Adding Value to Milk by Increasing Its Conjugated Linoleic Acid Content[1]

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Introduction

Milk from dairy cows has long been an important component of the human diet. Cattle and other ruminants have the unique ability to consume organic material indigestible to humans and convert it into products commonly found in milk. Milk is a food with high nutritional value and along with meat and eggs, it is considered to have the highest protein quality of all foods. Milk contains a large number of bioactive components that have various biological functions known to positively impact human nutrition and health (Table 1). One of the most promising bioactive components of milk is called conjugated linoleic acid (CLA). This is a naturally occurring fatty acid, and in laboratory animals it has been shown to inhibit cancer, promote the immune system, reduce the effect of type 2 diabetes, promote bone growth, and reduce blood clotting. The objective of this publication is to briefly review dietary strategies that have been used to increase CLA concentrations in milk and to show how this approach can be used to add value to milk and milk products.

Synthesis of Conjugated Linoleic Acid in the Cow

Conjugated linoleic acid is formed by microbes in the rumen and by tissue metabolism in the mammary gland (Badinga and Green 2006; Figure 1). The forages and grains fed to dairy cows contain relatively high amounts of the essential fatty acids known as linoleic and linolenic acids (18:2 and 18:3, respectively; Figure 1). Conjugated linoleic acid is formed by conversion of linoleic acid (*cis*-9, *cis*-12 double bonds) to CLA (*cis*-9, *trans*-11 double bonds). During this conversion, a *cis*-12 double bond is converted to a *trans*-11 double bond, which slightly alters the specific structure and activity of the compound. Conjugated linoleic acid has the same overall structure as linoleic acid (18 carbons and 2 double bonds), but CLA does not contain a methylene group (CH_2) between adjacent double bonds (Pariza et al. 2001; Figure 2). The word "conjugated" simply means to join together. This can easily be seen in Figure 2 where the "CH_2" group has been removed from the carbon involved in the double bond formation — thus, the name CLA. There also is evidence that much of the *cis*-9, *trans*-11 CLA found in milk is actually synthesized within the mammary gland from vaccenic acid (*trans*-11 18:1) through the action of an enzyme (Δ^9-desaturase) capable of adding a *cis*-9 double bond to vaccenic acid (Figure 2). Because much of the *cis*-9, *trans*-11 CLA is synthesized in the mammary gland, dietary conditions that increase vaccenic acid formation in the rumen are key to increasing CLA concentration in milk.

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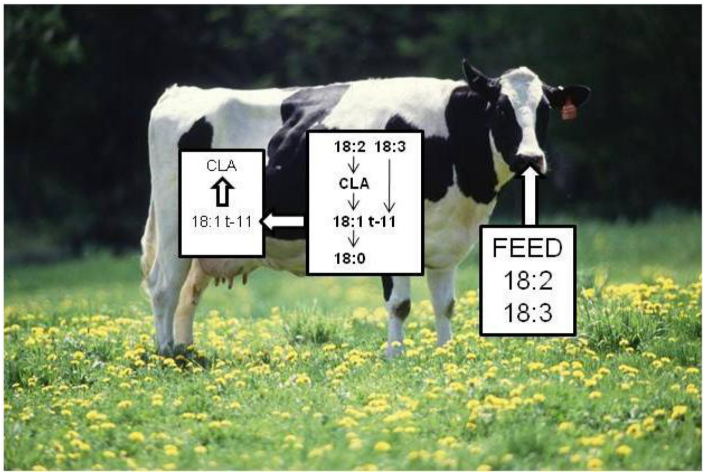

Figure 1. Formation of conjugated linoleic acid in the dairy cow. Conjugated linoleic acid is first produced in the rumen from dietary linoleic acid (18:2). Additionally, dietary linoleic and alpha linolenic (18:3) acids are converted to vaccenic acid (18:1 t-11), which escapes to the mammary gland, where it is enzymatically converted to conjugated linoleic acid.
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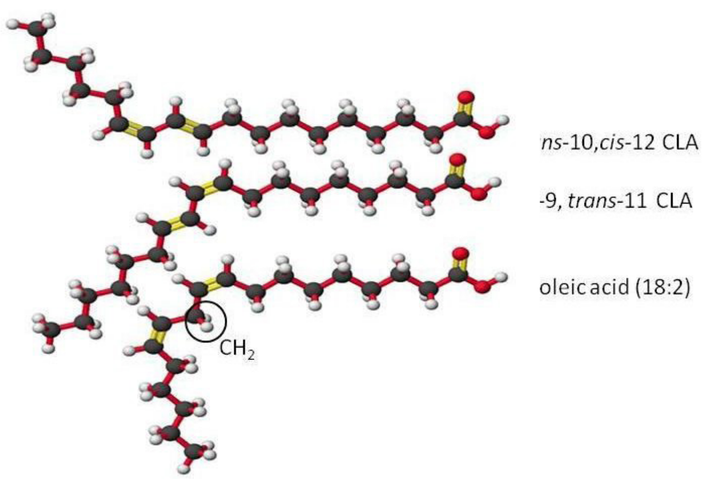

Figure 2. Structures of the most biologically active types of conjugated linoleic acid (top and center) and ordinary linoleic acid (bottom). Note the absence of CH_2 in conjugated linoleic acids. (Photo credit: Pariza et al. 2001)

Potential Health Benefits of Conjugated Linoleic Acid

Most substances in nature that demonstrate anti-cancer properties are of plant origin and are only present at trace levels. In contrast, CLA is found almost exclusively in ruminant products and has been shown to be one of the most potent naturally occurring anti-carcinogens. Research at the University of Wisconsin provided the first evidence for anti-cancer activity of the uncooked and fried hamburger. It was later shown that the anti-carcinogenic substance was actually a mixture of four isomeric derivatives of linoleic acid that had the ability to inhibit cancer formation. The anti-carcinogenic mixture was henceforth designated as conjugated linoleic acid or CLA.

Other reports have since indicated that CLA could have other physiological effects in addition to its cancer-fighting properties. Some of these effects include a role in reducing atherosclerosis and a role in the treatment of diabetes. There also is evidence that CLA can reduce body fat and increase lean mass in growing animals, counteract immune-induced muscle wasting in poultry, and enhance bone formation in rodents. These reports collectively suggest that consumption of CLA-enriched milk or milk products could lead to improved health in humans.

Increasing the Concentration of Conjugated Linoleic Acid in Milk

In light of potential benefits of CLA for human health, many researchers have looked at possible ways of increasing the concentration of CLA in bovine milk. Two practical approaches have been used to achieve this goal. The first approach is to use dietary modification in an attempt to increase cows' natural production of CLA. The second approach is to increase the concentration of CLA in milk through feeding mixtures of CLA isomers protected from the microbial biohydrogenation in the rumen.

Allowing cows to graze pasture has been found to result in a much higher concentration of CLA in milk fat than that achieved with typical total mixed rations based on hay and grains. Other dietary factors associated with high milk CLA concentrations include the source and availability of supplemental dietary oil to the rumen microbes. Dietary fish oil supplementation has been shown to increase the concentration of CLA in milk. It has been suggested that fish oils interfere with the conversion of vaccenic acid (18:1) to stearic acid (18:0), an effect that may account for increased concentrations of vaccenic acid in milk from cows supplemented with fish oil. The increased availability of *trans* vaccenic acid in milk can lead to increased synthesis of *cis*-9, *trans*-11 CLA in the mammary gland.

Conjugated linoleic acid can be synthesized in the laboratory from vegetable oils like sunflower oil. The CLA produced in this manner can be used to increase CLA concentration in milk fat if the CLA isomers are protected from the rumen environment. Methods available to reduce microbial biohydrogenation in the rumen include encapsulation of the fat in casein or feeding the fat as a calcium salt. If dietary fats are not protected from microbial biohydrogenation in the rumen, much of the dietary unsaturated fatty acids are quickly converted to saturated fats, a process that will decrease the ability of ruminants to synthesize beneficial compounds such as CLA in the rumen or mammary gland.

Conclusion

Commodity milk production will continue to support the U.S. dairy industry. However, if the U.S. dairy industry is to grow and compete with other multinational companies, production must be targeted to produce CLA-enhanced milk. As consumers continue to become more conscious of the link between diet and health, milk designed to have enhanced levels of CLA may provide new market opportunities for milk and milk products such as butter and cheese.

References

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Table 1. Milk components and associated health benefits

Milk components	Bioactive components	Health benefits
Fat	CLA, phospholipids, butyric acid, α-linolenic acid, milk fat globule membrane protein	Cancer prevention Diabetes prevention Immune enhancement Bone growth promotion Reduction of blood clotting Cardiovascular health
Proteins + enzymes	Immunoglobulins, lactoferrin, transferrin, folate binding protein, lactoperoxidase, transforming growth factor-ß, insulin-like growth factor-I, lysozymes	Immune enhancement Antibacterial activity Pre-biotic properties Aids in iron transport Cancer prevention Growth promotion
Minerals	Calcium, magnesium, phosphorus	Bone formation Slow bone mass loss Gum disease prevention
Vitamins	Niacin, vitamin D	Heart health
Source: Adapted from T. Mackle, *Milk of the Future*, Dairying Research Corporation, Private Bag 3123, Hamilton, New Zealand.		