AN OVERVIEW OF RESEARCH CONCERNING THE NUTRITIONAL VALUE OF MILK OF COWS

B. Miciński[1], J. Miciński[2], E. Dobruk[3], A. Taras[3]

University of Warmia and Mazury in Olsztyn
Poland, Olsztyn
Poland, 10-719 Olsztyn, Oczapowskiego 5
[1] – Faculty of Animal Bioengineering, Department of Cattle Breeding and Milk Evaluation.
[2] – Faculty of Veterinary Medicine, Department of Clinical Physiology.
EI «Grodno state agrarian University»
Grodno, Republic of Belarus
(Republic of Belarus, 230008, Grodno, 28 Tereshkova st.; e-mail: ggau@ggau.by)
[3] – Faculty of Biotechnology
Corresponding author: bartosz.micinski@uwm.edu.pl

Introduction

Human diet should vary in terms of nutritional components content. Przybojewska and Rafalski (2003) and Barr (2003) state that it should contain about 60 of these. Such components treated as a source of energy and cell regeneration, as well as regulators are used in repetitive biochemical and physiological processes, which are especially intense in young organisms (with their growth and development) and essential to a proper functioning of the older organisms. Milk plays a significant role in fulfilling an adult human needs because milk itself, as well as dairy products are a main part of consumable functional products in human's diet.

Research shows that the biological value of milk depends on the content of its bioactive (the so-called functional) components of pro-health value, which may play a huge role in human health maintenance preventing obesity and cancerous changes in cells among others (Parodi 1997, Barr 2003, Zemel 2003, Reklewska et al. 2005, Nałęcz-Tarwacka 2008). Proteins, peptides, amino acids, vitamins, enzymes, sterols, phospholipids, fatty acids are all called biologically active substances. Such components have a significant impact on changes taking place in a human organism. Polysaturated fatty acids deserve special attention due to their documented anticancer, antioxidative and antiatherosclerotical features. What is more, they have anti-inflammatory and antibacterial effects while also lowering blood pressure and increasing body's immunity (Regester 1997, Żegarska 1998, Reklewska and Bernatowicz 2002, Marciniak-Łukasiak and Krygier 2004, Barłowska et al. 2005, Król et al. 2006).

The nutritional value of milk is made up of its energetic value, digestibility and absorbability, as well as biological features. In the dry weight of milk basic components essential to proper functioning of our organisms are contained, among which the most important are: fat, protein, lactose, mineral components and vitamins. The energy value of milk in 49% results from the fat content, in 40% from milk sugar and in 11% from proteins. Milk composition is not constant and mainly depends on cow race as well as nutrition, subsequent lactation, phase of lactation, season, feeding or even herd maintenance (Walstra and Jenness 1984, Walstra et al. 1999, Lindmark-Månsson 2003, Jóźwik et al. 2009).

Pro-health features of milk

One of the main components of cow's milk is fat in the shape of liquid fat drops of 0.1 to 20 micrometer diameter, which gives it a pleasant flavor. It is characterized by a high digestibility reaching 99% (Puppel and Kuczyńska 2009). Fat content may range from 2,8 to 8,1% depending on race, nutrition, individual properties, lactation phase etc. (Barłowska and Litwińczuk 2009). Milk fats consist of simple and complex fats.

Simple fats (filling the interior of drops) consist of triacylglyceroles, forming about 98% of all milk fat, as well as the shell of fat drop, diacylglyceroles of share from 0,28% to 2,25% and monoacylglyceroles from 0,1% to 0,4%. Complex fats consist of phospholipids (from 0,2 to 1,1%), free fatty acids (0,1-0,4%), sterols (0,42%), carotenoids, cerebrosides (0,1%), gangliosides (0,01%) and fat-soluble vitamins (A, D, E and K) (Jensen and Newburg 1995, Reklewska and Bernatowicz 2002, Mac Gibbon and Taylor 2006, Górska et al. 2006).

From 400 to 500 different fatty acids (Tab. 1) are included in fat (Jurczak 1999, Reklewska and Bernatowicz 2002, Barłowska and Litwińczuk 2009). Fifty one of those stand for 95% of all acids in terms of weight. The content of the other acids is trace only (Jaworski 1995, Litwińczuk et al. 2004, Parodi 2004).

Table – Composition of milk' lipids (Barłowska and Litwińczuk, 2009)

Lipids group	Components	Content
Simple fats	triacylglyceroles	95.8-98.3 % of all fat
	diacylglyceroles	0.28-2.25 % of all fat
	monoacylglyceroles	0.003-0.38 % of all fat
Complex fats	phospholipids	0.2- 1.11 % of all fat
	cerebrosides	0.1 % of all fat
	gangliosides	0.01 of all fat
Free fatty acids		0.1- 044% of all fat
Derivatives	steroles	0.30- 0.45 % of all fat
	carotenoids	6-10 µg/g of fat

The rest of the table

Accompanying substances	Vitamin A	6-20 μg/g of fat
	Vitamin D	Traces
	Vitamin E	5-100 μg/g of fat
	Vitamin K	1 μg/g of fat

Fatty acids of ruminants' milk containing from 4 to 14 atoms of carbon are produced mainly during the fermentation processes in rumen from the so-called volatile fatty acids and are synthetized by the secretory tissue of the mammary gland. Acids of longer chains originate from the blood plasma (Barłowska and Litwińczuk 2009).

Short and medium-chained fatty acids are unique to cows' milk (14% of all fatty acids), which are used completely as the energetic fuel in muscles, heart, liver, kidneys, plasma cells and nervous system among others. Such acids do not play a role in an increase of level of lipids in blood and do not pose the risk of obesity (Rafalski 1996, Banaszkiewicz 2001). What is more, butyric acid plays a significant role in the prevention and therapy of colon cancer. It stops the synthesis of DNA in nuclei of cancerous cells, thus stopping their development. Short-chained fatty acids may have a therapeutic impact on some pathologic states in colon, including colon inflammation or ulcerative inflammation of colon (Przybojewska and Rafalski 2003).

Acids containing 16 and more carbon atoms in their chain are the so-called higher fatty acids. They are about 56 – 68% of all fatty acids (Barłowska et al. 2006, Jaworski 1995, Pisulewski 2000). Among the mentioned acids palmitic ($C_{16:0}$) [from 25 to 30% of all acids] and stearic ($C_{18:0}$) dominate (Kolanowski 2007, Pisulewski 2000, Reklewska and Bernatowicz 2002). Lauric ($C_{12:0}$) and myristic ($C_{14:0}$) acids increase the risk of circulatory system diseases (Skrzypek 1999, Sundram et al. 1994, Żegarska 1998). Stearic acid ($C_{18:0}$) is neutral and due to the fact that it easily transforms into the oleic acid ($C_{18:1}$) it is included into the unsaturated acids group. That is why more often features lowering cholesterol level in blood (Skrzypek 1999) are attached to it. Besides lauric and myristic acids the palmitic acid increases the low density lipoprotein (LDL) level and the overall content of cholesterol as well, at the same time increasing the tendency of platelet aggregation causing vascular clots. The overconsumption of LDL also increases the risk of circulatory system diseases and heart infarction on the atherosclerotic basis (Wilke and Clandinin 2005).

Remaining fatty acids of milk are the ones consisting of one or more double bonds. Among the total amount of fatty acids 30% of them are monoenoic ones, where 25% are oleic acids. A positive role of those acids in atherosclerosis prevention has been proved (Reklewska and Bernatowicz 2002, Żegarska 1998).

Milk fat contains a small amount of necessary unsaturated fatty acids (UFA) as well – about 3%. Those acids are not synthetized in the organism and that is why they have to be supplied with food and then polyunsaturated fatty acids (PUFA) are created from them in processes of dehydrogenation and chain elongation. They contain from 2 to 6 unsaturated double bonds. They belong to two families mainly i.e. α-linolenic acids, omega 3 (n-3) and linoleic acid, omega 6 (n-6). It is important to keep proper proportions between the share of n-6 to n-3 family acids, which should be somewhere between 4-10 : 1 (Simopoulos 2002).

The important acids from the health perspective are UFA (unsaturated fatty acids) acids: $C_{18:2}$ (linoleic acid) (n-6) and $C_{18:3}$ (α-linolenic acid) (n-3) as well as the long-chained acids created from them (more than 18 carbon atoms and more than 3 unsaturated bonds). Arachidonic acid ($C_{20:4}$, n-6), eicosapentaenoic acid ($C_{20:5}$, n-3) and docosahexaenoic ($C_{22:6}$, n-3) (Marciniak-Łukasiak and Krygier 2004).

Presented acids are essential, especially in newborns and infants nutrition in the first months of life. They have many different functions, condition proper development of the nervous system and eye retina. Their bioactive features are antisclerotic and anticholesterol actions among other. Unsaturated fatty acids are the precursors of prostaglandins and are a part of the cell wall' phospholipids, thus enabling them having an impact on all functions of cells (Reklewska and Bernatowicz 2002).

The most important fatty acids of the desired pro health action are oleic acid (from the n-9 family), which blocks the absorption of food cholesterol, lowers the content of LDL cholesterol, lowers the viscosity of blood and has an impact on the lowering of blood pressure, linoleic acid (from the n-6 family) and created from it arachidonic acid (the precursor of prostaglandins and leukotrienes), as well as fatty acids from the n-3 family (for example eicosapentaenoic and docosahexaenoic acids) (Nałęcz-Tarwacka 2008). Polyunsaturated fatty acids of the n-6 and n-3 groups are a part of the cellular wall phospholipids. Released from phospholipids they are substrates for eicosanoids synthesis including prostaglandins (PG), prostacyclins (PGI), thromboxanes (TXA) and leukotrienes (LT), as well as lipoxins (Turley and Strain 1993, Simopoulos 2002).

Health impact of polyunsaturated fatty acids is mainly connected to the effects of activity of eicosanoids which have an impact on regulation of action of cardio-vascular system, blood pressure, clotting processes, triacylglyceroles concentration in plasma, immunologic response and inflammatory processes, cell proliferation and cancer development, regulation of hormonal and neurotransmitters activity, gene expression, kidney functioning and pain reception, they prevent coronary insufficiency of heart, increase immunity, take part in lipid transportation, including cholesterol, as well as lower cholesterol level in circulating blood (Cichosz 2007, Kolanowski 2007, Nałęcz-Tarwacka 2008, Kowalski et al. 2010, Zwierzchowski et al. 2011).

Cow milk contains about 70% of saturated fatty acids and 30% of unsaturated acids. Among the unsaturated acids the monounsaturated fatty acids (MUFA) stand out as the ones which are about 83% of all unsaturated, acids as well as polyunsaturated acids (poly unsaturated fatty acids – PUFA), which are about 17% (Brzóska et al. 1999, Lindmark-Mansson 2003).

Conjugated dienes of linoleic acid (CLA) belong to the poly unsaturated acids category, where geometrical configuration of their double bounds may be both cis and trans. Bauman et al. (2000), while studying the CLA content in butter, isolated three forms: cis-trans, trans-trans and cis-cis. They have shown that these forms were: 85,8%, 9,4% and 4,8% appropriately with the overall CLA content in milk's fat being 5,3 mg/g. According to Parodi (2004) in the fat there may be over 30mg of CLA/g of fat, with the biologically active cis-9, trans-11 isomer dominating. The overall CLA content in cow milk products ranges from 2,9 to 11,3 mg/g of fat, with the CLA of cis-9, trans-11 configuration being 73-93% of all the acids from this group. The richest source of CLA is cheese.

Milk contains cholesterol as well, which is 0,2 to 0,4% of all milk lipids. The average cholesterol content in milk, with the fat share of 3,5% is 12mg, whereas in butter – 240mg/100g of fat. In the milk's fat about 90% of cholesterol appears in the free form, whereas the rest is esterified with the linoleic acids (18:2), palmitic (16:0) and oleic (18:1) (Żegarska 1998).

Pro-health features of fat in the ecological milk

The main assumption of the ecological milk production is feeding of the animals using volumetric feeds coming from the same farm or other farms using the ecological methods of production. Such feeds should cover both existential, as well as production needs of cows. In this system of breeding the quality of produced milk is more important than achieving the maximum performance of animals. Cows should use pasture with the lower feeds' share in the nutritional dose. As a result, cows kept in the ecological farms achieve lower yield than cows from the conventional farms in return producing milk of higher biological value.

Milk composition depends mainly on feeding and animal keeping, different in the ecological and conventional systems. Ecological milk contains more beneficial proteins than the conventional milk such as: α-lactalbumin, β-lactoglobulin and lactoferrin. Milk coming from pastured cows or fed with fresh feed, rich in species-varied plants, has a significantly higher ratio of unsaturated acids (PUFA) to saturated acids (SFA) and better ratio of PUFA Ω-6 to Ω-3. Ecological milk has a higher PUFA, CLA cis-9, trans-11, t-vaccenic acid (TVA) and α-linolenic acid (LNA) content in comparison to the conventional milk. The profile of fatty acids in cow milk fed with grass forage is more beneficial in comparison to the milk from cows which received corn forage. Red clover, linseed, rapeseed and fish oils all have a positive impact on fatty acids composition in milk. During the pasture period the milk of cows from the ecological farms has a higher content of vitamins soluble in fats (A, D, E and K) than the milk of animals not using pastures. The content of mineral components in cows' milk from the ecological farms depends on their content in soil and green forage.

"Bioactive components" mean components naturally appearing in food in small amounts, which have an impact on the consumer organism on the physiological, behavioral or immune response levels. Immunoglobulins, hormones, cytokines, growth factors, polyamides, nucleotides, peptides, enzymes and other bioactive peptides all belong to the bioactive substances of the protein fraction of milk category. Bioactive substances appear also in the fat fraction. Fatty acids belong to this one, and among them mono- and polyunsaturated ones, vitamins soluble in fats, carotenoids, as well as phospholipids and sphingomyelins. Mineral components contained in milk are also significant for human health.

Proteins and peptides make up a significant part of the dry weight of milk. The biggest share have caseins, which stand for about 80% of milk proteins. Four polypeptides called caseins are what makes these up and they are: αS1 (55%), αS2 (25%), β (15%) i κ (5%). Whey proteins: α-lactalbumins (α-LA), β-lactoglobulins (β-LG) and plasma albumins (serum), as well as immunoglobulins (IgA, IgM, IgG) and glutathione tripeptide are the next largest fraction in milk. In the research of Reklewska (2003) the concentrations of α-LA, β-LG and lactoferrin in the milk of pastured cows were: 1,14 g/l, 3,7 g/l, 116,2 mg/l appropriately and were significantly higher than their content in the milk of cows fed in the TMR system, appropriately: 1,0 g/l, 3,17 g/l and 88,3 mg/l.

Kuczyńska et al. (2011) reported similar dependencies (besides α-LA) in the ecological milk, while comparing to the conventional milk. Milk from cows from the ecological farms contained significantly more β-LG, lactoferrin and lysozyme, appropriately: 4,12 g/l, 334,9 mg/l, 15,68 μg/l in comparison to their concentration in the milk of conventionally kept cows (2,68 g/l, 188 mg/l, 12,56 μg/l). A positive impact of feeding animals with legumes on the content of the casein proteins in milk and the share of κ-casein in them was also observed.

Fat content in the cow's milk is highly variable and amounts from 30 to about 50 g/l. Most of the fat fraction in milk (about 95%) consists of triacylglyceroles, which consist of fatty acids of different chain lengths and varied level of saturation. Next fat fractions of milk are : about 2% of diacylglyceroles, less than 0,5% of cholesterol, about 1% of phospholipids and about 0,5% of free fatty acids. More than a half of the fatty acids in milk are saturated.

Unsaturated fatty acids can be separated into monounsaturated (MUFA) and polyunsaturated (PUFA). Among the PUFA acids n-3 and n-6 families are recognizable. The ratio of the amount of n-6 to n-3 acids is essential to human health. Bergamo et al. (2003) suggest that the n-6/n-3 ratio should range from 1 to 4. In the diet of citizens of highly developed countries it is sometimes about 7-10, or even more. One of the most essential MUFA acids is the oleic acid (C18:1, c9), which appears in milk in a high amount and stands for about 25% of the fatty acids mass. PUFA content in milk is about 2 g/l, including the biggest share of linoleic ($C_{18:2\ n\text{-}6}$) and α-linolenic acids ($C_{18:3\ n\text{-}3}$). The ecological milk is the richest source of CLA (conjugated linoleic acid) ($C_{18:2\ cis\text{-}9,\ trans\text{-}11}$) also called the rumen acid, as it is synthetized in the rumen from the linoleic acid.

Many studies confirmed the impact of feeding with fresh green forages on the profile of the milk' fatty acids. Kuczyńska [2011] showed a significant increase of content of such bioactive fatty acids as : vaccenic TVA, CLA and α-linolenic (LNA) in the milk of cows fed with fresh green forages. There is a positive, linear dependency between the share of green forage from pasture in the nutritional dose and the content of t-vaccenic and CLA acids in milk.

Ellis et al. (2006) stated that milk from the ecological farms contained 60% more polyunsaturated acids (PUFA) and n-3 as opposed to the conventional milk. As a result, the ecological milk was characterized by the lower (beneficial) ratio of the n-6 and n-3 acids, as well as a higher PUFA content in comparison to MUFA. Butler et al. (2011), after results' analysis of the observations held in several Western European countries stated that the ecological milk contains less n-6 acids and more n-3 acids, resulting in the n-6/n-3 ratio in the conventional milk being higher than 2,5, whereas in the ecological milk – less than 1,25.

In contrast to grass and legume silages, the corn silage has a negative impact on the composition of fatty acids in the milk of cows that consume it. Frelich et al. (2009) have shown that along with the increase of share of the corn silage in the feeding dose came the increase in content of the saturated acids in milk. In corn and grass silage feeding the content of saturated fatty acids in the pool of all fatty acids was 67,6 and 62,9% appropriately, whereas PUFA was 3,6 and 4,7%.

Content of fatty acids in the feed directly impacts their content in milk – especially PUFA, which are not synthetized by cow's organism. Wood et al. (2004) have proven the impact of flax, sunflower and rape seeds, as well as fish oil added to the feed on the level of desired fatty acids. Palmquist and Griinari (2006) have analyzed the impact of an addition of different proportions of oils from fish oil to the sunflower oil: 0,33, 0,67 and 1,0 on the profile of fatty acids in milk. They stated that the biggest share of CLA (Conjugated Linoleic Acid) (114 mg/g of fatty acids) was in the milk of cows, which received the addition of fish and sunflower oils in 0,33 and 0,67 proportions. The content of $C_{20:5,\ n\text{-}3}$ (EPA, eicosapentaenoic) and $C_{22:6,\ n\text{-}3}$ (DHA, docosahexaenoic) acids increased linearly and at the peak it amounted 6,8 mg/g and 0,9 mg/g of fatty acids only after the addition of fish oil. That is due to the content of those fatty acids in the fish oil – 120,4 and 101,1 mg/g of fatty acids, whereas in sunflower oil the content of these acids was below the detection level. However, the excess of fat in the feeding dose may lower the activity of the bacterial flora of rumen and as a consequence lower feed digestibility. In the case of fish oil use the deterioration of sensory values of milk may happen.

Conclusions

Milk, due to its rich and varied composition, is one of the most basic components of human diet. Contained proteins are a source of many easily absorbed amino acids, such as lysin, methionine or tryptophan. Milk's fat, rich in omega-3 and omega-6 fatty acids, makes it a source of essential unsaturated fatty acids. Milk is rich in easily absorbed macro- and microelements (calcium, phosphorus, chlorine, magnesium) as well which are essential to the proper course of biochemical processes in human organism.

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