GOAT'S MILK BIOACTIVE SUBSTANCES USED IN MEDICINE AND PHARMACY

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Abstract

High quality goat milk raises more and more interest in its use in medicine and pharmacy. Due to its low allergenicity and immunostimulating properties, goat milk can be used in the pre-vention of many diseases. Of particular importance are polyunsaturated fatty acids, including CLA, which are used in the prevention of cancer, obesity and atherosclerosis. Monounsaturated fatty acids inhibit skin lesions in the case of eczema, psoriasis or acne. Fatty acids together with sialic acid have a protective effect on nerve cells. Important bioactive substances in goat milk are proteins, oligosaccharides and vitamins. These substances are perfectly absorbed by the human body and can be used in the prevention of many diseases and skin regeneration.

Keywords: goat milk, health-promoting properties, body regeneration

Introduction

The most common type of milk used for human consumption in the food industry is cow milk. It has a similar basic chemical composition to goat milk, but there are differences in the qualitative composition of protein and fat and in the quantity of minerals. The dry solid content of goat milk is 12.97% and that of cow milk is 12.01%. Goat milk provides 69 kcal per 100 grams, while cow milk provides 61 kcal per 100 grams (Wójtowski et al., 2013). Due to its chemical composition, it is much easier for the human body to digest and absorb than cow milk. It contains many essential nutrients such as minerals, vitamins and easily absorbable protein with balanced amino acid profiles (Table 1).

With its health-promoting qualities, goat milk should be a staple in the diet of children and adults. This product has a probiotic effect and can be used to prevent metabolic diseases. Additionally, cosmetic products containing goat milk are a natural emollient for human skin. The small diameter of its fat globules allows the products to be absorbed through the epidermis, thus forming a protective, occlusive layer. Dermatological and cosmetic products based on goat milk cause water retention in the skin, while casein and unsaturated fatty acids have a moisturising effect that helps with skin regeneration.

Table 1. Chemical composition of sheep, goat, cow and human milk (Fox, 2003; Jandal, 1996)

Gatunek Species	Sucha masa Solids (%)	Tłuszcz Fat (%)	Białko Protein (%)	Kazeina Casein (%)	Białka serwatkowe Whey proteins (%)	Laktoza Lactose (%)	Popiół Ash (%)
Człowiek Human	12.2	3.8	1.0	0.4	0.7	7.0	0.2
Owca Sheep	19.3	7.4	6.2	5.1	0.8	4.8	1.0
Koza Goat	12.3	4.5	2.9	2.5	0.4	4.1	0.80
Krowa Cow	12.7	3.7	3.4	2.6	0.6	4.8	0.7

Health-promoting qualities of the fat fraction in milk

Goat milk is characterised by low cholesterol content and favourable fatty acid composition compared to cow milk. On average, 100 ml of goat milk contains 12-17 mg of cholesterol (Bernacka, 2011). That is half the quantity found in sheep milk. The daily recommendation for cholesterol intake should not exceed 300 mg/day. The quality of fat largely depends on the content of individual fatty acids. The fatty acid profile is more favourable in goat milk than in sheep and cow milk due to the PUFA/SFA ratio, i.e. 0.56 to 0.37 (Bernacka, 2011) (Table 2).

Table 2. Comparison of fatty acid content of sheep, cow and goat milk (Pełczyńska, 1995)

Kwas tłuszczowy Fatty acid	Zawartość w 100 g mleka owczego Content in 100 g of sheep milk	Zawartość w 100 g mleka krowiego Content in 100 g of cow milk	Zawartość w 100 g mleka koziego Content in 100 g of goat milk
Krótkołańcuchowe i średniołańcuchowe Short-chain and medium-chain	1.58	0.61	0.89
Długołańcuchowe nasycone Long-chain saturated	2.52	1.28	1.35
Jednonienasycone Monounsaturated	1.72	0.96	1.11
Wielonienasycone Polyunsaturated	0.31	0.12	0.15
Cholesterol	27	14	11

Short-chain fatty acids (SFA), such as octanoic, hexanoic, and decanoic acids, play an important role in maintaining correct body function, for example by regulating its homeostasis. In healthy humans, the presence of these acids in the intestine is the result of polysaccharide fermentation, and the proper functioning of the immune system is dependent on the presence of acetate, propionate and butyrate and their modification at various stages. By modulating migration to the inflammation site, these acids stimulate the activity of immune cells. Thus, they show significant anti-inflammatory potential (Czajkowska and Szponar, 2018). The high content of these acids in goat milk helps to prevent chronic gastrointestinal diseases and intestinal disorders caused by antibiotic intake (Mansbridge and Blake, 1997).

Goat milk contains significantly more capric acid (C6:0), caprylic acid (C8:0), caproic acid (C10:0), butyric acid (C4:0), lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0) and linolenic acid (C18:2n-3) in comparison with milk obtained from other ruminants. The first three fatty acids mentioned above owe their name to the word *Capra* (goat), as it was in this particular species that they were first discovered, not least because of their high concentration in milk. Furthermore, goat milk is characterised by a lower content of stearic acid (C18:0) and oleic acid (C18:1) compared to cow milk (Alonso, 1999; Haenlein, 2004).

Caprylic acid, capric acid and other medium-chain fatty acids have a therapeutic effect on the human body by supporting the treatment of various metabolic conditions such as fatty diarrhoea and malabsorption syndrome (Szmatoła et al., 2013). This dysfunction particularly contributes to deficiencies in vitamin B_{12}, folic acid and iron. Research has shown that a diet rich in goat milk improves intestinal function (Lopez-Aliaga et al., 2010). Medium-chain fatty acids are used in the diet of people who have undergone small intestine resection and in the nutrition of premature infants and new-borns (Haenlein, 2004). Capric and caprylic acid are used as supplements in the treatment of patients with anaemia, bone demineralisation and hypercholesterolaemia. Capric acid, caprylic acid and other medium-chain fatty acids are metabolised to provide energy to the body and do not accumulate in adipose tissue. This particular feature is utilised in the preventive treatment of cystic fibrosis or gallstones (Haenlein, 2004).

Capric and caprylic acids can be successfully used as carriers of beneficial compounds in creams and lotions, as they increase skin permeability. Due to its regenerative properties, caprylic acid is an important ingredient in moisturising cosmetics (Mahjour et al., 1993). As its fat globules are small in size, goat milk ingredients can easily penetrate the skin, allowing goat milk products to hydrate the skin.

Monounsaturated fatty acids can protect against diseases associated with metabolic syndromes, such as atherosclerosis. These include oleic acid (C18:1) found in goat milk at a concentration of 16 g/100 g. It is reported to have hypolipidermic properties, reducing cholesterol levels (Pastuszka et al., 2015). Also, this monounsaturated fatty acid increases fat oxidation, thereby boosting energy expenditure and helping to reduce visceral-abdominal obesity (Gillingham et al., 2011). A diet low in n-3 and rich in n-6 polyunsaturated fatty acids can lead to several skin conditions. Monounsaturated n-3 fatty acids are used in the treatment of psoriasis, acne and eczema, as people struggling with these skin conditions have low lipid levels. Therefore, goat milk products can alleviate their disease symptoms. Eicosapentaenoic acid and docosahexaenoic acid, α-linolenic acid and linoleic acid inhibit the pro-inflammatory production of eicosanoids from arachidonic acid and are also successful in alleviating the symptoms of skin diseases (Markiewicz-Kęszycka et al., 2013).

Polyunsaturated fatty acids (PUFA) contained in goat milk belong to the omega-3 group and therefore support the treatment of dementia. Goat milk given to mice with pharmacologically induced memory impairment helped regenerate their nerve cells, indicating that α-linolenic acid has neuroprotective properties (Kaura et al., 2022). The content of polyunsaturated fatty acids is 2-4 g/100 g of goat milk. These include linoleic acid (C18:2), which is an omega-6 fatty acid, and α-linolenic acid (C18:3), which belongs to the omega-3 group. Linoleic acid is a precursor of arachidonic acid (C20:4, n-6), and α-linolenic acid is a precursor of eicosapentanoic acid (C20:5, n-3) and docosahexanoic acid (C22:6, n-3). The n-3 fatty acids have a therapeutic effect on rheumatoid arthritis, dermatitis and, most importantly, help to reduce the symptoms of dementia and can be successfully used to treat late-stage Alzheimer's disease. Through the synthesis of mediators – lipid mediators (prostaglandins, leukotrienes), peptide mediators (cytokines), enzymes and superoxide – PUFA acids have a stimulating effect on acquired and natural immunity. The n-3 fatty acids and their derivatives help to alleviate atopic skin inflammation by influencing the metabolism of eicosanoids derived from arachidonic acid (C20:4, n-6), specifically prostaglandin E2 and leukotriene B4 (Calder, 2001).

One of the most significant sources of CLA (conjugated linoleic acid) is ruminant milk. Goat milk contains 25 mg of that acid per 100 g (Bernacka, 2011). Conjugated linoleic acid is reported to help with obesity, cancer, atherosclerosis and diabetes (Beppu et al., 2006). CLA trans-10 cis-12, which is one of the omega-6 acids, is responsible for proper skin firmness and hydration, as it helps protect against water loss from the skin surface. It also reduces hyperpigmentation. As reported by Tang et al. (2021), conjugated linoleic acid alleviates lesions similar to atopic dermatitis induced in mice. It significantly inhibits pro-inflammatory cytokines. Research has shown that topical application of CLA leads to epidermal regeneration and improves skin hydration by increasing the quantity of filaggrin in the skin. It also helps to maintain the correct pH. Conjugated linoleic acid is responsible for the basic regulation of protective functions, while also helping to combat inflammation.

Health-promoting properties of goat milk protein

The protein content of goat milk varies from 30 to 35 g/l of milk (Wójtowski et al., 2013). It differs from cow milk in its higher content of essential amino acids. This applies to as many as 6 of the 10 essential amino acids, in particular cysteine, which supports metabolic processes in the body. Goat milk contains 20-40 μmol more taurine than cow milk. Taurine is an amino acid involved in antioxidation, fatty acid absorption, formation of the infant brain, while also acting as a neurotransmitter in the nervous system. Thanks to its nucleotide content, which is similar to that of human milk, goat milk can be used to prepare milk substitutes for infants, and the polyamides present in it do not cause food allergies (Prosser et al., 2008). Consumption of goat milk alleviates eczema symptoms in children and reduces the risk of asthma (Lopez-Aliaga et al., 2010). Due to its content of peptides and phosphate groups, goat milk has an alkaline reaction, which may be important for people with hyperacidity of the stomach. The proteins of goat milk are 80% casein and 20% whey, i.e. α-lactalbumin and β-lactoglobulin. Casein is not a homogeneous protein and its main fractions include: αs1-, αs2-, β- and κ-casein. Compared to cow milk, goat milk contains more of the β-casein fraction. It is notable that αs1-casein contained in milk is the main cause of allergic reactions in humans (Milewski and Kędzior, 2010). Goat milk also contains lysozyme, immunoglobulins, lactoferrin and lactoperoxidase, all of which show antimicrobial properties. Lactoferrin is an iron-binding protein that is most commonly used as a supplement in the treatment of psoriasis and acne. Lactoferrin, present in milk, reduces inflammation and alleviates clinical signs of skin lesions (Kazimierska and Kalinowska-Lis, 2021; Kim et al., 2010). A study by Wszołek (2005) showed an increase in neutrophil granulocytes in the blood of people who consumed goat milk.

Milk proteins are a source of amino acids and peptides and act as a carrier for vitamin E, referred to as the 'vitamin of youth'. This vitamin is a powerful antioxidant as it helps to eliminate free radicals which accelerate skin ageing and cause wrinkles (Chan et al., 2017). Whey proteins such as α-lactalbumin are capable of binding zinc, cobalt and magnesium ions to promote apoptosis and cancer cell degradation. Whey proteins are also reported to possess antibacterial properties (Milewski and Kędzior, 2010). Furthermore, a study by Moreno-Montoro et al. (2017) demonstrated the beneficial effects of fermented beverages for the prevention of cardiovascular diseases associated with oxidative stress and hypertension. Peptides released from whey and casein during their digestion by gastric pepsin inhibit angiotensin-substituting enzymes, with angiotensin being instrumental in blood pressure regulation (angiotensin II is produced, causing vasoconstriction).

Casein hydrolysate, obtained from casein, is used in cosmetics and is non-allergenic, which makes it an excellent substitute without causing adverse reactions. Casein hydrolysate used in cosmetic products forms a protective layer on the surface of the epidermis. It prevents excessive evaporation of water from the skin surface. It thus has a moisturising and smoothing effect.

Whey is also used in cosmetics because of its valuable protein, which has water-binding, emulsifying and foaming properties. The action of whey proteins is similar to that of hyaluronic acid, which is why they are used to produce lotions and soaps for children. Clinical studies have shown that whey substances are effective against dermatitis. The proteins, vitamins and minerals it contains nourish and rejuvenate skin and hair cells. Baths with 1-2 cups (100-200 ml) of whey are also recommended to help maintain correct skin pH. Whey is also used as an anti-acne agent (Çelik et al., 2014).

Whey proteins are excellent for emulsion formation; β-lactoglobulin has the best antioxidant properties (King et al., 2014). In addition, they have a strengthening effect on the surface of the hair and skin, and prevent water loss from its surface. Milk amino acids such as proline, threonine and methionine are involved in collagen synthesis in nails, hair and skin. Arginine accelerates wound healing (Mehra et al., 2021). A study by Bhavaniramya et al. (2022) showed that goat milk proteins influence COVID-19 disease through an inhibitory interaction with interleukin-6 receptors. During COVID-19 disease, overexpression of interleukin-6 cytokines occurs. Milk peptides interrupted gp130 binding and so led to the inhibition of IL-6 expression. Çakır et al. (2021) extracted peptides, specifically β-lactoglobulins, from whey, which also proved to have a positive effect in the treatment of SARS-CoV-2. These peptides, used in *in silico* studies, inactivated viruses and inhibited host cell membrane receptor functions.

The role of carbohydrates in recovery

Lactose is the main sugar found in goat milk and accounts for approximately 44% of all milk carbohydrate components (Pastuszka et al., 2015). Twenty-five other oligosaccharides are also present in goat milk. The lactose content of goat milk ranges from 4.1% to 4.7% and is comparable to that of milk from other mammals (Silanikove et al., 2010). Goat milk oligosaccharides have anti-infective, prebiotic and anti-inflammatory properties. Goat milk oligosaccharides have also been shown to have a positive effect on amoxicillin-induced intestinal dysbiosis (Butts et al., 2021). Goat milk given to rats increased the number of *Bifidobacterium spp.* and *Lactobacillus spp.* in their intestines and colons. Some studies have demonstrated the presence of fucosylated glycoconjugates in goat milk, including 2'-fucosyllactose. That is an oligosaccharide that has so far only been detected in human milk, and it is responsible for inhibiting the binding of pathogens to the intestinal epithelium and stimulating the growth of beneficial bacteria in the intestines (Urashima et al., 2004; Meyrand et al., 2013). The carbohydrate content of goat milk is very similar to that of human milk and, therefore, goat milk-based products can be successfully used in the diet of and, in particular, as prebiotics for infants (Martinez-Ferez et al., 2005).

Sialic acid, an organic compound from the polysaccharide group, is also present in goat milk. It plays a role in the development of the nervous system. It is found in the grey matter of the brain and is responsible for transmitting information between cells. Feeding goat milk (and therefore sialic acid) to infants boosts their immunity (Kumar et al., 2012). Sialic acid and taurine improve memory function related to D-galactose-induced ageing processes. Goat milk inhibits the oxidative effects of D-galactose on the brain and improves short- and long-term memory in rats (Safdar et al., 2020).

Undigested oligosaccharides in the human body after the consumption of goat milk act as prebiotics. Prebiotics have a positive effect on the gastrointestinal tract by promoting the growth of beneficial bacteria in the intestines. They also prevent the growth of pathogenic bacteria. Oligosaccharides used during infancy reduce the incidence of infectious and allergicdiseases. Carbohydrates stimulate the immune system to defend itself against pathogens and stimulate the body’s intestinal flora to develop properly. A study by Boehm and Stahl (2007) showed that milk oligosaccharides have high molecular similarities to breast milk, in contrast to those of plant origin.

Lactose and the other oligosaccharides in goat milk are used in cosmetology, as they show anti-acne properties. When lactose is subjected to biotechnological processes, lactobionic acid (PHA) is obtained, which has an exfoliating and bacteriostatic effect. Products based on these substances are also used on sunburnt skin (Boehm et al., 2005).

Importance of vitamins and minerals in goat milk

The abundance B vitamins in goat milk (thiamin, riboflavin and pantothenic acid) makes it ideal for infants, as it covers their daily requirement for these components. Compared to cow milk, it contains higher amounts of vitamin B_3 (niacin) and is poorer in folic acid (B_9), cobalamin (B_{12}) and tocopherol (vitamin E). The quantities of other B vitamins, vitamin C and vitamin D are similar in milk from both species. Goat milk lacks β-carotene, which is why its colour is white (Pastuszka et al., 2015). β-carotene is entirely converted into retinol, which makes goat milk significantly more abundant in vitamin A than cow milk (Danków and Pikul, 2011). Vitamin A present in goat milk has antioxidant and anti-ageing properties.

The mineral content of goat milk, like other components, depends on the goats’ nutrition and lactation period. Their content ranges from 0.70 to 0.85%, these values being higher than in cow or human milk (Silanikove et al., 2010). Goat milk owes its alkalinity to its high calcium and potassium content (the amount of calcium is 135 mg/100 g and potassium 121 mg/100 g) (Kumar et al., 2012). Goat milk is also characterised by a high content of magnesium, which reduces nervous system tension and improves the body’s resistance to biometeorological and stress factors (Wszołek, 2005). In addition, thanks to the presence of selenium and the enzyme glutathione peroxidase, goat milk has a strong antioxidant effect, so its consumption may help to reduce the risk of cancer (Haenlein, 2004). Selenium is more readily available in goat milk compared to cow milk, thanks to the presence of medium-chain fatty acids and proteins soluble in milk (Zenebe et al., 2014). It is notable that selenium deficiency in the human body can lead to irreversible cardiomyopathy (Kumar et al., 2016). The high concentration of selenium in goat milk helps to combat the symptoms accompanying dengue fever by causing the regeneration of platelets whose number decreases during this disease (Kumar et al., 2016). The presence of bioorganic sodium in goat milk protects against arthritis (Getaneh et al., 2016); the lack of this mineral may be due to digestive disorders, as the human stomach is responsible for storing sodium. However, the consumption of highly processed products and alcohol consumption contribute to the reduction of sodium. The iodine content of goat milk is higher than that of human milk. Iodine is an essential component of thyroid hormones which are crucial in regulating metabolism.

Goat milk also contains a high concentration of trace elements such as manganese, iron, zinc and copper (Pastuszka et al., 2015). Despite the low amount of iron, it is better absorbed in the intestines than cow milk, since it contains specific nucleotides (Raynal-Ljutovac et al., 2008). Nucleotides present in goat milk regulate the body’s metabolic processes related to lipid metabolism, modulate the immune response, and promote tissue growth, development and regeneration. Nucleotides, including adenosine triphosphate (ATP), guanosine triphosphate (GTP), as well as their cyclic counterparts – cyclic adenosine monophosphate (cAMP) and cyclic guanosine monophosphate (cGMP) – are a major energy source and also play a role in signalling pathways. An important nucleotide present in goat milk but not found in cow milk is uridine monophosphate (UMP), which is required for the formation of synaptic connections and supports brain development and function. The interplay of bioactive substances in goat milk has positive and sometimes therapeutic effects on the human body (Milewski and Kędzior, 2010).

Summary

Thanks to its therapeutic effects, goat milk should be extensively included in nutrition as well as in skin regeneration products. It has a probiotic effect, is excellent for people suffering from metabolic diseases, has a protective effect on the intestines during antibiotic treatment and can therefore be excellent for convalescents. It does not cause significant allergic reactions of the digestive system and reduces the incidence of skin diseases. In addition, the ingredients contained in goat milk play a role in the proper development of infant brain. Importantly, goat milk has also found its use in the treatment of dementia and Alzheimer's disease. Its components are responsible for the proper functioning of the nervous system. The immunostimulating, anti-inflammatory, antioxidant, antimicrobial and anticancer properties of goat milk, which have been confirmed in research, foreshadow the wide possibilities of using this product in medicine and pharmacy.

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