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QUALITY AND COMPOSITION OF BOVINE COLOSTRUM

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Abstract

Colostrum is the first natural nutrient for new born calves. It is a rich source of energy, protein, fat and the only source of natural passive immunity available. Good quality colostrum has more than 50 mg/mL IgG, which is the major source of immunoglobulins providing passive immunity at early life of the calves. Besides immunoglobulins, nutritional and microbial quality is also important. Bacteria in colostrum attach to free immunoglobulins in the intestinal lumen and block absorption of these molecules by retarding pinocytosis through enterocytes of lumen, therefore the threshold level for total plate count (<1,00,000 cfu/ml) and Enterobacteriaceae (<10,000 cfu/ml) should be considered. Colostrum feeding should be done immediately after birth otherwise the IgG absorption diminishes and ceases approximately by 24 hours of life. Non-availability or inadequate absorption of sufficient IgG through colostrum would lead to failure of transfer of passive immunity (FTP) in calves and one of the major contributing factor for calf mortality.

Key word : Colostrum quality, Calf, Immunoglobulins, FPT

Introduction

Colostrum is the first lacteal secretion produced from the mammary gland immediately after parturition mostly secreted for 72 hours post-partum. Colostrogenesis starts during the last three weeks of gestation by transportation of immunoglobulin (passive transfer of IgG_1 and selective transfer of IgG_2) from serum to mammary gland under the influence of lactogenic hormones and other regulatory factors. This process continues throughout late gestation but abruptly stops at the time of calving. During colostrogenesis, up to 500 g/week of immunoglobulin G (IgG) can be transferred into mammary secretions, with highest concentration just before calving under the influence of prolactin hormone. Colostrum is considered as “liquid gold” for new born calf as it is rich in nutritional, antimicrobial, growth factors and is the only source of natural passive immunoglobulins (Ig) that are essential for stimulating immune defense system of the newborn calf. Immunoglobulin can’t cross placental structure in cattle because the separation of fetal and maternal blood supplies prevent *in utero* transfer of immune factors, so agammaglobulinemic calves are born with less circulating IgG or IgM. The proteolytic system in cattle remains immature from birth until three weeks of age and they are unable to digest proteins other than from milk. The pH of colostrum is low initially (with an average value of 6.32) and increases with time post-partum (reached 6.5 after 2 weeks). This low pH of colostrum is due to the increased concentration of citrate, protein, carbon dioxide and dihydrogen phosphate. The buffering capacity of colostrum is defined as the resistance to changes in pH with addition of acid or base and the principal buffering components present in colostrum are proteins, citrate, carbonate, soluble phosphate and colloidal calcium phosphate which results in higher buffering capacity of colostrum as compared to milk. Similarly, the titratable acidity of colostrum is approximately 2 to 2.5 times higher than that of milk (Tsioulpas *et al.,* 2007). Colostrum is yellow in color due

to the presence of carotenoids and β-carotene is responsible for 65% of variation in color index of colostrum (Calderon *et al.,* 2007). Due to the presence of high protein (casein) and calcium ion (Ca^{+2}) concentration, higher size of casein micelles are found in colostrum. Somatic cell count of colostrum is higher than milk but this is not due to mastitis. It is due to the penetration of cells through leaky tight junctions between the mammary epithelial cells. The main health benefits of colostrum are immune-modulation, improvement of gastro-intestinal function by inhibiting the colonization of harmful pathogens in gut and by promoting growth of beneficial bacterial colonies, growth stimulation by increasing bone density and delays aging process. Colostrum also possesses laxative effect that helps in passing of first stool, called meconium.

Composition

The composition (nutritional and biological value) and chemical properties of colostrum is highly variable.

Table-1.Chemical composition of colostrum and milk with each hour post-partum (Grodzki, 2011).

Colostrum(hours)	Protein (%)	Fat (%)	Lactose (%)	Casein (%)	Albumin,Globulin(%)
0	16.8	6.7	2.9	4.1	12.7
6	11.7	6.1	3.5	3.5	8.0
12	6.3	4.4	3.9	3.1	3.2
24	5.5	4.1	4.1	2.9	2.6
48	4.8	3.9	4.2	2.8	2.0
120	3.6	0.8	4.5	2.7	0.9
Milk	3.2	3.8	4.6	2.6	0.6

Casein is known as milk protein and its concentration is higher in colostrum along with alpha-lactalbumin, beta-lactoglobulin and bovine serum albumin that decreases gradually with subsequent milking. Colostrum is the rich source of immunoglobulins (Ig). These immunoglobulins are monomeric or polymeric proteins which are divided into different classes – A, D, E, G, H, M based on different biological, immunological and physicochemical properties in animals. Bovine colostrum contains IgG, IgA and IgM. Immunoglobulin G (IgG) is the major immunoglobulin (65-90%) present in colostrum which is produced from plasma cells of the lymphatic system and is known as primary Ig. There are two isotypes of IgG- IgG1 and IgG2 having ratio of 35:1. The calf produces its own immunoglobulin around 36 hours of age and through the first 3 weeks of age an approximate of 1g IgG is produced. IgM and IgA contribute 8-10% and 7-10% respectively of colostrum's immunoglobulin protein. Colostrometer helps in quantitative estimation of IgG in farms. Lactoferrin, an iron binding protein shows bacteriostatic effect and halts bacterial development but it does not show bacteriostatic effect on lactic acid bacteria and streptococcus as they require small amount of iron. The concentration of lactoferrin in colostrum is about 100 fold greater than that of raw bovine milk and ranges from 1.5-5 mg mL^{-1}(Indyk and Filonzi, 2005). Apart from major proteins, 29 minor proteins have been identified in colostrum such as α-antitrypsin, complement C3 α-chain, fibrinogen β-chain, chitinase 3-like 1, apolipoprotein H and gelsolin (Yamada *et al.,* 2002). Non-immunoglobulin proteins present in maternal colostrum are important for development of gastrointestinal tract.

The carbohydrate present in colostrum is known as lactose which consists of glucose and galactose, acts as a source of energy for new born calf. Lactose concentration is low in colostrum and the lowest value reported was 1.2% (Morrill *et al.,* 2012). But it is responsible for nearly half of the osmotic pressure of milk as it causes movement of water from cytosol of mammary epithelial cells into secretory vesicles and then into milk which regulate the milk volume production. Presence of low lactose concentration produces more viscous milk. Besides lactose, some other carbohydrates are present in trace amounts in the form of oligosaccharides which is of two types -neutral and acidic oligosaccharides. Colostrum is the rich source of acidic oligosaccharides and till now 40 oligosachharides have been identified in bovine colostrum with a concentration range varies from 0.7-1.2 g mL^{-1}.

Fat content is higher in colostrum than that of milk with high levels of long chain fatty acids. Because at the time of parturition, cows are in negative energy balance which results in mobilization of fatty acids from adipose tissue that incorporate into milk fat. This, higher level of long chain fatty acids inhibit the de novo synthesis of short-chain fatty acids.

Table 2: Approximate composition of colostrum and whole milk (Ahmadi *et al.,* 2011)

Parameter	Colostrum (1st milking) %	Whole milk (11th milking) %
Lactose	2.7	4.9
Casein	4.8	2.5
Immunoglobulins	6.0	0.09
Fat	6.7	4
Total solid	23.0	13.0
Total protein	14.0	4.0
Mineral	1.0	0.74

Minerals play an important role as the deficiency cause negative impact on growth of calves. The mineral component includes chloride, citrate and phosphate of sodium (Na^+), potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}) and H^+ which are present either in ionic form or in colloidal form. The most important minerals found in colostrum are calcium and potassium and their concentration is approximately 4-fold and 5-fold higher than milk which give bitter taste. Apart from these macro-minerals, nearly 20 other micro-minerals are also present. The average concentration of copper, manganese, iron and zinc were 1.7 fold, 3.3 fold, 10.7 fold and 10.9 fold higher than milk (Kehoe *et al.,* 2007).

Along with minerals like zinc and magnesium, vitamins are important in supporting the immune defense system of new born calves. Vitamins are two types- water soluble vitamins (vitamin B and C) and fat soluble vitamins (vitamin A, D, E, K). Concentration of these vitamins, are higher in colostrum except pantothenic acid and biotin. Vitamin A found in various form like β-carotene, retinol, retinal and retinoic acid. The deficiency of retinol cause increase chances of diarrhea caused by *Escherichia coli* by decreasing the protective capability of intestinal epithelium. The passive transfer of vitamin E does not occur, rather it shows the mechanism of low density lipoprotein. The calf can't synthesize endogenous vitamin C until 3 weeks of age.

The growth factors present in colostrum are epidermal growth factor (EGF), insulin-like growth factor I (IGF I), IGF II, platelet derived growth factor (PDGF), transforming growth factor β1 (TGF-β1), TGF-β2, betacellulin (BTC), fibroblast growth factor 1 (FGF 1) and FGF 2. The most abundant growth factors present in colostrum are IGF-I and IGF-II. Colostrum also

contains over 20 antibodies to specific pathogens including *Salmonella, E.coli, Streptococcus, Staphylococcus, H.pylori and Rotavirus* that plays a role in body's defence mechanism.

Approximately, 70 indigenous enzymes are present in colostrum like proteinase, lipase, lysozyme, lactoperoxidase, esterase, alkaline phosphatase, acid phosphatase, ribonuclease etc. Lysozyme has germicidal action and the increase in the level of lysozyme is associated with a decrease in the concentration of immunoglobulins. Lactoperoxidase has both germicidal and bacteriostatic properties. Colostrum also contain enzyme inhibitor such as proteinase inhibitor, trypsin inhibitor, bovine plasma elastase inhibitor. Cytokines present in colostrum include tumour necrosis factor (TNF), interferons (INF) and interleukins (IL) that modulate the immune system.

Colostrum feeding

Colostrum accounts for approximately 0.5% of a cow's annual milk output (Scammell 2001). Colostrum should be fed immediately after birth because the absorption of immunoglobulins across intestinal wall is very rapid during first 1-2 hours of life. Even 30 minutes delay in intake of colostrum leads to total decrease in immunoglobulin concentration by about 2 mg/mL. The ability to absorb IgG across the intestinal epithelium diminishes rapidly after birth and ceases by approximately 24hours of age. This is due to rapid postnatal growth which replaces foetal type intestinal enterocytes with adult type enterocytes. Colostrum feeding is a standard practice done @10% of body weight of calves for absorption of immunoglobulin within 6-12 hours of birth without measuring the quality of colostrum. In such cases though the requirement of calf is fulfilled but sufficient quantity of colostrum IgG is not absorbed and serum IgG level becomes less than 10 mg/mL. This condition is known as failure of transfer of passive immunity (FTPI) in calves. FTPI can be a result of inadequate colostrum formation, ingestion or absorption. FTPI itself is not a disease but it is the predisposing cause of diarrhea, dehydration and dullness which increase the morbidity rate, poor growth rate in calves with reduction in production performance. The management factor believed to have the greatest influence on FPT is colostrum volume because if the calf is left to nurse from dam they intake insufficient quantity of colostrum. Depending on the dairy breed, 3 to 4 L is the volume required to deliver an adequate immunoglobulin mass to the majority of calves.

Microbial quality of Colostrum

Bacteria present in colostrum attach to free immunoglobulins in the intestinal lumen and block absorption of these molecules by retarding pinocytosis through enterocytes of lumen, therefore the threshold level for total plate count (<1,00,000 cfu/ml) and Enterobacteriaceae (<10,000 cfu/ml) should be considered (Godden,2008). Provision of high quality colostrum (>50mg of IgG/mL) within first hours of life provide sufficient amount of immunoglobulins in first 30 to 90 days of life. This bacterial contamination has a negative impact on passive immune system of calves. So, proper udder hygiene should be maintained just before collection and sanitation of equipments used during collection, storage and feeding is necessary. Pooling of colostrum must be avoided due to increase chance of disease transmission. Variation in colostrum quality depends upon factors like individual, breed, parity, calving season, dry period length, pre-partum nutrition and post-partum time.

Colostrum quality is affected by breed of cattle. Among the dairy breeds, Holstein has lesser immunoglobulin concentration with greater coliform count and total plate count in colostrum than Jersey (Morrill et al., 2012). The ratio of dry matter, protein, fat and lactose in colostrum

of Holstein- Friesian (HF) cows is 25.8%, 16.6%, 6% and 3.2% respectively. But the density of colostrum is less in Ayshire and Brown Swiss breed than HF cows (Maunsell *et al.,* 1998).

Parity of cow affects colostrum quality. Multiparous cows produce more colostrum with higher concentration of Ig than primiparous cows due to increase incidence of various diseases. Parity 5+ cows had more colostral protein and IgG than first and second parity but the fat and lactose concentration in colostrum decreases with increase in parity (Dunn *et al.,* 2017). Spring calving cows produce colostrum with higher Ig than winter months due to the availability of fresh grass from pasture instead of silage. Also the fat content was greater in spring calving cows (Yaylak *et al.,* 2017). Dry period of cow affect both quality and quantity of colostrum. For regeneration of secretory epithelial cells and lactogenesis process to take place, the dry period should last at least 5 weeks. Cows having dry period of four weeks had higher protein and fat concentration in colostrum but the lactose concentration was higher in colostrym of cows that had a two week long dry period before calving (Kuczaj *et al.,* 2014). Cows supplemented with concentrate 0 to 3 weeks period before parturition had a greater colostral fat concentration than non-concentrate fed cows (Dunn *et al.,* 2017). The concentration of IgG in colostrum was greater in the sample collected <3 hours of post-partum as compared to >9 hours of post-partum (Cummins *et al.,* 2016).

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