Infrared Milk Fatty Acid Analysis: Experience in the Field for Farm Management

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Outline

• Where are we at on the “cow of interest”?  
  • Bulk Tank: completed study of about 170 farms from all over the US  
  • Instruments testing bulk tank milk for de novo, mixed performed, chain length, and unsaturation  
    • St Albans Cooperative, AgriMark Cooperative, and Cayuga Marketing Cooperative (1 instrument each)  
    • Sterns County and Zumbrota DHIA Labs, Minnesota (4 instruments)  
    • Cornell University, Miner Institute, and Texas Federal Milk Market Laboratory

• Review of herd level milk fatty acid analysis and interpretation.
• New data (herd level and individual cow level)  
  • milk fatty acids: relation to seasonality of fat and protein  
  • data on fatty acids and stage of lactation  
  • data from 167 farms from all over the US – bulk tank
• Future Directions

Outline

• Where are we at on the “cow of interest”?  
  • Individual Cows:  
    • Instruments testing bulk tank milk for de novo, mixed performed, chain length, and unsaturation.  
      • Sterns County and Zumbrota DHIA Labs, Minnesota (4 instruments)  
      • Cornell University and Miner Institute (continued research for further development of more herd management metrics and to develop a hardware approach that would integrate into a milking system for analysis of milk from every cow.)
**Status Cow of Interest?**

1) We are getting a much better understanding of how to use fatty acid data for whole herd or milking group diagnostics.

2) We need to develop hardware and software to integrate this approach into the milk system for analysis of milk from each cow.

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**Whole herd bulk tank data**

**Bulk Tank Milk Testing**

**Efficiency of forage utilization**

*(de novo fatty acids)*

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**Milk Fat Structure**

3 Fatty Acids + Glycerol

3 fatty acids per triglyceride

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**Milk Fatty Acid Origin**

*De novo*

- C4:0
- C6:0
- C8:0
- C10:0

- 35-40%
- 18-30%

*Mixed*

- C12:0
- C14:0
- C14:1
- C15:0

- 30-45%
- 35-40%

*Preformed*

- C16:0
- C16:1
- C18:0
- C18:1
- C18:2

- 30-45%
**De novo Fatty Acid Synthesis**

- **Feed**
- **Rumen fermentation**
  - acetate
  - butyrate
  - de novo synthesis
  - Milk fat

**Preformed Fatty Acids**

- **Feed**
- **Dietary fat**
- **Adipose**
  - NEFA and chylomicra
  - VLDL
  - Preformed FA
  - Milk fat

**Infrared (mid-FTIR) Milk Analysis**

Manual FTIR currently used at Cornell and Collaborator Laboratories - Delta Instruments Model FTA, The Netherlands

*de novo, mixed origin, and preformed fatty acids*

Fatty acid calibration was done once per month with reference milks produced at Cornell. The instrument tests about 50 to 70 samples per hour for all components, NPN/urea, and all fatty acid parameters. The automated model runs 600 samples per hour.

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- Where are we at on the “cow of interest”?
- Review of herd level milk fatty acid analysis and interpretation.
40 Farm Studies (2014 & 2015)

Collaboration: Cornell, Miner Institute, St. Albans Cooperative, Delta Instruments

1. Sort all 430 farm data from low to high values for de novo fatty acids as a percentage of total fatty acids within the Jersey group of farms and within the Holstein group of farms for a field study in 2014.

2. Select 10 Jersey farms with low de novo and 10 Jersey farms that have high de novo fatty acids.

3. Select 10 Holstein farms with low de novo and 10 Holstein farms that have high de novo fatty acids.

4. In 2015, we repeated the study with 40 Holstein farms: 20 high de novo and 20 low de novo farms.

Milk Composition: June 2012 – August 2013

Mean relative milk fatty acid composition for each group of 10 farms for the 15 month period: de novo, mixed origin, and preformed fatty acids

<table>
<thead>
<tr>
<th>Breed</th>
<th>Group</th>
<th>Fat %</th>
<th>True Protein %</th>
<th>$/100g FA DeNovo</th>
<th>$/100g FA Mixed</th>
<th>$/100g FA Preformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein</td>
<td>Low DeNovo</td>
<td>3.623</td>
<td>2.993</td>
<td>24.08</td>
<td>33.97</td>
<td>41.95</td>
</tr>
<tr>
<td>Holstein</td>
<td>High DeNovo</td>
<td>3.975</td>
<td>3.148</td>
<td>26.08</td>
<td>35.08</td>
<td>38.84</td>
</tr>
<tr>
<td>Jersey</td>
<td>Low DeNovo</td>
<td>3.917</td>
<td>3.093</td>
<td>25.04</td>
<td>33.35</td>
<td>41.61</td>
</tr>
<tr>
<td>Jersey</td>
<td>High DeNovo</td>
<td>4.804</td>
<td>3.616</td>
<td>27.41</td>
<td>34.62</td>
<td>37.96</td>
</tr>
</tbody>
</table>

Results of 40 Farm Study Year 1

- Half Holstein Herds and Half (Jersey – mixed breed)
- De novo FA as a % of total fatty acids (25.6 vs 23.7% relative %, P<0.01)
- Milk (26.3 vs 22.7 kg/d, P=0.06),
- Fat (4.33 vs 4.14%, P=0.10),
- True protein (3.41 vs 3.22%, P<0.01)
- MUN (11.4 vs 11.3 mg/dL, no significant difference)
- These differences for fat and protein between HDN and LDN herds at 25 kg of milk per 100 cows per year would result in a gross income difference of $8,544 for fat and $15,695 for protein.

Results of 40 Farm Study Year 2

- All herds were Holstein
- De novo FA as a % of total fatty acids (26.0 vs 23.8% relative, significant P< 0.01)
- Milk (31.9 vs 32.1 kg/d, no significant difference),
- Fat (3.98 vs 3.78%, P<0.01),
- True protein (3.19 vs 3.08 %, P<0.01)
- MUN (12.1 vs 12.9 mg/dL, no significant difference)
- These differences for fat and protein between HDN and LDN herds at 30 kg of milk would result in a gross income difference of $9,125 for fat and $6,935 for protein per 100 milking cows per year.
Factors Related to De novo Fatty Acid Synthesis

Less feed bunk space per cow (i.e., < 46 cm, or < 18 inches) was related to lower de novo fatty acids and lower fat and protein test.

Higher stall stocking density in pens (i.e., > 1.1 cows per stall) was related to lower de novo fatty acids and lower fat and protein test.

Higher average ether extract in the ration for lower de novo fatty acid farms.

Higher peNDF as a % of DM for the high de novo fatty acid farms (26.8 vs 21.4%) (P < 0.01)

40 Farms Holstein Farms 2015
St Albans - Fat
If you want a fat test > 3.75% fat in bulk tank with Holsteins, then the de novo fatty acids in grams per 100 grams of milk needs to be > 0.85 g/100 milk

Fat % vs DN + Mixed g/100 g Milk

Fat (%)  vs Preformed g/100 g Milk
If you want a fat test > 3.75% fat in bulk tank with Holsteins, then the double bonds per fatty acid in milk fat needs to < 0.31.

As double bonds per fatty acid increases in milk fat, the output of de novo fatty acids decreases. This metric seems to indicate the overall level of milk fat depression.

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**Stage of Lactation – Holstein**

Herd producing an average of about 92 lb (41.77 kg) per cow per day on TMR feeding system.
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**Stage of Lactation – Holstein**

**All Cows**

**DN & PF by Parity**

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  - data from Holstein 167 farms from all over the US – bulk tank

**Bulk Tank Milk – 167 Farms - Fat**
For milk composition data from an individual farm the following data are useful for the full herd or for groups of cows in combination with information on feed composition and management practices:

- Milk per cow per day
- Milking frequency (2X or 3X) – milk and component output expected to be 10 to 15% higher on 3X farms
- Milk SCC (cells/mL)
- Milk MUN (mg/dL or mg/100 g milk)
- Milk fat unsaturation (double bonds per fatty acid)
- Milk fat (g/100 g milk and g/day production)
- Milk protein (g/100 g milk and g/day production)
- Milk lactose (g/100 g milk and g/day production)
- Milk de novo fatty acids (g/100 g milk and g/day production)
- Milk mixed origin fatty acids (g/100 g milk and g/day production)
- Milk preformed fatty acids (g/100 g milk and g/day production)
Lactose: grams per cow per day.

When milk production per cow per day is low in a Holstein herd, is synthesis of lactose the first thing a dairy nutritionist thinks about?

It should be.

If a 3X Holstein multiparous cow is going to produce a lactation average of > 85 lb (38.6 kg) of milk per day, she is going to need to produce at least an average of 1800 grams of lactose per day. This is the foundation upon which to build high fat and protein output per cow per day.

Making more lactose per day (anhydrous lactose, not lactose by difference) makes more milk per day. To have a high output of lactose per cow per day, glucose supply, transport, and metabolism needs to be working very well.

Factors to consider are the production of propionate produced in the rumen and the undegraded starch that is leaving the rumen and available in the lower gastrointestinal tract.

Also, is there some cow health issue (immune system activation – mastitis, laminitus, leaky gut) or environmental factor (e.g., heat stress) in the herd that is putting a demand on the glucose supply and reducing the glucose available for milk synthesis?

Milk urea nitrogen: mg/100 g milk.

What is the concentration and day to day variation in MUN?

If the MUN is >14 to 16, it is likely that rumen ammonia levels are too high.

Another aspect of MUN is to look at the day-to-day variation in MUN within the same farm. MUN decreases rapidly when cows do not have access to feed.

Thus, day-to-day variation in MUN within the same farm is an index of how consistently the farm is keeping feed accessible to cows on a continuous basis (i.e., feed bunk management).

De novo and mixed origin fatty acids: g/100 g milk.

There is a strong correlation between changes on de novo FA concentration in milk and bulk tank milk fat and protein tests.

In general, when de novo (> 0.85 g/100 g milk) and mixed origin FA (>1.35 g/100 g milk) are high, it is an indication that rumen fermentation of carbohydrate is working well and the supply of volatile fatty acids from the rumen is good.

This can be the case with either a high or lower level of milk (i.e., lactose) production. Fixing the low lactose production issue will likely allow the cows to maintain high concentration of de novo and mixed origin but increase their per day output of fat and protein given an adequate supply of their precursors.
**Bulk Tank Milk – Questions**

**FA chain length and double bonds per fatty.**
Chain length and double bonds per fatty acid are useful indices of what is happening in the rumen, but they are less of a driver and more of a correlated outcome of other things that are happening.

In general, as double bonds per FA increases milk fat decreases. A rule of thumb based on our observations for Holstein herds is that when the double bonds per FA is > 0.31, the probability of trans FA induced milk fat depression is greatly increased for Holsteins.

A word of caution is that there is a large stage of lactation impact on double bonds per FA and cows in the transition period will have a high double bond per FA without having trans FA induced milk fat depression. Thus, be careful with interpretation of milk fat unsaturation on groups of early lactation cows.

**Conclusions**

1) Seasonality in fat and protein content of bulk tank milk is related to seasonality in de novo fatty acid levels in milk.

2) Stage of lactation has a large impact on milk fatty acid composition and when evaluating milk fatty acid data from feeding groups within a herd, mean days in milk needs to be considered when interpreting data.

3) The relationship between variation in milk fatty acid composition and bulk tank milk fat and protein content for Holstein herds in the Northeast US is consistent with data collected from a wide diversity of 167 Holstein farms from across north America.

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**Future Directions – New Metrics**

- **Management Indices on Individual Cows**

  - Blood Chemistry Measures (done on MILK!!! Every milking???)
    - Blood NEFA
    - Blood BHB
    - Milk urea nitrogen (MUN)
    - Stress/inflammation compounds?
    - others – related to reproduction??

  - **Used**: Milk Fat Depression, Predict Ketosis, DA, acidosis, and reproductive performance

- **Rumen Function**
  - prediction of rumen pH?
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