

Managed Milk Fat Depression

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Abstract

Dairy scientists have been studying milk fat synthesis for over a century. Primary objectives were to identify the cause and then prevent diet-induced milk fat depression, otherwise known as low-milk fat syndrome. This is because milk has historically been priced upon fat content, thus milk fat depression results in reduced economic return for dairy producers. Many theories have been proposed to explain the cause of milk fat depression, but ultimately have been deemed incorrect. Recently it has been discovered that milk fat depression is the result of an altered rumen fermentation pattern, which results in synthesis of unique fatty acids that inhibit milk fat synthesis. Production of these fatty acids requires both an altered rumen environment and dietary polyunsaturated fatty acids. These fatty acids are now available for use as dietary supplements and may allow producers to: manage the amount and type of milk fat produced, manipulate and improve energy balance in early lactation and during periods of heat stress, prioritize the production of other milk components (protein) and produce a low fat product.

Introduction

Milk is a valuable source of nutrients providing energy, high quality protein, and essential minerals and vitamins. Fat is the foremost energy component in milk and it accounts for many of the physical properties, manufacturing characteristics and taste qualities of milk and milk products. Milk fat is also the most energetically and economically expensive milk component to synthesize. Therefore, depending upon feed costs and changes in milk fat value, economics favor increased production of milk fat in some circumstances and decreased production in others. In addition, fat is the most variable among the major milk components and its synthesis is affected by many factors - especially dietary and environmental factors.

As the economic value of milk fat continues to decrease, relative to that of other milk components, there is greater interest in discovering methods of regulating milk fat synthesis. For example, Canada and many countries in Europe have quotas for the quantity of saleable milk fat, and these economies may favor milk production with a higher protein and lower fat content. In addition, reducing milk fat synthesis during specific times of lactation may be biologically advantageous because of its energetic costs. For example, the negative energy balance associated with early lactation is known to adversely affect reproduction and make cows more susceptible to metabolic disorders, thereby limiting milk yield over the entire lactation. Reducing milk fat synthesis during this period may alleviate the severity of negative energy balance in early lactation and thus improve performance and animal well-being. In addition to early lactation, there are times during the year when grazing cows may have an inadequate energy supply due to weather conditions and thus synthesis of milk and milk components will be limited. Heat stress is an additional weather-induced condition which results in reduced feed intake and thus decreased energy availability. Again, reducing milk fat synthesis during such periods of energy insufficiency could alleviate the energy deficit and may even allow for a more efficient use of nutrients for synthesis of other milk components (e.g. protein).

Conjugated Linoleic Acid

It is increasingly recognized that diet can be a contributing factor in the prevention, as well as in the development of some disease conditions. As the biological role of fat becomes better understood, interest in designing milk fat to improve its healthfulness as a food increases. Conjugated linoleic acids (CLA) are components of milk fat that have positive effects on human health and disease prevention. For example, dietary CLA has been shown to be potent a

anti-carcinogen and reduce the incidence of heart disease (Parodi, 1997). CLA are related to rumen biohydrogenation of polyunsaturated fatty acids (fatty acids commonly found in plant material) and are derived almost exclusively from food products of ruminant origin (Bauman et al., 2000; 2001). For further details on milk fat CLA and CLA's effects on human health see paper in this proceedings authored by Dr. Dale Bauman.

As a consequence of CLA's positive health effects, there has been a large effort to increase CLA content in milk, thus increasing the value of milk and milk products. However, in an attempt to enhance milk fat CLA it was discovered that providing CLA dramatically reduces milk fat percentage and yield (Chouinard et al., 1999; Loor and Herbein, 1998). Subsequent studies confirmed that a supplemental mixture of CLA significantly reduced milk fat yield (Mackle et al., 2002). Rumen-protected CLA (Ca^{++} salts) also decrease milk fat when fed to cows consuming either a TMR or rotationally grazed (Geisy et al., 1999; Medeiros et al., 2000). In general, depending upon amount fed, CLA supplements decrease milk fat content and yield by 15-50% (Baumgard et al., 2002). In addition, a dietary supplement of CLA has been reported to decrease the milk fat content in lactating pigs (Harrell et al., 2000) and nursing women (Masters et al., 1999).

The CLA supplements used in the studies referenced above contained various types of CLA. Based upon changes in milk fat composition when cows experience normal diet-induced milk fat depression, we hypothesized that a specific type of CLA was responsible for reducing milk fat synthesis. We examined this by infusing relatively pure CLA isomers (Figure 1). As anticipated, the *trans*-10, *cis*-12 CLA isomer resulted in over 40% reduction in milk fat percentage and yield whereas *cis*-9, *trans*-11 CLA had no effect (Baumgard et al., 2000). This isomer is a very potent inhibitor of milk fat synthesis with a dose of 3.5 g/d (0.006 lb/d) eliciting a 25% reduction in milk fat yield.

Effects of CLA on milk fat are rapid and apparent within 24 hrs (Figure 1). Equally important is that milk fat production returns to normal levels within a few days after CLA removal. Effects also appear to be specific for fat as other milk components have not changed. Most of CLA trials have been short term (4-5 days) and have utilized cows in mid to late lactation, and in these trials milk yield, milk protein, milk lactose and feed intake have generally been unchanged (Baumgard et al., 2000; Baumgard et al., 2001; Chouinard et al., 1999; Loor and Herbein, 1998). However, the decrease in milk fat secretion without a reduction in feed intake would cause a more positive energy balance. CLA could benefit production and animal well being by improving whole animal energy status during specific stages of lactation and at certain times of the year. As will be discussed in the following sections these benefits may include increased milk yield, increased synthesis of other milk components, decreased metabolic disorders and improved reproductive efficiency.

Production of low fat milk can be easily accomplished by a number of dietary situations including low fiber/high concentrate rations, small fiber particle size and the inclusion of certain oils. However, often a negative side effect of diet-induced milk fat depression is the increased risk of metabolic disorders including rumen acidosis, ketosis, displaced abomasums and lameness. Therefore, utilizing CLA to reduce milk fat synthesis while maintaining animal well-being and production offers an exciting new management tool for dairymen. For a review of milk fat depression and CLA role in diet-induced milk fat depression see review by (Bauman et al., 2000).

Transition Period

The period immediately prior to and following calving is associated with large metabolic adaptations. Characteristically, cows in this stage of lactation are synthesizing and secreting more energy (in their milk) than they can consume in feed (Drackley, 1999). As a consequence, animals experience a severe negative energy balance, which is associated with an increased risk of metabolic disorders and health problems (Drackley, 1999; Goff and Horst, 1997), decreased milk yield and reduced reproductive performance (Beam and Butler, 1999; Lucy et al., 1992). Improving energy balance immediately after calving has been intensely studied, with traditional methods being increasing dietary concentrates and feeding supplemental fat. However, negative energy balance remains a problem that reduces economic return for producers.

Milk fat is the major determinant of energy in milk and thus largely influences animal energy balance. Reducing the nutrient demand for milk synthesis via inhibiting milk fat production should conceivably alleviate the severity of negative energy balance. Improving energy balance will decrease the demand for fat mobilization and thus decrease blood NEFA concentrations thereby reducing the incidence of fatty liver and ketosis.

The extent of negative energy balance during the first few weeks postpartum negatively influences ovarian activity and largely determines the length of time to first estrus cycle after calving. Recovery of energy balance from its most negative level in early lactation toward a more positive balance provides an important signal for initiation of ovarian activity (Beam and Butler, 1999; Lucy et al., 1992). Reduced milk fat yield early in lactation may increase energy balance and allow a more rapid return of ovulatory estrous cycles. Similarly, conception rates are affected by energy balance (Lucy et al., 1992) and thus a CLA-induced reduction in milk fat may improve conception rates. Therefore, an improvement in energy balance during early lactation may have positive effects on several dimensions of reproductive performance. Consistent with this, studies from Dr. Bauman's group indicate that cows fed rumen-protected CLA, which caused a minor reduction in milk fat yield, tended to have improved reproductive success including days to first ovulation and conception rates (Overton et al., 2001).

Heat Stress

Heat stress negatively impacts milk synthesis and impairs reproductive performance. As a consequence, heat stress is a significant financial problem in many areas of the United States and most of the world. The mechanism by which this occurs is mainly via reduced feed intake, but also includes reduced rumination, digestion and absorption of nutrients and an increase in maintenance requirements (Collier and Beede, 1985). Essentially, because of reduced feed intake the dairy cow is putting herself in a negative energy balance, similar to the negative energy balance observed in early lactation. Inhibiting milk fat synthesis during periods of heat stress may alleviate the negative energy balance. As a result of the extra available energy, synthesis of other milk and milk components may increase (i.e., lactose and protein).

In addition to enhancing milk yield, inhibiting milk fat synthesis and thus improving energy balance may increase reproductive success. Heat stress induced reproductive failure is very costly to dairy producers. Typical management procedures are to increase the energy density (via increased grain and or increased fat) of the diet. However, decreased milk production and impaired reproductive performance remains costly during heat stress. Improving energy balance via reducing milk fat production represents an alternative approach to improve dairy farm profitability.

Milk Yield

Peak milk yield usually occurs approximately 40-60 days post-calving. Prior to and during this stage of lactation animals are in a negative energy balance. As a consequence, milk synthesis in high producing dairy cows may be limited by energy availability. This is especially pertinent during peak milk synthesis. Alleviating the energy crisis due to milk fat synthesis during this stage of lactation may cause an increase in production of other milk components and thus allow the animal to achieve its genetic milk yield potential. In the limited work-to-date utilizing rumen-protected CLA, cows treated in early lactation responded with an increase (approximately 10%) in milk yield (Chouinard et al., 1999) whereas no increases were observed in cows treated during established lactation (Perfield et al., 2001).

To illustrate the bioenergetic potential, consider a cow producing 45 kg/d (100 lb/d) of milk (normal composition). Feeding CLA during peak yield (40-60 days post calving) and inhibiting milk fat synthesis by 50% would free up enough energy to produce an extra 11 kg (24.2 lb) of milk. Assuming energy was limiting genetic potential for milk production and 100% of additional energy was utilized for milk synthesis, this would result in a peak milk yield of 56.1 kg/d (123 lb/d). This is particularly significant because each kg increase in peak milk yield equates to an increase in total lactation milk yield of approximately 127 kg (Dr. Bob Everett, Cornell University; Personal Communication; Figure 2). Therefore, in this example, using CLA to reduce milk fat synthesis during peak milk yield would result in an increase in total lactation yield of 1,400 kg (3,080 lb; normal composition). It is presumed the value of extra milk (normal composition) would exceed monetary losses to the production of low fat milk during CLA feeding (40-60 days post calving).

Milk Protein and Fat Quota's

Decreasing milk fat reduces energy requirements for milk production and as a consequence dietary CLA could increase milk protein yield if protein synthesis was limited by energy availability. This situation often occurs in grazing dairy cows, and Medeiros et al. (2000) demonstrated milk protein percentage and yield were increased 10 and 13%, respectively, when grazing cows received 90 g/d (0.2 lb/d) of a rumen protected CLA supplement.

As the economic value of milk fat continues to decrease, relative to that of milk protein, there is greater interest in discovering methods of regulating milk composition and in particular milk fat synthesis. For example, Canada and several European countries have quotas for the quantity of saleable milk fat, and these economies may favor milk production with a higher protein and lower fat content. Therefore, depending upon marketing regulation, in some instances a reduction in milk fat yield would be of economic value to producers.

Conclusions

Having the ability to safely manage milk fat yield will provide producers more flexibility in regulating overall production costs. In addition, regulating milk fat synthesis provides an alternative approach (as opposed to increasing the energy density of the diet) to manipulate and improve energy balance. Enhancing energy balance may allow for increased yield of milk and milk components, improve reproductive performance in early lactation and during heat stress, and decrease the incidence of metabolic disorders.

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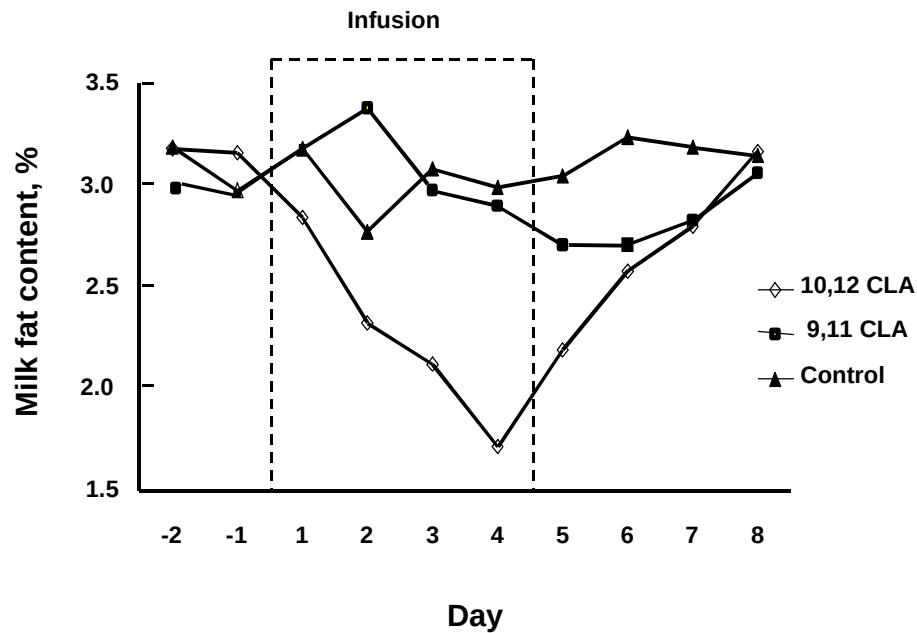


Figure 1. Temporal pattern of milk fat content during administration of two specific conjugated linoleic acid (CLA) isomers. Adapted from Baumgard et al., 2000

Hypothetical Lactation Curve

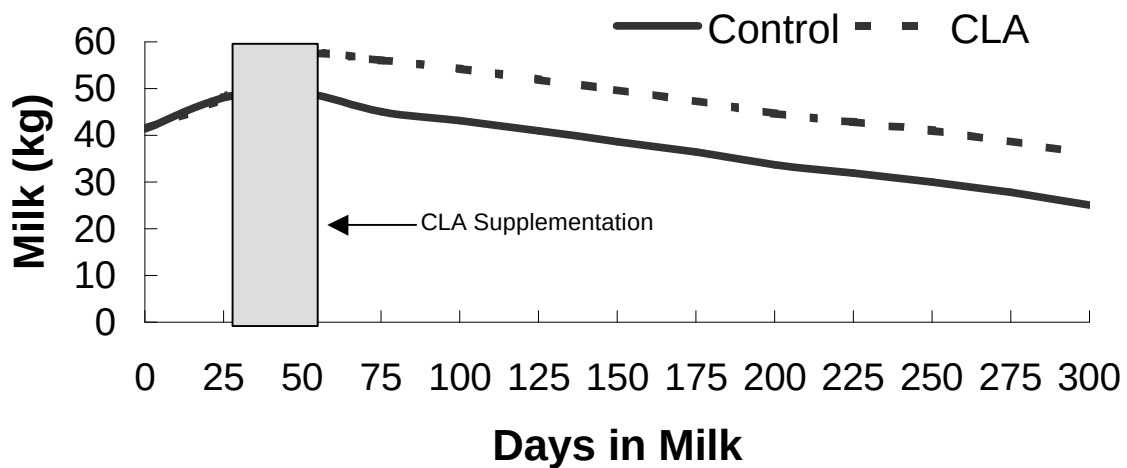


Figure 2. Hypothetical lactation curve using conjugated linoleic acid (CLA) to reduce milk fat synthesis during peak yield. Adapted from Baumgard et al., 2002