Chapter I

Milk: Composition, Properties and Nutritional Role

Objective

The purpose of this chapter is to understand the milk, its constituents, physic-chemical properties, and nutritional aspects of milk.

Introduction

Milk is an important part of daily diet of vast population on the earth, due to its high nutritional value. It is secreted by the *mammalians* for the nourishment of their new born. According to Food Safety and Standards Authority of India (FSSAI), milk is defined as "a secretion derived from complete milking of healthy milch animals." It shall be free from colostrums. Milk of different classes and of different species/designations shall conform to the standards prescribed in the act (Table 1.1). Chemically speaking "milk is a substance in which fat is present in emulsion, casein (major milk protein) together with some minerals in colloidal suspension and lactose, mineral salts and whey proteins in watery solution".

Dairy animals are capable of producing milk for nourishment of their off-spring due to presence of mammary glands

Table 1.1. Standards for different types of milk as per FSSAI

Class of milk **	Minimum (%)	
	Milk fat	Milk Solid-Not-Fat (SNF)
Buffalo milk	5.0 to 6.0*	9.0
Cow milk	3.0 to 4.0*	8.5
Goat or sheep milk	3.0 to 3.5*	9.0
Mixed milk	4.5	8.5
Standardized milk	4.5	8.5
Recombined milk	3.0	8.5
Toned milk	3.0	8.5
Double toned milk	1.5	9.0
Skim milk	Not more than 0.5	8.7

* Varies in different states

** When milk is offered for sale without indication of the class, the standards prescribed for buffalo milk shall apply

Composition of Milk

Milk is nearly complete natural food on the earth. It contains water, fat, protein, lactose and minerals as major constituents. The proportions of these constituents vary with species of the animal. For example, Mare's milk contains only about 1.6% fat, while Reindeer's milk contain 22.5% fat. Apart from this, the composition also varies with several other factors, viz., the breed of animal, the feeding pattern, season, lactation period, age of animal, environment, etc. The average compositions of milk from different species are given in the table 1.2.

Total solids in a milk is the Sum of milk fat and solid-not-fat (TS= fat + SNF)

Milk also contains several minor constituents like salts (Ca, PO_4, Cl, Na Mg, K, S, and citrate) and trace elements that are very important from physiological and nutritional point

of view. Several enzymes, non-protein nitrogenous substances, vitamins and pigment are also found in milk.

Table 1.2. Average compositions (per cent) of milk from different species

Constituents	Cow	Buffalo	Human	Goat	Mare	Sheep
Water	87.20	82.76	87.43	86.5	89.1	79.4
Fat	3.70	7.38	3.75	4.5	1.6	8.6
Protein	3.50	3.60	1.63	3.5	2.7	6.7
Lactose	4.90	5.48	6.98	4.7	6.1	4.3
Ash	0.70	0.78	0.21	0.8	0.5	1.0
Total Solids	12.8	17.24	12.57	13.5	10.90	20.6

Constituents of Milk

The major component of milk is water while remainder consists of fat, protein and lactose. Milk also contains minerals, vitamins, specific blood proteins and enzymes in smaller quantities. The major and minor constituents of milk are briefly explained below;

Fat

Milk fat is composed of various lipid, that comprises 98% triglycerides as a major lipid and 2% other minor lipids like diglycerides, monoglycerides, cholesterol, phospholipids, free fatty acids, cerebrosis and gangliosides. Particularly the fatty acids of milk fat vary widely in their length (4 to 20 carbon atoms) and unsaturation (0 to 4 double bonds). Milk fat also has a relatively high content of short-chain saturated fatty acids such as butyric (C_4) and capric (C_{10}) acids. These fatty acids are important to the flavour of milk products and off-flavours that may develop in the milk.

Protein

There are two groups of milk proteins casein and whey or serum proteins. The former constitutes about 80% while latter 15 % of the total milk protein. Non-protein nitrogen constitutes about 5% of the total nitrogen of milk. Caseins can be fractionated in to four distinct proteins such as a_{s1}, $a_{s2,}$ b, and k- caseins. These caseins play important role in

cheese making. The principal whey protein fractions are β-lactoglobulin, bovine serum albumin (BSA), α-lactalbumin and immunoglobulins.

Lactose

Lactose is a disaccharides present in milk as major milk sugar. It is composed of glucose and galactose. It imparts sweet taste to the milk. Lactose also acts as carbon source for majority of the spoilage causing organisms growing in milk. In products like dahi, yoghurt, lassi, shrikhand etc., lactose is the major components get converted in to lactic acid by the action of lactic acid bacteria.

Salts/Minerals

Milk salts consists mainly of chlorides, phosphates, citrates, sulfates and biocarbonates of sodium, potassium, calcium, and magnesium. Some of the milk salts (chlorides, sulfates, and compounds of sodium and potassium) are soluble and are present in milk as ions dissolved in milk whey. Others salts such as calcium and phosphate are much less soluble and at the normal pH (6.6-6.7) of milk exist partly in dissolved and partly in insoluble (i.e. colloidal) form in close association with the casein micelles. A large number of mineral elements such as, zinc, iron, and manganese are present in normal milk in trace amounts.

Vitamins and Enzymes

Milk also contains many vitamins that are fat soluble (e.g. A, D, E and K), water soluble, vitamin B complex (e.g. e.g. thiamine or B_1, riboflavin or B_2, niacin, pathothenic acid, pyridoxine or B_6, biotin, B_{12}, folic acid etc.) and vitamin C. Absence of vitamins in the diet over prolonged period causes deficiency diseases. The enzymes which are found in milk include lipase, proteases, peroxidase, catalase, lactoperoxidase and acid phosphatase. Some of the minor constituents play important function.

Water

It constitutes the medium in which the other milk constituents are either dissolved or suspended. Most of it is free and only a very small portion is in the bound form, being firmly bound by milk proteins, phospholipids etc.

Natural Inhibitory Substances in Milk

Several types of inhibitory substances are secreted in milk primarily for preventing infection in mammary gland or conferring resistance to new born. However, the same substances can also help in preservation of milk for some time, in natural form. One of the natural antimicrobial systems LP-system has been investigated thoroughly for extending the shelf-life of raw milk. Both specific and non-specific types of substances are secreted in milk and are shown in table1.3.

Table 1.3. Natural inhibitory substances present in milk

Inhibitory Substances	Description	Role
Immunoglobulins (Ig)	Types of antibodies and component of immune system produced locally in the udder (IgA) or transferred to milk from circulation (IgG)	Neutralize toxins, suppress bacterial growth and assist in the process of phagocytosis
Leucocytes	One of the types of cell present in milk. Total cell count of milk from uninfected udder ranges from 1 to 5 lakhs/ml, of which 10% are polymorphonulcear leucocytes (PMN)	Indicates normal or abnormal milk. These cells inhibit invading bacteria by phagocytosis
Complement	Component of immune system. About nine components of complements are found to be present in human milk	Associated with bactericidal (killing effect on organisms) activity
Bifidus factor	Bifidus factor is a nitrogen containing oligosaccharide present in human milk	Supports the growth of Bifidobacteria in infants, which helps in maintenance of intestinal health
Lactoferrins	Lactoferrins are iron binding proteins, The concentrations of lactoferrin in human and bovine milk are 2-4 and 0.02-0.35 mg/ml, respectively	Inhibit the growth of bacteria by depriving them of iron
Lysozyme	Enzyme present in much higher concentration (30 mg/100 ml) in human milk than bovine milk (0.01 mg/100 ml)	Exhibit lytic action on cell wall component of gram positive bacteria
Lactoperoxidase/ thiocyanate / hydrogen peroxide system (LP-System)	Lactoperoxidase is an enzyme naturally secreted in milk in concentration of about 30µg /ml. Thiocyanate is the substrate for this enzyme to act and is present in varying concentrations of 1 to 10 ppm. Hydrogen peroxide acts as a catalyst.	When all the three components are available, the system gets activated and produces unstable substances which are bacteriostatic (Inhibit organisms growth).
Miscellaneous substances	The other inhibitory substances in milk include vitamin binding proteins (vitamin B12 and folate) and fatty acids	Vitamin binding proteins inhibit the growth of bacteria by depriving them of vitamin.

Colostrums

The first secretion collected from the udder at the beginning of lactation known as colostrums. Colostrum or 'fore milk' differs from that of normal milk with respect to its composition and physic-chemical properties. Unlike milk upon heating colostrum get coagulated and can be observed like rubbery curd. Almost all milk constituents except lactose are present in higher quantities in colostrums. Colostrum has about 17.5 % protein (5.08 % casein and 11.34 % albumin), 5.10 % fat, 2.19 % lactose, 1.1% ash and 26.20 % total solids. It has a strong odour, bitter taste, slight reddish yellow colour, higher concentration of fat and protein, particularly immunoglobulins and a low content of lactose. The successive milking leads to the composition rapidly approaches to that of normal milk, however, it does not become fully normal until about 15 days after calving.

Physico-Chemical Properties of Milk

Milk can be described as a delicately balanced biochemical fluid. It contains more water than any other constituents and therefore, the properties of milk are primarily those of an aqueous system. Water is the continuous phase in which other constituents are either dissolved or suspended. Lactose and a portion of the mineral salts are found in solution, proteins and the remainder of the mineral is colloidal suspension and fat as an emulsion.

Flavour

This is composed of smell (odour) and taste. The flavor of milk is blend of the sweet taste of lactose and salty taste of minerals. The phospholipids, fatty acids and fat of milk also contribute to the flavor.

Colour

The colour of milk ranges from yellowish creamy white (cow milk) to creamy white (buffalo milk). It is a blend of the individual effects produced by i) the colloidal casein particles and dispersed fat globules, both of which scatter light and ii) the carotene which imparts a yellowish tint. The skim milk has a bluish and whey has a greenish yellow colour.

Acidity and pH of Milk

Freshly drawn milk is amphoteric in nature. The acidity of milk is determined by titration method using alkali and phenolphthalein indicator (Fig.1.1). It is also called natural acidity and

is caused by the presence of casein, citrate, acid phosphate etc., in milk. Developed or real acidity of milk is due to the production of lactic acid as a result of bacterial action on lactose. The titratable acidity is usually expresses as a percent of lactic acid. The acidity of cow milk varies from 0.13 to 0.14% lactic acid and buffalo milk from 0.15 to 0.17 % lactic acid.

The pH of normal milk usually varies from 6.4 to 6.6 for cow milk and 6.7 to 6.8 for buffalo milk. Higher pH values for fresh milk indicate that the animal suffered from udder infection (mastitis) and lower values indicate bacterial action.

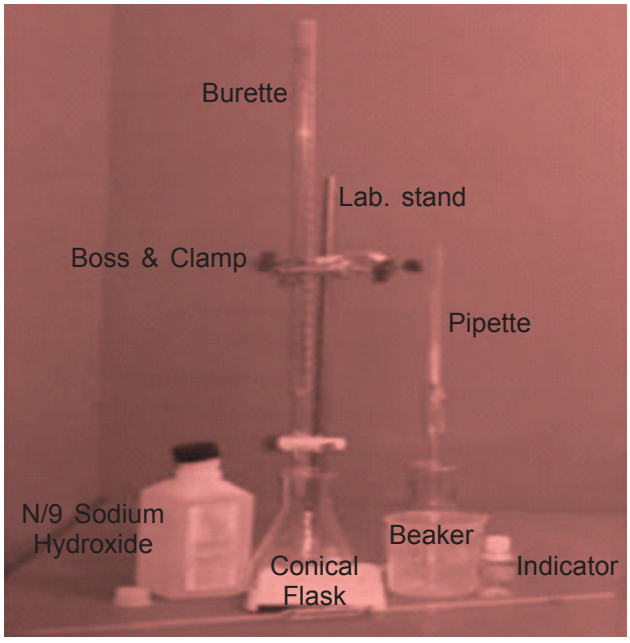

Fig.1.1. Titratable acidity apparatus

Viscosity

The viscosity of milk is mainly due to the milk proteins and fat present as colloidal system and to a minor extent due to lactose and salts in solution with water. It is measured by viscometer (Fig.1.2). Viscosity of milk is expressed in centipoises (cp). The relative viscosity of cow milk, buffalo milk, skim milk and whey is 2.0 cp, 1.80 cp, 1.50 cp and 1.20 cp respectively at 20°C and it decreases with an increase in temperature.

The absolute viscosity of water at 20°C is equal to 1.005 cp (centipoises). The viscosity of milk is influenced by state and concentration of protein, fat, temperature and age of the milk.

Fig.1.2. Viscometer for determination of viscosity of milk

Boiling Point

Any liquid boils at the temperature at which its vapour pressure is equal to that of the atmosphere. Since the vapour pressure of a solution is always less than the vapour pressure of the pure solvent, the boiling point of a solution will always be higher than that of the

pure solvent. Pure water boils at 100°C. Milk constituents are therefore, responsible for elevation of the boiling point of milk. Milk generally boils at 100.15°C.

Freezing Point

Milk freezes at temperature slightly lower than water due to the presence of soluble constituents such as lactose, soluble salts etc., which lower or depress the freezing point. The average freezing point depression of cow milk may be taken as 0.547°C and buffalo milk 0.549°C.

Density and Specific Gravity

Density of substance is its mass (weight) per unit volume, whereas specific gravity is the ratio of density of the substance to density of a standard substance (water). Since the density of a substance varies with temperature, it is necessary to specify the temperature when reporting densities or specific gravities. The specific gravity of milk is usually expressed at 15.6°C with help of lactometers (Fig.1.3). Three types of lactometers are generally used i.e.. Zeal, Quevenne and ISI lactometer. The average specific gravity ranges from 1.028 to 1.030 for cow milk, 1.030 to 1.032 for buffalo milk and 1.035 to 1.037 for skim milk. The specific gravity of milk is affected by its constituents, each of which has a different specific gravity (water-1.00, fat-0.93, protein-1.346, lactose-1.666, salts -4.12, Solid-not-fat 1.616). As milk fat is the lightest constituents, the more there is of it the lower the specific gravity will be, and vice versa.

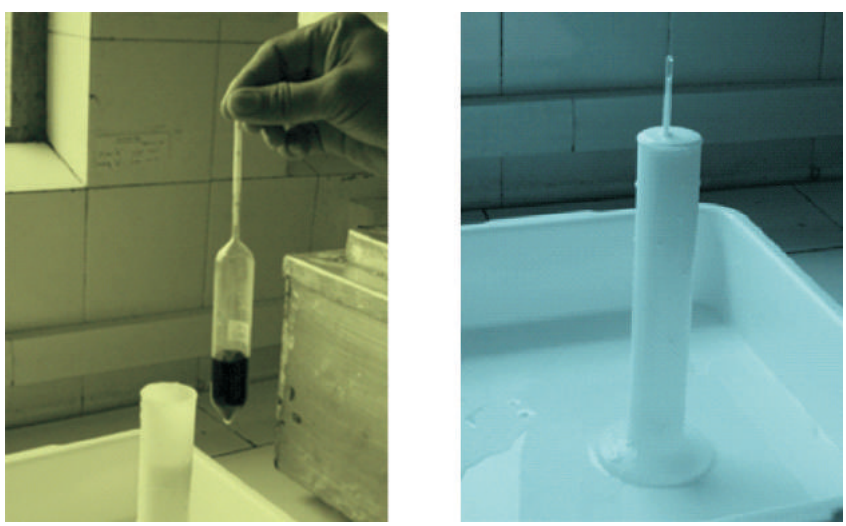

Fig.1.3. Determination of specific gravity of milk by ISI lactometer

Factors Affecting Composition and Physico-Chemical Properties of Milk

Milk differs widely in composition. All milks contain the same kind of constituents but in varying amounts. Milk from individual cows shows greater variation than mixed herd milk. The variation is always greater in small herds than in large ones. In general milk fat shows the greatest daily variation, then comes protein followed by ash and lactose. Factors affecting milk composition are summarized in a table 1.4.

Table 1.4 Factors affecting composition and physico-chemical properties of milk

Factors	Description
Species	Each species yields milk of a characteristic composition
Breed	Breeds producing largest quantity of milk yields lower percentage of fat
Individuality	Each animal tends to yield milk of a composition that is characteristics of the individual
Interval of milking	Longer milking interval is associated with more milk with a lower fat
Completeness of milking	Complete milking gives normal composition while incomplete gives lower
Frequency of milking	Frequency of milking whether two, three of four times a day does not affect composition in greater extent
Day-to-day milking	It may show variations for the individual animal
Disease and abnormal condition	Milk yield decreases and alters the milk composition
Stage of lactation	The first secretion after calving (Colostrum) is very different from milk in its composition and general properties
Feeding	It has temporary effect on milk composition
Season	The percentages of fat and SNF (solid-not-fat) show some variations during the course of the year
Age	The fat percentage in milk declines slightly as the cow grows older
Excitement	Yield and composition of milk are liable for transient fluctuation during periods of excitement
Administration of drugs and hormones	Certain drugs may bring temporary change in the fat percentage. Injection or feeding of hormones results in increase of both milk yield and fat percentage

Nutritional Value of Milk

Milk is nearly a complete food except that it is deficient in iron, iodine, copper and vitamin C. It has very high nutritive value and gives about 75 to 100 kilocalories per 100 g. Milk has sufficient quantity of major proteins like casein, ± α-*lactalbumin,* β-*lactoglobulin and bovine serum albumin.* They contain all essential amino acids and are useful in body building and other normal cell functions. The major milk sugar is lactose, whose primary function is supply energy, but it also helps to establish milk acidic reaction in the intestine which check growth of unwanted bacteria in the intestine and facilities assimilation of minerals

Milk fat has high energy value of 9.3 kilo calories/g. Besides, it contains significant amounts of essential fatty acids. Apart from this, fat contributes to the flavour and physical properties of milk which increase consumer preference for the milk.

Milk is an excellent source of essential minerals especially Ca and P which is very useful in bone formation. On an average milk contains, Ca-123, Mg-12, PO_4-95, Na-58, K-141, Cl-119, S-30, and citric acid-160 mg/100 ml. These minerals also play very important role in other physiological functions.

Vitamins are essential for normal healthy growth and reproduction of living organisms. Milk is a good source of Vitamin A, D, thiamine and riboflavin. However, it is deficient in Vitamin, C. Milk also contains a number of trace elements (those which are present in very small quantity, measured as few µg per litre), which may have important role in supporting nutritionally fastidious organisms.

REVIEW QUESTIONS

1. What is milk? What factors affect its composition?
2. Which naturally occurring inhibitory substances are present in milk?
3. How colostrum is different from normal milk?
4. What is the role of milk constituents?
5. Which minor components are deficient in milk?
6. Which apparatus is used to measure specific gravity of milk?