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Class-Milk Hygiene -1-

Milk composition and synthesis

Introduction to Milk

Milk is a complex biological fluid secreted by the mammary glands of mammals after parturition or calving. Its function to providing the nutrition, immune protection, and growth factors to the newborn during the early stages of life. Milk is also one of the most important foods for humans, contributing significantly to global nutrition and agricultural economies.

Economic value and livelihoods of milk production

The dairy sector is a powerful economic engine, directly supporting the livelihoods of approximately one billion people worldwide.

- Smallholder dominance: Small-scale farmers produce over 70% of the world's milk, making it a critical source of daily cash income and food security, particularly in developing countries.
- Job creation: The industry generates employment throughout the value chain, from farm-level production to processing, transportation, and marketing. Evidence suggests that every 100 litres of milk traded can create between 1.2 and 5.7 full-time jobs.
- Market scale: The global dairy market continues to grow, with a valuation of roughly $645 billion in 2024, driven by rising demand in Asia, particularly India and Pakistan.
- Structural impact: The sector encourages rural development by promoting investment in infrastructure (like cold chains) and enhancing women's economic participation and empowerment.

Milk is unique among natural foods because it contains all essential nutrients required for growth and maintenance, including proteins, fats, carbohydrates, minerals, vitamins, and bioactive compounds, in a highly digestible and bioavailable form. The composition of milk is species-specific and reflects the growth rate and physiological needs of the offspring. For example, milk from sheep and buffalo is rich in fat and protein to support rapid neonatal growth, whereas camel and human milk contain more protective and bioactive components.

Milk is synthesized by mammary alveolar epithelial cells, where nutrients derived from blood are converted into milk constituents such as casein, lactose, and milk fat. Milk secretion is regulated by a complex interaction of hormones, including prolactin, growth hormone, insulin,

and cortisol. The quality and quantity of milk produced are influenced by genetics, nutrition, stage of lactation, health of the mammary gland, and environmental conditions.

In veterinary medicine, milk holds special importance as:

- A nutritional resource for neonates and humans
- An indicator of animal health, especially udder health
- A potential vehicle for pathogens and toxins
- A key product in food safety, dairy technology, and public health

Composition of milk

1-Water- Water is the medium in which all the other components of milk (total solids) are dissolved or suspended. Water content varies from 83.18 % to 87.2 % in milk of different species of cows and buffaloes. In commercial milk, the range is 83.18 to 86.50 %.

2-Fat- Milk fat, though quite bland in taste, imparts richness/smoothness to fat-containing dairy products. In freshly secreted milk, it occurs as a microscopic globular emulsion of liquid fat in an aqueous phase of milk plasma. Fat is the most variable component of milk. The average size of fat globules in buffalo milk is larger (4.15 to 4.60 µm) than that of cow milk (3.36 to 4.15 µm.).

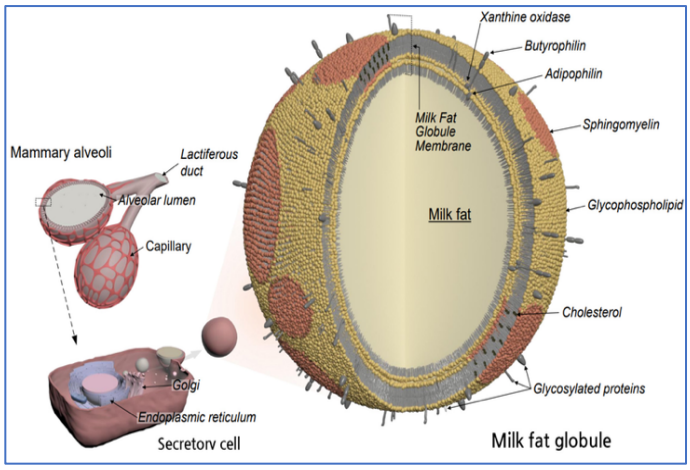

Figure 1: Structure of milk-fat globe.

Both buffalo and cow milk fats consist chiefly of the triglycerides of fatty acids, which make up 95-99 % of milk fat. The remaining portion of milk fat is composed of diglycerides (about 4.1% in buffalo milk and 1.26-1.59% in cow milk), monoglycerides (about 0.7% in buffalo milk and 0.016-0.038% in cow milk). High, medium and low molecular weight triglycerides in buffalo milk occur in the proportion of 42.5, 17.1 and 40.5%, respectively. Corresponding

values for cow milk fat are 52.9, 18.9 and 28.2%, respectively. Free fatty acid content of buffalo milk fat is lower (0.22%) as compared to that in cow milk fat (0.33%).

3-Phospholipids- The total phospholipids content of buffalo milk fat averages 21.04 mg/100 ml of milk, whereas for cow milk the corresponding value is 33.71 mg/100 ml. Phospholipids are essential bioactive components with significant benefits for human health, particularly in brain development, cognitive function, and immune support

4-Proteins- Casein, the principal milk protein, makes up 80 % of the total protein content, and whey proteins the remaining 20 per cent. These fractions, shown to be heterogeneous, consist of many proteins.

5- Casein: Typical of milk proteins, caseins display a distinctive structure as well as physical, biological and nutritional properties. These exist in milk as particles called casein micelles, which are made up of calcium phosphate and casein compounds. Milk contains four main types of casein proteins: αs1-casein, αs2-casein, β-casein, and κ-casein. The αs1- and αs2-caseins are calcium-sensitive proteins that play a major role in binding calcium and forming the internal structure of the casein micelle. β-casein is also calcium-sensitive and contributes to the stability and texture of milk; it has a more flexible structure and can dissociate from the micelle under certain conditions, such as low temperature. In contrast, κ-casein is calcium-insensitive and is located on the surface of the micelle, where it acts as a stabilizing protein that prevents the casein particles from aggregating. During cheesemaking, κ-casein is specifically cleaved by the enzyme rennet (chymosin), which allows the other caseins to aggregate and form curd.

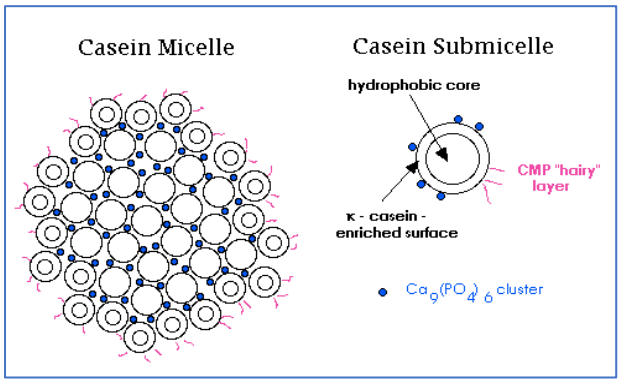

Figure 2: Casein micelles in cow milk.

Casein benefits

- Muscle Growth and Repair: Provides a steady, slow release of amino acids, making it ideal for consumption before bed to prevent muscle breakdown overnight.

- Weight Management: Increases feelings of fullness (satiety) due to its slow digestion, which can help reduce overall calorie intake.
- Bone Health: Rich in calcium and phosphorus, which are essential for maintaining strong bones.
- Immune System Support: Contains bioactive peptides that may aid in immune function.
- In non-food industries, casein has applications in making adhesives, paints, paper coatings, and biodegradable plastics.

6-Whey Proteins: Whey proteins consist of β **-** lactoglobulin and α - lactalbumin, bovine, serum albumin, immuno-globulins (mainly IgG1, IgG2 and IgM), lactoferrin, proteose-peptone, serum transferring, glycoprotein and enzymes.

A-β – lactoglobulin: This is the major whey protein present in buffalo and cow milk. The buffalo milk β **-**lactoglobulin displays molecular weight of about 38500 daltons, as compared to that of 37600 daltons observed in the cow milk β – lactoglobulin. This enzyme act as antioxidant and boost immunity especially for a newborn.

B-Immunoglobulins (Ig): They are antibodies synthesized in response to stimulation by specific antigens. These offer non-specific humoral response to Gram-negative enteric and respiratory bacteria. There are five major classes of immunoglobulins, viz., IgA, IgD, IgE, IgG and IgM

C-Lactoferrin: This glycoprotein displays a strong inhibitory effect towards Gram-negative enteropathogenic bacteria by virtue of its ability to bind free ionic iron, which is essentially required for the growth of enteropathogenic microorganisms

D-Proteose-Peptone: The average level of Proteose-Peptone in buffalo milk at about 330.5 mg/100ml is significantly higher when compared to 240 mg/100ml in cow milk.

E-Lactose: Also called milk sugar, lactose in the major carbohydrate of milk. It is a disaccharide of one residue each of D- glucose and D-galactose. Buffalo milk contains lactose in the range of 4.7-5.0%, while cow milk has slightly lower amounts of lactose in the range of 4.5-4.8%.

7-Minerals: Average normal milk contains 0.70 per cent ash, and this amount represents a salt content of about 0.90 %. The percentage of salt and ash in milk varies with the breed, feed, season, and stage of lactation and disease.

8-Enzymes: Milk is a repository of a variety of enzymes. Over 20 enzymes have been isolated and characterized in cow milk. However, information on enzymes in buffalo milk is very

limited. Several enzymes in milk are utilized for quality testing and control. Some important enzymes from the processing point of view are listed below:

A-Alkaline Phosphatase: This enzyme has assumed significance because of the relationship between the temperature at which it is inactivated, and the temperature employed for pasteurization of milk. Buffalo milk on an average contains about two-thirds the activity of alkaline phosphates as that of cow milk. Alkaline phosphates are distributed through milk although its concentration is higher in the cream fraction. (phosphatase test is used for testing pasteurisation of milk)

B- Lactoperoxidase (LP): This enzyme is naturally present in milk. One of its unique biological functions is an antibacterial effect in the presence of hydrogen peroxide and thiocyanate. Both these substances are naturally present in milk in varying concentrations. This enzyme has gained significance in view of its supportive role in preserving raw milk under ambient conditions through the LP-system. Lactoperoxidase activity in buffalo milk ranges between 5.2-9.8 units/ml, which is on average higher than the corresponding value of 4.4-7.2 units/ml for cow milk. This enzyme has benefits as antimicrobial agent for *Pseudomonas* spp and E. *coli* infection.

C-Lysozyme: This is a relatively small, single peptide chain protein. Its content in cow milk is about 13 μg/100 ml. recently emphasis has been focused on the antibacterial role of lysozyme as a natural defense in milk. During mastitis, lysozyme levels in milk tend to increase considerably, being in the range of 100 to 200 μg/100 ml.
9-Pigments: In cow milk, carotene is the major pigment and it is derived from feed. It gives cow milk a pale-yellow appearance. However, buffalo has the ability to convert carotene into Vitamin A before passing it into milk and so it appears white. Milk also contains bile pigments. Among them, biliverdin predominates.

The most prominent growth factors in bovine and human milk include:

- Insulin-like Growth Factor-I (IGF-I) and II (IGF-II): These are the most abundant growth factors in milk and colostrum, playing a major role in intestinal development, cell proliferation, and inhibiting apoptosis (cell death)
- Transforming Growth factors-beta (TGF-beta): These are critical for immune system development, regulating epithelial cell growth, and promoting gut maturation
- Epidermal Growth Factor (EGF): Highly present in human milk and colostrum, this factor promotes the proliferation, maturation, and repair of the intestinal epithelium.

- Basic Fibroblast Growth Factor (bFGF/FGF-2): Essential for cell proliferation and wound healing.
- Platelet-Derived Growth Factor (PDGF): Involved in cell growth and angiogenesis (new blood vessel formation).
- Vascular Endothelial Growth Factor (VEGF): Promotes angiogenesis and helps repair the gut lining.

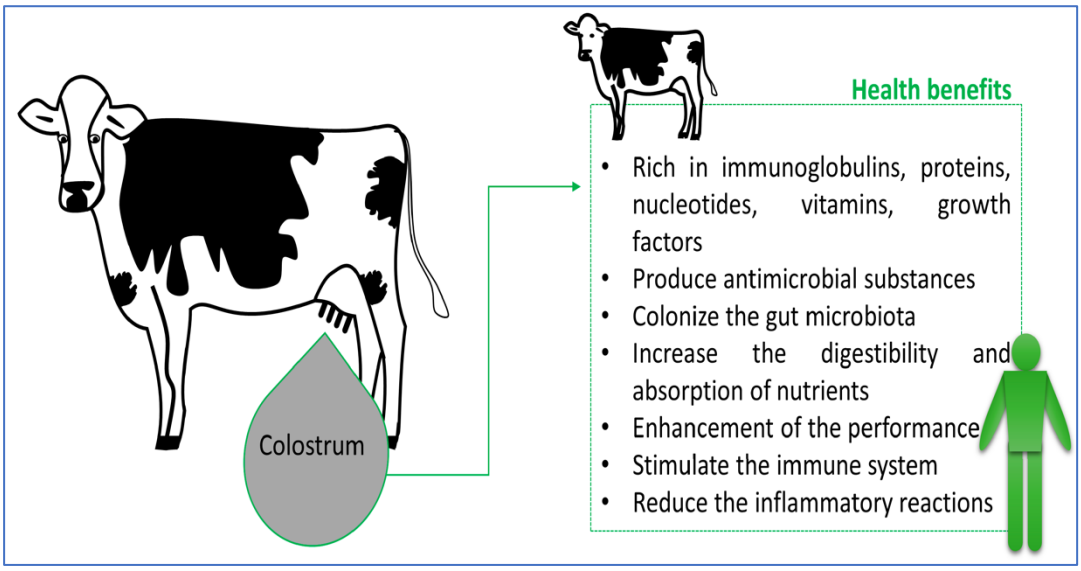

Figure 3: animal and human health benefits of bovine colostrum.

Functions of Hormones in Milk Production

The control of lactation is regulated by **galactopoeitic** hormones. Galactopoesis is defined as the maintenance of lactation. Many of the hormones involved in mammary growth are also responsible for fetal development. These hormones include: prolactin, growth hormones, thyroid hormones and steroid hormones.

PROLACTIN

Every time milk is removed from the cow the hormone prolactin is released which causes stimulation. Prolactin remains a key factor in milk secretion during lactation. Also, extended light periods increase concentrations of prolactin associated with milk production.

GROWTH HORMONES

Growth hormones help coordinate changes in physiological processes and in body tissues. Growth hormone is essential for maintaining lactation as it supports increase in synthesis of lactose, protein and fat in the mammary gland.

OVARIAN HORMONES

Ovarian steroids such as estrogen and progesterone are not necessary for maintenance of lactation. Progesterone alone has no effect because there are no progesterone receptors in the mammary gland during lactation. Increased blood concentrations of estrogen may affect milk production.

OXYTOCIN

Stimulation of the mammary gland, particularly the teats, results in the secretion of the hormone oxytocin. Oxytocin travels via the blood to the mammary gland and ultimately results in the physical removal of milk from the alveoli. Oxytocin is essential for milk removal.

THYROID HORMONES

Thyroids hormones are essential for maximum secretion of milk as they stimulate oxygen consumption, protein synthesis and milk yield. In addition, there is an inverse relationship between a cow's milk yield and blood levels of thyroid hormones in early lactation.