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IS MARE MILK AN APPROPRIATE FOOD FOR PEOPLE? – A REVIEW*

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Abstract

The use of equid milk in human nutrition is a very interesting research topic in relation to the specific characteristics of this drink. Mare's milk has a composition similar to human milk and is well digested, so it is a perfect alternative to cow's milk in the feeding of children who are allergic to cow's milk. Equid milk's low content of α-lactalbumin and β-lactoglobulin makes it appropriate for such children. Its high concentration of lactose allows for a better growth of intestinal microflora. Mare's milk is characterised by a high content of lysozyme, lactoferrin and lactadherin and has an inhibiting effect on the development of pathogenic bacteria. Research done so far indicates that it may be helpful in treating atopic dermatitis as well as in improving skin appearance. The high content of vitamin C in mare's milk influences its antioxidant value. Due to its lower content of fat and cholesterol it can be used to lower cholesterol intake as well as to control cardiovascular diseases. Mare's milk has been proved to play a role in curing Crohn's disease, ulcerative colitis, as well as hepatitis and chronic gastric ulcers. The qualities of mare's milk make it appropriate for use in children's and elderly people's nutrition in prophylaxis and as an aid to the process of curing various diseases.

Key words: mare milk, people's health and nutrition

The basic role of mare's milk is to provide the foal with the nutrients necessary in the first months of its development. However, it has also been used by the people of Central Asia in their everyday diet. Fatty acid analysis of the remains of fat from the shards of plates used by the Botai people inhabiting the north part of present-day Kazakhstan around 3500 BC established that their diet included not only horse meat,

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but also mare's milk, which indicates that horses were domesticated in that period (Outram et al., 2009). Mares are still used to produce milk in these areas, but the milk is not usually consumed raw as it may have diarrhoeal effects (Abdel-Salam et al., 2010). Instead, it is used in production of fermented beverages. The most popular of them, and the one that is most commonly mass produced, is kumis. Mare's milk and kumis have beneficial effects on health, thus they have been considered medicine in Bashkortostan, Kazakhstan, Uzbekistan and Ukraine (Danków et al., 2009). In the middle of the 19th century, in south Russia, mainly in the region of Samara and Orenburg but also in Moscow and Saint Petersburg, there were centres successfully using kumis therapy in treating lung diseases, mainly tuberculosis, and in strengthening the body (Jagielski, 1874). Institutions using fermented milk were also found during that time in Grochów and in Warsaw. At that time, kumis was recommended as a digestive, expectorant, anti-fever, nutritive and strengthening remedy, as well as a nervous system stimulant (Dręcki, 1875). Since the early 20th century in Germany, mare's milk has been a popular drink, sold and distributed to households. One of the earliest mentions of mare's milk in France was made by Bouchardat and Quevenne (1857). Currently, one can also observe an increase in its popularity also in France, Belgium, Austria and the Netherlands (Sheng and Fang, 2009). Yet, the largest number of dairy mares are kept nowadays in Mongolia and some parts of its neighbouring countries (Russian Buryatia and Inner Mongolia in northern China), Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, in Russian Kalmykia and Bashkortostan, also in Tibet and the Xinjiang autonomous region of China. Smaller herds of dairy mares are kept in Europe, mostly in Belarus and Ukraine (Sheng and Fang, 2009). The use of horses for milk is also gaining popularity in the United States. Depending on the region, different breeds of horses are used for this purpose: in Eurasia they are most often local breeds, mostly Bashkirian; in France – Percherons and in Belgium – Haflingers. Mare's milk is attracting more and more interest from consumers due to its high content of vitamins and minerals, better digestibility and lower content of fat in comparison with cow's milk (Sheng and Fang, 2009).

The aim of this review paper was the attempt to determine whether mare's milk is appropriate food for people. Hence, its content has been analysed with respect to the characteristics that may be beneficial to people's health.

The source of mare's milk – the structure of the mammary gland

The mammary gland of a mare consists of two halves separated with an intermammary groove. Each half consists of a mamma and a teat. Responsible for colostrum, and later milk excretion, are epithelial cells forming alveoli which are grouped into lobules; the number of these cells increases with gestational age and enlarges the excretory surface. The lobules are surrounded by myoepithelial cells responsible for the ejection of secretion, which is discharged via ducts into the lactiferous sinus. Two to four papillary ducts convey milk to a common teat opening. Each papillary duct has its separate set of lobules and milk canals (Włodarczyk-Szydłowska et al., 2005). The first secretion of the mammary gland is colostrum, whose content quickly changes within 12 hours after birth, notably the level of immunoglobulins drops rapidly (Włodarczyk-Szydłowska et al., 2005). The first three weeks after foaling are a transition period, after which the milk's content stabilises. The peak of lactation is 2 months after foaling, sometimes several weeks later (Oftedal et al., 1983). The amount of secreted milk in the first 12 weeks of lactation is approximately 3% of the mare's body weight and decreases to approximately 2% in the following 12 weeks, both in draught and warmblood breeds (Włodarczyk-Szydłowska et al., 2005). Lactation usually lasts between 5 to 8 months and the estimated production of milk is between 2000 to 3000 kg per lactation (Salamon et al., 2009). Half-bred mares produce about 10–12 kg of milk per day whereas draught mares produce 15–20 kg, but this amount may be as high as 29 kg per day (Oftedal et al., 1983) which is higher than the volume of milk obtainable during hand or mechanical milking. It seems that a foal's presence within the mare's sight is necessary for the latter to produce milk and for the former to obtain it due to oxytocin block (Amirante et al., 2004). The production of milk may also be sustained in the following months, but the amount of the solids content is lower. Mares' milk secretion is seasonal, mainly in spring and summer, but it is also limited to the time when a foal is kept with its mother. The stage of lactation is one of the most important factors influencing the yield and chemical composition of mare's milk together with season of lactation (Centoducati et al., 2012; Markiewicz-Kęszycka et al., 2015).

The aforementioned factors unfortunately make mare's milk an expensive product – the small amount obtained during milking, the difficult extraction process and its seasonal nature means that currently one litre of frozen milk costs approximately 4–7 Euro, and milk powder is between 100–150 Euro per kg.

Chemical composition of mare's milk, comparison with human and cow's milk

Mare's milk is the first and the only feed for the foal during the 2–3 months after birth. The growth and development of the young horse at this period depends on the concentration of protein, energy and macro- and microelements in mother's milk (Pieszka and Kulisa, 2003; Pieszka et al., 2004 b; Pieszka and Kulisa, 2005). Both the amount of milk produced and its composition depend on the stage of lactation, the mare's age and the type of fodder consumed (Hoffman et al., 1998; Markiewicz-Kęszycka et al., 2015; Pieszka et al., 2004 a). Mare's milk is characterised by high water content and low calorie content. The concentration of mare's milk components varies throughout lactation. Over the first 25 days of lactation, the amount of solids and protein decreases, after which the composition stabilises (Pagliarini et al., 1993; Pecka et al., 2012). At the end of lactation the amount of protein slightly diminishes, whereas the amount of solids and fat may increase or stay the same. The amount of lactose throughout lactation may increase or stay the same (Oftedal et al., 1983). The average percentage values of full mare's milk in the middle of lactation period are: solids 10.5%, fat 1.25–1.3%, protein 1.93–2.1%, lactose 6.4–6.91% (Oftedal et al., 1983; Nikkhah, 2012; Pieszka and Łuszczyński, 2013; Salimei and Fantuz, 2012).

Mare's milk and human milk are similar as to the content of crude protein and lactose. Yet, the amount of fat is much higher in human and cow's milk (36.4 g/kg and 36.1 g/kg respectively). There are also fewer mineral salts in mare's milk as compared to cow's milk (Clayes et al., 2014; Malacarne et al., 2002; Sheng and Fang, 2009). Due to its low content of casein and fat, mare's milk is not appropriate for cheese and butter production. Its structure is unstable at temperatures above 40ºC. For that reason mare's milk must be cooled quickly and used in liquid form within 6–9 hours after milking (Danków et al., 2006 b).

Table 1. Comparison of main components of mare, human and cow's milk (Clayes et al., 2014; Malacarne et al., 2002; Sheng and Fang, 2009)

Component	Mare's milk	Human milk	Cow's milk
Fat (g/kg)	12.1 (5–20)	36.4 (35–40)	36.1 (35–39)
triglycerides (%)	81.1	98.0	97.0
phospholipids (%)	5.0	1.3	1.5
saponifiable matter fractions (%)	4.5	0.7	1.5
free fatty acids (%)	9.4	trace	trace
Total protein (g/kg)	21.4 (15–28)	14.2 (9–17)	32.5 (31–38)
whey protein (%)	38.79	53.52	17.54
casein (%)	50.00	26.06	77.23
non-protein nitrogen (%)	11.21	20.42	5.23
Lactose (g/kg)	63.7 (58–70)	67.0 (63–70)	48.8 (44–49)
Ash (g/kg)	4.2 (3–5)	2.2 (2–3)	7.6 (7–8)

Fat

The fat content of mare's milk is significantly lower in comparison with human and cow's milk (Table 1). This fat contains fewer triglycerides, but it is richer in free fatty acids (FFA) and phospholipids. Mare's milk consists mainly of medium chain fatty acids, human milk has high concentration of long chain fatty acids whereas cow's milk is richer in short chain fatty acids (Sheng and Fang, 2009; Markiewicz--Kęszycka et al., 2014).

Milk lipids are in the form of globules, whose size in mare's milk is 2–3 μm, in human milk approximately 4 μm and in cow's milk 3–5 μm (Clayes et al., 2014). A single triglyceride globule is coated with three layers – an internal protein layer, an intermediate layer consisting of a phospholipid membrane and an external layer consisting of high-molecular-weight glycoproteins. In the case of mare's and human milk, there is a branched oligosaccharide structure on the surface of these glycoproteins. A lipid globule in cow's milk is coated with a thin protective coating, whose external layers consist of proteins and phospholipids (Barello et al., 2008; Malacarne et al., 2002; Sheng and Fang, 2009).

Phospholipids and unsaponifiable fractions

Phospholipids are contained in the lipoprotein layers of the cell membrane, they are composed mainly of polyunsaturated fatty acids. They are present in all living cells, including nerve cells. Mare's milk is richer in these than either human or cow's milk. The composition of phospholipids in mare's milk is different from that of human and cow's milk (Malacarne et al., 2002; Sheng and Fang, 2009). In comparison with human milk, mare's milk is richer in phosphatidylethanolamine and phosphatidylserine, it has a similar amount of sphingomyelin, but has less phosphatidylcholine and contains only traces of phosphatidylinositol.

The content of unsaponifiable constituents is higher in mare's milk in comparison to human or cow's milk (Table 1). The sterol fraction, which includes cholesterol, is comparable to cow and human milks and amounts to approximately 0.3–0.4% of all lipids (Malacarne et al., 2002). Pikul et al. (2008 b) stated that mare's milk lipids contain fewer triglycerides (81.1%) than human milk (98%) and cow's milk (97%), but more phospholipids (5%, 1.3%, 1.5% respectively) and a larger unsaponifiable fraction (4.5%, 0.7%, 1.5% respectively). Cholesterol constitutes 0.3–0.4% of the unsaponifiable fraction (Malacarne et al., 2002). Mare's milk contains low concentration of cholesterol (5–8.8 mg/100 ml milk) as compared to human (14–20 mg/100 ml milk) and cow's milk (13–31 mg/100 ml milk) (Clayes et al., 2014; Markiewicz--Kęszycka et al., 2014).

Triglycerides and fatty acids

Triglyceride structure has a significant influence on the activity of lipolytic enzymes. Pikul et al. (2008 b) stated that mare's milk lipids contain fewer triglycerides (81.1%) than human milk (98%) and cow's milk (97%). Palmitic acid (C 16:0) has a similar position in mare's and human milk, which is likely to affect lipid assimilation in a beneficial way (Malacarne et al., 2002). Mare's milk contains a high amount of free fatty acids whereas they are found only in trace amounts in human and cow milk (Pikul and Wójtowski, 2008; Pikul et al., 2008). In terms of unsaturated fatty acid concentration mare's milk is similar to human milk. However, there is a difference in the amount of free fatty acids (Table 1) (Csapo et al., 1995 a; Malacarne et al., 2002). As Rutkowska et al. (2011) state, the difference between fatty acid composition in mare's and cow's milk is affected by feeding seasons depending on different feeding systems and the specific structure of gastrointestinal tract. Complex processes of hydrogenation, which are characteristic for ruminants, practically do not take place in the gastrointestinal tract of horses. For that reason, vaccenic acid (C18:1 11t) present in cow's milk (1.08% during the summer feeding period and 1.65% during the pasture feeding period) may not occur in mare's milk. Nearly the same occurs with stearic acid (C18:0), which is significantly more present in cow's milk fat (10.89% during the winter feeding period and 10.77% during the summer feeding period) than in mare's milk (1.20 and 1.26%). The study conducted by Orlandi et al. (2002, 2003) showed a little amount of conjugated linoleic acid (CLA) in mare's milk – 0.05% during the winter feeding period based on hay and grains and 0.14% during the summer feeding period based on grass. The values of CLA in cow's milk samples were 0.43% and 0.67% respectively (Orlandi et al., 2003). The presence of these acids indicates the activity of bacteria that inhabit horses' caecum and act in a similar way to cow rumen bacteria. The comparative analysis of fatty acids composition in mare's milk done by Rutkowska et al. (2011) showed a high amount of saturated fatty acids (SFA): caprylic acid C8:0 (between 2.81 and 5.17%), capric acid C10:0 (between 6.30 and 11.34%) and lauric acid C12:0 (between 6.94 and 9.79%).

Table 2. Concentration of selected fatty acids (g/100g^{-1} of fat) and cholesterol (mgL^{-1}) in milk of mare, human and cow (Markiewicz-Kęszycka et al., 2014)

Component	Mare's milk	Human milk	Cow's milk
C18:0	2.09	5.63–6.45	10.51
C18:1 cis 9	25.04	31.26–37.45	20.5
C18:2*n-6* LA	3.81	15.24–17.73	3.13
C18:3*n-3* ALA	17.51	0.6–1.36	0.59
SFA	49.35	38.52–44.3	53.67–63.52
MUFA	33.59	36.56–42.92	30.12–38.19
PUFA	21.33	18.24–19.1	3.63–5.84
LA/ALA	0.23	25.4–33.24	5.3
PUFA/SFA	0.39	0.47	0.06–0.1
AI	0.85	0.74	1.63–2.3
TI	0.38	0.68–1.0	2.12–2.83
Cholesterol	2.04	100–200	155.1–195.8

Abbreviations: LA – linoleic acid; ALA – α-linolenic acid; SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; AI – atherogenic index; TI – thrombogenic index.

Essential fatty acids (EFA) improve the fat-soluble vitamin absorption and they also play a role in modulating inflammatory processes and immune protection. Proper proportion of EFA may support prevention and treatment of many human diseases such as cancers, heart diseases or Alzheimer's disease or even depression. Orlandi et al. (2002) showed that from the group of unsaturated fatty acids (UFA) mainly linolenic acid C18:2 (between 12.29 and 13.78%) and α-linolenic acid C18:3 (between 3.74 and 5.10%) were present in mare milk. Cow milk was richer in the following SFA: butyric acid C4:0 (between 2.37 and 2.63%), caproic acid C6:0 (between 1.78 and 2.06%) and stearic acid C18:0 (between 10.77 and 10.89%) but much less abundant in such PUFAs as linolenic acid (between 1.17 and 1.22%) and α-linolenic acid (between 0.38 and 0.48%). The total amount of polyunsaturated fatty acids (PUFAs) in mare milk fat was 17.44% during winter feeding period and 17.66% during summer period, and much smaller in cow milk fat: 1.98 and 2.32% (Orlandi et al., 2002). Markiewicz-Kęszycka et al. (2014) showed the highest concentration of C18:3*n-3* ALA as compared to cow and human milk while other unsaturated fatty acids were at average level (Table 2). Mare milk has an exceptional value of atherogenic and thrombogenic indexes which are similar to indexes presented by human milk and much lower than in cow milk. These indexes take into account the different effect that single fatty acid might have on human health and in particular on the probability of increasing the incidence of pathogenic phenomena, such as atheroma and/or thrombus formation. The indexes indicate the global quality of lipids (Ghaeni et al., 2013).

Protein

The average percentage of the protein fraction content in mare's milk as compared to human and cow's milk is shown in Tables 1 and 3.

Mare's milk is similar to human milk in terms of protein composition. Compared to other fractions, the percentage of whey protein in mare's milk is more than 20%

higher than in cow's milk, amounting to approximately 40%, but lower than in human milk (more than 50%). Cow's milk has the highest amount of caseins. For that reason it is called casein type milk, whereas mare and human milk are called albumin type milk (Malacarne et al., 2002; Pieszka and Kulisa, 2005; Pieszka, 2008). The large amount of whey protein and exogenous amino acids in mare's milk make it a more beneficial source of nutrients for people than cow's milk (Csapo-Kiss et al., 1995; Csapo et al., 2009; Markiewicz-Kęszycka et al., 2013).

Table 3. Average percentage of whey protein fractions in milk of mare, human and cow (% of total whey protein) (Malacarne et al., 2002; Sheng and Fang, 2009)

Component	Mare's milk	Human milk	Cow's milk
α-lactalbumin	28.55 (27.5–29.7)	42.37 (30.3–45.4)	53.59 (52.9–53.6)
β-lactalbumin	30.75 (25.3–36.3)	absent	20.10 (18.4–20.1)
Immunoglobulins	19.77 (18.7–20.9)	18.15 (15.1–19.7)	11.73 (10.1–11.8)
Serum albumin	4.45 (4.4–4.5)	7.56 (4.5–9.1)	6.20 (5.5–7.6)
Lactoferrin	9.89	30.26	8.38
Lysozyme	6.59	1.66	Trace

α-lactalbumin

α-lactalbumin, which acts together with N-acetyllactosaminide 3-α-galactosyltransferase, is responsible for the transformation of glucose into galactose and lactose synthesis. It has the ability to bind and transport Ca^{2+}. In addition, it shows a poor cell capacity (Sheng and Fang, 2009). It contains 123 amino acids similarly to bovine, caprine, ovine, asinine, camelid and human milk. It differs only in a few single amino-acid replacements (Uniacke-Lowe, 2010). Its largest percentage is present in cow's milk, in which it constitutes 50% of all whey proteins, whereas mare's milk contains the least of it (Table 3).

β-lactoglobulin

This substance has the ability to bind retinol. β-lactoglobulin II of mare's milk shows similarity to human retinol binding protein as far as its structure is concerned (Sheng and Fang, 2009). Research on cow's milk β-lactoglobulin showed that it has the ability to make bindings with fatty acids, cholesterol, vitamin D_3 and other fat-soluble vitamins (Górska et al., 2012). It is not present in human milk, and mare's milk contains more of it than cow's milk (Table 3). Probably the digestibility of equine β-lactoglobulin makes mare's milk a potential hypo-allergenic product (Inglingstad et al., 2010).

Lysozyme

This constitutes the main link of microbiological protection of milk, both mare and human: it catalyses hydrolysis of glycosidic bindings in the bacterial cell membrane. Mare's milk lysozyme plays an important role in the process of its coagulation, in addition it has the ability to bind calcium (Sheng and Fang, 2009). Lysozyme is characterised by antiviral properties – it makes insoluble complexes with viruses, probably as a result of interactions with nucleic acids (Uniacke-Lowe, 2010). Outside the cell, lysozyme inactivates viral toxins. Mare's milk lysozyme is stable in acidic solutions, unstable in alkaline solution, yet its stability is greater than that of human lysozyme (Uniacke-Lowe, 2010; Danków et al., 2006 a). In cow's milk, lysozyme is present in trace amounts, due to the fact that the protective role is played by colostrum immunoglobulins (Malacarne et al., 2002). Mare's milk, on the other hand is much richer in this substance than human and cow's milk (Table 3).

Lactoferrin

Lactotransferrin is homologous to serum transferrin, whereas lactoferrin is not present in plasma. They have different physicochemical properties, but both have the ability to bind iron. In addition, lactoferrin has a bactericidal and virucidal effect (Uniacke-Lowe, 2010). Its level in mare's milk is between 0.2 and 2 g/kg of milk and it is only slightly lower than in human milk, but 10 times higher than in cow's milk (Sheng and Fang, 2009; Markiewicz-Kęszycka et al., 2013).

Immunoglobulins

The main immunoglobulin occurring in mare colostrum is IgG but in milk is secretory IgA, which bears a resemblance to human secretory IgA. In a human mother IgG is transferred to the foetus in utero. In contrast in equids and ruminants, their newborns depend on the colostrum's supply of IgG. After 2–3 days their IgG level in blood plasma is similar to adults (Uniacke-Lowe, 2010). Similarly to lysozyme and lactoferrin IgG has bactericidal, antiphlogistic and immunomodulating properties (Foekel et al., 2009). Mare's and human milk contains comparable percentage of immunoglobulins, considerably higher than cow's milk (Table 3).

Albumin

Mare's milk albumin has the ability to bind fatty acids and contains approximately 2.9 mole of fatty acids/mole of proteins. Bound fatty acids have also been found in human milk albumin (Sheng and Fang, 2009). Human milk contains the highest percentage of albumin and mare's milk – the lowest (Table 3).

Caseins

Mare's milk contains αS1- and αS2-casein in the casein fraction, which comprises 40% of caseins. Similarly to cow's milk, mare's milk contains β-casein (approximately 50% of all caseins) and γ-casein (approximately 10%) (Clayes et al., 2014; Sheng and Fang, 2009). In addition κ-casein has been identified, which has similar properties to the κ-casein present in cow and human milk (Malacarne et al., 2002), but is present in lower amounts (Table 4). Casein micelles of mare's milk have a diameter of 255 nm and are larger than human milk micelles (64 nm) and cow's milk micelles (182 nm). The structure of mare's milk micelles, just like cow's milk micelles is spongy, whereas in human milk it is a structure of canals (Jasińska and Jaworska, 1991; Malacarne et al., 2002). The smaller content of caseins in mare's milk in comparison to cow's milk makes the time of its digestion shorter: mare's and human milk forms a smooth precipitate in the stomach which is digested within approximately 2 hours, whereas it takes between 3 and 5 hours to digest cow's milk coagulate (Inglingstad et al., 2010; Sheng and Fang, 2009).

Table 4. Comparison of the percentage composition of caseins in mare, human and cow milk (Malacarne et al., 2002; Sheng and Fang, 2009)

Component	Mare's milk	Human milk	Cow's milk
α-casein (%)	46.65 (40.2–59.0)	11.75 (11.1–12.3)	48.46 (48.3–48.5)
β-casein (%)	45.64 (40.1–50.4)	64.75 (62.5–66.7)	36.77 (35.8–37.9)
κ-casein (%)	7.71 (7.2–7.9)	23.5 (22.2–25.0)	12.69 (12.4–13.8)

Lactose and carbohydrates

Mare's milk contains much more lactose than cow's milk (Table 1); this lactose is the main source of carbohydrates. Lactose can be supplied to an organism only as a constituent of milk. As a part of milk, lactose can influence the process of seeding the gastrointestinal tract with microorganisms responsible for its breakdown. Galactose contained in lactose takes part in the process of fast brain development and myelination in young organisms, which require significant amounts of galactosylceramides and galactolipids (Sheng and Fang, 2009).

Carbohydrates occur also in the form of oligosaccharides which build the surface of external layer of lipid globules. They form a branched structure, similar to that of human milk, absent in cow's milk. Such a structure is likely to slow down the transport of fat through the gastrointestinal system and allows for a longer activity of bile salts and lipase. Some of the oligosaccharides also present in human milk demonstrate the ability to inhibit bacterial infections and enhance the growth and activity of bifidobacteria (Sheng and Fang, 2009).

Vitamins and minerals

Table 5 a. Comparison of fat soluble vitamins content in milk of mare, human and cow (Markiewicz-Kęszycka, 2014)

Vitamin (mg/kg)	Mare's milk	Human milk	Cow's milk
A (mg/L^{-1})	0.403	0.455	0.435–0.799
D_3 ($\mu g/L^{-1}$)	4.93	0.03–0.12	2.31–15.39
E (mg/L^{-1})	1.13	5.09	1.05–1.95
K_2 ($\mu g/L^{-1}$)	17.93	1.80	4.81–17
ß-carotene (mg/L^{-1})	0.388	0.002–0.375	0.166–0.380

Vitamins

The content of vitamins and other elements depends on the lactation period and feeding regime of the mare (Clayes et al., 2014). Mare's milk has been proven to contain vitamins A, D_3, E, K_2, C, B_1, B_2, B_3, $B_{6,}$ B_{12} as well as nicotinic, pantothenic and folic acids. With the exception of vitamin C, the content of other vitamins in mare's and cow's milk does not differ significantly (Markiewicz-Kęszycka et al., 2014; Salamon et al., 2009) (Table 5 a and 5 b). Mare's milk is much richer in vitamin C as compared to cow's milk, and this vitamin has a high nutritional value due to its resistance to oxidation and antiinflammatory properties. Its content in mare's milk around 1.5 month after foaling is 17.2 mg/kg, then drops to 12.87 mg/kg (Clayes et al., 2014; Sheng and Fang, 2009). Mare's milk contains a similar level of vitamin A as compared to cow's milk but Markiewicz-Kęszycka et al. (2014) pointed out that it is less than in human milk. Kuhl et al. (2012) have found that β-carotene supplementation of mares increased the level of this vitamin in colostrum and milk. Results of recent studies showed that vitamin D was found in greater amount in mare's milk as compared to human milk (Markiewicz-Kęszycka et al., 2014; Salamon et al., 2009). According to Glade (2012), supplementation with vitamin D significantly decreased the risk of premature death and death from cancer as well as supporting general health. Mare's milk is characterised by an average concentration of vitamins from the B group, while human milk contains less and cow's milk more as compared to mare's milk (Table 5 b). The level of cobalamin was shown to be higher and vitamins B_2 and B_9 to be lower in mare's milk compared to human and cow's milk (Clayes et al., 2014; Sheng and Fang, 2009).

Table 5 b. Comparison of water soluble vitamins content in milk of mare, human and cow (Claeys et al., 2014; Park, 2009)

Vitamin (μg/L^{-1})	Mare's milk	Human milk	Cow's milk
Thiamin B_1	20–40	14–17	28–90
Riboflavin B_2	10–37	20–60	116–202
Niacin B_3	70–140	147–178	50–120
Pantothenic acid B_5	277–300	184–270	260–490
Pyridoxine B_6	30	11–14	30–70
Folic acid B_9	0.13	5.2–16	1–18
Cobalamin B_{12}	0.3	0.03–0.05	0.11
Ascorbic acid	1280–8100	3500–10000	300–2300

Macro- and microelements

Mineral content is lower in human and mare's milk compared to cow's milk. Sodium in the form of cations plays an important role as a constituent of blood and extracellular fluid, potassium as a cation takes part in maintaining the integrity of intracellular fluid. Milk is generally a good source of calcium and phosphorus which are necessary for the process of bone growth and development, and also magnesium, which is needed for mineralisation of bones (Sheng and Fang, 2009). Mineral content is highest in the first week of lactation and then decreases. Due to the fact that the proportion of minerals is constantly changing in mare's milk, it is difficult to determine precisely their average concentration.

It is necessary to point out that a single sample is not representative of the whole lactation, but rather of a specific lactation stage (Schryver et al., 1986). These authors also observed a change in Ca:P ratio from 1.45:1 in the first week of lactation to 1.3:1 in the 15th–17th weeks, which is close to the optimal ratio of these elements in humans (between 1:1 and 1.3:1). In the same period Ca:Mg ratio changed from 11:1

to 16:1. The differentiation of mineral content as far as the mare's breed is concerned is shown in Table 6. The highest content of calcium can be observed in the milk of Bardigiano mares and Italian Saddlebred mares. The lowest values of magnesium and zinc were reported for Arabian mares (Table 6).

Table 6. The average content of macro- and micronutrients in the milk of mares of different breeds (Pieszka and Łuszczyński, 2013; Sheng and Fang, 2009)

Breed	Days of lactation	Macro- and micronutrients (mg/Dl)							
		Ca	P	Mg	Na	K	Zn	Fe	Cu
Arabian	2–30	914	394	29	132	632	0.89	1.46	0.25
Quarter Horse	3–180	787	504	75	171	701	-	-	-
Przewalski horse	85–250	804	419	62	137	344	1.90	1.10	0.23
Thoroughbred	6–120	811	566	53	140	410	1.90	0.27	0.25
Shetland Pony	6–120	857	418	77	127	250	1.70	-	0.37
Bardigiano	5–35	1220	668	-	198	662	2.79	1.06	1.06
Italian Saddlebred	5–35	1155	678	-	167	573	2.95	1.47	0.73
Haflinger	4–180	802	593	77	181	443	-	-	-

Table 7. Comparison of minerals content (mg/100 ml milk) in milk of mare, human and cow (Claeys et al., 2014)

Mineral component	Mare's milk	Human milk	Cow's milk
Ca	50–135	28–34	112–123
P	20–121	14–43	59–119
K	25–87	53–62	106–163
Mg	3–12	3–4	7–12
Na	8–85	10–18	58
Cl	19	60–63	100–119
Fe	0.02–0.15	0.04–0.2	0.03–0.1
Zn	0.09–0.64	0.2–0.4	0.3–0.55
Cu	0.02–0.11	0.02–0.06	0.01–0.08

There are major differences in the mineral content of mare's, cow's and human milk: the concentration of most minerals is higher in mare's milk than in human milk but much lower than in cow's milk (Table 7). The investigation of Clayes et al. (2014) showed that cow's milk contains about 50% more Ca and nearly twice as much P and K than mare's milk but horse milk contains about 2 times more Ca and P than human milk. Ca to P ratio of human and mare's milk are reported to be more favourable for intake of Ca compared to the ratio in cow's milk. Microelements concentration is low in all milks discussed. The biovailability of milk minerals might be affected by different factors, such as the content of other components of milk.

Other elements

There are more whey proteins in mare's milk (0.83%) than in cow's milk (0.57%) and human milk (0.76%), which promotes the availability of a greater amount of functional substances, hormones, immunoglobulins, and nitrogen compounds characterised by bactericidal activity, e.g. lysozyme and lactoferrin (Chifalo et al., 2006). In addition to lysozyme, mare's milk also contains the following enzymes: lipase, plasmin, dehydrogenase, aminotransferase. Lipase, taking part in lipolysis, is present in mare's milk in small amounts, similarly to endogenic plasmin. Lipase plays a role in β-casein hydrolysis; it shows much activity in fresh mare's milk. Dehydrogenase is responsible for dehydrogenation of lactic acid. It is present in mare's milk in the form of lactate dehydrogenase (LDH). Its activity is greatest during the first day of lactation, then it drops rapidly until the third day, slowly decreasing until the 20th day, to remain stable at the level of 80U/l afterwards. Aminotransferase is also present in small amounts. It affects the metabolism of carbohydrates, synthesis and the synthesis of amino acids. It is also a mediator of glutathione and facilitates the supply of ascorbinic acid to bronchia cells (Sheng and Fang, 2009). Mare's milk has been proven to contain insulin and insulin growth factor – 1 (IGF-1) which take part in the process of cell development and protection of the central nervous system; prolactin binding protein which promotes and limits prolactin activity; parathyroid hormone-related peptide (PTHrP) which plays a role in modulation of bone metabolism as well as differentiation and proliferation of cells; triiodothyronine (T_3) and 5'-deiodinase which foster the process of lactogenesis; progestogen and leptin, which influence regulation of appetite and play a role in angiogenesis and bone formation. Other constituents of mare's milk constituents include interleukin 1, carnitine binding long chain polyunsaturated fatty acids (LC-PUFA), lactadherin having antibacterial properties and amyloid A (Sheng and Fang, 2009).

Mare's milk bacteria

Mare's milk does not contain many bacteria – it is characterised by the smallest number of somatic cells among domesticated animals and a very small total bacterial count (Danków et al., 2006 b; Danków et al., 2011). However, as many as 191 types of lactic acid bacteria have been isolated. Those were mainly *Leuconostoc mesenteroides* (45%), *Leuconostoc pseudomesenteroides* (19%), *Lactococcus garviae* (7%), *Lc. lactis* ssp. *lactis* (8%), *Streptococcus parauberis* (16%) and *Enterococcus faecium* (6%) (An et al., 2004).

Mare's milk contains more growth factors for *Lactobacillus bifidus* var. *Penn*. than cow's milk, but much less than human milk (Sheng and Fang, 2009). The presence of bacteria considered as probiotics influences the diversification of intestinal microbial flora and enhances digestive processes. Furthermore, bactericides which are lactic bacteria metabolites have antimicrobial effect.

Kumis

Kumis is a traditional fermented drink consumed in Central Asia. Its tradition dates back to the times of Scythians, for whom it was the favourite beverage (Lv and Wang, 2009). It is made of mare's milk by the fermentation of lactose to lactic acid and alcohol at a temperature of approximately 25°C (Chen et al., 2010). Kumis is traditionally made in tight horse-skin containers. A dash of kumis is left at the bottom of them. It is the source of starter cultures that are mainly composed of lactic acid bacteria and yeast. Fresh milk is poured into the container, which is then closed and joggled from time to time to activate the fermentation process (Dręcki, 1875). This long-lasting process has been much shortened for the purpose of commercial production to approximately 3 hours (Lv et al., 2009). There are three types of kumis with different contents of lactic acid and thus, a slightly different bacterial composition. Light kumis is slightly acidic with a pH of 4.5–5.0 and with the composition dominated by *Streptococcus thermophilus* and *S. cremoris*; the medium kumis has a pH of 3.9–4.5 and consists of *Lactobacillus* cultures such as *acidophilus*, *plantarum*, *casei* and *fermentum*; strong kumis has a pH of 3.3–3.6 and contains *Lactobacillus bulgaricus* and *rhamnosus* (Lv et al., 2009). In the case of strong kumis, 80–90% of lactose is fermented, and after its decomposition by microorganisms its total amount in kumis is 1.4–4.4%. The product of the yeast present in kumis, which is represented by *Saccharomyces cerevisiae* and *Candida* spp., is alcohol, which may have an effect similar to that of an antibiotic. The bacteria mentioned play a part in the formation of available carbohydrates, which are the source of energy for metabolic processes. Lactic acid bacteria, through lipolysis of milk fat may contribute to the increase of free fatty acids content, they also have the ability to make CLA from linoleic acid (Lv et al., 2009). The process of fermentation makes proteins more easily digestible; bacteria and yeast activity increases the availability of essential free amino acids like: proline, lysine, leucine and histidine (Lv et al., 2009). Lactic acid bacteria, especially *Leuconostoc mesenteroides* 406, produce bactericides, which have been proven to have the effect of inhibiting the development of pathogenic bacteria, especially *Listeria monocytogenes* and *Clostridium botulinum* (Wulijideligen et al., 2012). Despite its popularity in the Eurasia regions, kumis is not widely available in Europe. The majority of studies focuses on the use of mare's milk itself (Chen et al., 2010). Danków et al. (2013) have done research on the properties of kumis produced in Poland on the basis of draught mares' milk. They have discovered that this beverage was characterised by a longer fermentation period than milk beverages produced from cow's, goat's or sheep's milk. During the 21 days of cold storage the level of acidity decreased from 4.60 to 4.33. Texture characteristics such as hardness and consistency showed an upward tendency, whereas cohesion and viscosity decreased. Also dynamic viscosity was gradually decreased. The changes in kumis' colour elements indicated a gradual greying of the drink. Lactic acid content during the storage period increased by 14.5%, and that of ethyl alcohol by 69% in relation to output values. A sensory analysis showed that the viscosity had changed from homogeneous to stratified, the flavour had become more acidic, tart and with an intense yeast smell (Danków et al., 2013).

Mare's milk as a functional food

A food is considered functional if in addition to having a nutritional effect on the human body it modulates the organs' functions through the enhancement of metabolic or physiological processes and thus reinforces the organism and limits the risk of pathological processes. This group of functional foods includes probiotics and prebiotics, which have a beneficial effect on intestinal flora and influence its proper growth as well as intestinal balance (Socha and Stolarczyk, 2002). When analysing the research that has been done so far on mare's milk, one can discern a number of characteristics which have a beneficial effect on human health. The energy value of human and cow's milk is similar (approximately 60 kcal/kg), but about 200 kcal/kg greater than mare's milk (Csapo-Kiss et al., 1995). Mare's milk is characterised by a low content of cholesterol and high content of unsaturated fatty acids, especially the exogenous ones like linoleic and α-linoleic, which are essential in human diet. It has been shown that linoleic acid is a forerunner of prostaglandin E which influences the prevention of intestinal ulcers (Malacarne et al., 2002). The aforementioned acids aid the proper functioning of blood vessels and proper development of the brain and retina. What is more, research done on male rats fed unsaturated fatty acids of mare's milk has shown that these fatty acids enhanced the body's immune response and influenced its non-specific immune resistance (Valiev et al., 1999), which may be found useful for people's preventive healthcare. The content of linoleic and α-linoleic acids in mare's milk may bring health benefits after being included in the diet. Since essential fatty acids have a similar effect to statins, milk may in the same way affect endothelial synthesis of nitric oxide, inhibit the production of inflammatory cytokines, reduce cholesterol levels and counter atherometosis as well as have a beneficial influence in cases of coronary heart diseases (Orlandi et al., 2003). Additionally, the CLA acid contained in mare's milk has a positive effect, showing anti-cancer and antioxidant activity. However, due to the small amount of this acid present this effect is not significant.

As it is similar to human milk, mare's milk can be used in feeding infants. The ratio of caseins and whey proteins similar to that of human milk influences its better digestibility. Because it remains in the stomach for a shorter period of time than cow's milk, mare's milk is a much better human milk substitute in baby feeding (Malacarne et al., 2002; Sheng and Fang, 2009). It is also a valuable infant food due to its lower content of mineral salts in comparison with cow's milk. It also has less αS1-caseine, which is responsible for allergic reactions in infants (Curadi et al., 2000). This reaction occurs mainly in children up to three years of age, but in the case of a severe hypersensitivity it may happen to older children as well. The allergy is an immune response to the presence of proteins, probably α-lactalbumin and β-lactoglobulin (El Agamy, 2007). The results of research conducted by Businco et al. (2000) showed that 96% of children observed with confirmed cow's milk allergy tolerated mare's milk. The author suggests that after undergoing a certain modification, mare's milk may be a good substitute of cow's milk.

Thanks to a significant amount of lactose the milk tastes nice, and may be more willingly accepted as substitute milk than hydrolysed proteins or soy-based milk (Businco et al., 2000). A high content of lactose in connection with carbohydrates present in the milk may have a positive influence on intestinal microflora's growth and as a result counter pathogens (Sheng and Fang, 2009). In addition, lactose stimulates intestinal absorption of calcium, which may be beneficial to the process of bone mineralisation in the first months after birth. Furthermore, the Ca:P ratio is similar to that which is optimal for calcium absorption and metabolism in human body (Businco et al., 2000). The high content of lactoferrin and lysozyme characteristic of mare's milk, which neutralise bacteria and viruses as well as being fungicidal, could be used in medicine. A clinical trial done on a group of people suffering from atopic dermatitis showed a major improvement of their health after having been given mare's milk (Foekel et al., 2009). Atopic dermatitis is caused by an improper immune reaction of an organism, which produces excessive amounts of IgE immunoglobulins in response to small amounts of antigens. The result is dry, red and itchy skin, and bacterial infections are likely to occur frequently. People who were given mare's milk experienced alleviation of their symptoms. In addition, amounts of IL-16, which is responsible for the occurrence and relapse of atopic conditions, were found to be smaller. Mare's milk's positive effect may be partly due to its regulating influence on intestinal flora, which affects the immune system. Lactoferrin, in combination with lysozyme, by stimulation of the growth of some bacteria cultures and together with excretory IgA inhibits the growth of pathogenic cultures (Foekel et al., 2009).

Mare's milk constituents have a modulatory effect on inflammatory processes through their influence on the chemotaxis process and lowering of the respiratory burst; hence, the milk may be helpful when curing illnesses with recurring inflammations (Ellinger et al., 2002). Mare's milk could be used in the treatment of hepatitis and gastric ulcers. Patients suffering from Crohn's disease and ulcerative colitis who were given mare's milk observed alleviation of abdominal and extra-intestinal pain and smaller amounts of blood in stool which in consequence allowed for a reduction of the amount of medicine taken. This research suggests a positive effect of mare's milk on the alleviation of these diseases' symptoms (Schubert et al., 2009).

Mare's milk in the form of a fermented drink, i.e. kumis has been recognised for centuries as a nutritional drink. Due to its small amount of lactose and numerous lactic acid bacteria that aid its breakdown, it does not cause the effect of lactose intolerance and has a regulatory influence on gastrointestinal tract. The content of flora considered probiotics, such as *Lactobacillus acidophilus* and *Bifidobacterium bifidum* as well as yeast influence the antibacterial effect of kumis. It also stimulates the synthesis of vitamins B_1, B_2 and B_{12}. Kumis has been proven to have a positive effect on the circulatory system in lowering hypertension, on the nervous system, on the functions of kidneys and endocrine glands as well as on the immune system (Lv et al., 2009). As has been stated before, kumis has been known to be helpful in treating tuberculosis. In Kazakhstan, a project is underway to market a drug containing mare's milk, which would be helpful in alleviating symptoms and curing this illness. Research on rats treated with mercury chloride proved that administering mare's milk containing an increased amount of fibre and cultures of probiotic bacteria improved the histology of their kidneys and brain and as a result reduced the effects of poisoning (Abdel-Salam et al., 2010). Further research will show whether similar results may be expected to be achieved as far as human organisms are concerned.

Mare's milk may be used raw, deeply frozen, lyophilised in the form of powder or capsules or after undergoing the process of fermentation as kumis, liqueur or even yoghurt and ice-cream. There is a wide range of cosmetics, which are recommended because they smoothen the skin and make it more elastic, and facilitate the absorption and water retention of the skin, which in consequence influences its condition.

The above-mentioned properties of mare's milk make it appropriate for use in the nutrition of children and elderly people as well as in prophylaxis and as a support of the process of the treatment of different diseases. Thus, it may become an alternative for cow's milk.

Conclusions

This work shows that mare's milk has a composition similar to human milk. It is well digested so it is a perfect alternative for cow's milk in the feeding of children or elderly people. Its low content of α-lactalbumin and β-lactoglobulin makes it appropriate for children allergic to cow's milk. A high concentration of lactose allows for a better growth of intestinal microflora. Mare's milk contains high levels of lysozyme, lactoferrin and lactadherin and has an inhibiting effect on the development of pathogenic bacteria. Research done so far indicates that it may be helpful in treating atopic dermatitis as well as improving skin appearance. The high content of vitamin C in mare's milk influences its antioxidant value. Due to its lower content of fat and cholesterol it can be used to lower cholesterol intake as well as to control cardiovascular diseases. Mare's milk has been proven to play a role in curing Crohn's disease, ulcerative colitis, hepatitis and chronic gastric ulcers as well as other burdensome diseases, especially in children and elderly people.

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