

FATTY ACID PROFILE OF MILK - A REVIEW

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Abstract

The article describes the recent data dealing with the fatty acid content in cow, goat, and sheep milk. A large body of evidence demonstrates that fatty acid profile in goat and sheep milk was similar to that of cow milk. Palmitic acid was the most abundant in milk. Goat milk had the highest C6:0, C8:0, and C10:0 content. Sheep milk was the richest source of conjugated linoleic acid and α -linolenic acid. Ewe's milk had lower value of n-6/n-3 than goat and cow milk.

Key words: ruminants, milk, fatty acids, human diet.

Milk and milk products are well balanced nutritious food in human diet. The premium nutritional quality of dairy products is highly correlated with milk fat quality and concerns: high concentration of fat soluble vitamins and n-3 fatty acids, as well as high content of conjugated linoleic acid (CLA). Moreover, milk fat influences processing of raw material and is a carrier of taste and aroma. The proportion of fat in cow's milk is typical - 3.3%-4.4% (14, 32, 33). Goat's and ewe's milk contains approx. 3.25%-4.2% and 7.1% of fat, respectively (6, 12, 13, 35). The concentration of fat in milk depends on factors such as: breed, nutrition, individual traits, and period of lactation.

The purpose of the paper is to review the specific characteristics of fatty acid profile of cow, goat, and sheep milk with an emphasis on health benefits for human organism, as well as milk fat modification methods enhancing content of unsaturated fatty acids in raw material.

Cardiovascular disease, cancer, obesity, and diabetes are collectively responsible for more than 80% of the disease-related mortality in the United States (2). Lipids play a critical role in all of these diseases, and the relative amounts and types of dietary lipids consumed are believed to be of a critical importance.

Polyunsaturated fatty acids. Until now, it was believed that due to a lack of appropriate enzymes mammals may not synthesise *de novo* two polyunsaturated fatty acids: α -linolenic acid (ALA) from the n-3 family and linoleic acid (LA) from the n-6 family, thus they were labelled essential fatty acids (EFA). Nowadays, it has been found that the term EFA

applied solely to ALA and LA is inadequate (7). It was discovered that ALA and LA may be formed in the human organism from hexadecatrienoic acid C16:3 and hexadecadienoic acid C16:2 (7). Moreover, most of the effects of EFAs result from their transformation into eicosanoids.

Human diet in developed countries is characterised by a too low proportion of n-3 fatty acids and too high content of n-6 fatty acids. LA and ALA compete for the same enzymatic systems. Long chain polyunsaturated fatty acids (LCPUFA) from n-3 family - eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) may be supplied to the organism with food or synthesised in the organism from ALA. It was observed that in the human organism up to 8% of the ALA in phospholipids may be converted to EPA but only about 8% of dietary ALA was incorporated into phospholipids (10). Nevertheless, the synthesis of DHA from ALA is highly limited and is more efficient in infants (about 1%) than in adults (3). Moreover, this process may still be further hindered by a high consumption of linoleic acid, which traps an enzyme, δ -6-desaturase, and prevents further elongation of ALA (19).

DHA is an n-3 fatty acid that constitutes the main structural component of the brain cinerea, retina, and semen. DHA has important functions in the development of premature babies and little children. It participates actively in the development of the nervous system, in the process of vision, and in preventing inflammations. In the elderly, it supports prevention and treatment of senile dementia. DHA requirement rapidly

increases in the last trimester of intrauterine life, at the time of extremely accelerated brain development (11).

The ratio of n-6/n-3 fatty acids in the diet of most people ranges from 15:1 to 16.7:1 (28). However, it is recommended to maintain a markedly lower proportion of n-6 fatty acids. According to Simopoulos (28), an optimal n-6/n-3 fatty acids ratio is specific to different diseases. In the diet of asthmatics it should be 5:1, while in case of patients suffering from rheumatoid arthritis and colon cancer the author recommended the n-6/n-3 ratio of 2.5:1 (28). The World Health Organisation and Food and Agriculture Organisation Expert Committee recommended the n-6/n-3 fatty acids ratio to be below 4 since at such a proportion a considerable (70%) reduction in the number of deaths caused by cardiovascular diseases was observed (25, 28).

Results of clinical studies indicate that increased share of n-3 fatty acids in the diet supports prevention and treatment of cancers, heart diseases, thrombosis, arterial hypertension, hyperlipidaemia, senile dementia, Alzheimer's disease, depression, or rheumatoid arthritis (19). Moreover, n-3 fatty acids are used in the treatment of skin diseases, *e.g.* psoriasis, acne, and lupus erythematosus.

Fish and seafood are primary sources of EPA and DHA from the n-3 family. Most vegetables and fruits contain LA and ALA at the 1:1 ratio, while in maize grain, soybeans, sunflower seeds, and certain nuts LA predominates. However, its most important sources include animal origin products, first of all meat, milk, and eggs.

Milk fat is one of the most complex natural fats that consist of approximately 400-500 fatty acids (1). Milk fat biosynthesis is a complex process, which requires coordinated control of many cellular processes and metabolic pathways that occur at various stages of development and functioning of the mammary gland (15, 29). Polyunsaturated fatty acids consumed by ruminants are microbially dehydrogenated in the rumen. In cow, sheep, and goat, milk EPA and DHA are found in trace amounts. In cow, goat, and sheep, milk PUFAs account for as little as ~3% of all fatty acids (8); however, Strzałkowska *et al.* (34) and Mayer and Fiechter (18) found more than 4% of PUFA in goat milk, and Cieślak *et al.* (6) found even more than 21% of PUFAs in milk of sheep fed rapeseeds.

The predominant n-3 FA in milk fat of the majority of mammals is α -linolenic acid. Milk of sheep and goats usually has a smaller value of n-6/n-3 ratio and greater concentration of ALA compared to cow's milk (Table 1).

Monounsaturated fatty acids. Monounsaturated fatty acids do not cause accumulation of cholesterol as saturated fats do, and do not turn rancid as readily as polyunsaturated fatty acids. Moreover, they have a positive effect on the concentration of high density lipoproteins (HDL), transporting cholesterol from blood vessel walls to the liver, where it is degraded by bile acids, which are afterwards excreted from the organism. At the same time, monounsaturated fats

reduce the concentration of low density lipoproteins (LDL), which when circulating over the entire organism are deposited in blood vessels.

The share of monounsaturated fatty acids (MUFA) is similar in sheep, cow, and goat milk fat and may range from about 20% to about 35%. Among the MUFA group, the oleic acid (C18:1) is characterised by the highest content, which is typical for milk of the majority of mammals (5, 18, 22, 27, 34, 36). Cow's milk is the richest source of oleic acid (24%), while its content in goat and sheep milk is on average 18% of all fatty acids (27, 36); however, some authors reported its higher concentration (more than 20% of all fatty acids) in sheep and goat milk (18). In ruminant's milk, there are also relatively small but significant contributions from other MUFA such as 14:1 (about 1%), 16:1 (about 1.5%), and very desirable vaccenic acid, which is a precursor of CLA in human organism (1.5%-5%).

Saturated fatty acids. Although a high proportion of MUFA and long-chain unsaturated fatty acids from the n-3 family has an advantageous effect on human health, saturated fatty acids (SFA) constitute the primary fat component of human diet. They are stable substances, originating mainly from animal products. An excessively high share of SFA in the diet may cause chronic diseases such as atherosclerosis, heart failure, or obesity. General dietary recommendations concerning the reduction of SFA and cholesterol consumption have contributed to an erroneous belief that dairy products, particularly full-fat, may lead to coronary heart disease (9).

The studies conducted since 2000 have contradicted the thesis that the consumption of milk and dairy products would increase the synthesis of LDL and the risk of coronary disease (24). At present, it is believed that the increased LDL blood concentration is attributable to lauric C12:0, myristic C14:0, and palmitic C16:0 acids, while the other saturated fatty acids found in milk neutralise their effect since they increase HDL level (24).

Taking into account a negative role of the C12:0, C14:0, and C16:0 acids, Ulbricht and Southgate (39) proposed atherogenic indices (AI) and thrombogenic indices (TI). Based on AI and TI values conclusions may be drawn concerning fat quality from the point of view of human diet. The results for AI and TI for goat, sheep, and cow milk are similar and depend on breed, stage of lactation, and diet; however, the lowest values of these indices were for sheep milk, which is favourable in a health perspective (Table 1). The values of AI and TI of ruminant milk can be improved by the administration of either olive cake, rapeseed oil, linseed oil, or camelina sativa cake to the diet (6, 36).

Saturated fatty acids in ruminant milk account for 60% to 70% of fatty acids. The main SFA in milk fat of the majority of mammals is C16:0. The fat present in sheep and goat milk is a rich source of medium-chain fatty acids. In goat milk, these are: C6:0, C8:0, and C10:0 fatty acids in particular (12, 18, 27, 34).

Table 1
Fatty acids profile in goat, sheep, and cow milk

Fatty acids (g 100g ⁻¹)	Goat	Sheep	Cow
C4:0; butyric	2.03 ¹	2.57 ²	2.87 ³
C6:0; caproic	2.78 ¹	1.87 ²	2.01 ³
C8:0; caprylic	2.92 ¹	1.87 ²	1.39 ³
C10:0; capric	9.59 ¹	6.63 ²	3.03 ³
C12:0; lauric	4.52 ¹	3.99 ²	3.64 ³
C14:0; myristic	9.83 ¹	10.17 ²	10.92 ³
C16:0; palmitic	24.64 ¹	25.1 ²	28.7 ³
C18:0; stearic	8.87 ¹	8.85 ²	11.23 ³
18:1 <i>cis</i> -9; oleic	18.65 ¹	20.18 ²	22.36 ³
18:2 <i>cis</i> -9, <i>cis</i> -12; linoleic	2.25 ¹	2.32 ²	2.57 ³
18:2 <i>cis</i> -9, <i>trans</i> -11; CLA	0.45 ¹	0.76 ²	0.57 ³
18:3 <i>cis</i> -9, <i>cis</i> -12, <i>cis</i> -15 ; α -linolenic	0.77 ¹	0.92 ²	0.5 ³
total n-6	1.78 ⁴	2.97 ⁵	2.83 ⁶
total n-3	0.44 ⁴	1.31 ⁵	0.56 ⁶
SFA	68.79 ⁴	64.23 ⁵	68.72 ⁶
MUFA	24.48 ⁴	29.75 ⁵	27.40 ⁶
PUFA	3.70 ⁴	4.82 ⁵	4.05 ⁶
n-6/n-3	5.00 ⁴	2.31 ⁵	6.01 ⁶
AI	2.88 ⁴	2.21 ⁵	2.55 ⁶
TI	3.17 ⁴	2.49 ⁵	3.22 ⁶
Total fat (g 100g ⁻¹)	4.27 ¹	6.09 ²	3.76 ³

SFA - saturated fatty acids; MUFA - monounsaturated fatty acids; PUFA - polyunsaturated fatty acids; AI - atherogenic index; TI - thrombogenic index.

Calculated as (39): AI = (C12:0 + (4*C14:0) + C16:0)/(MUFA + (n-6) + (n-3)); TI=(C14:0 + C 16:0 + C18:0)/(0.5*MUFA + (0.5*n-6) + (3*n-3) + (n-3/n-6)).

¹Average value (16, 18, 27, 34), ²average value (16, 18, 36), ³average value (8, 20, 22), ⁴average value (8, 38), ⁵average value (8, 36), ⁶average value (5, 8, 20)

The share of the acids in the pool of FA composing the goat milk fat is more than twice as high as in cow's milk (Table 1). A characteristic trait distinguishing goat milk from cow and sheep milk is the relation between lauric C12:0 and capric C10:0 acid (less than 0.5 and more than 1 in cow milk). It is an important indicator, as it may be used to detect falsifications of goat milk with cow's milk (34). A higher concentration of C6:0, C8:0, and C10:0 fatty acids in sheep and goat milk in comparison to cow's milk cause a specific aroma in milk of these little ruminants (34, 38). Furthermore, these fatty acids may have health-promoting effects on human health by inhibiting bacterial and viral growth, as well as dissolving cholesterol deposits.

Trans fatty acids. Fatty acids posing the greatest threat for human health are partly hydrogenated vegetable oils, being components of refined oils and margarines, which contain high amounts of trans isomers. Approximately 80% all trans fatty acids (TFAs) in human diet originate from food produced under commercial scale production conditions, while 20% come from milk and meat of ruminants (17). TFAs coming from these food sources considerably differ in their position isomerism. In individuals, consuming high amounts of partly hydrogenated vegetable oils there is a dependence between the incidence of coronary disease

and TFA consumption, while such a dependence has not been observed in case of dairy products (30). The main TFAs in ruminant milk are conjugated linoleic acid and vaccenic acid.

Conjugated linoleic acid. In the last twenty years, CLA has been of a considerable interest of researchers. CLAs are conjugated dienes of linoleic acid. This name refers to a group of position and geometric isomers of linoleic acid, characterised by a conjugated system of double bonds, separated by one single bond. There are 28 potential CLA isomers of which rumenic acid (C18:2 *cis*-9, *trans*-11) is dominant in milk fat. Studies on animals indicate that CLA exhibits immunostimulatory, antihypertensive, anticarcinogenic, and antiatherogenic properties and promotes a reduction of body weight (21, 37).

The effect of CLA on the human organism has been verified by a limited number of studies and their results are not conclusive. Mougios *et al.* (21) observed a reduction of skin fold thickness and percentage contents of adipose tissue in the organisms of individuals consuming 1.4 g CLA/day. In these studies, a trend was also recorded for a decrease in serum lipid content; although only the disadvantageous decrease in HDL level was statistically significant. Most research reports indicate a necessity to exercise caution while applying CLA. The advantageous effect of CLA as a

factor correcting the serum lipid profile, body weight, or the metabolism of insulin and glucose among patients with diabetes type II, has not been confirmed in most cases. Investigations conducted by Tricon *et al.* (37) on the effect of CLA-enriched dairy products by a modification of diet for milk-producing animals did not confirm their health-promoting effect.

The sheep and goat milk are usually richer in CLA than cow's milk, probably due to the semi-extensive nature of the system under which little ruminants are usually farmed (40). Several studies have found higher concentration of CLA in milk fat of ewes than of goats. Some authors observed the CLA concentration in ewe's milk as high as 2.2% of FA (16). Usually, under the same dietary treatment, sheep milk has higher CLA content than goat milk, what can be explained by the differences found in mRNA of their mammary adipocytes (40).

Milk fat improvement. Despite the fact that it is difficult to enrich ruminant's milk with PUFA by changing the feed ration, still many authors observed advantageous changes in the fatty acid profile in milk of cows, ewes, and goats consuming feed rations rich in green forages (5, 17). Several authors have found that organic milk has higher MUFA, PUFA, and CLA contents, and as a result they are healthier and have higher nutritional value than conventional ones (5, 23, 38). However, according to O'Donnell-Megaro *et al.* (23) the above difference is not enough to affect public health.

Stoop *et al.* (31) found that there is a considerable genetic variation for fatty acid composition, with genetic variation being high for C4:0 to C16:0 and moderate for C18 fatty acids. The moderate coefficient of variation in combination with moderate to high heritability indicates that fatty acid composition can be changed by genetic selection (31). Schennink *et al.* (26) found that the *DGATI* K232A polymorphism has a clear influence on milk fat composition. The *DGATI* allele that encodes lysine (K) at position 232 (232K) is associated with more saturated fat; a larger fraction of C16:0, smaller fractions of C14:0, unsaturated C18:3, and conjugated linoleic acid. In a whole genome association analysis, Bouwman *et al.* (4) found a total of 54 regions that were significantly associated with one of more fatty acids. Medium chain and unsaturated fatty acids are strongly influenced by polymorphisms in *DGATI* and *SCD1*. Other regions also showed significant associations with the fatty acids studied. This information helps in unraveling the genetic background of milk fat composition.

Supplementation of feed rations for ruminants with fish oils, vegetable oils, oilseeds, and other forms of protected fats may also, to a certain degree, influence an increase in the content of unsaturated fatty acids in milk (20, 27), but some authors reported their negative effect on milk flavour. Moreover, it can cause milk fat depression and decrease in milk yield. The change of fatty acid composition of milk can also alter the rheological properties of milk products *i.e.* a considerably softer butter. Nevertheless, in most studies,

supplementing dairy cows, ewes, and goats with vegetable oils or oilseeds improved milk fat composition. Milk was characterised by increased levels of beneficial nutritional factors, including MUFA and n-3 PUFA, and also by lower AI and TI (6, 12, 36).

The review presented the most recent data concerning fatty acid composition in cow, ewe, and goat milk. While there are a lot of data for FA profile of cow's milk, this area needs further investigations on goat and ewe's milk because of large differences in fatty acid profile among breeds within these species. Moreover, rapidly growing market for functional food and recent findings in the physiological effects of nutritionally desirable fatty acids, that are present in milk, have generated the need of improved knowledge on health-promoting effects of dairy products on human organism, and on possibilities of improvement of milk fat composition throughout various factors, such as feeding regime, production system, breed, or stage of lactation.

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