Applying fatty acid profiles from bulk tank milk on farm for decision-making support

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Abstract

Routine analysis of fatty acids (FA) in commercial bulk tank samples through Fourier-transform infrared (FTIR) spectroscopy is increasingly being used as a dairy management tool to assess feeding and farm management practices. Bulk tank FTIR milk FA profiles from 3,200 dairy herds in Quebec, Canada, over 3 years (April 2019–March 2022; 1.9M samples) were assembled in a national database (Lactanet, Canada) and matched with the nearest test day records. The emphasis was put on the de novo, mixed and preformed FA groups as they originate from synthesis in the mammary gland (*de novo*), feed intake or body fat mobilization (preformed), or both (mixed). Specifically, *de novo* FA were associated with improved fat and protein content in bulk tank milk (r_{corr} = 0.81–0.82). Seasonal changes were distinctive with decreased *de novo* and mixed FA and increased preformed FA during the summer months. Increasing the proportion of corn silage in the ration up to 50% was associated with increased *de novo* and decreased preformed FA (based on a subset of 513 Holstein herds with available feed records). The margin over feed costs (MOFC; in $ per kg of hl milk or per kg of milk fat) was greater with increased *de novo* FA and smaller with increased preformed FA, whereas no association was observed between the milk FA profile and MOFC per cow (based on a subset of 95 Holstein herds with available profitability records). Overall, with increasing herd performance (kg of milk fat/cow and day) *de novo* FA increased, and preformed FA decreased. This trend was inversed for high performing herds (≥1.70 kg milk fat/cow and day), which further emphasizes the need to compare herds with specific milk FA profiles to their appropriate peers. However, variation of milk FA profiles was high within cohorts of herds with similar milk performance, thus highlighting the importance for using herd-specific benchmarks in relation to historical farm data and strategic goals for a herd (internal benchmarking). An interactive dashboard application was developed to visualize milk FA profiles including benchmarks for the user to interpret their herd performance against their peers and identify best management practices. To facilitate early detection and decision making on farm, current research efforts include the detection of anomalies and changes in the overall trend of milk FA as well as the identification of their potential causes (diagnostic) through artificial intelligence.

Keywords: Decision support, fatty acid, mid-infrared spectroscopy, benchmarking.

Introduction

Fat is the most variable component of milk. Its concentration and its fatty acid (FA) profile vary according to several factors including the animal (parity, lactation stage, breed), the environment (season, management system) and nutrition (forage and grain type and proportion, amount, and composition of dairy fat supplements). Traditionally analyzed by gas chromatography, a laborious and costly technique, advances in technology over the last decade allow measuring major milk fatty acids routinely and rapidly by mid-infrared (MIR) spectroscopy. This technique offers the opportunity to monitor milk FA in bulk tank or individual cow samples alongside and, thus, at the same frequency as analyzing for major components (e.g., fat, protein, lactose, milk urea nitrogen, somatic cell counts). It is therefore possible to obtain the complete composition of a milk sample, including the FA profile with the main groups of FA. Management and dietary practicing that modulate cow behaviour and rumen conditions were previously found to be associated with changes in the FA synthetized *de novo* from rumen precursors based on northeastern US commercial dairy farms (44 and 39 farms, respectively; Woolpert *et al.*, 2016, 2017). Analyzing these FA routinely in bulk tank samples collected every other day therefore open the possibility to better monitor herd health and performance, and to better understand and monitor herd milk components and overall herd performance. Our main objective was to better understand herd milk FA profiles through benchmarking and the development of a decision-making tool to support producers in their daily management decisions.

Milk fatty acids origin

Milk FA can be divided in 3 main groups, according to their biological origin. These groups include de *novo* FA (short chain FA synthesized in the mammary gland from rumen precursors); Preformed FA (Long chain FA derived from dietary FA transferred into milk and FA mobilized from adipose tissue); and Mixed FA (Medium chain FA from mixed origin; Figure 1). Accordingly, changes in nutrition, management or metabolism of the cows and the herd will be reflected as changes in milk fatty acid profile.

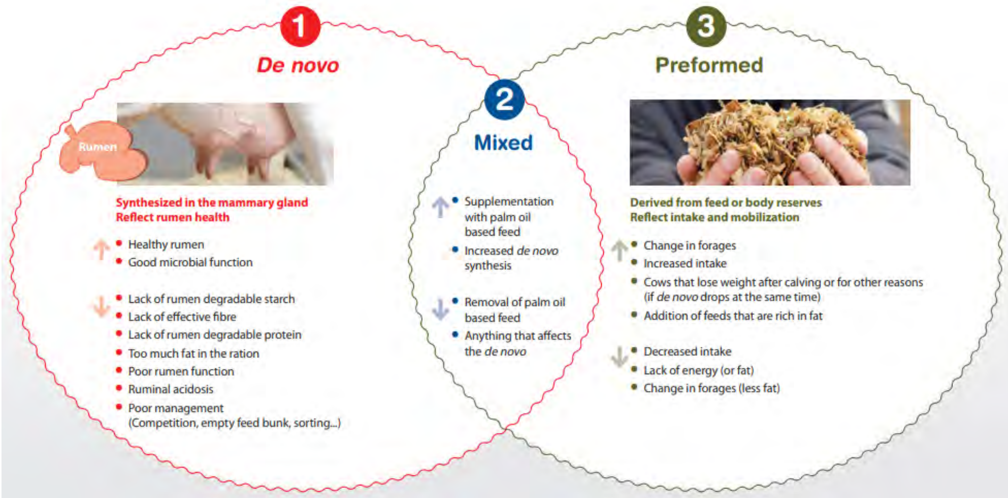

Figure 1. Milk FA groups based on origin and potential causes of increases or decreases of these groups in milk (g/100g milk).

Since April 2019, Lactanet offers routine milk FA profile analysis to all Quebec dairy producers, and more recently to some producers from other provinces in Canada as well. The objective is to implement this analysis across the labs in Canada and therefore be able to offer it across the country. Meanwhile, Quebec data was used to benchmark and compare FA results from herds based on different criteria, in order to provide a better understanding of this new metric.

Data analysis and main findings

Bulk tank milk samples from 3,200 dairy herds on milk recording in Quebec (N = 1.9M) analyzed from April 2019 to July 2022 were used in this analysis to evaluate the use of FA as a monitoring tool.

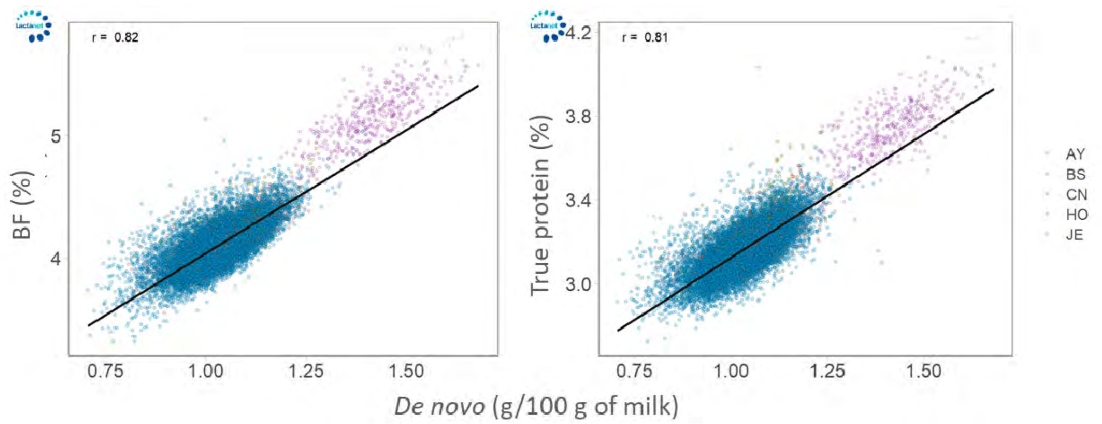

Figure 2. Relationship between de novo and main milk components (Butterfat. BF; and true protein) expressed in g/100g of milk for 1.9M bulk tank samples from 2019 to 2022 in Quebec dairy herds of different predominant breed type.

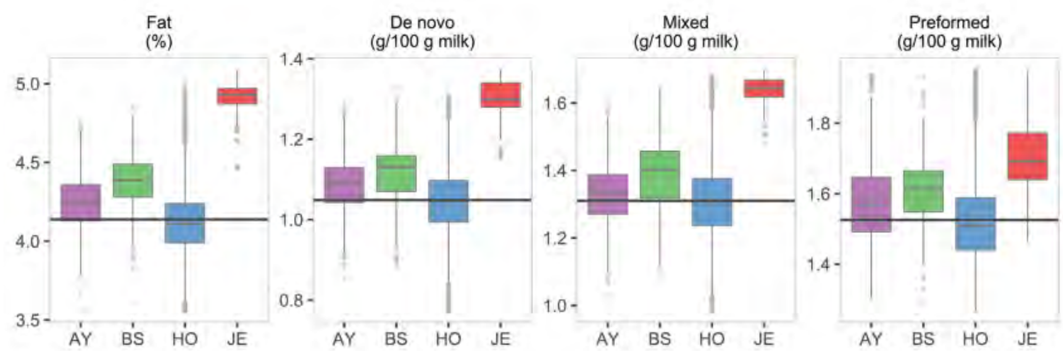

Figure 3. Boxplot representation of milk fat and fatty acid concentrations (g/100g milk) for 2821 Quebec herds of different breeds (AY = Ayrshire; BS = Brown Swiss; HO = Holstein; JE = Jersey). Horizontal line represents provincial average.

Milk fat and protein were correlated with de novo FA from bulk tank milk (rcorr=0.81–0.82; Figure 2) and to a lesser extent with preformed FA (rcorr=0.45 and 0.04, respectively). On a milk basis, each 0.1-percentage unit of increase in de novo FA increased milk fat content by 0.201 unit (r_{corr}=0.82) and milk protein content by 0.117 unit (r_{corr}=0.81); whereas each 0.1-unit increment in preformed FA increased milk fat by 0.099 unit (r_{corr}=0.45) and had no impact on milk protein (r_{corr}=0.04).

Fatty acid benchmarks

Several benchmarks were produced such as for milking system, organic status, herd size and milking frequency and are made available online (https://lactanet.ca/en/profilab-factsheets-with-benchmarks/). Main results are summarized below.

Bulk tank values were matched with the closest test-day results for milk recording herds (N=3700) in order to compare milk FA profiles of herds of different breeds or performance levels. On a milk basis (g FA/100g milk) Jersey (JE) herds had higher concentrations of all fatty acid groups, followed by other colored breeds and finally Holstein (HO) herds (Figure 3). Interestingly, the variation of FA concentrations within a breed was often higher than across different breeds, as shown on the previous Figure.

Holstein herds were classified in percentile ranking based on performance (kg milk/cow/day) to compare milk FA profiles of different production level groups (Figure 4). Again, results revealed bigger within-group difference than between-group variation. A similar comparison was performed with herd performance expressed as kg of milk fat/cow and day (Graph not shown). Overall, with increasing herd performance, *de novo* FA increased and preformed FA decreased. This trend was inversed for high performing herds (≥1.70 kg milk fat/cow and day), which further emphasizes the need to compare herds with specific milk FA profiles to their appropriate peers.

Organic status of herds and its seasonal impact on milk fat and fatty acids was also studied and revealed very distinct patterns for organic herds with a noticeable increased in preformed fatty acids and concurring decrease in de novo fatty acids coinciding with the onset of the pasture season (Figure 5).

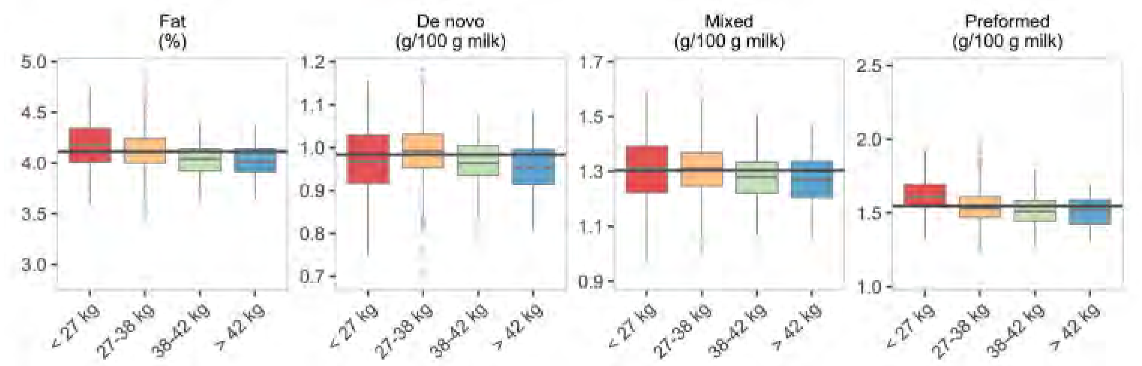

Figure 4. Boxplot representation of milk fat and fatty acid concentrations (g/100g milk) for 2652 conventional Holstein herds in Quebec, Canada based on their production level. Horizontal line represents provincial average.

A subset of 513 Holstein herds with available feed records was used to assess the impact of corn silage proportions in the ration on milk fat and fatty acid profiles. Herds were grouped based on the relative proportion of corn silage fed to the lactating herd (dry matter basis). Results suggest that increasing the proportion of corn silage in the ration up to 50% is associated with increased *de novo* and decreased preformed FA concentrations in milk (Figure 6).

Finally, the margin over feed costs (MOFC; in $ per kg of hl milk or per kg of milk fat) was greater with increased *de novo* FA and smaller with increased preformed FA, whereas no association was observed between the milk FA profile and MOFC per cow (results not shown).

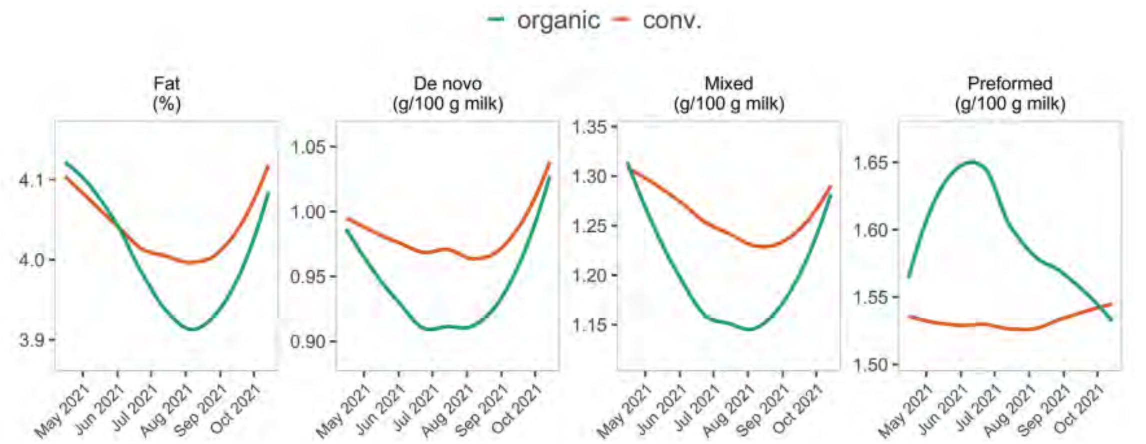

Figure 5. Seasonal variation of milk fat and fatty acid concentrations (g/100g milk) for 1572 conventional and 62 organic Holstein herds in Quebec, Canada.

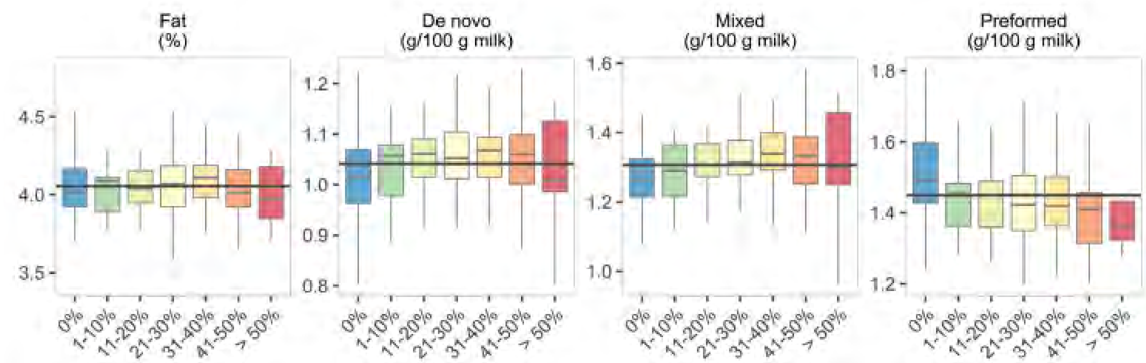

Figure 6. Boxplot representation of milk fat and fatty acid concentrations (g/100g milk) for 426 conventional Holstein herds in Quebec, Canada based on the proportion of corn silage in the ration (dry matter basis). Horizontal line represents provincial average.

Conclusion

In conclusion, variation of milk FA profiles within specific cohorts of herds is often greater than within cohorts, thus highlighting the importance for using herd-specific benchmarks in relation to historical farm data and strategic goals for a herd (internal benchmarking). An interactive dashboard application was developed to visualize milk FA profiles including benchmarks for the user to interpret their herd performance against their peers. Current usage in Quebec provides these values updated at every bulk tank pick-up, thus approximately every 48 hours. Future developments include the development of a cow-level monitoring tool as well as the use of artificial intelligence to provide support in the detection of variations and interpretation of milk fatty acid profiles at the herd level.

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