

# Nutrient Modelling to Fabricate Dairy Milk Constituents: Let Milk Serve More Than a Food Item

M.Aasif Shahzad\*, N.Mukhtar, M.Sarwar

**Abstract**—Dietary macro and micro nutrients in their respective proportion and fractions present a practical potential tool to fabricate milk constituents since cells of lactating mammary glands obtain about 80 % of milk synthesis nutrients from blood, reflecting the existence of an isotonic equilibrium between blood and milk. Diverting milk biosynthetic activities through manipulation of nutrients towards producing milk not only keeping in view its significance as natural food but also as food item which prevents or dilutes the adverse effects of some diseases (like cardiovascular problem by saturated milk fat intake) has been area of interest in the last decade. Nutritional modification / supplementation has been reported to enhance conjugated linoleic acid, fatty acid type and concentration, essential fatty acid concentration, vitamin B12 & C, Se, Cu, I and Fe which are involved to counter the health threats to human well being. Synchronizing dietary nutrients aimed to modify rumen dynamics towards synthesis of nutrients or their precursors to make their drive towards formulated milk constituents presents a practical option. Formulating dietary constituents to design milk constituents will let the farmers, consumers and investors know about the real potential and profit margins associated with this enterprise. This article briefly recapitulates the ways and means to modify milk constituents keeping an eye on human health and well being issues, which allows milk to serve more than a food item.

**Keywords**—Nutritional modification, fabricating milk composition, human health.

## I. INTRODUCTION

**D**AIRY milk constituents in context of their quality and quantity may reflect valuable information about the respective proportion of dietary nutrients [1]. The same has also been supported by the isotonic equilibrium which exists between blood and milk. Blood supplies about 80 % of the nutrients for milk biosynthetic activities [2]. Limiting any of these will reduce milk production and change its composition. To cash, this natural flexibility of milk nutritional components, multiple efforts have been made to modify milk constituents in context of human health with varying degree of success [3], [4], [5].

In developed countries like USA, every day dairy or dairy product food items has about 15–20% of human intake of total fat, 25–33% of saturated fat and about 15% of dietary cholesterol [6]. Currently, about 2% of total fatty acids (FA) in milk are polyunsaturated and about 70% are saturated, but less than 40% of saturated FA is considered to be less deleterious to healthy. Higher intake of saturated fat has been believed to have association with

cardiovascular disease risk factors [7], [8]. However, the values of milk fat constituents can be modified by changing the animal diets [7], [10]. Furthermore, concentration of desirable milk constituents like conjugated linoleic acid (CLA) can also be increased through dietary modification [4],[11],[12]. The CLA, a potential anti-carcinogen, inhibits the growth of a number of human cancer cell lines, suppresses chemically induced tumour development, inhibits cholesterol induced atherosclerosis in rabbits, mediates immune function and enhances lean body mass [13],[14]. Likewise, increasing concentration of vitamins (B12 & C) and some micro minerals (Se, Cu, I & Fe) would play their role to counter the health threats to human well being. Keeping in view the human health issues, fabricating dairy feed to design desirable milk constituents has gain significance attention in the last couple of decades.

Synchronizing dietary nutrients aimed to modify rumen dynamics towards synthesis of nutrients or their precursors to make their drive towards formulated milk constituents presents a practical option. Furthermore, formulating dietary constituents to design milk constituents will open new avenues for the farmers and food scientists as well to invest and harvest benefits and profits associated with this enterprise. This article is an attempt to briefly recapitulate the ways and means to modify milk constituents keeping an eye on human health and well being issues, which allows milk to serve more than a food item.

## II. BIOACTIVE MILK CONSTITUENTS

Milk contains numerous health benefits due to presence of bioactive components like oligosaccharides, conjugated linoleic acid, nutraceuticals and enzyme [15], [16]. Fabricating dietary nutrients for improved milk constituents for better human health has been area of intense research in the last decade [17]. Influence of dietary component on milk components have been briefly reviewed as under.

## III. DYNAMICS OF MILK FAT

Rumen ecology can be altered through nutritional manipulation which can be diverted to alter the content and composition of milk fat [18]. For fats and oils, bovine milk is considered the sixth largest source in world [19]. Animal products are considered the main source of saturated fat and cholesterol content in human diet. Milk fat is less stable milk constituent and offers a practical platform to enhance or modify milk content and constituents as milk fat percentage can be increased over a range of 3 percentage compared to milk protein which is only 0.5% in response to dietary manipulation. Milk on dry basis contains about 27% fat content with the majority of the saturated fatty acids (65%). About 50% calories in milk come from fat. Jenkins and McGuire (2006) reported that an ideal milk would contain no more than 8% saturated fatty acids, less than 10% polyunsaturated fatty acids, and the remainder (82%) as monounsaturated fatty acids [20]. There are multiple factors which influence the transfer of these dietary unsaturated fatty acids to milk, ruminal microorganisms and decreased absorption from intestine etc. So the knowledge of understanding and controlling fatty acid

\*Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, Pakistan. Phone: +92 321 6642404 Fax: +92 41 9200137  
e-mail: draasifshah@uaf.edu.pk, aasifshah9@hotmail.com [M.A.Shahzad]

destruction by ruminal microorganisms and the uptake and use of unsaturated fatty acids by the mammary gland provides the baseline information for designing the desired milk composition [20].

Medium- and long-chain saturated fatty acids are converted into monounsaturated fatty acids by stearoyl-CoA desaturase enzyme. In milk, higher proportions of monounsaturated fatty acids and conjugated linoleic acid are beneficial for human cardiovascular health. Cardiac risk by lowering the cholesterol in human being can be reduced by ensuring mono-unsaturated fatty acids and polyunsaturated fatty acids in the diet which can be manipulated through dietary interventions [21]. In addition to nutritional aspects, some additives like probiotic have been reported to enhance polyunsaturated fatty acids such as linoleic and linoleic acid in dairy milk. Improving concentration of these unsaturated fatty acids has been reported to increase the fatty acid profile of milk. It also improves CLA, unsaturated to saturated fatty acid profile and also decreases the n-6:n-3 ratio [17].

The CLA, an effective anticarcinogen, antidiabetic, and antilipogenic agent, can be enhanced in dairy milk constituents through nutritional modification for better human health. Rumen-undegraded fat or protected fats resist to biohydrogenation and also enhance the concentration of unsaturated fatty acids in milk while on other hand, fat (rumen degraded) supplementation reduces the protein concentration. Rumen-protected fat sources included whole oilseeds, amides of fatty acids and calcium salts of fatty acids effects the CLA isomers [20].

Feeding grain as an energy source in ruminants is a regular practice over the globe because of its higher digestibility and energy production. However, feeding grains to dairy animals has also been reported to stimulating milk yield and depress milk fat% in addition to altered milk fatty acid composition. Grain feeding decreases proportion of 6 to 16 carbons milk fatty acids while increases the 18-carbon unsaturated fatty acids which has been attributed to inadequate rumen production of acetate and butyrate. Increased production of trans-10 fatty acid isomers by rumen microbes in ruminants receiving grains has also been reported. The trans-10,cis-12 (CLA) is the most likely factor in milk fat depression [17]. Bypass fats like calcium salts of fatty acids and products enriched in saturated fatty acids alter microbial population in the rumen that transforms dietary unsaturated fatty acids.

Ruminal microorganisms transform unsaturated fatty acids into unsaturated to saturated by the process a process of biohydrogenation and also enhance their absorption and delivery to the mammary gland. Oleic acid concentration in milk fat varied from 18 to 24% of total fatty acids but during rumen-protected fats oleic acid in milk varied from 18 to 48%. Ethanol-fed animals had a decreased proportion of C22:6 n-3 fatty acid and an increase in medium-chain fatty acids and of several minerals [22]. Feeding rumen-protected fats increased concentration of linoleic acid upto 6.5%. Other ingredients like processed oilseeds enhance intake, or digestibility, which can significantly reduce their resistance to biohydrogenation. Ability of unsaturated fatty acids in calcium salts of palm oil resist the biohydrogenation and these calcium salts also enhance the absorption of unsaturated fatty acids.

Amides of unsaturated fatty acids are another way to enhance unsaturated fatty acids in milk. However, protection of amides from biohydrogenation depending on the specific fatty acid and amide linkage. Oleamide also enhance oleic acid concentration in milk. Regarding CLA, the cis-9,trans-11 CLA isomer in particular received the most attention for its Anticarcinogenic properties, which was known to arise from the biohydrogenation of linoleic acid. The trans fatty acid isomers including CLA in the rumen reduce the pathways of biohydrogenation [20]. However, for all these modifications, regulating the pathway of fatty acid biohydrogenation by ruminal

microorganisms played an important role in achieving the present day successes in nutritional manipulation of milk composition.

#### IV. MAMMARY GLAND IN CONTEXT OF DESIGNING MILK COMPOSITION

Designed milk composition can be achieved by nutritional manipulation and also by enhancing the nutrient uptake by mammary glands. Approximately 50 to 60% of the total fatty acids transferred and its quantity depend on composition, and degree of ruminal protection and digestibility.

Diets which contain the C16 to C18 fatty acids decrease the synthesis of C6 to C14 in mammary glands by increasing the amounts of C18 trans fatty acids which may inhibit lipogenesis and  $\Delta^9$ -desaturase activity. Mammary secretory cell in mammary glands converts the stearic acid in to oleic acids through desaturase activity which is the product of ruminal biohydrogenation. Whole this process enhances oleic acid at the expense of saturated fatty acids in milk.

The  $\Delta^9$ -desaturase was the source of the cis-9,trans-11 CLA isomer in milk which has a health benefits for health especially anticarcinogenic properties. Ruminal biohydrogenation which enhance the yield of the trans-11 isomer. Trans-11 arising from biohydrogenation in rumen, desaturated to cis-9,trans-11 CLA via the  $\Delta^9$ -desaturase via the mammary tissue. The CLA effects the synthesis and abundance of mRNA, a key mammary enzymes involved in de novo fatty acid synthesis.

#### V. MILK PROTEIN

Protein of milk is natural medium to deliver the essential micronutrients especially calcium and phosphate in addition to excellent source of amino acids and immunoglobulins [16]. The milk nitrogen has three bifurcation; casein (78%), whey (17%), and NPN (5%). DePeters and Cant (1992) reviewed that dietary alterations may have positive impact on milk and protein yields and has negative effects on protein content [23]. Forage diet ratio in ration reduces the milk protein. Rapidly fermentable carbohydrate has greater production of propionate and microbial protein synthesis thereby ensuring better supply of amino acid supply at post ruminal level and thereby yielding more milk and milk protein.

Milk protein increased from 2.85 to 3.27% as protein content in the diet increased from 15.0 to 19.5%. Protein content of milk increases 0.02 % for each 1 percentage increase in dietary protein [20]. It has also been noticed that despite ensuring adequate supply of amino acids in blood, the milk amino acid can't be increased. This might be attributed to reduced mammary gland ability to capture blood amino acids efficiently, probably due to decreased blood flow towards udder. Therefore, improving blood flow towards mammary glands also seems to be a doable practice to enhance milk protein contents. An interesting relation between dietary protein and fat does exist which may also contribute influence milk protein.

On average, protein content in milk declined 0.03 percentage units for every 100 g of supplemental fat intake. High blood fatty acids from the fat supplement decreased the release of somatotropin, which reduced mammary extraction of amino acids [24]. Berner (1993) reported a 7% drop in mammary blood flow by fat feeding which prevent increased removal of critical amino acids as milk synthesis increased [25]. Reduced milk protein concentration by reducing blood flow toward mammary gland which reduces extraction of blood amino acids. In neonate the gut is not simply an inert tube via which nutrients and bioactive substances pass from the mammary gland to the neonatal liver; it is also an organ of digestion and absorption capable of selection, reception, sorting, transformation, uptake, transfer, exclusion, degradation and excretion of substances that pass through it [27].

## VI. MILK CONSTITUENT AS ALTERED BY DIETARY MODIFICATION

Cereal grains and their by-products, are the main energy sources in ruminants ration and their variable lipid contents has direct impact on the fatty acid composition of the animal product like milk fatty acids [27]. Forage as diet is best source of unsaturated fatty acids in ruminants. It has been well documented that animals consuming fresh pasture will have a higher content of UFA in their milk than other cereal grains [10]. Grass is also good source of n-3 PUFA. Dewhurst et al. (2003) also reported high linolenic acid levels in milk due to white clover silage feeding than grass silage feeding [28]. Overall the grasses contain beneficial fatty acids [29]. Physical form of oilseed and different ingredient has desirable effect on fatty acids of milk. Oleic acid concentration in milk can be increased by addition of rapeseed oil [30], [31]. Higher concentration of C18:1 c-9 in milk fat was also because of efficient activity of desaturase by the mammary gland. A number of feed sources like lupin, naked oats, camelina, hemp and chia increase levels of beneficial UFA in dairy milk [17].

### REFERENCES

- [1] Greppi, G. F., A. Ciceri, M. Pasquini, U. Falasch, G. Enne. 1995: Milk yield in dairy goats and blood metabolites. In: Proceedings of IDF-Seminar on Production and Utilization of Ewe and Goat Milk, 19-21 October, Greece. 47 p.
- [2] Khaled, N.F., J.S. Illek, E.K. Gajd. 1999. Interactions between nutrition, blood metabolic profile and milk composition in dairy goats. *Acta Vet. Brno*, 68: 253-258
- [3] Noakes, M., P.J. Nestel and P.M. Clifton. 1996. Modifying the fatty acid profile of dairy products through feedlot technology lowers plasma cholesterol of humans consuming the products. *American Journal of Clinical Nutrition*, 63, 42-46.
- [4] Palmquist, D. L., D.A. Beaulieu and D.M. Barbano. 1993. Feed and animal factors in milk fat composition. *Journal of Dairy Science*, 76, 1753-1771.
- [5] Lin, T. Y. 2000. Conjugated linoleic acid concentration as affected by lactic cultures and additives. *Food Chemistry*, 69, 27-31.
- [6] Havel, R.J. 1997. Milk fat consumption and human health: recent NIH and other American governmental recommendations. In: Welch, R.A.S., Burns, D.J.W., Davis, S.R., Popay, A.I., Prosser, C.G. (Eds.), *Milk Composition, Production And Biotechnology*. CAB International, Wallingford, UK, pp. 13-22.
- [7] Ascherio, A., E.B. Rimm, E.L. Giovannucci, D. Spiegelman, M. Stampfer, W.C. Willett. 1996. Dietary fat and risk of coronary heart disease in men: cohort follow up study in the United States. *Brit. Med. J.* 313, 84-90.
- [8] Williams, C. M. 2000. Dietary fatty acids and human health. *Annales de Zootechnie*, 49, 165-180.
- [9] Tamminga, S. 2001. Effects of feeds, feed composition and feed strategy on fat content and fatty acid composition in milk. *Bull. Int. Dairy Fed.* 366, 15-24.
- [10] Chilliard, Y., F. Glasser, A. Ferlay, L. Bernard, J. Rouel, M. Doreau. 2007. Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat. *Eur. J. Lipid Sci. Technol.* 109, 828-855.
- [11] Elgersma, A., G. Ellen, H. Van Der, B.G. Muuse, H. Boer, S. Tamminga. 2004. Quick changes in milk fat composition after transition from fresh grass to a silage diet and effects on consumer health benefits. *Anim. Feed Sci. Tech.* 117, 13-27.
- [12] Elgersma, A., S. Tamminga, G. Ellen. 2003. Comparison of the effects of grazing and zero-grazing of grass on milk fatty acid composition of dairy cows. *Grassl. Sci. Eur.* 8, 271-274.
- [13] Parodi, P. W. 1999. Conjugated linoleic acid and other anticarcinogenic agents of bovine milk fat. *Journal of Dairy Science*, 82, 1339-1349.
- [14] Kritchevsky, D. 2000. Antimutagenic and some other effects of conjugated linoleic acid. *British Journal of Nutrition*, 83, 459-465.
- [15] Britton, J. R. and A.B.B.J. Kastin. 1991. Biologically Active Polypeptides in Milk. 301:00-00. *American J. Med. Sci.*
- [16] Livney, Y. D. 2010. Milk proteins as vehicles for bioactives. *Current Opinion in Colloid & Interface Sci.* 15:73-83
- [17] Woods, V. B. and A. M. Fearon. 2009. Dietary source of unsaturated fatty acids for animals and their transfer into meat, milk and egg: A review. *Live. Sci.* 126:1-20.
- [18] Ashes, J.A., S.K. Gulati, T.W. Scott. 1997. Potential to alter the content and composition of milk fat through nutrition. *J. Dairy Sci.* 80, 2204-2212.
- [19] Bourlieu, B., S. Bpouhallab and C. Lopez. 2009. Biocatalyzed modification of milk lipids: applications and potentialities. *Trends in food Sci. Tech.* 20:458-469.
- [20] Jenkins, T. C. and M. A. McGuire. 2006. Major Advances in Nutrition: Impact on Milk Composition. *J. Dairy Sci.* 89:1302-1310.
- [21] Menotti, A. 1999. Diet cholesterol and coronary heart disease: A perspective. *Acta Cardiol.* 54:169-172.
- [22] Cintia, R.P., I.C. Azara, C.N. Maia, M.A.C. Rangell, F.B. Renata, F.O. Serpa, G. Maria. 2008. Ethanol Intake during Lactation Alters Milk Nutrient Composition and Growth and Mineral Status of Rat Pups. *Biol Res* 41: 317-330
- [23] DePeters, E. J., and J. P. Cant. 1992. Nutritional factors influencing the nitrogen composition of bovine milk: A review. *J. Dairy Sci.* 75:2043-2070.
- [24] Casper, D. P., and D. J. Schingoethe. 1989. Model to describe and alleviate milk protein depression in early lactation cows fed a high fat diet. *J. Dairy Sci.* 72:3327-3335.
- [25] Berner, L. A. 1993. Roundtable discussion on milkfat, dairy foods, and coronary heart disease risk. *J. Nutr.* 123:1175-1184.
- [26] Weaver, L.T. 1997. Significance of bioactive substances in milk to the human neonate. *Live. Prod. Sci.* 50:139-146
- [27] Bargo, F., L.D. Muller, E.S. Kolver, J.E. Delahoy. 2003. Production and digestion of supplemented dairy cows on pasture. *J. Dairy Sci.* 86, 1-42.
- [28] Dewhurst, R.L., W.J. Fisher, J.K.S. Tweed, M.O. Humphreys. 2003. Comparison of grass and legume silages for milk production. 1. Production responses with different levels of concentrate. *J. Dairy Sci.* 86, 2598-2611.
- [29] Dewhurst, R.L., K.J. Shinfield, M.R.F. Lee, N.D. Scollan. 2006. Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. *Anim. Feed Sci. Technol.* 131, 168-206.
- [30] Fearon, A.M., C.S. Mayne, J.A.M. Beattie, D.W. Bruce. 2004. Effect of level of oil inclusion in the diet of dairy cows at pasture on animal performance and milk composition properties. *J. Sci. Food Agric.* 84, 497-504.
- [31] Murphy, J.J., J.F. Connolly, G.P. McNeil. 1995. Effects on cow performance and milk fat composition of feeding full fat soybeans and rapeseed to dairy cows at pasture. *Livest. Prod. Sci.* 44, 13-25.