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HUMAN AND MARE'S MILK – PROTEIN FRACTION AND LIPID COMPOSITION

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Scientific review
Pregledni znanstveni članak

SUMMARY

In human population if the infants are not breast-fed, a substitute for breast milk is needed. Use of cow's milk can induce allergies during the first 3 years of life. Alternative could be mare's milk. The objectives of this review were to compare human and mare's milk protein fraction and lipid composition as well as to determine adequacy of mare's milk as substitute for breast milk. Similarities are found regarding the protein and salt content; whey protein and NPN concentrations; structure of protein micelles and lipid globules; proportion of saturated fatty acids and unsaturated fatty acids. Taking into account determined similarities of human and mare's milk, it could be concluded that mare's milk is suitable nourishment for infants.

Key-words: human milk, mare's milk, protein fraction, lipid components

INTRODUCTION

Milk represents the essential source of nourishment of offspring during the first months of life. The composition of milk corresponds to the offspring requirements differing from species to species. Therefore, milk composition highly depends on animal species. If the babies are not breast-fed, a substitute for breast milk is needed because in early life milk is the only source of nutrition. Use of cow's milk as a substitute during infancy and early childhood can result in cow's milk allergy with prevalence of approximately 2.5% during the first 3 years of life (Businco et al., 2000). Worldwide around 30 million people regularly consume mare milk. For the human populations in central Asia a lactic-alcoholic beverage Koumiss traditionally produced through fermentation is one of the most important basic foodstuffs (Montanari et al., 1997). This beverage was also consumed throughout Eastern Europe, particularly in Hungary and Asiatic regions (Koroleva, 1988). At the present time Koumiss is produced at industrial level (Tamime et al., 1999). In Western Europe, the most important product of the cold-blooded horse breeds rearing is foals, therefore studies on mare's milk have been concerned mainly with the growth and health of the newborn horse. In recent years, interest in the use of mare's milk for human nutrition increased (Drogoul et al., 1992). Several studies analysed equine milk regarding the protein compound as indicator of caseins and whey proteins amount with some interest for a possible use as a substitute of cow's milk for children with intolerance or allergy (Businco et al., 2000; Curadi et al., 2001). Another aspect was to find new way of utilisation for local equine breeds (Pinto et al., 2001).

The objectives of this review were to compare human and mare's milk in terms of milk composition namely protein fraction and lipid composition as well as to determine adequacy of mare's milk as substitute for breast milk.

OVERALL COMPOSITION

In many studies the composition of mare's milk was researched (Jenness and Sloan, 1970.; Alais, 1974; Solaroli et al., 1993; Mariani et al., 1993; Salimei, 1999.). Generally speaking, the milk composition corresponds to the offspring requirements. The requirements differ from species to species. Therefore, milk composition highly depends on animal species. Mean values of energy value and milk composition reported in literature are presented in Figure 1.

Regarding energy value human milk has significantly higher values than mare's milk. The gross energy

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value of mare's milk, as reported in literature, ranged from 39 to 55 kcal/100 g; while for human it is 65 to 70 kcal/100 g. Regarding lactose and fat content, mare's milk has slightly lower lactose content reported in interval 58–70 g/kg compared to 63–70 g/kg in human milk. On the other hand, fat content that is reported in interval 5–20 g/kg and compared to 35–40 g/kg in human milk has noticeably lower values. The energy supply of mare's milk is clearly lower than that of human milk. The reported interval of ash content in mare's milk is similar to that in human milk (3–5 g/kg compared to 2–3 g/kg). Higher values for crude protein are reported in mare's (15–28 g/kg) than human milk (9–17 g/kg).

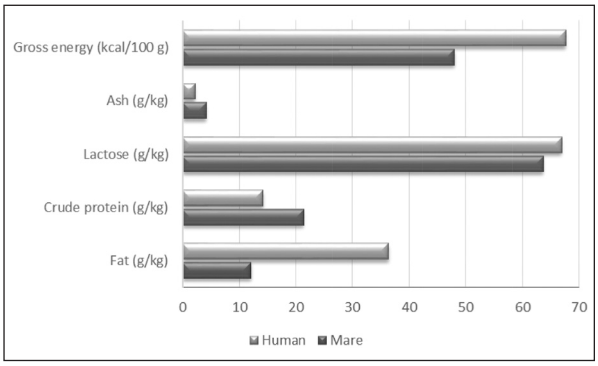

Figure 1. Overall composition of human and mare's milk – mean values reported in literature (Jenness and Sloan, 1970; Alais, 1974; Solaroli et al., 1993; Mariani et al., 1993, Salimei, 1999)

Grafikon 1. Ukupni sastav humanoga i kobiljega mlijeka – srednje vrijednosti navedene u referencama (Jenness i Sloan, 1970.; Alais, 1974.; Solaroli i sur., 1993.; Mariani i sur., 1993.; Salimei, 1999.)

Usability research considering overall composition concluded that mare's milk, considering the protein and salt content, is more suitable nourishment for infants than cow's milk (Stoyanova et al., 1988; Marconi and Panfili, 1998).

PROTEIN FRACTIONS

Considering single structural components qualitative differences between the different species milk are far greater. Mean values of main nitrogen components of human and mare's milk reported in the literature (Boland et al., 1992; Mariani et al., 1993; Pagliarini et al., 1993; Doreau, 1994; Csapo-Kiss et al., 1995; Martuzzi et al., 2000) are presented in Figure 2.

Regarding the main nitrogen components of human and mare's milk, similarities are reported for whey protein (6.8–8.3 g/kg compared to 7.4–9.1 g/kg) and NPN concentrations (2.6–3.2 g/kg compared to 1.7–3.5 g/kg). The whey protein fraction represents slightly less than 40% in mare's milk and slightly more than 50% in human making that milk typically albumineux. Hambræus (1994) concluded that the richness of mare's milk in whey protein content makes it more suitable to human nutrition than cow's milk. Regarding content of crude protein (9–17 g/kg compared to 15–28 g/kg) and casein (3.2–4.2 g/kg compared to 9.4–12.0 g/kg) significantly lower values were found in human milk.

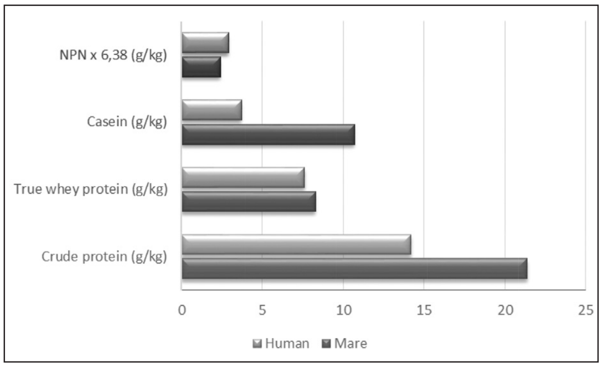

Figure 2. Main nitrogen components of human and mare's milk – mean values reported in literature (Boland et al., 1992; Mariani et al., 1993; Pagliarini et al., 1993; Doreau, 1994; Csapo-Kiss et al., 1995; Martuzzi et al., 2000)

Grafikon 2. Glavne dušične komponente humanoga i kobiljega mlijeka – srednje vrijednosti navedene u referencama (Boland i sur., 1992.; Mariani i sur., 1993.; Pagliarini i sur., 1993.; Doreau, 1994.; Csapo-Kiss i sur., 1995.; Martuzz i sur., 2000.)

Mean values of casein content of human and mare's milk reported in the literature (Buchheim et al., 1989; Creamer, 1991; Boland et al., 1992; Abd El-Salam et al., 1992; Cuilliere et al., 1999; Ochirkhuyag et al., 2000; Malacarne et al., 2000) are presented in Figure 3.

Mare's milk casein contains a similar proportion of β-casein and α_s-casein. Compared to human milk (11.1–12.5%) content of α_s-casein is significantly higher in mare's milk (11.1–12.5%). Regarding the β-casein (62.5–66.7% compared to 40.1–51.4%) and κ-casein (22.2–25.0% compared to 7.71%) content significantly higher values were found in human milk. Despite lower content of β-casein mare's milk could be considered as relatively rich in β-casein, and thereby able to supply children with abundant amounts of casomorphins (Clare and Swaisgood, 2000). Egito et al. (2001) concluded that κ-casein in mare's milk has biochemical characteristics similar to that of human κ-casein, such as the presence of carbohydrate moieties and susceptibility to hydrolysis by chymosin.

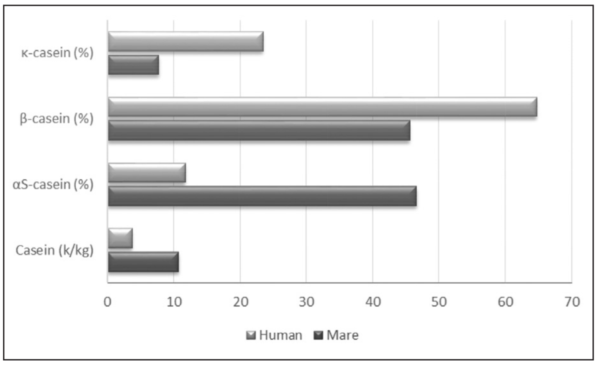

Figure 3. Caseins content of human and mare's milk – mean values reported in literature (Buchheim et al., 1989; Creamer, 1991; Boland et al., 1992; Abd El-Salam et al., 1992; Cuilliere et al., 1999; Ochirkhuyag et al., 2000; Malacarne et al., 2000)

Grafikon 3. Sadržaj kazeina humanoga i kobiljega mlijeka – srednje vrijednosti navedene u referencama (Buchheim i sur., 1989.; Creamer, 1991.; Boland i sur., 1992.; Abd El-Salam i sur., 1992.; Cuilliere i sur., 1999.; Ochirkhuyag i sur., 2000.; Malacarne i sur., 2000.)

Structure of micelles varies considerably from species to species. Jasinska and Jaworska (1991) reported that micelles in mare's milk has a spongy structure, while in human milk it is reticular, fairly regular and very loose, because of numerous canals and caverns. Micelles structure affects susceptibility to pepsin hydrolysis. Buchheim et al. (1989) assessed the size and observed that mare's milk micelles (255 nm) are significantly larger than human (64 nm).

The protein composition and micellar structure (caseins distribution and micelles size) influence the digestive utilisation of milk nutrients. Mare's and human milk forms a finer, softer precipitate physiologically more suitable for infant nutrition because it is more easily digestible than the firm coagulum of cow's milk (Kalliala et al., 1951; Solaroli et al., 1993).

LIPID COMPOSITION

Lipids in milk are dispersed as emulsified globules. In mare's milk fat globules have an average diameter about 2-3 mm, while in human they are are about 4 mm (Kharitonova, 1978; Welsch et al., 1988; Devle et al., 2012). The external membrane of fat globules, both in human and mare's milk, is coated with an array of glycoprotein filaments that may enhance digestion by binding lipases (Jensen et al., 1992; Koletzko and Rodriguez-Palmero, 1999). Claeys et al. (2014) stated that the structure of the fat globule interface significantly affect fat digestibility because gastric lipases must pass through this interface to gain access to the triacylglycerols. The mean value of fat content of mare's milk is significantly lower than that of human (36.4 compared to 12.1 g/kg). Mean values of lipids composition of human and mare's milk reported in literature (Pastukhova and Gerbeda, 1982; Jensen et al., 1990) are presented in Figure 4.

Mare's milk lipids have significantly lower concentration of triacylglycerols than human milk (98% compared to 80%). Parodi (1982) quoted that the number of carbon atoms in di- and tri- acylglycerols is a characteristic of species. Pagliarini et al. (1993) stated that distribution of fat in mare's and human milk fat follows a typical unimodal pattern with maximum at 50–52 carbon atoms.

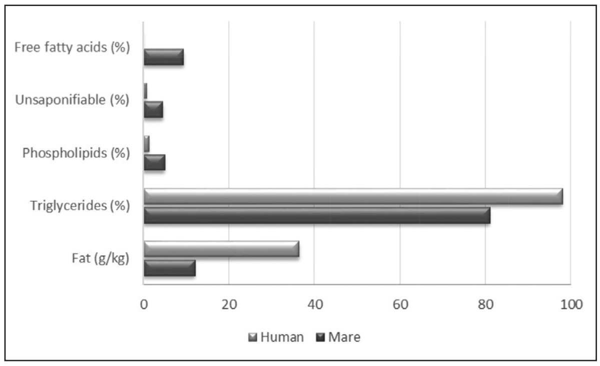

Figure 4. Lipids composition of human and mare's milk – mean values reported in the literature (Pastukhova and Gerbeda, 1982; Jensen et al., 1990)

Grafikon 4. Lipidne komponente humanoga i kobiljega mlijeka – srednje vrijednosti navedene u referencama (Pastukhova i Gerbeda, 1982.; Jensen i sur., 1990.)

The triacylglycerols structure is a main factor influencing the fat absorption that is activity of lipolytic enzymes and. Lien et al. (1993) and Winter et al. (1993) observed that location of palmitic acid (C16:0) on the sn-2 position is favourable for the assimilation of this fatty acid in children. In human and mare's milk C16:0 is preferentially associated with the sn-2 position (Parodi, 1982). Gastaldi et al. (2010) stated that in bovine milk, mainly fatty acids with a length of C4:0 to C10:0 are esterified at the sn-3 position.

Alais (1974) stated that phospholipids are complex compounds constituted mainly by polyunsaturated fatty acids. They are present in all living cells as components of the lipoprotein layers of the cell membrane, in particular of neural cells. Regarding content of phospholipids, unsaponifiable and free fatty acids higher values are reported for mare's than human milk (Figure 4). The phospholipid composition of mare's milk (Kharitonova, 1978) differ from human (Jensen et al., 1990) as follows: relatively richer in phosphatidylethanolamine (31% compared to 20%) and in phosphatidylserine (16% compared to 8%); lesser in phosphatidylcholine (19% compared to 28%) and phosphatidylinositol (trace compared to 5%); while sphingomyelin proportion is similar (34% mare compared to 39% human).

The fatty acid composition of milk is a function of the species, the breed, the lactation stage, the season, and animal nutrition. Generally speaking, nonruminant's milk fat contains a lower percentage of saturated fatty acids and monounsaturated fatty acids than ruminant's milk. Mean values of fatty acids content of human and mare's milk reported in literature are presented in Figure 5.

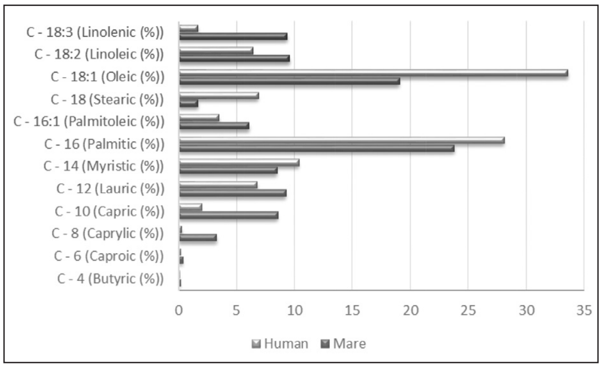

Figure 5. Fatty acids content of human and mare's milk – mean values reported in literature (Alais, 1974; Travia, 1986; Jensen et al., 1990; Doreau et al., 1992, 1993; Solaroli et al., 1993; Csapo et al., 1995; Salimei et al., 1996; Mariani et al., 1998; Martuzzi et al., 1998)

Grafikon 5. Sadržaj masnih kiselina humanoga i kobiljega mlijeka – srednje vrijednosti navedene u referencama (Alais, 1974.; Travia, 1986.; Jensen i sur., 1990.; Doreau i sur., 1992., 1993.; Solaroli i sur., 1993.; Csapo i sur., 1995.; Salimei i sur., 1996.; Mariani i sur., 1998.; Martuzzi i sur., 1998.)

Compared to human, mare's milk fat has significantly lower content of oleic, stearic and palmitic acids. Contents of linoleic, linolenic, palmitoleic, lauric, capric, and caprylic acids are significantly higher in mare's milk. Like human milk, mare's milk has a lower proportion of saturated fatty acids with a low and high number of carbon atoms (C4:0; C6:0; C16:0; C18:0).

Mean values of PUFA in human and mare's milk reported in literature are presented in Figure 6. The content of unsaturated fatty acids in mare's and human milk is similar and high. Solaroli et al. (1993) stated that this high value of unsaturation could represent a nutritional advantage. The percentage of monounsaturated fatty acids in mare's milk is lower than human milk.

Value of mare's milk is reflected through high content of linoleic acid (C18:2), of the omega-6 group, and alpha-linolenic acid (C18:3) of the omega-3 group, considered as essential fatty acids because animal organisms are unable to synthesise these compounds they have important biological functions (Alais, 1974; Travia, 1986; Doreau and Boulot, 1989).

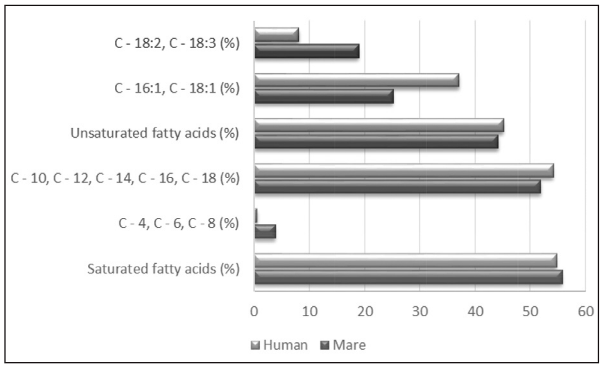

Figure 6. PUFA in human and mare's milk – mean values reported in literature (Antila et al., 1971; Alais, 1974; Travia, 1986; Jensen et al., 1990; Solaroli et al., 1993; Doreau et al., 1992, 1993.; Csapo et al., 1995; Salimei et al., 1996; Mariani et al., 1998; Martuzzi et al., 1998)

Grafikon 6. PUFA u humanome i kobiljem mlijeku – srednje vrijednosti navedene u referencama (Antila i sur., 1971.; Alais, 1974.; Travia, 1986.; Jensen i sur., 1990.; Solaroli i sur., 1993.; Doreau i sur., 1992., 1993.; Csapo i sur., 1995.; Salimei i sur., 1996.; Mariani i sur., 1998.; Martuzzi i sur., 1998.)

Research with humans has determined linoleic acid as a precursor of prostaglandin E, in the prevention of gastric ulcers (Grant et al., 1988). PUFA are precursors of long-chain polyunsaturated fatty acids (LC-PUFA) that are indispensable structural components of all cellular membranes. Furthermore, some LC-PUFA are precursors of eicosanoids, that is, molecules with a potent biological activity which modulates various cellular and tissue processes (Koletzko and Rodriguez-Palmero, 1999). Taking into account high concentration of named compounds the properties attributed to mare's milk and Koumiss as curative substances for hepatitis, chronic ulcer and tuberculosis (Solaroli et al., 1993) are completely understandable.

CONCLUSION

Regarding overall composition, the mare's milk, due to a lower fat supply, has a lower energy value that human. The lactose content is slightly lower in mare's than human milk. Considering the protein and salt content in mare's milk similar to that of human, mare's milk could be used as a replacement for breast milk.

Regarding protein fractions similarities are found for whey protein and NPN concentrations. Both milks are typically albumineux and the richness of mare's milk in whey protein content makes it more suitable to human nutrition than ruminant's milk. Mare's milk casein is composed of nearly equal parts of α_s-casein and β-casein; while in human β-casein has the highest proportion. Despite lower content of β-casein mare's milk could be considered as relatively rich in β-casein, and thereby able to supply children with abundant amounts of casomorphins. When taking into account structural factors, mare's and human milk form a finer, softer precipitate, easily digestible and more suitable for human nourishment.

Regarding lipid composition, milk fat globules average diameter, the external layer of milk fat globules and the distribution of di- and tri-glycerides in mare's and human milk are quite similar. Mare's milk lipids have significantly lower concentration of triglycerides and higher concentration of phospholipids, unsaponifiable and free fatty acids than human milk. Similar like human milk, mare's milk has a lower proportion of saturated fatty acids with a low and high number of carbon atoms. The content of unsaturated fatty acids in mare's and human milk is similar and high. This high value of unsaturation could represent a nutritional advantage. Mare's milk has high concentration of linoleic acid (omega-6) and alpha-linolenic acid (omega-3) considered as essential fatty acids. Mare's milk have, according to the human needs, almost ideal ratio between omega-6 and omega-3 acids.

Taking into account stated properties of mare's milk and all determined similarities of mare's and human milk, it could be concluded that mare's milk is suitable nourishment for infants.

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HUMANO I KOBILJE MLIJEKO – PROTEINSKE FRAKCIJE I LIPIDNE KOMPONENTE

SAŽETAK

U ljudskoj populaciji u novorođenčadi koja nije hranjena majčinim mlijekom potrebno je zamjensko mlijeko. Uporaba kravljega mlijeka može inducirati pojavu alergija tijekom prve tri godine života. Alternativa može biti kobilje mlijeko. Ciljevi ovoga rada bili su usporediti proteinske frakcije i lipidne komponente majčinoga i kobiljega mlijeka te utvrditi adekvatnost kobiljega mlijeka kao zamjene za majčino. Utvrđene su sličnosti glede sadržaja proteina i soli, proteina sirutke i NPN koncentracije, strukture proteinskih micela i globula masti te udjela zasićenih i nezasićenih masnih kiselina. Uzimajući u obzir utvrđene sličnosti humanoga i kobiljega mlijeka, može se zaključiti da je kobilje mlijeko adekvatna hrana za dojenčad.

Ključne riječi: humano mlijeko, kobilje mlijeko, proteinske frakcije, lipidne komponente

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