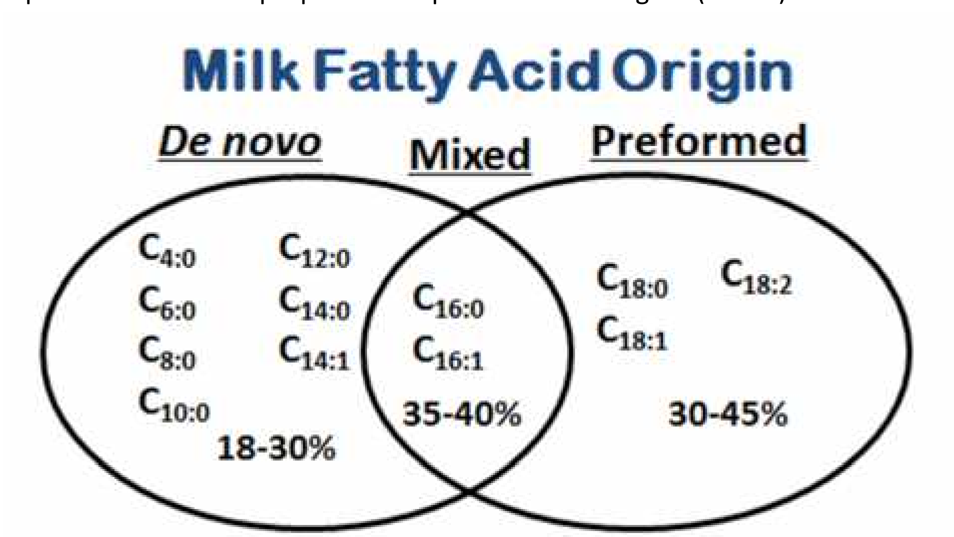
Using milk fatty acid data to improve bulk tank milk fat and protein content and production

D. M. Barbano[1], H. M. Dann[2], and R. J. Grant[2]

Researchers at Cornell University[1] and Miner Institute[2] have identified a positive correlation between groups of fatty acids and bulk tank milk fat and protein content and a rapid mid-infrared milk analysis method to measure fatty acids.

Milk fat is made up of 3 groups of fatty acids: de novo, mixed origin and preformed fatty acids. The de novo fatty acids and a portion of the mixed origin fatty acids are synthesized in the cow's udder using the end products of rumen fermentation of forage. Factors that affect digestion of forage in the rumen drive de novo and mixed origin fatty acid synthesis in the udder. Preformed fatty acids come from the mobilization of body fat (particularly in early lactation) and fat in the feed consumed. The identification of the specific fatty acids in each group and their relative proportions is provided in the figure (below).

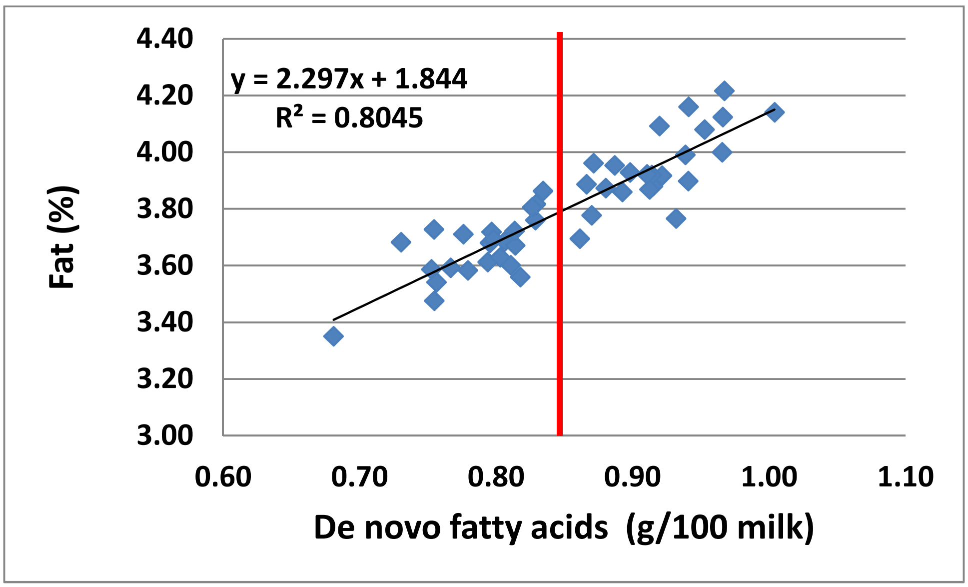


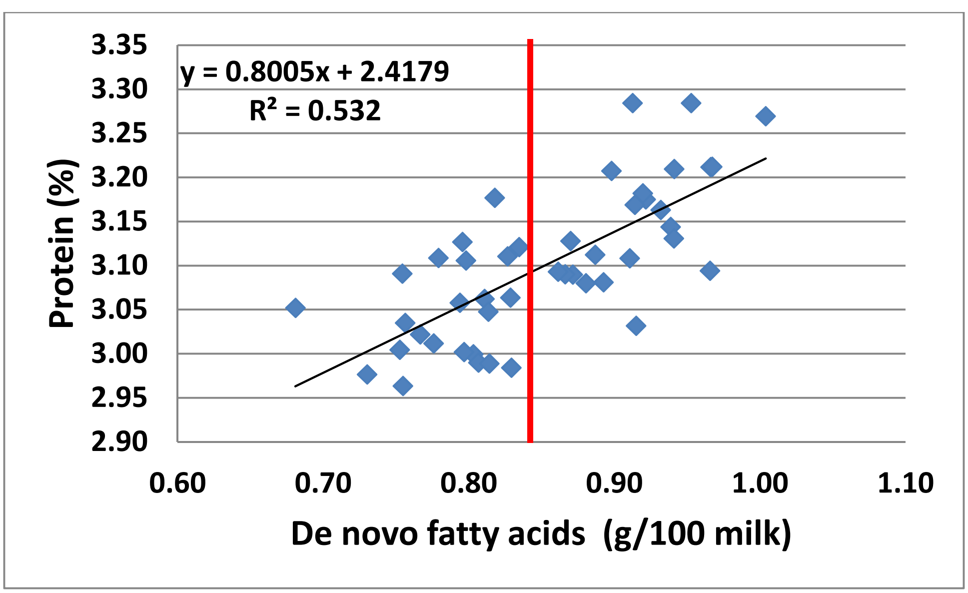
The sum of the de novo, mixed origin, and performed fatty acids in grams per 100 g of milk will be equal to about 94.5% of the bulk tank fat test. The reason that the sum of the fatty acids is lower than the fat test is because about 5.5% of the structure of milk fat is the glycerol backbone that the fatty acids are attached to.

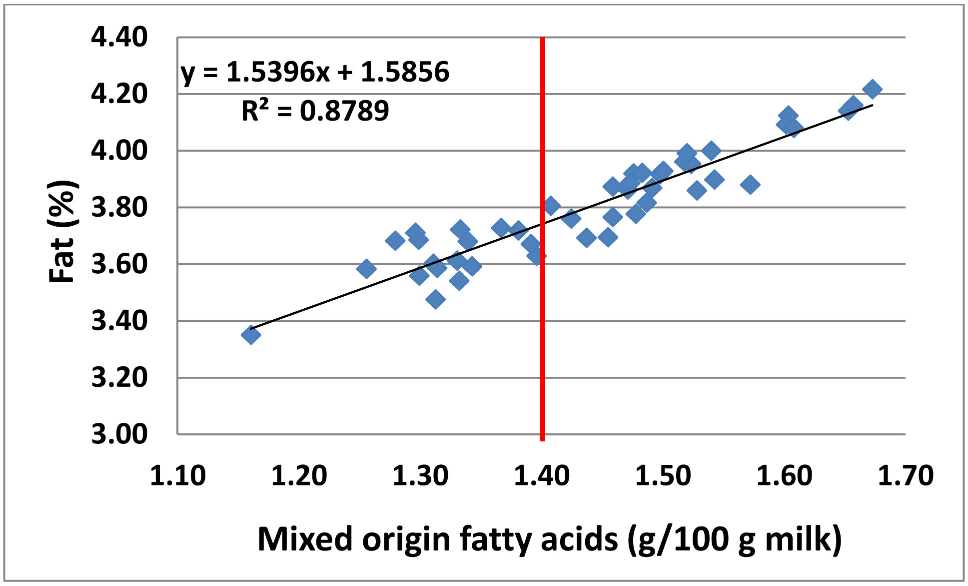
There are two possible methods of reporting of milk fatty acid results: 1) reporting each of the 3 groups of fatty acids as a relative percentage of the total fatty acids (i.e., will equal 100%) and 2) reporting each group as grams of fatty acid per 100 grams of milk (like the fat and protein test). We have been using the first method of reporting since February 2016 and guidelines that less than 23.5% de novo was low and higher than 24.5% was high for Holstein milk. We have gained experience with both methods of expression of the results (since February 2016) and with that experience, we are recommending that the unit of expression of g/100 g of milk is more useful for bulk tank milk. An additional fatty acid parameter that provides an index of milk fatty acid unsaturation seems to relate to milk fat depression and we find that useful. The red lines in the graphs below represent the goals for these parameters that will help a Holstein farm achieve a 3.75% bulk tank fat test.

Field Observations for Holstein Farms

As de novo and mixed origin fatty acids, expressed as g/100 g milk increase, bulk tank milk fat and protein concentration will also increase (3 figures below). For a Holstein herd to achieve a bulk tank milk fat test of > 3.75%, they will need have a de novo fatty acid level of 0.85 g/100 g milk and mixed origin fatty acid level of 1.4 g/100 g milk or higher. This may also result in a higher bulk tank milk protein, as shown below.

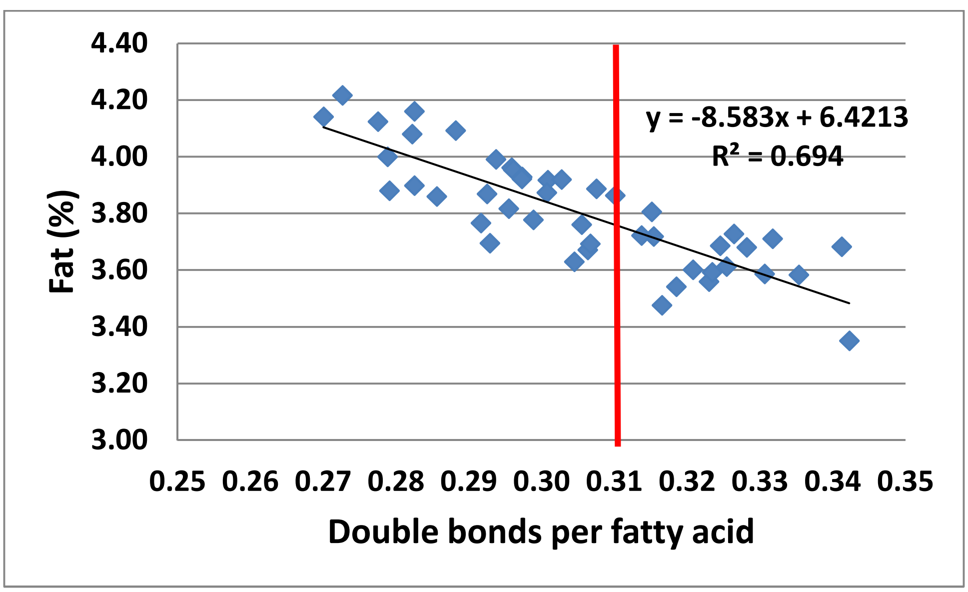






Milk Fatty Acid Unsaturation

Fatty acids also differ in structure by the number of double bonds per fatty acid (unsaturation). There is a high level of unsaturated fatty acids in feeds such as corn, soybean, and cottonseed products. In the last 3 years of measuring the fatty acid content of milk from many dairy herds, we find that as the unsaturation of milk fatty acids increases (i.e., double bonds per fatty acid), the milk fat and protein percent will decrease. It appears that the double bonds per fatty acid in bulk tank milk is correlated with the degree of milk fat depression, as shown in the graph below. For Holstein herd to achieve a bulk tank fat level of 3.75%, the double bonds per fatty acid should be lower than a value of about 0.31.



What fatty acid values are needed for a Holstein herd to achieve a 3.75% fat test?

If a Holstein farm is going to achieve a 3.75% fat and 3.10% protein test or higher, then that farm will need to achieve the following fatty acid metrics in their bulk tank milk. The de novo fatty acid level will need to be 0.85 g/100 g milk or higher, the mixed origin fatty acids will need to 1.40 g/100 g milk or higher, and the double bonds per fatty acid will need to be 0.31 double bonds per fatty acid or lower. As the average body condition score for the herd decreases (energy intake too low), it is expected that the preformed fatty acids will decrease in the milk from about 1.40 g/100 g of milk to about 1.1 g/100 g of milk. This has been observed in a study of farms in the Northeast (Barbano, et al. 2016) and these same relationships were confirmed with a large group of Holstein farms from all over the US (Barbano et al. 2017).

Risk Factors for Lower Milk Fat

Milk fatty acid composition is expected to do the following as bulk tank milk fat test decreases: mixed origin fatty acid concentration will decrease first, with additional time and further decrease in fat test de novo fatty acid concentration will decrease. If milk protein test also decreases and double bonds per fatty acid increase, this is an indication that the cows are going into milk fat depression. The level or load of unsaturated fatty acids in the diet is often called the rumen unsaturated fatty acid load (RUFAL). When the RUFAL level in the ration is too high, or if the quality of the feed is such that too much of these fatty acids are released in the rumen, then there can be a negative impact on the rumen fermentation and the cows go into milk fat depression. We think that when double bonds per fatty acid in the milk increases the RUFAL level or release of unsaturated fat in the rumen it too high.

Some factors related to milk fat depression are: yeasts and molds spoilage of feeds, farm management factors, forages/fiber, starch, and fats. Two factors that we are commonly seeing in the field are: 1) over-crowding that causes slug feeding, slug feeding caused by lack of access of the cows to feed for several hours , and 2) RUFAL content (or release) of the feed that is too high that contribute unsaturated fat in the diet. Greater feeding frequency, whether TMR or component fed herds, is associated with higher de novo fatty acids in the milk and better rumen conditions. Slug feeding may cause variation in rumen pH through the day and causes the rumen fermentation to favor production of trans fatty acids that cause milk fat depression. Lower physically effective fiber is also correlated with lower de novo fatty acid and lower fat test.

How Does All of This Fatty Acid Information Relate to Day to Day Variation in Bulk Tank MUN?

Another milk composition metric is milk urea nitrogen (MUN). MUN reflects the efficiency of the use of nitrogen sources in the rumen. If MUN is too high, it is an indication that nitrogen (dietary protein) may be higher than needed. It has been our experience from monitoring variation in MUN from day-to-day in bulk tank milk within each farm, that variation in MUN within a farm tells us information about farm management practices on the farm related to access to feed. When cows have no access to feed, MUN will decrease very rapidly. We have observed on farms where the cows that lack access to feed for 5 hours in the night will cause the bulk tank MUN to decrease from 13 to 9 (mg/dL), while milk fat will decrease by about 0.5% (g/100g milk). The decrease in milk fat is primarily due to lower de novo and mixed origin fatty acids. When this pattern of variable feed availability happens day after day, it results in slug feeding when feed is provided and daily cycling of rumen pH. Under these conditions the overall fat and protein test achieved by the herd will be lower than it should be due to lower conversion efficiency of feed to milk.

Energy Density of the Ration

Finally, when sources of forage and concentrates are changed, or the quality characteristics (e.g., starch availability) of a forage source (e.g., corn silage) changes with time, the milk fat and protein can change. When a ration change is made and the energy density of the ration decreases, it is expected that the cows will start to lose weight if the requirement for maintenance and lactation are not met. A lower energy intake shifts the cows in the direction of negative energy balance. When this happens, the mixed origin fatty acids will decrease in the milk and the cows will start losing weight because they are mobilizing body fat. This may cause the concentration of preformed fatty acids to increase in the milk, but as the cows continue to mobilize fat they will lose body condition score and ultimately the concentration of all 3 groups of fatty acids will decrease along with fat and protein content of milk and pounds of milk per day.

Examples of Milk Composition for Holstein Herds

1) A Holstein Herd when Everything is Working Right

Fat 3.89%, protein 3.13%, lactose 4.59%, MUN 10.9 (mg/dL), de novo 0.87 g/100 g milk, mixed origin 1.41 g/100 g milk, preformed 1.46 g/100 g milk, and double bonds per fatty acid of 0.279 that are producing 92 pounds of milk per day with a milk SCC of 160,000 cells/mL. This herd is doing well.

2) A Holstein Herd with Milk Fat Depression

Fat 3.46%, protein 3.10%, lactose 4.61%, MUN 11.2 (mg/dL), de novo 0.72 g/100 g milk, mixed origin 120 g/100 g milk, preformed 1.31 g/100 g milk and a double bonds per fatty acid of 0.342 that are producing 91 pounds of milk/day with a milk SCC of 200,000 cells/mL. This herd has a portion of the cows in milk fat depression, but the volume of milk is good and the protein has held. This herd appears to have a trans fatty acid induced milk fat depression at the level of the mammary cells due to excessive availability (level and rate of release) of unsaturated fatty acids in the rumen.

3) A Holstein Herd that has Multiple Problems

Fat 3.09%, protein 2.88%, lactose 4.53%, MUN 8.9 (mg/dL), de novo 0.65 g/100 g milk, mixed origin 1.08 g/100 g milk, preformed 1.16 g/100 g milk and a double bonds per fatty acid of 0.340 that are producing 79 pounds of milk/day with a milk SCC of 160,000 cells/mL. The high double bonds per fatty acid and low de novo and mixed origin fatty acids indicates that this herd is in milk fat depression due to release of too much unsaturated fat in the rumen and production of trans fatty acids. This has suppressed rumen fermentation and decreased microbial biomass that has limited the supply of essential amino acids and milk protein production. The low volume of milk seems is related to lower lactose production (grams/day). The herd average body condition score of cows in this herd was low and this is consistent with the low preformed fatty acids in the milk.

Conclusion

The new milk fatty acid metrics (de novo, mixed origin, and preformed fatty acids, and double bonds per fatty acid) provide additional information produced from the infrared milk testing of bulk tank milk at the same time the payment test is done with the same instrument. These data combined with the fat and protein test, MUN and average milk produced per cow provides a farm with a barometer of the combined impact of farm management practices and changes in feed on the revenue produced from milk and information that will help identify changes in feeding or management that will improve herd and business performance.

References:

Barbano, D. M. and C. Melilli. 2016. New Milk Analysis Technologies to Improve Dairy Cattle Performance. Pages 61 to 73 in Proceedings of the Cornell Dairy Nutrition Conference, Department of Animal Science, Cornell University, Ithaca, NY.

Barbano, D. M., C. Melilli, H. Dann, and R. J. Grant. 2017. Infrared Milk Fatty Acid Analysis: Experience in the Field for Farm Management. Page 159 to 174 in the 2017 Proceedings of the Cornell Nutrition Conference for Feed Manufacturers. October 17 to 19, 2017. Syracuse, NY.

Woolpert, M. E., H. M. Dann, K. W. Cotanch, C. Melilli, L. E. Chase, R. J. Grant, and D. M. Barbano. 2016. Management, nutrition, and lactation performance are related to bulk tank milk de novo fatty acid concentration on northeastern US dairy farms. J. Dairy Sci. 99:8486–8497.

Wojciechowski, K. L., and D. M. Barbano, Prediction of fatty acid chain length and unsaturation of milk fat by mid-infrared milk analysis.   J. Dairy Sci. 99:8561-8570.

Woolpert, M. E., H. M. Dann, K. W. Cotanch, C. Melilli, L. E. Chase, R. J. Grant, and D. M. Barbano. 2017. Management practices and physically effective fiber are related to bulk tank milk de novo fatty acid concentration on Holstein dairy farms. J. Dairy Sci. 100: 5097-5106.

Jenkins, T., and B. Prokop. 2013. You Control Milk Fat Depression –Don't Let It Control You. Pages 238 to 248 in Proceedings of the Western Dairy Management Conference, Reno Nevada.