:buffalo milk cheeses were almost similar to that for the pure goat milk cheeses.

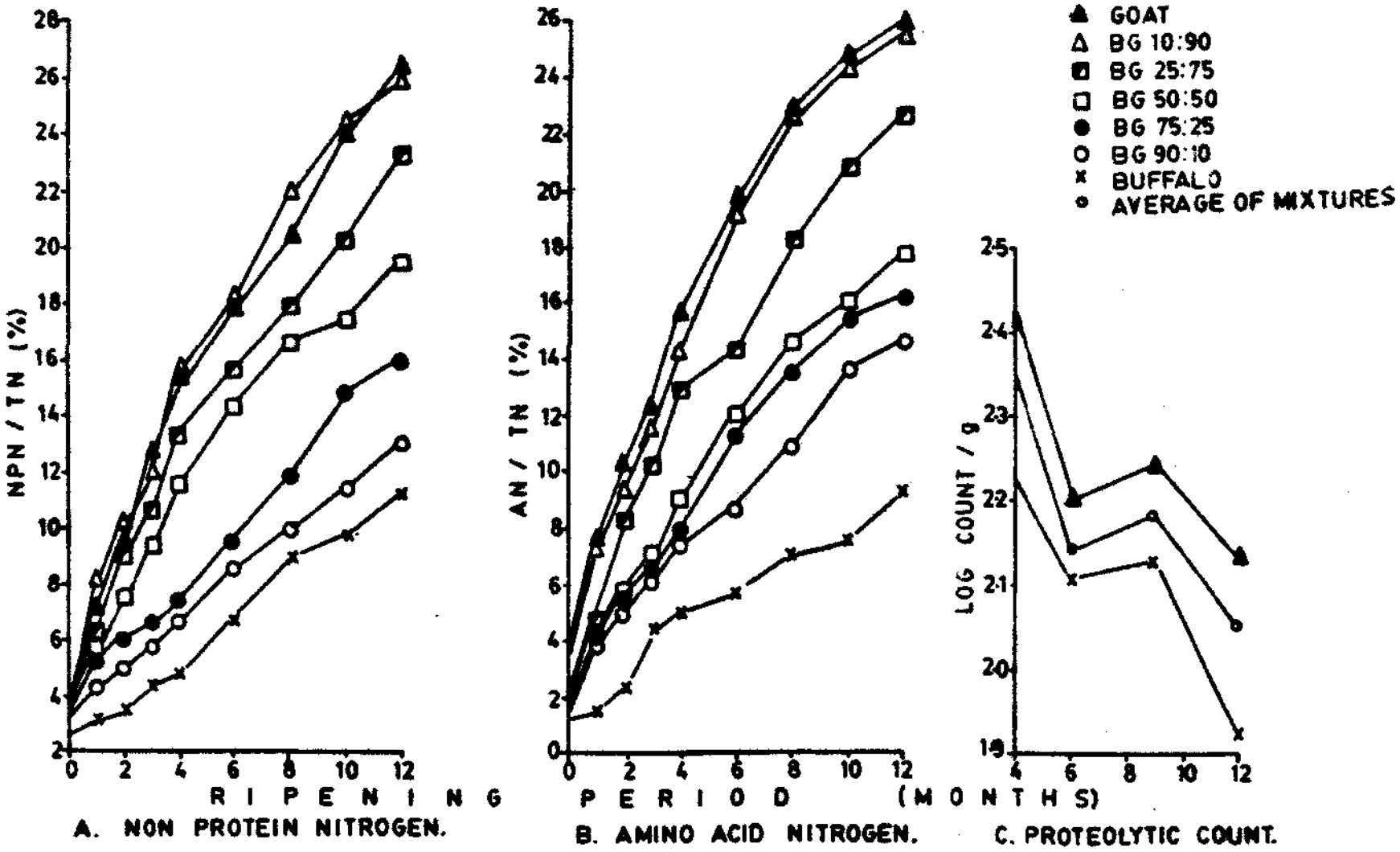


FIG. 17 CHANGES IN NPN, AN & PROTEOLYTIC COUNTS OF CHEESE DURING RIPENING.

5.4.3.4 Lipolytic changes

The data on the fat percentage, FDM, lipolytic counts and lipolytic changes determined in terms of TVFA and FFA are detailed in Appendix XI, XIX, XX, XXI and XXII. The average values for TVFA FFA and lipolytic count are depicted in Fig.18.

The initial fat percentage (Appendix-XIX) of the buffalo-goat mixed milk cheeses ranged between 29.50 per cent to 31.41 per cent. It showed an increasing trend with the increasing proportion of goat milk in the mixed milk system. The values were slightly higher than those observed for pure buffalo milk cheeses with only 29.49 per cent fat. These were somewhat lower in comparison to the pure goat milk cheeses which had an average fat per cent of 32.93.

The FDM values (Appendix-XX) for the mixed buffalo-goat milk cheeses were initially higher than those observed for the pure buffalo milk cheeses with an average value of 45.71. As the proportion of goat milk increased in the blend these values increased from 47.62 to 50.20 per cent in systems containing 10 to 90 per cent of goat milk. The values however, were less than those observed for pure goat milk cheeses with average FDM value of 53.52 per cent. The fat percentage of the mixed buffalo-goat milk cheeses

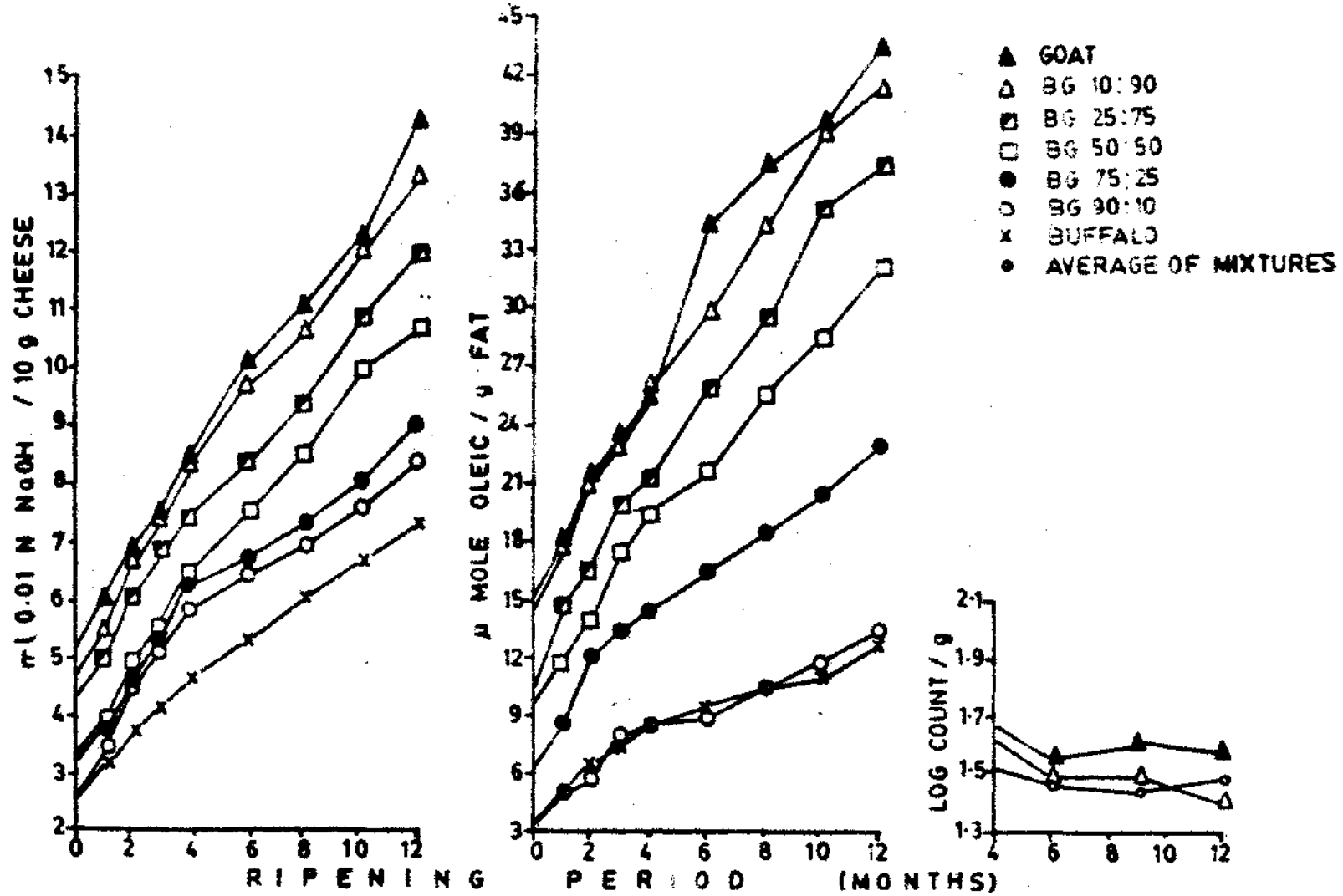


FIG. 18 CHANGES IN TVFA, FFA AND LIPOLYTIC COUNT OF CHEESE DURING RIPENING.

increased with the decrease in the moisture during ripening. As expected, the FDM remained more or less constant throughout ripening.

The lipolytic counts (Fig.18C) of the mixed buffalo-goat milk cheeses ranged between 300 to 400/g cheese. The counts were low in comparison to the pure goat milk cheeses with 450 organisms per gram cheese. These were equivalent to buffalo milk cheeses in case of the blend containing 10:90 proportion of buffalo goat milk. Other blends had even a slightly less lipolytic counts than the buffalo milk cheeses. A gradual decrease in the lipolytic counts was observed with the advancement of the curing period.

The TVFA and FFA values (Fig.18A and B) exhibited an increasing trend during the ripening period. The initial TVFA values at zero day for the mixed milk cheeses were higher than those observed for the pure buffalo milk. These values increased with the increased proportion of goat milk in the mixture. Similar pattern was exhibited by the FFA values. At the end of ripening, the difference in the TVFA values among the cheeses with lowest and highest proportion of goat milk in the mixture was upto the extent of one and a half times. The difference in these systems in terms of FFA values was three times. Although,

the lipolytic counts exhibited a pattern very similar to that of pure buffalo milk cheese, the TVFA and FFA values increased with increased proportion of goat milk in the system.

5.4.4 CURING CHARACTERISTICS OF MIXED MILK CHEESES

Cheddar cheese making studies with pure cow, buffalo and goat milk has revealed that in a sharp contrast to buffalo milk, cow and goat milk systems exhibited very similar curing behaviour and organoleptic properties. Even though the lipolytic count of goat milk cheeses was more similar to that observed for buffalo milk, these cheeses exhibited a very high lipolytic activity. The over all effect of mixing these two milks with the buffalo milk system has been to bring improvement in the curing characteristics and the product quality of the mixed milk cheeses. The extent of improvement increased as the proportion of cow or goat milk increased in buffalo milk containing system. As the proportion of either cow or goat milk increased in the system, it increasingly assumed the characteristics of pure cow or goat milk system. This is evident from the fact that during ripening the organoleptic and analytical values remained within the two extreme sets of results exhibited by the buffalo milk on one hand, and cow or goat milk on the other.

Effect of incorporating cow milk even to the extent of 10 per cent appeared to have a more dramatic effect in quicker curing of the mixed milk cheeses. Similar effect was also observed in the systems containing buffalo and goat milk mixtures. Basic benefit of mixing oow or goat milk with buffalo milk appeared to be the improvement of moisture retention power and correspondingly, lower levels of S/M. These in turn, promoted a more favourable environment for microorganisms to bring in curing. This has been reflected in the nature of proteolytic and lipolytic activity of the mixed milk cheeses. As these cheeses had higher proteolytic and lipolytic activities measured in terms of RI, NPN, AN and TVFA and FFA, respectigely.

5.5 PROCESSED CHEESE MAKING WITH PURE AND MIXED MILK SYSTEMS

In general, the cheddar cheese manufactured on large scale is converted into processed cheese. This aids to extend the keeping quality of the product and provides scope for utilizing cheese lots of different ages. The suitability of various cheeses made from pure milk systems and milk admixtures was, therefore, studied in limited laboratory trails.

Minced samples (about 1kg) of various cheeses were taken and to these emulsifier trisodium citrate

@ 2.5 per cent was added. Some water was also added to keep the final moisture level of the samples around 43 to 44 per cent. These were then melted at 75°C for 5 min. and then packed in pre-sterilized 240 g tins for storage at 5 ± 1°C.

The sensory evaluation of the samples was done by a panel of 5 expert judges. The data presented in Table-24 indicated that the pure cow and goat milk processed cheeses were ranked highest. The pure buffalo milk processed cheeses ranked lowest and were criticized for having mild flavour and tough body and texture qualitis. Processed cheeses made with mixed milk cheese either buffalo-cow or buffalo-goat milk mixtures were ranked according to the proportion of one milk into the other. The processed cheeses containing higher proportions of buffalo milk obtained scores similar to that of pure buffalo milk processed cheeses. The processed cheeses with increasing proportion of either cow or goat milk scored more and more with the increased proportion of either of the milk in buffalo milk. No difference was observed for the processed cheeses containing similar proportion of either cow or goat milk.

The results obtained with these limited trials on the manufacturing of processed cheeses indicated that the mixed milk cheeses can be

utilized for the purpose without any major difficulty. However, large scale trials with different blends would be necessary to confirm the results.

Table 24 : Organoleptic quality of processed cheese made from different milk systems.

(Average of 3 trials)

Type of cheese Buffalo milk content(%)	Attribute			Criticism
	Flavour	Body and texture	Colour	
	Buffalo-cow milk mixtures			
100	38.5	25.5	8	Mild flavour, tough body
90	38.5	25.5	9	Mild flavour, tough body
75	38.8	26.0	9	Slightly mild flavour
50	41.3	27.5	9	Normal
25	42.0	28.5	9	Normal
10	43.3	29.2	9	Normal
0	43.5	29.5	9	Normal
	Buffalo-goat milk mixtures			
90	38.7	25.6	9	Mild flavour
75	39.1	25.9	9	Normal
50	41.5	27.6	9	Normal
25	42.5	28.4	9	Normal
10	43.4	29.3	9	Normal
0	43.5	29.5	9	Normal

5.6 DISCUSSION

The major portion of the milk received by the organised sector of dairy industry in this country is of buffalo milk. However, many times small portions of cow or goat milks are also mixed with this. The technology of cheddar cheese preparation from cow milk has been well established since long (Davis,1965: Kosikowski,1966). Attempts have also been made to manufacture cheddar cheese from pure buffalo milk (Czulak, 1964; Godbersen, 1964; Burde and Srinivasan, 1967). This study attempted to observe the effect of using mixed milks (buffalo-cow and buffalo-goat) for cheddar cheese. This investigation further aimed to establish suitable technology of cheddar cheese manufacture with various milk mixtures.

Since no method was available for the manufacture of cheddar cheese from goat milk, development of technique for this milk had to be undertaken as the first step. One of the most encouraging outcome of this work has been the development of a manufacturing technique for cheddar cheese from pure goat milk. The cheeses prepared from goat milk by the technique developed were very much similar to those prepared from cow milk. These resembled

very closely cow milk cheddar in terms of the curing behaviour and organoleptic qualities.

Oneof the distinct characteristics of goat milk cheeses appeared to be related to its lipid systems. Due to the low melting point of goat milk fat, the appearance of oilyness on the cheese surface at room temperature may become a cause of concern. However, the presence of large number of small diameter fat globules (Jenness, 1980) appears to be very conducive to lipolytic changes essential for the development of typical flavour of cheddar cheese (Harper, 1959; Lawrence, 1967; Ohren and Tuckey, 1969).

Although it was apprehended that goat milk fat being higher in capric and caproic acids, might be associated with a "tangy" flavour defect. However, upto a 12 months curing period no such flavour defect was observed in goat milk cheeses.

In India approximately 3 per cent of the total milk production is obtained from goats. The large quantity of this milk is produced by the nomadic tribes. This milk either left unsold or fetches very less price. On the basis of this investigation it should now be possible to develop cheddar type cheese from goat milk on a commercial scale. This will be

particularly suitable under Indian conditions where, mild flavoured cheese varieties appear to be more popular.

Although there has been some work on cheese making using a mixture of cow and goat milks (Delforno, 1977), no attempts were made in this study to use such a mixed milk system for cheddar cheese making. On the basis of curing behaviour and organoleptic properties of cow and goat milk cheddar cheeses very little difficulty would be anticipated in preparing cheese from a mixture of cow and goat milks. However, this can only be confirmed on the basis of additional experimentation.

The manufacture of cheddar cheese involves the formation of a desirable coagulum, controlled expulsion of moisture from it, and curing under suitable conditions of temperatures and humidity. Coagulum formation and the moisture expulsion can be controlled by bringing some modifications in the manufacturing process. However, the curing depends largely upon the type of milk, coagulating enzyme, and the microflora existing in the cheese mass. The final quality of cheese depends upon the various chemical, physico-chemical, and biochemical changes which occur during ripening. The processes can also

be influenced by bringing some changes in the manufacturing procedures. This basic approach was used in this study to develop suitable techniques of cheddar cheese manufacture for the various milk mixtures containing various proportions of cow, buffalo, and goat milks.

Some other workers had used the 1:1 proportion of buffalo-cow mixed milk for cheddar cheese manufacture (Nejim, 1959; Nofal et al., 1977). However, these workers made cheddar cheese according to the cow milk procedure, using skim milk powder for increasing the T.S. level of the mixed milk. Our study revealed that the cheddar cheese manufacturing methods applicable to pure cow or buffalo milk systems can not be applied as such to the mixed milk systems. The investigation has demonstrated that the problem of manufacturing cheddar cheese from mixed milks can be handled in a relatively simple manner. The basic guide lines should be to use modified manufacturing technique (sec. 5.3.3.3) for mixed milk systems where buffalo milk is the major portion i.e. upto a level of 50 per cent or higher. The study has also indicated that the manufacturing methods applicable for pure cow (Kosikowski, 1966) and goat milk systems (sec. 5.3.2) appears to be

satisfactory for the remaining mixed milk systems where the proportion of buffalo milk is less than 25 per cent.

The blending of buffalo-cow, buffalo-goat milks indicated that although adjusted at a particular C/F ratio (0.70 or 0.65) the blends contained different levels of fat and casein. The resultant FDM in the cheese also did not remain the same. Even-though, the blends with higher proportion of buffalo milk had the higher initial values of fat, these contained low FDM in the final product. This indicated higher fat losses in blends with more proportion of buffalo milk.

Czulak (1964) method of cheddar cheese manufacture was chosen as standard for buffalo milk on the basis of the published work. However, the product obtained was not of satisfactory quality. The modified method for mixtures showed considerable improvements in the analytical parameters, various reaction rates measuring ripening, and ultimately the quality of ripened cheese, It will, therefore, be worth to apply these modifications to pure buffalo milk system also. The problems such as lower moisture retention, higher pH values, higher S/M and slow ripening in buffalo milk cheeses could possibly be overcome by the modified procedure.

The buffalo milk cheeses and the products containing higher proportion of buffalo milk in the blends exhibited a typical pH increase during ripening. The pH in cheese systems increased upto the 10th month age and then a sudden drop was noticed. The reason for this was not explored during this study. The microbial activity was generally at the lowest levels in the buffalo milk systems. The growth of lipolytic organisms in goat milk cheeses was similar to that for buffalo milk cheeses. The starters generally proven useful for cow milk systems, have been used in all the different milks used in these studies. Some starter organisms may not act similarly in different milk systems. This could be one of the factors contributing to the low microbial activity. Performance of various starters requires to be tested for use with buffalo and goat milk systems and for their blends.

In the curd forming studies also the blends exhibited properties more similar to the system to which they were closer. As had been seen, the RCT of cow milk was highest and that of goat milk the lowest. Buffalo milk had the RCT slightly higher than the goat milk. As the proportion of one milk into the other (either cow or goat milk in buffalo) increased or decreased the RCT followed the increasing or decreasing pattern for a particular milk. Rennet clotting time could form the basis of determining type of milk.

CHAPTER 6.

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SUMMARY

SUMMARY

1. In India, major portion of the milk collected by the organised dairy sector is of buffalo milk. At times small quantities of cow and goat milks are also mixed with buffalo milk.

2. Experiences with cheddar cheese, a variety of hard cheese popular in India, made from cow and buffalo milk had indicated that manufacturing steps recommended for one milk system are not applicable to the other, because of the compositional differences between the milk systems. The technology for manufacturing cheddar cheese from mixed milk is not available. The studies were ,therefore, taken up to develop suitable manufacturing procedure for buffalo milk admixed with different proportions of cow or goat milks.

3. The studies were carried out in three phases. In the first phase curd forming properties of the cow, buffalo, and goat milks and buffalo milk: admixtures

with cow and goat milks were studied in terms of clotting time, curd strength and protein loss in whey. In the second phase, cheese making procedures for goat milk and buffalo milk admixtures with cow and goat milks were developed. The curing characteristics of cheeses from various milk systems were studied in the third phase. Limited trials on suitability of various cheeses for processed cheese making were also undertaken.

4. The raw cow milk had the highest clotting time (75 sec.) followed by buffalo milk (41 sec.) and goat milk (38 sec.). Pasteurization (63°C/30 min.) slightly increased the clotting time of all the milk systems. Addition of $CaCl_2$ (8.0g/100 L) to cow and goat milks decreased the clotting time to the level of 56 and 31 seconds, respectively. The raw buffalo milk exhibited the highest curd strength followed by raw cow and goat milks. While the heat treatment decreased the curd strength, addition of $CaCl_2$ increased it. Protein loss in whey was highest (1.08%) in buffalo milk systems followed by cow (0.64%) and goat milks (0.86%). Addition of $CaCl_2$ or pasteurization did not have appreciable effect on protein loss in whey.

5. Clotting time of buffalo and cow milk mixtures increased with increasing proportion of cow milk in the system. The reverse trends were observed for the buffalo and goat milk mixtures. Buffalo milk admixtures exhibited a decreasing curd strength with increasing proportion of cow and goat milks in the system. The protein loss in whey also decreased with increased proportion of cow and goat milks in the system.

6. The goat milk cheese made with standard procedure exhibited slow rate of acid development during processing, lower moisture retention and dry body and texture.

A modified procedure involving the ( ) (a) adjustement of the C/F ratio to 0.65 (b) elimination of $CaCl_2$ addition (c) starter addition @ 1.25 per cent, and (d) lowering the cooking temperature to 38°C resulted in good quality cheddar cheese from goat milk.

7. The cheeses made from buffalo-cow and buffalo goat milk admixtures by Kosikowski (1966) method (for buffalo cow milk mixtures) and by method developed for goat milk (for buffalo-goat milk mixtures) indicated suitability of these methods only when the buffalo milk admixture contained upto 25 per cent portion of cow or goat milk in the system. Applying these methods

to equal proportion mixture of buffalo-cow or buffalo-goat milks resulted in cheeses with poor flavour and body and texture characteristics.

8. For milk mixtures containing 50 per cent or more buffalo milk, Czulak (1964) method proved more satisfactory in comparison to the method of Kosikowski (1966) or the one developed for goat milk. However, overall quality of cheeses obtained from mixtures containing 50 per cent or more buffalo milk was somewhat inferior.

Pasteurization of milk mixtures at 65°C/30 min., addition of 1% salt in milk prior to renneting, addition of starter @2.5%, reducing the setting temperature to 28°C and shortening the cooking period to 50 min. yielded a better quality cheddar cheese from mixtures containing 50 per cent or more buffalo milk.

9. During curing upto 12 months at 10°C and 75 per cent RH, the goat milk cheeses resembled very closely the developments in cow milk systems with the exception of lipolytic counts which were lower. Goat milk cheeses had a mild , pleasant, and well accepted flavour and waxy, smooth and mellow body and texture characteristics. These had the chemical and

microbiological activities similar to the cow milk cheeses. In terms of all indicators of cheese ripening, buffalo milk exhibited slowest rate of changes during ripening. This was associated with a lower level of moisture, a high S/M value, and a generally low level microbiological activities.

10. The overall effect of mixing cow or goat milk with buffalo milk system was in terms of improvement in the curing characteristics and the product quality of mixed milk cheeses. The extent of improvement increased as the proportion of cow or goat milk increased in buffalo milk containing systems. The organoleptic and analytical values remained within the two extreme sets exhibited by the buffalo milk on one hand and cow or goat milk on the other. Incorporation of even 10 per cent of cow or goat milk with buffalo milk had a quicker curing effect on the mixed milk cheeses. Mixing cow or goat milk to buffalo milk improved the moisture retention power of the cheeses and decreased the S/M levels in mixed milk cheeses. These cheeses had higher proteolytic and lipolytic activities in comparison to pure buffalo milk cheeses.

11. Limited trial for processed cheese making indicated that mixed milk cheeses can be used for this purpose without any major difficulty.

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A P P E N D I X

APPENDIX-II

Effect of mixing cow and goat milk on the curd forming properties of buffalo milk systems*.

(Average of 3 trials)

Buffalo milk content (%)	Clotting time (min.)	Curd strength (g)	Protein loss in whey (%)
	Cow milk containing systems		
100	46.66 (46.00-47.00)	22.80 (22.14-23.57)	1.09 (1.06-1.12)
90	47.66 (47.00-48.00)	22.77 (22.17-23.20)	0.97 (0.91-1.08)
75	49.00 (48.00-50.00)	19.77 (19.08-20.11)	0.94 (0.90-1.02)
50	52.66 (52.00-55.00)	17.36 (17.02-18.05)	0.91 (0.89-0.94)
25	60.66 (59.00-62.00)	17.00 (16.00-18.00)	0.81 (0.80-0.82)
10	85.00 (84.00-86.00)	16.88 (16.80-16.96)	0.70 (0.69-0.71)
0	95.00 (94.00-96.00)	16.67 (15.99-17.02)	0.66 (0.65-0.67)
	Goat milk containing systems		
90	47.66 (47.00-48.00)	22.77 (22.17-23.20)	1.00 (0.94-1.08)
75	44.66 (44.00-45.00)	19.42 (19.08-20.11)	0.99 (0.94-1.08)
50	43.00 (42.00-44.00)	16.77 (15.99-17.02)	0.96 (0.94-0.97)
25	42.00 (41.00-43.00)	15.54 (15.50-15.58)	0.91 (0.90-0.92)
10	41.33 (41.00-42.00)	15.10 (15.00-15.20)	0.90 (0.89-0.91)
0	41.00 (40.00-42.00)	14.62 (13.93-14.96)	0.88 (0.87-0.89)

* All milk systems at 0.7 C/F ratio.

APPENDIX-II

Effect of mixing cow and goat milk on the curd forming properties of buffalo milk systems*.

(Average of 3 trials)

Buffalo milk content (%)	Clotting time (min.)	Curd strength (g)	Protein loss in whey (%)
	Cow milk containing systems		
100	46.66 (46.00-47.00)	22.80 (22.14-23.57)	1.09 (1.06-1.12)
90	47.66 (47.00-48.00)	22.77 (22.17-23.20)	0.97 (0.91-1.08)
75	49.00 (48.00-50.00)	19.77 (19.08-20.11)	0.94 (0.90-1.02)
50	52.66 (52.00-55.00)	17.36 (17.02-18.05)	0.91 (0.89-0.94)
25	60.66 (59.00-62.00)	17.00 (16.00-18.00)	0.81 (0.80-0.82)
10	85.00 (84.00-86.00)	16.88 (16.80-16.96)	0.70 (0.69-0.71)
0	95.00 (94.00-96.00)	16.67 (15.99-17.02)	0.66 (0.65-0.67)
	Goat milk containing systems		
90	47.66 (47.00-48.00)	22.77 (22.17-23.20)	1.00 (0.94-1.08)
75	44.66 (44.00-45.00)	19.42 (19.08-20.11)	0.99 (0.94-1.08)
50	43.00 (42.00-44.00)	16.77 (15.99-17.02)	0.96 (0.94-0.97)
25	42.00 (41.00-43.00)	15.54 (15.50-15.58)	0.91 (0.90-0.92)
10	41.33 (41.00-42.00)	15.10 (15.00-15.20)	0.90 (0.89-0.91)
0	41.00 (40.00-42.00)	14.62 (13.93-14.96)	0.88 (0.87-0.89)

* All milk systems at 0.7 C/F ratio.

APPENDIX-III

Cheddar cheese making trials with cow and goat milks.

Particulars	Milk systems		
	Cow[1]	Goat[1]	Goat[2]
Quantity of milk(kg)	110	110	115
C/F ratio	0.7	0.7	0.65
Pasteurization temp./ time(°C/min.)	63/30	63/30	63/30
Acidity of milk(%LA)	0.162	0.135	0.135
Setting temp.(°C)	30	30	30
Quantity of $CaCl_2$(g)	8.8	8.8	-
Starter addition(%)	1.0	1.0	1.25
Colour (ml)	-	-	55
Ripening time (min.)	45	70	45
Quantity of rennet(g)	2.75	2.75	2.875
Renneting acidity(%LA)	0.180	0.153	0.153
Setting time (min.)	30	30	30
Whey acidity at cutting(%LA)	0.108	0.090	0.10
Maximum cooking temp.(°C)	39	39	38
Total cooking time (min.)	60	60	60
Draining whey acidity(%LA)	0.126	0.108	0.126
Fat loss in whey(%)	0.30	0.20	0.20
Protein loss in whey(%)	0.66	0.88	0.87
TS in whey(%)	6.45	6.74	6.69
Cheddaring time(min.)	180	210	180
Milling acidity(%LA)	0.49	0.47	0.495
Quantity of green curd(kg)	13.10	12.60	12.40
Rate of salt addition (%)	3	3	3
Mellowing time(min.)	15	15	15
0 day yield/100kg milk(kg)	9.3	9.7	9.7
0 day yield on TS basis(kg)	5.71	5.86	5.95
Remarks	Normal	Slow acid development	Normal

1. Kosikowski (1966) method.
2. Experimental.

APPENDIX-IV

Cheese making trials with buffalo cow milk mixtures containing upto 50 per cent cow milk*.

Particulars	Proportion of cow milk in the mixture(%)			
	100	90	75	50
Quantity of milk(kg)	110	100	100	90
C/F ratio	0.7	0.7	0.7	0.7
Pasteurization temp./time (°C/min.)	63/30	63/30	63/30	63/30
Acidity of milk(%LA)	0.162	0.153	0.162	0.153
Setting temp.(°C)	30	30	30	30
Quantity of $CaCl_2$(g)	8.8	-	-	-
Starter addition(%)	1.0	1.0	1.0	1.0
Colour(ml)	-	23	28	35
Ripening time(min.)	45	45	45	70
Quantity of rennet(g)	2.75	2.50	2.50	2.25
Renneting acidity(%LA)	0.180	0.170	0.180	0.170
Setting time(min.)	30	30	30	30
Whey acidity at cutting(%LA)	0.108	0.108	0.117	0.117
Maximum cooking temp.(°C)	39	39	39	39
Total cooking time(min.)	60	60	60	60
Draining whey acidity(%LA)	0.126	0.126	0.135	0.135
Fat loss in whey(%)	0.25	0.25	0.25	0.30
Protein loss in whey(%)	0.67	0.82	0.92	0.89
TS in whey(%)	6.47	6.77	6.96	7.18
Cheddaring time(min)	180	180	180	210
Milling acidity(%LA)	0.490	0.500	0.495	0.470
Quantity of green curd(kg)	13.10	12.20	12.40	12.90
Rate of salt addition(%)	3	3	3	3
Mellowing time(min.)	15	15	15	15
0 day yield/100kg milk(kg)	9.3	10.4	10.8	10.8
0 day yield on TS basis(kg)	5.72	6.39	6.64	6.70
Remarks	Normal	Normal	Normal	Slow acid development, poor cheddaring.

* Kosikowski (1966) method.

APPENDIX-V

Cheese making trials with buffalo goat milk mixtures containing upto 50 per cent goat milk*.

Particulars	Proportion of goat milk in the mixture(%)			
	100	90	75	50
Quantity of milk(kg)	115	100	100	90
C/F ratio	0.65	0.65	0.67	0.67
Pasteurization temp./time (°C/min.)	63/30	63/30	63/30	63/30
Acidity of milk(%LA)	0.135	0.135	0.144	0.153
Setting temp.(°C)	30	30	30	30
Starter addition(%)	1.25	1.25	1.25	1.25
Colour(ml)	55	50	50	45
Ripening time(min.)	45	45	45	70
Quantity of rennet(g)	2.875	2,5	2.5	2.25
Renneting acidity(%LA)	0.153	0.153	0.162	0.170
Setting time(min.)	30	30	30	30
Whey acidity at cutting(%LA)	0.10	0.10	0.10	0.117
Maximum cooking temp.(°C)	38	38	38	38
Total cooking time(min.)	60	60	60	60
Draining whey acidity(%LA)	0.126	0.126	0.126	0.135
Fat loss in whey(%)	0.20	0.20	0.20	0.30
Protein loss in whey(%)	0.88	0.79	0.91	0.96
TS in whey(%)	6.70	6.58	6.81	7.24
Cheddaring time(min.)	180	180	180	210
Milling acidity(%LA)	0.495	0.495	0.495	0.470
Quantity of green curd(kg)	12.40	11.80	13.00	12.50
Rate of salt addition(%)	3	3	3	3
Mellowing time(min.)	15	15	15	15
0 day yield/100kg milk(kg)	9.7	9.6	11.0	11.6
0 day yield on TS basis(kg)	5.89	5.84	6.67	7.03
Remarks	Normal	Normal	Normal	Slow acid development, poor cheddaring.

* As per method developed in Sec. 5.3.2.

APPENDIX-VI

Cheese making trials with buffalo cow milk mixtures containing 50 per cent or more buffalo milk*.

Particulars	Proportion of cow milk in the mixture(%)			
	50	25	10	0
Quantity of milk(kg)	90	90	90	90
C/F ratio	0.7	0.7	0.7	0.7
Pasteurization temp./time (°C/min.)	63/30	63/30	63/30	63/30
Acidity of milk(%LA)	0.153	0.162	0.162	0.160
Setting temp.(°C)	30	30	30	30
Starter addition(%)	1.5	1.5	1.5	1.5
Colour(ml)	35	38	40	45
Quantity of rennet(g)	2.25	2.25	2.25	2.25
Renneting acidity(%LA)	0.153	0.162	0.162	0.160
Setting time(min.)	30	30	30	30
Whey acidity at cutting(%LA)	0.108	0.108	0.117	0.108
Maximum cooking temp.(°C)	37.8	37.8	37.8	37.8
Time interval between cutting and half whey draining(min.)	50	50	50	50
Quantity of salt(g)	900	900	900	900
Total cooking time(min.)	70	70	70	70
Draining whey acidity(%LA)	0.126	0.126	0.137	0.126
Fat loss in whey(%)	0.30	0.30	0.30	0.30
Protein loss in whey(%)	0.88	0.91	0.95	1.08
TS in whey (%)	7.54	7.77	8.20	8.44
Cheddaring time(min.)	220	220	230	240
Milling acidity(%LA)	0.47	0.47	0.47	0.47
Quantity of green curd(kg)	12.5	13.3	12.9	13.10
Rate of salt addition(%)	2	2	2	2
Mellowing time(min.)	15	15	15	15
0 day yield/100kg milk(kg)	10.9	11.8	12.0	12.5
0 day yield on TS basis(kg)	6.76	7.32	7.44	7.75
Remarks	Slow acid development and poor cheddaring in all the systems.			

* Czulak (1964) method.

APPENDIX-VII

cheese making trials with buffalo goat milk mixtures containing 50 per cent or more buffalo milk*.

Particulars	Proportion of goat milk in the mixture(%)			
	50	25	10	0
Quantity of milk(kg)	90	90	90	90
C/F ratio	0.7	0.7	0.7	0.7
Pasteurization temp./time (°C/min.)	63/30	63/30	63/30	63/30
Acidity of milk(%LA)	0.153	0.162	0.162	0.160
Setting temp.(°C)	30	30	30	30
Starter addition(%)	1.5	1.5	1.5	1.5
Colour(ml)	45	45	45	45
Quantity of rennet(g)	2.25	2.25	2.25	2.25
Renneting acidity(%LA)	0.153	0.162	0.162	0.160
Setting time(min.)	30	30	30	30
Whey acidity at cutting(%LA)	0.108	0.108	0.117	0.108
Maximum cooking temp.(°C)	37.8	37.8	37.8	37.8
Time interval between cutting and half whey draining(min.)	50	50	50	50
Quantity of salt(g)	900	900	900	900
Total cooking time(min.)	70	70	70	70
Draining whey acidity(%LA)	0.126	0.126	0.137	0.126
Fat loss in whey(%)	0.30	0.30	0.30	0.30
Protein loss in whey(%)	0.91	0.95	0.98	1.05
TS in whey (%)	7.20	7.69	8.12	8.35
Cheddaring time(min.)	220	220	230	240
Milling acidity(%LA)	0.47	0.47	0.47	0.47
Quantity of green curd(kg)	12.4	13.2	13.1	13.10
Rate of salt addition(%)	2	2	2	2
Mellowing time(min.)	15	15	15	15
0 day yield/100kg milk(kg)	10.7	11.6	12.2	12.5
0 day yield on TS basis(kg)	6.73	7.30	7.68	7.87
Remarks	Slow acid development and poor cheddaring in all the system.			

* Czulak (1964) method.

APPENDIX-VIII

Cheese making trails with buffalo-cow milk mixtures containing 50 per cent or more buffalo milk*.

Particulars	Proportion of cow milk in the mixture(%)		
	50	25	10
Quantity of milk(kg)	90	90	90
C/F ratio	0.7	0.7	0.7
Pasteurization temp./time (°C/min.)	65/30	65/30	65/30
Acidity of milk(%LA)	0.153	0.162	0.153
Setting temp.(°C)	28	28	28
Quantity of salt in milk(g)	900	900	900
Starter addition(%)	2.5	2.5	2.5
Colour(ml)	35	38	40
Quantity of rennet(g)	2.25	2.25	2.25
Renneting acidity(%LA)	0.153	0.162	0.153
Setting time(min.)	70	65	65
Whey acidity at cutting(%LA)	0.126	0.126	0.126
Maximum cooking temp.(°C)	37	37	37
Total cooking time(min.)	50	50	50
Draining whey acidity(%LA)	0.144	0.144	0.144
Fat loss in whey(%)	0.50	0.50	0.50
Protein loss in whey(%)	0.91	0.94	0.98
TS in whey(%)	8.21	8.53	8.69
Cheddaring time(min.)	180	180	180
Milling acidity(%LA)	0.50	0.50	0.50
Quantity of green curd(kg)	11.70	12.80	12.50
Rate of salt addition(%)	2	2	2
Mellowing time(min.)	15	15	15
0 day yield/100kg milk(kg)	10.93	11.48	11.96
0 day yield on TS basis(kg)	6.70	7.09	7.44
Remarks	Normal	Normal	Normal

* As per method developed in Sec. 5.3.3.3.

APPENDIX-IX

Cheese making trials with buffalo goat milk mixtures containing 50 per cent or more buffalo milk.*

Particulars	Proportion of goat milk in the mixture(%)		
	50	25	10
Quantity of milk(kg)	90	90	90
C/F ratio	0.67	0.68	0.69
Pasteurization temp./ time(°C/min.)	65/30	65/30	65/30
Acidity of milk(%LA)	0.162	0.170	0.170
Setting temp.(°C)	28	28	28
Quantity of salt in milk(g)	900	900	900
Starter addition(%)	2.5	2.5	2.5
Colour(ml)	45	45	45
Quantity of rennet(g)	2.25	2.25	2.25
Renneting acidity(%LA)	0.162	0.170	0.170
Setting time(min.)	60	60	65
Whey acidity at cutting(%LA)	0.126	0.126	0.126
Maximum cooking temp.(°C)	37	37	37
Total cooking time(min.)	50	50	50
Draining whey acidity(%LA)	0.144	0.144	0.144
Fat loss in whey(%)	0.50	0.50	0.50
Protein loss in whey(%)	0.96	0.97	0.96
TS in whey(%)	8.68	8.63	8.74
Cheddaring time(min.)	180	180	180
Milling acidity(%LA)	0.495	0.495	0.504
Quantity of green curd(kg)	13.20	12.60	12.80
Rate of salt addition(%)	2	2	2
Mellowing time(min.)	15	15	15
0 day yield/100kg milk(kg)	11.50	11.80	12.10
0 day yield on TS basis(kg)	7.05	7.29	7.53
Remarks	Normal	Normal	Normal

* As per method developed in Sec.5.3.3.3.

APPENDIX-X

Organoleptic evaluation of cheeses during ripening.

(a) Flavour(maximum score:45)

Milk system	Ripening period(months) 4	6	8	10	12
			Pure milk systems		
Cow	38.6 (38.5-38.8)	40.4 (40.3-40.6)	41.4 (41.2-41.8)	42.3 (42.1-42.5)	43.4 (43.2-43.6)
Buffalo	34.3 (34.1-34.6)	35.2 (35.2-35.4)	36.4 (36.4-36.5)	37.7 (37.7-37.8)	38.9 (38.8-39.1)
Goat	38.5 (38.5-38.6)	39.7 (39.7-39.8)	41.0 (41.0-41.0)	42.1 (41.9-42.2)	43.2 (43.2-43.3)
BM:CM			Mixed buffalo cow milk systems		
90:10	34.5 (34.4-34.6)	35.7 (35.6-35.8)	36.9 (36.9-36.9)	38.0 (38.0-38.1)	39.1 (39.0-39.2)
75:25	35.2 (35.2-35.3)	36.3 (36.2-36.4)	37.2 (37.1-37.3)	38.5 (38.5-38.6)	39.5 (39.5-39.6)
50:50	36.7 (36.7-36.8)	37.8 (37.8-37.9)	39.9 (39.9-40.0)	40.9 (40.8-41.0)	42.2 (42.2-42.4)
25:75	37.8 (37.6-37.9)	38.8 (38.7-39.0)	40.0 (40.0-40.1)	41.3 (41.3-41.5)	42.8 (42.8-42.9)
10:90	38.3 (38.2-38.4)	39.9 (39.9-39.9)	40.9 (40.7-41.0)	42.1 (42.0-42.1)	43.1 (43.0-43.1)
BM:GM			Mixed buffalo goat milk systems		
90:10	34.7 (34.7-34.7)	35.7 (35.7-35.7)	36.8 (36.7-36.8)	37.9 (37.9-38.0)	38.9 (38.9-38.9)
75:25	35.2 (35.2-35.2)	36.2 (36.1-36.2)	37.1 (37.0-37.2)	38.4 (38.3-38.4)	39.4 (39.4-39.5)
50:50	36.6 (36.5-36.7)	37.7 (37.5-37,8)	39.8 (39.8-39.9)	40.8 (40.7-40.8)	42.0 (41.9-42.0)
25:75	38.2 (38.2-38.2)	39.5 (39.5-39.5)	40.7 (40.7-40.7)	41.1 (41.1-41.2)	42.8 (42.7-42.9)
10:90	38.4 (38.3-38.4)	39.8 (39.8-39.9)	41.0 (41.0-41.0)	42.0 (41.9-42.0)	43.0 (43.0-43.1)

BM-buffalo milk; CM-cow milk; GM-goat milk.

APPENDIX-X

(b) Flavour intensity(maximum score:9)

Milk system	Ripening period(months) 4	6	8	10	12
			Pure milk systems		
Cow	3.86 (3.75-3.95)	5.84 (5.82-5.85)	6.79 (6.78-6.80)	7.67 (7.65-7.70)	8.57 (8.50-8.67)
Buffalo	0.00 (0.00-0.00)	1.47 (1.42-1.50)	2.22 (2.15-2.35)	3.26 (3.24-3.30)	5.41 (5.35-5.50)
Goat	3.86 (3.85-3.87)	5.71 (5.69-5.75)	6.66 (6.60-6.79)	7.64 (7.60-7.68)	8.40 (8.35-8.45)
BM:CM			Mixed buffalo cow milk systems		
90:10	0.00 (0.00-0.00)	1.79 (1.75-1.82)	2.63 (2.54-2.69)	3.51 (3.49-3.54)	5.81 (5.75-5.89)
75:25	1.05 (1.00-1.15)	2.24 (2.22-2.25)	3.77 (3.69-3.87)	4.30 (4.25-4.35)	5.93 (5.90-5.95)
50:50	2.54 (2.50-2.58)	3.68 (3.65-3.70)	4.92 (4.90-4.95)	5.97 (5.95-5.98)	7.53 (7.50-7.55)
25:75	3.50 (3.45-3.55)	4.93 (4.90-4.95)	5.94 (5.90-5.98)	6.61 (6.59-6.65)	7.90 (7.85-7.95)
10:90	3.78 (3.75-3.80)	5.71 (5.69-5.74)	6.67 (6.65-6.69)	7.53 (7.50-7.55)	8.19 (8.15-8.22)
BM:GM			Mixed buffalo goat milk systems		
90:10	0.00 (0.00-0.00)	1.79 (1.75-1.81)	2.63 (2.61-2.65)	3.59 (3.58-3.60)	5.82 (5.81-5.83)
75:25	1.12 (1.00-1.20)	2.28 (2.25-2.30)	3.79 (3.71-3.85)	4.37 (4.23-4.45)	5.98 (5.95-6.00)
50:50	2.57 (2.54-2.61)	3.69 (3.68-3.71)	4.94 (4.90-4.97)	6.03 (5.95-6.15)	7.57 (7.55-7.60)
25:75	3.62 (3.60-3.65)	4.95 (4.93-4.98)	5.94 (5.91-5.97)	6.75 (6.71-6.80)	7.93 (7.90-7.95)
10:90	3.81 (3.80-3.82)	5.65 (5.63-5.67)	6.71 (6.70-6.74)	7.52 (7.50-7.55)	8.12 (8.10-8.15)

BM-buffalo milk; CM-cow milk; GM-goat milk.

APPENDIX-X

(c) Body and texture(maximum score:30)

Milk system	Ripening period(months) 4	6	8	10	12
			Pure milk systems		
Cow	25.1 (25.1-25.2)	26.2 (26.1-26.2)	27.3 (27.3-27.3)	28.2 (28.2-28.2)	29.2 (29.0-29.3)
Buffalo	20.3 (20.2-20.4)	21.2 (21.2-21.2)	22.3 (22.3-22.3)	23.4 (23.4-23.4)	25.5 (25.4-25.5)
Goat	25.1 (25.0-25.1)	26.1 (26.1-26.2)	27.3 (27.3-27.3)	28.1 (28.1-28.2)	29.2 (29.0-29.3)
BM:CM			Mixed buffalo cow milk systems		
90:10	20.6 (20.6-20.7)	21.8 (21.7-21.9)	22.9 (22.8-22.9)	24.0 (23.9-24.0)	25.9 (25.9-26.0)
75:25	21.2 (21.2-21.3)	22.3 (22.3-22.4)	23.6 (23.6-23.6)	25.0 (24.9-25.0)	26.1 (26.1-26.1)
50:50	23.7 (23.7-23.8)	24.5 (24.4-24.5)	25.5 (25.5-25.6)	26.5 (26.4-26.5)	27.5 (27.5-27.5)
25:75	24.3 (24.2-24.4)	25.5 (25.4-25.5)	26.5 (26.5-26.6)	27.7 (27.6-27.7)	28.4 (28.4-28.5)
10:90	24.9 (24.8-24.9)	25.9 (25.8-25.9)	26.9 (26.9-27.0)	27.8 (27.7-27.8)	28.9 (28.8-29.1)
BM:GM			Mixed buffalo goat milk systems		
90:10	20.5 (20.5-20.6)	21.5 (21.5-21.5)	22.7 (22.6-22.7)	23.8 (23.7-24.0)	25.8 (25.7-25.9)
75:25	21.2 (21.2-21.2)	22.2 (22.2-22.3)	23.3 (23.1-23.5)	24.8 (24.7-24.9)	26.0 (26.0-26.1)
50:50	23.7 (23.7-23.8)	24.4 (24.4-24.5)	25.5 (25.5-25.5)	26.4 (26.4-26.4)	27.4 (27.4-27.4)
25:75	24.3 (24.3-24.3)	25.4 (25.3-25.4)	26.4 (26.4-26.4)	27.5 (27.5-27.5)	28.6 (28.5-28.6)
10:90	24.8 (24.8-24.8)	25.9 (25.8-25.9)	26.8 (26.8-26.9)	27.9 (27.8-27.9)	28.8 (28.8-28.8)

BM-buffalo milk; CM-cow milk; GM-goat milk.

APPENDIX-X

(d) Colour (maximum score:10)

Milk system	Ripening period(months)				
	4	6	8	10	12
		Pure milk systems			
Cow	9.00	9.00	9.00	9.00	9.00
Buffalo	8.50	8.50	8.50	8.50	8.50
Goat	9.00	9.00	9.00	9.00	9.00
BM:CM		Mixed buffalo cow milk systems			
90:10	9.00	9.00	9.00	9.00	9.00
75:25	9.00	9.00	9.00	9.00	9.00
50:50	9.00	9.00	9.00	9.00	9.00
25:75	9.00	9.00	9.00	9.00	9.00
10:90	9.00	9.00	9.00	9.00	9.00
BM:GM		Mixed buffalo goat milk systems			
90:10	9.00	9.00	9.00	9.00	9.00
75:25	9.00	9.00	9.00	9.00	9.00
50:50	9.00	9.00	9.00	9.00	9.00
25:75	9.00	9.00	9.00	9.00	9.00
10:90	9.00	9.00	9.00	9.00	9.00

BM-buffalo milk; CM-cow milk; GM-goat milk.

APPENDIX-XI

Microbial changes in cheddar cheese during ripening.

Ripening period (months)	Pure milk systems			BM:CM Mixtures					BM:GM Mixtures				
	CM	BM	GM	90:10	75:25	50:50	25:75	10:90	90:10	75:25	50:50	25:75	10:90
a.						TOTAL VIABLE COUNT(x 10^5)							
4	495	355	430	360	355	360	360	410	345	350	370	355	385
6	335	200	265	215	217	230	235	275	245	255	260	272	282
9	85.0	19.5	57.5	21.0	21.5	23.5	23.0	37.5	25.0	20.5	23.5	25.0	24.0
12	65.0	4.0	40.0	5.0	5.5	7.5	6.0	5.0	7.0	6.5	8.5	5.5	7.5
b.						LACTIC COUNT (x 10^5)							
4	400	300	360	300	310	320	355	350	300	320	320	320	365
6	170	130	155	135	135	140	147	160	120	125	132	137	145
9	7.5	5.5	7.5	5.5	5.5	5.5	7.5	7.5	6.5	7.0	7.5	7.5	7.5
12	6.0	3.5	6.0	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	5.0	5.5
c.						LIPOLYTIC COUNT(x 10^2)							
4	6.0	4.0	4.5	3.0	3.0	3.0	2.5	3.5	3.0	3.0	3.5	3.0	4.0
6	3.5	3.0	3.5	2.5	2.5	3.0	4.5	3.5	3.0	2.0	3.0	3.5	3.5
9	4.5	3.0	4.0	3.0	2.5	3.0	3.0	2.5	2.0	3.5	2.5	3.0	2.5
12	3.5	2.5	3.5	2.5	2.5	2.0	2.5	3.0	2.5	3.0	3.0	3.5	3.0
d.						PROTEOLYTIC COUNT(x 10^2)							
4	28.0	16.5	26.5	17.5	20.5	20.0	24.5	25.0	19.5	21.5	23.5	23.5	27.0
6	17.5	13.0	16.0	14.0	15.5	15.5	12.5	15.5	12.5	13.5	14.5	14.5	15.5
9	17.5	13.5	17.5	14.0	15.0	15.5	17.0	17.0	13.5	14.0	14.0	15.0	15.5
12	12.5	8.5	13.5	9.5	10.0	10.5	11.5	12.0	8.5	11.0	12.5	12.0	12.5

BM-buffalo milk; CM-cow milk; GM-goat milk.