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Review Article

Colostrum: Composition, Pharamacological Properties and Therapeutic Applications

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ABSTRACT

Colostrum is the first milk produced during late pregnancy and the initial days after birth, is vital for neonatal survival, growth, and immune protection. Though secreted in small quantities, it is highly concentrated with immunoglobulins, immune cells, antimicrobial proteins, growth factors, vitamins, and minerals, specifically adapted to the newborn's physiological immaturity. Secretory IgA, IgG, and IgM provide passive immunity, while human milk oligosaccharides promote beneficial gut microbiota. Colostrum also exhibits immunomodulatory, anti-inflammatory, antioxidant, and gastroprotective properties, particularly benefiting preterm and low-birth-weight infants. Its unique composition underscores the importance of early breastfeeding for neonatal health and long-term development.

INTRODUCTION

Colostrum is the earliest form of milk produced by the mammary glands during the late stages of pregnancy and throughout the first 2–4 days after birth. It is distinctly different from mature milk in both composition and function, as it is uniquely tailored to support the physiological, nutritional, and immunological needs of the newborn. Although it is secreted in smaller volumes compared to mature milk, colostrum is highly concentrated with protective and bioactive substances that are essential during the early neonatal period.[1]

In terms of its physical properties, colostrum appears thick, sticky, and yellowish, which is mainly due to its high protein content and the presence of carotenoids and fat-soluble vitamins, particularly vitamin A. The limited quantity produced immediately after delivery is well suited to the newborn's immature digestive system and small stomach capacity, thereby preventing

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overfeeding while still providing sufficient essential nutrients.[2]

COMPOSITION OF COLOSTRUM:

Colostrum is a specialized biological secretion uniquely adapted to meet the immediate nutritional, immunological, and developmental needs of the newborn. In comparison with mature human milk, it is produced in smaller volumes but contains a significantly higher concentration of proteins, particularly those associated with immune defence. Secretory immunoglobulin A (sIgA) is the predominant antibody in colostrum and plays a crucial role in protecting the neonatal gastrointestinal tract by preventing the adhesion and invasion of pathogenic microorganisms. Other immunoglobulins, such as IgM and IgG, also contribute to early immune protection. Moreover, colostrum is rich in antimicrobial proteins, including lactoferrin and lysozyme, which provide broad-spectrum protection against bacterial, viral, and fungal pathogens.[1], [3], [4]

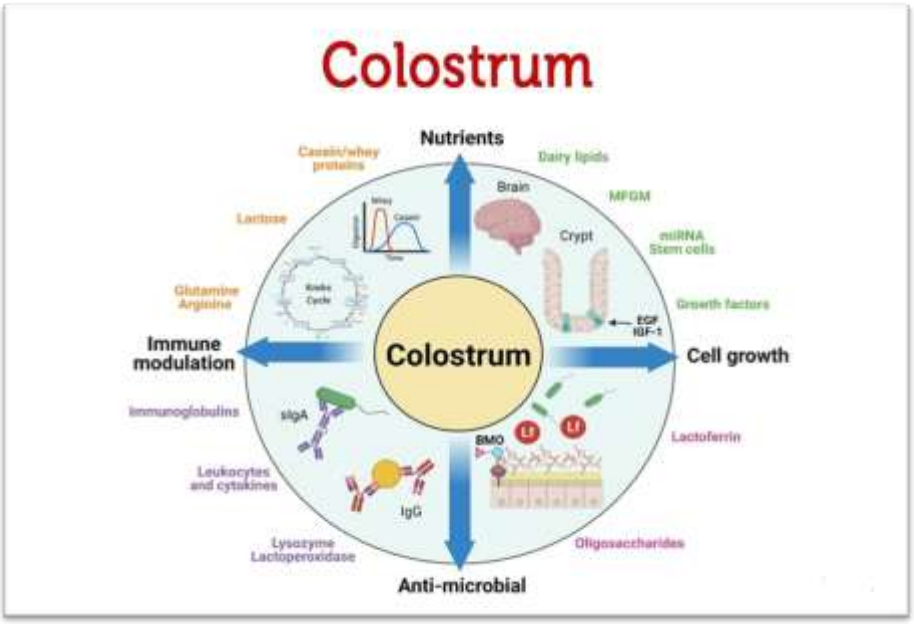
Along with soluble immune factors, colostrum contains numerous viable immune cells, such as macrophages, lymphocytes, and neutrophils, which actively contribute to immune regulation and host defence. In terms of its carbohydrate composition, colostrum contains lower levels of lactose than mature milk but is especially abundant in human milk oligosaccharides (HMOs). These oligosaccharides act as prebiotics by promoting the growth of beneficial gut microbiota and also function as decoy receptors that inhibit pathogen attachment to the intestinal epithelium. Although the lipid content of colostrum is relatively low, it supplies essential fatty acids, cholesterol, and phospholipids that are important for maintaining cellular integrity and supporting neurological development.[5], [6], [7]

In addition, colostrum is highly enriched with fat-soluble vitamins, particularly vitamin A and its precursor β-carotene, which are responsible for its characteristic yellow coloration and are essential for maintaining epithelial health, vision, and immune function. It also provides key minerals and trace elements, including sodium, potassium, zinc, iron, and selenium, which are necessary for enzymatic activity and effective immune responses. Furthermore, colostrum contains high concentrations of growth factors and cytokines, such as epidermal growth factor (EGF), insulin-like growth factors (IGFs), and transforming growth factor-β (TGF-β). These bioactive compounds play a vital role in promoting intestinal maturation, tissue repair, and immune modulation. Collectively, the diverse composition of colostrum highlights its critical importance in protecting the newborn and facilitating physiological adaptation during the early neonatal period.[8], [9]

Table 1

COMPONENT CATEGORY	COMPOSITION	BIOLOGICAL/ FUNCTIONAL ROLE
PROTEINS	Elevated protein levels; secretory IgA, IgM, IgG	Confers passive immunity and inhibits microbial attachment
ANTIMICROBIAL PROTEINS	Lactoferrin, lysozyme	Supresses bacterial, viral, and fungal growth and strengthens innate immune protection
IMMUNE CELLS	Macrophages, lymphocytes, neutrophils	Involved in immune monitoring, phagocytic activity and regulation of immune response
CARBOHYDATES	Reduced lactose; abundant human milk oligosaccharides (HMOs)	HMOs promotes beneficial gut flora and function as decoy receptors to block pathogen binding

LIPIDS	Lower overall fat contents; essential fatty acids, cholesterol, phospholipids	Supports structural integrity of cell membrane and contributes to brain and visual development
FAT SOULUBLE VITAMINS	Vitamin A, D, E, and K	Necessary for vision, epithelial maintenance, Immune function, and antioxidant defence
GROWTH FACTORS	Epidermal growth factor (EGF), insulin like growth factor	Stimulates intestinal development, tissue growth, and repair
TRACE ELEMENTS	Zinc, iron, copper, selenium	Essential for enzymatic activity, immune function, and antioxidant mechanisms



PHYSICAL CHARACTERISTICS:

1. Colour

Colostrum usually shows a yellow to deep golden colour, mainly due to its high concentration of β-carotene and vitamin A. The depth of this coloration can vary among mothers and is influenced by maternal diet and nutritional status. This characteristic hue reflects its abundance of fat-soluble vitamins and antioxidant compounds.[1]

2. Consistency and Texture

In comparison to mature breast milk, colostrum is thicker and more viscous. It is commonly described as sticky, dense, or creamy, owing to its high levels of proteins, immunoglobulins, and cellular elements. This thick consistency helps coat the neonatal gastrointestinal lining, forming a protective barrier against harmful microorganisms.[3]

3. Volume

Colostrum is secreted in small amounts, typically ranging from 2 to 20 mL per feeding during the first 24–48 hours after birth. Despite the low volume, it is highly concentrated, ensuring sufficient nutritional and immunological support for the newborn. This limited quantity is physiologically appropriate and corresponds to the small gastric capacity of the neonate.[9]

4. Taste

Colostrum has a mildly salty taste when compared to mature milk, mainly due to its higher levels of sodium and chloride and lower lactose content. This difference in taste is normal and does not influence the newborn's feeding behaviour or acceptance.[11[

5. Opacity

Unlike mature milk, which appears more translucent, colostrum is opaque and cloudy. This is because of its high concentration of proteins, immune cells, and various bioactive substances, highlighting its protective and immunological importance.[11]

6. pH

The pH of colostrum ranges from slightly acidic to nearly neutral, generally between 6.0 and 6.5. This pH range supports enzymatic activity and enhances the antimicrobial effects of its immune components, thereby aiding in the protection of the newborn's intestine.[12]

7. Cellular Content

Colostrum contains a large number of viable cells, including macrophages, lymphocytes, and epithelial cells. These contribute to its dense consistency and play an important role in immune defence as well as in the development of the neonatal gastrointestinal tract.[13]

8. Stability

Colostrum remains relatively stable at body temperature; however, due to its high protein content, it may thicken or show slight separation when left undisturbed. This is a normal physical feature and should not be considered a sign of spoilage.[14]

IMMUNOLOGICAL COMPONENETS OF COLOSTRUM:

1. Immunoglobulins (Antibodies)

Immunoglobulins are essential immunological components of colostrum, with IgA being the predominant type, followed by IgG and IgM. Secretory IgA (sIgA) functions as the first line of defence by coating the mucosal surfaces of the gastrointestinal tract and preventing the adhesion and invasion of microorganisms. IgG and IgM, although present in smaller quantities, offer additional protection against both systemic and mucosal infections. The high antibody content ensures immediate immune protection for newborns with immature immune systems.[1], [3]

2. Leukocytes

Colostrum contains a large number of viable immune cells, including macrophages, neutrophils, and lymphocytes. Macrophages are responsible for phagocytosis of pathogens, antigen presentation, and the release of bioactive cytokines that regulate neonatal immune responses. Lymphocytes, primarily T and B cells, contribute to both innate and adaptive immunity and play an active role in immune surveillance within the neonatal gastrointestinal tract.[15]

3. Cytokines and Growth Factors

Colostrum is rich in various cytokines, chemokines, and growth factors, including interleukins (IL-6, IL-10), tumour necrosis factor-alpha (TNF-α), and transforming growth factor-beta (TGF-β). These bioactive substances assist in immune cell differentiation, promote anti-inflammatory responses, and support the maturation of the mucosal barrier. Growth factors such as epidermal growth factor (EGF) aid in the development of the intestinal lining, enhance

nutrient absorption, and provide protection against pathogens.[16]

4. Complement Proteins

Colostrum contains complement proteins like C3 and C4, which contribute to bacterial opsonization, enhance phagocytosis, and facilitate the direct lysis of microorganisms. These components provide immediate antimicrobial defence in the neonatal gut, where the adaptive immune system is not yet fully mature.[17]

5. Other Bioactive Proteins

Colostrum also includes several additional bioactive proteins that support immune defence. Lactoferrin, an iron-binding protein, inhibits bacterial growth by limiting iron availability and also exerts direct antimicrobial and anti-inflammatory effects. Lysozyme, an antimicrobial enzyme, breaks down bacterial cell walls, thereby supporting innate immunity. Additionally, oligosaccharides act as prebiotics, promoting the growth of beneficial intestinal bacteria while preventing colonization by harmful pathogens.[18], [19]

6. Role in Passive Immunity

The immunological constituents of colostrum provide passive immunity to the newborn, which is essential during the early weeks of life when the infant's immune system is still immature. By supplying antibodies, immune cells, and bioactive compounds, colostrum protects against respiratory and gastrointestinal infections as well as sepsis, thereby reducing neonatal morbidity and mortality. [20]

BENEFITS OF COLOSTRUM TO THE NEWBORN:

Colostrum, often called "liquid gold," is the earliest form of milk produced after childbirth and plays an important role in supporting the newborn during the first days of life. Its composition is specially adapted to aid immunity, digestive system development, nutrition, and the baby's adjustment to life outside the uterus.

1. Enhanced Immune Protection

Colostrum contains a high concentration of antibodies, immune cells, and biologically active substances that help protect the newborn from infections. These components provide defence against bacteria, viruses, and other harmful agents while the infant's immune system is still developing. Early intake of colostrum is linked with better immune balance and lower inflammatory reactions, demonstrating its role in immune regulation.[21]

2. Improved Gut Function and Maturation

The active compounds present in colostrum contribute to the growth and development of the gastrointestinal tract and strengthen the intestinal barrier. This supports efficient absorption of nutrients and protects against harmful microbes. Intake of colostrum has been associated with improved enzyme activity in the intestine, increased villus development, reduced intestinal permeability, and a lower risk of gastrointestinal complications in early life.[22]

3. Reduction of Neonatal Infections and Morbidity

Regular consumption of colostrum is associated with a lower occurrence of infections such as necrotizing enterocolitis (NEC) and sepsis, especially in premature or low birth weight infants. Its immune components, including immunoglobulins and antimicrobial proteins like

lactoferrin, help strengthen gut defences and limit the spread of harmful bacteria into the bloodstream.[23]

4. Gut Microbiome Development and Growth

Colostrum supports the early formation of a healthy gut microbiome, which is essential for digestion and immune function. Substances such as oligosaccharides and antibodies encourage the growth of beneficial bacteria while restricting harmful microorganisms, contributing to long-term gut health and proper growth.[24]

5. Nutritive and Developmental Support

Colostrum provides a concentrated source of nutrients in small quantities, making it suitable for newborns with limited stomach capacity. It supplies essential proteins, vitamins, minerals, and growth factors that help meet early energy needs, support tissue formation, and promote healthy growth during the initial days after birth.[25]

FACTORS AFFECTING COLOSTRUM PRODUCTION:

The production of colostrum in humans is a multifaceted physiological process shaped by various maternal, physiological, and environmental factors. These influences can affect both the quantity and composition of colostrum, thereby impacting its role in providing nutrition and immune protection to the newborn.

1. Maternal Hormonal Regulation

Hormones are vital for initiating and regulating colostrum production. During pregnancy, increased levels of prolactin and oestrogen prepare the mammary glands for colostrum formation, while the decrease in progesterone after delivery initiates milk secretion. Any disturbance in these hormonal changes may delay or reduce colostrum production.[26]

2. Maternal Nutritional Status

The nutritional condition of the mother before and after delivery significantly influences colostrum production. Adequate intake of calories, proteins, vitamins, and minerals is essential to meet lactation requirements. Malnutrition or deficiencies in specific nutrients can decrease both the quantity and quality of colostrum, reducing its nutritional and immune benefits.[26]

3. Parity (Number of Pregnancies)

The number of prior pregnancies affects how efficiently colostrum is produced. Women who have experienced previous pregnancies tend to produce colostrum more effectively than first-time mothers (primiparous), likely due to earlier development of the mammary glands and hormonal adaptations.[27]

4. Maternal Body Mass Index (BMI)

Maternal BMI and body composition are linked to variations in colostrum volume and composition. Differences in fat content and microbial profile have been observed between underweight and overweight mothers, suggesting that BMI can influence milk production and quality.[28]

5. Mode of Delivery

The method of childbirth can influence both the production and composition of colostrum. For example, caesarean section may alter the levels of certain immune and growth factors due to changes in hormonal responses and stress during delivery.[29]

6. Gestational and Neonatal Factors

Factors such as gestational age and neonatal characteristics, including birth weight, can affect colostrum production. Preterm birth may influence both the timing and need for colostrum, while maternal conditions like gestational diabetes or obesity can alter nutrient distribution and colostrum composition.[30]

7. Maternal Diet and Lifestyle

The mother's dietary habits and lifestyle, including the intake of probiotics, fats, and micronutrients, can affect colostrum composition and possibly its production. For instance, consuming yogurt and certain fatty acids may modify the microbial content of colostrum.[31]

8. Physiological and Stress Factors

Maternal health, stress levels, and sleep patterns also influence lactation. High stress levels can suppress the release of oxytocin and prolactin, which are essential for milk ejection and production, potentially leading to reduced colostrum output.[32]

PHARMACOLOGICAL PROPERTIES OF COLOSTRUM:

1. Immunomodulatory Activity:

One of the most important pharmacological actions of colostrum is its immunomodulatory function, which is essential for neonatal immune system development. It contains high levels of immunoglobulins, especially secretory IgA, along with immune cells such as macrophages, lymphocytes, and neutrophils. These regulate both innate and adaptive immunity while preventing excessive inflammatory responses. Cytokines such as transforming growth factor-β (TGF-β) and interleukin-10 (IL-10) promote immune tolerance by suppressing pro-inflammatory pathways. This balanced immune response is crucial due to the immaturity of the neonatal immune system [4,16,18,33].

2. Antimicrobial and Antiviral Properties:

Colostrum exhibits strong antimicrobial and antiviral activity against a wide range of pathogens. Bioactive components such as lactoferrin, lysozyme, defensins, and immunoglobulins act together to inhibit microbial growth. Lactoferrin binds iron required for microbial metabolism, while lysozyme disrupts bacterial cell walls [5,17,34].

3. Anti-inflammatory Effects:

Colostrum has potent anti-inflammatory properties that protect developing tissues. Cytokines and growth factors reduce inflammatory mediators such as TNF-α, interleukin-1, and interleukin-6, helping maintain intestinal integrity. This is especially beneficial in preterm infants at risk of necrotizing enterocolitis and systemic inflammation [6,7,16].

4. Gastrointestinal Protective and Healing Properties:

Colostrum provides strong gastroprotective and mucosal healing effects. Growth factors such as EGF, IGF-1, IGF-2, and fibroblast growth factors promote epithelial growth, differentiation, and repair. These enhance intestinal maturation, strengthen the mucosal barrier, and reduce permeability, preventing pathogen entry into circulation [14,25].

5. Antioxidant Properties:

Colostrum contains antioxidants such as vitamins A and E, lactoferrin, carotenoids, and enzymatic antioxidants. These neutralize reactive oxygen species produced during the transition to

extrauterine life, thereby protecting neonatal tissues from oxidative damage [1,5].

6. Growth-Promoting and Anabolic Effects:

Colostrum has strong anabolic and growth-promoting properties due to the presence of growth factors. Insulin-like growth factors enhance protein synthesis, cell proliferation, and tissue differentiation, supporting early growth and organ development, especially in preterm infants [1,14,35].

7. Prebiotic and Microbiome-Modulating Effects:

Colostrum contains oligosaccharides that act as prebiotics, promoting beneficial gut bacteria such as *Bifidobacterium* and *Lactobacillus*. These improve digestion, nutrient absorption, and immune defense, while inhibiting pathogenic bacteria and supporting long-term gut health [9,25].

8. Cytoprotective and Anti-apoptotic Effects:

Colostrum components provide cytoprotective and anti-apoptotic actions. Growth factors and cytokines activate cell survival pathways and protect cells from programmed cell death, preserving tissue integrity and supporting neonatal adaptation [7,14].

9. Metabolic and Endocrine Regulatory Effects:

Colostrum supports metabolic and endocrine balance by maintaining glucose homeostasis, lipid metabolism, and hormonal stability. It helps prevent neonatal hypoglycaemia and supports early metabolic adaptation through bioactive hormones and peptides [3,20].

10. Therapeutic and Clinical Relevance:

Due to its wide range of pharmacological properties, colostrum is considered an important natural therapeutic and nutraceutical agent. It plays a role in infection prevention, immune enhancement, gastrointestinal protection, and recovery support. Its high bioavailability and safety make it valuable in neonatal care and research [2,8,11,35].

THERAPRUTIC APPLICATIONS OF COLOSTRUM:

1. Prevention and Control of Neonatal Infections:

An important therapeutic function of colostrum is its ability to protect newborns from infections. It is rich in secretory IgA, lactoferrin, lysozyme, and immune cells, which provide passive immunity during the early postnatal period when the infant's immune system is still immature. These components help prevent gastrointestinal and respiratory infections, lower the occurrence of neonatal sepsis, and reduce infection-related morbidity and mortality, particularly in preterm and low-birth-weight infants **[1]**.

2. Gastrointestinal Protection and Intestinal Disorders:

Colostrum offers significant therapeutic advantages for gastrointestinal health. Growth factors such as epidermal growth factor and insulin-like growth factors aid in intestinal development, epithelial repair, and maintenance of the mucosal barrier. Clinically, it has been shown to lessen the severity of conditions like necrotizing enterocolitis, diarrhoea, and inflammatory bowel diseases. Its ability to reduce intestinal permeability and prevent bacterial translocation is especially beneficial for high-risk neonates **[16]**.

3. Immune Function Enhancement:

Because of its immunomodulatory effects, colostrum is widely recognized for enhancing immune function. Cytokines, immunoglobulins, and bioactive peptides regulate immune responses, improve pathogen detection, and support immune tolerance. Therapeutically, it has been explored for boosting immunity in immunocompromised individuals, including newborns, older adults, and patients with chronic illnesses **[5]**.

4. Anti-inflammatory Effects and Tissue Repair:

Colostrum contains anti-inflammatory components such as transforming growth factor-β and interleukin-10, which help control excessive inflammatory responses. These actions promote tissue repair and regeneration by minimizing inflammation and supporting cellular healing. As a result, colostrum has been studied as a supportive therapy in inflammatory disorders affecting the gastrointestinal tract and other mucosal tissues **[7]**.

5. Support in Growth and Developmental Disorders:

The growth-enhancing properties of colostrum make it useful in conditions associated with impaired growth and delayed development. Insulin-like growth factors and other anabolic substances stimulate protein synthesis, tissue growth, and metabolic processes. Clinical studies indicate that colostrum supplementation can improve weight gain, nutrient uptake, and developmental outcomes in growth-restricted infants **[6]**.

6. Antioxidant and Cytoprotective Effects:

Colostrum contains antioxidants such as vitamins A and E, carotenoids, and lactoferrin, which protect tissues against oxidative stress. These antioxidants help reduce cellular damage during development and illness. In addition, colostrum exhibits cytoprotective effects by preventing apoptosis of epithelial and immune cells, thereby maintaining tissue integrity and facilitating recovery **[33]**.

7. Regulation of Gut Microbiota:

Colostrum helps establish a healthy gut microbiota through its prebiotic oligosaccharides. These substances promote the growth of beneficial bacteria like *Bifidobacterium* and *Lactobacillus* while inhibiting harmful microorganisms. A balanced gut microbiome enhances digestion, strengthens immune function, and reduces the risk of infections and inflammatory diseases **[34]**.

8. Nutraceutical and Pharmaceutical Applications:

Beyond neonatal use, colostrum is incorporated into nutraceutical products and dietary supplements aimed at improving immune function, supporting gastrointestinal health, and enhancing overall well-being. Its natural origin and wide range of biological activities make it a promising candidate in pharmaceutical research, particularly for developing functional foods and immune-supportive therapies **[35]**.

CONCLUSION

Colostrum is a uniquely specialized biological fluid that serves as the newborn's first and most crucial source of nutrition and immune protection. Although produced in limited quantities, it is highly concentrated with immunoglobulins, antimicrobial agents, immune cells, growth factors, vitamins, and essential minerals, making it ideally suited to meet the physiological immaturity and heightened vulnerability of the neonate during the early postnatal period.

The rich immunological profile of colostrum—particularly its high levels of secretory IgA, leukocytes, cytokines, and complement proteins—provides immediate passive immunity and significantly reduces the risk of gastrointestinal and respiratory infections. Bioactive components such as lactoferrin, lysozyme, and human milk oligosaccharides further enhance innate immune defences, support the development of a healthy gut microbiota, and promote intestinal maturation and immune regulation.

Beyond its nutritional and protective roles, colostrum exhibits important pharmacological properties, including immunomodulatory, antimicrobial, anti-inflammatory, antioxidant, and gastroprotective effects. These benefits are especially pronounced in preterm and low-birth-weight infants, highlighting the critical importance of early colostrum feeding. In conclusion, colostrum is an irreplaceable biological resource essential for neonatal survival, growth, and immune development, and the promotion of early breastfeeding remains a vital public health strategy for improving neonatal outcomes worldwide.

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