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# Fatty acid profile of milk

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**Abstract**. Quality, processing ability and sensory properties of milk are highly correlated with content and composition of milk fat. Biologically active lipid substances are primarily saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs; linoleic acid; C18:2 n-6) and polyunsaturated fatty acids (PUFAs; α-linolenic acid; C18:3 n-3). PUFAs with 20C, mainly docosahexaenoic acid (DHA; C20:5 n-3) and eicosapentaenoic acid (EPA; SC22:6 n-3), are precursors of eicosanoids, which regulate various physiological processes. Fatty acid composition depends on many different factors, such as animal species, breed, season, lactation stage, geographical location, and diet. Goat and sheep milk are rich in the medium chain fatty acids, caproic (C6:0), caprylic (C8:0) and capric (C10:0), which is the reason for the specific aroma of those kinds of milk. Goat and sheep milk have more conjugated linoleic acid, and usually lower n-6/n-3 ratios, with higher amounts of α-linolenic acid, compared to cow milk. Compared to goat and cow milk, sheep milk has the lowest amounts of lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids i.e. fatty acids associated with negative effects on human health. The addition of forage, especially fresh grass, to dairy animal diets enhances the proportion of unsaturated fatty acids in milk fat compared to SFAs and increases the amount of conjugated linoleic acid.

## 1. Milk fat and fatty acid profile

Nutritional quality, processing ability, taste and aroma of milk and dairy products are highly correlated with content and composition of milk fat. Cow milk contains from 3.3 to 4.4% milk fat, goat milk from 3.25 to 4.2% and sheep milk contains approximately 7.1% milk fat. Milk fat contains a complex mixture of various lipid substances. These lipids are primarily triglycerides (triacylglycerides) which, by weight make up 98% of the total milk fat, while other milk lipids are diacylglycerides (0.25-0.48%), monoacylglycerides (0.02-0.04%), phospholipids (0.6-1.0%), cholesterol (0.2-0.4%), glycolipids (0.006%) and free fatty acids (0.1-0.4%). Over 400 different fatty acids, with unique physico-chemical and biological properties, constitute the triclycerides in milk [1]. Biologically active lipid substances are primarily monounsaturated fatty acids (MUFAs), oleic acid (C18:1 n-9), polyunsaturated fatty acids (PUFAs), linoleic acid (LA; C18:2 n-6) and α-linolenic acid (ALA; C18:3 n-3). PUFAs with 20C, mainly docosahexaenoic acid (DHA; C20:5 n-3) and eicosapentaenoic acid (EPA; C22:6 n-3), are precursors of eicosanoids, which regulate various physiological processes [2].
From the aspect of human health, consumption of SFAs, mainly lauric, myristic and palmitic (C12:0, C14:0, C16:0, respectively) fatty acids, is associated with increased concentrations of low density lipoprotein (LDL) in blood, while other SFA from milk neutralise their effect because they increase high density lipoproteins (HDL) in blood. On the contrary, unsaturated fatty acids are regarded as beneficial for human health. DHA constitutes the main structural component of the brain cinerea, retina, and semen. It also participates in development of the nervous system, in the vision process, in development of premature babies and children, and has a role in prevention of inflammation [3, 4, 5, 6]. Historical facts indicate that the n-6/n-3 fatty acid ratio 1:1 was an important factor for human evolution. Global replacement of saturated animal fats with unsaturated plant fats, as well as intensive milk and meat production, primarily based on intensive grain fattening of animals, has led humans to

increased intake of linoleic acid (LA), precursor of the n-6 PUFA group. Since the n-6 PUFA group are competitors with the n-3 PUFA group for desaturation enzymes, the ratio of n-6/ n-3 fatty acids in the diet of today's humans has been altered from 1:1 to 10-20:1, or even higher, which can partly explain the rise of modern diseases, such as cardiovascular disease, cancer, obesity and diabetes [7]. The n-3 fatty acids are associated with improved neurological functions, coronary heart disease protection, and anti-carcinogenic effects [8]. Both n-groups of PUFA are constituents of cell membrane phospholipids, where they have a role in maintaining the functionality of the membrane [9].

The concept of functional dairy products has recently gained attention due to the positive effects of conjugated linoleic acid (CLA), long chain PUFA, especially the two isomers *cis*-9, *trans*-11 (rumenic acid) and *trans*-10, *cis*-12, on human health. In ruminants, CLA is produced naturally from dietary LA, ALA and *trans* vaccenic acid. CLA is synthesised in the rumen during ruminal biohydrogenation of dietary fatty acids, or in tissues by Δ-9 desaturase enzyme activity. *Trans* vaccenic acid provides the substrate for endogenous synthesis of CLA through the activity of Δ-9 desaturase, especially in the mammary gland and other body tissues [10]. Rumenic acid, which makes 75-90% of total CLA content in milk fat, is the most active biological natural isomer of CLA in dairy products [11]. CLA protects against cancers in various experimental animal models and human cells. Also, CLA has anti-obesity and anti-atherogenic effects in humans and animals [12, 13, 14, 15].

## 2. Variation in milk fatty acids content

Given the fact that the cow milk fatty acid profile depends on the fatty acids originating from feed and the biohydrogenation process that occurs in the rumen, the fatty acid composition depends on many different factors such as breed, season, lactation stage, lactation number, age of dairy cows, geographical location, and, as most important factor, the diet, which is responsible for 95% of the variance in cow milk fat [8, 16, 17, 18]. Lock and Garnsworthy [19] showed seasonal variability in the CLA content, measured *via* Δ9-desaturase activity, while Elgersma et al. [20] noted seasonal changes in cow milk CLA content between winter and summer. Peterson et al. [21] showed individual animal differences in Δ9-desaturase activity, which is an indirect indicator of the variation in fat content. The seasonal changes of the feed ratio between grass silage and fresh herbage influence the fatty acids, meaning increased amounts of long chain fatty acids (C17-24), increased unsaturated/saturated fatty acid ratio, and decreased amounts of medium chain fatty acids (C12-C16) [4]. The average content of rumenic acid in milk of pasture-fed cows is two to three times higher than in barn-fed cows [11]. Soyeurt et al. [22] showed differences in the fatty acid content of milk across the studied dairy breeds, which suggest milk and dairy products with improved fatty acid composition could result from choosing the right breed. However, variations within breeds were also found [22].

Beside these variations, there are differences between fatty acid profiles of milk from different animal species. Cow milk fat contains on average 60-70% SFA. The main SFA in most mammals' milk fat is palmitic acid (C16:0). The fat of goat and sheep milks is rich in the medium chain fatty acids, caproic, caprylic and mostly, capric fatty acid (C6:0, C8:0, C10:0, respectively). Sheep milk, compared to goat and cow milk, had the lowest amount of lauric, myristic and palmitic acids (C12:0, C14:0, C16:0, respectively), associated with negative effects on human health. A characteristic of goat milk is a lauric/capric acid ratio <0.5, while this ratio in cow and sheep milk is >1. This parameter can be important indicator for detection of milk falsification. The higher concentrations of caproic, caprylic and capric fatty acids in goat and sheep milks than in cow milk is the reason for the specific aroma of goat and sheep milks. Goat and sheep milks have more CLA than cow milk, probably because small ruminant breeding practices are usually semi-extensive, and consequently, their diet is more rich in forage [6].

The amount of MUFA is similar among cow, goat and sheep milks, and it ranges from 20% to 35% of the milk fat. Oleic acid is the most abundant fatty acid from this group. In cow milk, there is about 24%, while in goat and sheep milks, there is about 18% oleic acid. Goat and sheep milks usually have lower n-6/n-3 ratios, and higher amounts of ALA than cow milk [6, 22].

**Table 1.** Fatty acid composition in milk of three dairy animal species (molar percentage) [23]

| Fatty acid | Cow | Sheep | Goat |
|---|---|---|---|
| Short chain | | | |
| C4:0 | 11 | 8 | 8 |
| C6:0 | 5 | 5 | 5 |
| C8:0 | 1 | 4 | 4 |
| Medium chain | | | |
| C10:0 | 3 | 6 | 13 |
| C12:0 | 3 | 5 | 7 |
| C14:0 | 10 | 10 | 12 |
| Long chain | | | |
| C16:0 | 23 | 22 | 24 |
| C18:0 | 10 | 10 | 12 |
| C18:1 | 29 | 22 | 17 |
| C18:2 | 2 | 4 | 3 |
| C18:3 | <1 | <1 | <1 |

*Common fatty acids of cow, sheep and goat milk are C16:0, C18:0, C18:1, C18:2 and C18:3

## 3. The influence of feed on the milk fatty acid composition

One of the strategies to prevent chronic non-infectious disease development in humans is to change the fatty acid composition of their diets. This strategy is based on reduced intake of SFA, increased intake of MUFA and PUFA, and especially, the change of the n-6/n-3 fatty acid ratio, while maintaining the sensory properties of milk and milk products.

Interest in milk's fatty acid composition and the opportunity to change it with dietary/feed modifications, began in the 1980s, when some authors published studies about the use of linseed oil in cow diets and the effect on milk fat composition. However, until the appearance of gas-liquid chromatography, such studies were rare [24]. Nowadays, the composition of milk fatty acids is of great interest with respect to human nutrition, as alteration of fatty acids in cow diets can influence human health [25].

The diet of dairy cows, which affects the microbiological processes in rumen, and the changes in the biohydrogenation processes, are the key to modifying the fatty acid composition of milk fat [26, 27]. Lipid metabolism, specifically ruminal biohydrogenation, is influenced by factors such as rumen pH, and the amount, source and fatty acid profile of the fat supplements in the animal diets [28].

Still, in spite of data confirming that milk fatty acids are susceptible to changes depending on the animal diet, the results often cannot be compared, due to the large differences in feed composition. While short chain (4 to 8 carbons) and medium chain fatty acids (10 to 14 carbons) are synthesized *de novo*, very few long chain fatty acids can be synthesized *de novo* by ruminants; instead, these fatty acids must be ingested with the feed [20, 27, 28]. Milk fat content generally increased with increasing fibre content of different forage [27, 29, 30]. The addition of forage, especially fresh grass, enhances the proportion of unsaturated fatty acids in cow milk fat compared to saturated fatty acids [20, 31]. Similarly, Chilliard et al. [28] reported that the content of PUFA, especially C18:3, C18:0 and C18:1, and SFA, especially C16:0, can be changed if the content of the hay, fresh grass and maize silage in the diet is increased. Also, the intake of fresh grass increases the concentration of CLA, the major 9-*cis*, 11-*trans* isomer, a biologically active compound with anti-carcinogenic and other beneficial effects on human health [12, 32]. Similar to this, other authors suggested that when fat supplements are added to diet, the response in milk production and composition is more variable than when diets are totally or mostly based on corn silage as forage [26, 27]. On the other hand, diets with higher concentrate contents can provide large amounts of digestible carbohydrates, and reduced amounts of fibrous components, which can cause milk fat depression and change of the milk fatty acid profile [27, 30]. A dairy cow diet containing added linseed oil, which is rich in ALA, increases PUFA in milk, especially ALA and *cis*-9, *trans*-11 CLA [33], while addition of sunflower and fish oil increases vaccenic acid and *cis*-9, *trans*-11 CLA [34]. If the ruminal biohydrogenation process is complete, unsaturated fatty acids are transformed to SFA, which is main cause of concern for human health. But if this rumen process is controlled and unsaturated fatty acids transform to stearic acid, it should be possible to improve the healthiness of cow milk, through increased amounts of CLA and n-3 fatty acids [35]. Fish oil, containing EPA and DHA, inhibits the complete biohydrogenation of C18 unsaturated fatty acid, which increases the *trans* 18:1 isomer available for synthesis of CLA isomers [36].

## 4. Conclusion

Differences in the fatty acid content in milk across the species, breed and season, or differences based on diet, provides us with the ability to choose the right breed, diet or breeding conditions to obtain milk and dairy products with improved nutritional quality and more valuable fat composition. Consuming milk with a more valuable composition should positively influence consumer health.

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