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Colostrum- A perfect meal: Review

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Abstract
Colostrum is the first secretion of lactation mammalian after parturition. Its composition is highly variable, it changes every hour and also breeds to breed. Colostrum gives nutraceutical properties due to its nutritional composition. The presence of proteins, growth hormones, growth factors, minerals, enzymes, vitamins, and lipids make it nutritious so it gives different health benefits. From ancient times different types of products are prepared from the colostrum it has different methods of preparations. The composition of colostrum is responsible for the formation of a gel. β- lactalbumin is responsible for the formation of permanent disulfide bonds due to the presence of the cysteine amino acid. The presence of whey, salts, casein, fat, and lactose in colostrum provides protection to the immunoglobulins, growth hormones, and growth factors from heat damage.

Keywords: colostrum, composition, health benefits, milk, gel

Introduction
The 1st secretion of the memory gland after childbirth is known as colostrum, which is different than the composition of matured milk, and changes significantly (Rathe *et al*., 2014) [37]. Colostrum is yellow-brownish in color and more viscous as compared to normal milk (Eisenbrand and Schreier, 2006) [10]. The immunological components present in the colostrum give passive immunity to the calf, it protects and gives helps to develop the gastrointestinal tract (Nikolic *et al*., 2017). The presence of antimicrobial factors in the colostrum helps to protect the calf against infection, in the 1st week after birth (Menchetti *et al*., 2016) [25].
Colostrum is rich in immune components and nutrients, as compared to normal milk. Colostrum contains more amount of protein, immunoglobulins, nonprotein nitrogen, fat, vitamins, and minerals (Signh *et al*., 2011). It has components that contain immune-enhancing properties such as Immunoglobulins, lactoferrin, lysozyme, lactoperoxidase, α-lactalbumin, β-lactoglobulin, or fat that carries important vitamins and polyunsaturated fatty acids. The concentration of this compound differs and depend on factor like breed, productivity, parity, feeding intensity, the season of the year, and/or production system (Puppel *et al*., 2019) [20].

Composition
According to individuality, breed, parity, prepartum ration, length of dry period of cows, and time postpartum composition and physical characteristics are varied.

Protein
The protein present in bovine colostrum is high in amount than in mature milk, due to the presence of a high level of immunoglobulin and casein. Protein constituents are present in two groups: Whey protein is a soluble constituent and casein protein is an insoluble constituent both have nutritional and bioactive properties. About 75% part of the casein protein is present in milk (Playford and Weiser 2021) [33]. Colostrum contains more amount of casein than milk (Cerbulis and Farrell 1975) [6] after post-partum it decreases at each milking (Parrish *et al*. 1948) [31].
The major class of immunoglobulin are present in the colostrum IgA, IgM, and IgG. They are present at 1% in total milk protein and 6% of total whey protein respectively (Farrell *et al*. 2004) [12]. Elevated levels of IgG, IgA, and IgM contain in colostrum (Smolenski *et al*. 2007) [43], 70-80% of total protein in colostrum is due to the immunoglobulin (Larson 1992), which is important to the calf, to transfer passive immunity into them which is not occur via the placenta (Zhang *et al*. 2011) [46]. Beta-lactoglobulin (β-LG) and Alpha-lactalbumin (α-la) concentrations are higher in colostrum as compared to the normal milk (Marnila and Korohnen 2002; Georgiev 2008) [24, 15]. The bovine serum albumin concentration is higher in colostrum than in milk (Zhang *et al*. 2011) [46]. Lactoferrin i.e. iron binding lactoprotein of mammary origin plays a significant role in the defense mechanism of the mammary gland (Farrell *et al*. 2004) [12]. Minor proteins are also present in the milk report has been observed in some literature. Detection and identification of minor proteins are difficult due to the presence of a high level of major protein, which reduces the detection and sensitivity of mass spectroscopy. Fibrinogen β-chain, chitinase

3-like 1, α-antitrypsin, complement C3 α-chain, gelsolin, and apolipoprotein are detected in colostrum (H. Smolenski *et al*. 2007) [43].

Carbohydrate

Lactose

Lactose concentration is low in colostrum and it increases after postpartum (Parrish *et al*. 1950) [30]. After the postpartum low level of lactose, gradually increases till the milk reaches normal (Parrish *et al*. 1948, 1950; Klimes *et al*. 1986; Kehoe *et al*. 2007; Tsioulpas *et al*. 2007; Georgiev 2008) [30, 31, 22, 21, 45, 15]. Colostrum contains a low level of lactose concentration is 1.2% (Kehoe *et al*. 2007) [21]. lactose concentration reaches normal within 7 days (Brian A et. al 2016) [4].

Oligosaccharides

Milk contains traces amounts of other sugars than lactose which are glucose, fructose, glucosamine, galactosamine, N-acetylneuraminic acid, and oligosaccharides. Oligosaccharides present in milk are of two types neutral and acidic (Gopal and Gill 2000) [16].

Approximately 0.7 to 1.2 g.mL−1 of oligosaccharides are present in colostrum (Nakamura *et al*. 2003) [27] mostly they are acidic, in matured milk they contain traces amount (Gopal and Gill 2000) [16]. 3′Sialylactose (3′SL), 6′ sialylactose (6′SL), 6′ sialylactosamine (6′SLN), and disialyllactose (DSL) are mostly founded oligosaccharides in colostrum, 3′SL is present about 70% (Nakamura *et al*. 2003) [27].

Growth Factors

The principal growth factors present in colostrum milk are epidermal growth factor (EGF), insulin-like growth factor I (IGF-I) and IGF-II, Transforming growth factor (TGF-β1), and (TGF-β2), Fibroblast growth factor 1 and 2 (FGF1 and FGF2), and platelet-derived growth factor (PGDF).

After the post-partum concentration of growth factors is higher initially then it decreases with time (Collier *et al*. 1991). IGF-1 and IGF-II are present in colostrum in large quantity (Marnila and Korohnen 2002) [24]. TGF-β2 concentration is higher in colostrum than in milk (Pakkanen 1997) [29]. The concentration of growth factors is dependent on the method used for quantification.

Enzyme

In milk approximately 70 indigenous enzymes were present and they originated from four principal sources they are blood plasma, secretory cell cytoplasm, milk fat globule membrane (MFGM), and somatic cells (Fox and Kelly 2006) [14]. Colostrum contains higher enzymes than milk (Shahani *et al*. 1973) [41].

Antioxidant Enzymes

Lactoperoxidase enzyme from the peroxidase family present in the milk catalyze the oxidation of thiocyanates and generate intermediate compounds which antimicrobial, in the presence of hydrogen peroxidase (Fox and Kelly 2006) [14]. Lactoperoxidase contain in Colostrum and milk is 13 to 30 mg.L−1, 11–45 mg.L−1 respectively. The concentration of lactoperoxidase is low initially in colostrum but increases rapidly after postpartum within 3-5 days and reaches a maximum level (Korohnen 1977) [23].

Proteinases

The principal indigenous protein present in milk is plasmin which is a serine protease derived from plasminogen. The concentration of plasmin in colostrum is 10 times higher than in milk (Dupont *et al*. 1998) [9]. Plasmin activity get decreases in the transition state from colostrum to milk (Pyorala and Kaartinen 1988) [34].

Lipases and Esterases

The principal lipase present in milk is Lipoprotein lipase. After parturition, mammary lipoprotein lipase activity increases rapidly and remains high throughout lactation. Lipoprotein lipase activity is low initially in colostrum but increases after a few days of parturition and remains constant throughout lactation (Brian *et al*., 2016) [4].

Other enzymes

Milk contains different types of phosphates enzyme they are alkaline and acid phosphates (Fox and Kelly 2006) [14]. The concentration of alkaline phosphates is very high in colostrum and it gets reduced within 1-2 weeks of parturition (Shakeel Ur-Rehman and Farkye 2002) [42]. Acid phosphates concentration is low initially in colostrum then increases within 5-6 days post-partum, again get decrease and stays low up to the end of lactation (Shakeel urRehman and Farkye 2002) [42]. Acid phosphatase activity is lower in colostrum (about 2%) than in alkaline phosphate (Shakeel ur-Rehman and Farkye 2002) [42].

Five types of Ribonucalese present in the milk are, A, B, C, D, and II-1 respectively (Bingham and Zittle 1964) [3]. Colostrum contains 5-10 times more ribonuclease II-1 than milk and has 3 times more total ribonuclease activity (Meyer *et al*. 1987) [26]. The concentration of ribonuclease is higher in 3rd milk after postpartum then again decreases within one month to reach the normal level (Roman *et al*. 1990) [38].

The activity of lysozyme is higher in colostrum than in milk (Korohnen 1977) [22]. γ- Glutamyl transferase (γ-GT), activity is higher in colostrum than in milk and it's about 2.5-fold to 3-fold (Hadorn *et al*. 1997) [17].

Enzyme Inhibitors

Colostrum and milk contain high no of enzyme inhibitors and concentration get decreases after post-partum (Georgiev 2008) [15]. These inhibitors play important role in the absorption of immunoglobulins components in calf (Carlson *et al*. 1980) [5]. Colostrum contains seven-plasma derived proteins they are α2-macroglobulin, C1-inhibitor, inter-α-trypsin inhibitor, antithrombin III, bovine plasma elastase inhibitor, α2-antiplasmin, and bovine plasma trypsin inhibitor (Christensen *et al*. 1995) [7]. The concentration of these inhibitors is high initially in colostrum and after 3 days of post-partum get reduced and reaches to normal level (Christensen *et al*. 1995) [7].

Trypsin inhibitors are present in the colostrum. 100 times higher concentration of trypsin inhibitors seen in the colostrum than in milk (Brian *et al*., 2016) [4]. In colostrum 560 mg trypsin inhibitor.L−1 is present (Quigley *et al*. 1995) [35].

Two types of cysteine protease inhibitors are present in the colostrum and they belong to kininogen and cystatin subfamilies. Colostrum contains a higher concentration of α2-macroglobulin than milk (Brian *et al*., 2016) [4]. α2- macroglobulin is a large plasma glycoprotein and has broad spectrum protease inhibitory activity (Barrett and Starkey 1973) [2].

Nucleotides and Nucleosides

The non-protein-nitrogen part that is nucleotides and nucleosides are present in milk in sub-mili gram amount per liter (Brian *et al*., 2016) [4]. They have an important role in nucleic acid synthesis, enhancement of immune response, etc (Schaller *et al*. 2004) [40]. Nucleotides and nucleosides affect the metabolism of fatty acids, help in iron absorption and improve gastrointestinal health (Brian *et al*., 2016) [4].

Nucleotides and nucleosides concentration is higher in colostrum than in milk. Initially, colostrum contains less amount of nucleotides and nucleosides concentration but it reaches maximum level within 24-48 hr after parturition, then again decreases with lactation up to the third week (Brian *et al*., 2016) [4].

Cytokines

Cytokines belong to a group of proteins, peptides, or glycoproteins. They help to improve the immune system, they also contain interleukins (IL), tumor necrosis factors (TNF), and interferons (INF). Cytokines are present in Colostrum in large quantities but the concentration in milk is not measured. IL-1β, IL-6, TNF-α, INF-γ and IL-1ra concentration high in colostrum than milk (Brian *et al*., 2016) [4].

Lipids

Usually but not all the time fat content of colostrum is higher than milk (Parrish *et al*. 1950; Foley and Otterby 1978; Marnila and Korohnen 2002) [30, 13, 24]. Colostrum contains a large amount of fat (Kehoe *et al*. 2007) [21].

The concentration of stearic acid, oleic acid, and short-chain fatty acids (C4–C10) is low initially after postpartum, and as time passes it gets increases. The concentration of short chain fatty acids except C4 are low initially and get increase within 8 weeks after parturition. The proportion of meristic and palmitic acid is high initially but get decrease as time passes. Short-chain fatty acids synthesis is inhibited by a high level of long-chain fatty acids. Colostrum contains a few no trans fatty acids and cis-9 trans-11 C18:2 (CLA) than milk (Brian *et al*., 2016) [4].

All five major subclass of phospholipids are present in lower concentration in colostrum than in milk, Total phospholipids content of milk get rises from the 3rd to 7th day of lactation. From 95% cholesterol, only 0.3 % sterols are present in milk and it's a very minor quantity. Sterols like campesterol, stigmasterol and β-sitosterol are identified in milk. The cholesterol content of colostrum is significantly higher than milk (Brian *et al*., 2016) [4].

Minerals

A mineral component present in milk is citrate, chloride, and phosphate of H, K, Na, Mg, and Ca they are present in colloidal form with casein (Brian *et al*., 2016) [4].

Milk is saturated with calcium and phosphate ions which exhibit in serum and colloidal form (Brian *et al*., 2016) [4]. Calcium and phosphate are present in higher concentrations in colostrum than in milk. The concentration of calcium and phosphate decreased after parturition from 2168 and 1635 mg.kg−1, respectively. The concentration of calcium and phosphate in colostrum is 4-fold and 5-fold higher than in milk (Kehoe *et al*. 2007) [21].

The concentration of calcium and magnesium increased in colostrum (Tsioulpas *et al*. 2007; Abd El-Fattah *et al*. 2012) [45, 1]. Low level of potassium in colostrum at parturition but get increased after some days (Toshiyoshi *et al*. 1982, Klimes *et al*. 1986) [44, 22]. Concentration of potassium in colostrum get decreased after parturition from 1795 mg.kg−1 to 650 mg.kg−1 after 14 days (Abd El-Fattah *et al*. 2012) [1]. Concentration of potassium in colostrum is range from 983 to 5511 mg.kg−1 (Tsioulpas *et al*. 2007 and Kehoe *et al*. 2007) [45, 21].

Trace elements are present in the colostrum of up to 20 different types like copper, iron, zinc, and manganese, little work had been seen on the concentration of this mineral in colostrum and milk in the early postpartum period (Brian *et al*., 2016) [4]. The average concentration of copper, Iron zinc, and manganese are 1.7-, 10.7-, 10.9- and 3.3 respectively, and their concentration is higher in colostrum than in milk (Kehoe *et al*. 2007) [21]. Abd ElFattah *et al*. (2012) [1] studied that the concentration of copper, iron and zinc decreases in colostrum after 108h of postpartum period, Copper concentration changes frequently during 1st 24 hr of postpartum, but then it gets decreases gradually, similarly the concentration of iron and zinc also get decreases.

Vitamins

Fat-soluble vitamins

Vitamin A present in different forms in milk like retinol, retinal, retinoic acid, retinyl esters, and also provitamin A carotenoids such as β-carotene, Several authors studied that vitamin A concentration increases in colostrum (Brian *et al*. 2016) [4]. The concentration of vitamin A decrease in colostrum after the first few days of lactation and gets stabilized after 5 days (Parrish *et al*. 1948; Abd El-fattah *et al*. 2012) [31, 1].

Vitamin E is present in two forms tocopherols (α-, β-, γ- and δ-) and tocotrienols (α-, β-, γ- and δ-) (Brian *et al*. 2016) [4]. The transfer of vitamin E does not occur by passive transfer of lipids but it occurs through the low-density lipoproteins. In colostrum the concentration of vitamin E is higher than in milk (Brian *et al*. 2016) [4]. Kehoe *et al*. (2007) [21] studied the concentration of vitamin E in colostrum between the range 60 to 1040 μg.100 g−1, and the mean value of 292 μg.100 g−1 respectively. The concentration of vitamin E gets decreases in colostrum after the first six milking postpartum (Parrish *et al*. 1949) [32]. γ- Tocopherol and α-tocotrienol their present in trace amounts in milk and colostrum (Brian *et al*., 2016) [4].

Two major different forms of vitamin D are cholecalciferol (vitamin D3), which get synthesis in the skin of cows after exposure to ultraviolet radiation, and ergocalciferol (vitamin D2), which get synthesis when plants exposure to the ultraviolet radiation. Vitamin D content gets reduced after 5 days of postpartum from 1.2 to 0.36 IU.g−1 fat. Colostrum contains a higher concentration of vitamin D than milk (Brian *et al*. 2016) [4].

Vitamin K is of two types phylloquinone (vitamin K1) and menaquinones (vitamin K2). The concentration of phylloquinone is higher in colostrum than in milk, it gets decreases after 5 days of lactation (Brian *et al*. 2016) [4].

Water-Soluble Vitamins

Vitamin C is synthesized in the liver of a cow but calves cannot synthesize vitamin C on their own for up to 3weeks that's why calves have to depend upon the milk for the vitamin C and vitamin C content in colostrum is sightly higher than in milk (Brian *et al*. 2016) [4].

B group vitamins are also present in milk, from that colostrum contains a higher concentration of thiamine, riboflavin, folate, vitamin B6 and B12 than milk, pantothenic acid, and biotin are low in concentration in colostrum than milk, and niacin content approximately same in both colostrum and milk(Marnila and Korohnen 2002) [24]. The concentration of thiamine and riboflavin in colostrum fall into ranges from 0.3 to 2.1 μg.mL−1 and 2.4 to 9.2 μg.mL−1, respectively, and its mean values of 0.9 and 4.5 μg.mL−1 (Kehoe *et al*. 2007) [21]. The concentration of riboflavin 3.3 fold higher in colostrum than in milk and its value sharply get decreases from 1st and 2nd milking and it's more gradually get decreases from 2nd to 10th milking(Brian *et al*. 2016) [4]. Concentration of pantothenic acid Increased when colostrum transit to milk, and the niacin concentration remains the same (Brian *et al*. 2016) [4]. Kehoe *et al*. (2007) [21] reported that the milk contains a higher concentration of niacin than colostrum. Hirano *et al*. (1991) [18] studied that biotin content in colostrum is low initially, it gent increased after progression of lactation.

Cobalamin concentration in milk is about <1 μg.100 g−1 and remains constant throughout the lactation, during the colostral period it remains very high concentration (Brian *et al*. 2016) [4]. The concentration of pyridoxine is lower in colostrum than in milk (Kehoe *et al*. 2007) [21]. The concentration of folic acid decreased 24 hours after parturition (Brian *et al*. 2016) [4].

Ancient Colostrum Products

Ginna

Ginna is a colostrum-based Indian food product prepared from the 1st-day milk after calving by addition of sugar or jaggery powder with cardamom flavor cooked in a closed vessel and served with roti, dosa, or idly (Sarkar *et al*., 2015) [39].

Kharwas

Kharwas is also another Indian colostrum-based product prepared in ancient times in India. Its method of preparation is varied in different parts of India. Colostrum is mixed with normal milk and for sweetness sugar or jaggery powder is added for flavoring cardamom and saffron is added and cooked in a pressure vessel. In some parts of India for cooking purposes idly vessel is also used.

Health benefits

1. Energy booster for Athletes

Growth factors, IGF-1 and IGF-2 help to increase lean muscle mass burns body fat, and decrease adipose tissue and this is an athlete's requirement so colostrum is helpful for athletes. Growth factors are helpful to recover the leaky gut mucosa in athletes by supplementing the colostrum to them. Performance of cyclers increases by supplementing the colostrum before eight weeks of competition (*Rajamanickam et al., 2016*) [36].

2. Act against cancer

Conjugated linoleic acid present in the colostrum helps to lower the concentration of immunosuppressive substances like Leukotriene's and prostaglandins and also it helps to increase the production of interleukin-2 and lymphocyte by 29% and 32%, respectively. These interleukin-2 and lymphocytes act as anticarcinogenic substances they induce apoptosis by inhibiting eicosanoid synthesis (*Rajamanickam et al., 2016*) [36].

3. Infant food supplement

Immunoglobulins present in colostrum protect an infant from diarrhea. Lactoferrin present in colostrum helps to prevent rotavirus and salmonella typhi infection. IgA present in large amount in colostrum have the ability to protect from poliovirus, *Herpes simplex* virus, Streptococcus, Influenza A, *E. coli*, and *Shigella flexneri*. Colostrum is also effective in problematic eye lesions by tropical application and it is also effective in tropical eye dryness (*Rajamanickam et al., 2016*) [36].

4. As a wound healer

The growth factor present in colostrum are TGF-α and β, IGFs-1 and 2 act as a muscular-skeletal repair and has muscle growth capacities so colostrum act as a wound healer (*Rajamanickam et al., 2016*) [36].

Gel formation theory/changes occur on heating of colostrum

Colostrum can form gel due to its composition, it does not require any gelling agent for that. In colostrum gelling starts from the upper phase at 46℃ (sol-gel transition temperature) than in a mixed and lower phase, just because high-fat content at the top phase which packed more closely (Judith *et al*., 2021) [20].

The high protein content in colostrum is the major reason for gel formation in colostrum. β- lactoglobulin is the major protein responsible for gel formation because it contains 178 amino acids of which 7 cysteine molecules. Insulin-like growth factors IGF-1 and IGF-2, protein polypeptide N-acetylgalactosaminyl-transferase, and lactoferrin also contain cysteine amino acids and they have the ability to form a permanent disulfide bond with different amino acids (Judith *et al*., 2021) [20].

In the mixed phase, there is the strongest interaction between different charges on the surface of native protein causing an electrostatic cross-linking and contributing to the occurrence of gelation point at 60-65℃ (Judith *et al*., 2021) [20].

Colostrum rich in calcium ions is also responsible for the gelation property. On heating, these positively charged calcium ions bind negatively charged a lateral group of amino acids residue (glutamic and aspartic acid) and form an ionic link it causes aggregation and increases in viscosity(Judith *et al*.,2021) [20].

The whey protein present in the colostrum on heating gets denature and causes an increase in casein fraction and the formation of large miscell takes place. At 70℃ in the lower phase gel formation takes place (Judith *et al*., 2021) [20].

Colostrum's whey, salts, casein, fat, and lactose provide protection to the immunoglobulins, growth factors, and growth hormones so they do not get damaged during heat processing (Elfastrand *et al*., 2002) [12].

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