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 & 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

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

Medium- and long-chain saturated fatty acids are converted into
monounsaturated fatty acids by stearyl-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
depolyunsaturated fatty acids in the diet which can be manipulated
through dose of 6 to 16 carbons [21]. Fatty acids with nutritional effects
some additives like probiotic have been reported to enhance
depolyunsaturated 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 anticarcinogenic, anti-diabetic, and
tumorigenic 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
enhances the concentration of unsaturated fatty acids in milk, while on
the other hand, fat (rumen degraded) supplementation reduces the protein
concentration. Rumen-protected fat sources included whole oilseed,
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 deprec milk fat% in addition to
altered milk fatty acid composition. Grain feeding decreases proportion
of 6 to 16 carbons [22]. milk fatty acids while increases the 18-
carbon unsaturated fatty acids which has been attributed to
adequate 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 after microbial population in the rumen that
transforms dietary unsaturated fatty acids.

Ruminal microorganisms transform unsaturated fatty acids into
unsaturated to saturated by the 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 up to 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 D-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 Δ9-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 was
enhance the yield of the trans-11 isomer. Trans-11 arising from
biohydrogenation in rumen, desaturated to cis-9,trans-11 CLA via the
Δ9-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 cereals 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