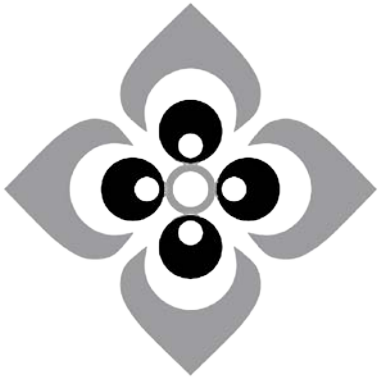

Consortium for Educational Communication

Module on

MILK COMPOSITION AND NUTRITIONAL SIGNIFICANCE

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1.0 Milk Composition

Definition

Milk may be defined as the whole fresh clean lacteal secretion obtained by the complete milking of one or more healthy milch animals, excluding that obtained within fifteen days before or five days after calving or such periods as may be necessary to render the milk practically collostrum free and containing the minimum prescribed percentages of milk fat and milk solids not fat.

Milk is the liquid food secreted by the mammary gland for the nourishment of the newly born, containing water, fat, protein lactose and minerals. Milk contains on average of 87 percent water, 3.9 percent fat, 4.9 percent lactose, 3.5 percent protein and 0.7 percent minerals, vitamins, and other minor constituents.

Milk of ruminants like cow, buffalo and goat is ideally suited for human consumption and meet the basic dietary requirement of human beings.

Milk may be defined as the lacteal secretion practically free from collostrum obtained by the complete milking of one or more healthy milch animals. According to PFA rules (1976) cow milk should contain not less than 8.5 percent milk solids not fat and not less than 3.5 percent of milk fat while buffalo milk should contain not less than 9 percent milk solids not fat and not less than 6 percent of milk fat.

The advent of parturition is concomitant and simultaneous with the biosynthesis and secretion of milk, a biological phenomenon triggered by lactogenic hormones. For the first few days after parturition mammary glands secrete a fluid known as collostrum which has a strong odour, a bitter taste, a slight reddish yellow colour and contains a high percentage of immunoglobins. It is rich source of all milk constituents except lactose, potassium and pantothenic acid. The Table 1.0 shows the gradual change from collostrum to normal milk. After about 5 days after parturition, the secretion of udder is considered as the normal milk.

Table1.0 Transition from collostrum to normal milk

Time after	Total protein (%)	Casein (%)	Albumin (%)	Fat (%)	Lactose (%)	Ash (%)	Total solids (%)
0	17.5	5.08	11.34	5.14	2.19	1.01	26.20
6	10.0	3.51	6.30	6.85	2.71	0.90	20.46
12	6.05	3.00	2.96	3.80	3.71	0.89	14.53
24	4.52	2.76	1.48	3.40	3.98	0.86	12.77
36	3.98	2.77	1.03	3.55	3.97	0.84	12.22
48	3.74	2.63	0.99	2.80	3.97	0.83	11.46
72	3.86	2.70	0.97	3.10	4.37	0.84	11.86
96	3.76	2.68	0.82	2.80	4.72	0.83	11.85
120	3.86	2.68	0.87	3.75	4.76	0.85	12.67
168	3.31	2.42	0.69	3.45	4.96	0.84	12.13

Milk Composition: The Key components in milk are:

1. **Water** - typically the major component

2. **Fat** - Complex mixture of lipids
   - Triglycerides are the major type
   - Major energy source of young
   - Extremely variable between species and within a species

- Specific desaturase in mammary gland that produces oleic acid (18:1), 25-30% of fatty acid by weight

- contains conjugated linoleic acid (CLA), a potent anti-carcinogen (18:2), *cis-9, trans*-ll) formed in biohydrogenation of linoleic acid (normally about 0.5% of total fatty acids in milk)

- main lipid class is triglycerides (97-98%)
- fatty acids made from acetate and butyrate (50%) and from performed (diet or body stores) fatty acids (50%)
- glycerol made from glucose
- fatty acids are mostly saturated
- rumen hydrogenation of unsaturated fatty acids

3. **Protein** - several types found in milk
   - Major milk proteins unique to milk
   - Milk proteins have ideal amino acid pattern for growth of young
   -Milk proteins made from amino acids
   - Milk proteins specifically produced in mammary gland and present in milk

- **caseins** (80% of total nitrogen)
- *major whey proteins:*
    - alpha-lactalbumin
    - beta-lacto globulins
- *minor whey proteins:*
    - serum albumin
    - immunoglobulins

4. Lactose -major carbohydrate in milk

- Disaccharide composed of glucose and galactose
- Unique to mammary gland
- Major Osmole of milk (the primary component that draws water into milk)
    - Disaccharide of glucose and galactose
    - formed by enzyme lactose synthase
    - Glactosyl transferase
    - Alpha-lactalbumin
- Major Osmoregulator of milk (drives water movement)

5. Minerals (Ash)

- Potassium, calcium, & phosphorous present in largest amounts
- secreted in complex with casein

6. Others

- Vitamins

Fat soluble: A, D, E & K

Water soluble: B &C.

- Milk cells - mostly leukocytes (white blood cells)

The percentage composition of Holstein cow's milk is water 87.8%, total solids 12.2%, fat 3.5%, solids not fat 9.0%, protein 3.2%, lactose 4.8%, ash 0.7%,Ca 0.13%, P 0.10%, K 0.14%, Cl 0.11%, Mg 0.01% and Na 0.05%. The percentage composition of some species is given in table 2.

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Species	Percentage by Weight					
	Water	Fat	Protein	Lactose	Ash	Energy (*kcal/100 g*)
Cow	87.8	3.5	3.1	4.6	0.7	66
Human	87.1	4.5	0.9	7.1	0.2	72
Buffalo	81.0	8.8	4.3	5.2	0.8	117
Sheep	82.0	7.2	4.6	4.8	0.9	102
Goat	85.2	5.6	3.7	4.7	0.8	72
Horse	88.8	1.9	2.5	6.2	0.5	52
Camel	87.61	5.98	2.98	3.26	0.70	84

Physico-chemical properties of milk constituents:

A. Major Milk constituents:

a) **Water:** Water 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.

b) **Milk fat (lipid):** The bulk of the fat in milk exists in the form of small globules, which average approximately 2 to 5 microns (range 0.1 to 22 microns). This is an oil-in-water type emulsion. The surface of these fat globules is coated with an adsorbed layer of material commonly known as the fat globule membrane. This membrane contains phospholipids and proteins in the form of a complex, and stabilizes the fat emulsion. In other words, the membrane prevents the fat globules from coalescing but keeps separated from one another. The emulsion may, however be broken by agitation (at low temperatures), heating, freezing, etc. When milk is held undisturbed, the fat globules tend to rise to the surface to form a cream layer. The thickest cream layer is secured from milks which have a higher fat content and relatively larger fat globules.

Chemically, milk fat is composed of a number of glyceride-esters of fatty acids; on hydrolysis, milk fat furnishes a mixture of fatty acids and glycerol. The fatty acids are saturated and unsaturated. Saturated fatty acids are relatively stable. The unsaturated fatty acids play important role in physico-chemical properties of milk fat.

c) **Milk Proteins:** The proteins of milk consist mainly of casein, β-lactoglobin, α-lactalbumin, etc. Casein exists only in milk and is found in the form of a calcium caseinate-phosphate complex. It is present in the colloidal state. It forms more than 80 percent of the total protein in milk. It may be precipitated by acid, rennet, alcohol, heat and concentration. Casein itself is composed of α, β, γ fractions. The heterogenous nature of α-casein can be observed by electrophoresis. α-casein is the component in casein micelle that is responsible for the stabilization of the micelle in milk. α-casein is composed of at least two subfractions, viz., αs_1-casein also called 'calcium sensitive casein' precipitable by calcium-ion under certain conditions and K- casein, also called calcium insensitive casein, not precipitable by calcium ion. β-lactoglobin and α-lactalbumin are also known as whey or serum proteins. They are also present in the colloidal state and are easily coagulable by heat.

d) **Milk sugar or lactose:** This exists only in milk. It is in true solution in milk serum. On crystalisation from water, it forms hard gritty crystals. It is one-sixth as sweet as sucrose. Chemically lactose is composed of one molecule of glucose and galactose. Lactose occurs in two forms, α and β, both of which occur either as the hydrate or the anhydride. It is fermented by bacteria to yield lactic acid and other organic acids and is important both in the production of cultured milk products and in the spoilage of milk and milk products by souring.

e) **Mineral matter or Ash:** The mineral matter or salts of milk although present in small quantities, exert considerable influence on the physico-chemical properties and nutritive value of milk. The major salt constituents include potassium, sodium, magnesium, calcium, phosphate, citrate, chloride, sulphate and bicarbonate; the trace elements include all other minerals and salt compounds. The mineral salts are determined after ashing. Although milk is acidic, ash is distinctly basic. Part of mineral salts occurs in true solution, while a part is in the colloidal state.

B. Minor Milk Constituents

a) **Phospholipids**: In milk there are three types of phospholipids viz. lecithin, cephalin and sphingomylin. Lecithin which forms an important constituent of the fat globule membrane contributes to the richness of flavour of milk and other dairy products. It is highly sensitive to oxidative changes, giving rise to oxidized/metallic flavours. Phospholipids are emulsifying agents and stabilize milk fat emulsion.

b) **Cholesterol:** This appears to be present in true solution in the fat, as part of the fat globule membrane complex and in complex formation with protein in the non-fat portion of milk.

c) **Pigments:** These are (i) fat soluble, such as carotene and xanthophylls and (ii) water soluble, such as riboflavin. Carotene is fat soluble and responsible for the yellow colour of milk, cream, butter, ghee and other fat rich dairy products. Carotene acts as an antioxi-

dant and as a pre-cursor of vitamin A. One molecule of β-carotene yields two molecules of vitamin A, α-carotene yields only one. The carotenoid content of buffalo milk varies from 0.25 to 0.48 µg/g, while that of cow milk may be as high as 30 µg/g, hence buffalo milk is more white in colour than cow milk.

Riboflavin is a greenish yellow pigment gives characteristics colour to whey.

d) **Enzymes.** The important milk enzymes and their specific actions are as follows: (i) Analase (diastase) - starch splitting (ii) Lipase-fat splitting, leading to rancid flavour (iii) phosphate-capable of splitting certain phosphoric acid esters (basis of phosphatase test for checking efficiency of pasteurization (iv) Protese-protein splitting (v) Peroxidase and Catalase-decomposes hydrogen peroxide.

e) **Vitamins:** Those found in milk are: Fat soluble vitamins A, D, E and K and water soluble vitamins of the B Complex group(thiamine or B_1, riboflavin or B_2, pantothenic acid, niacin, pyridoxine, or $B_{6,}$ biotin, $B_{12,}$ folic acid, etc.) and vitamin C (ascorbic acid)

2.0 Nutritional Significance of milk:

Nutrients in milk: Milk is one of the most nutritionally complete foods. It is naturally a good provider of a whole range of nutrients essential to growth, development and maintenance of the human body and contains no artificial preservatives or colourings. Relatively small quantities of milk can provide a significant proportion of daily nutrient requirements for all age groups making it nutrient rich relative to its energy content. In addition to its contribution to nutrient intake, increased milk consumption has also been linked to reducing the risk of numerous health problems such as osteoporosis, cancer, cardiovascular disease, type 2 diabetes and obesity to name but a few. Milk therefore makes a significant contribution to the human diet through provision of the macro-nutrients, vitamins and minerals.

Macro-nutrients in milk

Energy: Foods provide us with energy in the form of calories (Kcal). Calories effectively act as the fuel that powers our bodies and enables us to function. The calorie/energy content of milk varies depending on the fat content. For example, whole standardised milk (3.5% milk fat) provides 68kcals per 100ml; semi-skimmed milk (1.7% milk fat) provides 47kcals/100ml and skimmed milk (0.3% milk fat) provides 35kcals /100ml.Milk can be described as “nutrient dense” relative to its energy content as it is such a good source of many vitamins and minerals. Higher calorie milks are more suitable for those who have increased energy requirements e.g. children and adolescents, or those with poor appetites who need nutrient dense foods to provide as many calories as possible in small amounts e.g. the elderly. Lower calorie milks are suitable for the majority of the population and are especially useful when consumed as part of a calorie controlled diet for contributing to weight loss.

Protein: Protein is essential for growth and repair of tissues and for the production of hormones and enzymes which are essential to the correct functioning of the body. Milk is a source of “high biological value” protein - which means that it provides with all the essential amino acids that the body cannot make itself. Milk contains approximately 3.5% protein by weight which can be divided into two main groups: caseins and whey proteins. Approximately 80% of the protein in milk is casein based and 20% is whey based. Casein is the predominant protein in milk and can be divided into four major types: alpha, beta, gamma and kappa caseins. Whey protein comprises the rest of the milk protein and is composed predominantly of beta -lactoglobulin and alpha-lactalbumin. But other whey proteins include serum albumin, immunoglobulins (IgA, IgG, IgM), protease peptones, lactoferrin and transferrin.

Carbohydrate: Carbohydrates provide the energy required for most functions in the body. The form of carbohydrate found in milk is known as lactose and is the least damaging sugar with regards to tooth decay. For this reason, plain milk and water are the only 2 drinks recommended by dentists to be safe to consume between meals. There is approximately 9.7g of lactose in 1 glass/200ml of semi skimmed milk. Plain milks contain no added sugar, but flavoured milks may contain varying amounts of added sugar depending on the product. Flavoured milks are therefore not recommended for consumption between meals however they still contain all the same nutrients as plain milks and are a great alternative to fizzy and sugary soft drinks.

Fat: Fat is required for many functions in the body including storage and provision of energy, production of hormones, protection, warmth and provision of fat soluble vitamins amongst many others. The fat in milk contributes unique characteristics to the flavour, texture, appearance and satiability of dairy foods as well as providing a source of fat soluble vitamins, essential fatty acids and other health promoting compounds. The fat present in milk exists as small globules throughout the milk. The fat globules are less dense than water and rise to the top forming a cream layer. The process of “homogenisation” stops this occurring as the fat globules are broken up into smaller globules and therefore do not rise to the top. The fat content of milk varies depending on the product e.g. whole standardised milk has a minimum fat content of 3.5g/100ml or 3.5% fat, semi skimmed milk contains 1.7g/100ml or 1.7% fat, 1% fat milk contains 1g/100ml and skimmed milk contains 0.3g/100ml or 0.3% fat. Fats are made from a range of different fatty acids and the composition of the fatty acids in milk varies depending on the breed of cow from which it was produced, the feed given to the cow, the geographical location, the season and the stage of lactation. About one third of the fat in milk is monounsaturated - the same type of fat that olive oil contains. The remainder is mostly saturated, but some polyunsaturated fats and other minor fatty acids are also present. Saturated fatty acids are usually associated with increased risk of cardiovascular disease through their cholesterol raising effects; however studies have indicated that this does not apply to all saturated fatty acids in milk. In fact some of the saturated fatty acids in milk may reduce the cholesterol raising effects of other saturated fatty acids. Some are even associated with a direct cholesterol lowering effect which is linked with reducing the risk of cardiovascular disease. Studies have also identified other fats in milk

such as Conjugated Linoleic Acid (CLA) - a Trans fat - which may potentially protect against several major chronic illnesses.

Vitamins in milk:

Fat soluble vitamins

Vitamin A: Whole milk contains some vitamin A, however levels in semi skimmed and skimmed milks are much lower. This is because vitamin A is dissolved within the milk fat fraction which is removed to varying levels when producing lower fat milk products. Vitamin A is required for good vision, immune health and for normal growth and development of body tissues. Whole milk contains approximately 62µg of vitamin A per glass (200ml) which provides about 9% of an adult's daily vitamin A requirement.

Vitamin D: Vitamin D plays an important role in the absorption of calcium and phosphorus and is essential for healthy bones and teeth. There are two sources of vitamin D, it is made in the skin by exposure to sunlight and there are a few dietary sources, such as oily fish, eggs, and fortified foods including margarine (which is required by law to contain vitamin D), some yogurts and breakfast cereals. There is very little vitamin D in milk and in fact only in trace amounts.

Vitamin E : Vitamin E plays an important role in preventing damage to structures such as cell membranes. Substances which prevent damage in this way are called anti-oxidants and have been linked with reducing the risk of diseases such as cancer. Vitamin E is naturally found in low levels within milk, a 200ml serving of semi-skimmed milk typically provides 0.04mg of vitamin E.

Vitamin K: Vitamin K is essential for correct blood clotting. There is little or no vitamin K naturally found in milk although small amounts may be found in cheese.

Water soluble vitamins

B vitamins: Milk contains appreciable amounts of many of the B vitamins, and is particularly rich in vitamin B_{12}.

Vitamin B_{12}: It is required for maintenance of healthy nerves and red blood cells, energy production and normal cell division. It is predominantly found in foods of animal origin and therefore milk and dairy products are excellent sources.1 glass/200ml of semi skimmed milk will provide an adult (19-50 years) with the full daily requirement for vitamin B_{12}.Exclusion of milk and dairy products from the diet can therefore significantly reduce vitamin B_{12} intakes. This is of particular concern when all animal products are excluded from the diet - as with the vegan diet - which can lead to vitamin B_{12} deficiency if suitable alternatives or supplements are not taken. Thiamin (vitamin B_1) and riboflavin (vitamin B_2) are also present in milk.

Thiamin (vitamin B_1): It is necessary for carbohydrate metabolism, neurological and cardiac function.

Unlike fat soluble vitamins, water soluble vitamins are not stored well in the body other than in small amounts, and therefore must come from the diet.1 glass/200ml of semi skimmed milk will provide an adult (19-50 years) with 15% of their daily requirement for thiamin.

Riboflavin (vitamin B_2): It is necessary for the release of energy from foods and healthy membranes and skin, again riboflavin is a water-soluble vitamin and does not store in the body, and any excess amounts are excreted unchanged in the urine. A 200ml glass of semi-skimmed milk provides 45% of an adult's (19-50 years) daily requirement for riboflavin.

Niacin: It is involved in energy metabolism, the recommended amount for children and adults is 6.6mg/1000kcal and milk provides an individual with up to 3% of the daily requirement for niacin.

Folate: It is an important vitamin essential for cell division and correct development of tissues. A 200ml glass of semi-skimmed milk provides a 6 year old child with 18.6% of his or her daily folate requirement and an adult with 9.3%. It is important that women planning pregnancy consume 400 micrograms of folic acid every day before conception and during early pregnancy to prevent neural tube defects such as spina bifida.

Pyridoxine (Vitamin B_6): It is an essential vitamin involved in protein metabolism and is required for the formation of red blood cells and for maintaining a healthy immune and nervous system. This vitamin is only present in small amounts in milk.

Vitamin C: Vitamin C is required for the correct structure and maintenance of blood vessels, cartilage, muscle and bone. Unlike other animals, humans cannot make vitamin C within the body and it must therefore come from the diet. Good sources in the diet include many fruits and vegetables and milk also makes a contribution. A glass/200ml of semi-skimmed milk will provide a child with 14% of the daily requirement for vitamin C and an adult up to 10.3%.

Minerals in milk:

Calcium: Milk is a source of calcium, which is essential for the healthy growth and maintenance of teeth and bones and is a vital function in blood clotting and muscle contraction. A 200ml glass of semi-skimmed milk can provide a 6-year-old child with over half (55%) of his or her calcium requirement and can provide an adult (19-64years) with over a third (35%) of his or her daily calcium requirement.

Phosphorus: The main sources of phosphorus in the UK diet come from milk and milk products. It is the second most abundant mineral in the body and plays a vital role in calcium and protein metabolism. Phosphorus is also essential for healthy bones and teeth as well as

cell membrane structure, tissue growth and regulation of pH levels in the body. A glass/200ml of semi skimmed milk will provide a child of 6 years with 55% of their daily requirement for phosphorus and an adult (19-50 years) with 36%.

Iodine: Milk is a source of iodine in the UK diet. Iodine forms part of the hormones thyroxine and triiodothyronine. These hormones are produced in the thyroid, a gland in the neck and regulate the body's rate of metabolism (how quickly the body burns energy and the rate of growth).1 glass (200ml) of semi-skimmed milk will provide a child of 6 years with 96% of their daily requirement for iodine and an adult (19-50 years) with 44%. (These figures are for winter milk, which may contain slightly higher levels of iodine than summer milk.)

Magnesium: Magnesium is abundant in bone and in all cells in the body. Magnesium is essential for skeletal development, protein synthesis, muscle contraction and nerve function. 1 glass/ 200 ml of semi skimmed milk will provide a child of 6 years with 19% of their daily requirement for magnesium and an adult (19-50 years) with 7.5%.

Zinc: Zinc is a constituent of many enzymes in the body; its role is to fight infections, growth development, for sexual development, wound healing and for our sense of taste.1 glass/ 200 ml of semi skimmed milk will provide a child of 6 years with 12.3% of their daily requirement for zinc and an adult (19-50 years) with 11%.

Potassium: Potassium is mainly present in the fluid of the cells in the body and is important for fluid balance, muscle contraction, nerve conduction as well as for the correct functioning of the heart. 1 glass/ 200 ml of semi skimmed milk will provide a child of 6 years with 29% of their daily requirement for potassium and an adult (19-50 years) with 9%.

Other minerals: Sodium, selenium and iron are also found in milk in low levels.