

Nutrition of Breast Milk Components in Humans

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Abstract

Human milk contains multiple biological components that maintain intestinal mucosal homeostasis and regulate neonatal small intestinal maturation. Milk lipids contributes to 50 - 60% calories for infant's growth and energy requirements and provides a good supply of long-chain polyunsaturated fatty acids to impact the behavior and learning. The digested components of lipids can strongly inhibit microorganisms in the stomach and small intestine of breast-fed infants. Protein in the milk supports rapidly growing breast-fed infants by providing essential amino acids. The concentration of protein during lactation is higher in early lactation, lower at 3 - 4 months of lactation and stable from 6 months toward the end of lactation. Human milk proteins play various physiological roles in nutrient absorption, pathogen inhibition, gut microflora stimulation and gut development. The main carbohydrate in human milk is lactose which provides high energy requirement for the human brain. Oligosaccharides (HMO) in human milk has a remarkable stability against the hydrolysis and reaches the colon to offer protection for neonates by preventing the adhesion or invasion of pathogenic bacteria into the intestinal epithelium. Minerals and vitamins, not directly involved in energy metabolism, are still very important to support the growth and development of infants. As the only food source, breast milk plays a vital role in the health and development of infants.

Keywords: Breast Milk; Lipids; Whey Proteins; Oligosaccharides

Biological Components of Breast Milk

Infant formulas are continually improved and provide better nutrition and higher quality than earlier, but they still do not reach the quality and function of human milk. It is reasonable to suppose that milk of each species is well adapted to the particular needs of that neonate due to its developmental needs. The major base of most infant formulas is cow's milk, which lacks many biologically active components present in breast milk [1]. It is likely that evolution has provided the naturally designed food - breast milk, to supply enough nutrients for human newborns [2].

The dominant form of milk lipids is triglycerides (98%), which contribute around 50-60% calories for infant's growth and energy requirements. Besides triglycerides, phospholipids (0.8%), cholesterol (0.5%) and free fatty acids are parts of milk components [3]. Although saturated fatty acids are the major fraction of milk fat, it also provides a good supply of long-chain polyunsaturated fatty acids (PUFA) at 1.1 - 1.8% [4,5]. The specific distribution of fatty acids in PUFA forms essential fatty acids, including linoleic acid (18:2n-6) and α -linolenic acid (18:3n-3), which cannot be synthesized de novo by humans, but play important roles in behavior and learning, for example, linoleic acid derived fatty acids are structural components in the brain and α -linolenic acid-derived ones, such as DHA (docosahexaenoic acid), are precursors of hydroxyl fatty acid with biological activities [6,7]. Due to its insolubility, milk lipids are coated by special membrane proteins and bilayer phospholipids to form globules, designated as milk fat globule membranes (MFGM) with a size range between 1 - 10 μ m [8,9]. Lipids can be digested by lingual and gastric lipases into free fatty acids and monoglycerides, which, at the concentrations in the stomach and small intestine of breast-fed infants, can strongly inhibit microorganisms, such as viruses, some bacteria and protozoans [3,10]. A recent clinical study shows that bovine MFGM added into formula reduced the risk of acute otitis media in infants [11].

Proteins comprise about 0.9% of milk components in humans, which supports rapidly growing breast-fed infants by providing essential amino acids. The concentration of protein during lactation is not consistent, being higher in early lactation (14 - 16 g/L), lower at 3 - 4 months (8 - 10 g/L) of lactation, and stable (7 - 8 g/L) from 6 months toward the end of lactation [12-14]. Mucins, caseins and whey proteins are three components of milk proteins according to their different locations [15]. Mucins are only a small part of total proteins in milk and are part of MFGM together with lipids. They have been shown to inhibit the adhesion of S-fimbriated *Escherichia coli* to buccal epithelial cells [16]. Caseins provide about 20% of protein in human milk, from which β -casein is the major component and κ -casein is the minor component [14]. Whey proteins are the dominant part in milk and the general ratio of whey and casein is 60:40, but it changes during the different stages of lactation. Human milk proteins play various physiological roles in nutrient absorption (bile salt stimulated lipase, amylase, α_1 -antitrypsin, β -casein, lactoferrin, haptocorrin, folate-binding protein, α -lactalbumin and insulin-like growth factor-binding proteins); pathogen inhibition (immunoglobulins, lactoferrin, lysozyme, κ -casein, lactoperoxidase and α -lactalbumin); gut microflora stimulation (lactoferrin and secretory IgA); immunocompetence (cytokines and lactoferrin); and gut development (growth factors) [17]. Infant formulas are based on cow milk and have very different protein composition compared to human milk. The major fraction of whey protein in cow milk is β -lactoglobulin, which is not found in human milk. Human milk has a high concentration of lactoferrin whereas cow's milk contains much less lactoferrin [1].

Lactose is the main carbohydrate in human milk and its concentration is higher in mid-lactation than in early and late lactation [18]. It can be hydrolyzed to glucose and galactose for absorption and transport [19]. The high level of lactose in human milk, compared to other species, is correlated with the high-energy requirement of the human brain [20]. In addition to providing energy for infants, earlier studies found that lactose helps the absorption of calcium and magnesium in the intestine [21].

Oligosaccharides (HMO) are highly abundant in human milk and exceed the total amount of protein [22]. Their concentration is around 20 g/L in colostrum and 12 to 14 g/L in mature milk, while only 1 g/L oligosaccharides is found in mature cow milk [23]. They have been found to offer protection for neonates by preventing the adhesion or invasion of pathogenic bacteria into the intestinal epithelium and promote the growth of *Bifidobacterium bifidum* [24,25], which is supposed to be beneficial for the infant. Therefore, milk oligosaccharides have to resist digestion in the stomach and reach the upper gastrointestinal tract in their intact form. *In vitro* studies shows that all neutral and acidic fractions of human milk oligosaccharides have a remarkable stability against hydrolysis by secreted pancreatic and mucosa-bound glycosidase [25]. The investigation on the fate of HMO in breast fed infants find that the profile of oligosaccharides in urine and feces mimics that of milk HMO profiles, while it does not work in the same way for formula-fed infants [26,27]. These findings demonstrate that although some HMO could be absorbed intact in the small intestine, the majority of them reach the colon unchanged and impact on bacteria populations.

The three macronutrients carbohydrates, fats and proteins, provide energy to satisfy the requirements for infant rapid growth, but other nutrients in human milk, such as minerals and vitamins, that although not directly involved in energy metabolism, they are still very important to support the growth and development of infants. The level of iron, zinc and copper in human milk is higher than that in bovine milk, but lower than that in infant formulas [28,29]. Calcium and phosphate are important for bone health and have been found to maintain the stability of casein micelles [30].

Conclusion

It is evident that breast milk not only contains vital nutrients but also many bioactive components. As the only food source, it plays a vital role in the health and development of infants. This review characterizes the information for our understanding of the functional advantages conferred by breast milk to the newborn infant and puts forward directions for infant feeding.

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