



**International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)**

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

WHY DONKEY MILK IS A VIABLE CHOICE FOR ORPHAN INFANTS AND CHILDREN DEPRIVED OF MOTHER'S MILK

VASHISHT V¹, VERMA S¹, DEEP S¹, NASA A¹, CHATURVEDI S¹ AND
SHRIVASTAV S^{1*}

SGT College of Pharmacy, SGT University, Gurugram, Haryana, India

*Corresponding Author: Dr. Sonika Shrivastav: E Mail: sonika_pharmacy@sgtuniversity.org

Received 20th Dec. 2023; Revised 25th Jan. 2024; Accepted 6th July 2024; Available online 1st April 2025

<https://doi.org/10.31032/IJBPAS/2025/14.4.8957>

ABSTRACT

This review paper delves into the critical significance of the initial thousand days of a child's life, emphasizing the transformative impact on their physical and cognitive development. While breast milk is universally acknowledged as the optimal source of nutrition, challenges such as maternal health issues may hinder its accessibility. Scientists explore alternatives like formula milk, but concerns arise due to preservatives and allergic reactions. An intriguing option gaining attention is donkey milk, historically consumed for purported health benefits. Modern research validates its nutritional alignment with human milk, presenting it as a viable substitute. Donkey milk's low-fat content, balanced protein profile, and bioactive compounds mirror human milk, offering a promising solution for infants with maternal milk unavailability. Studies indicate its hypoallergenic nature and antimicrobial properties, addressing concerns of allergies and infectious diseases. However, widespread adoption necessitates careful consideration of ethical, cultural, and economic dimensions, respecting the significance of donkeys in certain societies. Despite promising findings, the review underscores the need for comprehensive clinical trials to establish safety and efficacy across diverse populations. In conclusion, while donkey milk emerges as a compelling alternative, its integration into infant nutrition demands thoughtful evaluation of multifaceted considerations.

Keywords: Donkey milk, Infant tolerability, Hypoallergenic, Immunomodulatory properties

INTRODUCTION

The initial thousand days of a child's existence mark a transformative period, shaping the trajectory of their physical and cognitive development [1]. Within this critical timeframe, the importance of optimal nutrition, primarily derived from breast milk, cannot be overstated. Recognized universally as the ideal source of nourishment, human milk provides an intricate amalgamation of nutrients, immune-boosting elements, and developmental cues imperative for the foundation of robust health [2]. However, the ideal scenario of maternal breastfeeding is not always attainable, as various circumstances such as maternal health issues, premature births, or maternal mortality may impede access to this fundamental source of sustenance, leaving infants and children vulnerable to nutritional deficiencies [3].

In response to these challenges, scientists and nutritionists have been compelled to explore unconventional alternatives to bridge the nutritional gap for infants and children who are deprived of their mother's milk. A myriad of formula milk options exists for infants to address nutritional gaps; however, concerns arise due to the inclusion of preservatives in these formulations, which may not be suitable for early-age

consumption. While formula milk offers a balanced nutritional alternative, it lacks the natural immune-boosting components present in breast milk. Additionally, allergic reactions have been observed in response to certain formula milk varieties, challenging their candidacy as an ideal substitute. These considerations underscore the importance of further research and development in creating more suitable alternatives for infant nutrition.

One such emerging alternative that has garnered attention is donkey milk. This curiosity is not new; historical records from ancient civilizations, including the Greeks and Romans, depict the consumption of donkey milk for its purported health benefits [4]. Contemporary scientific scrutiny has substantiated the historic claims, revealing a nutritional profile in donkey milk that remarkably aligns with human milk, positioning it as a viable substitute for infants and children facing maternal milk unavailability [5].

The nutritional composition of donkey milk sets it apart, characterized by a low-fat content, a balanced protein profile, and elevated levels of essential fatty acids. These constituents closely mimic the nutritional content of human milk, surpassing conventional cow or goat milk in

their resemblance [6]. Beyond macronutrients, donkey milk harbors an array of bioactive compounds, including lysozyme, lactoferrin, and immunoglobulins, endowing it with potential immunomodulatory and anti-inflammatory properties [7]. This distinctive combination of essential nutrients and bioactive compounds renders donkey milk a promising contender for addressing the nuanced nutritional needs of orphan infants and children deprived of their mother's milk. Extensive research has been dedicated to understanding the tolerability of donkey milk by infants. Findings consistently indicate that donkey milk is not only well-tolerated but also associated with a lower risk of allergic reactions compared to other animal milks. The hypoallergenic nature of donkey milk is attributed to structural similarities between its proteins and those found in human milk, thereby reducing the likelihood of adverse reactions in vulnerable populations [8]. This quality has positioned donkey milk as a potential solution for infants grappling with cow's milk protein allergies or lactose intolerance.

Moreover, donkey milk has demonstrated antimicrobial properties that could play a pivotal role in safeguarding the health of infants and children. Bioactive components such as lysozyme and lactoferrin contribute

to its antimicrobial activity, potentially fortifying the immune defenses in developing infants [7]. In regions where access to clean water and sanitation is limited, the antimicrobial properties of donkey milk could mitigate the risk of infectious diseases, a critical concern for child health [9].

While the nutritional and immunological promises of donkey milk are compelling, the broader adoption of this alternative warrant's careful consideration of ethical, cultural, and economic dimensions. Donkeys hold cultural and historical significance in certain societies, and the promotion of donkey milk as a viable alternative necessitates sensitivity to these factors. Additionally, the economic feasibility of large-scale donkey milk production and distribution demands scrutiny to ensure accessibility for those in need [10].

As the scientific community advances in understanding the potential benefits and challenges associated with donkey milk, it is crucial to acknowledge the existing research's limitations. Thorough clinical trials, encompassing comparisons of nutritional outcomes and health effects between donkey milk and established alternatives, along with extended follow-ups, are essential for confirming its safety

and efficacy across diverse populations [11].

In conclusion, the exploration of alternative sources of nutrition for orphan infants and children deprived of mother's milk has brought donkey milk to the forefront. Its nutritional composition, hypoallergenic nature, and bioactive properties make it a compelling candidate for addressing the unique needs of vulnerable populations. However, the adoption of donkey milk as a viable choice for infant and child nutrition requires careful consideration of ethical, cultural, and economic factors. This research article aims to provide a comprehensive review of the existing literature on donkey milk, shedding light on its potential role in safeguarding the health and well-being of infants and children facing the challenge of maternal milk unavailability.

REVIEW OF LITERATURE:

Human breast milk adapts to the infant's needs throughout growth, with its composition and nutrients changing according to the child's age. The milk comprises carbohydrates, hormones, vitamins, antibodies, proteins, growth factors, antibacterial agents and cytokines. The composition varies based on factors like maternal diet, mammary gland physiology, and the developmental stage of the infant

[12][13]. For example, preterm milk tends to have higher protein and fat content compared to term milk [13]. The nutrient composition of breast milk is dynamic, ensuring that the infant receives the optimal nutrition for their development and immune modulation [12][13]. Several studies have highlighted that the varied bioactive components present in breast milk influence immune system functions, gastrointestinal tract functions, and brain development. Consequently, breast milk is widely recognized as a biological fluid essential for the optimal development and growth of infants. Recent investigations have further indicated that breast milk might provide protection against type 2 diabetes and obesity, particularly reducing the predisposition to late-onset metabolic diseases in infants [14].

"For the first six months after giving birth, breastfeeding is the most suitable and prevalent method of nutrition for infants. Alternative dietary sources are needed when breastfeeding is not an option. Cow's milk and human milk differ significantly in terms of macro- and micronutrient content [15]. "High amounts of proteins and minerals in cow's milk might cause digestive difficulties. Moreover, cow milk is deficient in iron, vitamin C, and a few essential lipids for developing infants. Because of this,

before the age of twelve months, cow milk shouldn't be the primary beverage; nevertheless, it can be added in modest amounts to complementary foods [16]. In addition, cow milk develops Cow Milk Allergy (CMA), Between 0.5 to 3.8% of newborns and young children suffer with IgE-mediated CMA, the most common food allergy [17-19]. Though some children retain their CMA for life [20], most children outgrow it and develop a tolerance to cow's milk [21]. As cow's milk proteins are commonly present in infant formulas, they often constitute one of the initial food exposures for babies, making cow's milk protein allergy (CMA) one of the earliest food allergies identified in infants [22]. After consuming a dairy product made from cow's milk, symptoms of IgE-mediated CMA typically start to show up quickly—within a few minutes [23]. These symptoms can include vomiting, diarrhea, skin rashes, urticaria, breathing difficulties, and potentially fatal anaphylaxis [24].

Commercial baby formulae are frequently used as substantial replacements for breast milk or as additions to a baby's diet. It's important to carefully construct the baby milk alternatives to ensure that the nutritional needs for healthy growth are sufficiently satisfied. The majority of baby formulae are made from cow milk that has

undergone modifications to make it more like human milk. Protein hydrolysate and soy-based formulae are the other categories. Plant-based milk substitutes do not provide all the nutrients that babies need in a balanced, healthful dose [25]. But the soy-based formula milk wasn't accepted by parents; they complained of loose, foul-smelling faeces, diaper rash, and discoloured clothes. Isolated soy protein was added to formulae in the middle of the 1960s. In terms of acceptance and appearance, these formulae were far more similar to those based on milk. Nevertheless, the majority of the vitamin K in the soy was eliminated during the synthesis of the isolated soy protein, and a few cases of vitamin K insufficiency were noted. Federal restrictions pertaining to the nutrient content of formulas were developed in part because of the prevalence of nutrient deficits in newborns fed formulas without milk [26]. Examining cow-based formula milk, it is evident that cow's milk stands out as a widely accessible and highly nutritious source of mammalian proteins globally. It serves as the primary alternative to breast milk during infancy when breastfeeding is impractical or insufficient. However, despite its popularity, cow's milk allergy (CMA) is the most prevalent type of food allergy in newborns, impacting up to 3.8%

of young children [27]. Another disadvantage of infant formula milk is ingredient used in infant formula milk include preservatives like Sulphur dioxide and various additives, which are added to prevent spoilage and extend shelf life, sweeteners, vegetable oil, synthetic flavors, coloring agent and Carrageenan. These ingredients can aggravate food allergies in infants and have been linked to health problems such as hypersensitivity and behavioral disorders [28].

In the realm of alternative dairy options, diverging from the familiar terrain of cattle milk unveils a captivating and largely uncharted territory. Within this unexplored domain, donkey milk emerges as a distinctive and noteworthy choice, offering not only heightened benefits but also a nutritional profile that surpasses conventional expectations. This intriguing alternative beckon exploration for those seeking a more enriching and healthful dairy experience.

Donkey milk, a non-bovine alternative, is gaining popularity, especially for its potential advantages in infants with cow's milk allergy (CMA) and its prospective use as a protein source in infant formula in the future. According to a clinical study by Carroccio, the feeding of donkey milk proves to be a safe and effective treatment

for a majority of complex cases involving multiple food intolerances [29]. The discovery that the composition of donkey milk closely mirrors that of human milk has spurred a growing number of studies investigating its potential impacts in vitro and in vivo. Numerous clinical investigations, using in vivo or ex vivo techniques, have been conducted to assess the safety of donkey milk in individuals with cow's milk allergies. Consistently, over 80% of the patients with cow's milk allergy included in these studies demonstrated tolerance to donkey milk after Oral Food Challenge (OFC), a consistent and notable finding across the investigations [30-34]. Due to this observed tolerance, donkey milk is often considered a valuable substitute for hypoallergenic baby formulas in managing cow's milk allergy in newborns and young children [35].

Donkey milk extends beyond its role as an alternative for those with cow milk allergies; it has historical significance in the scientific exploration of infant feeding. Dr. Parrot, based at l'Hospice des Enfants Assistés in Paris during the nineteenth century, conducted pioneering research on the use of donkey milk. In his studies, he fed children afflicted with congenital syphilis directly from the donkey's udder. Dr. Parrot conducted the first controlled trials

comparing donkey milk to cow and goat milk, meticulously documenting milk intake, weight gains, and analyzing the chemical composition of donkey milk. This groundbreaking research by Dr. Parrot ultimately led to the establishment of a donkey farm dedicated to nourishing orphaned children [36].

Numerous investigations have demonstrated DM's broad-spectrum antiviral and antibacterial activity, as was recently reviewed [37]. It's interesting to note that DM has antibacterial properties against both foodborne bacteria and fungus [38]. The primary contributors to the antibacterial activity of donkey milk have been recognized as lactoferrin, which is notably less abundant in donkey milk compared to human milk (0.08 vs 0.3–4.2 g/L), and lysozyme, present in the range of 0.3–1.1 g/L [39]. The preservation of antibacterial activity in protein hydrolysates of donkey milk is likely attributed to the release of bioactive peptides or the proteolytic resistance of lysozyme [40, 41]. The combined action of immunoglobulins, lactoferrin, and whey lysozyme to limit microbial development may have significant health effects by lowering the risk of gastrointestinal infections in young children. Nevertheless, as DM was active against Gram-negative bacteria as well as

Listeria monocytogenes, and it inhibited them more successfully than *Staphylococcus aureus* [42, 43], other ingredients ought to be added to enhance its overall antibacterial activity.

Donkey milk serves not only as an infant supplement but has also demonstrated impact on the osteogenesis process. Researchers have indicated its utility in treating arteriosclerosis, aiding in the rehabilitation of individuals with coronary heart disease or premature senescence, and contributing to hypocholesterolaemia diets [44].

While the nutritional and immunological promises of donkey milk are compelling, the broader adoption of this alternative warrants' careful consideration of ethical, cultural, and economic dimensions [45]. Donkeys, revered for their historical and cultural significance in certain societies, are not merely utilitarian animals but hold symbolic value [46]. The promotion of donkey milk as a viable alternative necessitates sensitivity to these factors to avoid potential conflicts with cultural practices and beliefs [47].

Moreover, the economic feasibility of large-scale donkey milk production and distribution demands scrutiny to ensure accessibility for those in need [48]. Donkey milk's potential benefits should not

inadvertently exploit these animals, jeopardizing their welfare for the sake of commercial gains [49]. Sustainable practices and ethical considerations must be at the forefront of any efforts to scale up production.

Considering the intricate balance between cultural respect, ethical considerations, and economic feasibility is essential for the successful integration of donkey milk into mainstream consumption patterns. Collaborative efforts involving local communities, policymakers, and industry stakeholders are crucial to navigating these complex dimensions and ensuring that the adoption of donkey milk aligns with ethical and cultural values while promoting economic sustainability [50].

Composition of Different available milk sources

In the scientific community, there has been a renewed focus on donkeys in recent decades, especially regarding biodiversity recovery, the conservation of endangered donkey breeds, and the investigation of donkey milk. This interest further encompasses the exploration of donkey milk as a viable alternative in agriculture. Although the majority of studies on donkey milk quality have been carried out in Italy, there is also accessible data on milk from Chinese and Balkan donkey breeds [35, 51].

The growing global prevalence of food allergies, especially in childhood, has prompted a focus on the demand for "natural" milk alternatives. Cow's milk protein allergy (CMPA) is a significant concern, affecting a notable percentage of children under three years old [52]. The rise in CMPA, particularly in economically developed countries, has led to an urgent need for alternative milk options that are not only hypoallergenic but also palatable, addressing the taste preferences of children [53].

The symptoms of CMPA, ranging from gastrointestinal to dermatological and respiratory issues, emphasize the importance of finding suitable alternatives [54]. Despite the availability of hydrolysates of cow's milk proteins, amino acid formulas, soy, and rice beverages, some still carry allergenic risks and may not serve as comprehensive foods, necessitating supplementary measures. Additionally, the taste and palatability of specific alternative milks can pose challenges, potentially influencing the growth of children.

The quest for a natural, tasty, and hypoallergenic milk alternative has become a pertinent research focus, and the potential of donkey milk emerges as a promising candidate in addressing these concerns.

Research in this area has not only contributed to the recovery of endangered donkey breeds but also positioned donkey milk as a viable and appealing option for those seeking alternatives due to food allergies, especially in the context of childhood nutrition.

Plenty of research on the nutritional qualities and chemical makeup of donkey milk (DM) have established that it is similar to human milk (HM) but different from other mammals [51]. These differences primarily stem from lactose, mineral content, fatty acid composition, and protein

composition [52]. It has the potential to serve as a novel dietetic food or a viable alternative to human milk for infants [57, 58]. Infant formulas incorporating powdered donkey milk are viewed as promising alternatives to human milk in situations where breastfeeding is not feasible, ensuring that newborns are not deprived of maternal milk [59, 60]. Clinical studies have affirmed that a diet incorporating donkey milk is a secure and effective therapeutic approach for addressing complex cases of food allergy [61].

Table 1: Composition of Human, Donkey and cow milk

Composition		Human	Donkey Milk	Cow	References
Proteins (g/l)					
1.	Total proteins	9–15	13–18	32.0	[62],[55]
2.	Total caseins	5.6	6.6	27.2	[62],[55]
3.	Total whey proteins	8.0	6.5	4.5	[62],[55]
4.	α 1-casein	0.8	n.d.	10.0	[62],[55]
5.	α 2-casein	n.d.	n.d.	3.7	[62],[55]
6.	β -casein	4.0	n.d.	10	[62],[55]
7.	k-casein	1.0	Trace	3.5	[62],[55]
8.	α -lactalbumin	1.9–2.6	1.80	1.2	[62],[55]
9.	β -lactoglobulin	n.d.	3.7	3.3	[62],[55]
10.	Lysozyme	0.04–0.2	1.0	Trace	[62],[55]
11.	Lactoferrin	1.7–2.0	0.08	0.1	[62],[55]
12.	Immunoglobulins	1.1	n.d.	1.0	[62],[55]
13.	Albumin	0.4	n.d.	0.4	[62],[55]
Non – Protein Nitrogen (g/100g)		0.26 – 0.32	0.18 – 0.41	0.1 – 0.19	[63],[35]
NPN, %		20.42	15.76	5.23	[63],[35]
Water-Soluble Vitamin (μM)					
1.	Thiamine (vitamin B ₁)	0.12	0.66	0.59	[75],[55]
2.	Riboflavin (Vitamin B ₂)	0.08	0.17	2.12	[76],[55]
3.	Niacin (Vitamin B ₃)	4.64	18.75	2.43	[79],[55]
4.	Piridoxine (Vitamin B ₆)	0.48	5.38	5.50	[64],[55]
5.	Folic acid (Vitamin B ₉)	0.37	0.83	0.02	[74],[55]
6.	Cyanocobalamin (Vitamin B ₁₂)	n.d.	n.d.	3.3×10^{-3}	[73],[55]
7.	Vitamin C [36]	60 mg/L	57 mg/L	27 mg/L	[65],[55]
Fat-Soluble Vitamin					
1.	Vitamin A	60 μ g/100 mL	58 μ g/100 mL	41 μ g/100 mL	HM [66],[55] DM [67],[55]
2.	Vitamin D	0.06 μ g/100 mL	2.23 μ g/100 mL	0.08 μ g/100 mL	

3.	Vitamin E	237 µg/100 mL	5.2 µg/100 mL	113 µg/100 mL	CM [66],[55]
4.	Vitamin K	0.2 µg/100 mL	n.d.	1.1 µg/100 mL	
	Ph	7.0 – 7.5	7.0 – 7.2	6.6 – 6.8	[63],[35]
	Fat (g/100g)	3.5 – 4.0	0.3 – 1.8	3.5 – 3.9	[68],[35]
	Lactose (g/100g)	6.3 – 7.0	5.8 – 7.4	4.4 – 4.9	[68],[35]
	Ash (g/100g)	0.2 – 0.3	0.3 – 0.5	0.7 – 0.8	[69],[35]
	Total Solid (g/100g)	11.7 – 12.9	8.8 – 11.7	12.5 – 13.0	[63],[35]

The casein content found in equine milks, comprising around 40%–45% of the total protein, closely mirrors the proportions observed in human milk, as indicated in **Table 1**. In both these mammalian species, more than 50% of the total milk protein is constituted by whey protein, as highlighted in **Table 1**. Within whey proteins, donkey milk has been found to contain a total of 1.0 mg/mL of lysozyme, whereas bovine milk exhibits a minimal amount (trace) [53]. Although β -lactoglobulin is present in the whey proteins of donkey milk, there is only a 60 percent sequence homology between the isolated β -lactoglobulin from donkey milk and that from cow milk [70]. In 1990, the notable resemblance in milk proteins between equine and human milk opened avenues for investigating the potential of donkey milk in managing severe IgE-mediated cow's milk protein allergy (CMPA) in children [71].

The comparable chemical composition identified in both equine and human milk, as

illustrated in Table 1, implies that donkey milk could serve as a dietary substitute for children experiencing IgE- and non-IgE-mediated cow's milk protein allergy (CMPA) in situations where breast milk is unavailable. While bovine milk is conventionally viewed as the primary alternative to human milk in infant nutrition, it markedly differs in both macronutrients and micronutrients. Notably, it presents distinct levels of vitamins and minerals when compared to human milk [72, 71].

The vitamin C level found in donkey milk (57 mg/L) closely matches the reported content in human milk (60 mg/L), as outlined in **Table 1**. The eight B-complex water-soluble vitamins play vital roles in diverse cellular functions by acting as coenzymes in various catabolic and anabolic enzymatic reactions. Recently, the Vitamin B6 content in donkey milk has been analysed for the first time [73], alongside other B-complex vitamins like thiamine, riboflavin, and nicotinic acid. These

vitamins are known for their lipid-lowering effects, with folic acid, in particular, playing a significant role in the growth of children [74].

Table 1 illustrates notable differences in the concentrations of various B-complex vitamins and vitamin C between donkey milk and other mammalian milks. Thiamine concentration in donkey milk (0.66 μM) surpasses that in human milk (0.12 μM) [75], while riboflavin content (0.17 μM) is higher than in human milk (0.08 μM) but lower than in cow and goat milk [75, 76]. Riboflavin acts as the precursor for two essential cofactors involved in oxidation-reduction reactions in biological processes, namely flavin adenine mononucleotide (FMN) and flavin adenine dinucleotide (FAD). The elevated levels of both thiamine and riboflavin in donkey milk contribute to its acknowledged health benefits in human nutrition [77, 78].

Nicotinic acid (Vitamin B3) content in donkey milk (18.75 μM) exceeds that in human milk (4.64 μM) but aligns with goat milk values [79]. Nicotinic acid, known for its lipid-lowering effects, is present in appreciable amounts in donkey milk [73]. The Vitamin B6 content in donkey milk, measuring 5.38 μM , is significantly greater than that in human milk (0.48 μM) but similar to the levels found in cow milk [80].

This vitamin plays a vital role in diverse biochemical pathways.

Folic acid (Vitamin B9) content in donkey milk (0.83 μM) surpasses that in human milk (0.37 μM), highlighting its significance, especially in early childhood development [74]. Vitamin B12 is absent in donkey milk, possibly due to differences in digestive systems between equids and ruminants [81]. Vitamin C, a vital antioxidant, is present in donkey milk at 57 mg/L, closely resembling the content in human milk (60 mg/L). This makes donkey milk a valuable source of vitamin C for infants, providing the recommended daily intake for children aged 0–12 months in a 500 mL serving [82].

Vitamin A plays a crucial role in the nutrition of children, impacting the growth of newborns, the development of immunity, and supporting eye health, all while contributing to the maintenance of epithelial integrity [83]. The concentration of Vitamin A in milk is intricately linked to the overall fat content of the milk, which is influenced by factors such as the animal's diet and seasonal variations [84]. The Vitamin A content in human milk is marginally higher at 60 $\mu\text{g}/100$ mL, compared to 58 $\mu\text{g}/100$ mL in donkey milk, as indicated in **Table 1**. In Western countries, Vitamin A deficiencies are typically uncommon.

human milk is generally adequate in Vitamin A but fortification practices are employed in certain regions to ensure enhanced nutritional benefits, particularly for children [85].

Vitamin D is pivotal for calcium and bone metabolism, exerting antirachitic activity and functioning as a hormone, especially crucial for the growth of mammals [86]. Human milk contains a minimal amount of Vitamin D, measuring 0.06 $\mu\text{g}/100\text{ mL}$ (refer to Table 1). In contrast, donkey milk showcases a higher total Vitamin D level at 2.23 $\mu\text{g}/100\text{ mL}$, surpassing values observed in various mammalian species, including human milk [87]. Recent clinical trials have explored the multifaceted properties of Vitamin D, including its anticarcinogenic, anti-celiac, and immunomodulatory effects, in addition to its well-established role in bone mass formation and osteoporosis prevention [88, 89].

Vitamin E, comprising eight biologically active forms with antioxidant activity, is represented by both α -tocopherol and γ -tocopherol in donkey milk [90]. While human milk boasts a high Vitamin E content at 237 $\mu\text{g}/100\text{ mL}$, donkey milk contains a lower amount at 5.2 $\mu\text{g}/100\text{ mL}$, as shown in **Table 1**. Vitamin E serves as a major natural antioxidant, providing protective

effects against oxidation or peroxidation processes in cell membranes [91].

Regarding Vitamin K, it remains undetected in donkey milk, distinguishing it from mare milk, which boasts about three times the Vitamin K content found in cow milk. Human milk, based on the available data, exhibits a notably low level of Vitamin K content [92].

Recent progress in comprehending the nutritional aspects of donkey milk, specifically its vitamin content, supports its potential as a nutraceutical option for individuals with sensitivities. The striking similarity in the chemical compositions of human and donkey milk, along with the presence of distinct bioactive compounds in donkey milk, has generated interest in its potential application in infant nutrition, especially for children dealing with cow's milk protein allergy (CMPA).

Donkey milk, like human milk, maintains a neutral or slightly alkaline pH, which can be attributed to its lower levels of caseins and phosphates, setting it apart from cow milk.

Compared to bovine milk [**Table 1**], donkey's milk has lower levels of fat, protein, and inorganic salts but higher lactose content, approaching that found in human milk. The abundance of lactose in donkey milk serves as a rapid energy source, contributing to its sweetness, palatability,

and favorable reception by children. The increased lactose content in donkey milk not only enhances the intestinal absorption of calcium, essential for infant bone mineralization and nervous system development [93], but also indicates its possible utility for probiotic purposes [94]. This is due to its suitability as an optimal substrate for the proper development of intestinal lactobacilli. Moreover, the abundant lactose content renders donkey's milk a favorable medium for crafting probiotic beverages, particularly when incubated with strains of *Lactobacillus rhamnosus* [95].

The other mentioned [Table 1] content like NPN, Total solid and ash value showcasing more similarity between human and donkey milk rather than cow milk. Milk encompasses a variety of nutrients. The mineral content in donkey milk surpasses that of human milk but is notably lower than in ruminant milk, as indicated [96].

MATERIAL AND METHODS:

- i) Systematic Classical review of published paper in National Institute of health, Web of science, Scopus indexed, WHO sites and PubMed etc.
- (ii) Review of published literature in context of specific to donkey and human milk.
- (iii) Critical analysis and comparative studies of their nutritional value and

drawbacks.

RESULT:

Upon reviewing the existing literature, it is evident that donkey milk exhibits promising characteristics that position it as a potential substitute for breast milk when the latter is not available for infants. Several studies have investigated the nutritional composition of donkey milk, revealing similarities with breast milk in terms of essential nutrients. Donkey milk is found to contain proteins, fats, and carbohydrates, making it a valuable source of nutrition for infants.

Research has also explored the digestibility and tolerability of donkey milk in infants, with findings suggesting that it can be well-tolerated and may be suitable for those with certain dietary sensitivities. Additionally, studies have highlighted the potential health benefits associated with donkey milk consumption, such as antimicrobial properties and immunomodulatory effects. These factors add to the increasing body of evidence that underscores the suitability of donkey milk as a potential substitute for breast milk in specific situations.

Furthermore, the promotion of donkey breeding for health benefits, rather than for carrying loads, emerges as a significant recommendation from the

literature. By emphasizing the role of donkeys in milk production, communities can potentially derive economic and health advantages. Encouraging sustainable and ethical practices in donkey breeding may not only contribute to infant nutrition but also offer socio-economic benefits to communities engaged in such practices.

In the context of cow milk protein allergy, several studies suggest that donkey milk can be a suitable alternative for infants who are intolerant to cow milk. Donkey milk's protein composition differs from that of cow milk, and it has been reported to be well-tolerated by individuals with cow milk protein allergy. This adds an extra layer of significance to the potential use of donkey milk in infant nutrition.

CONCLUSION:

In conclusion, the reviewed literature suggests that donkey milk holds promise as a potential substitute for breast milk when other options are not available for infants. The nutritional composition, digestibility, and potential health benefits of donkey milk make it a viable alternative, opening avenues for further exploration and research.

The call to promote the breeding of donkeys for health benefits, rather than for carrying loads, is a key takeaway from this review. This shift in focus recognizes the potential

of donkey milk as a valuable resource for infant nutrition. Moreover, in the context of cow milk protein allergy, donkey milk emerges as a potentially beneficial alternative.

However, it is crucial to approach donkey breeding with ethical considerations and in adherence to regulatory frameworks to ensure the well-being of the animals and sustainability of such practices.

As we navigate the complexities of infant nutrition, particularly in cases of cow milk protein allergy, the promotion of responsible donkey breeding practices stands out as a potential avenue for addressing nutritional gaps. Future research and initiatives should continue to explore the practical implementation of such strategies, taking into account both the health of infants and the welfare of the donkey population.

REFERENCES:

- [1] Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, & Uauy R. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*. 2013;382(9890):427-451.
- [2] Horta BL, Victora CG. Long-term effects of breastfeeding: A systematic review. Geneva: World

- Health Organization; 2013.
- [3] World Health Organization. Infant and young child feeding. [Internet]. 2017 [cited 2024 Feb 29]. Available from: <https://www.who.int/en/news-room/fact-sheets/detail/infant-and-young-child-feeding>
- [4] Salimei E, Fantuz F. Equid milk for human consumption. *International Dairy Journal*. 2012;24(1):130-142.
- [5] Soto-Del Rio MD, Sotomayor-Zarate R, Bueno-Sanchez JC, Oviedo-Solis CI, Schumacher M, Echeverria F, ... & Valenzuela CA. Lactoferrin effects on proinflammatory events, heroin self-administration, and relapse of extinguished heroin seeking. *Pharmacology, Biochemistry, and Behavior*. 2016;150-151:153-161.
- [6] Tafaro A, Magistrelli D, D'Alessandro AG, Amoresano A, Cozzolino R, Panico A, ... & Schiraldi C. Donkey's milk detailed lipid composition. *Frontiers in Bioscience (Elite Ed.)*. 2011;3:779-787.
- [7] Magistrelli D, Coppola R, & Seganti L. Antiviral activity of lactoferrin towards naked viruses. *Biometals*. 2011;24(5):847-855.
- [8] Tresoldi G, Cardinale F, Menis C, Maestri L, Gaiaschi A, Cavaletti E, ... & Mastella G. Cow's milk allergy in a child with Dravet syndrome. *Epilepsy & Behavior Case Reports*. 2015;4:22-24.
- [9] Uniacke-Lowe T, & Fox PF. Equid milk: Chemistry, biochemistry and processing. *Food biochemistry and food processing*. 2012;491-530.
- [10] Benhamou AH, Belli DC, Eigenmann PA, & Schäppi T. An overview of cow's milk allergy in children. *Swiss medical weekly*. 2009;139(2122):300-.
- [11] Soto-Del Rio MD, Sotomayor-Zarate R, Bueno-Sanchez JC, Oviedo-Solis CI, Schumacher M, Echeverria F, ... & Valenzuela CA. Lactoferrin effects on proinflammatory events, heroin self-administration, and relapse of extinguished heroin seeking. *Pharmacology, Biochemistry, and Behavior*. 2016;150-151:153-161.
- [12] Kim SY, & Yi DY. Components of human breast milk: from macronutrient to microbiome and microRNA. *Clin Exp Pediatr*. 2020;63(8):301-309.
- [13] Ballard O, & Morrow AL. Human milk composition: nutrients and bioactive factors. *Pediatr Clin*

- North Am. 2013;60(1):49-74.
- [14] Weseler AR, Dirix CE, Bruins MJ, & Hornstra G. Dietary arachidonic acid dose-dependency increases with arachidonic acid concentration in human milk. *Journal Nutrition*. 2018;138:2190–2197.
- [15] Savino F, Bebeti S, Lignori SA, Sorrenti M, Cordero D, Montezemolo L. Advances on human milk hormones and protection against obesity. *Cell. Mol. Biol*. 2013;59:89–98.
- [16] Del Prado M, Villapando S, Elizondo A, Rodriguez M, Demmelair H, Koletzko B. Contribution of dietary and newly formed arachidonic acid to human milk lipids in women eating a low-fat diet. *American Journal Clinical Nutrition*. 2011;74:242–247.
- [17] Zepeda-Ortega B, Goh A, Xepapadaki P, Sprickelman A, Nicolaou N, Hernandez REH, ... & Hussaini BA. Strategies and Future Opportunities for the Prevention, Diagnosis, and Management of Cow Milk Allergy. *Front. Immunol*. 2021;12:1877. doi: 10.3389/fimmu.2021.608372.
- [18] Schoemaker AA, Sprickelman AB, Grimshaw KE, Roberts G, Grabenhenrich L, Rosenfeld L, ... & Dubakiene R. Incidence and natural history of challenge-proven cow's milk allergy in European children—EuroPrevall birth cohort. *Allergy Eur. J. Allergy Clin. Immunol*. 2015;70:963–972. doi: 10.1111/all.12630.
- [19] Flom JD, Sicherer SH. Epidemiology of cow's milk allergy. *Nutrients*. 2019;11:1051. doi: 10.3390/nu11051051.
- [20] Høst A. Frequency of cow's milk allergy in childhood. *Ann. Allergy Asthma Immunol*. 2002;89:33–37. doi: 10.1016/S1081-1206(10)62120-5.
- [21] Skripak JM, Matsui EC, Mudd K, Wood RA. The natural history of IgE-mediated cow's milk allergy. *J. Allergy Clin. Immunol*. 2007;120:1172–1177. doi: 10.1016/j.jaci.2007.08.023.
- [22] Hochwallner H, Schulmeister U, Swoboda I, Spitzauer S, Valenta R. Cow's milk allergy: From allergens to new forms of diagnosis, therapy and prevention. *Methods*. 2014;66:22–33. doi: 10.1016/j.ymeth.2013.08.005.
- [23] Walsh J, Meyer R, Shah N, Quekett

- J, Fox AT. Differentiating milk allergy (IgE and non-IgE mediated) from lactose intolerance: Understanding the underlying mechanisms and presentations. *Br. J. Gen. Pract.* 2016;66:e609–e611. doi: 10.3399/bjgp16X686521.
- [24] Fiocchi A, Dahdah L, Albarini M, Martelli A. Cow's milk allergy in children and adults. *Chem. Immunol. Allergy.* 2015;101:114–123.
- [25] Stevens EE, Patrick TE, Pickler R. A history of infant feeding. *Journal of Perinat. Education.* 2019;18:32–3.
- [26] Fomon SJ, Ziegler EE, Nelson SE. 1993. Erythrocyte incorporation of ingested ⁵⁸Fe by 56-day-old breast-fed and formula-fed infants. *Pediatr Res* 33:573–576.
- [27] Maryniak NZ, Sancho AI, Hansen EB, Bøgh KL. Alternatives to Cow's Milk-Based Infant Formulas in the Prevention and Management of Cow's Milk Allergy. *Foods.* 2022 Mar 23;11(7):926.
- [28] 3 Problems With Baby Formula Ingredients & What To Do About It | She Births Bravely. (n.d.). Retrieved from <https://shebirthsbravely.com/probl-ems-with-baby-formula-ingredients/>
- [29] Carroccio A, et al. "Intolerance to hydrolysed cow's milk proteins in infants: clinical characteristics and dietary treatment." *Clinical & Experimental Allergy* 30.11 (2000): 1598-1603.
- [30] Sarti L, Martini M, Brajon G, Barni S, Salari F, Altomonte I, Ragona G, Mori F, Pucci N, Muscas G, et al. Donkey's Milk in the Management of Children with Cow's Milk protein allergy: Nutritional and hygienic aspects. *Ital. J. Pediatr.* 2019;45:102. doi: 10.1186/s13052-019-0700-4.
- [31] Tesse R, Paglialunga C, Braccio S, Armenio L. Adequacy and tolerance to ass's milk in an Italian cohort of children with cow's milk allergy. *Ital. J. Pediatr.* 2009;35:4–7. doi: 10.1186/1824-7288-35-19.
- [32] Barni S, Sarti L, Mori F, Muscas G, Belli F, Pucci N, Novembre E. Tolerability and palatability of donkey's milk in children with cow's milk allergy. *Pediatr. Allergy Immunol.* 2018;29:329–331. doi: 10.1111/pai.12871.
- [33] Monti G, Bertino E, Muratore Cristina M, Coscia A, Cresi F,

- Silvestro L, Fabris C, Fortunato D, Giuffrida Gabriella M, Conti A. Efficacy of donkey's milk in treating highly problematic cow's milk allergic children: An in vivo and in vitro study. *Pediatr. Allergy Immunol.* 2007;18:258–264. doi: 10.1111/j.1399-3038.2007.00521.x.
- [34] Monti G, Viola S, Baro C, Cresi F, Tovo PA, Moro G, Ferrero MP, Conti A, Bertino E. Tolerability of donkey's milk in 92 highly-problematic cow's milk allergic children. *J. Biol. Regul. Homeost. Agents.* 2012;26:75–82.
- [35] Guo HY, Pang K, Zhang XY, Zhao L, Chen SW, Dong ML, & Ren FZ. (2007). Composition, physiochemical properties, nitrogen fraction distribution, and amino acid profile of donkey milk. *Journal of dairy science*, 90(4), 1635-1643.
- [36] Lauzier AC. Pratiques D'allaitement à Port-Royal et Aux Enfants-Assistés à la Fin du XIXe Siècle. *Gynécologie et Obstétrique.* [(accessed on 18 March 2021)];2011 HAL Id:dumas-00625364. Available online: <https://dumas.ccsd.cnrs.fr/dumas-00625364>
- [37] Picariello G, Ferranti P, Mamone G, Klouckova I, Mechref Y, Novotny MV, & Addeo F. (2012). Gel-free shotgun proteomic analysis of human milk. *Journal of chromatography A*, 1227, 219-233.
- [38] Ishihama Y, Oda Y, Tabata T, Sato T, Nagasu T, Rappsilber J, & Mann M. (2005). Exponentially modified protein abundance index (emPAI) for estimation of absolute protein amount in proteomics by the number of sequenced peptides per protein* s. *Molecular & Cellular Proteomics*, 4(9), 1265-1272.
- [39] Van Herwijnen MJ, Zonneveld MI, Goerdayal S, Nolte EN, Garssen J, Stahl B, et al. Comprehensive proteomic analysis of human milk-derived extracellular vesicles unveils a novel functional proteome distinct from other milk components. *Molecular & Cellular Proteomics*, 15(11), 3412-3423.
- [40] Tidona F, Criscione A, Devold TG, Bordonaro S, Marletta D, & Vegarud GE. (2014). Protein composition and micelle size of donkey milk with different protein patterns: Effects on digestibility. *International Dairy Journal*, 35(1),

- 57-62.
- [41] Sun Y, Nonobe E, Kobayashi Y, Kuraishi T, Aoki F, Yamamoto K, Sakai S. Characterization and expression of L-amino acid oxidase of mouse milk. *Journal of Biological Chemistry*. 2002;277(21):19080-19086.
- [42] Georgi G, Bartke N, Wiens F, Stahl B. Functional glycans and glycoconjugates in human milk. *The American journal of clinical nutrition*. 2013;98(2):578S-585S.
- [43] Girardet JM, N'negue MA, Egito AS, Campagna S, Lagrange A, Gaillard JL. Multiple forms of equine α -lactalbumin: evidence for N-glycosylated and deamidated forms. *International dairy journal*. 2004;14(3):207-217.
- [44] Chiofalo, Biagina, Elisabetta Salimei, and Luigi Chiofalo. "Ass's milk: exploitation of an alimentary resource." *Riv. Folium* 1.Suppl 3 (2001): 235-241.
- [45] Bimonte M, Piazza S, Gervasi F. Donkey milk for manufacture of novel functional fermented beverages. *Nutrients*. 2019;11(2):458.
- [46] Yilmaz O, Eser A, Yilmaz C. Ethical issues and beliefs about the use of animals in research and teaching: An empirical study of Turkish veterinary faculty. *Journal of Agricultural and Environmental Ethics*. 2020;33(3):377-391.
- [47] Martínez-Morcillo S, Mañas R, Risco L, Soto JL. The social perception of the donkey in Spain and its value as a cultural and ecosystem service. *Frontiers in Veterinary Science*. 2021;8:655568.
- [48] Cappelli K, Capomaccio S, Felicetti M, Silvestrelli M, Verini-Supplizi A, Antognoni MT. The first application of DNA barcodes for the identification of the botanical origin of donkey (*Equus asinus*) milk lysozyme. *International Dairy Journal*. 2016;56:37-41.
- [49] Guerzoni ME, Forni M, Rosi F, Winkel BS, De Sanctis R. The equid milk industry: Advances, challenges and perspectives. *Small Ruminant Research*. 2017;148:62-70.
- [50] Perna A, Intaglietta I, Simonetti A. Assessing the welfare of donkeys in the tourism industry: The importance of including all stakeholders. *Journal of Applied*

- Animal Welfare Science. 2018;21(3):312-322.
- [51] Grief, Samuel N. "Food allergies." *Primary Care: Clinics in Office Practice*. 2016;43(3):375-391.
- [52] Dreborg S. Debates in allergy medicine: food intolerance does not exist. *World Allergy Organization Journal*. 2015;8:37.
- [53] Vincenzetti S, Polidori P, Mariani P, Cammertoni N, Fantuz F, Vita A. Donkey's milk protein fractions characterization. *Food Chemistry*. 2008;106(2):640-649.
- [54] Businco L, Giampietro PG, Lucenti P, Lucaroni F, Pini C, Di Felice G, Orlandi M. Allergenicity of mare's milk in children with cow's milk allergy. *Journal of Allergy and Clinical Immunology*. 2000;105(5):1031-1034.
- [55] Vincenzetti S, Santini G, Polzonetti V, Pucciarelli S, Klimanova Y, Polidori P. Vitamins in human and donkey milk: functional and nutritional role. *Nutrients*. 2021;13:1509.
- [56] Bidasolo IB, Ramos M, Gomez-Ruiz JA. In vitro simulated gastrointestinal digestion of donkeys' milk. Peptide characterization by high performance liquid chromatography–tandem mass spectrometry. *Int Dairy J*. 2012;24:146–52.
- [57] Giosuè, C., Alabiso, M., Russo, G., Alicata, M. L., & Torrisi, C. (2008). Jennet milk production during the lactation in a Sicilian farming system. *Animal*, 2(10), 1491-1495.
- [58] Bordonaro, S., Dimauro, C., Criscione, A., Marletta, D., & Macciotta, N. P. P. (2013). The mathematical modeling of the lactation curve for dairy traits of the donkey (*Equus asinus*). *Journal of Dairy Science*, 96(6), 4005-4014.
- [59] Garhwal, R., Sangwan, K., Mehra, R., Kumar, N., Bhardwaj, A., Pal, Y., Kumar, H. (2022). A systematic review of the bioactive components, nutritional qualities and potential therapeutic applications of donkey milk. *Journal of equine veterinary science*, 115, 104006.
- [60] Seyiti, S., & Kelimu, A. (2021). Donkey industry in China: current aspects, suggestions and future challenges. *Journal of Equine Veterinary Science*, 102, 103642.

- [61] Martini, M., Altomonte, I., Tricò, D., Lapenta, R., & Salari, F. (2021). Current knowledge on functionality and potential therapeutic uses of donkey milk. *Animals*, 11(5), 1382.
- [62] Vincenzetti S., Pucciarelli S., Polzonetti V., Polidori P. Role of Proteins and of Some Bioactive Peptides on the Nutritional Quality of Donkey's Milk and Their Impact on Human Health. *Beverages*. 2017;3:34.
- [63] Anantakrishnan, C. P. (1941). 278. Studies on ass's milk: Composition. *Journal of Dairy Research*, 12(2), 119-130.
- [64] Navrátilová P., Borkovcová I., Kaniová L., Dluhošová S., Zachovalová H. The content of selected vitamins and iodine in mare's milk. *Acta Veterinaria Brno*. 2019;88:473–480.
- [65] Vincenzetti S., Savini M., Cecchini C., Micozzi D., Carpi F., Vita A., Polidori P. Effects of Lyophilization and Use of Probiotics on Donkey's Milk Nutritional Characteristics. *Int. J. Food Eng.* 2011;7:1–14.
- [66] Wijesinha-Bettoni R., Burlingame B. Milk and dairy products composition. In: Muehlhoff E., Bennett A., McMahon D., editors. *Milk and Dairy Products in Human Nutrition*. F.A.O.; Rome, Italy: 2013. pp. 41–102.
- [67] Martini M, Altomonte I, Licitra R, Salari F. Technological and seasonal variations of vitamin D and other nutritional components in donkey milk. *J Dairy Sci.* 2018;101:8721–8725. doi: 10.3168/jds.2018-14776.
- [68] Chiavari C, Coloretti F, Nanni M, Sorrentino E, Grazia L. Use of donkey's milk for a fermented beverage with lactobacilli. *Le Lait*. 2005;85(6):481-490.
- [69] Salimei E, Fantuz F, Coppola R, Chiofalo B, Polidori P, Varisco G. Composition and characteristics of ass's milk. *Animal Research*. 2004;53(1):67-78.
- [70] Cunsolo V, Saletti R, Muccilli V, Gallina S, di Francesco A, Foti S. Proteins and bioactive peptides from donkey milk: The molecular basis for its reduced allergenic properties. *Food Res Int.* 2017;99:41–57. doi: 10.1016/j.foodres.2017.07.002.
- [71] Mori F, Sarti L, Barni S, Pucci N, Belli F, Stagi S, Novembre E.

- Donkey's Milk Is Well Accepted and Tolerated by Infants With Cow's Milk Food Protein-Induced Enterocolitis Syndrome: A Preliminary Study. *J Invest Allergol Clin Immunol.* 2017;27:269–271. doi: 10.18176/jiaci.0167.
- [72] Inglingstad RA, Devold TG, Eriksen EK, Holm H, Jacobsen M, Liland KH, Rukke EO, Vegarud GE. Comparison of the digestion of caseins and whey proteins in equine, bovine, caprine and human milks by human gastrointestinal enzymes. *Dairy Sci Technol.* 2010;90:549–563. doi: 10.1051/dst/2010018.
- [73] Vincenzetti S, Pucciarelli S, Santini G, Klimanova Y, Polzonetti V, Polidori P. B-Vitamins Determination in Donkey Milk. *Beverages.* 2020;6:46. doi: 10.3390/beverages6030046.
- [74] Batra B, Narwal V, Kalra V, Sharma M, Rana J. Folic acid biosensors: A review. *Process Biochem.* 2020;92:343–354. doi: 10.1016/j.procbio.2020.01.025.
- [75] Ren X, Yang Z, Shao B, Yin SA, Yang X. B-Vitamin Levels in Human Milk among Different Lactation Stages and Areas in China. *PLoS ONE.* 2015;10:e0133285. doi: 10.1371/journal.pone.0133285.
- [76] Haug A, Høstmark AT, Harstad OM. Bovine milk in human nutrition—A review. *Lipids Health Dis.* 2007;6:25. doi: 10.1186/1476-511X-6-25.
- [77] Aspri M, Economou N, Papademas P. Donkey milk: An overview on functionality, technology, and future prospects. *Food Rev Int.* 2017;33:316–333. doi: 10.1080/87559129.2016.1175014.
- [78] Tafaro A, Magrone T, Jirillo F, Martemucci G, d'Alessandro A, Amati L. Immunological Properties of Donkeys Milk: Its Potential Use in the Prevention of Atherosclerosis. *Curr Pharm Des.* 2007;13:3711–3717. doi: 10.2174/138161207783018590.
- [79] Pieszka M, Łuszczynski J, Zamachowska M, Augustyn R, Długosz B, Hedrzak M. Is mare milk an appropriate food for people?—A review. *Ann Anim Sci.* 2016;16:33–51. doi: 10.1515/aoas-2015-0041.
- [80] Qian B, Shen S, Zhang J, Jing P. Effects of Vitamin B6 Deficiency

- on the Composition and Functional Potential of T Cell Populations. *J Immunol Res.* 2017;2017:1–12. doi: 10.1155/2017/2197975.
- [81] Nayak CM, Ramachandra CT, Nidoni U, Hiregoudar S, Ram J, Naik N. Physico-chemical composition, minerals, vitamins, amino acids, fatty acid profile and sensory evaluation of donkey milk from Indian small grey breed. *J Food Sci Technol.* 2020;57:2967–2974. doi: 10.1007/s13197-020-04329-1.
- [82] Zhang H, Yao J, Zhao D, Liu H, Li J, Guo M. Changes in Chemical Composition of Alxa Bactrian Camel Milk During Lactation. *J Dairy Sci.* 2005;88:3402–3410. doi: 10.3168/jds.S0022-0302(05)73024-1.
- [83] Yao Y, Zhao G, Yan Y, Mu H, Jin Q, Zou X, Wang X. Milk fat globules by confocal Raman microscopy: Differences in human, bovine and caprine milk. *Food Res Int.* 2016;80:61–69. doi: 10.1016/j.foodres.2015.12.017.
- [84] Pereira PC. Milk nutritional composition and its role in human health. *Nutrients.* 2014;30:619–627. doi: 10.1016/j.nut.2013.10.011.
- [85] Miller BD, Welch RM. Food system strategies for preventing micronutrient malnutrition. *Food Policy.* 2013;42:115–128. doi: 10.1016/j.foodpol.2013.06.008.
- [86] Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, Murad MH, Weaver CM. Evaluation, Treatment, and Prevention of Vitamin D Deficiency: An Endocrine Society Clinical Practice Guideline. *J Clin Endocrinol Metab.* 2011;96:1911–1930. doi: 10.1210/jc.2011-0385.
- [87] Altomonte I, Salari F, Licitra R, Martini M. Donkey and human milk: Insights into their compositional similarities. *Int Dairy J.* 2019;89:111–118. doi: 10.1016/j.idairyj.2018.09.005.
- [88] Vici G, Camilletti D, Polzonetti V. Possible Role of Vitamin D in Celiac Disease Onset. *Nutrients.* 2020;12:1051. doi: 10.3390/nu12041051.
- [89] Polzonetti V, Pucciarelli S, Vincenzetti S, Polidori P. Dietary Intake of Vitamin D from Dairy Products Reduces the Risk of Osteoporosis. *Nutrients.*

- 2020;12:1743. doi: 10.3390/nu12061743.
- [90] Gentili A, Caretti F, Bellante S, Ventura S, Canepari S, Curini R. Comprehensive Profiling of Carotenoids and Fat-Soluble Vitamins in Milk from Different Animal Species by LC-DAD-MS/MS Hyphenation. *J Agric Food Chem.* 2012;61:1628–1639. doi: 10.1021/jf302811a.
- [91] Lima MSR, Dimenstein R, Ribeiro KD. Vitamin E concentration in human milk and associated factors: A literature review. *J Pediatr.* 2014;90:440–448. doi: 10.1016/j.jpmed.2014.04.006.
- [92] Ballard O, Morrow AL. Human milk composition: Nutrients and bioactive factors. *Pediatr Clin N Amer.* 2013;60:49–74. doi: 10.1016/j.pcl.2012.10.002.
- [93] Schaafsma G. Nutritional significance of lactose and lactose derivatives. *Encyclopaedia of Dairy Science.* 2003;3:1529–33.
- [94] Coppola R, Salimei E, Succi M, Sorrentino E, Nanni M, Ranieri P, Belli Blanes R, Grazia L. Behaviour of *Lactobacillus rhamnosus* strains in ass's milk. *Ann Microbiology.* 2002;52:55–60.
- [95] Coppola R, Salimei E, Sorrentino E, Nanni M, Succi M, Belli Blanes R, Grazia L. Latte d'asina: un substrato ideale per la preparazione di bevande probiotiche. *Proc 36° Simp Internazionale Zootecnico Ancona, Italy.* 2001;57–61.
- [96] Fantuz F, Ferraro S, Todini L, Piloni R, Mariani P, Salimei E. Donkey milk concentration of calcium, phosphorus, potassium, sodium and magnesium. *Int Dairy J.* 2012;24(2):143–45.