Review

Cow vs goat milk in infant's nutrition: What is better?

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Infant formula is the main source of nutrition for babies who cannot be fed human milk, which is the best source of feed for them. Modern trends spreading through social media are questioning the suitability of commercial infant formula for children. The growth in cow's milk protein allergies among the population and the increase in the percentage of premature infants with low birth weight are focusing attention on cow's milk-based infant formula substitutes. Recently, goat's milk-based infant formulas have become available. A comparison of the composition requirements of infant formula and premature infant formula shows the need to modify both milks for use in infant formula. Differences in milk composition and functional properties can compensate for technological and nutritional differences. The lower allergenicity of goat milk, smaller fat globules and softer curd can cause a different body reaction in goat's milk based infant formula than cow's milk based infant formula. The choice of commercial infant formula should not be made based on the reactions of other children but should be selected taking into account the individual's ability to grow and develop appropriately during the use of particular infant formula.

Keywords: infant nutrition, infant formula, milk

1 Introduction

After the birth of the baby, it is necessary to continue caring for the baby in the most appropriate way for it. According to WHO (2018) the best source of nutrition for infants is exclusively breastfeeding. If breastfeeding is not reasonably possible, there is a commercial infant formula (IF) which is manufactured to imitate human milk (PROSSER, 2021). The IF must meet nutritional requirements and should cause normal growth and development in fed infants (Koletzko et al., 2005; Regulation Commision (EU) 609/2013).

IF is traditionally product based on animal milk, mostly cow's and/or other ingredients suitable for feeding infants, without imposing a metabolic or other physiological burden on their organism. That is only in such amounts that serve to meet nutritional needs, provide benefits to infants or are necessary from a technological point of view. To demonstrate IF suitability it is necessary to scientifically demonstrate the nutritional safety and its adequacy for normal growth and development of infants (Koletzko et al., 2005; Koletzko & Shamir, 2006).

Preterm infants with low birth weight are not capable to being oral feeding until the age 33 weeks after conception due to immaturity of the gastric tract. The best source of nutrition for them is human preterm milk (HPM), which lacks protein and minerals and needs to be fortified. However, due to low availability, HPM is unreliable and there is need to use IF. Preterm low birth weight IF has been designed to meet the special nutritional needs of preterm infants, which are different from those who were born at term (Klein et al., 2002).

Consumption of IF is conditional on trends spreading via social media for 19% of parents worldwide. Blogs are a source of parenting information for an estimated 35% of millennial mothers in North America. Information on online platforms is concerning trends which are in recent time-sharing warnings about the use of commercially

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made IF (Davis et al., 2020). There has been a significant increase in consumer demand for cow's milk based IF (CIF) alternatives (Gallier et al., 2020). Initially, there were concerns based on the low adequacy of evidence on nutritional properties of goat milk protein in IF (EFSA, 2014). Therefore, the aim of this work is to compare the quality of CIF with goat's milk based IF (GIF) and briefly clarify the differences that are often misinterpreted on social medias.

2 Infant formula composition requirements

It is very necessary to modify the animal milk for feeding infants. Unmodified milk could increase methionine and phenylalanine levels in infants and could cause incorrect screening results for metabolic disorders in new-borns. What´s more, there is a risk of electrolyte imbalance and deficiencies in vitamins (folate, B_{12}) and iron. Cow's and goat's milk has very high content of minerals and protein which can cause serious health issues like acute stroke, metabolic acidosis, and dehydration (Prosser, 2021).

The composition of goat's milk differs from cow's milk in ingredients that affect important digestibility properties (Gallier et al., 2020).

2.1 Energy

In case of insufficient energy intake, protein oxidation occurs to supplement energy instead of brain development (Cormack et al., 2019). Therefore, malnutrition is associated with a serious neurological impact on preterm infants (de Nardo et al., 2022). Those extremely preterm infants (EPI) who have inadequate energy intake in first month after birth has very high risk of suffering severe retinopathy of prematurity (ROP) (Sjöström et al., 2016). On the other hand, higher energy intake shows reduction of risk of this disease and bronchopulmonary dysplasia as well (Klevebro et al., 2019). The energy content is also crucial for the infant due to its relationship with fluid balance. If the energy content is low, the infant needs a large amount to meet his needs, on the other hand, too high energy content reduces fluid intake (Klein, 2004).

2.2 Protein

Human milk much differs from cow milk in casein/whey ratio 80/20 to 50/50 in human and 18/82 in cow milk. Due to the different amino acid profile of casein and whey protein, the amino acid concentration in IF must not be lower than that in human milk (Klein, 2004; MARTIN et al., 2016). Higher protein content can cause dehydration, while lower amounts are not sufficient for proper growth (Davis et al., 2020). In goat's milk, there is a much lower concentration of α_{s1}-casein, which is considered the main milk allergen, compared to cow's milk (Prosser, 2021). During digestion cow's and goat's milk protein in infant formula act differently. Both are coagulating with similar speed, but goat protein is forming smaller protein aggregates which is leading to faster digestion. It seems to be affected by different casein micelles composition (Ye et al., 2019). According to He et al. (2021) protein in GIF coagulate in more open structure and lower firmness than CIF which allows more effective digestion of goat milk proteins. Unlike YE et al. (2019) in GIF they observed slightly bigger aggregates than CIF. Decreasing the size of particles from pH 4.5 in GIF compared with pH 3.5 shows differences in speed of initial digestion and conclude that GIF and CIF protein digestion is different from human milk physicochemical behaviour. Maathius et al. (2017) found that the quality of protein between human milk, CIF and CIF are not different, but the speed of protein digestion in GIF is more like human milk.

2.3 Fat

There is a practice of using skimmed milk with the subsequent addition of vegetable oils or milk fat to meet the concentration of fat requirements. Preference of vegetable oils is supported by its lower price, higher level of mono- and poly- unsaturated fatty acids and absence of dioxins contamination (Hageman, et al., 2019). The problem with the vegetable oil is that it does not provide fatty acid content in amounts that are similar to human milk. They could contain contaminants and undesirable fatty acid esters from the oil refining processes. For that reason, milk fat is preferred for IF, especially in Europe (Gallier, et al., 2020; Klein, 2004). Using whole goat's milk is more similar in fatty acids content and the IF has much complex structure without need of using plant oil. Low levels of α_{s1}-casein in goat milk are associated with higher content of unsaturated fatty acids (Gallier et al., 2020). Fat is present in milk in form of fat globules which has in goat milk smaller diameter (1.5 µm) than cow's one (2.5–3.5 µm) and has higher percentage of globules lesser than 1.5 µm, which is 28% compared to 10% in cow milk. The fat globule consists of core formed out of nonpolar triglycerides and surface-active material – the milk fat globule membrane (MFGM). In this membrane are present proteomes which are under focus of studies. It was described 776 MFGM proteins in goat's and cow's MFGM, out of which were 166 shared and 427 special for cow's milk and 183 for goat's milk. About 21% of goat's MFGM are related to metabolic processes whereas almost half of cow's MFGM proteins are related to pathways associated with disease (Sun et al., 2019; Manoni, et al., 2020). (Lad et al., 2017) Goat milk fat has in comparison with cow's milk fat two to three times higher content of medium chain fatty acids C6:0, C8:0 and C10:0 which are

Table 1 Comparation requirements for IF and preterm IF with cows and goats milk composition per 100 g

Component per 100 g	IF requirements (max–min)		CM	GM	IF		Preterm IF		Sources
	interm IF	preterm IF			CM	GM	CM	GM	
Energy (kJ)	251–292.9	272–355.6	262	270	yes	yes	no	no	1–3
Proteins (g)	1.2–2	1.5–2.2	3.3	3.4	no	no	no	no	1–3
Total fat (g)	2.9–4	4.4–5.7	3.3	3.9	yes	yes	no	no	1–3
Linoleic acid (g)	0.2–0.8	0.3–1.4	0.3	0.3	yes	yes	yes	yes	1; 2; 4
α-linolenic acid (mg)	33–NS	77–228	19.8	9.8	no	no	no	no	1; 2; 4
Ratio linoleic/α-linolenic acids	5 : 1–15 : 1	6 : 1–16 : 1	15 : 1	31 : 1	yes	no	yes	no	1; 2; 4
Lauric + myristic acids (% of fat)	NS-13.2	NS–24	16.8	12	no	yes	yes	yes	1; 2; 4
Trans fatty acids (% of fat)	NS-2	min. amount feasible	1.4	1.2	yes	yes	yes	yes	1–3
Erucic acid (% of fat)	NS* 0.7	–	0.09	0.07	yes	yes	yes	yes	1; 2; 4
Total carbohydrates (g)	5.9–9.24	6.34–10.23	5	4.4	no	no	no	no	1–3
Vitamin A (µg RE)	39.6–118.8	134.64–250.8	37	48	no	yes	no	no	1–3
Vitamin D_3 (µg)	0.7–1.65	1.2–4.5	0.2	0.1	no	no	no	no	1–3
Vitamin E (mg α-TE)	0.12–1.2	based on PUFA content	0.08	0.05	no	no	no	no	1–3
Thiamine (µg)	39.6–198	19.8–165	40	30	yes	no	yes	yes	1–3
Riboflavin (µg)	52.8–264	52.8–409.2	200	130	yes	yes	yes	yes	1–3
Niacin (µg)	198–990	363–3,300	130	240	no	yes	no	yes	1–3
Vitamin B_6 (µg)	23.1–115.5	19.8–165	40	50	yes	yes	yes	yes	1–3
Vitamin B_{12} (µg)	0.1–0.3	0.05–0.46	0.51	0.07	no	no	no	yes	1–3
Pantothenic acid (µg)	264–1320	198–1254	400	300	yes	yes	yes	yes	1–3
Vitamin C (mg)	6.6–19.8	5.5–24.4	1	1.1	no	no	no	no	1–3
Biotin (µg)	1–5	0.7–24.4	2	2.5	yes	yes	yes	yes	1–3
Iron (mg)	0.2–0.9	1.1–2	0.1	0.3	no	yes	no	no	1–3
Calcium (mg)	33–92.4	81.2–122.1	112	118	no	no	yes	yes	1–3
Phosphorus (mg)	16.5–59.4	54.1–72	91	100.4	yes	yes	yes	yes	1–3
Ratio calcium/phosphorus	1 : 1–2 : 1	1.7 : 1–2 : 1	1.2 : 1	1.8 : 1	yes	yes	no	yes	1–3
Magnesium (mg)	3.3–9.9	4.5–11.2	11	14	no	no	no	no	1–3
Sodium (mg)	13.2–39.6	25.7–41.6	42	44	no	no	no	no	1–3
Potassium (mg)	39.6–105.6	39.6–105.6	145	202	no	no	no	no	1–3
Manganese (µg)	0.7–33	4.2–16.5	8	18	yes	yes	yes	no	1–3
Selenium (µg)	0.7–5.94	1.2–3.3	1.8	1.1	yes	yes	yes	no	1–3
Copper (µg)	23.1–52.8	66–165	17	40	no	yes	no	no	1; 2; 5
Zinc (mg)	0.3–1	0.7–1	0.4	0.3	yes	yes	yes	no	1–3

Sources: 1. Koletzko et al., 2005; 2. Klein, 2004; 3. Muehlhoff et al., 2013; 4. Wang, et al., 2020; 5. Soliman, 2005
IF – infant formula; CM – cow milk; GM – goat milk; RE – retinol equivalent (1 µg = 3.33 IU vitamin A); α – TE – α-tocopherol equivalent; NS – not specified; PUFA – polyunsaturated fatty acid

absorbed in gastrointestinal tract more easily what make goat's milk fat digestibility better than cows. In order to increase digestion, infant formulae are adjusted by medium-chain fatty acids (C6:0 to C12:0) by 8.62–10.49% On the other hand, cow's milk fat has higher amount of C16:0 which makes one quarter of all human milk fatty acids (Gallier et al., 2020; Ramiro-Cortio et al., 2020; Chen et al., 2022).

2.4 Carbohydrates

Human breast milk shows high number of complex oligosaccharides which seems to have vital importance in infant development as prebiotics for bacteria producing short-chain fatty acids with crucial impact on guts health, pathogen inhibitors and immune modulators (van Leeuwen et al., 2020; Walsh, et al., 2020). Goat's milk oligosaccharides (MOS) has slightly higher structure variability than cow's milk MOS. Studies described that goat's milk contains 250–300 mg.L^{-1} of MOS which is multiple times more than 30–60 mg.l^{-1} in cow's milk (van Leeuwen et al., 2020). What's more the goat's MOS among ruminants most similar to human's what is beneficial for infants with inflammatory bowel disease and can be used to treat these problems (Lad et al., 2017; Prosser, 2021). Fucosylated and sialylated oligosaccharides are the most prevalent in goat's milk as well as in humans. It has anti-infection properties with very high capability of resistance to diarrhoea toxins produced by *Campylobacter* and *E. coli* (Leong et al., 2019). Lactose is the preferred carbohydrate in formulas for infants (EFSA, 2014). Utilization of vitamin D as well as intestinal absorption of calcium, phosphorus and magnesium is happening with presence of lactose (Muelhoff et al., 2013). IF based on goat's and cow's milk exhibit similar amount of lactose when additional sugar was not used as source of energy. GIF in comparation with CIF shows significantly lower levels of concentration of Nε-(carboxymethyl)lysine (CML), which is an indicator of glycation. Statistically significant higher amount of CML in GIF than in CIF were observed in IF with longer shelf life (Xie et al., 2023).

2.5 Minerals and vitamins

Goat's milk is higher in content of minerals, especially calcium and phosphorus. Although goat's milk needs to be fortified. Modified goat's milk with minerals and vitamins has similar efficacy to fortified cow's milk, what made them equal for in IF from this perspective. Goat's milk is favoured to cow's milk in antioxidants especially vitamin C. It is also a good source of vitamin A (Lad et al., 2017; Prosser, 2021). The IF is affected by interaction of components which occurs during homogenization and pasteurization. This interaction shows in redistribution of minerals (especially Ca, P, Mg, Zn and Fe) and nitrogen. This resulting in occurrence of fat globules in pellet fraction of protein and bondage of proteins to the fat globules (Hendricks, et al., 2001). The casein content effects dialyzability of Fe and Zn, whereas whey rich IF is not prone to component interaction and are increasing mineral, Fe and Zn availability (Hendricks and Guo, 2014). Deficiency of folic acid and vitamin B_{12} is a major concern in goat's milk products for infants, as it leads to megaloblastic anaemia in infants on an exclusively goat's milk diet (Green and Mitra, 2017).

3 Milk protein allergies

Human milk contains bioactive components with allergy-protection effect (Kao et al., 2020). According to literature, it is widely believed that goat's milk is hypoallergenic or can be used as substitution for infants suffering from cow's milks allergies, and to treat patients suffering from asthma, eczema, abdominal pain, hay fever and many others (Nayik et al., 2022) According to Ferry et al. (2023), infants who were fed on GIF has 33% lower occurrence of atopic dermatitis than those who were fed on CIF.

Allergy to cow's milk is reported more often than an allergy to goat's milk. Due to lower level of α_{s1}-casein in goat milk, it is considered to be less allergic than cow milk. Although lower cross-reactivity has been observed in goat's milk low in α_{s1}-casein in children with cow's milk allergy, there is evidence of the absence of an allergic reaction to goat's milk in the absence of α_{s1}-casein. However, it is not recommended to consider goat milk hypoallergic (Ballabio et al., 2011; Prosser, 2021). For manufacturing IF is preferred milk from goats with low α_{s1}-casein. It is also more suitable for infant's gastric tract because it is forming softer curds (Gallier et al., 2020). Valid alternatives for breastfeeding are amino-acid formula and extensively hydrolysed formula (Arasi, Cafarotti, & Fiocchi, 2022). Park and Haenline (2021) described harmful effect of bovine A1 variant of β-casein since it produces beta-casomorphin7 by hydrolyzation of peptide in gastrointestinal digestion whereas A2 variant is recommended for not producing symptoms of lactose intolerance.

4 Conclusions

The nutritional requirements on food of babies can satisfy only human milk. Composition of human milk is much different from the composition of goat's and cow's milk. The modification of animal milk is mandatory for using in infant feeding to prevent from causing damage to babies in form of malnutrition, allergy reaction, digestion problems or others.

When choosing IF, it is a good idea to give preference to infant formula using milk fat instead of vegetable oil as a source of fat. IF from goat's milk and cow's milk should be equal because of the modification. Although it can have a different effect on the digestion system of children due to the different size of fat globules, milk protein allergenicity and different strength of curd. IF from whole fat goat's milk with hydrolysed milk protein should be the best option for those who have an CIF problem. IF should not be selected according to trends or feelings about it, but according to the reaction of a particular fed baby.

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