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CHARACTERISTICS OF MILK FROM DIFFERENT SPECIES OF FARM ANIMALS WITH SPECIAL EMPHASIS ON HEALTH-PROMOTING INGREDIENTS

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ABSTRACT

Nowadays, consumers choose food products, pay attention not only to their nutritional value and taste, but also to health-promoting properties. Milk from various animal species is a rich source of health-enhancing components present in the fat, protein and water fractions. They exert a multidirectional impact on the human organism and limit the risk of development of many lifestyle diseases. There are differences in the content of bioactive ingredients in milk from various animal species. In comparison with cow milk, which is of key importance in the world production, sheep and donkey milk contains higher amounts of whey proteins (mainly β-Lg) and polyunsaturated acids. Camel milk deserves special attention as well due to its high content of antibacterial substances, i.e. lactoferrin and lysozyme, as well as vitamins C and E. Importantly, milk and dairy products are a rich source of essential amino acids and minerals (mainly calcium), indispensable for normal functioning of the human organism. Due to the presence of antioxidants, i.e. β-Lg, lactoferrin, CLA, and vitamins E and C, they are classified as natural antioxidants.

Key words: milk, health-promoting, protein, vitamins, amino acid, fatty acid

INTRODUCTION

At present, products exerting a beneficial effect on the human organism are assigned great importance by consumers. Undoubtedly, one of such products is milk and dairy products, which account for approximately 25–30% of the average human diet [Khan et al. 2019]. They play an important role in human nutrition as a source of not only essential nutrients but also active biological components, which have a wide range of health-enhancing properties beneficial for the human organism. These components are contained in the fat, protein, and water milk fractions [Kuczyńska et al. 2013, Vanitcharoen et al. 2018]. Noteworthy, cow milk is definitely the most popular in most countries of the world – 85% of the world milk production is derived from cattle. However, in certain parts of the world, milk from other animal species also has a significant share in milk consumption. Except for bovine milk, 11% of the world production is from buffalo milk, followed by caprine and ovine milks, 12.3 and 1.7%, respectively [FAO 2015]. In turn, camel milk is widely consumed in Arab countries. Donkey milk has also gained popularity recently, as it has the most similar composition to that of human milk in (Table 1).

Milk protein

The main protein in milk is casein, which accounts for about 80% of the total protein content. In turn, 20–25% of cow milk proteins are whey proteins, i.e. albumin (α-lactalbumin, β-lactoglobulin, and bovine serum albumin), immunoglobulins, and proteose-peptones as well as glycomacropeptides, lactoferrin, growth factors, hormones, and numerous enzymes, including lysozyme [Król et al. 2011, Brodziak et al. 2017].

In addition to their obvious nutritional value, milk proteins and their decomposition products serve numerous biological functions. Casein is the most useful protein for the synthesis of hemoglobin and blood plasma pro-

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Table 1. Basic chemical composition of milk from different animal species and human

	Cow	Goat	Sheep	Buffalo	Camel	Donkey	Human
Dry matter, (%)	12.4–13.0	12.1–15.0	17.0–19.1	15.7–17.2	12.4	9.0–11.7	10.7–12.9
Protein, (%)	3.2–4.0	2.8–5.2	4.5–7.0	3.6–4.7	3.0–3.3	1.4–2.0	0.9–1.9
Fat, (%)	3.4–4.5	3.4–4.5	5.3–9.3	5.2–9.0	3.2–3.8	0.3–1.8	2.1–4.0
Lactose, (%)	4.4–5.4	3.9–5.0	3.9–5.0	3.2–4.7	4.3–4.5	5.8–7.4	6.3–6.9
Ash, (%)	0.7–0.8	0.7–0.9	0.9–1.0	0.8–0.9	0.8–1.1	0.3–0.5	0.2–0.3

Table based on research conducted by Park et al. 2007, Giambra et al. 2014, Kapadiya et al. 2016, Temerbayeva et al. 2018, Khalifa and Zakaria 2019, Numpaque et al. 2019, Soliman and Shehata 2019, Vianna et al. 2019, da Silva et al. 2020, Faccia et al. 2020, Derdak et al. 2020, Garau et al. 2021.

Table 2. Biological activity of whey proteins

Protein	Biological activity
Casein	– enhancement of calcium and phosphorus availability – synthesis of hemoglobin and blood plasma proteins – anti-cancer activity – opioid effect – reduction of blood pressure
β-lactoglobulin	– involvement in the binding, translocation, and accumulation of fat-soluble compounds, e.g. retinoids, free fatty acids, or vitamin D – ability to bind and transport sodium, calcium, or mercury ions – anticarcinogenic, antiviral, and antibacterial properties – potential antioxidant role – involvement in passive immunity – role of a precursor of bioactive peptides
α-lactalbumin	– effector of lactose synthesis in the mammary gland – calcium carrier – anticancer effect – stimulation of the growth of normal intestinal microflora; activity against Gram–positive bacteria – antiviral activity – immunological factor increasing immunity in newborns – precursor of bioactive peptides
Serum albumin	– participation in the metabolism, binding, and transport of fatty acids and other small molecules, including metal ions (e.g. calcium) – prevention of fatty acid peroxidation – anticancer effect (especially in breast and colon cancer) – precursor of bioactive peptides
Immunoglobulins	– specific immune protection
Glycomacropeptide	– antibacterial and anticoagulant effect – regulator of gastrointestinal hormones
Lactoferrin	– binding of iron, calcium, copper, aluminum, and manganese ions – bactericidal and bacteriostatic activity – antioxidant effect – anticancer effect – component of non-specific systemic immunity – cell growth regulator – antifungal activity – antiviral activity – antiparasitic activity – precursor of bioactive peptides
Lactoperoxidase	– antibacterial activity
Lysozyme	– antibacterial activity; synergistic effect with immunoglobulins, lactoferrin, and lactoperoxidase – component of non-specific humoral immune mechanisms – antifungal properties – anti-inflammatory properties – analgesic activity

Table based on research conducted by Król et al. 2011, Kuczyńska et al. 2013, Bučević-Popović et al. 2014, Piovesana et al. 2015, Beghelli et al. 2016, Al-Asmari et al. 2017, Arab et al. 2017, Ayyash et al. 2017, Brodziak et al. 2017, Homayouni-Tabrizi et al. 2017, Khan et al. 2019, Yilmaz-Ersan et al. 2018, Mercha et al. 2019, Bulca and Güvenç 2020.

teins in mammalian organisms. It is involved in the concentration, stabilization, and supply of elements, mainly calcium and phosphorus. One of its important functions is to support digestion and prevent retention of food contents in the stomach [Haque et al. 2010, Barłowska et al. 2011]. It should be emphasized that the content of whey proteins is particularly important for health. They have biological activity and strong antibacterial, antiviral, and antioxidant properties [Sharma and Singh 2014, Yadav et al. 2015, Homayouni-Tabrizi et al. 2017, Mercha et al. 2019], Table 2. They have an impact on the gastrointestinal, immune, circulatory, and nervous systems and reduce the risk of many lifestyle diseases, e.g. atherosclerosis, obesity, diabetes, cancer, and even Alzheimer's disease or HIV [Król et al. 2011, Kuczyńska et al. 2013]. The content of proteins in the diet, mainly immunoglobulins, lactoferrin, and lysozyme, is one of the determinants of the proper immune response of the organism [Król and Brodziak 2015]. Whey proteins, especially β-LG and lactoferrin, exhibit the highest antioxidant potential in comparison with proteins present in other food products. This is related to the high content of sulfur amino acids, especially cysteine, which is essential for glutathione synthesis [Yilmaz-Ersan et al. 2018].

The content of different proteins in milk obtained from different animal species varies (Table 3). The richest source of protein is sheep milk, which contains the highest content of casein, e.g. two- to three-fold higher amounts of β-casein and β-lactoglobulin in comparison with milk from other species [Balthazar et al. 2017, Claeys et al. 2014, Selvaggi et al. 2014]. Human and camel milk does not contain β-lactoglobulin, i.e. the basic whey protein in the milk of ruminants. In turn, this type of milk is a richer source of antibacterial proteins (lactoferrin and lysozyme) than milk from other lactating animals [Szwajkowska et al. 2011]. Donkey milk is becoming increasingly popular among consumers. It is regarded as the best substitute for human milk due to the similar chemical composition [Monti et al. 2012, Polidori et al. 2015]. In turn, buffalo milk has the most similar composition to that of cow milk, but the former contains more casein [Abd El-Salam and El-Shibiny 2011, Islam et al. 2014].

Essential amino acids, which are abundant in milk and dairy products, are highly important for the human organism [Rafiq et al. 2016, Khan et al. 2019]. As shown in Table 4, milk is the rich source of essential amino acids. It fully covers the demand for these compounds. Whey proteins are characterized by a high total level of essential amino acids, which are of great importance in human nutrition. They have high contents of sulfuric amino acids, which exert a positive effect on human health, indirectly contributing to protection against the growth of cancer cells. Whey proteins are also a rich source of tryptophan, which increases the ability of the organism to cope with stress and is the basis for the biosynthesis of vitamin PP necessary for the proper functioning of the brain and nervous system as well as the production of sex hormones. In comparison with other food proteins, whey proteins have a higher level of lysine, isoleucine, leucine, tryptophan, and threonine. The content of amino acids in selected proteins is presented in table 5. The consumption of 14 g of whey proteins fully covers the daily requirement for amino acids in an adult person weighing 70 kg. This amount is equivalent to 23 g of casein or 17 g of egg white [Szczurek 2008].

As suggested by current hypotheses, in addition to its basic functions, each protein can play the role of a precursor of bioactive peptides [Abdel-Hamid et al. 2017, FitzGerald et al. 2020]. Released bioactive peptides exert a beneficial effect on the human organism through their antithrombotic, antibacterial, antioxidant, and opioid activity [Behera et al. 2012, Islam et al. 2014, Martínez-Augustin et al. 2014, Saini et al. 2014, Shanmugam et al. 2015, Tenore et al. 2015, Marcone et al. 2017, Guha et al. 2021]. Noteworthy, milk and dairy products, mainly cheese and fermented beverages, are a rich source of bioactive peptides [Szwajkowska et al. 2011, Garau et al. 2021]. Many peptides are produced during cheese ripening, e.g. casomorphine, which is an opioid from the same family as morphine. Casomorphines can cross the human intestinal barrier and influence the nervous, gastrointestinal, and immune systems. They are also believed to exert an impact on the cardiovascular and respiratory systems [Park and Nam 2015]. In turn, casoplatelins, i.e. anticoagulant peptides preventing the formation of an insoluble fibrin clot from fibrinogen, are formed during yoghurt production. Peptides with similar activity to that of morphine are also produced from whey proteins; they are referred to as lactorphins. Concurrently, they act as inhibitors of ACE (angiotensin-converting enzyme), which catalyses the generation of angiotensin II, i.e. a hormone increasing blood pressure. Additionally, β-lactotensin, lactokinin, and β-lactosine have been isolated in β-LG sequences. These peptides are ACE inhibitors as well [Król and Brodziak 2015, El-Sayed and Awad 2019]. Milk and dairy products are also the primary source of peptides with antioxidant properties [Tenore al. 2015]. These peptides usually consist of 5–11 amino acid residues, including hydrophobic ones (proline, histidine, tyrosine, tryptophan, or cysteine) exerting antioxidant activity in the free form [El-Sayed and Awad 2019]. Such activity is demonstrated by β-casein and released peptides with the VKEAMAPK, AVPYPQR, KVLPVEK, VLPVPEK sequences and by α_{s1}-casein with the YFYPEL sequence [Darewicz et al. 2015]. Timón et al. [2014] identified three peptides with radical scavenging activity in Burgos cheese derived from α_{s1}-casein (SDIPNPIGSENSEKTTMPLW) and β-casein (YQQPVLGPVRGPFPIIV; LLYQQPVLGPVRGPFPIIV). A large number of antioxidant biopeptides have also

Table 3. Protein content in milk from various species animals and human

Protein, $g \cdot L^{-1}$	Cow	Goat	Sheep	Buffalo	Camel	Donkey	Human
Total casein	24–28	23–46	42–59	32–49	26	6.4–10.3	2.4–4.2
α_{S1}-casein	9.5–12	3.0–7.0	11–22	9	4–5	1.5	0.77
α_{S2}-casein	1.6–4	3.0–4.0	0–13	5	2–3	0.1	–
β-casein	9–15	11–15	15–36	12–21	12–13	4	3–5
κ-casein	2.0–3.5	2–7	5–12	4–6	0.7	–	1–3
Total whey protein	6–8	3.7–7.0	6–9	5–6	5.9–8.1	4.9–8.0	6.2–8.3
α-lactoalbumin	1.0–1.8	1.7–3.3	1.35	1.4	1.3	1–2	2–3
β-lactoglobulin	2.8–3.5	3.0	4.6–7.0	3.9	–	3.3–4.0	–
serum albumin	0.43–0.57	–	0.4–0.6	0.29	0.4	–	0.3
lactoferrin	0.1–0.2	0.1	0.28	0.03–3.4	0.2	0.08	1–3

Table based on research conducted by Korhonen 2009, Abd El-Salam and El-Shibidy 2011, Selvaggi et al. 2014, Hazebrouck 2016, Mati et al. 2016, Pastuszka et al. 2016, Balthazat et al. 2017, Vincenzetti et al. 2017, Khan et al. 2019, Verruck et al. 2019, Garau et al. 2021.

Table 4. Amino acid content ($g \cdot 100\ g^{-1}$) in milk from various species animals

Amino acid	Cow	Goat	Sheep	Buffalo	Camel
Aspartic acid	7.8	7.4	6.5	7.1	6.9
Threonine	4.5	5.7	4.4	5.7	4.1
Serine	4.8	5.2	3.4	4.7	4.3
[a]Glutamic acid	23.2	19.3	14.5	21.4	18.1
Proline	9.6	14.6	16.2	12.0	12.0
[a]Cysteine	0.6	0.6	0.9	0.6	1.9
Glycine	1.8	2.1	3.5	1.9	2.1
Alanine	3.0	3.6	2.4	3.0	2.1
[a]Valine	4.8	5.7	6.4	6.8	4.1
[a]Methionine	1.8	3.5	2.7	0.9	2.0
[a]Isoleucine	4.2	7.1	4.6	5.7	4.9
[a]Leucine	8.7	8.2	9.9	9.8	6.1
[a]Tyrosine	4.5	4.8	3.8	3.9	3.1
Phenylalanine	4.8	6.0	4.3	4.7	4.0
[a]Histidine	3.0	5.0	6.7	2.7	2.1
Lysine	8.1	8.2	7.8	7.5	–

[a]Amino acid has antioxidant acivity in milk and dairy products.
Table based on research conducted by Barłowska et al. 2011, Medhammar et al. 2012, Ren et al. 2015, Khan et al. 2019.

been isolated and identified from β-LG hydrolyzed with Corolase PP [Hernández-Ledesma et al. 2006].

Milk fat

The fatty acid profile is an important parameter of milk fat quality [Tao and Ngadi 2017]. Milk from ruminants is characterized by high content of saturated fatty acids (SFA) associated most often with the risk of obesity, hypercholesterolemia, and atherosclerosis [Hanuš et al. 2018]. It should be emphasized that the presence of saturated short-chain acids, which are used as a source of energy indispensable for organism functioning, is a unique feature of milk fat. Table 6 shows the fatty acid profile of milk from various animal species. A characteristic feature of goat milk is the high content of short-chain acids, which are responsible for its specific smell, as suggested by many authors [Barłowska et al. 2011]. In turn, sheep milk is rich in unsaturated fatty acids, mainly C18:1 and C18:2 [González-Martín et al. 2017].

Table 5. Percentage content of exogenous and relatively endogenous amino acids in different types of proteins

Amino acid	Milk		Rennet cheese	Tvarog	Pork meat	Wheat	Soybean	Hen egg
	Whey Protein	Casein						
Isoleucine	6.2	5.1	4.8	4.9	5.0	4.3	5.0	5.4
Leucine	10.1	9.4	8.9	9.5	7.3	6.7	7.9	8.6
Lysine	9.0	7.5	7.7	7.8	8.2	2.8	6.4	7.6
Methionine + cysteine	4.4	2.8	3.1	3.2	3.7	3.5	3.3	5.7
Phenylalanine + tyrosine	6.7	10.0	10.4	12.1	7.5	8.7	8.7	9.3
Threonine	7.3	4.1	3.5	4.9	4.3	2.9	3.9	4.7
Tryptophan	1.9	1.3	1.4	1.4	1.1	1.2	1.3	1.7
Valine	6.2	6.1	5.7	5.9	5.2	4.6	5.2	6.6

Table based on research by Szczurek 2008, Siemianowski and Szpendowski 2014, Teter et al. 2020.

Table 6. Total fatty acid profile and cholesterol content in milk from various species animals

Fatty acid	Cow	Goat	Sheep	Buffalo	Camel
SFA (%)	46.7–67.7	59.9–73.7	57.5–74.6	62.1–74.0	47.0–69.9
MUFA (%)	22.7–30.3	21.8–35.9	23.0–39.1	24.0–29.4	28.1–31.1
PUFA (%)	2.4–6.3	2.6–5.6	2.5–7.3	2.3–3.9	1.8–11.1
CLA (%)	0.3–2.4	0.3–1.2	0.6–1.1	0.4–1.0	0.4
Cholesterol (mg · 100 mL^{-1})	13.1–31.4	10.7–18.1	14.0–29.0	4.0–18.0	31.3–37.1

Table based on research conducted by Gastaldi et al. 2010, Devle et al. 2012, Claeys et al. 2014, Crowley et al. 2018.

Table 7. Impact of selected fatty acids on human health

Fatty acids	Function
C4:0	– beneficial effect on the human intestinal flora and gastrointestinal tract wall mainly as a direct source of energy for colonocytes – one of the factors preventing the progression of colorectal and mammary cancer – inhibition of cell growth, promotion of differentiation and induction of apoptosis in various human cancer cell lines – possible prevention of tumor invasion through an inhibitory effect on urokinase – potential broad anti-inflammatory effect through the influence on immune cell migration, cytokine adhesion and expression, and cellular processes such as proliferation, activation, and apoptosis
C12:0 C14:0 C16:0 C18:0	C12: 0, C14: 0, and C16: 0 are associated with an increased risk of atherosclerosis, hyperlipidemia, high content of low-density lipoprotein cholesterol, obesity, and ischemic heart disease C18: 0 and C14: 0 – increase thrombogenicity and cholesterol levels
C18:1 c9 C18:3 n-3	– anti-cancer and anti-atherosclerotic properties – positive effect on cholesterol levels – improvement of immune response (anti-inflammatory effect)
C18:2 n-6	– improvement of insulin sensitivity thereby reducing the prevalence of type 2 diabetes
CLA *cis9*, *trans11* CLA *trans10*, *cis12*	– reduction of tumor growth – reduction of the risk of ischemic heart disease – inhibition of the proliferation and growth of neoplastic cells in humans – modification of lipid metabolism (with a decrease in adipose tissue mass)
AA EPA	– neutralization of C12: 0, C14: 0, and C16: 0 through an increase in the level of high–density lipoprotein cholesterol – anti-cancer, antihypertensive, and anti-inflammatory properties
DHA	– positive effect on brain cells, which is important for remission of Alzheimer's disease – anti-cancer, antihypertensive, and anti-inflammatory properties

Table based on research by Hanuš et al. 2018.

Table 8. Content of vitamins in milk from various species animals

Vitamin, mg · 100 g^{-1}	Cow	Goat	Sheep	Buffalo	Camel
Vitamin A	37–46	55–185	64–146	35–69	20.1
Vitamin E	0.21	0.03	n.d.	0.19	0.32
Vitamin D	2	1.33	2	2	3
Vitamin B6	0.04–0.06	0.045	0.08	0.33	–
Vitamin B12	0.36–0.45	0.66	0.71	0.40	–
Vitamin C	1.94	1.29	4.16	2.2	3.3

Table based on research conducted by Barłowska et al. 2011, Kuczyńska et al. 2013, Wijesinha-Bettoni and Burlingame 2013, Claeys et al. 2014, Ren et al. 2015, Balthazar et al. 2017, Khan et al. 2019, Brodziak et al. 2020.

Table 9. Function of the main vitamins

Vitamin	Function
A	– retinol precursor, – essential in the process of vision and fetal development, – involvement in the processes of growth and differentiation of nervous and skeletal cells, – effective protection of the organism against bacteria and pollution
D	– key role in calcium and phosphorus metabolism, – key role in proper development of the skeletal system and teeth in infants and children
E	– antioxidant effect (free radical scavenging, inhibition of lipid peroxidation reactions), – involvement in many important functions of the organism, i.e. blood clotting, immunity, and reproduction
K	– involvement in the blood clotting process
B_1	– important role in transduction of stimuli from nerves to muscles and regeneration of the nervous system after strenuous activity, – support of the proper development, fertility, and breastfeeding ability and regulation of appetite
B_2	– indispensable component for proper functioning of the nervous system, – support of the skin healing process
B_6	– support of the immune system through regulation of cell specialization and division
B_{12}	– indispensable in the formation of morphotic elements of blood, – involvement in cell division as a coenzyme; hence, it is regarded as a growth factor
C	– antioxidant activity, – indispensable factor involved in numerous metabolic processes in the human organism

Table based on research conducted by Rashad et al. 2011, Kuczyńska et al. 2013, Zaborska et al. 2015, Mann et al. 2016 Brodziak et al. 2017, Vanitcharoen et al. 2018.

Table 10. Content of minerals in milk from various species animals

Minerals, mg · 100 g^{-1}	Cow	Goat	Sheep	Buffalo	Camel
Calcium	122–125	134	195–200	112–184	114
Phosphorus	95–119	121	124–158	89–99	–
Potassium	141–152	181	136–140	92–102	156
Magnesium	12	16	18–21	8–19	12.3
Sodium	58	41	44–58	35–45	–

Table based on research conducted by Park at al. 2007, Raynal-Ljutovac et al. 2008, Al-Haj and Al-Kanhal 2010, Barłowska et al. 2011, Wijesinha-Bettoni and Burlingame 2013, Khan et al. 2019.

An important group of fatty acids are unsaturated acids, which constitute the largest group of bioactive components in the milk fat fraction [Haug et al. 2007, Król and Brodziak 2012, Hanuš et al. 2018]. Approximately 35% of all fatty acids in milk fat are MUFAs with a dominant level of oleic acid (C18:1). Its effect on the human organism is extremely important, as it reduces the content of total cholesterol, LDL frac-

Table 11. Functions of the main macroelements

Element	Effect on the organism
Calcium	– involvement in formation of bones and teeth, – impact on the function of muscles, – regulation of blood coagulation processes, – regulation of the function of parathyroid glands
Magnesium	– involvement in the regulation of the cell cycle, – involvement in DNA repair processes, – impact on ATP and ADP synthesis, – counteraction of myocardial ischemia and regulation of blood pressure
Phosphorus	– involvement in vitamin C synthesis, – support of the maintenance of normal bone mass, – impact on hormonal homeostasis, – involvement in calcium metabolism and zinc, magnesium, and copper absorption
Potassium	– involvement in the maintenance of water and acid–base homeostasis, – involvement in the generation of the resting and action potential of nerve cells, – support of the circulatory system function

Table based on research by Gijsbers et al. 2016, Brodziak et al. 2017, Górska-Warsewicz et al. 2019.

tion, and triglycerides, thereby reducing the risk of cardiovascular diseases [Król and Brodziak 2012]. PUFAs, also called essential fatty acids (EFAs), are the most valuable unsaturated acids in terms of human physiology. They should be supplied with food, as they are not synthesized in the human organism, but their deficiency leads to pathological phenomena with clinical manifestations. This group comprises linoleic acid (C18:2 LA n-6), α-linolenic acid (C18:3 n-3), and their metabolites synthesized in the human organism or supplied with the diet, i.e. arachidonic acid (C20:4 AA n-6), eicosapentaenoic acid (C20:5 EPA n-3), and docosahexaenoic acid (C22:6 DHA n-3) [Haug et al. 2007]. These acids serve a number of biological functions in the human body (Table 7). The properties of EPA and DHA have been confirmed by the approval of the following health-related findings: EPAs and DHAs contribute to proper cardiovascular function, docosahexaenoic acid (DHA) contributes to the maintenance of normal vision and normal brain function, and the beneficial effects of n-3 polyunsaturated acids are ensured by consumption of 250 mg of DHA/EPA per day [EU Regulation 2012]. Noteworthy, donkey milk has several-fold higher content of unsaturated fatty acids (14.6%) than milk from other animals [Claeys et al. 2014]. As reported by Wszołek et al. [2014] with such a high level of PUFAs, donkey milk fat is more beneficial for human health than milk obtained from other species. Conjugated linoleic acid (CLA) is arousing growing interest due to its potential anti-atherosclerotic, anti-cancer, and antioxidant properties. It is represented by 28 isomers, but only two, i.e. 9-cis, 11-trans and 10-trans, 12-cis, have biological activity [Wang and Lee 2015]. Sheep milk contains the highest levels of CLA (Table 6), almost twice as high as cow milk.

Milk vitamins

Milk is a valuable source of both water-soluble and fat-soluble vitamins (Table 8). Noteworthy, sheep milk differs from the milk of other animal species, as it has higher levels of vitamins A and C [Bano et al. 2011]. Camel milk also has valuable properties due to the high content of vitamins E and C (30-fold higher than cow milk). Vitamins are indispensable for the proper function of the human organism, especially in children (Table 9). Vitamin A plays an important role in many physiological processes in the human organism. It is primarily known to be involved in proper vision, as it is part of the photosensitive retinal pigment (rhodopsin) responsible for receiving visual stimuli [Zaborska et al. 2015]. Vitamin E with its active form α-tocopherol and vitamin C are the main antioxidants in milk [Vanitcharoen et al. 2018]. Their action consists in organic free radical scavenging, lipid peroxidation inhibition, and singlet oxygen quenching [Rashad et al. 2011, Mann et al. 2016]. Similar activity is also exhibited by β-carotene (provitamin A), as it quenches singlet oxygen and scavenges organic peroxides generated in the lipid peroxidation process [Cichosz et al. 2017, Khan et al. 2019].

Milk minerals

Milk is an important source of such minerals as calcium, phosphorus, magnesium, sodium, and potassium, which are characterized by very high bioavailability and optimal proportions (Table 10). Calcium is important mainly in the nutrition of children and adolescents, as it supports the development and growth of the organism. It is the most important component of bones and teeth [Barłowska et al. 2011]. Calcium also serves many other functions in the organism, e.g. it is involved in the transduction of nerve stimuli and regulation of nerve excitability, muscle contractility, enzyme activation, and blood coagulation (Table 11). It also contributes to reduction of the risk of colon, prostate, and breast cancer. With its elevated concentration of calcium and magnesium, sheep milk is an attractive source of food for infants [Slačanac et al. 2010]. In turn, donkey milk has the lowest amounts of minerals [Potortì et al. 2013].

CONCLUSIONS

Ingredients showing a positive effect on human health are present in all fractions of milk, i.e. fat (fatty acids, lipophilic vitamins: A, D_3, E, K), protein (whey proteins, casein, amino acid, peptides) and water (minerals, mainly calcium). Compared to cow's milk, which is crucial in world production, sheep's and donkey's milk contain a greater amount of whey proteins (mainly β-Lg) and polyunsaturated acids. Camel milk also deserves special attention due to the high content of antibacterial proteins, i.e. lactoferrin and lysozyme, as well as vitamins C and E. It should be emphasized that due to the specific therapeutic properties of the milk components, regardless of the species of animals from which the milk was obtained, they are used in the production of functional food and nutraceuticals.

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CHARAKTERYSTYKA MLEKA RÓŻNYCH GATUNKÓW ZWIERZĄT GOSPODARSKICH ZE SZCZEGÓLNYM UWZGLĘDNIENIEM SKŁADNIKÓW PROZDROWOTNYCH

STRESZCZENIE

W dzisiejszych czasach konsumenci sięgając po produkty spożywcze zawracają uwagę nie tylko na wartość odżywczą i walory smakowe, ale również na właściwości prozdrowotne. Mleko pozyskiwane od różnych gatunków zwierząt jest bogatym źródłem składników prozdrowotnych, które występują zarówno we frakcji tłuszczowej, białkowej i wodnej. Wykazują one wielokierunkowe oddziaływanie na organizm człowieka, ograniczając ryzyko wystąpienia wielu chorób cywilizacyjnych. Wykazano zróżnicowanie międzygatunkowe w zawartości składników bioaktywnych w mleku. W porównaniu do mleka krowiego, które stanowi kluczowe znaczenie w produkcji światowej, mleko owcze i ośle zawiera więcej białek serwatkowych, w tym β-Lg oraz kwasów wielonienasyconych. Na wyróżnienie zasługuje również mleko wielbłądzie, ze względu na wysoką zawartość substancji antybakteryjnych, tj. laktoferyny i lizozymu oraz witaminy C i E w porównaniu do pozostałych gatunków. Należy podkreślić, iż mleko i produkty mleczne są bogatym źródłem aminokwasów egzogennych oraz składników mineralnych (głównie wapnia), niezbędnych do funkcjonowania organizmu człowieka. Z uwagi na obecność substancji antyoksydacyjnych, tj. β-Lg, laktoferyny, CLA oraz witaminy E i C, które zaliczane są do naturalnych przeciwutleniaczy.

Słowa kluczowe: mleko, właściwości prozdrowotne, białka, witaminy, aminokwasy, kwasy tłuszczowe

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