In a Tier Pricing System: Feeding & Managing for Milk Components

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Introduction

Dairy producers are largely paid for the pounds of milk fat and protein shipped. Milk fat and protein concentration and yield are responsive to multiple dietary, genetic, and environmental factors (Figure 1). Diet-induced milk fat depression explains large decreases in milk fat that occur during disrupted rumen fermentation and was the predominant focus of milk fat research for many decades. A large number of dietary and environmental factors contribute to the risk for diet-induced milk fat depression including large contributions from dietary unsaturated fatty acids and fermentability. More recently, research has focused on other dietary and non-nutritional factors that impact milk fat and protein yield. Importantly, these factors have broad application to allow small, but economically important increases in milk fat yield and profitability. The seasonal variation in milk component concentration and yield has also been characterized and is important for setting goals and expectations. Genetics also affect milk fat and protein, which are highly heritable traits. Large variation exists in genetic potential between cows within a herd, despite there being little variation between herds. Additionally, the average genetic potential has increased in recent years, so goals need to be continually updated. Maximizing milk fat and protein yield requires a holistic approach that spans from nutrition to management and continues to evolve as we gain a better understanding of the impact of each factor.

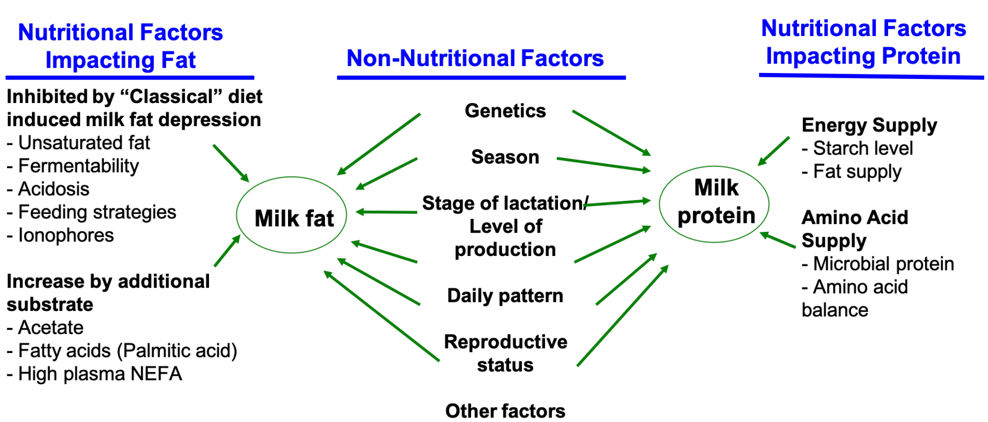

Figure 1. Nutritional and non-nutritional factors influencing milk fat and protein synthesis.

Factors Influencing Milk Fat and Protein Concentration and Yield

Milk fat and protein yield is impacted by many factors that can be broadly categorized as nutritional and non-nutritional factors (Figure 1).

Most of the interest on regulation of milk fat synthesis has focused on diet-induced milk fat depression (MFD), which causes large decreases in milk fat yield. More recently, methods to increase milk fat by providing substrate for milk fat synthesis through fat supplementation and increasing acetate supply have been reported. Fat supplements have recently increased in price and are less available. Remember to consider dietary supply from forages, commodity byproducts, and oilseed along with dry fat supplements. Increasing fiber digestibility will increase acetate supply and may be a good opportunity to increase milk components economically.

Milk protein synthesis can also be modified by nutrition, although responses generally are of a smaller magnitude, in agreement with the less variation observed in milk protein concentration in general. Milk protein is responsive to energy status of the cow through insulin and IGF-I signaling pathways (Mackle et al., 1999) that can be modified by increasing starch and starch fermentability of the diet. It is also responsive to amino acid supply and balance through substrate supply for milk protein synthesis and activation of mTOR signaling pathways (Castro et al., 2016). We generally expect milk protein to increase with increasing metabolizable protein and improving amino acid balances through maximizing microbial protein synthesis, balancing with high quality rumen escape protein, and feeding effective rumen protected amino acid supplements.

Non-nutritional factors are a broad category including seasonal rhythms, stage of lactation, genetics, parity, and other farm and cow factors that have not been well characterized. These factors can impact both milk fat and protein synthesis and are important to consider in analyzing if a herd is meeting its potential and long-term decisions that will maximize components in the future.

What is "Diet-Induced Milk Fat Depression"?

The term "milk fat depression" is a common term used and is defined as a decrease in milk fat associated with disrupted rumen fermentation (Griinari et al., 1998, Bauman and Griinari, 2003). It is important to note that this is a specific condition and not simply any change in milk fat yield. Up to a 50% reduction in milk fat concentration and yield can be observed with no decrease in milk or milk protein yield. Extensive work over the past 20 years has demonstrated that diet-induced MFD is caused by unique bioactive conjugated linoleic acid (CLA) isomers that are made during rumen biohydrogenation of unsaturated FA by an altered rumen microbial community. Investigating this condition has provided insight into the regulation of milk fat synthesis and management strategies to reduce inhibition of milk fat synthesis (Reviewed by Harvatine et al., 2009). Large decreases in milk fat (>15%) is almost undoubtably biohydrogenation-induced MFD, but this mechanism does not explain many other smaller changes in milk fat synthesis. The occurrence of BH-induced MFD is best diagnosed by milk fat concentration of *trans*-10 C18:1, although this requires analysis by gas chromatography.

Variation in Milk Fat and Protein Between and Within Herds

Milk fat and protein concentration and yield are variable between farms because of differences in diet, management practices, and herd genetics among other factors. This variability demonstrates both challenges and opportunities. Milk fat averaged 3.73% [standard deviation (**SD**) = 0.33], but the 10th and 90th percentiles were 3.34 to 4.12% in a database of DHIA test days of Holstein herds in Minnesota, Pennsylvania, Texas and Florida from 2004 to 2016 from the Dairy Records Management Database (http://www.drms.org/; Unpublished).

Milk protein averaged 3.04% (SD = 0.15) and the 10th and 90th percentiles were 2.86 to 3.23%. Average milk fat and protein has been increasing over the last decade based on USDA milk market data and we expect a higher average, but probably similar variation, in current herds. There is also substantial variation in milk fat and protein concentration and yield between cows within a farm. This variation, when consuming the same diet, highlights the influence of non-nutritional factors. A considerable portion of this variability is likely genetics and physiological changes associated with stage of lactation.

The variation between cows and herds highlights the opportunity to increase milk fat. It is important to keep in mind that average milk fat can be increased by two different approaches. You can increase all cows a small amount, but it is probably difficult to increase cows who are already high in the distribution, as they are at their genetic and physiological potential. Alternatively, the cows in the lower part of the distribution are likely below their genetic and physiological potential and interventions may result in substantial increases (25+%). Large increases in these cows can result in an increase in the herd average.

Non-Nutritional Factors Impacting Milk Fat and Protein Yield

Genetics of Milk Fat Concentration and Yield

Milk fat and protein concentration and yield are highly heritable (Welper and Freeman, 1992). We recently characterized the variation in predicted transmitting ability for fat and protein production between nearly 6,000 herds available in the Dairy Records Management System database. Very little variation was observed between herds, although larger variation is observed between cows within a herd. Importantly, average genetic potential has increased considerably over the past decade due to changes in selection indexes and genomic selection, which should be considered when evaluating if a farm is reaching its potential.

Annual Rhythms in the Dairy Cow

Rather than simply *responding* to a change in the environment after it occurs, time keeping mechanisms in the hypothalamus allow the animal to *anticipate* yearly environmental changes before they occur. Yearly patterns of milk production have been recognized for over 40 years (Wood, 1970). When examining average monthly bulk tank records from the United States Federal Milk Marketing Orders, the presence of an annual rhythm is apparent. These yearly patterns fit a robust cosine function, suggesting that they represent a biological rhythm (Salfer et al., 2019). The variation in milk fat concentration due to the annual rhythm is between 0.15 and 0.30 percentage units, depending on the region, with a lower amplitude in southern regions of the United States. The presence of yearly production rhythms was confirmed using ten years of DHIA data from individual herds in Minnesota, Pennsylvania, Texas and Florida (Salfer et al., 2017). Although fat and protein concentration both peak near the first of the year, the annual rhythm of milk yield peaks between late March and early April, right around the vernal equinox (Salfer et al., 2017). Fat and protein yield peak between late February and early March. Contrary to the rhythms of fat and protein concentration, amplitudes of annual milk yield rhythms are greater in the southern U.S. compared to the north. Fat and protein yield also oscillated more in the southern U.S. than the northern U.S. Producers and nutritionists should change their goal for milk fat concentration and yield across the year and future work may provide insight into how to reduce the impact of the cycle on production.

Circadian Patterns of Milk Fat and Protein

Circadian rhythms are daily patterns, and the dairy cow has a daily pattern of milk synthesis that impacts milk yield and composition. Generally, milk yield is highest in the morning, but milk fat and protein concentration are higher in the evening (Gilbert et al., 1972, Quist et al., 2008). We have also observed milk yield and milk composition vary across the day while milking every 6 h in multiple experiments. The first consideration is that care needs to be taken in interpreting milk composition of a single milking. We have also observed that daily rhythms are dependent on the timing of feed intake and length of time without feed each day. This demonstrates the importance of feed management, including selecting feeding times and frequency, on milk production

Milk Flow

Milk fat concentration is top of mind for producers and nutritionists, but milk fat and protein yield are what is economically important. Fat yield is influenced both by milk fat concentration and milk yield. First, care needs to be taken to not decrease milk yield when attempting to increase milk fat concentration. This is especially important considering that decreases in milk yield are highly likely to also decrease milk protein yield. Secondly, maximizing milk fat and protein yield requires optimal production. Milk yield is under complex regulation with major influence from endocrine mechanisms and can be limited by nutritional, health, or environmental stressors. With this in mind, all good management practices that increase reproductive efficiency, cow health, cow comfort, etc. and increase level of milk production likely also increase milk fat yield.

Take Home Messages

- There is large variation in milk fat and protein between and within herds, which are impacted by many dietary, genetic, and environmental factors and their interactions make it difficult to manage.
- It is important to consider non-nutritional factors, such as genetic potential, season of the year, and milking sampled, when setting goals and interpreting data.
- Diet-induced milk fat depression explains large decreases in milk fat and is caused by fundamental issues with stable rumen fermentation.
- Increasing dietary fat can increase milk fat, but is most consistent when feeding enriched palmitic acid supplements. Increasing acetate supply by increasing fiber digestibility supports higher milk fat yield.
- Milk protein is impacted both by amino acid supply and energy signals that stimulate protein synthesis. We need to think both about amino acid balancing and optimal energy supply.

References

Bauman, D. E. and J. M. Griinari. 2003. Nutritional regulation of milk fat synthesis. Annu. Rev. Nutr. 23:203-227.

Castro, J. J., S. I. Arriola Apelo, J. Appuhamy, and M. D. Hanigan. 2016. Development of a model describing regulation of casein synthesis by the mammalian target of rapamycin (mtor) signaling pathway in response to insulin, amino acids, and acetate. J. Dairy Sci. 99:6714-6736.

Gilbert, G. R., G. L. Hargrove, and M. Kroger. 1972. Diurnal variation in milk yield, fat yield, milk fat percentage, and milk protein percentage of holstein-friesian cows. J. Dairy Sci. 56(3):409-410.

Griinari, J. M., D. A. Dwyer, M. A. McGuire, D. E. Bauman, D. L. Palmquist, and K. V. Nurmela. 1998. Trans-octadecenoic acids and milk fat depression in lactating dairy cows. J. Dairy Sci. 81(5):1251-1261.

Harvatine, K. J., Y. R. Boisclair, and D. E. Bauman. 2009. Recent advances in the regulation of milk fat synthesis. Animal 3(1):40-54.

Mackle, T. R., D. A. Dwyer, K. L. Ingvartsen, P. Y. Chouinard, J. M. Lynch, D. M. Barbano, and D. E. Bauman. 1999. Effects of insulin and amino acids on milk protein concentration and yield from dairy cows. J. Dairy Sci. 82:1512-1524.

Welper, R. D. and A. E. Freeman. 1992. Genetic parameters for yield traits of Holsteins, including lactose and somatic cell score. J. Dairy Sci. 75(5):1342-1348.

Wood, P.D.P.. 1970. A note on the repeatability of parameters of the lactation curve in cattle. Anim. Prod. 12:535-538.