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Camel Colostrum: A Comprehensive Review of Its Therapeutic Properties and Role in Disease Prevention

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Abstract Camel colostrum, the first secretion from the mammary glands following parturition, is a unique biological fluid distinguished by its superior nutritional and immunological content . In the first day after postpartum, camel colostrum contain high levels of immunoglobulins reaching (20-50 g/L), another immuno protein and lactoferrin, is approximately (1-2g/L). The fat content may reach to(25-26%).Lactose is initially low2-3%.Vitamins A and E are concentrated in early colostrum. This report aims to give a complete analysis of the qualities of camel colostrum, with a focus on its therapeutic and preventive effects, as well as important differences between it and mature camel milk and bovine colostrum. The report studies the chemical and physical components of colostrum, such as immune proteins, growth factors, and bioactive substances, in order to clarify how they enhance immunity and prevent inflammation and illnesses. Furthermore, it investigates the potential therapeutic applications of colostrum in human health (children, immunocompromised individuals, the elderly) and animal health, as well as its expanding economic importance in the food, pharmaceutical, and cosmetic industries. The study finds that camel colostrum is an important resource for therapeutic and immunological purposes, and it recommends additional research and industrial development to fully benefit on its unique features.

Keywords: Camel, colostrum, Immunity Lactoferrin, Preservation, Therapeutic

Introduction Camels are essential to the cultural and economic lives of arid and semi-arid regions, providing food, transportation, and a means of livelihood. Camel milk, especially colostrum, has been highly valued in traditional medicine due to its unique nutritional and therapeutic benefits. Many of these claims are now supported by modern scientific research, which highlights camel colostrum as a unique bio fluid with nutritional and medicinal properties (1).

Camel colostrum, consider first milk secret by the mammary gland after birth, differs from mature camel milk in both physical characterization and chemical composition. It is exceptionally in micro nutrients, macronutrients, as well as bioactive compound that are essential for survive and growth of newborn (2,3). Studies showed that the Protein is colostrum is particularly high, about 14.2% shortly after birth, related to 2.5-4.5% in mature milk (4).

The Immunoglobulin concentration in colostrum can be exceed 120 mg/ml, but they drop considerably to below 10 mg/ml in mature milk, this dramatic difference emphasizes the significance of colostrum in passive immunity transfer (5). This immune function is especially critical because the camel's placenta during structural prevents maternal antibodies from crossing the placenta during pregnancy (6,3).

Camelids are unique in producing heavy chain antibodies (HCAbs), which are smaller, more rebust, and have a greater ability to penetrate tissues compared to regular antibodies, this gives neonates enhanced immunological protection (7). Other bioactive proteins, such as lactoferrin (3.0-3.5 mg/ml in colostrum vs. 1.5-2.0 mg/ml in mature

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milk), lactoperoxidase, lysozyme, and growth factors, help with antibacterial, oxidative, and immunomodulatory qualities (8).

Aside from proteins, camel colostrum contains distinct patterns of fat, lactose, minerals, and vitamins. The fat concentration varies from 0.2-3.9% in the first hours to 6-7% after one month, with mature milk typically holding 2-5.5% fat. Lactose levels begin low (2.7-3.5%) and rise by more than 5% five days after delivery, eventually stabilizing around 4.6% in mature milk (2). Also, total dry substance in early colostrum can approach 30%, then mature milk has 11-14%, representative a high nutritious load (4).

Minerals contain calcium (~103 mg./100 ml), potassium (~128 mg./100 ml), and phosphorus (~43 mg./100 ml) show vital role in supporting skeletal development support, supporting enzymatic activities, and maintaining electrolyte balance. Raw camel milk also contains fat-soluble vitamins A and E, which boost immunity and enhance antioxidant defenses, additional mature camel milk contains significant amounts of vitamin C (3-7.5 mg/100 ml), often higher than the level than that found in cow's milk and breast milk (9).

Despite its cultural and historical significance, camel colostrum receives less attention than bovine colostrum. Recent research has emphasized the need for further exploration in to bioactive components, mechanism of action, and potential therapeutic uses (10). With its impressive protein profile, high immunoglobulins content, and range of protective compounds, should be considered not only as diet for newborn, but also as a comprehensive immunological and therapeutic system.

Literature review

General chemical composition of camel colostrum.

Protein content.

Protein content in camel colostrum has been found to range from 3.7% and 7.0%, with an average of around 4.95%. However, it is impotent to note that the highest concentrations occur immediately after birth, reaching up to 14.23% in the first few hours after calving. (2). This temporary range emphasizes the neonate's immediate need for these essential macromolecules.

The protein content of camel colostrum is extraordinarily diverse, containing a wide range of major protein groups. Caseins are the key milk proteins that form micelles to transport calcium and phosphate. Although their percentage relative to total protein in colostrum is lower than in mature milk, they still provide accrual source of amino acids that support growth and tissue repair. (11).

Immunoglobulins (antibodies) are essential for passive immunity transfer.in addition to the typical antibodies (IgG, IgA, and IgM) camelids produce unique heavy chain antibodies (HcAbs), which are plentiful in colostrum, are smaller, more stable, and can penetrate tissues more effectively, enhancing defiance mechanisms against pathogen. IgG is the most prevalent type of immunoglobulin, plays avital role in overall immunity.

Lactoferrin is a potent iron-binding glycoprotein with numerous antibacterial (bacteriostatic and bactericidal), antiviral, antifungal, anti-inflammatory, and immunomodulatory properties. Its high content in colostrum is an important first line of defense against newborn infections (12). Lactoperoxidase is an enzyme that, when coupled with thiocyanate and hydrogen peroxide, forms an antibacterial system that is effective against a range of bacteria. Lysozyme is an enzyme that hydrolyses bacterial cell walls and is particularly effective against Gram-positive bacteria. Serum albumin is a protein that transports molecules and helps to keep the osmotic balance.

Alpha-lactalbumin and beta-lactoglobulin, are present in camel colostrum, primarily serving as nutritive proteins. However, albeit beta-lactoglobulin also has ability to bind hydrophobic substances. (2).

Fat content.

While camel colostrum is a rich source of energy, its fat content increases in unique way that set it apart from the colostrum of other common dairy animals, such as cow. The fat content varies from 0.4% to 3.92%, with an average of 3.1% (4).

Surprisingly, multiple studies have found that colostrum fat content can be relatively low in the first hours after birth, ranging from 0.2% to 0.5%. This initial low level then climbs rapidly during the first 48 hours to around 1.27% and continues to rise, possibly peaking at 6.91% after one month (2,9). This pattern stands in stark contrast to bovine colostrum, which is typically high in fat from the beginning. The reason for the initial low-fat concentration in camel colostrum is unclear, but it may be to the early focus on delivering protein (especially immunoglobulins) and carbohydrates, with fat storage increasing as the calf's digestive system matures.

Total solids.

Proteins, lipids, lactose, minerals (ash), and vitamins are the non-water components of colostrum that make up its solids. Camel colostrum has an exceptionally high total solids content, particularly in the first hours after birth making it inceasdibly nutrient dense. The reported total solids content of camel colostrum ranges from 11.4% to 14.6%, with an average of 12.88% (4). However, like protein, the highest

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concentrations are detected immediately after delivery, with values reaching up to 30.4% in the first few hours (2). This extremely high concentration represents the newborn's dense nutritional package, which contains a concentrated amount of energy, building blocks, and protective components in a small amount. This high density is crucial for neonates as they a small stomach stomachs but high energy needs.

Ash –A Marker of mineral content.

The ash content in camel colostrum reflects its comprehensive of mineral makeup, which is vital of physiological processes, including bone development, electrolyte balance, enzymatic activity, and function of the nervous system. camel colostrum typically contains an ash level of 11%, indicating avoid mineral (4).

Camel colostrum is a rich source of macro minerals and trace elements. Calcium (Ca): 103 mg/100 mL – play critical role in bone development, blood clotting, muscle contraction, and neural function. Magnesium (Mg): 15.4 mg/100 mL supports around 300 enzymatic process, muscle and nerve activity, blood glucose regulation, and blood pressure control. Sodium (Na): 14.0 mg/100 mL – crucial for fluid balance, nerve signal transmission, and muscular contraction. Potassium (K): 128 mg/100 mL – key for fluid regulation, neural signaling, and muscle function. Inorganic Phosphate (P): 43.4 mg/100 mL – vital for bone and teeth formation, energy metabolism (ATP), and cell membrane structure; optimal bone growth development it dependent on the Calcium-to: Phosphorus ratio. In addition to these major minerals, camel colostrum also provided essential trace elements such as Iron (Fe): 0.25 mg/100 mL is necessary for synthesis hemoglobin, oxygen transport, and enzymatic activities. Copper (Cu): 0.17 mg/100 mL is playing role in iron metabolism, enzyme activity, and growth connective tissue. Other important trace elements include zinc (Zn), manganese (Mn), and selenium (Se), contribute to immune function, antioxidant protection, and overall growth. (13).

Vitamins – Essential cofactors for growth and immunity.

Vitamins are crucial chemical compound required in small amounts to supports optimal metabolism, growth, and overall health. Camel colostrum contains a arrange of fat-soluble and water-soluble vitamins, all of which play vital role in neonatal development, immune system function, and adapting to life outside the womb.

Vitamin C (ascorbic acid): the concentration ranging from 4.9 to 20.4 mg. per 100 mL (14). Camel colostrum and milk usually have (three to ten times) as more than vitamin C as cow's milk. This is significantly important, as, similar in human neonates, camel calves may experience reduced endogenous vitamin C. synthesized in their first days of the life. Vitamin C is an influential antioxidant that maintenance's immune function., formation of collagen, and iron absorption, and playing to the protective properties of camel colostrum.

Vitamin A (retinol) is a fat-soluble vitamin essential for vision, immunity function, cell differentiation, and reproductive health. Camel colostrum typically contains more vitamin A than mature milk, highlighting its importance for rapidly developing newborns (13,14).

Vitamin E (tocopherol): this fat-soluble vitamin, acts as an effective antioxidant helping stabilizes and protects cell membranes from oxidative stress. Its role complements of selenium in preventing antioxidant defense mechanisms, thus reducing cellular damage during the critical early days of life.

Differences between colostrum and mature camel milk.

Raw and mature milk differ significantly in protein content. Colostrum is rich in immunoglobulins, particularly IgG, with concentration reaching up to 120 mg/mL, compared to less than 10 mg/mL in early milk (10,15). This high immunoglobulin content passive immunity to the newborn at a during critical period supplemented by bioactive proteins like lactoferrin, lysozyme, lacto-peroxidase, and growth factors that assist intestinal maturation and organ development (16).

Total protein content decline significantly as lactation progresses from approximately 17% immediately postpartum to 4.2% within one week and stabilizes between 2.5 and 4.5% for the remainder of lactation (17). Mature camel milk is rich in casein (52-87%), particularly β-casein with whey proteins, including α-lactalbumin, serum albumin, lactoferrin, and immunoglobulins, provide 20-25% (18). Camel milk lack β-lactoglobulin, making it less allergenic than cow's milk (19).

After the initial colostral phase, the protein concentration in camel milk rapidly decease, reaching mature milk levels (typically 2.5% to 3.5%) within 3 to 7 days (4). While mature milk still continues to provide beneficial proteins like caseins (for nutritional value) and some whey proteins, its primary function shifts from immune defense to long-term nutritional supports for growth and maintenance. Although immunological components remain present, their concentration is substantially lower as the calf immune system mature.

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The fat composition also differs notably between colostrum and mature milk. Some studies show low fat levels in colostrum, ranging from 0.2 to 0.5 which gradually increase to about 7% in the following days (2,4). however, other report large initial fat content up to 25.9%, which then dropped to around 3.1% within a week (20).

Mature milk typically has constant fat level ranging from 2.0 and 5.5% (17) Comparison and characterization of fat and protein composition for camel, hydration status significantly affecting the fat content which up to 1.1% during dehydration (21). Camel milk fat contains small globules and higher proportion of Linoleic acid, a long-chain polyunsaturated fatty acid, which enhances its nutritional value compared to cow's milk its nutritional value when compared to cow's milk (22).

Mineral composition varies between colostrum and mature milk as well. Colostrum contains a high level of calcium, magnesium, potassium, and phosphorus, essential for bone mineralization and early metabolic action (20). These concentrations decrease to more stable levels in mature milk, although camel milk outperforms cow milk in trace elements such iron, copper, and manganese, while zinc levels are often comparable (23). Environmental and physiological factors, especially hydration, greatly effect on sodium and potassium concentrations but have little impact on iron levels (21).

Vitamins have distributed differently in Colostrum and mature milk. Colostrum contains fat-soluble vitamins, such as vitamins A and E, which protect against oxidative stress and supports immune function (24,2). In contrast mature milk, is rich in vitamin C, with concentration ranging from 3 to 7.5 mg/100 g, three to five times higher than in bovine milk and comparable to human breast milk (25).

Vitamin C content in camel milk contribute to its high antioxidant activity, which may increase in the first days after birth (26). Camel milk is also a excellent source of vitamin D, especially in Bactrian camels, with reported level exceeding 600 IU/L compared to only 20-30 IU/L in cow's milk (14). The B-complex vitamins show variable profile, with some studies reporting higher levels of vitamin B12 and folic acid, while others find lower levels of thiamine and riboflavin compared to bovine milk (25).

Factors Affecting Camel Colostrum Composition

Environment / Climate.

Cold conditions activate the sympathetic nervous system, leading to higher cortisol and adrenaline levels, which, in turn, trigger in fat tissue. This process transports free fatty acids to the mammary glands, enriching the colostrum with lipids that are highly energy -dense. Protein synthesis, including immunoglobulins, is also increased to support neonatal thermogenesis and immunity.

Warm temperatures induce a shift in mammary metabolism away from fat and protein synthesis toward the production of lactate, which serves to rehydrate the neonate and reduce heat stress. In addition, the influence of humidity on evaporative cooling is important. When the humidity is high, less water is lost through the skin and the respiratory tract, leading to thinner colostrum containing lactose. Long hours in winter raise melatonin, activate prolactin, and increase protein and fat synthesis; short summer nights limit this impact, resulting in milk with more water and lactose (27).

Water Availability.

Water restriction decreases the supply of colostrum but increases concentration of solids (protein, fat minerals) to ensure adequate immunological and energy support of babies. This function is hormonally regulated by vasopressin and aldosterone that help conserve bodily fluids and immunoglobulin transmission.. Camels can lose water up to 25-30% of their body weight without experiencing serious physiological collapse, because to oval, osmotically resistant red blood cells and renal specialization for concentrated urine and dry faces. Forage water content also effects colostrum hydration, with green pastures producing more hydrated colostrum than dry forages (28,29).

Diet and Nutrition.

Nutritional factors greatly impact colostrum quality. Protein-rich diets enhance immunoglobulin synthesis, while fat- and vitamin-rich diets enhance energy density and antioxidant function. Camel colostrum is high in vitamins A and E, which support epithelial growth, mucosal immunity, and lipid protection. Vitamin B1 facilitates energy metabolism in newborns. Malnutrition and deficiencies in trace elements such as zinc and selenium can also inhibit immune modulation and antioxidant capacity. (30,31).

Lactation Stage.

Colostrum is only secreted in the first 3-5 days after delivery. Early colostrum has extremely high levels of immunoglobulins (IgG, IgA, and IgM), antibacterial proteins (lactoferrin and lysozyme), growth hormones, fat-soluble vitamins (A and E), vitamin B1, and important minerals. As lactation develops, immunoglobulin levels fall but lactose rises, indicating a shift from immunological defense to energy provision for growth. Neonatal gut permeability is critical: the "open gut" phase in the first 24 hours allows for efficient immunoglobulin

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absorption before closing in 36-48 hours (32,29). Camel colostrum contains increased immune proteins slightly longer than cow, as an adaptation to desert circumstances.

Breed and Genetics.

The composition of colostrum varies amongst camel breeds. Bactrians generate richer, more nutrient-rich colostrum than dromedaries, allowing them to adapt to cold temperatures. Genetic differences affect milk protein genes, immunoglobulin levels, and vitamin enrichment. Comparative studies demonstrate that Bactrians had the highest IgG and lactoferrin concentrations, hybrids intermediate, and dromedaries lower, indicating the influence of heredity in immunological composition.

Stress, Disease, and Poor Body Condition.

Colostrum production is directly related to dam health. Stress, mastitis, or systemic disease lower immunoglobulins, lactoferrin, and lysozyme levels while raising somatic cell count (SCC). Energy is shifted to immunological defense, resulting in reduced breast secretory output. Mastitis harms epithelial cells, reducing immunological protein release (28,33).

Parity and Age.

Due to cumulative antigen exposure, multiparous camels produce more immunoglobulin-rich colostrum than primiparous camels. Younger camels compensate with increased lactose levels, which provide energy but no immunological protection (30).

Milking Time and Frequency.

Colostrum obtained right after calving has the best immunological and nutritional content. Delayed or frequent milking increases the shift to mature milk while diluting immune proteins. Early suckling, ideally within two hours after birth, is required for maximum passive immunity transfer (34).

Therapeutic, Preventive, and Immunological Significance of Camel Colostrum

Immunological Significance

Passive Immunity Transfer to Newborns.

Camel colostrum has significantly more immunoglobulins, particularly IgG, than mature milk. This high IgG content compensates for camels' limited transplacental antibody transfer caused by their synepitheliochorial placenta, which prevents maternal antibodies from reaching the fetus. Camel calves are thus born largely agammaglobulinemic, relying solely on colostrum for early immunological protection (35).

During late pregnancy, hormonal changes - a drop in progesterone and an increase in prolactin and cortisol - cause the mammary gland to concentrate IgG in colostrum. FcγR receptors in mammary epithelial cells facilitate the transfers of IgG from the mother's blood stream into colostrum, offering passive immunity (36).

In addition to immunoglobulins, camel colostrum contains antioxidant compounds like vitamins, lactoferrin, and enzymatic proteins, which minimize oxidative stress and protect tissues during the vital newborn period. Feeding natural colostrum to calves increases circulating T lymphocytes ($CD4^+$, $CD8^+$), B cells, and cytokine expression (IL-1β, IL-2, IFN-γ), leading to stronger innate and adaptive immune activation (37).

Timely intake during the first 12-24 hours after birth is critical for survival, immunity, and proper gut barrier formation. Camel colostrum contains extra immunomodulatory proteins such as lactoferrin and lysozyme, which assist enhance the immune system and support metabolic adaption to the harsh desert environment (37).

Enhancement of Innate and Adaptive Immune Responses

Camel colostrum boosts both innate and adaptive immunity in newborn calves and, potentially, humans. innate immunity; Bioactive proteins such as lactoferrin, lysozyme, and lactoperoxidase disrupt microbial membranes, sequester nutrients like iron, and generate reactive oxygen species. These compounds act as the first line of defense in the gastrointestinal tract, limiting harmful bacterial colonization while supporting beneficial microbiota (11,38).

During the "open gut" immediately after birth, High levels of immunoglobulins (IgG, IgA, and IgM) are absorbed systemically, providing passive humoral immunity (35, Szyzka *et al*., 2025). Camel colostrum also contains antioxidant vitamins (A, E, and C) and enzymatic proteins that reduce oxidative stress, protect immune cells, and sustain proper intracellular signaling. It promotes lymphocyte survival, proliferation, and cytokine signaling (36).

Recent studies have demonstrated that maternal colostrum stimulate lymphocyte proliferation and cytokine activation more efficiently than commercial colostrum substitutes. Calves fed with maternal colostrum exhibit higher $CD4^+$ and $CD8^+$ T cells, along with an increased production of cytokines such IL-1β, IL-2, and IFN-γ, which regulate immune cell development, proliferation, and function (37).

Immunoglobulins and bioactive proteins activate signaling pathways such as NF-κB and MAPK by binding to binding to pattern recognition receptors and lymphocyte surface receptors, respectively. IL-2 promotes T-cell expansion and B-cell antibody

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production, IFN-γ activates macrophages and encourages Th1 polarization, and IL-1β aids in recruiting and activating immune cells. (39,40).

Antioxidants in colostrum protect immune cells from free radical-induced apoptosis while also maintaining cellular integrity and functional capacity. This dual strategy, which includes direct immune stimulation via immunoglobulins and cellular protection via antioxidants, ensures that innate and adaptive immunity develop optimally.

Antimicrobial effects: bacterial & fungal

Camel colostrum demonstrated significant antibacterial and antifungal properties due to its high concentration of bioactive proteins and peptides such as lactoferrin, lysozyme, immunoglobulins, and other antimicrobial peptides. Colostral IgG and IgA directly neutralize enteropathogenic bacteria like *Escherichia coli* and *Salmonella spp*. (12,41). Lactoferrin further aids in combating bacterial membranes to induce lysis (42).

Camel colostrum also supports the development of the neonate's intestinal barrier, which is vulnerable to pathogens due to its permeability and immaturity. Early intake of colostrum provides both structural and functional protection to the gastrointestinal epithelium, offering both passive and active immunological defense (35). The cytokines and soluble mediators present in colostrum active and modify the neonatal immune response, influencing the maturation of both innate and adaptive immunity and helping to establish a well-balanced defense system in the newborn (36,43). Additionally, antioxidants and growth factors in camel colostrum protect cells from oxidative damage and enhance immune signaling (32,33,40).

Camel colostrum also aids in the development of the neonate's intestinal barrier, which is immature and very porous, making it vulnerable to pathogen invasion. Early colostrum ingestion provides structural and functional protection for the GI epithelium, ensuring both passive and active immunological defense (11,35). Colostrum-associated cytokines and soluble mediators begin and modify the neonatal immune response, influencing the development of both innate and adaptive immunity and resulting in a well-balanced newborn defense system (Scieszka *et al.,* 2025; Hussen *et al.,* 2021b). Antioxidants and growth factors also protect cells from oxidative stress and improve immunological signaling (32;33).

Lactoperoxidase and lysozyme in camel colostrum also exhibit is antifungal activity that damage cell walls and inhibiting spore germination. Lactoferrin has antifungal effects against *Candida albicans*, reducing its ability to adhere and form biofilms (5,44). Furthermore, oligosaccharides in colostrum acts as prebiotic-like substances, fostering beneficial gut microbiota while suppressing pathogenic colonization (10).

These antimicrobial properties are particurly crucial during the early stage of life when passive immunity plays avital role, contributing to immediate defense and shaping a resilient microbiome and mucosal immunity (45).

Antiviral effects.

Camel colostrum possesses unique antiviral characteristics, owing to high levels of immunoglobulins (IgG, IgA, IgM), lactoferrin, lysozyme, and bioactive peptides. These compounds employ both direct virus inactivation and indirect immunomodulation mechanisms (46).

Lactoferrin, a crucial antiviral protein, prevents viral attachment by binding to heparan sulphate proteoglycans on host cells surface, blocking viral entry. It has shown effectiveness against several viruses, including rotavirus, influenza virus, and coronavirus. (16 ,42).

Lactoferrin isolated from camels has been shown to enhance the activity of NK (natural killer) cells while promoting the production of IFN-γ, both of which create an environment less conducive to viral replication. Lactoferrin as well as other immunomodulatory proteins present in camel colostrum stimulate NK cell activity by binding to receptors found on the NK cell surface, including Toll-like receptors, low-density lipoprotein receptor-associated proteins. Once bound, they stimulate intracellular signaling pathways, leading to the activation of NK cells and enhanced production of cytotoxic proteins such as perforin and granzymes. These chemicals induce apoptosis in virus-infected cells, preventing viral spread before the adaptive immune system fully develop. Additionally, immunoglobulins and bioactive peptides in colostrum further enhance NK cell activity, fostering an integrated antiviral environment that facilitates direct viral neutralization and regulates immune signaling critical for newborns during postnatal period (44;47).

Anti-inflammatory actions.

Camel colostrum is recognized for its potent anti-inflammatory properties due to the high levels of immunoglobulins, lactoferrin, lysozyme, growth factors, and antioxidant substances present in its composition. These bioactive compounds work synergistically to modulate inflammatory pathways both locally (gut) and systemically. Lactoferrin, a multifunctional glycoprotein, plays a key role in this process.. Lactoferrin suppresses the release of anti-

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inflammatory cytokines like TNF-α and IL-6, while promoting the reals of anti-inflammatory cytokines like IL10. This shift in the cytokine balance helps reduce excessive inflammation and protects tissues. (47,48).

In addition, antioxidant compounds in camel colostrum, including vitamins A, C, and E, as well as enzymatic antioxidants like superoxide dismutase and catalase, neutralize reactive oxygen species (ROS), mitigating inflammation caused by oxidative stress (36,5).

Since ROS are known to trigger inflammatory cascades, their removal helps in preserve the intestinal barrier and the prevent of systemic inflammatory responses. Furthermore, bioactive peptides formed during colostrum digestion contribute to reducing inflammation by inhibiting NF-κB signaling, a crucial pathway involved in the production of pro-inflammatory mediators. Overactivation of NF-κB can negatively impact intestinal and immunological development in newborns (49).

Raw milk consumption has been linked to reduced systemic inflammation in ruminants, as demonstrated by lower levels of acute phase proteins such haptoglobin and serum amyloid A (35; 43).

Antioxidant effects.

Camel colostrum contains potent antioxidants that protect neonatal tissues from oxidative stress, particularly in the early postnatal period when endogenous antioxidant mechanisms are underdeveloped (Scieszka *et al*., 2025). Lactoferrin, which is abundant in colostrum, binds free iron to inhibit ROS formation through the Fenton reaction while simultaneously acting as a radical scavenger (47,44).

Raw milk contains high levels of antioxidant vitamins (A, C, and E), which work together to neutralize singlet oxygen, superoxide, and peroxyl radicals. Vitamin C, which is found in higher concentrations than mature milk, regenerates oxidized vitamin E, enhancing its antioxidant action (5,10). Superoxide dismutase (SOD), catalase, and glutathione peroxidase are enzymatic antioxidants that convert ROS into less damaging molecules, complementing non-enzymatic antioxidants (49).

The functionality of colostrum proteins can also be evaluated via proteolytic hydrolysis. Several proteolytic enzymes were utilized to hydrolyze camel milk and colostrum proteins, and the degree of hydrolysis was assessed to determine bioactivity and functional potential, as shown in Figure 5-2-4 (50).

Preventive role.

Protects newborns against early infections

One of the most essential functions of camel colostrum is to protect newborn camels against infection early in life, when their immune systems are immature and susceptible to microbial invasion. Ruminants, including camels, are born agammaglobulinemic, which means they do not have any circulating immunoglobulins (36).

These immunoglobulins work by neutralizing bacterial toxins, inhibiting viral attachment, and enabling opsonization, resulting in instant passive protection. For example, IgG molecules wrap harmful bacteria, increasing their clearance by phagocytic cells, while IgA aids to mucosal protection in the gut, restricting early colonization by enteropathogens such as Escherichia coli and Salmonella spp. (43).

In addition to immunoglobulins, camel colostrum contains innate immune proteins such lactoferrin, lysozyme, and lactoperoxidase, which limit microbial development. Lactoferrin binds iron, depriving bacteria of avital nutrient, while lysozyme disrupts bacterial cell walls, and lactoperoxidase generates reactive chemicals with bactericidal effects (48). Collectively, these compounded from a robust, broad-spectrum antibacterial defense that helps compensate for the newborn's undeveloped adaptive immunity.

Prevention of gastrointestinal disorders.

Camel colostrum, rich in immunoglobulins, lactoferrin, lysozyme, growth hormones, and bioactive peptides play key role in preventing gastrointestinal (GI) diseases in newborn camels and other ruminants. Newborn ruminants, with their immature immune systems and intestinal permeability, are particularly susceptible to intestinal infection and diarrhea. Raw colostrum provided both passive immunity and mucosal protection, reducing in the early stage of life (36).

Immunoglobulins (IgG, IgA, and IgM) in camel colostrum bind to pathogens in the intestinal lumen, neutralizing bacterial toxins and virus particles before they can reach the epithelial cells. Secretory IgA is particularly important for mucosal defense, inhibiting the *Escherichia coli, Salmonella spp*., and rotavirus. These antibodies work synergistically with innate proteins such as lactoferrin and lysozyme to suppress microbial growth and enhance gut immunity. (5).

Conclusion:

Camel colostrum is rich in immunoglobulins (IgG, IgA, and IgM), lactoferrin, lysozyme, growth factors, vitamins (A, C, and E), and minerals. Furthermore, the camel colostrum contains antibacterial, antiviral, anti-inflammatory, and antioxidant characteristics that help human health, especially in newborns, immunocompromised people, and those who are

prone to gastrointestinal illnesses. Although the camel colostrum bioactive components improve intestinal barrier integrity, alter immunological responses, and promote gut microbial balance, serving as a natural nutraceutical. Functional foods and dietary supplements made from CC preserve their bioactive qualities, providing preventative and therapeutic benefits. Camel colostrum has shown potential in boosting systemic immunity, lowering oxidative stress, and avoiding infections, demonstrating its importance beyond animal nutrition.

Conflict of interest

There is no conflict of interest in this study as stated by the authors.

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