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Nutritional Value and Health-Promoting Properties of Mare's Milk – a Review

*Ewa Jastrzębska[1], Ewa Wadas[1], Tomasz Daszkiewicz[2], Renata Pietrzak-Fiećko[3]**

[1]Department of Horse Breeding and Riding, Faculty of Animal Bioengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland

[2]Department of Commodity Science and Processing Raw Materials of Animal Origin, Faculty of Animal Bioengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland

[3]Department of Commodities and Food Analysis, Faculty of Food Science, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland

**Corresponding author: renap@uwm.edu.pl*

ABSTRACT

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Recent interest in mare's milk is associated with the fact that it contains a wide variety of valuable nutrients with health-promoting properties. Among milks of many mammal species, it is the mare's milk that is highly appreciated for similarity to human milk in terms of chemical composition allowing its use as a substitute for mother's milk in infant feeding. It can also be used in feeding people with various health conditions. The global market offers still more food products and cosmetics containing mare's milk. This review summarizes the current knowledge of the nutritional value and health-promoting properties of mare's milk.

Keywords: chemical composition; breed; lactation; fatty acids

An analysis of the fatty acid residues in relics of vessels used by people who inhabited the area of what is now Kazakhstan has shown that the diet of those people at about 3500 B.C. included not only horse meat, but also mare's milk, which evidences that horses were domesticated at the time (Outram et al. 2009). Nowadays, mares are still used for dairy production mainly in parts of Central Asia, a.o. Mongolia, Kazakhstan, Kyrgyzstan, Russia, and China (Choi 2016; Pieszka et al. 2016). Mares' milking is intensively practiced and the milk is an important part of local food economies.

Characteristics of mare's milk. Organoleptically, mare's milk is not similar to cow's milk. It is clear, whitish, and sweeter than cow's milk, which makes it similar to human milk (Solaroli et al. 1993; Curadi et al. 2000; Potocnik et al. 2011). According to Di Cagno et al. (2004), it has a coconut aftertaste and smells of hay.

Mare's milk differs greatly from milk of other bred animals in terms of the major components content. Its characteristic features include a low content of fat and proteins and a high content of lactose (Table 1). Proteins present in mare's milk comprise 50–55% of casein and 45% of globulins and albumins. Therefore, it is an albumin-type milk like human milk with ca. 50% of globulins and albumins and is unlike the casein-type milk of ruminants (80% casein content) (Malacarne et al. 2002) (Table 1).

Due to a high percentage of whey proteins and exogenous amino acids, mare's milk is a better

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Table 1. Composition of mare's, bovine, and human milk (Malacarne et al. 2002)

Component	Mare's milk	Bovine milk	Human milk
Fat (%)	1.21	3.61	3.64
Protein (%)	2.14	3.25	1.42
Lactose (%)	6.37	3.25	6.71
Ash (%)	0.42	0.76	0.22
Energy (kcal/kg)	480	674	677

source of nutrients for humans than cow's milk (Csapo-Kiss et al. 1995; Martuzzi et al. 2000; Csapo et al. 2009) (Table 2).

Mare's milk contains less fat (1.21%) compared to cow's milk (3.61%) and human milk (3.64%) (Malacarne et al. 2002). In consequence, the calorific value of mare's milk is lower than that of human and cow's milk (680 kcal/kg) by approximately 200 kcal/kg (Csapo-Kiss et al. 1995). Moreover, fat in mare's milk is dispersed as globules with a diameter of ca. 2–3 μm (4 μm in human milk), which do not combine easily and make skimming difficult (Malacarne et al. 2002).

According to literature data (Jaworski et al. 1982; Mirowski and Didkowska 2015; Pieszka et al. 2016), the content of different fatty acids in the fat of mare's milk varies. Pietrzak-Fiecko et al. (2009b) reported differences between the content of fatty acids in milk fat from mares of various breeds. The milk of Wielkopolski Horse mares was characterized by the prevalence of the unsaturated fatty acids (61.32%), whereas in the samples originating from Konik Polski mares saturated fatty acids predominated (54.98%). It contains much more unsaturated fatty acids (44%) than cow's milk (32%) and only slightly less than human milk (45.2%) (Csapo et al. 1995; Malacarne et al. 2002). The ratio of unsaturated-to-saturated fatty acids in mare's milk (1 : 3) is close to that in human milk (1 : 2), whereas it deviates from the values typical of cow's milk (2 : 1). Mare's milk is a good source of linoleic acid (n-6 acid) and α-linolenic acid (n-3 acid), which are not synthesized by the human body and which are essential to the growth and development of the nervous system (Csapo et al. 1995; Di Cagno et al. 2004; Salamon et al. 2009). An analysis of the fatty acid profile in mare's milk should take into account the fact that it may depend on the phase of lactation. This has been demonstrated by the results of analyses of milk obtained from the Polish Konik (Pikul et al. 2008; Pietrzak-Fiecko et al. 2013), which contained a higher percentage of unsaturated fatty acids in milk fat when acquired during late lactation (Table 3).

Mare's milk contains relatively few minerals (0.5%) compared to cow's milk (0.8%) and other domesticated animals (Table 4) (Potocnik et al.

Table 2. Whey proteins distribution of mare's, bovine, and human milk (Malacarne et al. 2002)

Component	Mare's milk	Bovine milk	Human milk
Whey proteins (g/kg)	8.30	5.70	7.60
β-Lactoglobulin (%)	30.75	20.10	lack
α-Lactoalbumin (%)	28.55	53.59	42.37
Immunoglobulins (%)	19.77	11.73	18.25
Serum albumin (%)	4.45	6.20	7.56
Lactoferrin (%)	9.89	8.38	30.26
Lysozyme (%)	6.59	trace amount	1.66

Table 3. Fatty acid composition of mare's milk from different breeds (Pietrzak-Fiecko et al. 2009b)

Fatty acid	Wielkopolski horse	Polish Konik horse	Cold-blooded horse
8:0	2.05	2.97	3.88
10:0	4.07	5.52	8.34
12:0	4.98	5.56	9.16
13:0	0.25	0.08	0.08
14:0 *iso*	0.01	0.03	0.02
14:0	5.25	6.53	8.70
15:0	0.76	0.94	0.63
16:0 *iso*	0.22	0.19	0.15
16:0	19.64	23.42	22.64
17:0	0.50	0.59	0.35
18:0	0.98	1.14	1.00
10:1	1.31	1.23	1.70
12:1	0.23	0.14	0.34
14:1	0.57	0.58	0.73
16:1	5.01	7.26	4.86
17:1	0.05	0.13	0.00
18:1	18.01	23.96	14.47
18:2	15.86	5.93	12.72
18:3	20.28	13.35	10.20
SFA	37.81	47.37	54.98
UFA	61.32	52.58	45.02

SFA = saturated fatty acids, UFA = unsaturated fatty acids

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2011; Pieszka et al. 2016). However, its calcium-to-phosphorus ratio (1.6–1.8 : 1) is more favourable to the proper growth of the skeleton of young organisms than cow's milk (approximately 1.4 : 1) and is closer to that in human milk (approximately 1.9 : 1) (Sheng and Fang 2009).

Mare's milk contains a similar level of fat-soluble vitamins (A, D_3, E) to that in cow's milk and a higher level of vitamin C, although it is much lower than in human milk (Salamon et al. 2009). Considering the fact that mare's milk contains about one-third of the fat level present in cow's milk, the concentration of vitamins soluble in it is higher than in cow's milk (Csapo et al. 1995).

Mare's milk has a very good hygienic and sanitary status. It differs from the milk of other farm animals in that it has the lowest content of somatic cells and a very low overall microorganism count (Dankow et al. 2006; Kulisa et al. 2010). The chemical composition of mare's milk is determined by feeding and a number of environmental factors, including the location of the animals (Pietrzak-Fiecko et al. 2009a) (Table 4).

The composition of mare's milk may differ from one animal breed to another (Kulisa et al. 2010; Bilandzic et al. 2014). This was confirmed by Mirowski and Didkowska (2015), who compared the milk from mares of four breeds: the Wielkopolski, the Cold-blooded, the Hucul Pony, and the Polish Konik. The milk of female Cold-blooded horses, the breed showing the highest milk yield, had the lowest dry matter (9.28%), fat (0.49%), and free fatty acids contents. The Polish Konik's milk was found to contain the largest proportion of dry matter (9.95%), fat (1.14%), lactose (7.73%), and urea (0.09%). The highest concentration of proteins was found in milk from the female Hucul Pony (1.85%) and the lowest in that from the Polish Konik (1.15%). The qualitative composition of milk is affected by the parity and phase of lactation (Fuentes et al. 1993; Pagliarini et al. 1993; Dankow et al. 2006; Pecka et al. 2012; Mirowski and Didkowska 2015; Pieszka et al. 2016). During the lactation phase, the composition of mare's milk adapts to the growing foal's needs for different nutrients (Tomczynski et al. 1999; Pieszka and Kulisa 2005; Mirowski and Didkowska 2015). The percentage of whey proteins decreases during the first month after delivery and that of casein increases (Zicker and Lonnerdal 1994). The percentage of different fractions of whey proteins also changes (Ciesla et al. 2009). The milk obtained in the first days after delivery is characterized by the highest activity of lysozyme (Hatzipanagiotou et al. 1998; Sarwar et al. 2001). In this period also other biologically active compounds of the milk protein fraction are present at the highest concentrations (Berg et al. 2007). An inter-breed differentiation in terms of the content of mare's milk main chemical components is also observable during the period of lactation (Tomczynski et al. 1999) (Table 5).

The composition of milk is largely affected by animal feeding and the season of the year (Felkner-Pozniakowska et al. 2012). Naert et al. (2013) claim

Table 4. Comparison of fat soluble vitamins and water soluble vitamins content in milk of mare, human, and cow (Park 2009; Clayes et al. 2014; Markiewicz-Keszycka et al. 2014)

Specification	Mare's milk	Human milk	Bovine milk
Vitamin A (mg/l)	0.403	0.455	0.435–0.799
Vitamin D_3 (µg/l)	4.93	0.03–0.12	2.31–15.39
Vitamin E (mg/l)	1.13	5.09	1.05–1.95
Vitamin K_2 (µg/l)	17.93	1.80	4.81–17
β-Carotene (mg/l)	0.388	0.002–0.375	0.166–0.380
Thiamin (B_1) (µg/l)	20–40	14–17	28–90
Riboflavin (B_2) (µg/l)	10–37	20–60	116–202
Niacin (B_3) (µg/l)	70–140	147–178	50–120
Pantothenic acid (B_5) (µg/l)	277–300	184–270	260–490
Pyridoxine (B_6) (µg/l)	30	11–14	30–70
Folic acid (B_9) (µg/l)	0.13	5.2–16	1–18
Cobalamin (B_{12}) (µg/l)	0.3	0.03–0.05	0.11
Ascorbic acid (µg/l)	1 280–8 100	3 500–10 000	300–2 300

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Table 5. Results of physico-chemical estimation the experimental mare's milk (Tomczynski et al. 1999)

Day of lactation	Breed	Specification						
		crude protein (%)	casein (%)	fat (%)	dry matter (%)	lactose (%)	specific gravity (g/cm^3)	pH
7	WLKP	2.77	1.67	0.8	9.93	5.08	1.034	6.68
	PK	2.37	1.27	0.6	9.04	5.88	1.035	6.50
30	WLKP	2.04	1.10	0.4	9.09	4.84	1.034	6.75
	PK	1.04	1.04	0.7	8.78	5.47	1.033	6.40
90	WLKP	1.81	0.86	0.4	7.27	4.80	1.030	6.53
	PK	0.90	0.90	0.5	8.59	4.14	1.034	6.30
180	WLKP	1.68	0.66	0.4	6.17	3.55	1.024	6.82
	PK	0.71	0.71	0.4	8.18	4.39	1.033	6.40
Average WLKP		2.08	1.07	0.5	8.12	4.57	1.031	6.70
Average PK		1.26	0.98	0.6	8.65	4.97	1.034	6.40

WLKP = mares of Wielkopolski horse, PK = mares of Polish Konik horse

that the milk of mares fed bulky feed *ad libitum* and larger amounts of concentrated feed contains increasing levels of linoleic acid (18:2 n-6) and decreasing levels of α-linolenic acid (18:3 n-3). Moreover, those researchers reported considerable differences in the composition of milk from different farms, especially in terms of fat content, which could be attributed to the horse feeding. Doreau et al. (1992) reported that the milk of mares fed with fodder containing a high percentage of hay contained more fat and protein and less lactose, with fat containing more α-linolenic acid and less linoleic acid compared to milk from mares receiving more concentrated feed. The impact of the year season was observed in a study by Minjigdorj et al. (2012), in which the milk composition of mares grazing on Asian steppes and forest steppes was examined. Tomczynski and Smoczynski (1982) also claimed that switching from stable to pasture feeding of horses resulted in a slight decrease in the content of fat in mare's milk. The findings of the studies suggest that the composition of mare's milk is linked to feeding, which indicates that the addition of certain ingredients to fodders may change the content of some components of milk, e.g. fatty acid profile, the level of β-carotene and α-tocopherol (Mirowski and Didkowska 2015).

Obtaining mare's milk. The low popularity of mare's milk is a consequence of such factors as, for example, its limited availability. This, in turn, arises from issues associated with obtaining it. Factors which make obtaining mare's milk difficult include the small size of the mare's udder and the presence of a foal, which is necessary to trigger the milk secretion reflex. The disposable amount of mare's milk is also limited by the need to feed a foal.

The peak of lactation occurs in the second month following foaling, sometimes several weeks later (Oftedal et al. 1983). The amount of milk secreted during the first 12 weeks is close to 3% of the mare's body weight and decreases to about 2% during the subsequent 12 weeks (Wlodarczyk-Szydlowska et al. 2005). The daily milk production yield varies. According to different sources (Wlodarczyk-Szydlowska et al. 2005; Pieszka et al. 2016), it fluctuates between 10 kg and 29–30 kg of milk daily. Half-breed mares produce 10–12 l of milk a day and mares of heavy breeds produce 15–20 l. A mare can produce 1200–3000 kg of milk during the first 5–6 months of lactation (Dankow et al. 2012). Milk productivity is affected by the individual characteristics of a mare. According to one of producers of mare's milk in Poland, from 1 to 2 (sometimes 2.5) litres of milk can be obtained from one mare in one milking, which is repeated several times a day. The foal's needs must be accommodated when milking.

Health promoting properties of milk and its products. Mare's milk is still not a well-known product, although it is part of the daily diet in Asian countries (Pieszka et al. 2016). Interest in mare's milk is growing in Western Europe and in the USA as it can be given to allergic children and adults (Drogoul et al. 1992; Businco et al. 2000; Curadi et al. 2000; Wszolek et al. 2007; Dankow

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et al. 2012; Pieszka et al. 2016). There are farms in these countries which specialize in the production of mare's milk. The milk obtained there is cooled down immediately after milking, poured into immediate (glass or plastic) packages and sold. Excess milk is frozen or lyophilized (Dankow et al. 2013b). The lyophilisate is packed into sachets or capsules and sold in pharmacies. It is intended for a direct consumption after being dissolved in a small amount of water, or used as an addition to yoghurt or kefir (Dankow et al. 2012; Pieszka et al. 2016).

Mare's milk has been forgotten as a food product in Europe for many years, although it was used as a supportive medicine in gastrointestinal (gastric ulcer, liver cirrhosis, cholecystitis, and pancreatitis) and respiratory (tuberculosis, bronchitis, pertussis, asthma) system diseases in the late 1950s (Solaroli et al. 1993). Mare's milk was given as a prophylactic measure to infants, especially to prematurely born children, in the paediatric departments of hospitals in Paris, Liburn, Le Mans, Berlin, and London. Mare's milk was used as a substitute for human milk until the end of the 19th century (Dankow et al. 2012). It facilitates detoxication of the body, slows down cell ageing and has bactericidal, anti-viral, and anti-inflammatory properties and it supports the treatment of migraine and removal of heavy metals from the body (Hoffken 2002; Abdel-Salam et al. 2010). Mare's milk has a positive effect on patients with cardiovascular diseases by facilitating and increasing calcium absorption. It stimulates growth of granulation tissue in skin diseases and promotes wound healing. Its use in people with diabetes helps reduce the dose of insulin and improves the glycaemic index. Moreover, it is used in the treatment of anaemia, cancer therapy, and in post-chemo- and post-radiotherapy recovery; it is also recommended during the period before vaccination and during antibiotic therapy (Csapo et al. 1995; Csapo-Kiss et al. 1995; Kucukcetin et al. 2003; Chifalo et al. 2006; Dankow et al. 2012). MMF (Mares Milk Factor) and MMF forte with collagen and calcium are produced from mare's milk. They are effective in such diseases as pharyngitis, influenza, inflammations of the respiratory tract, urinary system and inflammation of the ear (Formaggioni et al. 2003). The high content of polyunsaturated fatty acids in mare's milk, which are present in easily-absorbable forms (linolenic and linoleic acids), has a beneficial effect on the growth of brain and nerve cells (Koletzko and Rodriguez-Palmero 1999). Studies are being conducted on the effect of mare's milk on people with Alzheimer's and Crohn's diseases (Dankow et al. 2012; Pieszka et al. 2016).

Apart from the beneficial content of the basic nutrients, other advantages of mare's milk are the presence of other health-promoting compounds, such as lactoferrin, orotic acid, and lysozyme. Lactoferrin is a glycoprotein classified as transferrin, which – as confirmed by *in vitro* and *in vivo* studies – has immunomodulatory (inhibits a disease activity), antibacterial, antiviral, anti-inflammatory, and antifungal properties (Dankow et al. 2012, 2013b). Orotic acid (also known as vitamin B_{13}), is very difficult to find in a traditional diet. It is one of the few vitamins to prevent ageing of skin as well as cirrhosis and fatty degeneration of the liver (Kuczynska et al. 2013). Furthermore, lysozyme is responsible for one of the mechanisms of the immune response and it exhibits antibacterial properties (Dankow et al. 2012; Kuczynska et al. 2013; Pieszka et al. 2016).

After being obtained, mare's milk must be cooled down quickly and, when fresh, used within 6–9 hours after milking. Due to a decreased content of protein (κ-casein) and fat, it is not a good raw material for cheese production (Dankow et al. 2006). Mare's milk serves for production of a fermented beverage called kumis. It is an alcoholic milk beverage, produced by alcoholic fermentation of lactose. Apart from reduced amounts of lactose and products of its fermentation, it contains the other components of milk in approximately the original ratio. It is milky-bluish-white with a pinkish tinge. It is sour, slightly tart, with a slightly sweet aftertaste and a characteristic smell. When consumed, it leaves an almond flavour in one's mouth. Depending on the duration of the fermentation stage in kumis production, it contains from 1% (one-day kumis) to 3% of alcohol (8-day kumis) (Mojka 2013; Pieszka et al. 2016).

Kumis (koumiss, airag, chigee) is a traditional beverage in Central Asia (Mojka 2013; Choi 2016), and it is regarded as a national medicinal product in Bashkortostan, Kazakhstan, Uzbekistan, Kyrgyzstan, and in Ukraine (Dankow et al. 2013a). According to Herodotus (484–424 B.C.), specially prepared mare's milk was a favourite beverage of the Scythians (Pieszka et al. 2016); further descriptions indicate that in fact it was kumis. Mare's

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milk is the most frequently used raw material for the preparation of kumis, but sometimes it is replaced by the milk from yak, donkey, camel, sheep or cow. Kumis is believed to stimulate the nervous system and to boost the immune system. In the early 20th century it was recommended to support the tuberculosis treatment. It helps in treating the diseases of the cardiovascular, respiratory, gastrointestinal, and urinary systems. It is recommended for people with AIDS, cancer, herpes, depression, insomnia, ADHD and in the cases of food poisoning caused by meat and of scurvy (Solaroli et al. 1993; Danova et al. 2005; Trojanowska 2006; Dankow et al. 2013a). Kumis contains enzymes, trace elements, antibiotics, vitamins A, B_1, B_2, B_{12}, D, E, and C (Dankow et al. 2013a; Mojka 2013). It is recommended for people recovering from a disease and even to pregnant women. It has been administered in many Central Asian sanatoriums (the best-known e.g. Yumatovo, Gluchovskaya, and Schafranovo) as a supportive treatment. Some sanatoriums have their own mares to produce milk and their own kumis production facilities. Kumis is the only alcoholic beverage which can be drunk by Muslims without violating the laws of the Koran (Dankow et al. 2013a).

The properties of mare's milk make it potentially usable in the cosmetic industry. It has nutritional, anti-inflammatory, and toning properties with a very little potential for sensitisation (Curadi et al. 2000; Dankow et al. 2012; Pieszka et al. 2016). Products made of it include commercially available creams and balms.

Over 80% of those suffering from psoriasis have dry skin issues, which arise from the disease itself and from adverse effects of drugs or phototherapy. Therefore, supplementary treatment, aimed at moisturising the skin, involves the application of externally applied measures, i.e. moisturisers (creams, ointments, lotions) and oil baths. However, their action is restricted to the epidermis, which is a thin, outer layer of the skin, thereby ensuring only 20% moisturising. As a consequence, psoriasis patients should take a dietary supplement containing concentrated mare's milk, which moisturizes the deeper layers of the skin (Pieszka et al. 2016).

Mare's milk, like donkey's milk, is now used as an ingredient of luxury soap for women. Such soaps destroy free radicals, thereby slowing down the skin ageing process (Cosentino et al. 2015). Mare's milk, along with other products obtained from horses (meconium, horse hair), is also used in homeopathy.

CONCLUSION

According to the research findings, mare's milk and the products based on it provide valuable nutrients for the human body. Such products can also be used as supportive therapies in disease treatment and recovery due to their health-promoting substances and limited allergenic properties. The beneficial properties of mare's milk have also been noted by the cosmetic industry using it still more often in various products. The broad spectrum of the possibilities of using mare's milk suggests that with sufficient promotion and increased availability it could win favour with consumers around the world, all the more so that breeding mares for milk is not as controversial as breeding horses for meat.

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