Dietary Manipulation to Improve Milk Fatty Acids Profile Beneficial to Human Health

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Abstract: This review was conducted with the objective of assessing some dietary manipulation options to improve milk fatty acids profile beneficial to human health. Different research outputs, review papers and conference papers have been reviewed to address the issues of this paper. Developing foods that enhance human health is central to dietary approaches for preventing and reducing the economic and social impact of chronic diseases, including cancer, cardiovascular disease and obesity. Milk quality is dependent on its fatty acid (FA) composition. Milk fat contains a substantial concentration of saturated fatty acids (C_{14:0} and C_{16:0}) and relatively low concentrations of monounsaturated and polyunsaturated fatty acids. The PUFA content of milk fat is an important aspect of establishing its dietetic quality. Among the milk fatty acids that has gained attention is conjugated linoleic acid (CLA) (C_{18:2} cis-9 trans-11) because it is unique in its ability to inhibit carcinogenesis in experimental animals. It has been observed to reduce the incidence of tumours in a number of experimental animal models and serve as a cytotoxic agent against existing tumour cells. It has also been shown that CLA may have positive effects on cardiovascular risk factors in animal. The biohydrogenation in the rumen that can alter the CLA production in milk fat is affected by the type and the amount of fatty acid substrate and forage to grain ratio in the diet. A variety of fat sources as calcium salt have been fed to increase the concentration of CLA as a method to protect dietary lipids from ruminal biohydrogenation. Feeding strategies that optimize rumen function also maximize milk production and milk composition and yield. Nutritional manipulation of the rumen ecosystem provides a strategy to alter the content and composition of milk fat beneficial to human health.

Key words: Dietary Manipulation • Milk • Fatty Acids • Conjugated Linoleic Acid • Human Health

INTRODUCTION

Milk is the most preferred item accounting for 70% of the expenditure on livestock based foods. It is an important component of human diet supplying high quality protein, energy and a variety of minerals and vitamins. Although dairy products provide 15–25% of the total fat in the human diet, they provide about 25–35% of the total saturated fat [1, 2]. Over the years, the demand for value added dairy products has increased at about 7.6% per annum, registering a higher growth in urban than in rural areas [3]. Milk quality is dependent on its fatty acid (FA) composition, which influences the physical properties (e.g. melting point and hardness of butter, crystallization and fractionation of milk fat) as well as its nutritional properties (e.g. potential effects of specific FA on human health).

Bovine milk, in spite of being the most desired component of the balanced human diet has been criticized because it contains a less desirable balance of fatty acids than vegetable or fish oils. According to Kennelly and Glimm [4], milk fat contains a substantial concentration of saturated fatty acids (C_{14:0} and C_{16:0}) and relatively low concentrations of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). The ideal milk fat would contain 10 % PUFA, 8 % saturated fatty acids (SFA) and 82 % MUFA. The difference in fatty acid composition between the ideal and the actual milk

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fats is enormous. Increasing MUFA and PUFA at the expense of SFA (C_{16:0} and C_{18:0}) is desirable from a human health perspective. Human dietary recommendations indicate the need to decrease intake of medium-chain SFA (lauric acid, myristic acid and palmitic acid) to reduce the frequency of cardio-vascular diseases. Moreover, an increased dietary intake of PUFA stimulates the immune system and reduces the frequency of cancer and cardio-vascular diseases [5, 6].

The improvement of milk quality by genetic manipulation involves a long time. Nutrition may, therefore, be a more appropriate means of altering milk composition to meet today’s market demands. The nutritional value of milk fat can be improved by lipid supplementation of the diet [7]. Pasture feeding [8], changing the forage-to-concentrate ratio [9] are some of the important areas being explored. This review paper is aimed to overview some of nutritional strategies to improve the milk fatty acid concentration beneficial to human health.

**Milk Lipids:** Bovine milk typically contains 3.5% fat but the level varies widely, depending on several factors, including: breed, individuality of the animal, stage of lactation, season, nutritional status, type of feed, health and age of the animal, interval between milking and the point during milking when the sample is taken [10]. According to Jensen and Newburg [11], milk fat consists mainly of triglycerides, approximately 98%, while other milk lipids are diacylglycerol (about 2% of the lipid fraction), cholesterol (less than 0.5%), phospholipids (about 1%) and free fatty acids (FFA) (about 0.1%). In addition, there are trace amounts of ether lipids, hydrocarbons, fat soluble vitamins, flavour compounds and compounds introduced by the feed [12].

The principal function of milk lipid is to serve as a source of energy for the neonate and milk lipids and are also important as a source of essential fatty acids (i.e. fatty acids which cannot be synthesized by higher animals, especially linoleic acid, C_{18:2}) and fat soluble vitamins (A, D, E, K) [10].

**Fatty Acid Profile of Milk Lipids:** Milk fat triglycerols are synthesized from more than 400 different fatty acids, which make milk fat the most complex of all natural fats [10]. The concentrations of the principal fatty acids in milk fats of different species of animals which serve as the sources of dietary fatty acids are shown on Table 1.

| Table 1: Principal fatty acids (g/100g fat) in milk triglycerols [10] |
|---------------------------------|---------|---------|---------|---------|
| Fatty acids (g/100g)            | Cow     | Buffalo | Goat    | Sheep   |
| Butyric (C_{4:0})               | 3.3     | 3.6     | 2.6     | 4.0     |
| Caproic (C_{6:0})               | 1.6     | 1.6     | 2.9     | 2.8     |
| Caprylic acid (C_{8:0})         | 3.1     | 1.1     | 2.7     | 2.7     |
| Capryl acid (C_{9:0})           | 3.0     | 1.9     | 8.4     | 9.0     |
| Lauric acid (C_{12:0})          | 9.5     | 8.7     | 10.3    | 11.8    |
| Myristic acid (C_{14:0})        | 26.3    | 30.4    | 24.6    | 25.4    |
| Palmitic acid (C_{16:0})        | 14.6    | 10.1    | 12.5    | 9.0     |
| Palmitoleic acid (C_{16:1})     | 2.3     | 3.4     | 2.2     | 3.4     |
| Stearic acid (C_{18:0})         | 28.7    | 28.5    | 20.0    |         |
| Oleic acid (C_{18:1})           | 0.8     | 2.5     | 2.2     | 2.1     |
| Linolenic acid (C_{18:3})       | 0.8     | 2.5     | 0.9     |         |

Nearly all of these acids are present in trace quantities and only about 15 acids at the 1% level or higher. Many factors are associated with the variations in the amount and fatty acid composition of bovine milk lipids [13]. Milk fat contains significantly higher concentrations of short-chain fatty acids and MCFA and relatively lower concentrations of unsaturated fatty acids (UFA) as compared to other dietary sources of vegetable and animal fat [14, 15].

**Origin of Milk Fatty Acids:** Fatty acids incorporated into milk fat triacylglyceride (TAG) are derived from two sources, mammary de novo synthesis and the uptake of preformed fatty acids from peripheral circulation. Direct uptake typically contributes to about 60% of total fatty acid secretion in milk fat [2]. Both acetate and β-hydroxybutyrate derived from organic matter digestion in the rumen are used by mammary epithelial cells to synthesize short- and medium-chain fatty acids. Mammary de novo synthesis accounts for all C_{4:0} to C_{12:0}, most of the C_{14:0}(95%) and about 50% of C_{16:0} secreted in milk, while all 18 carbon and longer chain fatty acids are derived entirely from circulating plasma lipids [16].

Acetate and to a lesser extent β-hydroxybutyrate, contribute to the initial four carbons units required for fatty acid synthesis. Acetate is converted to acetyl-CoA in the cytosol and incorporated into FA via the malonyl-CoA pathway, whereas β-hydroxybutyrate is incorporated directly following activation to butyl-CoA. Acetyl, butyl and malonyl-CoA condense within the fatty acid synthetase complex and chain elongation occurs through continual loading of additional malonyl-CoA groups. A distinctive feature of the bovine mammary gland is its ability to release fatty acids from the synthetase complex at various stages, resulting in the secretion of a wide range of short and medium chain fatty acids [2].
According to Chilliard et al. [2], mammary uptake of C_{16:0} and all longer fatty acids are derived from the absorption of fatty acids in the small intestine and during mobilization of tissue adipose. Absorbed fatty acids derived from the diet, microbial fatty acid synthesis in the rumen and endogenous lipids are used for the assembly of triglycerides in the intestinal epithelium and transported as plasma chylomicrons and very low density lipoproteins (VLDL). Long-chain fatty acids taken up by the mammary gland are obtained from the triglycerides fractions of circulating VLDL and chylomicrons via the action of mammary lipoprotein lipase. Fatty acids incorporated into cholesterol esters and phospholipid and transported in plasma mainly as high-density lipoproteins (HDL) that are relatively poor substrates for lipoprotein lipase. Even though plasma triglycerides and non-esterified FA represent less than 3% of total plasma lipids these sources contribute to about 60% of fatty acids secreted in milk.

**Lipid Metabolism in the Rumen and Synthesis of CLA:** The rumen is the site of an intense microbial lipid metabolism. Lipolysis of dietary glycolipids, phospholipids and triglycerides leads to free FA which is hydrogenated to a large extent. When dietary lipids enter the rumen, the initial step in lipid metabolism is the hydrolysis of the ester linkages found in triglycerides, phospholipids and glycolipids. Hydrolysis of dietary lipids is predominantly due to rumen bacteria with little evidence for a significant role by rumen protozoa and fungi or salivary and plant lipases. The hydrolysis of lipids is extracellular and the glycerol and sugars that are liberated are readily metabolized by the rumen bacteria. Although the extent of hydrolysis is generally high (> 85%), a number of factors that affect the rate and extent of hydrolysis have been identified [17, 18].

Biohydrogenation of unsaturated fatty acids is the second major transformation that dietary lipids can undergo in the rumen. Ruminal biohydrogenation, defined as the disappearance of linoleic and linolenic acids between the mouth and duodenum, is extensive in most cases with an average value of about 80 and 92% for linoleic and linolenic acids respectively [19]. For example, linoleic acid (cis-9, cis-12 C_{18:2}) is isomerised to conjugated linoleic acid (CLA) (cis-9, trans-11 C_{18:2}) and then hydrogenated firstly to trans vaccenic acid (trans-11 C_{18:1}) and then to stearic acid (C_{18:0}) (Figure 1). In fact, the biochemical pathways are numerous and dependent on the microbial ecosystem [19]. Among trans monounsaturated FA (TMUFA), the trans-11 isomer (trans vaccenic acid) is the main one, but a total of 12 trans isomers have been found [2, 20].

According to Kramer et al. [21], conjugated linoleic acid refers to a mixture of positional and geometric isomers of linoleic acid (18 carbons) with two double bonds separated by one single bond. Further, each double bond can be in the cis or trans configuration. Therefore, many forms of CLA are possible [22, 23, 24], but the main form present in foods from ruminant animals is the cis-9, trans-11 CLA, which was recently given the trivial name rumenic acid.

The CLA found in milk and meat fat of ruminants originates from two sources [25]. One source is CLA formed during ruminal biohydrogenation of linoleic acid (Figure 1). The second source is CLA synthesized by the animal’s tissues from trans-11 C_{18:1}, another intermediate in the biohydrogenation of unsaturated fatty acids. Ruminant mammary (and adipose) cells are able to synthesize cis-9, trans-11 CLA from trans-11 C_{18:1} and other CLA isomers from other trans C_{18:1} isomers, by action of the delta-9 desaturase on trans C_{18:1}. The importance of both of these sources has been studied and mammary synthesis may account for up to 70 to 90% of total CLA found in milk [18, 26]. However, it is important to keep in mind that the substrate for mammary CLA synthesis originates in the rumen through microbial biohydrogenation.

**Potential Health Benefits of Conjugated Linoleic Acid:** Even though other CLA isomers can be found in foods for humans, traditionally the predominate form has been rumenic acid. Rumenic acid represents greater than 80% of the CLA present in milk fat and over 75% of the CLA present in beef fat [21, 22, 27].

**CLA and Atherosclerosis:** It was demonstrated by a few workers [28] that rabbits fed an atherogenic diet providing 0.5 g CLA/d exhibited lower circulating LDL cholesterol and somewhat lower triglyceride concentrations. They also concluded from examination of the aortas that plaque development was reduced. In another study, [29] fed hamsters atherogenic diets containing varying levels of CLA were found to have lower concentration of total circulating cholesterol. However, fatty streak formation was unaffected. Interestingly, recent epidemiological evidence shows no increase in risk of coronary heart disease with greater butter consumption, but intake of margarine, which lacks CLA, actually was associated with an increased risk of heart disease [30].
CLA and Immune System: The findings of Cook et al. [31] determined that CLA enhanced a T-cell-dependent response to intradermal foot pad injections of phytohemagglutinin in rat. Albers et al. [32] demonstrated CLA promoted the humoral immune response in human subjects, as reflected by an increased seroprotection rate after vaccination.

CLA and Cancer: Research has found that CLA can be effective in inhibiting initiation, promotion and progression of breast, colon, skin and prostate cancers [33]. Early work showed potent anti-carcinogenic actions of CLA using the mouse skin cancer and fore-stomach models [34, 35] which showed that CLA reduced subsequent tumour development by 50%. More recent work has concentrated on effects of CLA against mammary tumour development in the rat which confirmed a dose dependent reduction in tumour yield when CLA was given prior to carcinogen treatment [35, 36]. A dosage equivalent to 0.04 g/kg body weight was shown to reduce tumour incidence by 36%.

CLA and Diabetes: Feeding of CLA to rats prone to developing diabetes normalized glucose tolerance and improved hyperinsulinemia as effectively as currently used medications [39]. The CLA was a mixture containing approximately 90% isomers of CLA with 42% cis-9, trans-11 and trans-9, cis-11 CLA, 43.5% trans- 10, cis-12 CLA, 1% cis-9, cis-11 CLA, 1% cis-10, cis-12 CLA, 1.5% trans-9, trans-11 and trans-10, cis-12 CLA, 0.5% linoleic acid, 5.5% oleic acid and 5% unidentified compounds. These fatty acids were fed at 1.5% (by weight) of the diet for 2 wk. The study was short-term and needs to be replicated and extended before the results can be applied to human health. Nonetheless, if CLA can improve glucose homeostasis and inhibit body fat accretion as demonstrated in mice, rats and pigs, then CLA may be beneficial to humans prone to diabetes.

Dietary Manipulations to Alter Milk Fatty Acid Profile Roughage to Concentrate Ratio: Diets that are high in concentrate and low in forage have long been known to depress the milk fat percentage of dairy cows. High proportions of concentrate in the diet often depress ruminal pH, lower fiber digestibility and result in altered ruminal function and affect ruminal biohydrogenation process. Increasing roughage: concentrate in the diet of...
cows increased milk fat production, confirming results of study [40] in which it was observed that feeding high roughage (R:C ratio 50:50) diets substantially increased milk fat percentage (6.72%) as compared to R:C ratio 70:30 diet. Similarly, Kalscheur et al. [41] observed reduction (P <0.01) in milk fat (3.67%) of cows fed low fibre (F:C ratio 25:75) diets compared with cows fed high fibre (F:C ratio 60:40) diets (4.16%). This effect has been commonly reported for high concentrate diets [42, 43, 44, 45] and is clearly an indication of milk fat depression due to ruminal processes [18, 46]. Forage diets high in cellulose give rise to acetic acid, while concentrate diets give rise to propionic acid thereby reducing the proportion of acetic acid [47]. High levels of concentrate are conducive to production of propionic acid in the rumen, which in turn promotes partition of energy towards synthesis of body fat instead of milk fat synthesis, resulting in a decrease in milk fat content [48, 49].

The dietary roughage proportion increased from 50:50 to 70:30 roughage to concentrate ratio, there was a significant (P <0.05) reduction in the concentration of C10:0, C12:0, C14:0 and C16:0 fatty acids [40]. Lower percentages of these fatty acids in cows fed high fiber diet were also reported by AlZahal et al. [50]. Similarly, Martini et al. [51] also observed decreased values of some medium chain fatty acids viz. C12:0 (14.89%) and C14:0 (4.03%) with the increase in roughage level in the diet of lactating ewes. On the other hand, an inverse effect (P <0.05) was observed in relation to the palmitoleic (C16:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2) and linolenic (C18:3) acids, which increased with the level of increased roughage in the diet.

According to Netsanet et al. [40], total long chain fatty acids (TLCFA), total unsaturated fatty acids (TUFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) increased significantly (P <0.05) with the increased proportion of roughage in the diet. Total MUFA content varied from 28.38% (50:50 roughage: concentrate) to 33.37% (70:30 roughage: concentrate) of milk fat. The concentration of PUFA was highest in (70:30 roughage: concentrate) of milk fat (7.66 % of milk fat) and lower in 50:50 roughage: concentrate (3.24 % of milk fat). Polynsaturated fatty acids content of milk fat (g/100g fat) was increased by 68.93 and 141.75% in 60:40 roughage: concentrate and 70:30 roughage: concentrate, respectively over 50:50 roughage: concentrate [40]. Polynsaturated fatty acids are not synthesized by the tissue of ruminants, so their concentration in the milk strictly depends on the amount of the fat absorbed in the intestines and, therefore, on the amounts released in the rumen. Therefore, the increase in the roughage level proportionally decreases the concentrate contents and hence the availability of unsaturated fatty acids to be used by the mammary gland in the synthesis of milk lipids [52, 53, 54].

The concentration of CLA in bovine milk fat can vary quite substantially depending on the feeding strategy adopted. According to Tyagi et al. [55] total milk CLA content averaged 18.0 and 6.6 mg/g in berseem and concentrate fed animals, respectively which showed 3 fold increases in total CLA by green fodder feeding. Similarly, concentrations of CLA in diets contained 70:30 roughage: concentrate increased by 50.92 and 17.36% over 50:50 roughage: concentrate and 60:40 roughage: concentrate, respectively [40]. Schroeder et al. [56] recorded 2-3 fold higher milk CLA concentration in dairy cows fed pasture as compared with TMR. Similarly, Dhiman et al. [8] pasture feeding has been found to result in a much higher milk fat CLA (22.1mg/g fat) concentration than that achieved with typical TMR (3.8mg/g fat) based on conserved forage and grain. Results suggest that milk FA produced from diets based on more than 58% grass silage contained more myristic (10–15%) and palmitic (34–40%) acids and less oleic (18–25%), linoleic (0.6–2.0%) and γ-linolenic (0.3– 0.7%) acids than milks produced on pasture Chilliard et al.[7]. A study comparing confinement feeding of a TMR with pasture plus TMR and pasture plus concentrate clearly shows that feeding pasture elevated the CLA in milk.

**Vegetable Oils, Oil Seeds and Fats:** A reduction of milk fat due to inclusion of linseed in the diets at the rate of 4-5% [24] or 5.1-7.5% as ground linseed [22]; Grinari and Bauman [25] in dairy cows has been reported. On the contrary, milk fat percentage was not affected by dietary inclusion of ground linseed at the rate of 8.5% or linseed oil at 3%; however, cows fed groundnut cake (GNC) based concentrate (40% GNC) tended to have higher milk fat as compared to others [58]. Feeding of ground linseed and linseed oil to cows, led to the lower concentration of

### Table 2: Human dietary equivalents of conjugated linoleic acid levels shown to produce protective effects in animals [34]

<table>
<thead>
<tr>
<th>Action</th>
<th>Active dose level in animals</th>
<th>Equivalent diet level in humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-carcinogen</td>
<td>0.04 g/kg body weight</td>
<td>3.0–3.5 g/d</td>
</tr>
<tr>
<td>Anti-lipogenic</td>
<td>0.05% diet</td>
<td>15–20 g/d</td>
</tr>
<tr>
<td>Anti-atherogenic (early lesions)</td>
<td>5 g/kg</td>
<td>400 g/d</td>
</tr>
</tbody>
</table>

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150
milk fatty acids C14:0 and C16:0 as compared to the control group [57]. Similarly, [6, 26, 27, 28] who reported a decrease in C14:0 and C16:0 FA in milk from cows fed either whole or rolled linseed. A lower proportion of short – and medium – chain fatty acids indicated a reduction in de novo synthesis of fatty acids in the mammary gland [29]. As in Gillman et al. [30] who cited two possible reasons for reduction of the short chain fatty acids in milk; an adverse effect of polyunsaturated fatty acids which decrease the supply of acetate and β-hydroxybutrate for de novo synthesis of these fatty acids and direct inhibitory effect of dietary long chain fatty acids on acetyl-coenzyme-A carboxylase activity (rate-limiting enzyme for de novo fatty acid synthesis).

Cows fed on linseed oil had significantly (P <0.05) higher concentration of C18:0 (21.67g/100g of milk fat) than those fed on ground linseed (18.95g/100g of milk fat), while the concentration of C18:1 was highest in cows fed the control diet Netsanet et al. [57]. The concentration of monounsaturated fatty acids (MUFA) C18:1, which comprised 87.45% of total MUFA, was highest in cows fed GNC based concentrate mixture diet.

Fat supplementation and feed sources richer in unsaturated fatty acids have been shown to increase CLA in milk. This is due to the lipid substrate available by the plant oils for biohydrogenation to CLA and CLA precursors in the rumen. Fats, oils and oilseeds can be quite different in their FA composition (Table 3) and accordingly could be expected to have varying effects on milk fat CLA content. A closer look at the results observed indicates that fats, oils and oilseeds that are rich in linoleic acid are very effective in increasing milk fat CLA content of cows fed TMR containing 50% forage and 50% concentrate Dhiman et al. [58]. Therefore, it could be anticipated that oils or the seeds of soybean, sunflower, safflower, solin and cottonseed would increase the CLA content of cows’ milk fat when fed in TMR. Similarly the oil or seeds from linseed, which is rich in linolenic acid and rapeseed, canola, peanut and olive, which are rich in oleic acid (cis-9, C18:1) and also have some linoleic acid and linolenic acid, have been shown to increase milk fat CLA [58]. AlZahal et al.[50], who supplemented dairy cows diet with 4% linseed oil cis-9, trans-11 CLA production was increased by 150% and a similar increase in cis-9, trans-11 CLA by 120 to 169 % Loor et al.[59] observed. In other investigation, supplemented dairy cows diet with 3% linseed and 3.74% ground linseed, increased the CLA production by 112% and 182%, respectively (Netsanet et al., 2015) and these value was substantially higher than the average values of CLA (0.3 to 0.6% milk fat) reported in the literature [17]. When the effect of different oil treatments (peanut oil, sunflower oil and linseed oil, high in oleic, linoleic and linolenic acid, respectively) on milk fat CLA were compared, sunflower oil resulted in highest CLA concentration in milk fat [60]. Similarly, Dhiman et al. [58] demonstrated that soybean oil is more effective than linseed oil in increasing the milk fat CLA content.

In other study, feeding 4% rapeseed oil to dairy goats Chilliard et al. [2] greatly increased milk fat CLA content (by 204%) and more efficiently than similar doses of rapeseed in dairy cow diets. Feeding linseed oil (α-C18:1-rich oil) greatly increases milk fat CLA content [61] and is at least as efficient as C18:2-rich vegetable oils. Dietary fish oil is more efficient at increasing milk CLA content than an equal amount of plant oils. Biohydrogenation of long-chain polyunsaturated fatty acids (PUFA) C20:5 (EPA) and C22:6 (DHA) is unlikely to yield CLA or trans-11 C18:1 directly. However, fish oil increases ruminal [2] and milk Lacasse et al. [62] trans-11 C18:1, possibly through inhibition of the reduction of this FA in the rumen.

Rumen Protected Fat: A number of processes such as hydrogenation, conversion to calcium salt, formaldehyde treatment, prilling and encapsulation are commonly used to modify lipid and minimize or even eliminate changes of fermentation in the rumen [63]. The addition of calcium salt of soybean oil fatty acids (CaSO) or linseed oil fatty acids (CaLO) to the cows ration caused a significant decrease in the proportion of saturated FA C16:0, while a significant increase in the proportions of long chain fatty acids, namely, C18:0, C18:1, C18:2, Vaccenic acid (VA) and CLA as compared with diets without CaSO [64] or CaLO [57]. In the same study, the cis9, trans11-CLA content of milk increased by 125% for the CaSO supplementation than that of diets without CaSO or CaLO. In the case of CaLO supplementation, the VA increased by 114% to 117% and the cis9, trans11-CLA increased by 94% to 96% compared to diets without CaSO or CaLO. This result is supported by the previous study of Chouinard et al. [65]. In other investigation, supplemented dairy cows diet with 3.5% Ca-salt of linseed oil increased the CLA production by 129% [57].

Ashes et al. [67] studied the effect of diets supplemented with formaldehyde treated canola seeds in cows ration at 6.5% of the diet DM, the milk unsaturated fatty acids (UFA) yield was increased by 54% (143 g/d) and medium-chain saturated fatty acids (MCLA), (lauric acid, myristic acid and palmitic acid) yield was reduced by 10% (38 g/d).
Table 3: Principal fatty acids (% of fat) present in the dietary ingredients used for enhancing CLA content in milk and Meat [66]

<table>
<thead>
<tr>
<th>Dietary ingredients</th>
<th>C_{14:0}</th>
<th>C_{16:0}</th>
<th>C_{18:0}</th>
<th>C_{18:1}</th>
<th>C_{18:2}</th>
<th>C_{18:3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton seed/oil</td>
<td>-</td>
<td>-</td>
<td>23.4</td>
<td>2.2</td>
<td>16.5</td>
<td>57.4</td>
</tr>
<tr>
<td>Soy oil</td>
<td>-</td>
<td>14.5</td>
<td>3.8</td>
<td>1.5</td>
<td>57.2</td>
<td>21.4</td>
</tr>
<tr>
<td>Rapeseed/oil</td>
<td>-</td>
<td>4.9</td>
<td>1.5</td>
<td>1.5</td>
<td>57.2</td>
<td>21.4</td>
</tr>
<tr>
<td>Linseed/oil</td>
<td>-</td>
<td>5.6</td>
<td>3.7</td>
<td>17.7</td>
<td>15.4</td>
<td>57.2</td>
</tr>
<tr>
<td>Sunflower seed/oil</td>
<td>0.1</td>
<td>4.6</td>
<td>2.3</td>
<td>17.7</td>
<td>15.4</td>
<td>57.2</td>
</tr>
<tr>
<td>Safflower seed/oil</td>
<td>0.1</td>
<td>5.9</td>
<td>2.4</td>
<td>15.2</td>
<td>76.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Canola seed/oil</td>
<td>-</td>
<td>4.1</td>
<td>1.8</td>
<td>58.9</td>
<td>22.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Palm oil</td>
<td>1.5</td>
<td>43.6</td>
<td>3.2</td>
<td>45.7</td>
<td>2.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Olive oil</td>
<td>-</td>
<td>-</td>
<td>13.0</td>
<td>2.5</td>
<td>74.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Peanut seed/oil</td>
<td>-</td>
<td>12.3</td>
<td>3.2</td>
<td>51.5</td>
<td>33.2</td>
<td>-</td>
</tr>
<tr>
<td>Corn oil</td>
<td>-</td>
<td>10.6</td>
<td>2.0</td>
<td>27.3</td>
<td>57.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Fish oil</td>
<td>14.0</td>
<td>26.0</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Tallow</td>
<td>3.2</td>
<td>26.6</td>
<td>20.0</td>
<td>44.0</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

Human Dietary Intake Level of CLA: The average milk fat contains 0.3 to 0.6 % CLA [8]. The CLA concentration in milk is relatively stable over a range of processing, manufacturing and storage conditions. Thus, the CLA levels found in dairy products are dependent on the CLA concentration in raw milk. The ability to quantify the CLA content of the human diet has previously been limited by lack of accurate data on the CLA content of major food sources. The data on the CLA content of food products produced under varying conditions have become available allowing estimates of human intakes to be made [35, 36]. Studies have suggested intakes of CLA to be in the range of 0.5-1.5g/d [35, 68] and in another study based on appropriate extrapolation of data from animals to humans, an adult human would require 0.72 to 0.80g of CLA/d to inhibit tumor growth [69, 70, 71].

Consumer Acceptance and Processing Quality of Fat-Modified Milk: Sensory attributes play a key role in determining consumer acceptability for dairy products. Consumer acceptability of synthetic CLA-enriched dairy products containing extremely high level of CLA appears to be low and unrealistic because of cost constraints [72]. Ramaswamy et al. [73] studied the oxidized flavor scores of CLA-enriched milk and butter from cows fed fish, oil, extruded soybeans, or their combination and observed no difference between low- and high-CLA milk or butter. According to Khanal et al. [71] the consumer panel scores of milk for mouth-feel, color, flavor and overall quality did not differ between low- and high-CLA milk, indicating that CLA-enriched (0.11 to 0.12g of CLA/227-ml serving) from cows grazing pasture was acceptable to consumers and was also comparable with milk purchased at a grocery store.

The influence of dietary supplemental fat on the quality of milk and milk products and required processing method will depend on the extent to which the fatty acid composition is altered. Elevating the level of polyunsaturated fatty acids in milk results in softer butter and a lighter color but it tends to be more susceptible to oiling off at 10°C or higher [14]. The major concern associated with increased concentrations of PUFAs is that milk is more susceptible to autoxidation. Approaches taken to control autoxidation include supplementing the cow diet with α-tocopherol, direct addition of antioxidants to milk and modifications to the processing system involved in the production of butter, cheese and other dairy products. Increasing the level of α-tocopherol in milk by dietary supplementation or intramuscular injection has recently been successfully used to control oxidized flavor in milk [75].

CONCLUSION

Milk is considered as a nearly complete food since it is a good source for protein, fat and major minerals. Milk fat contains a substantial concentration of saturated fatty acids (C_{14:0} and C_{16:0}) and relatively low concentrations of mono- and polyunsaturated fatty acids. Dietary saturated fatty acids have been demonstrated to have undesirable hypercholesterolemic effects and increase the risk of coronary heart disease. On the other hand, conjugated linoleic acid and the long-chain polyunsaturated fatty acids, especially linoleic and linolenic have anticarcinogenic and potentially cardioprotective roles in humans. Among the milk fatty acids that has gained attention is conjugated linoleic acid (CLA) (C_{18:2} cis-9 trans-11) because it is unique in its ability to inhibit carcinogenesis in experimental animals. Developing foods that enhance human health is central to dietary approaches for preventing and reducing the economic and social impact of chronic diseases, including cancer, cardiovascular disease and obesity. The nutritional value of milk fat in dairy ruminants may improve by supplementation of oil-seeds, vegetable-oils, protected fat and by different roughage to concentrate ratios.
REFERENCES


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