CONJUGATED LINOLEIC ACID: A MIRACLE IN DAIRY PRODUCT

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INTRODUCTION

Conjugated linoleic acids represent a mixture of positional and geometric isomers of an 18-carbon fatty acid with two double bonds (C_{18}:2). The double bonds present in fatty acids generally have a methylene group between them but in CLA, they have a conjugated arrangement. The presence of fatty acids with conjugated double bonds was first demonstrated in food products by Booth et al. (1935) and Parodi (1977) was the first to demonstrate the presence of cis-9, trans-11 CLA in milk fat. This is the major isomer and it represents about 75-90% of the total CLA in milk fat. This is of special importance because the cis-9, trans-11 CLA isomer has been shown to be anticarcinogenic in biomedical studies with animal models. The others prevalent CLA isomer in milk fat are trans-7, cis-9 and trans-10, cis-12 CLA representing 10% and 2% of the cis-9, trans-11 CLA content respectively.

HEALTH BENEFITS OF CONJUGATED LINOLEIC ACID

i) Role in reducing obesity: CLA have been shown to alter body composition in growing mice, causing an increase in energy expended, increasing body muscle and reducing body fat. Feeding of 1.0% CLA to 6 weeks old mice for 28-32 days reduced total adipose tissue mass by over 50% compared to control diet (Park et al., 1997). Long term feeding of CLA (1.0% CLA for 8 months) appears to have a lipodystrophic effect in female mice, leading to complete ablation of brown adipose tissue, reduced leptin,, increased fat accumulation in the liver and eventual development of insulin resistance (Tsuboyama-Kasaoka et al., 2000). Supplementation of CLA (3.4-6.0 g/day) for 12 weeks led to significant reduction of fat mass in obese humans (Blankson et al., 2000). Other studies have also demonstrated CLA supplementation to reduce body weight, leptin and adiposity in human subject (Smedman et al., 2001, Thom et al., 2001).

ii) Role in type II diabetes: In type II diabetes associated with obesity or over weight, CLAs may have the ability to normalize glucose metabolism. Ryder et al. (2001) showed that feeding a mixture of CLA isomers induces adipose-lowering effects and enhances glucose uptake into muscle of ZDF rats.

iii) Role in cardiovascular diseases: Coronary heart disease is generally related to abnormal level of fat in the blood, particularly high levels of low-density lipoproteins cholesterol (Bad cholesterol). In animal model a number of studies show potential benefits of CLA on cardiovascular diseases. Supplementation of CLA to hyper cholesterolemic diet of rabbit for 12 weeks significantly reduced serum triglyceride and low density lipoprotein cholesterol. Aortas of rabbits fed the CLA containing diet exhibited less atherosclerotic plaque formation (Lee et al., 1994). However, a limited number of studies on humans have not provided consistent evidence for beneficial effects of CLAs on blood fats and atherosclerosis.

iv) Role in carcinomas: CLA can inhibit cancer formation and growth. Most studies in animals have shown beneficial effect of CLA on heart, skin, liver and colon cancers. Synthetic mixture of CLA isomers inhibits chemically induced skin tumor promotion as well as mammary and colon tumor genesis when added to semi synthetic diets (Belury et al., 1996; Ip et al., 1991; Liew et al., 1995). Although clinical studies are limited but low risk of breast cancer was found to be associated with high intakes of CLAs. Further human studies are needed to follow up these promising results.

v) Role in other diseases: CLA has also been found to be associated with bone formation and modulation of immune system in animal models. Rat pups exposed to CLA (0.5%) either in utero or during the first 7 days of life had significantly longer tail lengths (a measure of skeletal growth) compared with pups fed a diet without CLA (Poulos et al., 2001). CLA also modulates the events of immunity by decreasing the eicosanoid and histamine production. Arachidonate derived eicosanoids, derived through cyclooxygenase and lipoxygenase pathways are produced by numerous types of immune cells and are thought to regulate cytokine synthesis and inflammation.

In view of the foresaid discussion, CLA seems to have potential beneficial effects on health status of humans.

SYNTHESIS OF CLA IN THE RUMINANTS

Conjugated linoleic acid (CLA) is formed as an intermediate product of dietary fat digestion in the rumen. In ruminants dietary fat source is mainly forages and seed oil. The lipid composition of forages consists largely of glycolipids and phospholipids while lipid composition of seed oils is predominantly triglyceride. Major unsaturated fatty acid in these lipids is linoleic acid (C_{18}:2). Minor unsaturated fatty acids are linolenic acid (C_{18}:3) and oleic acid (C_{18}:1). During digestion process lipids ester hydrolysis by microbial lipases to release fatty acids. Then there is biohydrogenation of the unsaturated fatty acids by rumen bacteria mainly (protozoa of minor importance).The biohydrogenation pathway of linoleic acid involves an initial isomerization step resulting in the formation of a conjugated cis-9, trans-11 acid which then undergoes hydrogenation of its cis double bond leaving trans-11 octadecenoic acid (also called vaccenic acid). The final step is a second reduction resulting in the formation of stearic acid, a saturated fatty acid (C_{18}:0). The first two steps, ester hydrolysis and formation of vaccenic acid are rapid whereas the final step is slow. As a consequence vaccenic acid accumulate in the rumen (Harfoot and Hazlewood, 1997) and is, therefore, more available for absorption. Because of the extensive bio-hydrogenation of linoleic acid to vaccenic acid it has been suggested that there is little accumulation of Cis-9, trans-11 in the rumen. Much of the Cis-9, trans-11, CLA found in bovine milk is actively synthesized within the mammary gland from vaccenic acid (Griinari and Bauman, 1999). This is possible through the action of stearoyl-CoA desaturase (SCD), an enzyme capable of adding a Cis-9 double bond to vaccenic acid (C_{18}: 1 trans-11) to give cis-9, trans-11 CLA. A no. of studies (Griinari et al., 2000; Cori et al., 2001; Lock and Garnsworthy, 2002) showed that endogenous synthesis via ?^{9}- $\triangle^9$ desaturase represented the predominant source of Cis-9, trans-11 CLA in milk fat over a wide range of diets. trans-7, cis-9 CLA in milk fat is also synthesized via ?^{9}- $\triangle^9$ desaturase in the mammary gland (Cori et al., 2002). In contrast, other CLA isomers found in trace amounts in milk fat appear to originate solely as intermediates from incomplete biohydrogenation in the rumen.

FACTORS AFFECTING CLA CONTENT OF MILK

The amount of CLA found in whole milk is generally about 4.5 to 5.5 mg/g fat, although variation of as much as 2.5 to 18 mg/g fat has been reported. Breed, age of the animal and stage of lactation may influence the milk CLA content. The CLA contents of meat and dairy products are altered little by processing, storage or cooking and hence, the concentration in food depends primarily on the ruminal production of vaccenic acid and to a lesser extent CLA and the tissue activity of ?^{9}- $\triangle^{9}$ desaturase. Differences in CLA content of milk are largely related to diets. However, individual variation among cows under identical diet and management condition is also reported.

i) Dietary factors: Various dietary factors affecting CLA content of milk can be grouped under three categories based upon potential mechanism of action (Bauman et al., 2001).

a) Dietary factors that provide lipid substrate: Plant oils high in unsaturated fatty acid like linoleic acid and linolenic acids are particularly effective. Kelly et al. (1998) supplemented the basal diet with 53 g/kg DM of peanut oil (high oleic acid), sunflower oil (high linoleic acid) or linseed oil (high linolenic acid). CLA concentrations were 13.3, 24.4 and 16.7 mg/g milk fat, respectively. The increase in CLA levels observed with the sunflower oil treatment represented levels approximately 500% greater than those typically seen in traditional diets. Chouinard et al. (1998) fed diets supplemented with 4% DM of calcium salts of fatty acids from canola oil, soybean oil or linseed oil. The resulting milk CLA concentrations were 13.0, 22.0, 19.0 mg/g fat for canola oil, soybean oil and linseed oil respectively and 3.5 mg/g fat for control. Soybean oil, which is high in linoleic acid, was most effective at increasing the CLA. However, saturated fatty acids do not play any role.

b) Dietary factors affecting bacteria involved in rumen biohydrogenation: Forage to concentrate ratio can affect the biohydrogenation in the rumen environment. Kelly and Bauman (1996) found that the CLA levels in milk were halved when the forage concentrate ratio of the diet was changed from 50:50 to 20:80. Griinari et al. (1998) showed that high concentrate diets could alter the products of rumen biohydrogenation of polyunsaturated fatty acids resulting in an increase in the proportion of vaccenic acid and trans-10, Cis 12 CLA isomers.

c) Dietary factors that involve a combination of lipid substrate and modification of rumen biohydrogenation: Cows on lush spring pasture will have a CLA content in milk that is 2 to 3 fold greater than corn based total mixed rations. However, as pasture matures, this difference ceases.

Dietary supplementation of synthetic CLA through abomasal infusion also increases CLA in milk fat. Denatured protein coated fat containing CLA can also be given. Results prove that supplements of CLA result in dose-related increase in the concentration of CLA in milk fat.

ii) Individual factors: CLA content of milk for individual cows varies relative to diets ranging from total mixed rations to pasture in a consistent pattern. A rank order is maintained between individual cows when they are switched among diets (Peterson et al., 2002; Kelsey et al., 2002). This individual variation may be due to difference in ruminal production of vaccenic acid and CLA, even when animals are consuming the same diet. The ruminal production variation may be due to feeding pattern and chewing frequency that affect the rumen environment. Some genetic variation may be reason which affects the ?^{9}-desaturase activity and endogenous synthesis of CLA in the mammary gland (Peterson et al., 2002).

CONCLUSION

CLA have been found to exhibit a number of beneficial health effects in cancer, cardiovascular diseases and diabetes in animal model. The biosynthesis of CLA and dietary factors that cause variation in the content of CLA in milk fat have been identified. So there is a great opportunity to increase the concentration of CLA in dairy products by diet manipulation and also by genetic selection of cows. Overall, the presence of CLA in milk fat show that milk and dairy products contain micro components that provide benefits beyond that associated with traditional nutrients.

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