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Review Article

The effects of bovine milk fat on human health

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ABSTRACT

Introduction: Recent years have witnessed a growing interest in the nutritional value and health benefits of food products of animal origin. Numerous research studies have been undertaken to evaluate the effects of bovine milk, a key dietary component, on human health. Fat is one of the most important components in bovine milk, and its content ranges from 2.8% to 8.1%, subject to the breed of cattle, nutritional aspects, individual characteristics, lactation period, milk production hygiene and season.
Aim: The aim of this study was to review the latest literature concerning the health effects of components found in bovine milk fat.
Materials and methods: This paper is a literature review, and it analyzes the composition of bovine milk fat and its effects on human health. The available sources were grouped thematically, and an attempt was made to characterize various milk fat components and their effects on human health.
Discussion: The unique nutritional value of bovine milk can be attributed to the presence of short-chain fatty acids and medium-chain fatty acids which are important sources of energy for the muscles, heart, liver, kidneys, blood platelets and nervous system. They do not pose an obesity risk; they prevent ulcerative colitis, cancer, atherosclerosis and hypertension; they have anti-inflammatory and antibacterial effects, and they boost natural immunity. Milk contains cholesterol, a lipid derivative which stabilizes and stiffens cell membranes, builds the cell cytoskeleton, protects nerve fibers and acts as a precursor of steroid hormones, bile acids and vitamin D_3. Bovine milk lipids do not exert hypercholesterolemic or atherogenic effects in the human body.
Conclusions: A growing tendency to replace animal fats, mainly milk fat, with vegetable fats is a matter of concern.

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1. Introduction

Recent years have witnessed a growing interest in the nutritional value and health benefits of food products of animal origin. Numerous research studies have been undertaken to evaluate the effects of bovine milk, a key dietary component, on human health. Fat is one of the most important components in bovine milk, and its content ranges from 2.8% to 8.1%, subject to the breed of cattle, nutritional aspects, individual characteristics, lactation period, milk production hygiene and season. Milk fats contain simple lipids, compound lipids, free (unesterified) fatty acids, lipid derivatives (sterols and carotenoids) and accompanying substances, including fat-soluble vitamins A, D, E and K (Table 1).[4] Milk fat is synthesized in the form of lipid globules in mammary gland cells when glycerol binds with fatty acids. Raw milk is an emulsion of fat globules with a diameter of 0.1–20.0 μm in the aqueous phase. Lipids can be directly absorbed in the digestive system without hydrolysis, which contributes to the very high digestibility of milk fat (97–99%).

2. Aim

The aim of this study is to analyze the effects of compounds found in bovine milk lipids on the health of consumers of milk and dairy products.

3. Materials and methods

This paper involves a literature review, and it analyzes the composition of bovine milk lipids and their effects on human health. The consequences of excessive consumption or a dietary deficit of milk fat compounds are discussed.

Table 1 – Milk lipid composition.[4,30]

Lipid group	Components	Content	
		Of total fat (%)	Of fat (μg/g)
Simple lipids	Triacylglycerols	95.8–98.3	
	Diacylglycerols	0.28–2.25	
	Monoacyloglycerols	0.003–0.380	
Compound lipids	Phospholipids	0.20–1.11	
	Cerebrosides	0.1	
	Gangliosides	0.01	
Free fatty acids		0.1–44.0	
Derivatives	Sterols	0.30–0.45	
	Carotenoids		6–10
Accompanying substances	Vitamin A		6–20
	Vitamin D		Trace
	Vitamin E		5–100
	Vitamin K		1

4. Discussion

Bovine milk fat contains 400–500 fatty acids, of which 15 have an estimated 95% weight share of the total fatty acid pool in milk.[30] In ruminant milk, fatty acids are synthesized mainly by fermentation of volatile fatty acids in the rumen. The resulting fatty acids contain 4–14 carbon atoms. Long-chain fatty acids (LCFAs) are synthesized in blood plasma.[4,20,31,39,50]

The following fatty acids are found in bovine milk lipids:

(1) *Short-chain saturated fatty acids (SCFAs)* – butyric, propionic, acetic, valeric and isovaleric acid;
(2) *Long-chain saturated fatty acids* – palmitic and stearic acid (which regulate the synthesis of cholesterol and triglycerides);
(3) *Monounsaturated fatty acids (MUFAs)* – mainly oleic acid (n-9) which inhibits the absorption of dietary cholesterol, lowers low-density lipoprotein (LDL) cholesterol levels, decreases blood viscosity, lowers blood pressure, and vaccenic acid which demonstrates anti-atherosclerotic and anticarcinogenic activity;
(4) *Polyunsaturated fatty acids (PUFAs)* – linoleic acid (n-6) (LA) and linolenic acid (n-3) (ALA) which play important biological functions: they lower LDL cholesterol levels, limit triglyceride synthesis, regulate insulin secretion and are a source of tissue hormones, eicosanoids.

The presence of SCFAs and medium-chain fatty acids (MCFAs) (25% of total fatty acids) is a unique attribute of bovine milk. In the human body, these acids are used as sources of energy for the muscles, heart, liver, kidneys, blood platelets and nervous system. They are converted to heat during metabolic processes, and they do not pose the risk of obesity. Butyric acid prevents colorectal cancer by inhibiting DNA synthesis in the nuclei of neoplastic cells and preventing their growth. SCFAs may also play an important role in the prevention of ulcerative colitis.[3,4,40,41]

Fatty acids with long C chains account for 56–65% of total fatty acids. LCFAs have anticarcinogenic, anti-atherosclerotic, anti-hypertensive, anti-inflammatory, antibacterial and immunity-boosting effects.[4,44]

Bovine milk contains approximately 70% of saturated fatty acids and 30% of unsaturated fatty acids. The latter are composed of 83% of MUFAs and 17% of PUFAs.[7,36] PUFAs from the n-6 and n-3 families are components of cell membrane phospholipids. PUFAs regulate cardiovascular activity, blood pressure, hormonal activity, kidney functions and the immune response.[65] Dietary supplementation with n-3 PUFAs during pregnancy prevents preterm birth, contributes to the healthy body weight of the fetus and the infant, and minimizes the risk of allergic reactions.[4,18,33]

Mammals are incapable of synthesizing PUFAs; consequently, their diets should be supplemented with these crucial fatty acids. Milk, in particular human milk, is a rich source of PUFAs. Bovine milk, which contains lower levels of PUFAs, in particular indispensable n-3 fatty acids, LA ($C_{18:2}$) and ALA ($C_{18:3}$), may be a substitute for human breast milk. LA is an essential component of cell membrane phospholipids and lipoproteins which participate in fat transport. Both LA and ALA can be further metabolized to arachidonic acid ($C_{20:4}$ n-6) (ARA) and eicosapentaenoic acid ($C_{20:5}$ n-3) (EPA) as a result of D6-desaturation, elongation and D5-desaturation. Those acids are precursors of prostaglandins and leukotrienes which control the activity of health-promoting cells in the body.[15,26,28,42,62,63]

In further metabolic processes, EPA may be transformed into $C_{22:6}$ n-3 docosahexaenoic acid (DHA) which, unlike n-6 fatty acids, has specific transport pathways to tissues and phospholipids. DHA plays a crucial role in the development of the central nervous system. Numerous *in vitro* and *in vivo* studies have demonstrated that n-6 and (in particular) n-3 PUFAs demonstrate a wide range of health benefits. They lower the risk of cardiovascular disease, type 2 diabetes, hypertension, cancer and certain neurological dysfunctions.[1,14,17,23,25,27,34,42,52,63,64,66,69] Fatty acids from the n-3 family can be used in the treatment of inflammatory diseases, such as rheumatoid arthritis, and alleviating the symptoms of mental dysfunctions, including depression and dementia. DHA was found to be effective in treating late stages of Alzheimer's disease.[38,51]

Milk contains cholesterol, a lipid derivative whose levels are determined by the total fat content in milk. In healthy individuals, cholesterol has a 0.2–0.4% share of total lipids. In humans, cholesterol stabilizes and stiffens the cell membrane; it builds the cell cytoskeleton and the myelin sheath which protects nerve fibers; and it acts as a precursor of steroid hormones, bile acids and vitamin D_3. In humans, cholesterol is found in both exogenous (dietary) and endogenous (synthesized in the body) forms. Approximately 500 mg of cholesterol is synthesized in the liver, intestines and skin on a daily basis. Another 500 mg of this lipid is supplied with food (milk, butter and eggs). High cholesterol levels are not always a consequence of an unhealthy diet, but they may be caused by problems with the biosynthesis of endogenous cholesterol.[53]

In blood plasma, cholesterol is often found in tissues along with PUFAs in the form of esters which are known as lipoproteins. Quantitative analyses of lipoprotein levels support evaluations of their effects on human health. LDLs have the highest (60%) share of the total lipoprotein pool, high-density lipoproteins (HDLs) account for 30% and very-low-density lipoproteins (VLDLs) for 10% of total lipoproteins. HDLs remove LDLs from blood vessels and transport them to the liver where they are excreted. High quantities of PUFAs (with the n-6 : n-3 ratio of 3 : 1) are required for healthy lipid control in the human body.[4] In healthy adults, the demand for PUFAs can be covered by a diet with the calorific value of 2000 kcal and 35% share of bovine milk lipids.[8]

Saturated fatty acids, which have the highest share of bovine milk lipids, are generally believed to have adverse health effects. This view is contradicted by the low incidence of atherosclerosis among the people of Greenland who consume foods rich in saturated fatty acids in combination with low levels of n-3 PUFAs. This leads to the conclusion that the consumption of milk which contains approximately 25% of saturated fatty acids in milk lipids with the addition of n-3 PUFAs prevents atherosclerosis.[6,8,35]

The group of PUFAs includes conjugated linoleic acid (CLA) which accounts for up to 30 mg/g of fat. CLA lowers total cholesterol levels, thus improving the LDL:HDL ratio in blood plasma. This significantly contributes to the prevention of ischemic heart disease and atherosclerosis, improves fat metabolism, inhibits the development of osteoporosis, lowers sugar levels and boosts immunity.[4,45]

In ruminants, LA may be converted to CLA during the combined process of biohydrogenation by ruminal bacteria and endogenous synthesis in the body. LA is bioconverted to vaccenic acid by LA isomerase, a microbial enzyme. Vaccenic acid is transformed by the D_9-desaturase enzyme into CLA which is secreted in milk. Although the gastrointestinal tract is colonized by enormous numbers of bacteria (about 10^{11}), only several strains are involved in the discussed bioconversion process.[21,22,37,42,56]

Under *in vitro* and *in vivo* conditions, CLA demonstrates properties which are not observed in its constituent compounds. CLA has been found to lower the risk of cancer, hypertension, atherosclerosis and diabetes, and it stimulates immune functions.[42]

There are 28 CLA isomers, but only 2 of its forms, *cis*-9, *trans*-11 and *trans*-10, *cis*-12, are believed to deliver health benefits. Small quantities of conjugated linolenic acid (CLnA), a semi-product of ALA biohydrogenation, were identified in milk lipids. Those compounds inhibit the growth of neoplastic cells which cause colorectal cancer.[2,13,16,24,43,49,61,67,68]

MCFAs contain 8–12 carbon atoms and belong to the group of saturated fatty acids which enhance metabolic activity. It is believed that MCFAs may help reduce the risk of metabolic syndrome, a cluster of metabolic disorders, including dyslipidemia, hypertension, obesity and glucose intolerance, where insulin resistance is the core phenomenon and co-occurrence is associated with increased cardiovascular risk.[48]

The results of previous studies indicate that the dietary substitution of medium-chain triglycerides (MCT) with long-chain triglycerides (LCT) can affect the energy balance and prevent obesity. MCFAs are hydrolyzed and metabolized more effectively than LCFAs. Having crossed the epithelial barrier, they are transported directly to the liver. By contrast, LCFAs are first absorbed by chylomicrons, and they reach the liver via the lymphatic system. MCFAs can follow various catabolic pathways, including beta-oxidation, omega-oxidation and peroxisomal oxidation.[42]

In a study of patients whose body mass index (BMI) was higher than 23 kg/m^2, Tsuji et al.[60] demonstrated that daily consumption of 10 g of MCT over a period of 12 weeks led to a significant decrease in body weight, a drop in the content of fat tissue and subcutaneous fat in the waist and hip area. The above results suggest that MCT can effectively prevent obesity in individuals with high BMI scores.

In studies by Isaacs[29] and German and Dillard,[19] the compounds present in bovine milk lipids were characterized by antibacterial properties and exhibited high levels of activity against enveloped viruses which were completely degraded at higher fatty acid concentrations.[59] Another study revealed that lauric acid, LA and ALA have antibacterial properties and decrease the invasiveness of *Listeria monocytogenes* in the enterocyte-like Caco-2 cell line.[47]

An analysis of the antibacterial properties of bovine milk lipids, performed after partial hydrolysis with calf perigastric lipase, revealed that lauric acid was a more potent inhibitor of Gram-positive cocci, whereas caprylic acid was more effective in fighting Gram-negative *Escherichia coli* bacteria.[58] In 2007, Sun et al.[57] carried out an *in vitro* study which demonstrated that hydrolyzed bovine milk fat completely eliminated *Helicobacter pylori*. Interestingly, free fatty acids from bovine whey cream have been shown to inhibit the germination of *Candida albicans in vitro*, which was mainly attributed to lauric acid, myristoleic acid ($C_{14:1}$ n-5), LA and ARA.[11,42,55] A more recent study demonstrated that capric acid, lauroleic acid ($C_{12:1}$), 11-methyldodecanoic acid (iso-$C_{13:0}$), myristoleic acid ($C_{14:1}$ n-5) and gamma-linolenic acid ($C_{18:3}$ n-6) from bovine whey cream also exhibited antifungal activities against *Aspergillus fumigates* as well as *C. albicans*.[12,42]

Human milk is a source of both fat-soluble vitamins (A, D, E and K) and water-soluble vitamins (B_1, B_2 and C). Vitamins stimulate the immune function, regulate growth processes and improve eyesight. One liter of milk covers 25% of the recommended daily intake of beta-carotene and vitamin A and 10% of the recommended daily intake of vitamins D and E.[46] Milk is also a rich source of hormones, including leptin which is produced by adipose tissue cells. Milk contains mostly multi-molecular hormone forms which play an important role in early lactation, after which their levels decrease visibly. Milk is also a source of growth factors and defensins, bioactive components with antibacterial and antiviral properties.[5]

5. Conclusions

This study indicates that bovine milk lipids do not have hypercholesterolemic or atherogenic effects on humans. The consumption of milk fat in combination with small quantities of n-3 PUFAs prevents the formation of atherosclerotic plaques. A growing tendency to replace animal fats, mainly milk fat, with vegetable fats is a matter of concern. Vegetable oils, excluding palm oil and coconut oil, are characterized by a high content of essential fatty acids and low levels (below 15%) of saturated fatty acids. They also differ with regard to the ratio of MUFAs to n-3 and n-6 PUFAs. Sunflower oil, corn oil and grape seed oil have n-6:n-3 ratios of 335:1, 141:1 and 173:1, respectively.[9,10]

PUFAs that occur naturally in vegetable oils, LA ($C_{18:2}$ n-6) and ALA ($C_{18:3}$ n-3), are essential for normal development and bodily function, and their deficit in the diet may lead to health problems. PUFAs are not synthesized in the human organism (double bonds cannot be introduced in the n-6 and n-3 positions of the carbon chain); therefore, they have to be supplied with food.[10,30,32]

Vegetable oils (sunflower oil, corn oil, soybean oil and grape seed oil) are characterized by unhealthy proportions of n-6 to n-3 PUFAs; therefore, they are not a recommended source of n-3 essential fatty acids. They contain mostly n-6 LA whose surplus leads to the synthesis of highly biologically active eicosanoids from n-6 arachidonic acid. Excessive eicosanoid levels have potentially harmful effects on the human body.[9,10,54]

Conflict of interest

None declared.

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