Unit I - Topic 2

Physico chemical properties, Macro components - Micro components.

Introduction

Milk is a complex biological fluid consisting of seven main components: water, fat, protein, sugar (lactose), minerals, vitamins and enzymes. It is a white opaque fluid in which fat is present as an emulsion, protein and some mineral matters in colloidal suspension and lactose together with some minerals and soluble proteins in true solution. The opacity of milk is due to its content of suspended particles of fat, proteins and certain minerals. The colour varies from white to yellow depending on the carotene content of the fat. Milk has a pleasant, slightly sweet taste, and pleasant odour. It is an excellent source of calcium, phosphates and riboflavin.

Physical Properties of Milk

Colour and optical properties

Milk appears turbid and opaque owing to light scattering by fat globules and casein micelles. Optical properties are influenced by the manner of scattering of light by the molecules. Light scattering occurs when the wavelength of light matches the magnitude of the particle. Thus, smaller particles scatter light of shorter wavelengths and vice versa. Skim milk appears slightly blue because casein micelles scatter the shorter wavelengths of visible light (blue) more than the red. Beta-carotene, the carotenoid precursor of vitamin A, is responsible for the creamy colour of cow milk. The greenish tinge in whey is due to the presence of riboflavin. Refractive index of milk is an optical property and ranges from 1.3440 to 1.3485 at 20ºC. The relation between solids content of milk and refractive index is linear, and the contributions of the several constituents is additive.

Flavour of milk

The natural sweet flavour of milk is due to the combined effect of its components. Off-flavours are very quickly developed in milk owing to several factors. The feed consumed by animals may lead to some undesirable flavours. Bacterial growth in milk causes fruity, barny, malty or acid flavours. Enzyme activities also may lead to unnatural flavours, rancidity due to lipase action being a classic example. Oxidative reactions may cause a cardboard flavour in milk. Processing of milk may produce cooked flavours.

Specific gravity and density

Milk is heavier than water. The specific gravity of cow milk varies from 1.018 to 1.036 and of buffalo milk from 1.018 to 1.038. Though specific gravity varies with temperature, (lower at higher temperature and vice versa), the rate of this variation is not uniform.

The density of milk varies within the range of 1.027 to 1.033 kg/cm3 at 20°C. The density of milk is used to estimate the solids content, to convert volume into mass and vice versa and to calculate other physical properties such as dynamic viscosity. It is dependant on temperature at the time of measurement, temperature history of the sample, composition of the sample (particularly fat content) and inclusion of air.

Viscosity

Viscosity of milk depends on the temperature and the amount and state of dispersion of the solid constituents, mainly casein and fat. Viscosity of the whole milk at 25°C is about 2.0 cP. Cooler temperatures increase viscosity due to the increased voluminosity of casein micelles whereas temperatures above 65°C increase viscosity due to the denaturation of whey proteins. An increase or decrease in pH of milk also causes an increase in casein micelle voluminosity. The effect of agitation on viscosity is not uniform. Sometimes, agitation causes partial coalescence of the fat globules, hence increasing the viscosity and at other times, agitation may disperse fat globules that have undergone cold agglutination, leading to a decrease in viscosity.

Surface tension

The surface activity of milk is related to proteins, fat, phospholipids and fresh fatty acids present in it. Homogenization and heat sterilization increase the surface tension of milk. Milk has a surface tension of 50 dyne/cm at 20°C.

Freezing and boiling points of milk

The freezing points of cow and buffalo milk vary from -0.512 to -0.572ºC and from -0.521 to -0.575ºC respectively. Freezing point of milk is mainly used to determine added water. The boiling point of milk is 100.17ºC.

Acidity and pH

Freshly drawn milk has a pH value in the range of 6.5 to 6.7 and contains 0.14 to 0.18% titratable acid calculated as lactic acid. There is no developed acidity in freshly drawn milk, the slightly lower than the neutral pH being attributed to the presence of carbon dioxide, citrate, casein etc.

Heat stability of milk

Heat stability is defined as the length of time required to induce coagulation at a given temperature or the temperature required to induce coagulation in a given time. The stability of milk system at the high processing temperatures to which milk is exposed for the manufacture of certain products is very important. Caseins and salt balance of milk governs its heat stability. Added citrates, phosphates and calcium have a great impact on the heat stability

MACRO-COMPONENTS OF MILK – FAT AND LACTOSE

Fat

Fat is the most commercially significant and most variable constituent of milk. Fat content varies from breed to breed and also among individuals of the same breed, the variation being caused by many factors. Most of the (> 95%) milk fat exists in the form of globules of 0.1-15 µ diameter (cow milk fat – ~ 3-8 µ, buffalo milk fat – ~ 4-10 µ). A thin membrane (8-10 nm thick) covers these liquid fat droplets. The properties of this membrane are vastly different from both milk fat and plasma. The fat globule membrane is rich in phospholipids and also contains lipoproteins and other glycerides. These phospholipids are involved in the oxidation of milk. The membrane decreases the lipid-serum interface to very low values, 1-2.5 mN/m, preventing the globules from immediate flocculation and coalescence, as well as protecting them from enzymatic action. Fat comprises of different glycerides of low melting point. The composition of fat varies with the feed plan, nutrition, stage of lactation, breed and species, the first being the most important.

The size and number of fat globules vary depending on the breed of the animal and method of milking. The globules become smaller and more numerous as lactation advances. Machine milking produces fat globules of more uniform size than hand milking. Homogenization reduces the fat globules to a small size and reduces the tendency of separation during storage. The larger the size of the globules, the quicker they rise as cream to the top of the milk and easier it is to churn such cream into butter. For this reason buffalo milk fat is more easily churned into butter than cow milk fat. The milk of animals in advance lactation is less suitable for being churned into butter. Milk containing small globules is, however, more suitable for cheese making, since less fat is lost in whey. Milk fat is quite bland in taste and imparts smoothness and palatability to fat-containing dairy products.

In milk fat, butyric, caproic, caprylic and capric acids, present in high proportions, are characterized by strong odours and flavour. These volatile acids are not present in such high proportion in other naturally occurring fats. The fatty acid content of milk fat can also be influenced by the amount and type of feeds consumed, stage of lactation and breed of the animal. Milk fat also contains cholesterol, thus differentiating it from vegetable fats, which contain phytosterols. Milk contains 0.1 to 0.23% phospholipids, viz. lecithin, phosphatidyl serine, sphingomyelin, inositol, cerebrosides etc. Some of these phospholipids serve as antioxidants in prolonging the shelf-life of ghee.

The colour of fat depends upon its carotene content and varies with the species, breed and feed of the animal. The yellow colour of cow milk is due to the carotene. Buffalo milk does not contain carotene. Ghee from cow fed on an abundant green fodder is more yellow than when fed on dry food. Similarly some breeds such as Jersey and Guernsey may produce milk deep yellow in colour.

Saturated fatty acids (no double bonds), such as myristic, palmitic and stearic constitute two thirds of milk fatty acids. Oleic acid is the most abundant unsaturated fatty acid in milk with one double bond.

Lactose

Lactose is the major milk sugar or carbohydrate. Fresh milk also contains other carbohydrates in small amounts, including glucose, galactose, and oligosaccharides. Lactose is present in true solution and, therefore, goes into whey when caseins are separated. Lactose constitutes 4.8 to 5.2% of milk, 52% of milk SNF, and 70% of whey solids. Lactose can be quickly fermented by micro-organisms to lactic acid and is, therefore, essential in the manufacture of cultured dairy products like cheese, dahi and butter-milk. It contributes to the nutritive value of milk and milk products, and is responsible for the texture and miscibility of some milk products. Lactose imparts colour and flavour to dairy products heated to high temperatures. Sucrose is six times sweeter than lactose.

Lactose is a disaccharide made up of two monosaccharides, glucose and galactose . Lactose is hydrolyzed by the enzyme µ-galactosidase (lactase), the results being the two monosaccharides, increased sweetness and depressed freezing point. People suffering from lactose intolerance lack this enzyme and therefore, cannot digest lactose. This sugar crystallizes in an alpha form and results in the defect called sandiness in ice cream.

MICRO COMPONENTS OF MILK

Vitamins

Vitamins are organic substances that are essential to normal life processes, but cannot be synthesized by the body. They occur in very small concentrations in both plants and animals. Milk is a good source of vitamins . Milk contains the fat soluble vitamins A, D, E, and K. As milk fat is an important dietary source of vitamin A, low fat products are normally supplemented with this vitamin. The content of Vitamin D, which also aids in the absorption of calcium, is influenced by the feed of the animals. Milk is a fair source of vitamin E. It is also a fairly good source of water soluble B vitamins such as thiamine (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxine (B_6) and cyanocobalamin (B_{12}). Milk is, however, a poor source of vitamin C (ascorbic acid). The little quantity of vitamin C that is present in raw milk is very heat-labile and easily destroyed by pasteurization.

Lactoferrin

Lactoferrin (LF) is a single-chain, metal-binding glycoprotein. It is a red coloured iron-binding protein and may also mediate some effects of inflammation and have a role in regulating various components of the immune system. It has antibacterial, antifungal, anti-endotoxin, and antiviral activities. It inhibits enteropathogenic organisms due to its ability to bind iron, as iron is an essential nutrient often required for bacterial growth. It promotes the growth of beneficial bacteria such as bifidobacteria. Lactoferrin is an anti-oxidant that naturally occurs in many body secretions such as tears, blood, breast milk, saliva and mucus. Lactoferrin in milk might play a role in iron absorption and/or excretion in newborns, as well as in promotion of intestinal cell growth. Its level in human milk is about 1 g/L and in human colostrums, about 7 g/L. As the levels of this protein in cow milk is only about one-tenth of that in human milk, this has caught the attention of those involved in designing human milk replacement formulae.

Lactoperoxidase

Lactoperoxidase is an oxido-reductase enzyme that occurs in milk, saliva, tears, cervical mucus. It is a single polypeptide chain with a molecular weight of 77,000 – 100,000. It is a relatively heat resistant enzyme whose activity remains sufficient even after pasteurization. Cow milk has 1.4 units/ml of lactoperoxidase, whereas buffalo milk has 0.9 units/ml. The thermal stability of buffalo milk lactoperoxidase is higher than that of cow milk. Lactoperoxidase has been widely researched for its ability to preserve raw milk. The amount of this enzyme required for preservation is 0.5-1 mg/L, much lower than its concentration in cow milk (30 mg/L).

Lysozyme

Lysozyme is an enzyme that is abundantly present in the mucosal membranes that line the human nasal cavity and tear ducts. It can also be found in high concentration in egg white. Lysozyme destroys bacterial cell walls by hydrolyzing the polysaccharide component of the cell wall. Human milk contains 0.4 g/L of lysozyme, an enzyme that contributes to antibacterial activity in human milk. Lysozyme content of buffalo milk is 15.2 µg/100 ml which is lower than cow milk. Although lysozyme from egg white had found more industrial applications in the past, it has now been recognized that the enzyme isolated from human or bovine milk has far greater lytic activity compared to egg lysozyme.