Development and Use of Mid Infrared Spectra to Measure Milk Fatty Acid Parameters and Estimated Blood NEFA for Farm Management

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2018ICAR Meeting

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Outline

- **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**

- **Future Directions**

Current Status

- **Milk fatty acid analysis for farm management?**

  - **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). Hopefully, ADM lab in Clovis in March 2018.**

    - **Cornell University, Miner Institute, and Texas Federal Milk Market Laboratory**

Current Status

- **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 MIR for ProactiveFarm Management?

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.
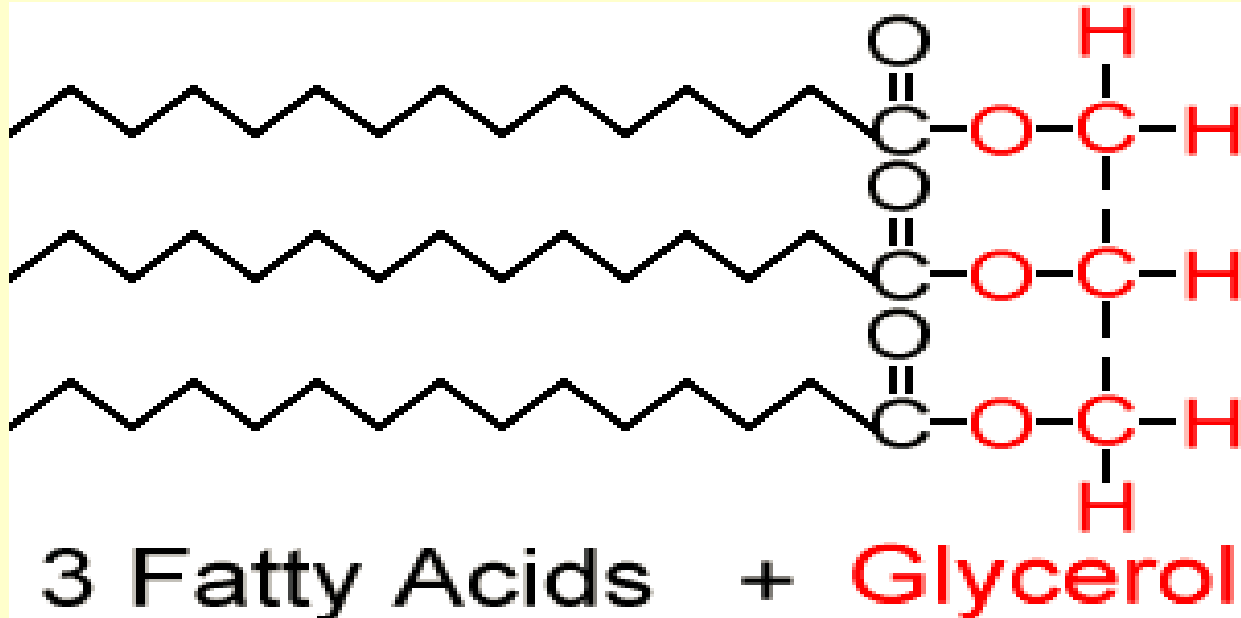
Outline

- Where are we at on the "cow of interest"?

- **Review of herd level milk fatty acid analysis and interpretation.**

Bulk Tank Milk Testing

Efficiency of forage utilization (*de novo* fatty acids)
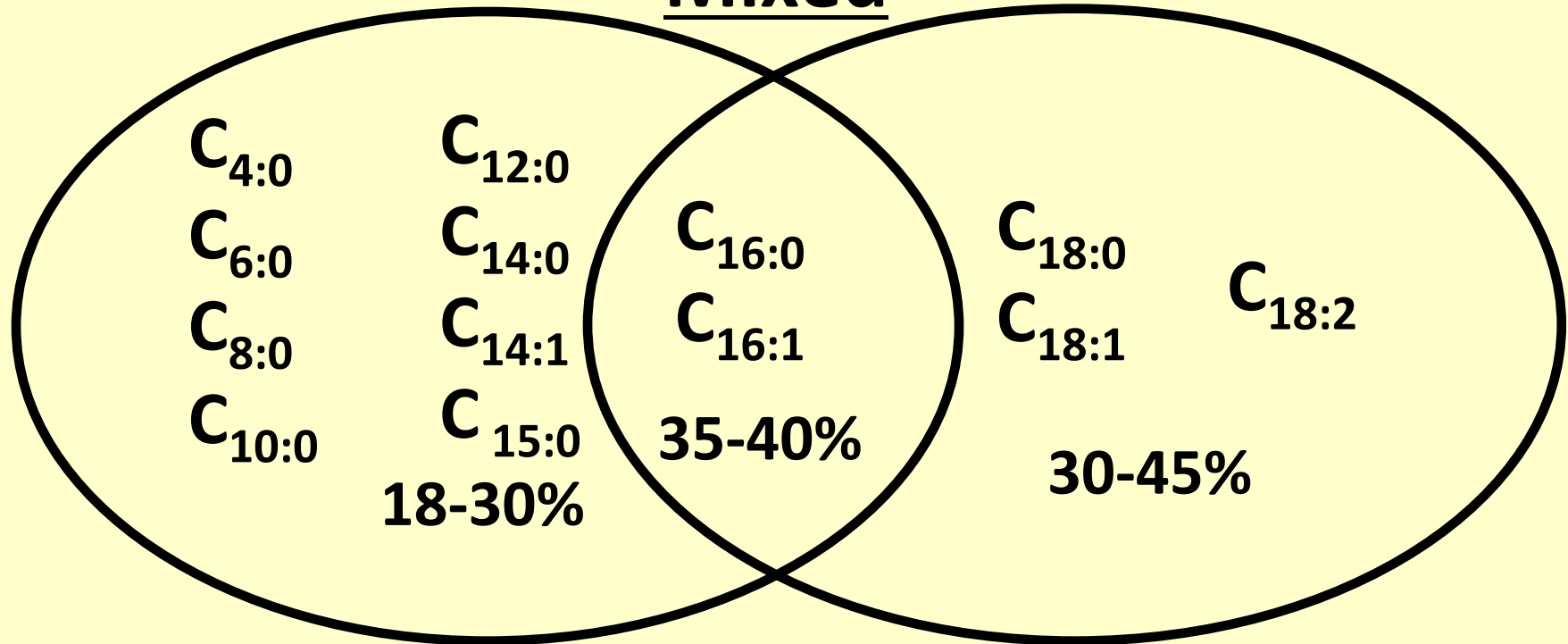
Milk Fat Structure

3 Fatty Acids   +   Glycerol

3 fatty acids per triglyceride

Milk Fatty Acid Origin

De novo

$C_{4:0}$ $C_{12:0}$
$C_{6:0}$ $C_{14:0}$
$C_{8:0}$ $C_{14:1}$
$C_{10:0}$ $C_{15:0}$

18-30%

Mixed

$C_{16:0}$
$C_{16:1}$

35-40%

Preformed

$C_{18:0}$
$C_{18:1}$ $C_{18:2}$

30-45%

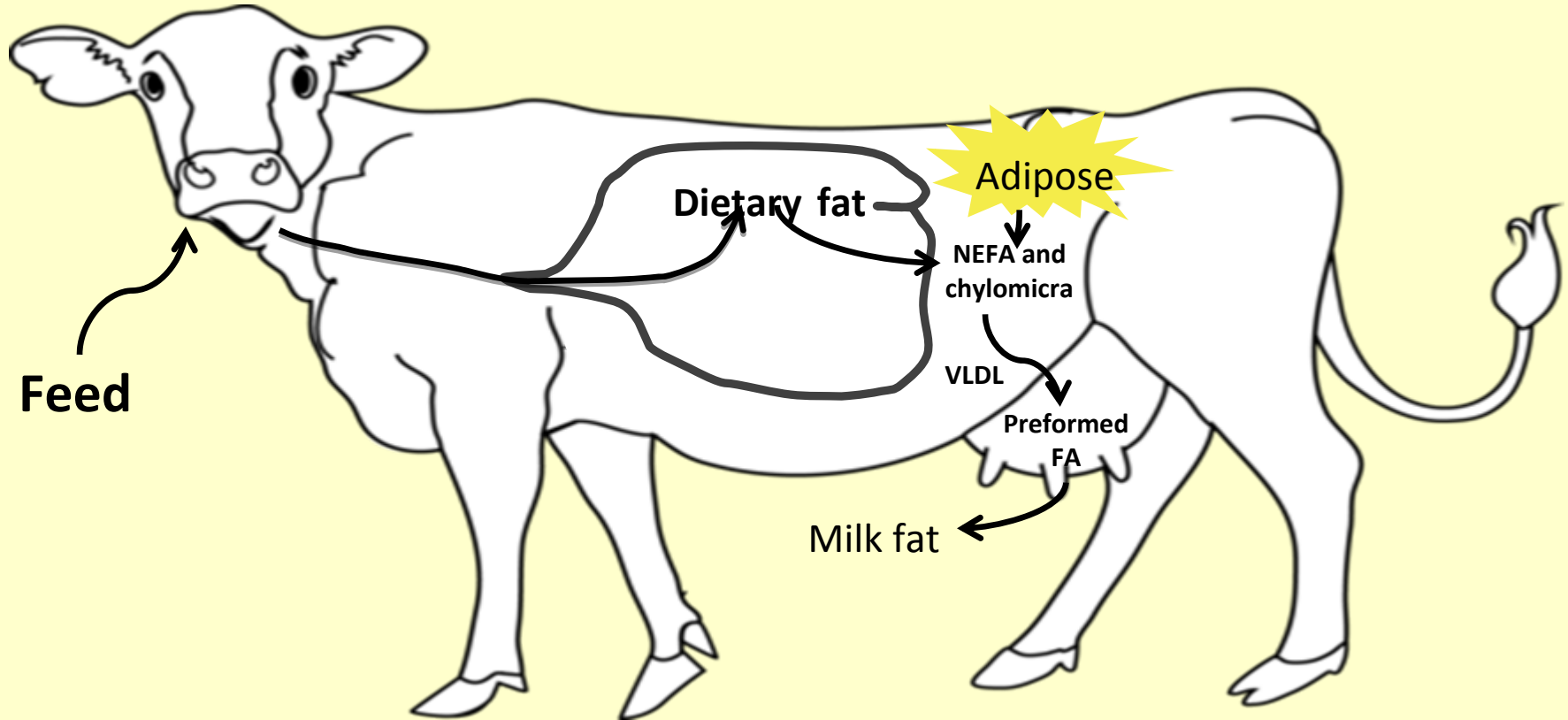# De novo Fatty Acid Synthesis

Feed

Rumen fermentation

acetat

butyrate

de novo synthesis

Milk fat
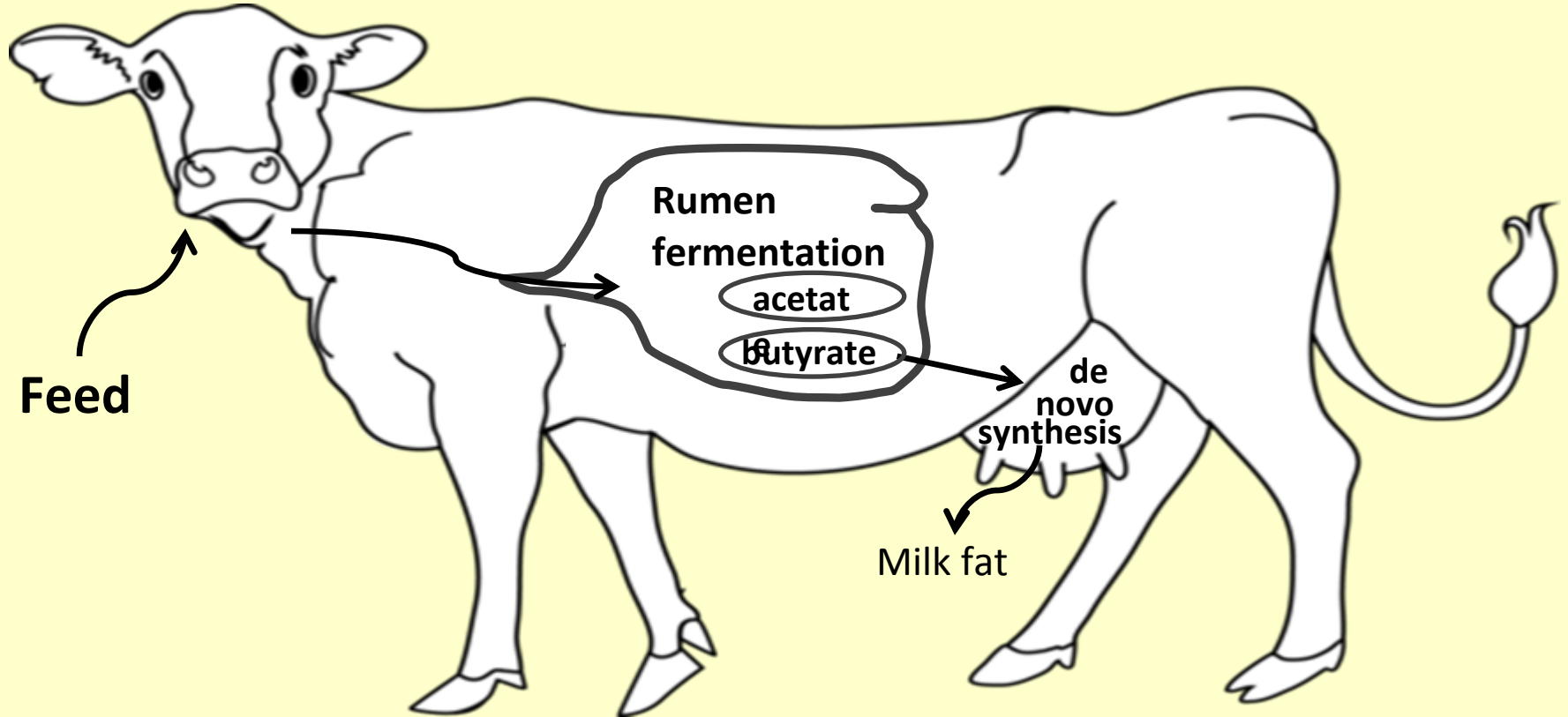
Preformed Fatty Acids

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.

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

St Albans   June 2012 through August 2013

Breed	Group	% Fat	% True Protein	g/100 g FA Denovo	g/100 g FA Mixed	g/100 g FA Preformed
Holstein	Low *DeNovo*	3.623	2.993	24.08	33.97	41.95
Holstein	High *DeNovo*	3.975	3.148	26.08	35.08	38.84
Jersey	Low *DeNovo*	3.917	3.093	25.04	33.35	41.61
Jersey	High *DeNovo*	4.804	3.616	27.41	34.62	37.96

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 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

$y = 2.297x + 1.844$
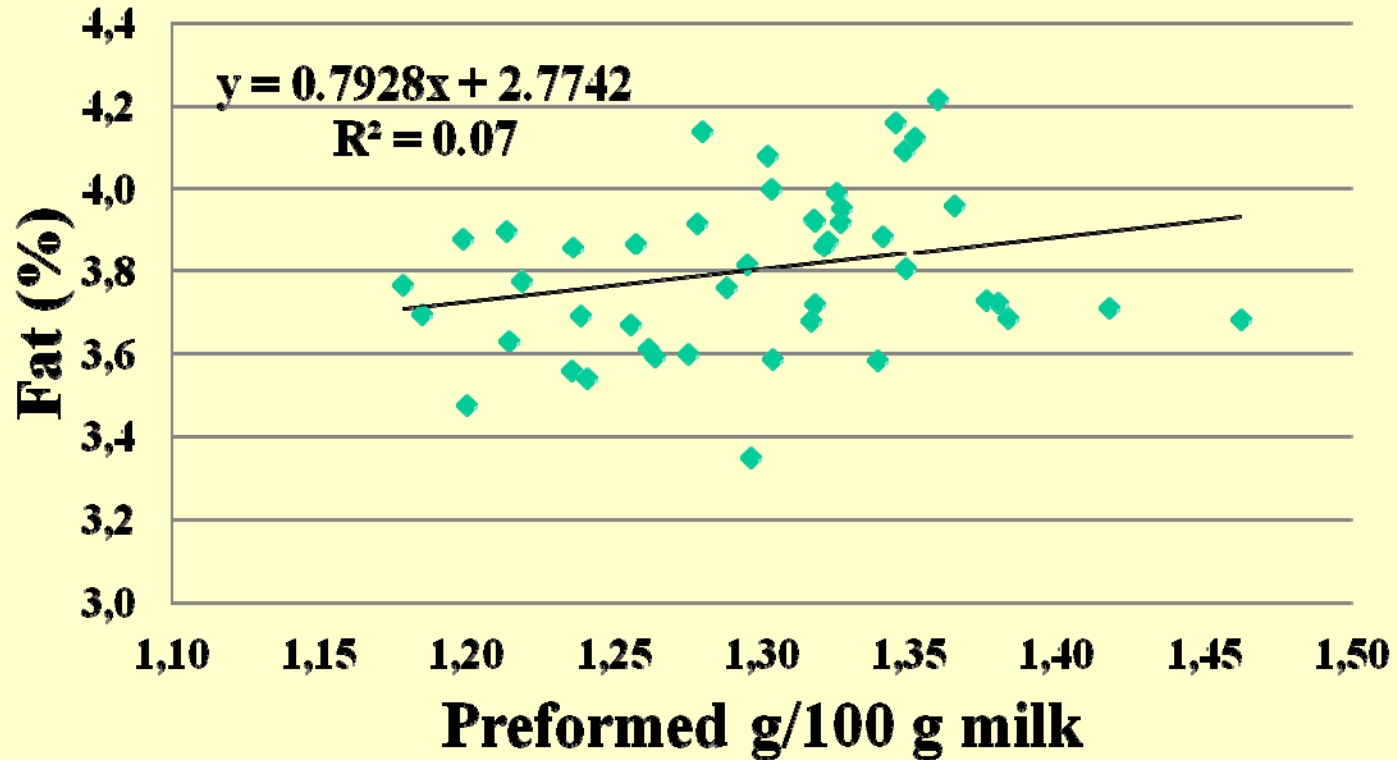$R^2 = 0.80$
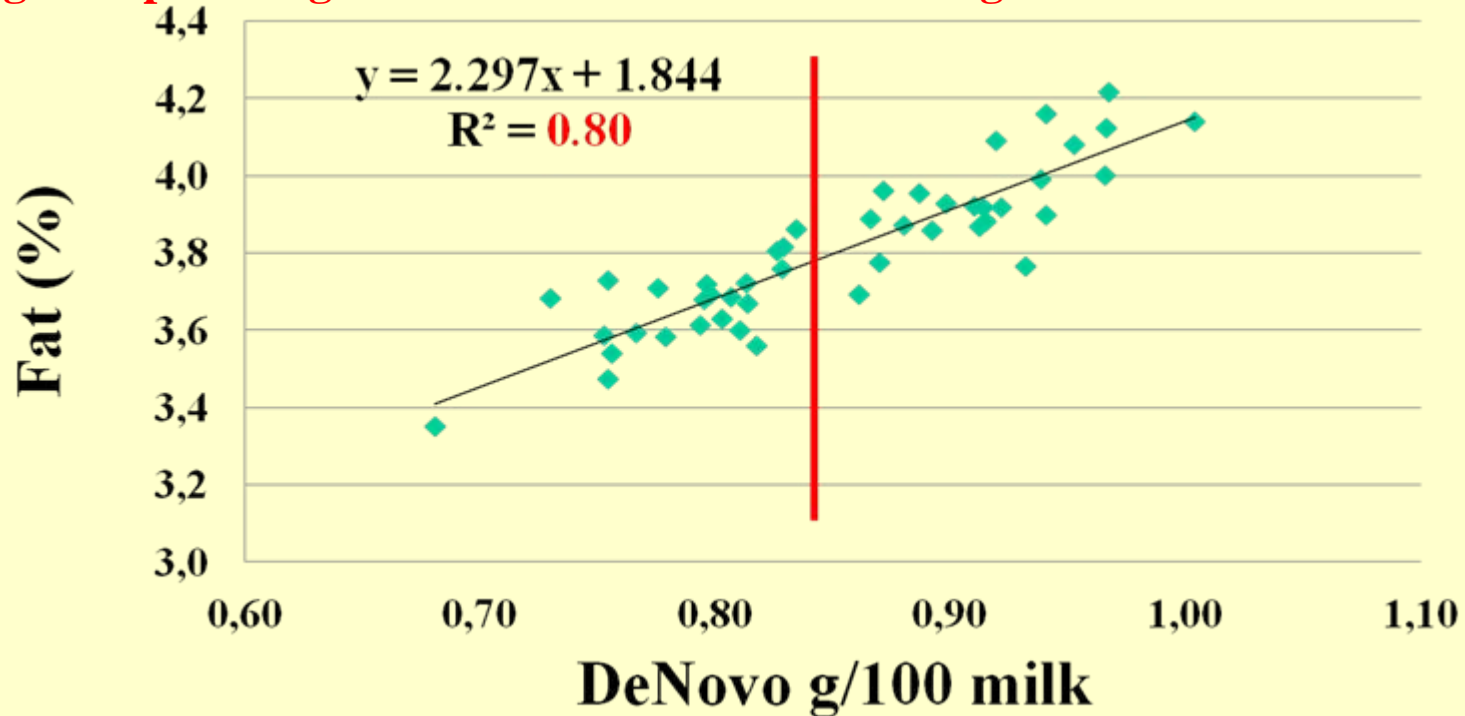
40 Farms Holstein Farms 2015
St Albans - Fat

If you want a fat test > 3.75% fat in bulk tank with Holsteins, then the denovo + mixed fatty acids in grams per 100 grams of milk needs to be > 2.25 g/100 milk

Fat % vs DN + Mixed g/100 g Milk
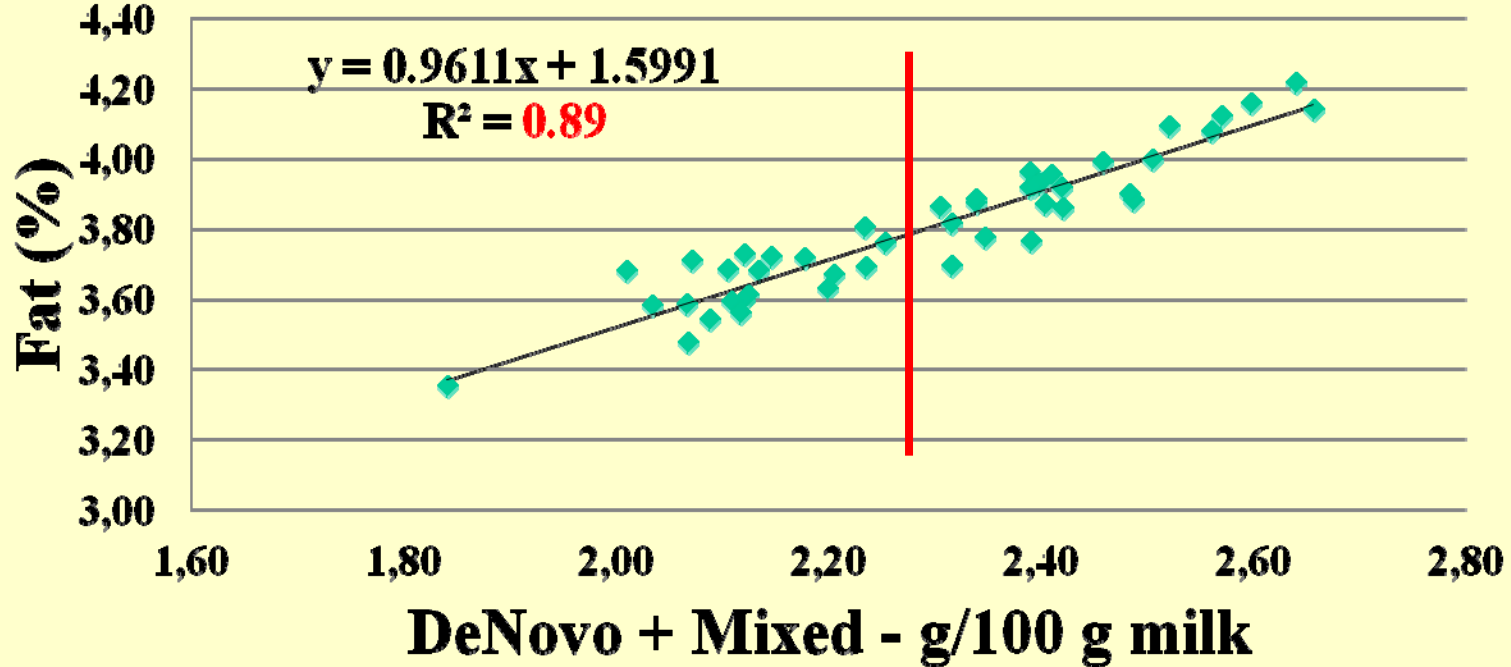
$y = 0.9611x + 1.5991$

$R^2 = 0.89$

40 Holstein Farms 2015
St Albans - Fat

y = 0.7928x + 2.7742
R² = 0.07

Fat (%) vs Preformed g/100 g milk

40 Holstein Farms 2015
St Albans - Fat

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.

Fat % vs double bonds per fatty acid

$y = -8.583x + 6.4213$

$R^2 = 0.694$

High risk trans fatty acid induced milk fat depression
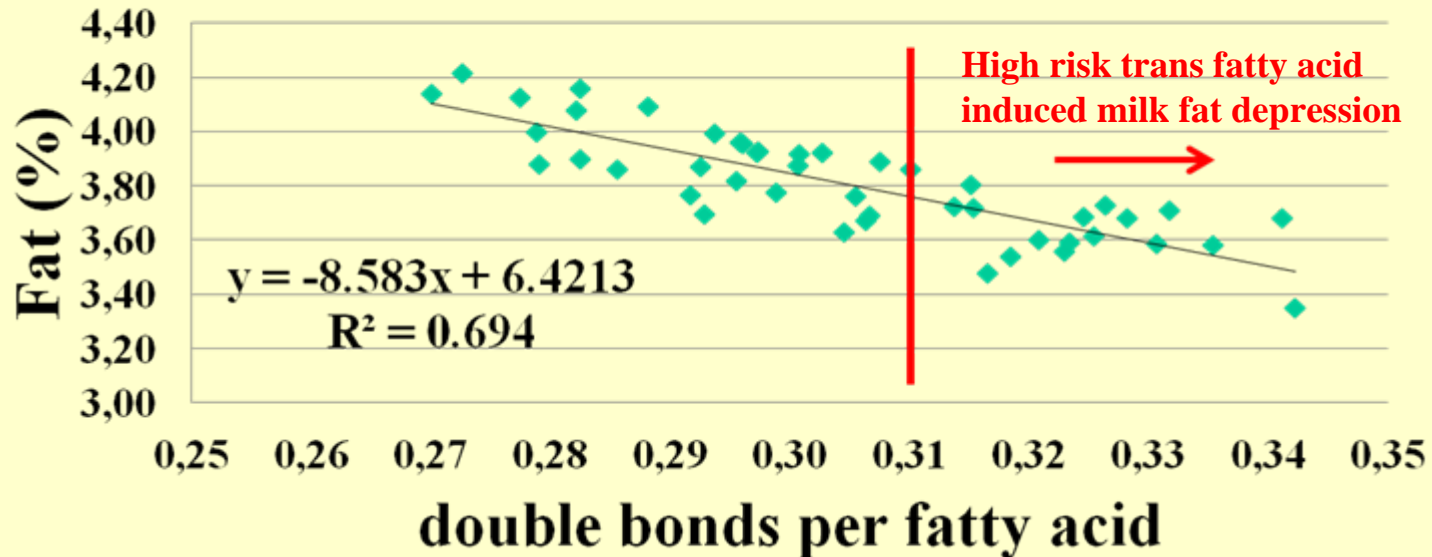
40 Holstein Farms 2015
St Albans – Milk Fat Depression

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

de novo fatty acids vs double bonds per fatty acid

$y = -3.7138x + 1.9858$

$R^2 = 0.85$

De novo FA - g/100 g milk

double bonds per fatty acid
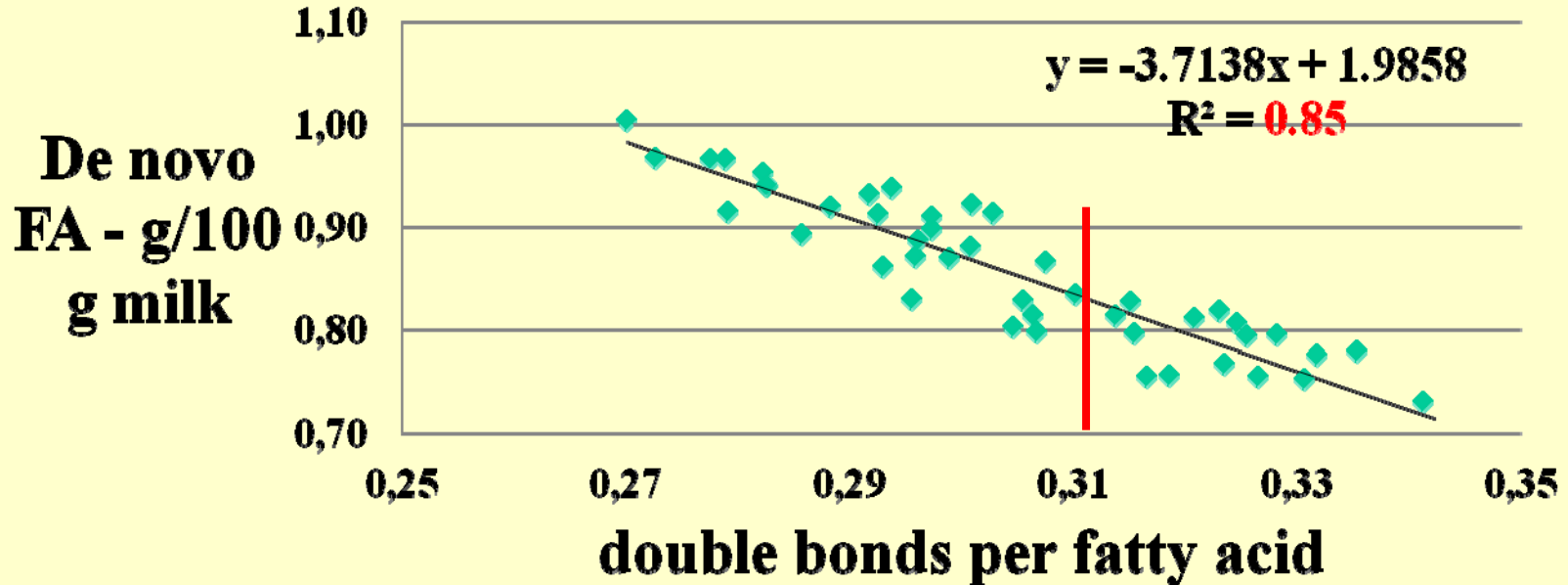
**40 Holstein Farms 2015**
St Albans - Protein
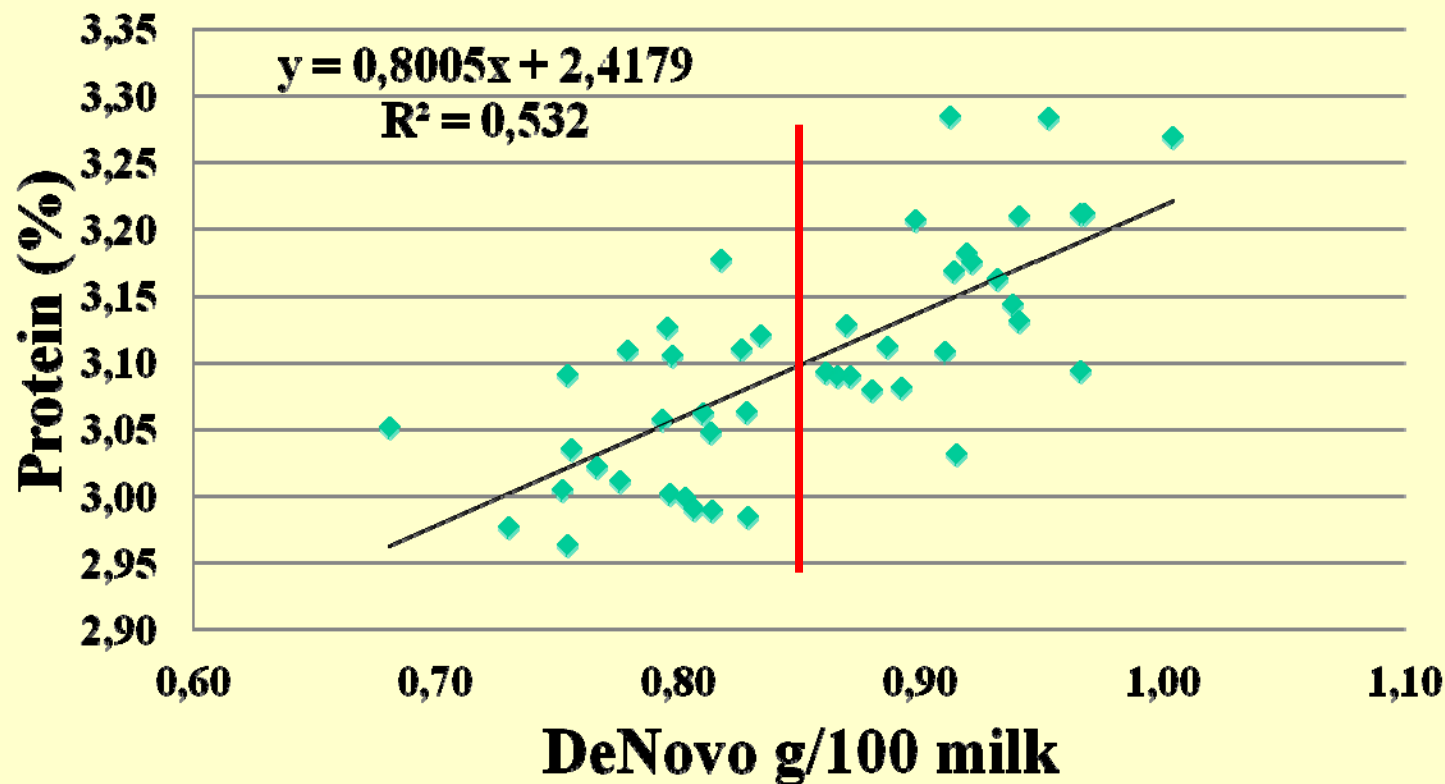
Outline

- Were are we at on the "cow of interest"?

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  - milk fatty acids: relation to seasonality of fat and protein

Seasonality of Bulk Tank Milk - Fat

Mean of 40 farms: St Albans Cooperative (g/100 g milk)
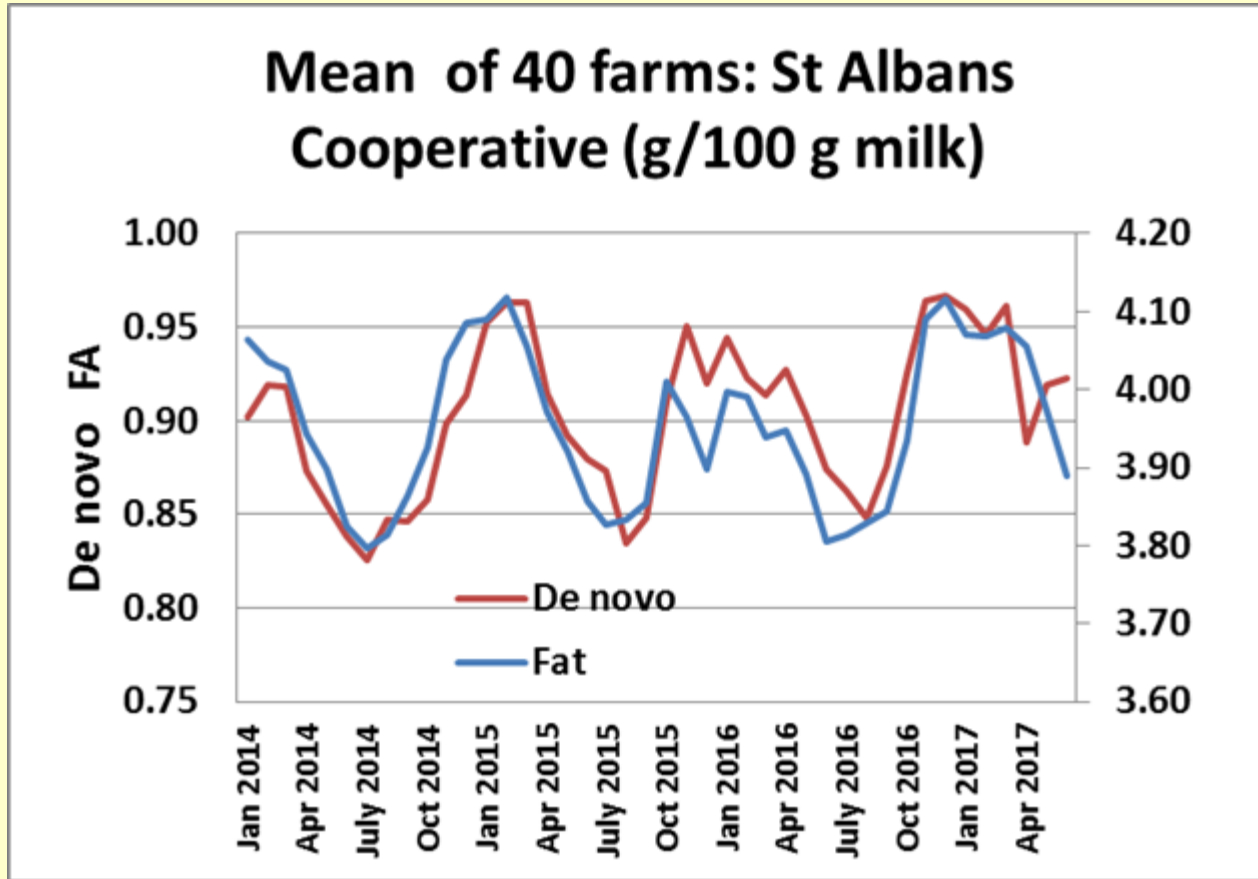
Seasonality of Bulk Tank Milk – Protein
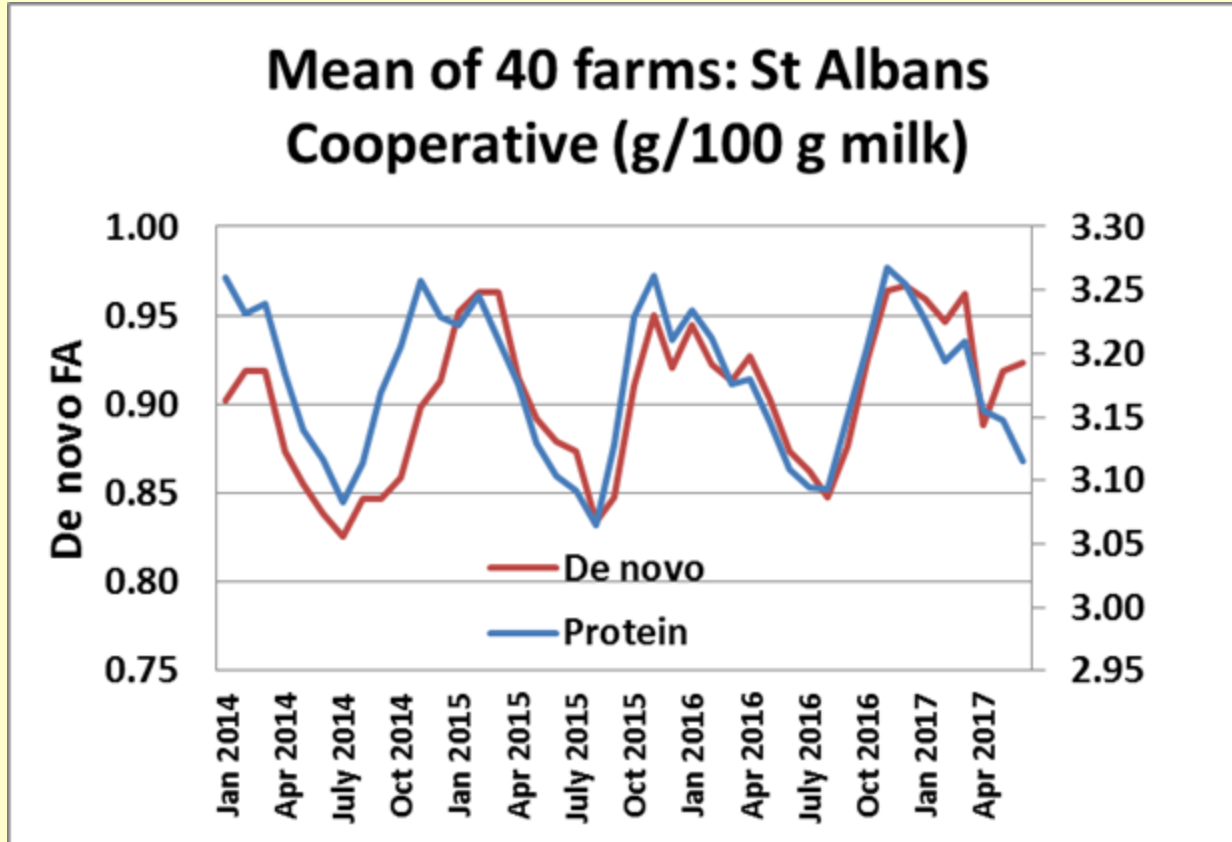
Mean of 40 farms: St Albans Cooperative (g/100 g milk)

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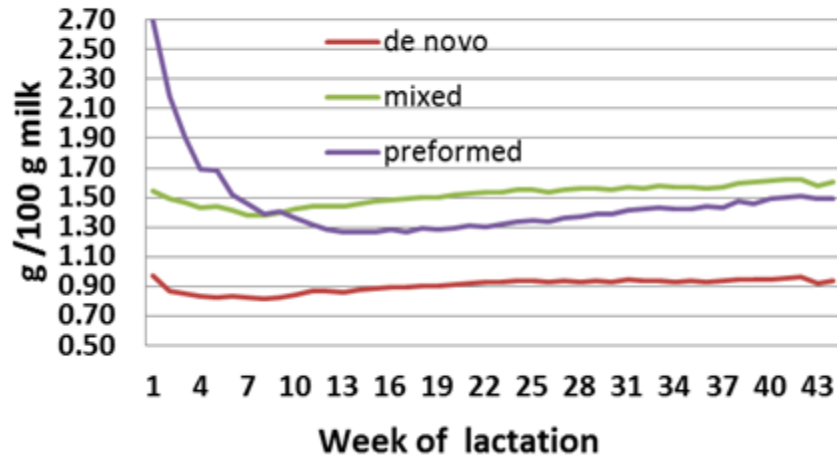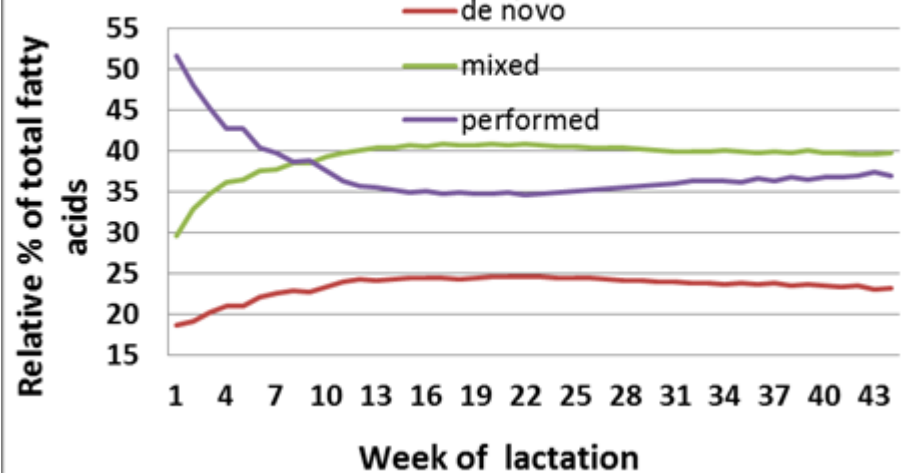
Herd producing an average of about 92 lb (41.77 kg) per cow per day on TMR feeding system.

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 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. (data not shown)**

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  - **data on fatty acids and stage of lactation**

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

- **Future Directions**

Future Directions – Transition Cow Health Diagnostics

1) **Measurement of milk estimated blood NEFA and de novo fatty acid expressed on a relative basis (i.e., % of total fatty acids) allows rapid identification (day 4 to 7 in lactation) of transition cows that are going to diagnosed with clinical ketosis or with a displaced abomasum.**

2) **These milk-based transition cow analytical tools provide an opportunity to intervene earlier thereby improving recovery while reducing the negative impact of these adverse metabolic health events on animal welfare and lactation performance.**
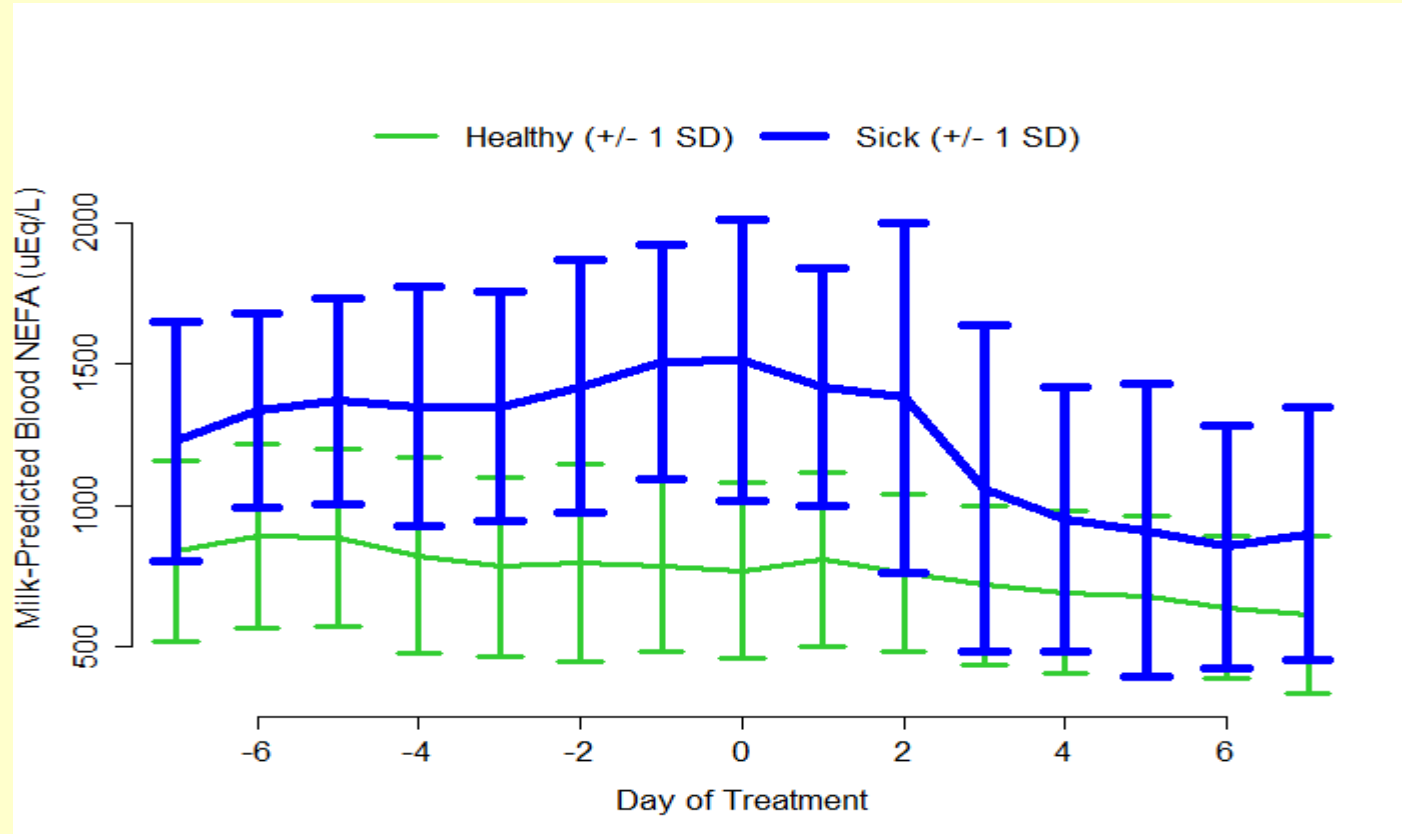
Future Directions:(estimated blood NEFA)
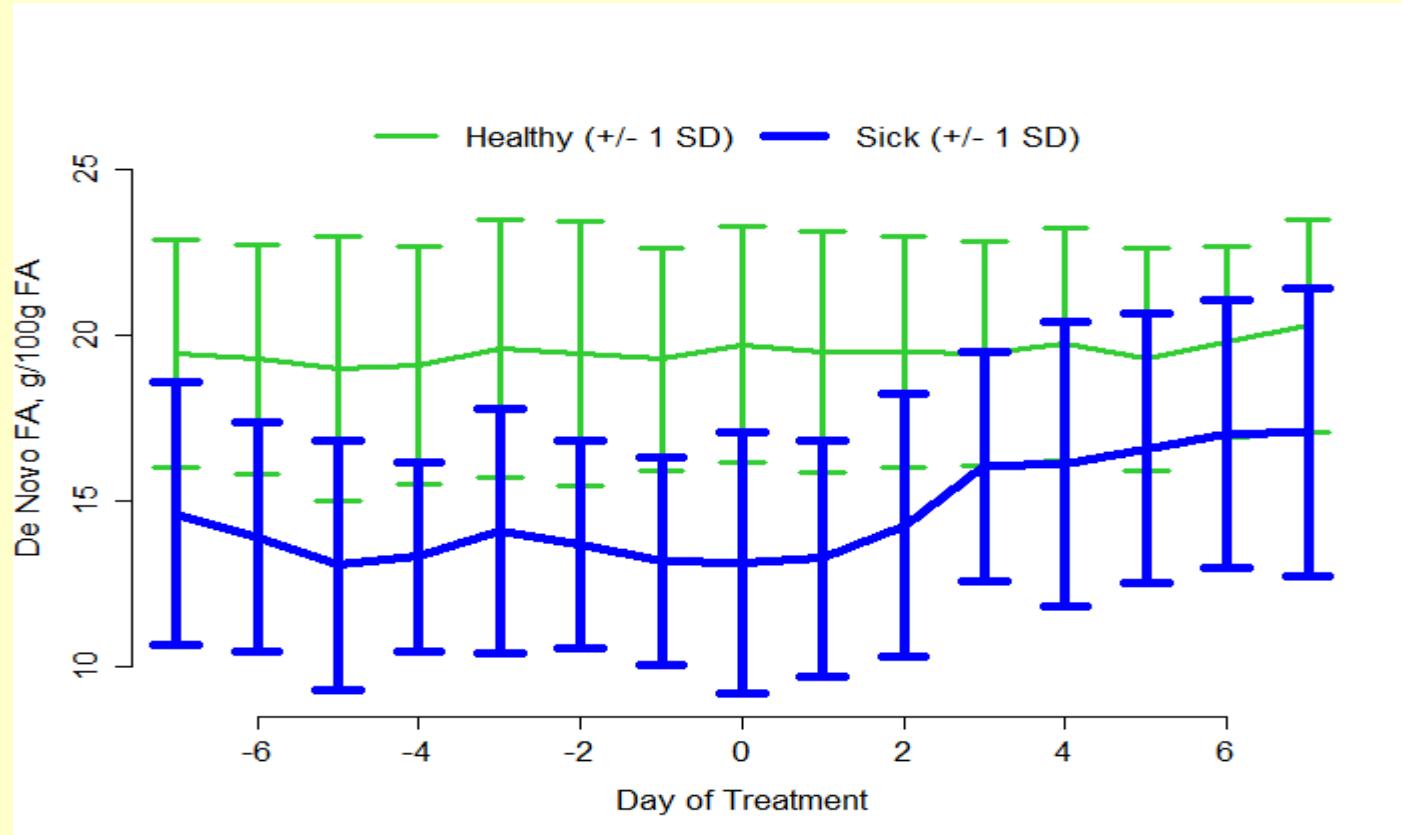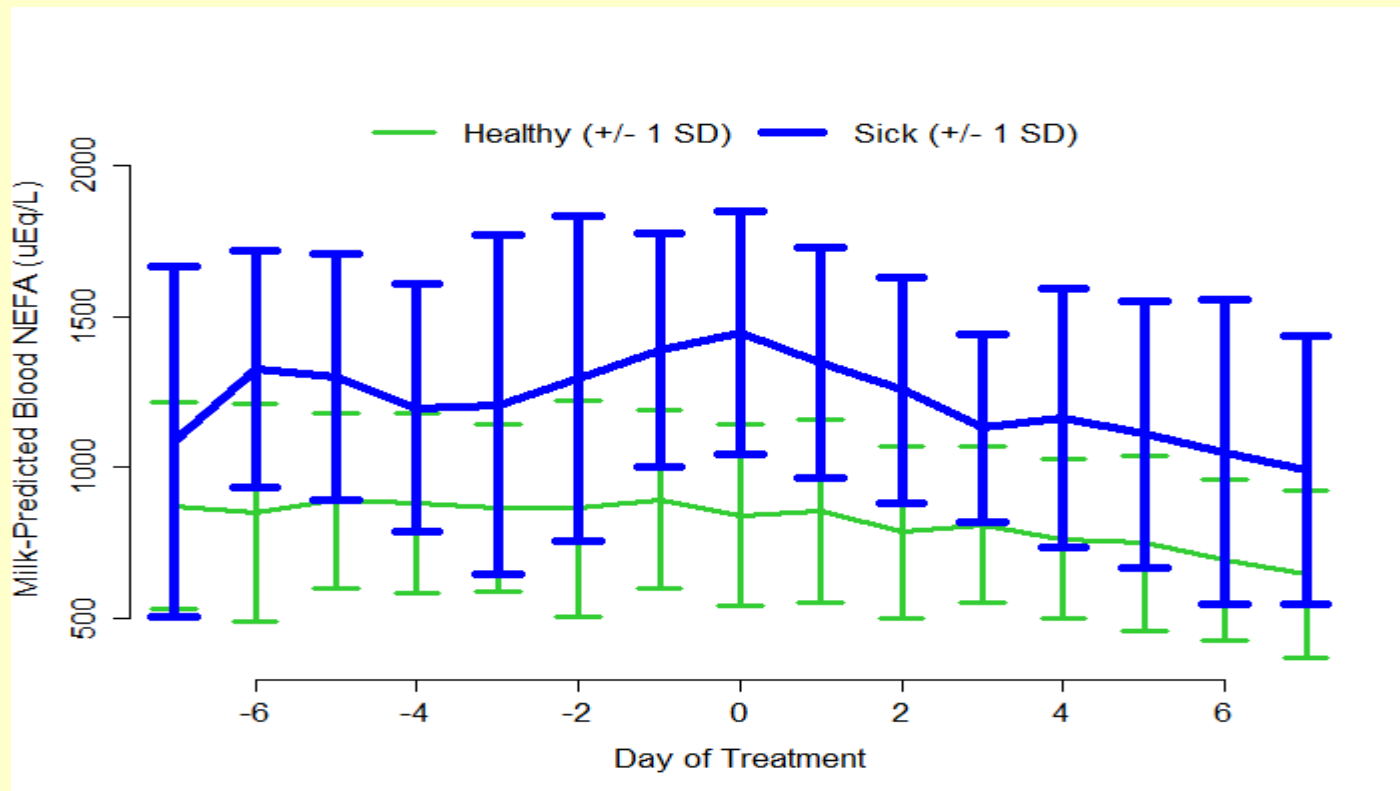
Change in estimated blood NEFA with days in milk
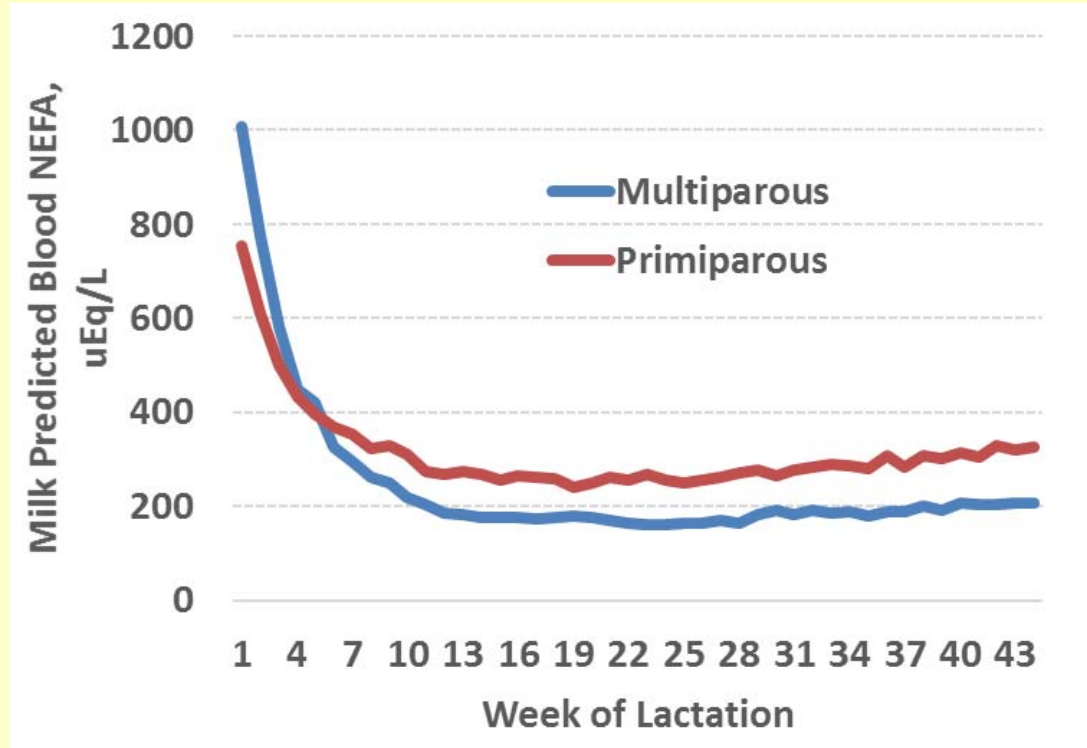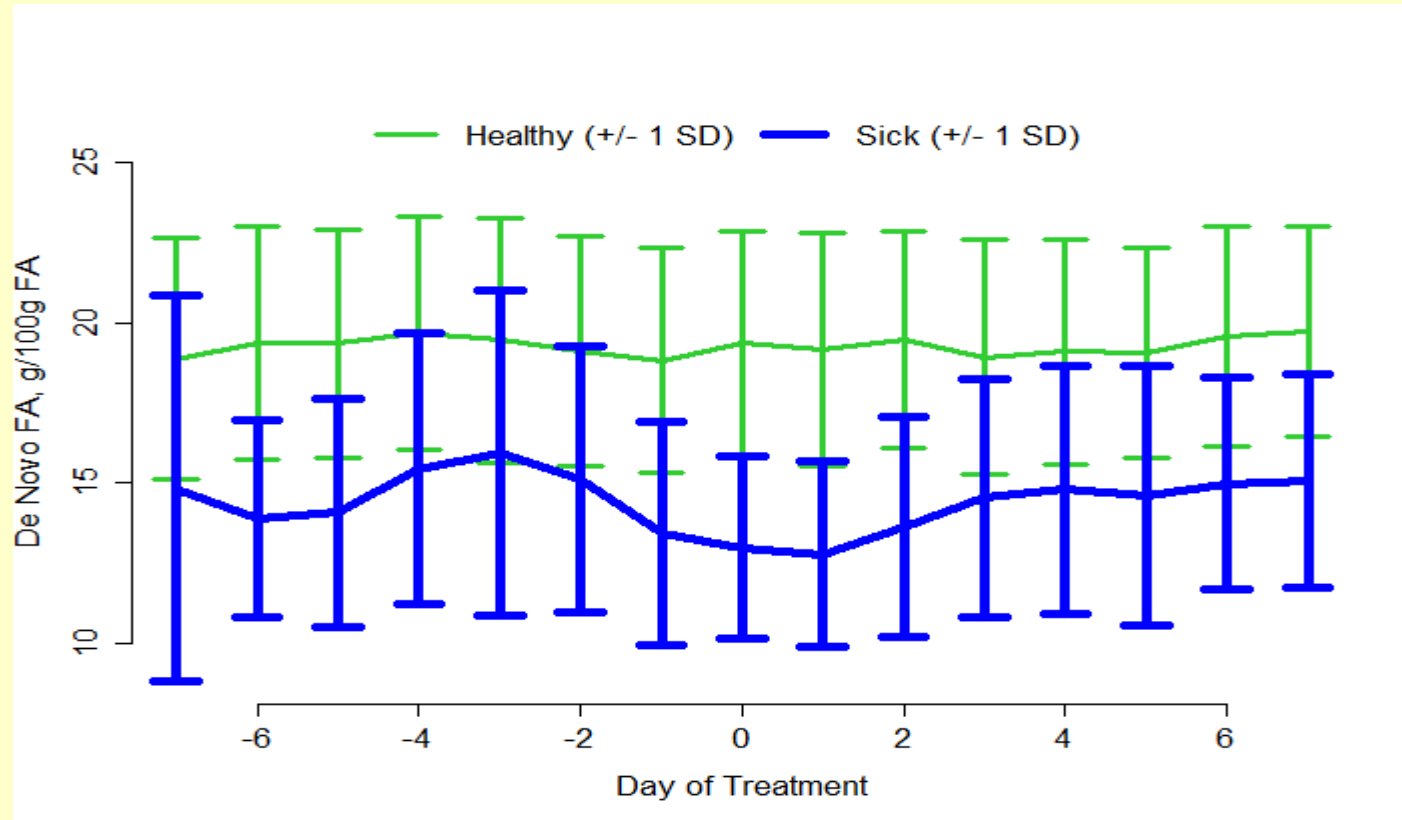
Future Directions –Displaced Abomasum (blood NEFA)

Future Directions –Displaced Abomasum (de novo FA)

Future Directions – Clinical Ketosis (blood NEFA)

Acknowledgments

The lab staff at St. Albans Cooperative for infrared milk testing of fatty acid composition of bulk tank milk of 430 farms over 4 years and Miner Institute (R. Grant, H. Dann, M. Woolpert and many others) for individual cow milk and blood samples.

Delta Instruments for technical support in development of calibration models.

The USDA Federal Milk Markets for support of the development of improved milk testing methods.