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THE UNIQUENESS OF THE COMPOSITION OF GOAT'S MILK AND THE ADVANTAGES OF USING FORMULAS BASED ON IT IN INFANTS DEPRIVED OF BREAST MILK

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Abstract. The article presents a review of the scientific literature on the peculiarities of the composition of goat's milk. It is noted that whole milk of any farm animals, including goats, is not recommended for use by infants, since their composition does not correspond to breast milk and the body of infants is not capable of adequate digestion and assimilation of phylogenetically unsupported food. It is reflected that the use of innovative technologies in the production of adapted dairy formulas based on goat's milk for infants allows you to preserve all the natural valuable components of raw materials. Clinical studies confirming the effectiveness of using starter formulas based on goat's milk are presented.

Keywords: *breast milk, cow's milk, goat's milk, aS1-casein, aS2-casein, β-casein, β-casomorphin, oligosaccharide, adapted milk formula*

УНИКАЛЬНОСТЬ СОСТАВА КОЗЬЕГО МОЛОКА И ПРЕИМУЩЕСТВА ИСПОЛЬЗОВАНИЯ ФОРМУЛ НА ЕГО ОСНОВЕ У МЛАДЕНЦЕВ, ЛИШЕННЫХ ГРУДНОГО МОЛОКА

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Резюме. В статье представлен обзор научной литературы по особенностям состава козьего молока. Отмечено, что цельное молоко любых сельскохозяйственных животных, в том числе и коз, не рекомендовано для употребления детьми грудного возраста, так как их состав не соответствует грудному молоку и организм младенцев не способен к адекватному перевариванию и усвоению филогенетически не предусмотренной пищи. Отражено, что применение инновационных технологий при производстве адаптированных молочных формул на основе козьего молока для младенцев позволяет сохранить все естественные ценные компоненты сырья. Приведены клинические исследования, подтверждающие эффективность использования стартовых формул на основе козьего молока.

Ключевые слова: *грудное молоко, коровье молоко, козье молоко, aS1-казеин, aS2-казеин, β-казеин, β-казоморфин, олигосахара, адаптированная молочная формула*

INTRODUCTION

A complete, properly organised diet can have a protective long-term effect on human health. This is especially relevant for the growing organism, since the transition to lactotrophic nutrition triggers significant processes in it: the formation of the gut microbiome, epithelial barrier, immune and central nervous systems [1].

Despite the widespread use of cow's milk and products prepared on its basis in the nutrition of children and adults, goat's milk (GM) has attracted and continues to attract special interest of the peoples of different countries of the world for many centuries.

Traditionally, GM was prescribed in Ayurvedic practice (Ayurveda is the art of healthy lifestyle, in which all harmful environmental influences are powerless before perfect health) as a medicine. Abu Ali ibn Sina (Avicenna) wrote about its usefulness, stating that it preserves health and mental clarity. Hippocrates used the healing properties of this product to treat lung and stomach diseases.

In the Middle Ages, cheese made from GM was widely used to treat children with rickets.

In the early twentieth century, the trigger for the study of the beneficial qualities and composition of GM was the observation of infants who did not receive mother's milk. The mortality rate of children whose diets used goat's milk instead of breast milk (BM) was significantly lower than among those fed cow's milk.

In 1900 Paris Academy of Medical Sciences officially recognised GM as a highly dietary product and recommended it for the nutrition of children and people with poor health. In Russia children's doctor and nutritionist V.N. Zhuk, author of the popular book 'Mother and Child', was an active propagandist of GM. With his active support and participation, a farm was organised in the suburbs of St. Petersburg to breed a special species of goat, brought by special order of the government from Switzerland [2].

Currently, the benefits of GM consumption for the human body are actively discussed, including hypoallergenicity, improvement of gastrointestinal disorders, growth rate, bone mineral density, blood serum levels of cholesterol, calcium, vitamin A, thiamine, riboflavin, niacin and others. However, most claims about the benefits of GM are based on unofficial data that are used in industry promotional materials and in the media [3].

For example, one of the main characteristics of GM that has contributed to its appeal as an alternative to cow's milk is its lower allergenicity. Thus, to avoid consuming cow's milk in children with intolerance, families often switch to goat's milk. Until the 1990s, there were sporadic studies indicating its weak sensitisation to cow's milk protein allergy (CMPA) [4, 5].

CMPA is the most common food allergy in early childhood, while in adults the remission rate to this protein is 85–90% [6]. In a review published in J. Dairy Sci (1980) it was noted that in many cases the clinical picture of CMPA did not improve when patients were transferred to GM [7].

C. Ballabio et al. (2011) examined individual milk samples from 25 goats with different genotypes of αS1-CN (the largest of the three subfractions of α-casein) by SDS-PAGE and immunoblotting (IB) using monoclonal antibodies specific to bovine α-casein (α-CN) and sera from children allergic to cow's milk and showed that GM sensitisation is a function of the αS1-CN genetic polymorphism. Lower reactivity was observed for samples with αS1-CN null genotypes (0101 or 01F). This work confirmed that caution should be exercised before offering GM to patients with CMPA as an alternative product [8].

The same conclusion was reached by M. Lisson et al. (2014), who indicated that although genetic variants of ruminant caseins differ in their allergenicity, they are highly homologous (>80–90%) and have similar structural, functional and biological properties. For example, the sequences of αs1-, αs2- and β-caseins of cow, goat and sheep have 87–98% homology [9]. Therefore, the cross-reactivity of goat and buffalo IgE antibodies with cow's milk caseins limits the use of products based on them in patients with CMPA [10].

Currently, it is recommended to prescribe products based on deep hydrolysis of bovine protein (whey or casein) or amino acid formulas for children with CMPA, depending on the form and severity [11, 12].

MAIN DIFFERENCES BETWEEN GOAT'S AND COW'S MILK

1. Protein component of milk

Goat and cow's milk are casein-dominant products as the major proteins are represented by 80% casein (CN) and only 20% whey proteins (globulins — β-LG and albumin — α-LA).

Analysis of the composition of major nutritional milk samples conducted at National Milk Laboratories (Wolverhampton, UK, 2019) noted

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that compared to cow's milk, GM has a lower concentration of total protein and casein in particular [13].

The casein fraction includes different types: αS1-CN, αS2-CN, αS3-CN (the αS3-CN fraction is less than 3%, so it is rarely mentioned in the literature), β-CN, κ-CN [7].

GM proteins are different from cow's milk proteins. The former is dominated by low molecular weight proteins (α-LA and β-CN), which facilitates their digestion by proteolytic enzymes, reduces sensitisation and allergic attitudes not only from the gastrointestinal tract (GIT), but also from the whole organism [7]. In addition, M.E. Pintado and F.X. Malcata (2000) found faster hydrolysis and digestion of β-lactoglobulin by GM [14] and S. Bevilacqua (2001) suggested that low αS1-CN content in GM contributes to more efficient digestion of β-lactoglobulin [15].

At the turn of the century, the properties of α-casein GM were actively studied. The hypothesis of genetic regulation of αS1-CN production has been proposed. At least 10 different genetic variants were found to affect the expression of αS1-CN phenotype, which are related to goat breed, milk composition and coagulation properties [16, 17]. Later, it was reported that in goats, about 16 alleles are associated with αS1-CN protein synthesis [18].

C. Cebo et al. (2012) in their work showed that genetic polymorphisms in the αS1-CN locus affect both the structure and composition of milk fat globules. It has even been observed that in mid-lactation, goats with the αS1-CN genotype produce larger fat globules with low levels of polar lipids in the milk fat globule membrane (MFGM) than goats with the αS1-CN null genotype [19].

Recently, the β-casein protein fraction has gained clinical importance. The gene responsible for β-CN production has two common alleles, A1 and A2, which are characterised by the presence of different amino acids at the 67th position. Thus, the A1 allele contains the amino acid histidine, while A2 contains proline. In the milk of goats and sheep, β-CN-A1 is practically absent and the milk of these animals is sometimes called A2 milk [20, 21].

Under the action of peptidases β-CN-A1 β-casomorphins are formed in the stomach from β-CN-A1: BCM-5, BCM-7, BCM-9, which can act as ligands to opioid receptors. In animal experiments it was shown that oral administration of β-casomorphins affects the motility of the digestive tract and exhibits analgesic effect [9, 22, 23]. It does not occur when β-CN-A2 is digested [21, 24].

BCM-7 has been found to slow intestinal motility, cause abdominal bloating, abdominal pain, and increase the synthesis of proinflammatory cytokines (myeloperoxidase and IL-4) and faecal calprotectin [20, 25, 26].

In a study by J.S.J. Chia et al. (2017) provided evidence that BCM-7, derived from β-CN-A1, serves as a trigger for the development of type 1 diabetes mellitus in people with hereditary predisposition [27]. In addition, BCM-7 is considered as a possible cause of the development of sudden death syndrome in children and the formation of neuropsychiatric disorders such as autism and schizophrenia [28].

The difference in the digestion of goat and cow milk proteins *in vitro* has been noted. Thus, 96% of goat casein is completely hydrolysed by trypsin and only 76–90% of cow casein [29]. The low content or complete absence of αS1-casein in GM, as shown above, with a relatively high albumin content, favours the formation of a soft, delicate clot and small loose flakes, facilitating the digestion of milk by proteolytic enzymes [15, 21, 26–31].

GM differs little from cow's milk in amino-acid composition. GM contains slightly more leucine, while cow's milk contains isoleucine. The amount of valine is similar in both types of milk. GM has a relatively lower content of the essential amino acid lysine, but a higher level of the essential amino acid histidine, which is essential for children, and the sulfur-containing amino acid cystine, which is able to bind heavy metals and is recognised as a powerful antioxidant [32].

It is especially necessary to note the high level of taurine in GM, which is 20–40 times higher than in cows' milk [33]. Taurine is involved in the formation of bile acid salts, osmoregulation, antioxidant defence, calcium transport, central nervous system activity, blood pressure regulation, reduces cardiovascular disorders [34], increases tolerance to physical activity, due to which it is often used in combination with steroids to improve metabolic processes [35].

Of particular importance are the growth factors contained in GM, which can stimulate cell growth and the expression of various functions. In studies on laboratory animals it was found that transforming growth factor β (TGF-β) reduces the severity of inflammatory reaction, induces the synthesis of secretory IgA in the intestine and participates in the formation of immunological tolerance [36, 37]. Insulin-like growth factor 1 (IGF-1) regulates the growth processes of bone and cartilage tissue, thus providing prevention of osteoporosis, and also stimulates gut maturation in rats [36, 38].

It should be noted that both cow's and GM have a complex plasmin enzyme system consisting of plasmin (PL), plasminogen (PG), plasminogen activators (PA), plasminogen activator inhibitors [39].

For the first time I. Politis et al. (1994) demonstrated that tissue plasminogen activators (t-PA) are located in casein and serum fractions of GM, and urokinase plasminogen activators (u-PA), in addition, in somatic cells [39].

Electrophoretic studies by A.J. Trujillo (1997) showed that plasmin hydrolyses the same regions of β-casein in bovine and GM [40]. The plasmin system is also involved in mammary involution. Moreover, higher PL and PA activity is observed in late lactation of cows [41].

The effect of casein fractions on the state of intestinal microbiota was evaluated by sequencing of *16SrRNA* gene in experimental animals. The study revealed correlation of β-casein with bacteria of *Enterococcus* and *Allobaculum* genera, and αS1-casein — with microorganisms of *Akkermansia*, *Bifidobacterium* and *Eubacterium* genera. It was observed that the formation of the intestinal microbiome was slightly more active when mice were fed with GM, and the metabolic rates of pyruvate, nucleotides and linoleic acid were significantly higher than with cow's milk [42].

In a recent study, the benefits of GM peptides were investigated and proved that they have the potential to inhibit IL-6 overexpression and control COVID-19 disease. In this study, peptides derived from β-lactoglobulin, which inactivates both the virus and its receptors in the host cell, were identified using *in silico* computer analysis. The following candidate peptides were studied: *YLGYLEQLLR*, *VLVLDTDYK* and *AMKPWIQPK* with strong conformations demonstrated the ability to bind to the IL-6 receptor, inhibiting the activity of SARS-CoV-2 virus without adversely affecting other proteins of the immune system [43].

2. Fat component of milk

Goat's milk fat resembles cow's milk fat in relation to the lipid fractions of whole milk and cream, containing 97 to 99% free lipids, of which 97% are in the form of triglycerides. Bound lipids (1–3%) are represented by neutral fat, glycolipids and phospholipids.

The main distinguishing criteria of GM fat composition are, firstly, the relatively small size of fat globules, which are about 10 times smaller than those of cow's milk, and, secondly, the fact that non-fat GM has more free lipids than cow's milk [7, 44].

GM lacks agglutinin, which 'glues' fat globules together. Therefore, the small globules create a larger surface area available for the action of pancreatic lipase, providing a relatively high digestibility of GM fat compared to cow's milk fat [44, 45].

In addition, a peculiarity of GM fat is its fatty acid composition: it has a significantly higher content of short- and medium-chain fatty acids (SCFAs and MFAs: caproic, caprylic, caprine, lauric and myristic acids [7]).

It is well known that SCFAs are an energetic substrate for enterocytes that repair damaged intestinal mucosal cells, which improves nutrient transport across the basolateral membrane [46].

MFAs are absorbed in the intestine directly into the venous network, bypassing the lymphatic network, without the involvement of pancreatic lipase and bile acids, which facilitates the digestion of goat fat, unlike cow fat [47].

SCFAs and MFAs have antibacterial and antiviral properties and dissolve cholesterol deposits.

In terms of unsaturated fatty acid content, GM is superior to cows' milk as it includes higher amounts of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) with their derivatives such as eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA), which have beneficial effects on all human tissues and organs [7, 13].

The lipoprotein lipase (LPL) system of GM is lower than that of cows. It is more tightly bound to fat globules (compared to casein micelles in cows) and has a pronounced correlation with spontaneous lipolysis (lipolysis at 4 °C). LPL activity in animals is affected by the stage of lactation, milking frequency, starvation and lipid supplementation [48].

3. Carbohydrate component of milk

The main carbohydrate in GM, as in any other milk, is lactose, the concentration of which is comparable in goat and cow's milk.

The second carbohydrate ingredient of GM is oligosaccharides, the level of which is 4–10 times higher and the "palette" of their structure is more diverse than in cow's milk [49–52]. In total, GM contains about 40 different oligosaccharides [52, 53].

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The profile of oligosaccharides, in contrast to cow's milk, is similar to breast milk oligosaccharides (BMOs). Therefore, they can be considered as a natural source of human oligosaccharides with positive effects on the health of GM receivers [54].

The functions of oligosaccharides are related to biological and antibacterial properties. Reaching the small intestine, oligosaccharides stimulate the growth of commensal microbiota, block pathogen receptors, inhibit the thermostable fraction of E. coli enterotoxin, and inhibit the interaction between leukocytes and endothelial cells, thus fulfilling an anti-inflammatory function [54].

The anti-inflammatory effect of oligosaccharides was demonstrated in experimental animal models with hapten-induced and dextran-sulfate-sodium induced colitis [55, 56].

4. Mineral substances and vitamins of milk

Minerals are essential to the human body as they play many vital functions including, but not limited to, activation of cofactors, enzymes, metalloproteins, bone formation, oxygen transport, and others.

Milk from goats and cows contains high congruent concentrations of calcium and phosphorus. At the same time, the GM content of iodine, potassium, copper, manganese, molybdenum is higher, and sodium, sulphur, zinc — lower than in cow's milk [57].

Some articles report lower iron values in GM [58, 59], which is attributed to genetic variability of dairy goat breeds, climatic and geographical zones of pasture location, and differences in feed composition. But, despite this, in some experimental studies the better bioavailability of iron and calcium from GM compared to cow's milk was noted [60, 61].

As in any milk, in the milk of the discussed farm animals determine almost identical content of some vitamins, namely: B_1, B_2, B_6, D [15, 57, 62]. However, there are also differences. Thus, in GM, compared to cows, the level of ascorbic acid and retinol is higher, while folate and vitamin B_{12}, necessary for normal hematopoiesis, are lower [61, 62].

Insufficient content in GM of a number of essential nutritional factors, vitamins and trace elements, in particular, vitamin B_{12}, folic acid and iron can lead to anaemia, accompanied by disorders in the development of the central nervous system and the formation of the immune response.

An illustration of the above is the work of C.A. Elvehjem (1953), which was carried out in the middle of the last century, but has not lost relevance and today. In his scientific work the author showed that when rats were fed GM they had a slower growth rate than when they were given cow's milk. The addition of folic acid and cyanocobalamin to the diet of laboratory animals helped to accelerate growth performance. Apart from experimental studies, clinical observations have recorded cases of severe anaemia in infants associated with receiving GM. In this regard, the term "goat milk anaemia" was even introduced [63].

Folic acid and vitamin B_{12} deficiency in children receiving GM exclusively was the subject of research in 1970 on megaloblastic anaemia and continues to be a concern today [64–66].

5. Cellular components of milk

It has long been known that goat milk naturally contains increased levels of somatic cells (SCC) and some isoflavonoids compared to cows due to the apocrine secretory system of the mammary gland [13, 67]. The special live SCC defence cells destroy pathogenic bacteria in the gut and stimulate the growth of beneficial microbiota. Phytoestrogens, including lignans, isoflavones, and coumestans (particularly equol), have been associated with the reduced risk of cardiovascular disease, type 2 diabetes mellitus, cancer, and symptoms of osteoporosis, metabolic syndrome, and menopause [13].

GOAT MILK-BASED FORMULAS

Although BF is the most appropriate way to feed infants in the first months of life, most infants stop receiving the mother's breast during this period of life [68–72].

According to the Federal State Statistics Service of Russia, as of December 2020, the number of children receiving mother's breast from 3 to 6 months of age was 43.9% and from 6 to 12 months — 39.2% [71]. At the same time, the average duration of only BF (when a child receives only the breast of his/her biological mother) corresponded to only one month against the WHO recommended 6 months, predominantly BF (along with breast milk, irregular supplementation with formula milk in the amount of no more than 100 ml per day or other liquid/thick food in the amount of no more than 30.0 ml per day is possible) — 4 months, and the total duration of BF (only BF + predominantly BF) — 10.6 months

[72]. Among all regions of the Russian Federation, Moscow has the lowest duration of BF: only BF — 0.3 months, predominantly BF — 2 months, any BF — up to 6 months on average. This low frequency of BF is most likely due to the intensity of life in the country's largest metropolitan area and the mother's earlier retirement from her maternity leave [73].

There are different reasons and circumstances in which a child is deprived of mother's milk. But whatever the case, it should always be remembered that the introduction of complementary feeding or complete transfer of the child to artificial feeding (AF) should be strictly justified and carried out only when the need to introduce milk formula into the child's diet is objective, and the entire arsenal of means aimed at stimulating lactation has proved ineffective.

In such a situation, the paediatrician is always faced with the difficult question of choosing a high-quality milk formula, which, although developed with maximum adaptation of farm animal milk to the composition of breast milk, can never be a complete copy of it.

The growth in global GM production has prompted the creation of milk formulas and the entire line of infant nutrition products based on it, since whole milk from ruminants, including goats, is not recommended for consumption by infants. This restriction is due to the mismatch of GM composition with female composition and the imperfection of the infant's gastrointestinal tract to digest and assimilate phylogenetically not provided food [74–76]. Scientists have proved that consumption of any kind of whole milk (goats, cows, sheeps, etc.) with high concentration of protein and mineral compounds by children of the first year of life disturbs the function of kidneys, liver, secretory activity of the digestive tract, irritates the intestinal mucosa with subsequent development of microdiapedesis haemorrhages, increases intestinal permeability for food proteins, causing sensitisation and azotemia [62, 74].

In connection with the foregoing, despite the good digestibility of GM milk protein, fat, microelements in adults, for the nutrition of infants, it is necessary to use infant formulas based on it, to the maximum extent adapted to the "gold standard": the composition of women's milk [74, 77].

Goat milk-based infant formulas (GMF), which are approved by the European Food Safety Authority (EFSA), are available in many countries of the world, including Russia [78].

A systematic review and meta-analysis of four randomised controlled trials (RCTs) conducted in accordance with the recommendations of the Cochrane Guidelines [79] summarised the current evidence on the effectiveness of goat milk-based starter formulas (GMF) compared with identical cow's milk-based formulas (CMF) and presented the results in accordance with the Reporting for Systematic Reviews and Meta-Analyses (PRISMA) [80]. Children on exclusively BF served as controls. The data presented showed no significant differences in anthropometric parameters and stool frequency, or in symptoms of food allergy and/or atopic dermatitis between children fed GMF compared to CMF. Adverse events were similar in both groups [81].

There is no doubt that GM has high nutritional value and beneficial properties [82, 83]. RCTs have proved the adequacy of using GMF in the nutrition of both healthy infants and infants with severe nutritional deficiencies in comparison with CMF. The dynamics of weight-growth gains on the background of receiving the investigated products in the groups were identical [84, 85].

To confirm the safety and biological value of GMF, it is necessary to assess the taste preferences of young patients, since the sensory characteristics of infant milk formulas are the key factor contributing to their acceptance by a child on formula feeding.

Most studies have investigated the palatability of conventional CMF compared to formulas based on soya or deep hydrolysis of BKM [86–89].

A multicentre, double-blind, multicentre RCT conducted in and around Paris evaluated the eating behaviour and appetite of children in the first four months of life on AF. A total of 64 healthy infants participated in the study and were divided into two groups based on the product offered (GMF and CMF). The authors noted that infants who received GMF showed better overall appetite than infants who were fed with CMF. This diversity in infants preference may have been due to differences in the composition of these formulas, namely protein and lipid profiles. In addition, babies fed GMF had a better quality of life. There was no difference in food enjoyment between the groups [90]. These results suggest that GMF may be an attractive alternative to CMF.

The composition of GMF is not significantly different from CMF, but there are some special characteristics that provide the former product with technological (physicochemical) advantages

[74, 77, 91, 92]. This is most likely due to the composition of the raw materials used for the production of these formulations. The composition of milk nutrients has been found to be influenced by several factors, the most significant of which are considered to be: type and age of animal, breed, method of animal husbandry, season of milk collection, milking method, diet and duration of lactation [93–95]. For example, H.C. Lythgoe directly analysed 335 samples from individual goats from 21 herds in Massachusetts back in 1940. Milk samples were collected over a period of 16 months. The work confirmed high individual and seasonal variability in total solids content. This was primarily related to variability in the fat component, which was more pronounced in goats than in cows [96].

Recently, much attention in the development of infant formulas has been paid to biologically active components such as free amino acids, nucleotides, polyamines, and growth factors because they are contained in breast milk [77].

The use of innovative technologies in the manufacture of adapted products for infants makes it possible to preserve all those valuable natural components present in whole GM and to balance its composition in accordance with regulatory documents [97, 98].

In the formulas, as in whole milk, α-lactalbumin and β-CN remain dominant, with β-CN-A2, and αS1-CN is practically absent, which resembles the protein composition of women's milk. Due to this combination of proteins, it is possible to reduce the symptoms of digestive discomfort (such as colic, bloating, abdominal pain, defecation difficulties) in infants [74, 77].

The fat component of the formula is enriched with essential PUFAs of the omega-3 and omega-6 class, and recently their derivatives: docosahexaenoic (DHA) and arachidonic (ARA) fatty acids have been introduced. This brings the composition of the product closer to the fatty acid spectrum of breast milk. The biological role of long-chain PUFAs is in the synthesis of eicosanoids (prostaglandins and leukotrienes) that regulate the processes of inflammation and immune response, as well as in the formation of virtually all cell membranes of the body, especially in nerve cells of the brain and eyes. DHA makes up about 40% of all polyunsaturated fats found in the human brain. Formulas manage to retain small-sized fat globules [74, 77].

The total lactose content of the formulas is close to the recommended content. Oligosaccharides are naturally present in infant GMFs. In a study by A. Leong et al. (2019) investigated the prebiotic and anti-infective properties of natural oligosaccharides in infant formulas (starter and follow-up) based on goat's milk. The results proved the bifidogenic (enhanced growth of bifidobacteria and lactobacilli) and antipathogenic adhesive properties (reduced adhesion of *E. coli NCTC 10418* and *S. typhimurium)* of the oligosaccharides present in the products. In addition, 14 oligosaccharides similar to those found in whole GM were identified in the formulas. Of these, five (2'-fucosyl-lactose, 3'-sialyl-lactose, 6'-sialyl-lactose, lacto-N-hexaose and lacto-N-neotetraose) were found to be identical to breast milk oligosaccharides (BMO). Of great importance, these 14 studied GMFs retained their properties during heat treatment during formula production [52–54].

Dairy GMFs contain vitamins and minerals according to the physiological needs of children.

Considering the low level of vitamins E, C, B_{12}, folic acid, iron in GM, these important nutrients are necessarily added to the composition of the products. In addition, they are introduced: L-carnitine, taurine, choline, nucleotides, which favourably affect metabolic processes in the body, brain and vision development, maturation of the immune and digestive systems [74, 77].

An extremely important aspect in the development of milk formulas is the osmolality index (the number of osmotically active particles in 1 litre of solution), which is determined by the concentration of proteins and salts. The permissible concentration is calculated in such a way that the kidney load is within the capacity of the infant's body. The osmolality of breast milk is 240–280 mOsm/l, which corresponds to the capabilities of the child's organism. It is no coincidence that these values serve as the "gold standard" and are recommended by WHO for starter milk formulas [97, 98].

CONCLUSION

Thus, milk formulas, especially starter formulas based on goat's milk, have a strictly balanced macro- and micronutrient composition, are enriched with essential nutritional factors, comply with sanitary and hygienic requirements for this category of food products to ensure optimal growth and development of infants, which allows us to consider them as an alternative to modern infant formulas based on cow's milk and to use them in the nutrition of not only healthy infants, but also in the presence of a mild form of malnutrition.

ADDITIONAL INFORMATION

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