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A 10-Year Systematic Review (01 May 2015 to 30 April 2025) on the Benefits of Human Colostrum (Early Breast Milk)

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Abstract

The human colostrum is the first milk produced by mothers after childbirth and is crucial in the development of newborns due to its nutritional quality. Further to its role in development, components within colostrum also confer immunoprotection. To further understand the benefits of human colostrum, a systematic review was conducted based on studies conducted within a 10-year period from 1 May 2015 to 30 Apr 2025. A search performed on PubMed revealed 170 articles, and 22 primary articles included for this review. These 22 articles were categorized into 3 themes; namely, (i) development aspects of newborns, (ii) protective effects in newborns, (iii) colostrum's role in formation of gut microbiota in newborns. This review shows that human colostrum is beneficial to newborns, and there is merit in encouraging breastfeeding infants.

Keywords: Human colostrum; Development; Infants; Gut microbiome; Breastfeeding

Introduction

The human colostrum is defined as the first milk produced by mothers after childbirth [1]. It is often described as a thick, yellowish fluid and is crucial in the growth and development of newborns [2]. Human breast milk is widely considered the best form of nutrition to newborns as it contains all the nutrients needed for energy, as well as fundamental biomolecules needed to form tissues for development [3].

To help with the development of the newborn, the human colostrum contains a variety of proteins and unique amino acids which provide essential nutrients for the rapid growth of the neonatal. Studies have shown that human milk typically contains a relatively higher proportion of whey proteins compared to casein proteins [4, 5] with whey proteins making up over 90% of all proteins in breast milk during the first few days of childbirth [6]. Whey proteins, some of which are enzymes and protein binders, are involved in various functions in the development of the newborn [3]. Albeit in small amounts, early breast milk also contains hemopoietic stem cells, which are needed for differentiation into different blood cell types, for functions such as blood clotting and oxygen transport [7].

A prominent protein in colostrum is α-lactalbumin, which makes up an estimated 10 to 20% of total protein in human milk [8]. Alpha-lactalbumin is composed of many essential amino acids which become precursors to various biochemicals involved in developmental signalling pathways. An essential amino acid found in comparatively large amounts in α-lactalbumin is tryptophan, with studies showing that feeding infants with milk formulas containing increased proportion of α-lactalbumin in milk formulas had comparable growth outcomes to breast-fed infants [9, 10]. Tryptophan is also a precursor to serotonin and melatonin, which regulate sleep and synchronization of the wake/sleep cycle in newborns [11] and is essential for brain development [12]. Other examples of proteins present in the colostrum, including Lactoferrin and Haptocarrina, which aid in absorption of iron [13] and vitamin B12 respectively [14].

Beyond its role in growth development of the newborn, α-lactalbumin has also been shown to play an active role in regulating gastrointestinal functions of the newborns' immature gut [6]. Bioactive peptide chains released following digestion of α-lactalbumin form precursors to biomolecules which contribute to gut health and functions. Examples include glutamate and quinolinic acid, which influence intestinal motility and provide immunoprotection [15]. Alpha-lactalbumin also enhances the absorption of trace minerals essential for the growth of newborns, due to the high affinity of α-lactalbumin and their biopeptides to minerals such as zinc and iron [16, 17]. Additionally, α-lactalbumin influences the pH environment of the gastrointestinal tract; thereby, increasing the absorption of these minerals [18].

Components within human colostrum also play a role in immunoprotection of the newborn against pathogenic microorganisms. Studies have shown that antibacterial biopeptide products of processed α-lactalbumin confer immunoprotection against infections caused by pathogenic bacteria; such as *Escherichia coli*, *Staphylococcus aureus*, and *Klebsiella pneumoniae* [19, 20]. These biopeptides also influence the microbiome of the infant's gut by promoting the growth of beneficial bacteria through their prebiotic activities [21]. Other than α-lactalbumin, cells and biochemicals related to the immune system play a role in providing the infant with immunity against infections. The human colostrum and early breast milk have been shown to contain higher amounts of immune cells compared to mature breast milk [7], and promote immunity against harmful pathogens in newborns via transmission of the mother's major immune cells such as B-lymphocytes, T-lymphocytes and their cellular components [22, 23]. In addition to these immune cells, it has also been reported that immunogenic pathways in the intestinal tract of newborns are modulated by oligosaccharides present in the human colostrum [24].

Aside from the benefits conferred to newborns, mothers who had breastfed were observed with lower risk of diseases; such as breast and ovary cancers, diabetes [25] and obesity [26]. Psychologically, mothers also have improved mental health and self-assurance from the strong family dynamics and relationship [27]. To build on the known benefits of human colostrum, this paper aims to provide a review of benefits conferred by human colostrum based on recent studies conducted.

Methods

A PubMed search was performed to identify studies on benefits of human colostrum published within a 10-year period from 1 May 2015 to 30 Apr 2025 using the following search URL: https://pubmed.ncbi.nlm.nih.gov/?term=(human+AND+(colostrum+OR+"early+breast+milk")+AND+benefi*)+NOT+bovine&filter=dates.2015/5/1-2025/4/30. The obtained studies were excluded using the following exclusion criteria: (A) non-free full text articles; (B) articles which were not in English, (C) non-primary articles; (D) articles which were not relating to human breast milk or colostrum; and (E) articles which were not relating to benefits of human colostrum or early breast milk. The remaining articles were included in this systematic review.

Results

The PubMed search revealed 170 articles; of which, 148 articles were excluded. This resulted in 22 primary articles, which were included this systematic review (Figure 1); and themed into three themes (Table 1).

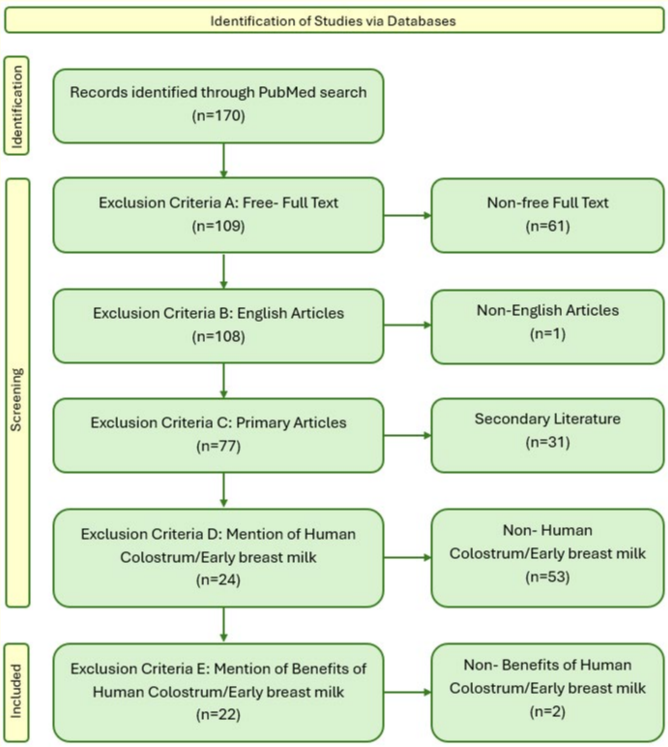

Figure 1: PRISMA flow diagram illustrating the exclusion criteria which were applied to identify the final pool of articles used for the review.

Theme	***Numbers of Articles***	***Percentage of Themes***
Development effects of colostrum	7 [28-34]	32%
Protective effects of colostrum	12 [35-46]	55%
Factors affecting colostrum and its potential effects on infants	3 [47-49]	13%

Table 1: Theme table describing the number and percentage of articles which were categorized into each of the 3 broad themes.

Theme 1: Human colostrum in development of the newborn. The human colostrum contains a variety of biochemical metabolites which are essential for the development and growth of the newborn. It was reported that a variety of free apocarotenoids and apocarotenoid fatty acid esters are present in human colostrum [28]. These compounds are produced from oxidative cleavage of their precursor molecules, a group of biocompounds called carotenoids, and are known to influence the signalling of pathways related to development via regulation of transcriptional activities and gene expression [34].

Antioxidant molecules, notably vitamins A and E, within human colostrum provide protection against oxidative stress during the metabolism of carbohydrates and lipids for energy production. Compared to other stages of human breast milk, colostrum had the highest total antioxidant capacity and lowest total oxidant status, indicating that colostrum had the highest ability to combat oxidative stress [50]. This is crucial in preterm neonates, who are prone to conditions such as Bronchopulmonary Dysplasia (BPD) and necrotizing enterocolitis (NEC) arising from accumulation of reactive oxygen species during metabolism. In the case of BPD, Merino-Hernandez and her team [51] observed that colostrum provides a protective effect to newborns who were at risk of BPD, even if the milk does not originate from the newborns' biological mothers. No differences in incidence rates of BDP were observed between the groups of newborn feds with their own mother's breastmilk or milk containing predominantly pasteurized donor milk.

Endogenous protein peptides involved in preadipocyte proliferation and support of fat cell formation during the development of the newborn were also observed in the colostrum [30]. Interestingly, varied profiles of these protein peptides were produced by mothers who delivered macrosomic and non-macrosomic infants, suggesting that composition of colostrum could potentially be influenced by the newborn's development within the mother's womb. In a similar vein, colostrum sampled from mothers with infants who were either born large-for-gestational-age and intrauterine growth restricted had a higher composition of nutrients such as lactose, choline and citric acid compared to mothers who had given birth to infants with appropriate weight [31]. The variation in colostrum profiles suggests that the nutritional aspects of colostrum are tailored to the infant's growth conditions in order to support development.

Activin A, a protein which belongs to the transforming growth factor beta superfamily, was found in higher concentrations in colostrum compared to transitional and mature breast milk [32], promoting the infant's development of the central and peripheral nervous systems during the early stages of their lives. Activin A is involved in neuroprotection within the central nervous system and protects specific populations of neurons in the brain against damage. In addition, this protein acts as a survival factor in nerve tissues, neurogenic clonal cell lines involved in cell differentiation and neurogenesis, as well as various neurons in the retina and midbrain.

Human colostrum also positively influences blood pressure, and potentially long-term cardiovascular health. Miliku et al. [34] reported that newborns fed with human colostrum and breast milk, including those limited to their first few days of life, were observed with lower blood pressure when they were three years of age. While the exact mechanism on how colostrum improves cardiovascular health has to be further studied, stem cells and vascular endothelial growth factors present in colostrum could potentially help increase the elasticity of blood vessels and improve blood flow [52] while long chain polyunsaturated fatty acids in colostrum also contribute to formation of the vascular endothelium [53].

Theme 2: Protective effects of colostrum in newborns. Besides supporting development, human colostrum also confers immunoprotection to the newborn via different immune related pathways. Components within human colostrum influence the function of the intestinal mucosal barrier, preventing harmful microorganisms and toxins from entering the bloodstream via the intestinal tract. In a study using a healthy pediatric human enteroid (intestinal epithelial cells) model, Noel et al. [36] observed that the cell monolayer had improved epithelial barrier function such as reduced ion permeability and enhanced tight junction function when exposed to human colostrum, when compared to non-treated monolayers. In addition, cells which were exposed to human colostrum also elicited an increase in amounts of α-defensin, an antimicrobial peptide which plays a crucial role in enteric immunity [54], in addition to the modulation of cytokine production. Translocation of maternal IgA antibodies to the epithelial surfaces, together with elevated secretion of its receptor were also observed, providing further protection against harmful pathogens.

The enhanced function of the gut barrier resulting from colostrum was also observed by Rodriguez-Camejo et al. [37] when in-vitro gut epithelial cells were exposed to raw or pasteurized colostrum compared to mature human milk. Even though both colostrum and mature milk elevated proliferation of cells, a stronger immune response to lipopolysaccharide, a signalling molecule in bacteria which causes inflammation, was observed in cells exposed to raw colostrum compared to mature milk. Importantly, only cells exposed to raw colostrum elicited a response which interfered with E. coli and epithelial cell adhesion, possibly due to the neutralizing effect of latent antibodies within raw colostrum. The absence of immunoprotective effects against lipopolysaccharide in cells treated with pasteurized colostrum could be due to the influence of heat on the antibodies during the pasteurization process, which suggests the importance of raw colostrum in providing antibody-induced immunity.

An important antibody involved in the immunity of newborns is secretory immunoglobulin A (sIgA), which binds to harmful pathogens and biomolecules in the intestinal tract, thereby inhibiting their binding to epithelial cells. When studying the stools of newborns who were fed with colostrum, fecal sIgA was found in higher concentrations as compared to infants who were fed with formula milk

[38], showing that IgA-related immunity is conferred to the newborn via transfer of sIgA present in colostrum.

Chemokines and their receptors also play a crucial role in the regulation of immune pathways, thereby influencing the immunological functions in the newborn. Polat et al. [39] studied samples of human milk between human colostrum and mature human milk, and observed higher levels of Interleukin-8 (IL-8) in colostrum, even though the receptors of IL-8, CXCR-1 and CXCR-2 were found in similar concentrations. This suggests that colostrum is important in providing newborns with IL-8-induced immunity via breastfeeding, where IL-8 interacts and recruits with neutrophils in the event of an infection.

Martin-Alverez et al. [40] demonstrated that preterm neonates who were administered with mother's colostrum oropharyngeally for the first months of their lives had lower amounts of pro-inflammatory cytokines and greater expression of anti-inflammatory cytokines in their blood plasma. This showed that colostrum helped in modulating the inflammatory responses in preterms, which is especially important in preterm births as systemic inflammation could lead to disease morbidity even in the absence of infections. Due to its protective effects, it was also observed that oropharyngeal administration of colostrum in preterm infants could improve clinical outcomes, such as increased feeding tolerance and decreased time needed to reach full feeding orally [41]. Oropharyngeal administration of colostrum to underweight infants can also lower the incidence of NEC and sepsis in infants [42].

Glycoproteins present in human milk, for instance a-1-acid glycoprotein, are another component which contributes to immune responses due to their anti-inflammatory properties. Orczyk-Pawiłowicz et al. [35] observed that a-1-acid glycoproteins present in the human colostrum contain O-linked oligosaccharides modifications, sialylated and asialylated T as well as Tn antigens, which are not present in the glycoproteins within the mother's plasma. The glycoforms profiles differed between colostrum and mature milk, with the sialylated glycoforms of T antigen most abundant in colostrum. These modifications provide the newborn with innate immunity against pathogens, such as sialic acid-depending rotaviruses, by inhibiting the binding of these pathogens to their intended targets; thereby, providing a prebiotic effect.

In addition to O-linked glycan modifications on glycoproteins, the presence of N-linked glycans is also reported on proteins present within the colostrum, with a high proportion of N-linked glycans fucosylated in colostrum [43]. Further to their antibacterial and antiviral effects, glycoproteins containing N-linked oligosaccharides modifications play a role in immune system regulation. In particular, fucosylated N-linked glycans enhance the affinity of IgG antibodies and influence signalling pathways in the immune system [55].

Zika and Usutu viruses are additional viruses which colostrum protects the newborn against. When tested in vitro, antiviral activity was observed in cells which were exposed to colostrum, by inhibiting binding of these viruses to the host cells via colostrum-derived extracellular vesicles and glycosaminoglycans [44]. Human Immunodeficiency Virus (HIV) is another virus which colostrum provides protection against. Jeffries et al. [46] reported that immunoglobulin G (IgG) antibodies produced by B cells present in colostrum play a role in protecting newborns from HIV infection during breastfeeding. These HIV envelope-specific antibodies could prevent HIV acquisition in the infant by inhibiting binding of virions to the intestinal epithelial cells and preventing transfer of virion genetic material to targeted CD4+ cells. These antibodies also act by neutralizing the virions during mucosal infection.

In mothers infected with COVID-19, the protein expression profiles of colostrum confer the newborn with immunity against the SARS-CoV-2 virus. Compared to colostrum of mothers who had been infected with COVID-19 previously, proteins involved in immune pathways and protein trafficking, along with antibodies components, were increased in milk of mothers with active infection [45]. Possible protective effects were also observed in the colostrum of mothers who had recovered from previous COVID-19 infection, albeit to a lesser extent. In such cases, overexpression of these proteins related to leukocyte-mediated immunity and humoral immunity, coupled with secretion of exosomes, facilitates development of COVID-19 immunity in the infant.

Theme 3: Factors affecting colostrum and its potential effects on infants. Besides modulating immunogenic pathways in the gut, oligosaccharides in human colostrum also play an important role in development of gut microbiota composition in the infant. Aakko et al. [48] showed that the content and profile of oligosaccharides present within each mother's colostrum influences the microbiota composition present within the milk. The association between certain groups of oligosaccharides with certain types of bacteria results in this variation of microbiota composition, which in turn influences the developing gut microbiota of the newborn. For example, sialylated oligosaccharides were found to be positively associated with *Bifidobacterium breve*, while fucosylated HMOs were observed to be associated with *Akkermansia muciniphila*. Both of these bacteria species are probiotics which inhibit intestinal inflammation and play a role in modulating intestinal immune responses [56, 57].

The varying species of bacteria present in colostrum colonize the gut of the newborn, forming the microbiome, some of which act as probiotics beneficial for the development of the infant's gut as well as providing immunity against infections. Various factors may affect the composition of microflora bacteria found in the colostrum of mothers. For example, higher amounts of beneficial bacteria species, such as *Lactobacilli* and *Bifidobacteria*, were observed in colostrum of mothers administered with probiotics supplement during the perinatal period of pregnancy. Mothers who delivered their child vaginally also had higher amounts of these bacteria species in their colostrum [49].

It may also be possible that environmental and genetic factors influence the microflora makeup of colostrum. In a study involving Pakistani mothers, four novel strains of *Lactobacillus* with probiotic potential were found in their colostrum. These strains were observed to be protective against pathogens and may help in reducing plasma cholesterol and presence of conjugated intestinal bile salts due to their bile salt hydrolase activity [47].

Discussion

The benefits of colostrum to newborns cannot be understated due to its nutritional and protective aspects, supporting development and conferring immunoprotection in the newborn during the early stages of their lives. In addition, biomolecules and microflora present in the colostrum are transferred from the mother to the infant via breastfeeding, promoting the colonisation of beneficial bacteria species during the early development of the gut microbiota. Newborns can also acquire immunity against viruses such as COVID-19 and HIV via breastfeeding, if their mothers had been infected with these viruses previously. Breastfeeding is also associated with a lower risk of chronic diseases in infants, such as lower blood pressure and better cardiovascular health. These benefits highlight the importance of breastfeeding, especially in preterm or malnutritioned babies, where better clinical outcomes were reported after these groups of infants were fed with breast milk [41, 42].

Due to the benefits of human colostrum, the World Health Organization has recommended that newborns should be (i) initiated with breastfeeding within the first hour of birth; (ii) fed exclusively with breast milk for the first 6 months of their lives and; (iii) continued breastfeeding up to 2 years of age, complimented with solid foods to meet nutritional needs. However, the practice of breastfeeding for infants is not common, with less than half of infants globally receiving breast milk based on the WHO's recommendations. Crucially, the prevalence of exclusive breastfeeding in infants under 6 months remains low at about 40% [58] despite its benefits in reducing morbidity of respiratory and gastrointestinal infections [59, 60]. This falls short of WHO's target of having at least 50% of infants exclusively during the first six months of their life by 2025.

The uptake of breastfeeding is especially important in low- and middle-income countries, where it has been reported that breastfeeding is linked to a lower rate of malnutrition [61] and mortality in infants due to its protective effects against infections and diseases [25]. While the rate of breastfeeding has seen improvements over the years in developing countries, in particular West and Central Africa [62], factors such as improving accessibility and enhancement of healthcare services, introducing community support and maternity protection policies can greatly help in encouraging breastfeeding practices [63].

Across the world, determinants such as the skin-to-skin contact time between newborns and mothers after birth [64], Cesarean section birth, availability of infant milk formulas as substitutes, perceived insufficient breast milk supply [63], as well as inconvenience or/and fatigue of mothers [65] can adversely influence breastfeeding practices. To tackle such challenges, education on the benefits of breastfeeding and interventions at hospitals, such as allowing contact time between mothers and newborns after birth, should be introduced to improve breastfeeding practices. This would enable progression towards achieving WHO's target of at least 70% of infants under 6 months being exclusively breastfed by 2030.

The profile of colostrum from different mothers can vary due to the mode of child delivery, environment, genetics and medical history. In addition to these factors, the use of dietary supplements during perinatal and lactation periods can alter the composition of breast milk. For instance, probiotic supplements can increase the levels of cytokines, antibodies and growth factors in colostrum, and may be beneficial towards gastrointestinal development in infants [66]. Another example is the increase of retinol levels in colostrum following administration of vitamin A supplements to mothers with vitamin A deficiencies [67], thereby increasing antioxidant capacity during development of the newborn. This highlights the potential of using supplements in enhancing the quality of colostrum, especially in regions where mothers are deficient in certain vitamin deficiencies or following high-risk pregnancy, where a lower concentration of antioxidants is observed in the colostrum [68]. This would enable the infants to obtain all their nutritional needs to reduce the risk of disease morbidity or even infant mortality.

Despite the differences in protein and microflora profiles of colostrum across mothers, donor human milk may be a good alternative in cases where the mother's milk is not available or insufficient due to environmental and genetic variations [69]. Crucially, it is reported that administration of donor milk in preterm infants led to positive clinical outcome [70], highlighting the potential of donor human milk in development of preterm infants. While the use of donor human milk on healthy infants is not well-studied, possible neurodevelopmental and immuno-related benefits could be conferred to this group of infants [71].

A less preferred alternative to human colostrum and breast milk is infant milk formula (IMF), in the event when the mother's colostrum or donor human milk is not available. Due to the unique composition of colostrum, devising infant milk formula to mimic the different aspects of colostrum remains a topic of research. Even though IMF may provide newborns with fundamental nutrients needed for development in the early stages of their lives through the addition of proteins such as α-lactalbumin [72], there is difficulty in providing infants with immunoprotection as biomolecules involved in regulation and activation of the immune pathway are not conferred to the infant. In recent years, prebiotics and probiotics are included in IMF to boost gut development in newborns, and facilitate colonisation of beneficial gut microflora [73]. Despite the advancement in IMF, further studies would still need to be done before IMF can be considered a suitable substitute for human breast milk.

The use of human colostrum in therapy is a further potential application which should be explored further. As breast milk can elevate intestinal permeability, using breast milk as a vehicle in the delivery of liposome-facilitated therapy can enable for a more effective targeted delivery system to transport therapeutic agents (such as mRNA, proteins, and other macromolecules) across the intestinal barrier more efficiently [74]. Stem cells isolated from breast milk are also reported to improve recovery in mice with spinal cord injury, suggesting the therapeutic potential of breast milk stem cells in spinal cord injuries [75]. While the promising outcomes of these studies demonstrate the therapeutic potential of breast milk, further studies would need to be carried out before being applied in colostrum.

Conclusion

Human colostrum provides development and immune-related benefits to the newborn. In addition, biomolecules within the colostrum promote colonisation of beneficial microflora in the gut, forming the gut microbiota which influences physiological processes. While donor human milk and infant milk formula can be alternatives, human colostrum remains the best form of nutrition for infants during the first months of their lives. As such, breastfeeding should be encouraged.

Supplementary Materials

Supplementary materials can be downloaded from https://bit.ly/Colostrum_SR.

Conflict of Interest

The authors declare no conflict of interest.

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