You Control Milk Fat Depression –Don't Let It Control You

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Abstract

Diet-induced milk fat depression (MFD) continues to have major economic impact in the dairy industry. Finding solutions to this problem remains a priority. Current thinking links MFD with certain types of conjugated linoleic acid (CLA) produced from lipid metabolism in the rumen by the mixed microbial population. This paper will discuss a systematic approach to understanding and addressing the nutritional interactions that cause MFD.

Introduction

Sustained drops in milk fat yield translate into significant economic loss on a dairy because milk pricing is based on components in most Federal Orders. Fortunately, many producers experience few problems with MFD because their nutritionists have developed and maintain a consistent, well formulated feeding program. Even the best nutritionist, however, can fall victim to MFD after responding to changes in feed prices, limited availability of some feed ingredients, or unexpected changes in nutrient composition of feed ingredients. Apparently logical changes in the feeding program can drop milk fat several fractions of a percentage point to more than a full percentage point in a short period of time. It can take several weeks to months to identify the nutritional cause and return milk fat to normal.

CLA - bioactive lipids made by microorganisms in the rumen from unsaturated fatty acids in the feed.

MFD is caused by nutrition-driven changes in the rumen. Lipids in feed are metabolized by the rumen microbial population, which leads to the formation of bioactive lipids. "Bioactive" means the lipids affect living cells and tissue. These bioactive lipids are referred to as conjugated linoleic acid or CLA. Microorganisms in the rumen produce more than twenty types of known CLA but three have been shown to cause MFD. This discussion will refer to these three as CLA_{MFI}, because these CLA act as milk fat inhibitors (MFI). The CLA_{MFI} produced in the rumen travel via the blood to the mammary gland, where they inhibit the synthesis of milk fat by impairing the production of several enzymes essential for fat synthesis in the mammary gland. CLA_{MFI} are also present in cows that produce acceptable milk fat levels, but at concentrations too low to cause MFD.

CLA_{MFI} – the three CLA produced in the rumen that are milk fat inhibitors and cause MFD.

The bottom line is that the type of feed the cow consumes affects rumen conditions, which in turn affects the amount and type of CLA produced. Since CLA_{MFI} overproduction in the rumen leads to MFD, excess CLA_{MFI} and therefore MFD can be controlled by paying close attention to several key nutritional risks. This paper outlines these risks and thus grants the nutritionist control of milk fat synthesis.

What Nutritionists Worry About in Trying to Prevent or Overcome MFD

Do I Have a Case of MFD That Can Be Controlled Nutritionally?

When considering the milk fat status at any given time for a given herd, there are a few basic questions that nutritionists will ponder before diving into aggressive dietary changes that may or may not improve milk components. A few of these include:

- Am I satisfied with the herd's milk fat production and should I take the risk of messing up a good thing?
- I've seen a drop in milk fat percentage but is the drop in lbs of fat really large enough to affect my milk check?
- I've seen a drop in milk fat recently but is it a sustained trend or just part of the normal variability in fat tests?
- Is the drop in fat test I've seen a nutritional problem or could it be regular seasonal changes in lactation that occur each year?

What are the Nutritional Factors That Can Cause MFD?

Five independent nutritional factors are currently targeted for influencing rumen production of CLA_{MFI} and development of MFD (represented in Figure 1). Each will be discussed. More is known about the influence of forages, starch, and fat in the diet. These factors will receive more detailed consideration in this paper than yeast and management influences, which have been less tested and documented.

Figure 1. Circles representing the independent nutritional and management factors associated with increased risk of MFD in lactating dairy cows.

Too much fat in the diet of dairy cows is a classic cause of MFD. Nutritionists are keenly aware that fat must be limited to lower levels than protein or carbohydrate to avoid impaired rumen fermentation, reductions in feed intake, and MFD. It is tempting to push the limit on feeding fat when prices are favorable for high-fat byproducts, when grain prices reach record levels making commercial fats more competitive, or when the farm has access to (perceptually inexpensive) high-fat waste products from a nearby food processing plant. The key to preventing MFD from these high-fat ingredients is to fully understand the nutritional and chemical impact these ingredients have on both the rumen microbes and the cow, and to choose a feeding rate that will provide the most benefit with the least risk of detriment to the production of milk and components.

Fat supplements pose different degrees of MFD risk. Low-risk fats are those that cause little disruption of the microbial population in the rumen and thus maintain normal fermentation and limited production of $CLA_{MFI.}$ Low-risk fats are generally characterized by high saturated fatty acids or calcium salts of fatty acids. Most commercial bypass fats are based on one or both of these characteristics, so the risk of MFD is low. Bypass fat feeding rate is usually limited by cost and availability. In addition, bypass fats are dry solid products, rather than liquid fats, and therefore easier to package, transport, and mix on the farm without specialized equipment. Bypass fats are also called rumen-inert fats to emphasize their lower risk to disrupt the rumen.

High-risk fat supplements contain more unsaturated fatty acids (Table 1) that are typically found in forages, cereal grains, and oilseeds (cottonseed, soybeans, canola, sunflower, etc). A high concentration of unsaturated fatty acids in the rumen from one or more of these sources can inhibit some microbial species in the rumen. This change can favor species that produce $CLA_{MFI,}$ the

Table 1. Individual and total unsaturated fatty acid (UFA) values for fat sources used as energy supplements in cattle rations.

Fat	Oleic	Linoleic	Linolenic	Total UFA
	---------------------- % of total--------------------			
Tallow	42	3		45
Animal-vegetable	34	16	2	52
Palm	43	10		53
Poultry fat	41	19	1	61
Restaurant grease	48	20	3	71
Cottonseed	19	53		72
Soybean	25	53	7	85
Corn	29	55	1	85
Canola	60	20	10	90

accumulation of which can lead to MFD. These unsaturated high-risk fat supplements are referred to as rumen-active fats to emphasize their tendency to disrupt rumen conditions.

A convenient tool to monitor risky unsaturated fatty acid intake is called RUFAL or Rumen Unsaturated Fatty Acid Load. RUFAL reflects the total unsaturated fatty acid supply entering the rumen each day from feed. RUFAL accounts for unsaturated fatty acids from all feed ingredients rather than fatty acids only from fat supplements. RUFAL may better indicate potential rumen fermentation disruption than simply calculating the percentage of fat added to the diet. Studies show that increasing RUFAL causes fermentation disruption, which can hurt animal performance. Excessive RUFAL can lead to MFD. Although a single RUFAL cutoff to prevent MFD has not been established, values below 500 g/day are viewed as low fat intakes while those above 500 g/day indicate fatty acid intakes that may be at risk of being too high. It should be noted that herds with milk fat above 3.8% have fed RUFAL in excess of 1,000 g/day, so the tool only suggests a guideline for identifying diets low or high in fat.

Of the many strategies to feeding fat to dairy cows, perhaps the most important, yet most elusive, is the proper amount to feed. A proper feeding rate can usually prevent MFD associated with fat supplements. To effectively use the vast array of fat products available, practical guidelines must be developed that match sources of fat with proper supplementation. Many recommendations to limit rumen-active fats suggest a single feeding rate for added fat in dairy rations. These single numbers are easy to remember and calculate, but don't account for fatty acid contributions from the basal diet or adjust fat feeding rates in relation to fat supplement composition. An alternative approach includes the following two calculations:

1. Limit the total fat consumed from all sources (basal ingredients plus fat supplements) so that

$$\text{lbs total fatty acid intake} = \text{lbs milk fat produced}$$

2. Limit rumen-active fats so that

$$\text{lbs. rumen-active fatty acids} = \frac{4 * \text{NDF} * \text{DMI}}{\text{UFA} * 100}$$

Where,
NDF is % of the dairy TMR
DMI is dry matter intake of cows in lbs/day
UFA is % unsaturated fatty acids in the rumen-active fat supplement

Detailed instructions on using these calculations including examples can be seen at http://virtusnutrition.com/. Click on the window labeled "**What's Your Fat Feeding Strategy?"**

High grain diets are also known to cause MFD. Rapid fermentation of starch can cause acid accumulation and lower pH in the rumen. Factors that can result in marked changes in rumen pH through any 24-h period include: dietary carbohydrate profile and rates of degradation of the carbohydrate fractions as affected by source, processing, and moisture; physically effective NDF (peNDF) supply as affected by source and particle size; and production of salivary buffers as a function of peNDF supply and source. Despite our general understanding of these factors, the degree and duration of low rumen pH

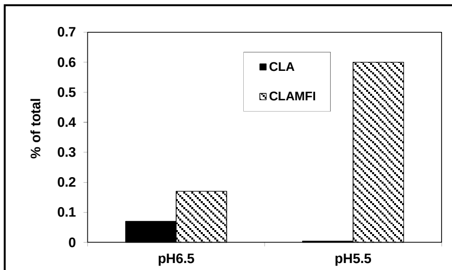

Figure 2. Rumen culture data taken from Fuentes (2009) showing an increase in CLA_{MFI} (cross-hatched bars) but a decrease in an alternative CLA (solid bars) as pH declined from 6.5 to 5.5.

required for accumulation of CLA_{MFI} in the rumen is not known. Although data are limited, rumen pH changes are most likely associated with MFD because they alter bacterial populations by favoring those that have alternative pathways of biohydrogenation.

Studies show that low pH alters the microbial population in the rumen and causes accumulation of $CLA_{MFI.}$ In a study by Fuentes et al. (2009), the pH of rumen cultures was lowered from 6.5 to 5.5, causing a shift in CLA production that included increased CLA_{MFI} (Figure 2). Although milk fat percentages often decline as rumen pH values decrease, there is still a lot of variation seen as scatter around the line in Figure 3. This indicates that rumen pH is not the only factor controlling CLA_{MFI} and milk fat percentage. Therefore, rumen acidosis should not be viewed as a prerequisite for MFD.

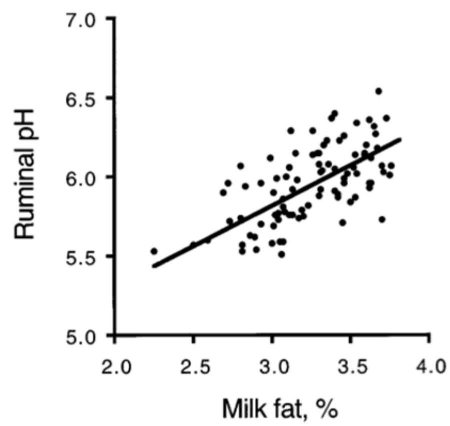

Figure 3. Relationships between rumen pH and milk fat % as reported by Allen (1997).

The rate of degradability of the starch fraction in grains also determines risk for MFD. Field observations and inferences from studies indicate that rapid rates of starch fermentability are linked to a greater risk of MFD. Fermented feeds with high grain content such as corn silage and high moisture corn carry the highest risk. Differences in corn varieties, silo storage time, and climate conditions for plant growth can all lead to rapid rates of starch degradation in silage and high-moisture corn. Longer storage can lead to higher rates of starch degradability. A study by Newbold et al. (2006), using an in vitro test in rumen fluid over three hours, found a 30% increase in degradability in corn silage stored for 2 months vs. 10 months. If high rates of starch degradability in forages are suspected as a cause of MFD, usually there is little that can remedy the situation. One option is to dilute the forage with less degradable feed, but often that is not available. An alternative option is to focus on other risk factors (such as rumen pH and dietary fat) to minimize CLA_{MFI} production.

Maintaining adequate forage levels in dairy diets decreases the risk of MFD. As explained previously, forage can help maintain rumen pH and limit the synthesis of CLA_{MFI}. This approach emphasizes peNDF to sustain cud-chewing and production of salivary buffers. Nutritionists use specific forage guidelines tailored for specific dairies with individualized forage needs. Within those guidelines, however, maintaining a consistent forage program is the first line of defense against problems with MFD.

Again, the rate of starch degradability in forage also affects CLA_{MFI} production. High rates of starch degradability in silage has been associated with an increased risk of MFD, which means that silage NDF alone, as a proxy of forage level and assumed peNDF, is not enough to explain all occurrences of MFD.

A lesser known and often ignored attribute of forages related to MFD is their contribution to the cow's total fat intake. For example, fatty acids in corn silage typically average around 1.5 to 2.0% of DM, but can reach 3.5% or higher. It is important to remember that fatty acid content is not the same as crude fat content when requesting a forage analysis (Figure 5). Fat content has traditionally been determined as the ether-extractable component of the feed. In addition to extracting fat, ether also extracts some carbohydrate, vitamins, and pigments. Therefore, crude fat in cereal grains, forages, and the total mixed ration often contain less than 60% fatty acids. Forage containing 3.5% total fatty acids could contain 5 to 6% crude fat.

- High fat content with fatty acids 2.5% or more of plant DM.
- High free fatty acids reaching 50% or more of total fatty acids.
- High rates of starch degradability reaching 85% or more in a 7-hour in vitro test.
- High yeasts and molds. Alarms go off with yeast counts approaching 1 million cfu/g.

Figure 4. Characteristics of corn silage often associated with increased risk of MFD.

Crude Fat

- estimated by extracting a ground feed sample with organic solvents
- low cost and AOAC DEFINE approved
- higher than fatty acid values because includes fatty acids plus other nonlipid contaminants such as pigments, carbohydrates, and some vitamins.

Total Fatty Acids

- isolates only the fatty acid fraction in feed lipids using gas chromatography
- higher cost and not AOAC approved
- lower values than a crude fat analysis because includes only fatty acids and no other contaminants.

Figure 5. Key differences between a lipid analysis of forages by crude fat vs. total fatty acids.

Given the large quantities of corn silage fed to cows in some operations, this amounts to significant fat intakes just from silages alone. High fatty acid intakes have also been reported in grazed forages, but again challenges face proper analysis. Ryegrass at Clemson University grazed by cows November through March 2009 had an initial fatty acid content of 6.8% of DM and fell to 4.7% by the end of grazing. Importantly, hay analysis does not represent grazing intakes. Cutting and drying plant material during haymaking causes extensive loss of fatty acids and other nutrients because plant metabolism continues for a time after the grass is cut. To best represent what a cow consumes during actual grazing, ryegrass samples in the Clemson University grazing study were clipped and immediately immersed in liquid nitrogen to stop all plant metabolism. Then, samples were freeze-dried and kept frozen before analysis.

Yeasts/molds and management factors are both regarded as significant risk factors for MFD, but little is known about exactly how they affect rumen function and the accumulation of CLA_{MFI}. Speculative theories about molds and yeasts suggest they may produce antimicrobial substances as part of their metabolism, which in turn may negatively impact the rumen microbial population; however much remains to be proven in this regard. High yeast and mold counts in fermented feeds is undesirable, not only for risk of MFD, but also because it can reduce feed intake, negatively effect animal health, and decrease overall lactation performance, in addition to incurring additional feed losses through ‘shrink.” In well-preserved silage, yeast counts below 10,000 CFU/g are common. Counts that effect animal health and preformance poorly are not well defined and likely depend on the specific strain of yeast or mold infecting the plant. As a general rule, yeast counts at or above a million CFU/g should cause concern.

A number of management factors also have been connected with increased risk of MFD. Among these are bunk space, stocking density, and mixing of the TMR. These factors can all cause sorting and slug-feeding of grain resulting in low rumen pH and subsequent production of CLA_{MFI} in the rumen. In general, all attempts to maintain cow comfort and maintain good overall herd management will minimize the risk of MFD.

Why Do I Still Sometimes Have MFD Problems Even when I Follow All The Proper Guidelines?

The answer to this question is because the circles shown in Figure 1 are better depicted in Figure 6. Instead of being independent, the nutritional risks for MFD are interconnected. A subtle change in one nutritional parameter, even within accepted guidelines, can imbalance the whole rumen environment and cause accumulation of CLA_{MFI}. Thus, if you are within the proper guidelines, but still have MFD, then the overall balance of all parameters has been upset.

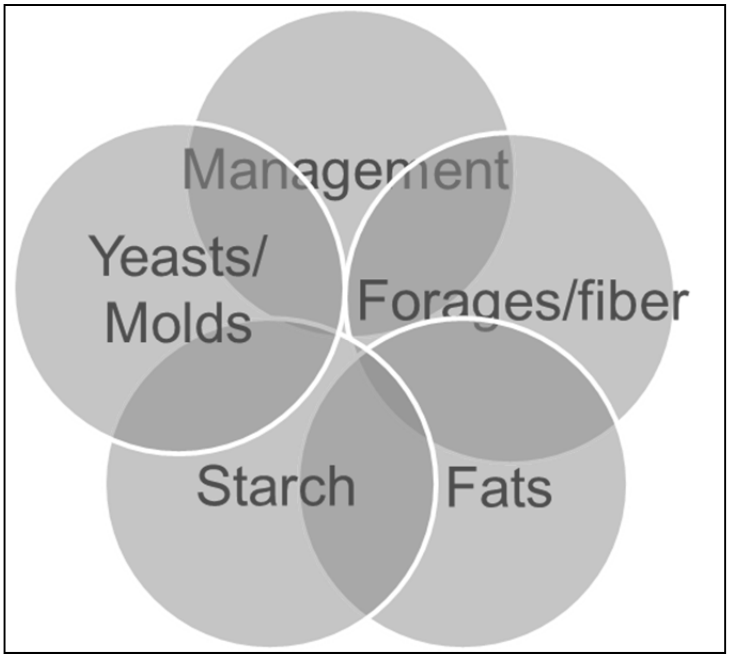

Figure 6. An alternative depiction of the interaction among individual factors associated with increased risk of MFD. Dark shaded areas of the circle represent interactions of one MFD risk factor with other MFD risk factors.

For example, cultures of rumen microorganisms were fed either a high corn or high barley diet along with the presence or absence of soybean oil (0 and 5%) and of the presence or absence of monensin (0 and 25 ppm). A lipid compound called *trans*-10 18:1 was monitored as a proxy for CLA_{MFI} (the production of the two are highly related and *trans-10* was more reliably analyzed at the time of this study). The addition of soybean oil increased *trans*-10 18:1 concentrations in the cultures for both the corn and barley diets (Jenkins et al., 2003). To a lesser extent, monensin also increased *trans*-10 18:1 for both corn and barley. However, when monensin and soybean oil were both added to the diets the combination interacted. Adding monensin with soybean oil did not elevate *trans*-10 18:1 when the diet was corn-based. When the diet was barley-based, adding monensin with soybean oil elevated *trans*-10 18:1 more than either risk factor alone.

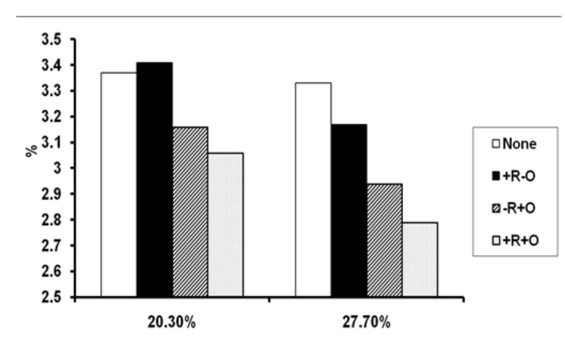

Figure 7. Milk fat percentages from cows fed low starch vs. high starch diets supplemented with monensin (R) or corn oil (O). From Van Amburgh et al. (2008).

A similar grain, monensin and fat interaction was examined in lactating dairy cows (Van Amburgh et al., 2008). Eighty Holstein cows were assigned either a high (27.7%) or low (20.3%) starch diet for 21 days, followed by the addition of monensin (13 ppm) or corn oil (1.25%) for an additional 21 day. Then, cows were switched to diets with opposite corn oil levels for a final 21 day period, providing eight treatments. Oil level was a higher risk factor for MFD compared to monensin: corn oil decreased milk fat from 3.32 to 2.99% versus 3.20% to 3.11% for monensin. Feeding high-starch diets had borderline effects on MFD: milk fat declined from 3.25 to 3.06%. Starch degradability may have contributed to MFD in this study because the diets contained steam-flaked corn, which has an inherently fast rate of rumen starch degradation. Therefore degradability, compounded by high dry matter intake, may be a more potent MFD risk factor than starch intake alone.

Take-Home Message

The breakthrough in MFD occurred with the discovery that it was linked to CLA production in the rumen. Feeding management controls MFD by limiting accumulation of CLA_{MFI} in the rumen. In general, no single dietary factor is responsible for MFD, and interactions among various dietary components can increase the rumen outflow of CLA_{MFI}. All risks have to be considered with regard to the combination of factors at play in a given ration formulation and with regard to the limitations of management and physical plant. Further research is required to better understand the rumen conditions that promote the formation of CLA_{MFI} that may trigger MFD. An improved understanding of these events will provide the critical framework with which to better troubleshoot MFD.

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