Bovine Milk Fat Characteristics

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Abstract: Bovine milk fat is important in aspects of nutrition, human health and milk products technology. Milk fat is an basic component of human's diet, but its chemical composition and secretion is still not fully understood. Many scientific experiments related to fat secretion and lipogenesis were conducted on human, mouse and goat models. Most studies are currently concentrating on milk fatty acids (FA) profiles and milk fat globules (MFGs) structure and functions. The knowledge broadening in this area would allow to modify fat chemical composition into positive nutritional aspect and to find new bioactive compounds.

Keywords: Fat, milk, mammary gland, lipogenesis, fatty acids.

INTRODUCTION

Actual topics of International Dairy Federation, tackled at World Dairy Summits are: the role of probiotics, functional foods, the role of proteins in the growth of muscle mass and maintain bone health, and the role of whey proteins in reduction of blood glucose levels. One of the new areas of interest is the milk fat- raises questions about the impact of protein diet in combination with saturated fatty acids and cholesterol in relation to civilization diseases- cardiovascular disease, and obesity. Liquid milk is a daily meal for 44% of the population in the world. A cow's milk is 84% of total world milk production. The reports of both the Index of Tetra Pak Dairy and Dairy World Summit FIL/ IDF(2011) - "IDF SituationReport 2011", in the long-term forecasts assume growth in global milk production. According to the IDF at a rate of 2.1% annually over the next decade. World Milk production in 2010 increased by 13 million tones (1.9%) compared with 5.3million tones in 2009 (0.8%). However, according to Tetra Pak, consumption of milk and dairy products will increase globally by 30% (over 10 years, to 2020 from 270 to 350 billion liters per year). It is related to the effect of global population growth, as well as with the effect of improving the wealth of consumers and their nutritional awareness. Asia is having highest importance in consuming (39% of total milk consumption), then Europe (29%) and North America (13%). People are increasingly interested in the nutritional value of food products and their impact on health. Milk and dairy products are being promoted as a source of valuable nutrients (milk protein, the role of calcium in ensuring the health of teeth and bones in different stages of human life, and a source of easily digestible macronutrients important in the diet of the elderlies). There is a global need to step up educational and promotional activities of the positive features of nutrition and health of dairy products. Dairy products are one of the main sources of cholesterol in the diet, especially for children [1]. Despite the knowledge of cholesterol in other species, the issue of cholesterol homeostasis in cattle remains almost unknown.

MILK FAT CHARACTERISTICS

Mammalian milk fat differs in amount and composition, depending on species, maternal diet, and period of lactation. Average fat content in cow's milk is 3.4% (2,7-5%). Milk fat is an extraordinary source of energy (e.g. it corresponds to 40 up to 55% of the total energy intake for human milk), fat-soluble nutrients (like micronutrients – vitamins) and bioactive lipids for humans. Is pointed out by the Food and Agriculture Organizationof the United Nations (FAO, 2008) as being the main source of saturated fatty acids (SFA) in human diets [2]. Milk fat is one of the most complex natural sources of fatty acids (FA) from C2 to C28 [3]. Approximately 98% of all milk lipids are glycerides of fatty acids (more than 400 different FA have been identified in bovine milk) [4], the remaining are free fatty acids (FFA), phospholipids, and sterols (including cholesterol). A small position of a quantity belongs to carotenoids and fat-soluble vitamins. A SFA coming from the fermentation occurring in the rumen. Unsaturated fatty acids (UFA) (3 to 5%) are provided with feed and then distributed. Part of UFA derived from the feed is hydrogenated (saturated) by the microbiota in the rumen fermentation. Milk fat synthesis depends on 2 general sources of FA (i.e. de novo synthesis of FA in the mammary gland and transfer of

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preformed FA from blood triglycerides -TG). The short- and medium-chain FA (SMCFA; C4-C14) and half of C16 are synthesized de novo, whereas the rest of the FA, including 50% of C16 and other long-chain FA (LCFA) are derived from TG in the blood or from NEFA (Non essential fatty acids), mainly during negative energy balance.

FA in cow's milk are determined on 30-35g /l, as compared to human milk: 40 g/l. The bovine milk fat composition differs from the human, because cattle have a rumen and consume a very different diet compared to humans. Fatty acids delivered to the mammary gland and synthesized de novo in the epithelial cells are almost equal amounts (mol) of the milk fatty acid composition. Milk and dairy products are often considered as examples of products with high and dangerous to human health contents of cholesterol, however, scientists are having conflicting opinions. There are evidences, that human breast milk contains twice more cholesterol than cow's milk (25 and 12 mg/100gof milk) [5]. But still there are many differences in cholesterol calculation between scientists [6]: from 10–20 mg/dl to 204–382 mg/100 g milk fat. Furthermore, in most studies that analyzed dairy products, a positive correlation between the fat content and the cholesterol content in the product is found. The homeostasis of cholesterol in dairy cows remains almost unknown until now.

The negative nutritional image of milk fat is mostly related to the current conception that the intake of milk fat is associated with an increased risk of developing coronary heart disease (CHD) or metabolic syndrome [7]. Fat contained in the milk is more differentiated from the FA composition in other products of animal origin.The composition of bovine milk fat is influenced by many factors, both internal (cattle breed, age, stage of lactation, etc.) and external (feeding systems, seasonal changes, milking frequency and milking system) [3]. Indications exist that nutrition affects mammary lipogenic gene expression [2]. The increase in milk somatic cell count (SCC) has been also associated with changes in bovine milk components. Several studies have reported decreases in lactose, fat and casein contents in milk [8]. These modifications in milk composition, in conjunction with proteolysis, result in lower cheese yields and altered manufacturing properties. However, there is a disagreement in the effect of milk SCC on lipolysis activity. It has been suggested that milk cells could be responsible for sufficient lipolysis of milk fat globule triglyceride to provide FFA-based flavor defects. On the contrary, other studies signaled no relationship between milk SCC and lipolysis level.

Digestibility of milk fat is very high, 97-99%, because it is emulsified into small globules. In bovine milk, fat globules have a mean diameter of ~3.5 to 4 μm, compared to those of goat milk (~3.4 μm), sheep milk (~5 μm), buffalo milk (~5.2 μm) and dromedary milk (~2.6 μm) [3]. Variations in bovine milk fat globule (MFG) size exist between bovine species and can be achieved naturally through breed selection and feeding. Authors reported a positive relation between the size of MFG and the fat concentration in the milk. The secretion of small MFG requires the production of high amounts of membrane material to cover the whole surface of the lipid droplets, and thus a high synthesis activity of the lactating cells. Female mammals secreting small fat globules could have a potential higher mammary metabolic activity than those secreting large fat globules. Lipid composition and relative lipid content are different between different size particle classes: large milk fat particles (5–10 μm) have triglycerides, cholesterol, and phospholipids. Smaller particles (<1 μm) do not contain detectable amounts of cholesterol and TG, but are enriched with trans-UFA. It is suggesting a new function for small milk globules, called lactosomes (studies on human’s milk revealed that they are nondifferentiable) [9, 10].

PROFILING OF MILK FAT

Milk lipids have important immuno-suppressive, anti-inflammatory, and antimicrobial properties. We have recently witnessed a growing interest in genomic selection programs aiming to alter milk-fat composition, due to the growing awareness that fatty acid intake has a negative effect on serum lipids. Especially remembering that milk and milk derived foods are the main source of dietary SFA across Europe [11]. Over the last decade, the feasibility of genetic selection for improved FA profile in bovine milk has been investigated towards the objective of producing dairy food with higher UFA content, which is considered to be healthier for humans. Milk FA profile also influences on technological and sensory properties of dairy products, and it could be related to the metabolism and the environment of the cows (e.g. animals energy balance status or methane eructation) [12].

Milk fat synthesis is highly responsive to nutritional manipulation and nutrition has been used as a practical tool to alter milk fat yield and FA composition. Certain dietary alterations, including high concentrate diets and diets high in PUFA, can induce a low-fat milk syndrome, reducing milk fat % and fat yield up to 50%, which is commonly referred as milk fat depression (MFD [13]: a reduction of up to 50% in milk fat yield, with no change in the yield of milk and other milk components). The Short and medium-chain fatty acids (SMCFA) are essential for formation of milk TG and for maintaining the fluidity of milk fat [14]. Fat supplements are used in diets for dairy cows, for increasing energy intake and milk production, so the feed FA composition affects on milk FA composition.

The presence of particular FA in foods has attracted public interest. Milk fat contents such as eicosapentaenoic (EPA, 20:5 n-3) and docosahexaenoic acid (DHA, 22:6 n-3) and the conjugated linoleic acid (CLA) are interesting because of potential beneficial effects on human health [6, 7, 15] A specific preventive effect of α-linolenic acid (C18:3 n-3) on coronary heart diseases has been shown, and milk enriched with n-3 PUFA and oleic acid (C18:1 cis-9) has been shown to decrease the risk of cardiovascular diseases. A specific decrease in the content of palmitic acid (C16:0) in milk is desired in combination with an increase in the content of cis MUFA and cis PUFA. For the last years, modification of the FA profile of milk fat to yield greater PUFA and lower SFA contents (particularly the 16:0) has been a major research focus for the dairy industry in many countries. National Institute of Health has published specific recommendations for the daily intake of fatty acids, including 650 mg of C20:5*n*-3 and C22:6*n*-3, 2.22 g of C18:3*n*-3 and 4.44 g of C18:2*n*-6.1. It has been proposed that 95 mg of CLA daily is enough to show positive effects in the reduction of breast cancer risk in women, epidemiological data are linking increased milk consumption with reduced breast cancer [16]. The main strategies available to increase the concentration of PUFA in milks produced for commercial applications are post- and on-farm strategies. Post-farm-strategies are (1) technology, mainly with dry fractionation of fat, (2) mixing milk fat with other fats rich in unsaturated fatty acids, for example vegetable or fish oil, and (3) chemical and enzymatic interresterification. On-farm strategies are (1) selection of animal and (2) dietary manipulation by means of feeding dairy animals (e.g. based diet with rapeseed, linseed etc.). Regarding human milk lipids, studies reported that it is possible to increase health-promoting components, e.g. PUFA (n-3; DHA, EPA), by adapting the diet of mothers during pregnancy and lactation. Such milks with improved fatty acid profiles may favor breast-fed newborns health [4].

Milk lipid synthesis as well as droplet formation and secretion, received particular interest due to their influence on the manufacturing properties and organoleptic quality of milk and dairy products [17]. The profile of fat in milk is influencing on fat profile in milk products. E.g. yogurts fat fraction contains mainly FA and cholesterol. During production and storage yogurts cholesterol may undergo oxidation (by access to oxygen, light, high temperature, presence of UFA, presence of free radicals and peroxides, presence of enzymes, etc). Oxysterols (oxidized derivatives of cholesterol) have a negative impact on the human health, because they work as: cytotoxic, immunosuppressive, carcinogenic, also inhibit the DNA synthesis [18].

Milk fat globules (MFGs) are secretory vesicles formed and secreted by mammary epithelial cells during lactation. They consist of a triglyceride core, surrounded by a thin membrane derived from the apical membrane of the lactating cells, called the milk fat globule membrane (MFGM). This membrane (10–20 nm) protects the globules from aggregation and enzymatic degradation [19]. Currently, most MFG studies have characterized lipids and proteins in the milk fat globule membrane. Lipid droplets are not only lipid storage depots but complex cell organelles with multiple functions, such as distribution of neutral lipids, phospholipids, and membrane-trafficking proteins. The phospholipids in the MFGM have an unique composition when compared to other commercially available sources of polar lipids [20]. The polar lipid fraction of the MFGM comprises sphingolipids, which might manifest an effect on cancer cells (e.g. colon cancer cells) [21], such as inhibition of cell growth, induction of apoptosis, and/or modulation of senescence. Were also found to have chemopreventive and chemotherapeutic effect. They are associated with age-related diseases up-regulating COX-2 expression, and resulting increase in production of prostaglandin E2 (PGE2) in age; and they exert bactericidal effect. MFGM protein fractions are suggested to have anti-cancer effects because they contain e.g. fatty acid binding proteins (FABP; found as inhibiting some breast cancer cell lines *in vitro*) and onco-suppressor BRCA1 and BRCA2 involved in DNA repair (BRCA2 additionally regulates some cytokines) [21, 22]. Xanthine dehydrogenase/ oxidase (XDH/OX) is a high abundant protein in MFGM with direct antibacterial activity, it inhibits the growth of bacteria (e.g. *Staphylococcus aureus, E.coli, Salmonella enteritidis*) [19]. Due to the multiple benefits of its bioactives, MFGM components have been isolated and characterized and were added into food products such as buttermilk [23]. To optimize the production processes of MFGM proteins, it is essential that the bovine MFGM protein composition need to be similarly known to the human MFGM profile.

CONCLUSIONS

Clearly, deep understanding of mammary physiology and molecular adaptations to diet and/or physiological state are required for efficient manipulation of milk component synthesis and development of dairy products with specific characteristics (e.g. more UFA, more CLA). Changing FA composition through the feed regime or genetic selection also requiring a precise and regular measurement.

Investigation of the cellular mechanisms in the regulation of milk fat synthesis during established lactation will continue to be a fruitful direction for future research. Recent advances demonstrate the importance of both the cow and mouse as models to investigate the role of bioactive FA in the regulation of milk fat synthesis during lactation and the value of their continued use. Future advances using these animal models will have important implications for general understanding of mammary biology as well as invaluable applications in the dairy industry.

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