Composition and Nutritive Value of Milk

Quadrant - I

Milk is nature's ideal food for infants and growing children. The importance of milk in our diet has been recognized since Vedic times, and all modern research has only supported and reinforced this view. In fact, milk is now considered not only desirable but essential from the time the child is born. The baby is recommended to be breast-fed until it is weaned and thereafter given cow/buffalo/goat milk till he or she reaches 12 years of age.

Milk is almost an ideal food. It has high nutritive value. It supplies body-building proteins, bone-forming minerals and health-giving vitamins and furnishes energy-giving lactose and milk fat. Besides supplying certain essential fatty acids, it contains the above nutrients in an easily digestible and assimilable form. All these properties make milk an important food for pregnant mothers, growing children, adolescents, adults, invalids, convalescents and patients alike.

Factors affecting milk composition:

Genetic

Breed and individual cow: Milk composition varies considerably among breeds of dairy cattle: Jersey and Guernsey breeds give milk of higher fat and protein content than Shorthorns and Friesians. Zebu cows can give milk containing up to 7% fat.

Variability among cows within a breed: The potential fat content of milk from an individual cow is determined genetically, as are protein and lactose levels. Thus, selective breeding can be used to upgrade milk quality. Heredity also determines the potential milk production of the animal. However, environment and various physiological factors greatly influence the amount and composition of milk that is actually produced. Herd recording of total milk yields and fat and SNF percentages will indicate the most productive cows, and replacement stock should be bred from these.

Environmental

Interval between milkings: The fat content of milk varies considerably between the morning and evening milking because there is usually a much shorter interval between the morning and evening milking than between the evening and morning milking. If cows were milked at 12-hour intervals the variation in fat content between milkings would be negligible, but this is not practicable on most farms. Normally, SNF content varies little even if the intervals between milking vary.

Stage of lactation: The fat, lactose and protein contents of milk vary according to stage of lactation. Solids-not-fat content is usually highest during the first 2 to 3 weeks, after which it decreases slightly. Fat content is high immediately after calving but soon begins to fall, and continues to do so for 10 to 12 weeks, after which it tends to rise again until the end of the lactation.

Age: As cows grow older the fat content of their milk decreases by about 0.02 percentage units per lactation. The fall in SNF content is much greater.

Feeding regime: Underfeeding reduces both the fat and the SNF content of milk produced, although SNF content is more sensitive to feeding level than fat content. Fat content and fat composition are influenced more by roughage (fibre) intake.

The SNF content can fall if the cow is fed a low-energy diet, but is not greatly influenced by protein deficiency, unless the deficiency is acute.

Disease: Both fat and SNF contents can be reduced by disease, particularly mastitis.

Completeness of milking: The first milk drawn from the udder is low in fat while the last milk (or strippings) is always quite high in fat. Thus it is essential to mix thoroughly all the milk removed, before taking a sample for analysis. The fat left in the udder at the end of a milking is usually picked up during subsequent milkings, so there is no net loss of fat.

Physical and chemical properties of milk

Milk is an emulsion or colloid of butterfat globules within a water-based fluid that contains dissolved carbohydrates and protein aggregates with minerals. Because it is produced as a food source for

the young, all of its contents provide benefits for its growth. The principal requirements are energy (lipids, lactose, and protein), biosynthesis of non-essential amino acids supplied by proteins (essential amino acids and amino groups), essential fatty acids, vitamins and inorganic elements, and water. Butterfat is a triglyceride (fat) formed from fatty acids such as mystiric, palmitic, andoliec acid.

Lipids: Initially milk fat is secreted in the form of a fat globule surrounded by a membrane. Each fat globule is composed almost entirely of triacylglycerols and is surrounded by a membrane consisting of complex lipids such as phospholipids, along with proteins. These act as emulsifiers which keep the individual globules from coalescing and protect the contents of these globules from various enzymes in the fluid portion of the milk. Although 97-98% of lipids are triacylglycrols, small amounts of di- and monoacylglycerols, free cholesterol and cholesterol esters, free fatty acids, and phospholipids are also present. Unlike protein and carbohydrates, fat composition in milk varies widely in the composition due to genetic, lactational, and nutritional factor difference between different species.

Like composition, fat globules vary in size from less than 0.2 to about 15 micrometers in diameter between different species. Diameter may also vary between animals within a species and at different times within a milking of a single animal. In unhomogenized cow's milk, the fat globules have an average diameter of two to four micrometers and with homogenization, average around 0.4 micrometers. The fat soluble vitamins A, D, E, and K along with essential fatty acids such as

linoleic and linolenic acid are found within the milk fat portion of the milk.

Proteins: Normal bovine milk contains 30–35 grams of protein per liter of which about 80% is arranged in casein micelles.

The largest structures in the fluid portion of the milk are 'casein micelles' aggregates of several thousand protein molecules with superficial resemblance to surfactant micelles, bonded with the help of nanometer-scale particles of calcium phosphate. Each casein micelle is roughly spherical and about a tenth of a micrometer across. There are four different types of casein proteins: αs1-, αs2-, β-, and κ-caseins. Collectively, they make up around 76–86% of the protein in milk, by weight. Most of the casein proteins are bound into the micelles. There are several competing theories regarding the precise structure of the micelles, but they share one important feature: the outermost layer consists of strands of one type of protein, k-casein, reaching out from the body of the micelle into the surrounding fluid. These kappa-casein molecules all have a negative electrical charge and therefore repel each other, keeping the micelles separated under normal conditions and in a stable colloidal suspension in the water-based surrounding fluid.

Milk contains dozens of other types of proteins beside the caseins including enzymes. These other proteins are more water-soluble than the caseins and do not form larger structures. Because the proteins remain suspended in the whey left behind when the caseins coagulate

into curds, they are collectively known as *whey proteins*. Whey proteins make up approximately 20% of the protein in milk, by weight. Lactoglobulin is the most common whey protein by a large margin while lactoalbumin is also present in meager amounts.

Carbohydrates: Milk contains several different Carbohydrates including lactose, glucose, galactose, and other oligosaccharides. The lactose gives milk its sweet taste and contributes approximately 40% of whole cow's milk's calories. Lactose is a disaccharide composite of two simple sugars, glucose and galactose. Bovine milk averages 4.8% anhydrous lactose, which amounts to about 50% of the total solids of skimmed milk. Levels of lactose are dependent upon the type of milk as other carbohydrates can be present at higher concentrations that lactose in milks.

Salts, minerals, and vitamins: Minerals or milk salts are traditional names for a variety of cations and anions within bovine milk. Calcium, phosphate, magnesium, sodium, potassium, citrate, and chlorine are all included as minerals and they typically occur at concentration of 5-40%. The milk salts strongly interact with casein, most notably calcium phosphate. It is present in excess and often, much greater excess of solubility of solid calcium phosphate In addition to calcium, milk is a good source of many other vitamins. Vitamins A, B6, B12, C, D, K, E, thiamine, niacin, biotin, riboflavin, folates, and pantothenic acid are all present in milk.

Nutritional Components in Milk

Energy

The energy in milk comes from its protein, carbohydrate and fat content, with the exception of skim milk that has virtually no fat. The calorie/energy content of milk varies depending on the fat content. For example, whole standardized 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.

Water

Milk is approximately 87% water, so it is a good source of water in the diet. The water content of milk varies from one type to another type of milk, animal and their species.

Carbohydrate

Milk is approximately 4.9% carbohydrate in the form of lactose. Lactose is a disaccharide made up of glucose and galactose bonded together. Before it can be used by the body, the bond must be broken by the enzyme lactase in the small intestine. People that have decreased activity of lactase in the small intestine may have problems digesting lactose and this is referred to as lactose intolerance or malabsorption. There is approximately 9.7g of lactose in 1 glass/200ml of semi skimmed milk.

Fat

Milk is approximately 3.4% fat. The fatty acids in milk fat are approximately 65% saturated, 29% monounsaturated, and 6% polyunsaturated. The polyunsaturated fatty acids in milk fat include small amounts of the essential fatty acids linoleic and linolenic, and approximately 5% *trans* fatty acids. An important *trans* fatty acid in milk fat is conjugated linoleic acid (CLA, 18:2). There are several types (isomers) of CLA in milk that have been shown to inhibit cancer and help maintain lean body mass while promoting the loss of body fat. Cholesterol is associated with fat so the content will vary depending on the fat content of the dairy product. One glass of 2% fat milk contains around 8% of the Daily Reference Intake (DRI) for cholesterol.

Protein

Milk is a source of "high biological value" protein - which means that it provides us 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. Whey proteins have

been proposed to have some benefits to athletes for muscle recovery and for preventing mental fatigue.

Fat soluble vitamins

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. 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 plays an important role in the absorption of calcium and phosphorus and is essential for healthy bones and teeth. There is very little vitamin D in milk and in fact only trace amounts so processed milk is fortified with vitamin D.

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 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

Milk contains appreciable amounts of many of the B vitamins, and is particularly rich in vitamin B_{12}. 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. 1 glass/200ml of semi skimmed milk will provide an adult (19-50 years) with 15% of their daily requirement for thiamin. Similarly 200ml glass of semi-skimmed milk provides 45% of an adult's (19-50 years) daily requirement for riboflavin.

Milk provides an individual with up to 3% of the daily requirement for niacin. 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%.

Pyridoxine (Vitamin B_6) 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 is required for the correct structure and maintenance of blood vessels, cartilage, muscle and bone. 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 and trace elements

Milk is a good 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 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%.
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 is abundant in bone and in all cells in the body. 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 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 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.

Minor Biological Proteins and Enzymes

Other minor proteins and enzymes in milk that are of nutritional interest include lactoferrin and lactoperoxidase. Lactoferrin is an iron binding protein that plays a role in iron absorption and immune response. The use of lactoferrin as an antimicrobial agent is also very important.

Lactoperoxidase is an enzyme that, in the presence of hydrogen peroxide and thiocyanate, has antibacterial properties. Lipase is a group of enzymes that break down fats, are present in milk but are inactivated by pasteurization, which increases the shelf life of milk. A

popular belief among raw milk consumers is that the native lipase in milk plays an important role in the digestion of fat. Lactase (ß-galactosidase) is the enzyme responsible for the breakdown of lactose into glucose and galactose for digestion.

Table 2. Nutrient content of milk varieties by 100 g reference amount. Compiled from the USDA Nutrient Data

		Cow						
Component	**Unit**	**Whole (3.25 % fat)**	**Reduced Fat (2% fat)[1]**	**Lowfat (1% fat)[1]**	**Skim[1]**	**Goat**	**Sheep**	**Water Buffalo**
Overall Composition (Amount per 100 g)								
Water	g	88.32	89.33	89.92	90.84	87.03	80.70	83.39
Energy	kcal	60	50	42	34	69	108	97
Carbohydrate (Lactose)	g	4.52	4.68	4.99	4.96	4.45	5.36	5.18
Fat	g	3.25	1.97	0.97	0.08	4.14	7.00	6.89
Protein	g	3.22	3.30	3.37	3.37	3.56	5.98	3.75
Minerals (Ash)	g	0.69	0.71	0.75	0.75	0.82	0.96	0.79
Vitamins								
Vitamin A	µg	28	55	58	61	57	44	53

Thiamin (Vitamin B1)	mg	0.044	0.039	0.02	0.045	0.048	0.065	0.052
Riboflavin (Vitamin B2)	mg	0.183	0.185	0.185	0.182	0.138	0.355	0.135
Niacin (Vitamin B3)	mg	0.107	0.092	0.093	0.094	0.277	0.417	0.091
Pantothenic Acid (Vitamin B5)	mg	0.362	0.356	0.361	0.357	0.310	0.407	0.192
Vitamin B6 (Pyridoxine)	mg	0.036	0.038	0.037	0.037	0.046	0.060	0.023
Vitamin B12 (Cobalamin)	µg	0.44	0.46	0.44	0.53	0.07	0.71	0.36
Vitamin C	mg	0.0	0.2	0.0	0.0	1.3	4.2	2.3
Vitamin D	IU	40	43	52	41	12	ND[3]	ND
Vitamin E	mg	0.06	0.03	0.01	0.01	0.07	ND	ND
Folate	µg	5	5	5	5	1	7	6
Vitamin K	µg	0.2	0.2	0.1	0.0	0.3	ND	ND
Minerals (Ash)								
Calcium	mg	113	117	119	125	134	193	169
Copper	mg	0.011	0.012	0.010	0.013	0.046	0.046	

Iron	mg	0.03	0.03	0.03	0.03	0.05	0.10	0.12
Magnesium	mg	10	11	11	11	14	18	31
Manganese	mg	0.003	0.003	0.003	0.003	0.018	0.018	0.018
Phosphorus	mg	91	94	95	101	111	158	117
Potassium	mg	143	150	150	156	204	137	178
Selenium	µg	3.7	2.5	3.3	3.1	1.4	1.7	ND
Sodium	mg	40	41	44	42	50	44	52
Zinc	mg	0.40	0.43	0.42	0.42	0.30	0.54	0.22

Composition of milk obtained from different mammals

SPECIES	**FAT %**	**PROTEIN %**	**LACTOSE %**	**ASH %**	**TOTAL SOLIDS %**
Buffalo,	10.4	5.9	4.3	0.8	21.5
Camel	4.9	3.7	5.1	0.7	14.4
Cow:					
Ayrshire	4.1	3.6	4.7	0.7	13.1
Brown	4.0	3.6	5.0	0.7	13.3
Swiss	5.0	3.8	4.9	0.7	14.4
Guernsey	3.5	3.1	4.9	0.7	12.2
Holstein	5.5	3.9	4.9	0.7	15.0
Jersey	4.9	3.9	5.1	0.8	14.7
Zebu					
Goat	3.5	3.1	4.6	0.79	12

Human	4.5	1.1	6.8	0.2	12.6

Table is adapted from course notes by Robert D. Bremel, University of Wisconsin and from Handbook of Milk Composition, by R. G. Jensen, Academic Press, 1995.