Proceedings

Dairy Day

at

Miner Institute

Wednesday, December 5, 2018
10:00 AM - 3:00 PM
Chazy, New York
Dairy Day at Miner Institute
Wednesday, December 5, 2018
10:00AM -3:00 PM

10:00-10:45 Dr. Rick Grant, Miner Institute, “A Tale of Two Fibers: Optimizing peNDF and uNDF”

10:45-11:45 Dr. Mike Van Amburgh, Cornell University, “Colostrum as a communication vehicle to the calf.”

11:45-1:00 Lunch and Door Prizes

1:00-1:45 Dr. Mike Van Amburgh, “Nutritional and economical management of heifers.”

1:45-2:15 Mike Miller, Miner Institute, “The Next Step in Corn Silage Hybrid Evaluation: Fiber and Starch Yields”

2:15-3:00 Dr. Heather Dann, Miner Institute, “Milk fatty acid testing - useful for the herd, the group, and the individual cow”
**A Tale of Two Fibers:**
Optimizing peNDF and uNDF

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**Introduction**
Economic, environmental, and social considerations are encouraging use of higher fiber diets (Martin et al., 2017)
- Forage and non-forage
NDF alone does not explain all observed variation in DMI and milk yield as dietary source and content vary
Incorporate measures of particle size and digestibility

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**Physical effectiveness factor (pef) and peNDF**

pef = physical effectiveness factor
% of sample retained on ≥1.18-mm screen as fed
peNDF = physically effective NDF

Recommendation:
21-23% DM
(Martens, 1997; Martens, 2007)
function of DSS fermentability and feeding management (Zebeli papers)

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**Current: Fiber Digestion 3-pool Model**
(Martens, 1977; Raffrenato and Van Amburgh, 2010; Cotanch et al., 2014)

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**uNDF240 and peNDF**
(Smith et al., 2018; ADSA abstracts)

Practical feeding questions:
- What are separate and combined effects of peNDF and uNDF240 in diets fed to lactating cows?
- Can we adjust for lack of peNDF by adding more dietary uNDF240?
- If forage uNDF240 is higher than desired, can we partially compensate by chopping more finely?
- How important is particle size?
- Answer likely affected by source of fiber.

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**uNDF240 as a Benchmarking Tool**
uNDF240 is sensitive to
Genetics
Maturity at harvest
Growing environment

Measurement of iNDF using uNDF240 provides dynamic estimate of Kd
In the field, nutritionists have begun to use uNDF within herds along with NDF, NDFD, peNDF

[Nousiainen et al., 2003; 2004; Cotanch, 2015; Van Amburgh et al., 2015]
**Miner Institute Study Objective**

Evaluate the effect of feeding different dietary concentrations of uNDF240 and peNDF on chewing behavior, rumen fermentation, and lactation performance of Holstein cows.

**Dietary Fiber and Forage Processing**

Two uNDF240 concentrations:
- Target: 8.5 vs 11.5% uNDF240
- Adjusted forage % and NFFS

Two peNDF concentrations:
- Timothy hay
  - Haybuster (hammer mill)
  - High pef: 0.58 ± 0.04
  - Low pef: 0.24 ± 0.01

**Screens in Hammer Mill**

<table>
<thead>
<tr>
<th>Screens</th>
<th>Hammer mill</th>
<th>3 and 2 in</th>
<th>1/2 and 3/8 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2 and 5.3 cm</td>
<td>1.3 and 0.95 cm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dietary Ingredient Composition**

<table>
<thead>
<tr>
<th>Ingredient, % of DM</th>
<th>Low uNDF240</th>
<th>High uNDF240</th>
<th>Low peNDF</th>
<th>High peNDF</th>
<th>Low peNDF</th>
<th>High peNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>34.7</td>
<td>34.7</td>
<td>34.7</td>
<td>34.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw, wheat</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy hay – short</td>
<td>10.5</td>
<td>...</td>
<td>24.2</td>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy hay – long</td>
<td>...</td>
<td>10.5</td>
<td>24.2</td>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beet pulp, pelleted</td>
<td>12.9</td>
<td>12.9</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain mix</td>
<td>40.3</td>
<td>40.3</td>
<td>39.2</td>
<td>39.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dietary Carbohydrate Composition**

<table>
<thead>
<tr>
<th>Item, % of DM</th>
<th>Low uNDF240</th>
<th>High uNDF240</th>
<th>Low peNDF</th>
<th>High peNDF</th>
<th>Low peNDF</th>
<th>High peNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage</td>
<td>46.8</td>
<td>46.8</td>
<td>60.5</td>
<td>60.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>24.5</td>
<td>24.6</td>
<td>23.4</td>
<td>23.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>4.3</td>
<td>4.3</td>
<td>4.6</td>
<td>4.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td>33.1</td>
<td>33.3</td>
<td>35.7</td>
<td>36.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peNDF240</td>
<td>8.9</td>
<td>8.9</td>
<td>11.5</td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peuNDF240</td>
<td>20.1</td>
<td>21.8</td>
<td>18.6</td>
<td>21.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peuNDF240</td>
<td>5.4</td>
<td>5.9</td>
<td>5.9</td>
<td>7.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

New concept: "peuNDF240" = pef x uNDF240
### Dry Matter and Fiber Intake

<table>
<thead>
<tr>
<th>Item</th>
<th>Low uNDF240</th>
<th>High uNDF240</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lbs/d</td>
<td>60.6a</td>
<td>60.2a</td>
<td>60.4a</td>
<td>54.9b</td>
</tr>
<tr>
<td>DMI, % of BW</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF, lbs/d</td>
<td>20.13±</td>
<td>19.97±</td>
<td>21.47±</td>
<td>19.75±</td>
</tr>
<tr>
<td>uNDF240, lbs/d</td>
<td>5.31c</td>
<td>5.36c</td>
<td>6.86a</td>
<td>6.33b</td>
</tr>
<tr>
<td>uNDF240, % of BW</td>
<td>0.35±</td>
<td>0.36±</td>
<td>0.45a</td>
<td>0.43±</td>
</tr>
<tr>
<td>peNDF, lbs/d</td>
<td>3.24c</td>
<td>3.51b</td>
<td>3.55b</td>
<td>3.84a</td>
</tr>
</tbody>
</table>

abc Within a row different superscripts differ (P ≤ 0.05).

### Milk Yield, Composition, and Efficiency

<table>
<thead>
<tr>
<th>Item</th>
<th>Low uNDF240</th>
<th>High uNDF240</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, lbs/d</td>
<td>101.6a</td>
<td>99.0ab</td>
<td>97.0bc</td>
<td>93.9c</td>
</tr>
<tr>
<td>Fat, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein, %</td>
<td>2.93±</td>
<td>2.88±</td>
<td>2.96±</td>
<td>2.84±</td>
</tr>
<tr>
<td>ECM, lbs/d</td>
<td>103.6b</td>
<td>100.8ab</td>
<td>102.3ab</td>
<td>98.3b</td>
</tr>
<tr>
<td>ECM/DM, lb/lb</td>
<td>1.71±</td>
<td>1.68±</td>
<td>1.70±</td>
<td>1.79±</td>
</tr>
</tbody>
</table>

### Chewing Responses

<table>
<thead>
<tr>
<th>Item</th>
<th>Low uNDF240</th>
<th>High uNDF240</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating time, min/d</td>
<td>255 b</td>
<td>263b</td>
<td>279ab</td>
<td>300a</td>
</tr>
<tr>
<td>Rumination time, min/d</td>
<td>523 ±</td>
<td>527 ±</td>
<td>532 ±</td>
<td>545 ±</td>
</tr>
</tbody>
</table>

abc Within a row different superscripts differ (P ≤ 0.05).

### Dietary Forage and Behavior Responses

- Corn silage-based rations
- Increased chewing time (mostly longer eating time) at expense of resting time
Forage fiber and feeding behavior (Grant and Ferraretto, 2018)

Greater eating time and possible lower DMI associated with:

- **Higher forage content** (Koohmaraee et al., 2012; Jiang et al., 2017)
  - Corn silage and haycrop silage

- **Lower NDF digestibility** (Miron et al., 2007; Cotanch et al., 2012)
  - Corn silage, sorghum silage

- **Longer particle size** (Fernandez et al., 2002; Kononoff and Heinrichs, 2003; Miller et al., 2017)
  - Alfalfa silage, corn silage, wheat straw

### Particle Size of Ingested Feed
(Schadt et al., 2011)

<table>
<thead>
<tr>
<th>Forage type</th>
<th>NDF of DM</th>
<th>Feed size, mm</th>
<th>Bolus size, mm</th>
<th>Chews/g NDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long rye grass hay</td>
<td>57.1</td>
<td>10.3</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>5.5-mm rye &quot;hay&quot;</td>
<td>58.6</td>
<td>42.2</td>
<td>9.8</td>
<td>3.5</td>
</tr>
<tr>
<td>8-mm PSPS hay</td>
<td>57.9</td>
<td>43.5</td>
<td>10.3</td>
<td>2.2</td>
</tr>
<tr>
<td>1.1-mm PSPS hay</td>
<td>59.1</td>
<td>25.1</td>
<td>10.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Grass silage</td>
<td>53.1</td>
<td>13.8</td>
<td>11.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Corn silage</td>
<td>86.1</td>
<td>12.0</td>
<td>15.0</td>
<td>0.7</td>
</tr>
<tr>
<td>TMR</td>
<td>17.2</td>
<td>13.1</td>
<td>12.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Suggested PSPS Targets: Miner Institute (2017)

<table>
<thead>
<tr>
<th>Sieve mm</th>
<th>PSPS 2013 %</th>
<th>Miner 2017 %</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 19</td>
<td>2.8</td>
<td>&lt;5</td>
<td>Portable material, too long, increases time needed for eating; especially if &gt;10%</td>
</tr>
<tr>
<td>Mid 1 8</td>
<td>30-50</td>
<td>&gt;50</td>
<td>Still long and functional pel, there are no less than 4 mm particle. Maximize amount on this sieve, 50-60%</td>
</tr>
<tr>
<td>Mid 2 4</td>
<td>10-20</td>
<td>10-20</td>
<td>Functions as pel sieve, no recommendation for amount to retain here other than total on the top 3 sieves = pel</td>
</tr>
<tr>
<td>Pan</td>
<td>30-40</td>
<td>25-30</td>
<td>40-50% grain diet results in at least 25-30% in the pan</td>
</tr>
</tbody>
</table>

- Keep feed in front of cow
- Comfortable stalls
- Part of a system

### Perspectives and Applications

- **Low uNDF240, Low peNDF vs High uNDF240, High peNDF: "Book Ends"**
  - Consistently differing in animal response
  - DMI, Milk Yield and Composition; Behavior

- **Low uNDF240, High peNDF vs High uNDF240, Low peNDF**
  - Frequent lack of difference in animal response
  - DMI and Milk Yield
  - Altering either peNDF or uNDF240
  - Chop length (TLOC)

### Preliminary Synthesis: uNDF240 and peuNDF240 versus DMI and ECM

Combined data from three studies...

**Study 1:** peNDF and uNDF240 (Smith et al., 2018)
- 13% haycrop silage (mixed mostly grass)
- 36 to 55% corn silage (bm3 or conventional)

**Study 2:** approximately 50 or 65% forage in ration DM (Cotanch et al., 2014)
- Approximately 42 to 60% corn silage (bm3 or conventional) and 2 to 7% fine vs coarse-chopped wheat straw (fine vs coarse chopped) (Miller et al., 2017)
A Tale of Two Fibers

Research needed to test relationship with:
- Alfalfa-based diets
  - Potential differences between grasses and legumes
- Pasture systems
  - Forage vs non-forage fiber sources
- Feeding scenarios markedly different than high corn silage diets

There appears to be value in integrating two measures of fiber - uNDF240 and peNDF - when formulating rations.
RELATIONSHIPS BETWEEN UNDIGESTED AND PHYSICALLY EFFECTIVE FIBER IN LACTATING DAIRY COWS

R. J. Grant¹, W. A. Smith¹, M. D. Miller¹, K. Ishida², and A. Obata²
¹William H. Miner Agricultural Research Institute, Chazy, NY
²Zennoh National Federation of Agricultural Cooperative Associations, Tokyo, Japan

INTRODUCTION

Economic, environmental, and even social considerations are encouraging the use of more forage in dairy cattle rations (Martin et al., 2017). Although regional economics and forage availability may determine the balance between dietary forage and non-forage sources of fiber, we appear to be at the threshold of a new era in our ability to effectively feed fiber to lactating dairy cows. Nutritionists have long realized that neutral detergent fiber (NDF) content alone does not explain all of the observed variation in dry matter intake (DMI) and milk yield as forage source and concentration in the diet vary. Incorporating measures of fiber digestibility and particle size improves our ability to predict feed intake and productive responses.

Waldo et al. (1972) recognized that NDF needed to be fractionated into digestible and indigestible pools for calculation of digestion rates. The recognition that there is an indigestible portion of fiber led to research that improved our understanding of the digestibility of fiber in ruminant diets and the beginning of dynamic models of fiber digestion. Research has focused on a three-pool model of ruminal NDF digestion: indigestible NDF measured as undigested NDF at 240 hours of in vitro fermentation (uNDF240) plus a fast- and slow-fermenting pool of NDF (Mertens, 1977; Raffrenato and Van Amburgh, 2010; Cotanch et al., 2014). To-date more research has focused on defining biologically relevant digestion pools than particle size pools within the rumen, although both digestion and particle size characteristics of a fiber particle are important for explaining ruminal fiber turnover (Mertens, 2011). In a classic paper, Mertens (1997) laid out a comprehensive system for integrating NDF content and particle size, based on the 1.18-mm dry sieved fraction of particles, known as physically effective NDF (peNDF). Although the peNDF system is based solely on particle size as a measure of physical form, it explains a substantial amount of the variation in chewing activity, ruminal pH, and milk fat elicited among forage sources.

Recently, we have focused on the relationship between undigested and physically effective NDF at the Institute, and have conducted a study designed to assess the relationship between dietary uNDF240 and particle size measured as peNDF. The potential interaction between peNDF and uNDF240 is a hot topic among nutritionists with several practical feeding questions being asked in the field:

- What are the separate and combined effects of peNDF and uNDF240 in diets fed to lactating cows?
- Can we adjust for a lack of dietary peNDF by adding more uNDF240 in the diet?
Similarly, if forage uNDF240 is higher than desired, can we at least partially compensate by chopping the forage finer to maintain feed intake?

The bottom line question becomes: are there optimal peNDF concentrations as uNDF240 content varies in the diet and vice versa? The answer to this question will likely be affected by the source of fiber: forage or non-forage, since they differ dramatically in fiber digestion pools and particle size. Some nutritionists have even questioned how important particle size actually is as we better understand fiber fractions (i.e., fast, slow, and uNDF240) and their rates of digestion. This is a complicated question, but the short answer is – yes – particle size is important, although maybe for reasons we haven’t always appreciated, such as its effect on eating behavior even more so than rumination.

MINER INSTITUTE STUDY: UNDIGESTED AND PHYSICALLY EFFECTIVE FIBER

Dietary Treatments: peNDF and uNDF240

To begin addressing the questions above, we conducted a study in 2018 to assess the effect of feeding lower (8.9% of ration DM) and higher (11.5% of ration DM) uNDF240 in diets with either lower or higher peNDF (19 to 20 versus ~22% of ration DM). The diets contained approximately 35% corn silage, 1.6% chopped wheat straw, and chopped timothy hay with either a lower physical effectiveness factor (pef; fraction of particles retained on ≥1.18-mm screen; 0.24) or a higher pef (0.58).

Table 1. Ingredient and chemical composition of experimental diets (% of DM).

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Low uNDF240&lt;sup&gt;1&lt;/sup&gt;</th>
<th>High uNDF240</th>
<th>Low peNDF&lt;sup&gt;2&lt;/sup&gt;</th>
<th>High peNDF</th>
<th>Low peNDF</th>
<th>High peNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>34.7</td>
<td>34.7</td>
<td>34.7</td>
<td>34.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat straw, chopped</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy hay, short chop</td>
<td>10.5</td>
<td>---</td>
<td>24.2</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy hay, long chop</td>
<td>---</td>
<td>10.5</td>
<td>---</td>
<td>24.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beet pulp, pelleted</td>
<td>12.9</td>
<td>12.9</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain mix</td>
<td>40.3</td>
<td>40.3</td>
<td>39.1</td>
<td>39.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage</td>
<td>46.8</td>
<td>46.8</td>
<td>60.5</td>
<td>60.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aNDFom&lt;sup&gt;3&lt;/sup&gt;</td>
<td>33.1</td>
<td>33.3</td>
<td>35.7</td>
<td>36.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uNDF240om</td>
<td>8.9</td>
<td>8.9</td>
<td>11.5</td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peNDom&lt;sup&gt;4&lt;/sup&gt;</td>
<td>20.1</td>
<td>21.8</td>
<td>18.6</td>
<td>21.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peuNDF240&lt;sup&gt;4&lt;/sup&gt;</td>
<td>5.4</td>
<td>5.9</td>
<td>5.9</td>
<td>7.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Undigested NDF at 240 h of in vitro fermentation.
<sup>2</sup>Physically effective NDF.
<sup>3</sup>Amylase-modified NDF on an organic matter (OM) basis.
<sup>4</sup>Physically effective uNDF240 (physical effectiveness factor × uNDF240).
We used a Haybuster (DuraTech Industries International, Inc., Jamestown, ND) with its hammer mill chopping action to achieve the two particle sizes of dry hay. In addition, for the lower forage diets we partially replaced the timothy hay with nearly 13% pelleted beet pulp to help adjust the fiber fractions. The lower uNDF240 diets contained about 47% forage and the higher uNDF240 diets contained about 60% forage on a DM basis (Table 1).

A New Concept: Physically Effective uNDF240

To explore the relationship between physical effectiveness and uNDF240 among these four diets, we calculated a “physically effective uNDF240” (peuNDF = pef x uNDF240). In Table 1 we see that this value ranged from 5.4% of DM for the lowUNDF240/low peNDF diet to 7.1% of DM for the high uNDF240/high peNDF diet. And by design, the two intermediate diets contained 5.9% of ration DM. A key assumption underpinning our focus on a peuNDF value is that uNDF240 is uniformly distributed across the particle size fractions, particularly above and below the 1.18-mm screen when a sample has been dry sieved. We are currently addressing that question in our Forage Research Laboratory at the Institute.

When feeding these four diets, we expected the bookend diets to elicit predictable responses in DMI based on their substantial differences in uNDF240 and particle size (Harper and McNeill, 2015). We considered them as “bookends” because these diets represent a range in particle size and indigestibility that would reasonably be observed in the field for these types of diets. And most importantly, we wondered if the two intermediate diets would elicit similar responses in DMI given their similar calculated peuNDF content.

In fact, the high uNDF240/high peNDF diet did limit DMI compared with the lower uNDF240 diets (Table 2). When lower uNDF240 diets were fed, the peNDF did not affect DMI. But, a shorter chop length for the higher uNDF240 diet boosted DMI by 2.5 kg/d. As a result, NDF and uNDF240 intakes were highest for cows fed the high uNDF240 diet with smaller particle size. Overall, and as expected, uNDF240 intake was greater for the higher versus lower uNDF240 diets. But, the important take-home result is the 0.45% of BW intake of uNDF240 for cows fed the high uNDF240 diet with hay that had been more finely chopped. The intake of peNDF was driven first by the uNDF240 content of the diet, and then by particle size within each level of uNDF240 (Table 2).

The intake of peuNDF (calculated as the product of pef and uNDF240) was stretched by the bookend diets: 1.47 versus 1.74 kg/d for the low/low versus high/high uNDF240/peNDF diets, respectively. And of greatest interest, we observed that the two intermediate diets resulted in similar peuNDF intake; we were able to elicit the same intake response by the cow whether we fed lower uNDF240 in the diet chopped more coarsely, or whether we fed higher dietary uNDF240, but with a finer particle size.
Table 2. Dry matter and fiber intake for cows fed diets differing in uNDF240 and peNDF.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low uNDF240&lt;sup&gt;1&lt;/sup&gt;</th>
<th>High uNDF240</th>
<th>SE</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low peNDF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>High peNDF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>27.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMI, % of BW</td>
<td>4.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.73&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NDF intake, kg/d</td>
<td>9.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.96&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>uNDF&lt;sub&gt;240&lt;/sub&gt; intake, kg/d</td>
<td>2.41&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.43&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NDF intake, % of BW</td>
<td>0.35&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.43&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>peNDF intake, kg/d</td>
<td>5.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.44&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>peuNDF&lt;sub&gt;240&lt;/sub&gt; intake, kg/d</td>
<td>1.47&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.59&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.74&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>abc</sup>Means within a row with unlike superscripts differ ($P \leq 0.05$).
<sup>1</sup>Undigested NDF at 240 h of in vitro fermentation.
<sup>2</sup>Physically effective NDF.

Lactational Responses to peNDF and uNDF240

A key question becomes: does lactation performance follow these observed responses in feed intake? Generally, milk and energy-corrected milk (ECM) production responded similarly to peuNDF intake (Table 3). In particular, production of ECM was lowest for cows fed the high/high uNDF240/peNDF diet and greatest for the low/low diet (Table 3). Tracking with DMI, the ECM yield was similar and intermediate for the low/high and high/low uNDF240/peNDF diets. Interestingly, milk fat percentage appeared to be more related to dietary uNDF240 than peNDF content. More research is needed to understand the relative responsiveness of milk fat to uNDF240 and peNDF.

Table 3. Milk yield, composition, and efficiency of solids-corrected milk production.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low uNDF240&lt;sup&gt;1&lt;/sup&gt;</th>
<th>High uNDF240</th>
<th>SE</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low peNDF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>High peNDF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>46.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>44.0&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>42.6&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk fat, %</td>
<td>3.68&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.92&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk true protein, %</td>
<td>2.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.88&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.84&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk urea N, mg/d</td>
<td>8.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.4&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>10.1&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>11.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Energy-corrected milk, kg/d</td>
<td>47.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>46.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>44.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ECM/DMI, kg/kg</td>
<td>1.71&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.68&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.70&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.79&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>abc</sup>Means within a row with unlike superscripts differ ($P \leq 0.05$).
<sup>1</sup>Undigested NDF at 240 h of in vitro fermentation.
<sup>2</sup>Physically effective NDF.
Milk true protein appeared to be boosted by lower peNDF and cows fed the high/high uNDF240/peNDF diet had the lowest milk protein percentage, with cows fed the low/high uNDF240/peNDF diet being intermediate (Table 3). The MUN concentration was reduced first as dietary uNDF240 decreased, and then as peNDF decreased within a level of uNDF240.

Chewing Response to peNDF and uNDF240

Dietary uNDF240 and peNDF had a greater impact on eating than ruminating time (Table 4). This observation that dietary fiber characteristics may have a substantial effect on chewing during eating and time spent eating has been observed in multiple studies. A recent review found that higher forage content, greater NDF or peNDF content, and/or lower NDF digestibility may all increase time spent eating for a wide range of forages (Grant and Ferraretto, 2018). The cows in our study spent up to 45 min/d more or less eating depending on the diet (Table 4). In fact, cows on the high/high uNDF240/peNDF diet spent 45 min/d longer eating and yet consumed nearly 3 kg/d less DM than cows fed the low/low uNDF240/peNDF diet. An important and practical management question is whether or not cows would have sufficient time to spend at the bunk eating with greater dietary uNDF240 that is too coarsely chopped? And if we consider an overcrowded feedbunk environment, the constraint on feeding time could be even more deleterious.

Cows fed the high/high peNDF/uNDF240 diet had the greatest eating time compared with cows fed the low uNDF240 diets (Table 4). Finely chopping the hay in the high uNDF240 diet reduced eating time by about 20 min/d and brought it more in-line with the lower uNDF240 diets.

Table 4. Chewing behavior as influenced by dietary uNDF240 and peNDF.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low uNDF240&lt;sup&gt;1&lt;/sup&gt;</th>
<th>High uNDF240</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low peNDF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>High peNDF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating time, min/d</td>
<td>255&lt;sup&gt;b&lt;/sup&gt;</td>
<td>263&lt;sup&gt;b&lt;/sup&gt;</td>
<td>279&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>300&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ruminating time, min/d</td>
<td>523</td>
<td>527</td>
<td>532</td>
<td>545</td>
</tr>
</tbody>
</table>

<sup>abc</sup>Means within a row with unlike superscripts differ (P ≤ 0.05).

<sup>1</sup>Undigested NDF at 240 h of in vitro fermentation.
<sup>2</sup>Physically effective NDF.

Part of the reason why eating time was more affected than ruminating time is related to the observation that cows tend to chew a bolus of feed to a relatively uniform particle size prior to swallowing. Grant and Ferraretto (2018) summarized research that showed that particle length over a wide range of feeds was reduced during digestive chewing to approximately 10 to 11 mm (Schadt et al., 2012). Similarly, in our current study, we confirmed that cows consuming all four diets swallowed bolii of total mixed
ration with a mean particle size of approximately 7 to 8 mm (Table 5) regardless of uNDF240 or peNDF content of the diet.

Table 5. Particle size of swallowed total mixed ration bolus versus diet offered (% retained on sieve; DM basis).

<table>
<thead>
<tr>
<th>Diet</th>
<th>Sieve size, mm</th>
<th>Mean particle size, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Low peNDF(^1), low uNDF240(^2)</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>High peNDF, low uNDF240</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Low peNDF, high uNDF240</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>High peNDF, low uNDF240</td>
<td>32</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low peNDF, low uNDF240</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>High peNDF, low uNDF240</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Low peNDF, high uNDF240</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>High peNDF, low uNDF240</td>
<td>5</td>
<td>12</td>
</tr>
</tbody>
</table>

\(^1\)Physically effective NDF.
\(^2\)Undigested NDF at 240 h of in vitro fermentation.

Ruminal Fermentation: peNDF and uNDF240

Mean ruminal pH followed the same pattern of response as DMI and ECM yield (Table 6). Although not significant, time and area below pH 5.8 numerically appeared to be more related with dietary uNDF240 content than peNDF. Total VFA concentration followed the same pattern as DMI, ECM yield, and mean ruminal pH with cows that consumed similar peuNDF240 having similar total ruminal VFA concentrations (Table 6). Tracking with milk fat percentage, the ruminal acetate + butyrate:propionate ratio was more influenced by uNDF240 than peNDF in our study.

When we assessed ruminal pool size and turnover, we found that the pool size of NDF tended to be greater for cows fed higher uNDF240 diets, and that the pool size of uNDF240 was greater for cows fed these same diets (Table 6). Ruminal turnover rate of NDF tended to be slower for cows fed the higher uNDF240 diets with the high/high uNDF240/peNDF diet having the slowest ruminal turnover of fiber. Overall, the differences among diets in ruminal pool size and turnover were small, but it appeared that higher uNDF240 diets increased the amount of uNDF240 in the rumen and slowed the turnover of NDF. The higher ruminal NDF turnover for cows fed the finely chopped high uNDF240 diet helps to explain the observed increase in DMI.

If future research confirms the results of this initial study, it suggests that when forage fiber digestibility is lower than desired, then a finer forage chop length will boost feed intake and lactational response. The enhanced lactational performance was associated with less eating time as well as more desirable ruminal fermentation and fiber turnover for cows fed the higher uNDF240 diet with lower peNDF.
Table 6. Ruminal fermentation and dynamics of fiber turnover.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low uNDF240&lt;sup&gt;1&lt;/sup&gt;</th>
<th>High uNDF240</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low peNDF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>High peNDF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-h mean pH</td>
<td>6.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.17&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.22&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Time pH &lt; 5.8, min/d</td>
<td>253</td>
<td>208</td>
<td>166</td>
<td>164</td>
</tr>
<tr>
<td>AUC, pH &lt; 5.8&lt;sup&gt;3&lt;/sup&gt;</td>
<td>52.0</td>
<td>49.6</td>
<td>33.5</td>
<td>30.0</td>
</tr>
<tr>
<td>Total VFA, mM</td>
<td>122.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>120.6&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>118.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>112.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Acetate+butyrate:propionate</td>
<td>3.33&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.39&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.54&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ruminal pool size, kg</td>
<td>12.7</td>
<td>12.3</td>
<td>12.9</td>
<td>12.4</td>
</tr>
<tr>
<td>OM</td>
<td>8.2</td>
<td>7.9</td>
<td>8.7</td>
<td>8.4</td>
</tr>
<tr>
<td>aNDFom</td>
<td>3.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.5</td>
<td>4.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ruminal turnover rate, %/h</td>
<td>8.7</td>
<td>8.8</td>
<td>8.4</td>
<td>8.0</td>
</tr>
<tr>
<td>OM</td>
<td>4.4&lt;sup&gt;x&lt;/sup&gt;</td>
<td>4.4&lt;sup&gt;x&lt;/sup&gt;</td>
<td>4.2&lt;sup&gt;xy&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>uNDF240om</td>
<td>2.7</td>
<td>2.8</td>
<td>3.0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

<sup>1</sup>Undigested NDF at 240 h of in vitro fermentation.
<sup>2</sup>Physically effective NDF.
<sup>3</sup>Area under curve pH < 5.8; ruminal pH units below 5.8 by hour.

PRELIMINARY SYNTHESIS:
PHYSICALLY EFFECTIVE, UNDIGESTED NDF AND COW RESPONSES

We have combined data from three experiments conducted at the Institute to further explore the relationship between dietary uNDF240 and DMI and ECM yield as well as the relationship between dietary peuNDF240 and DMI and ECM yield. The dietary formulations for these three studies were:

- **Study 1**: the study just described (see Table 1; Smith et al. 2018a; 2018b).
- **Study 2**: approximately 50 or 65% forage in the ration DM, with 13% haycrop silage (mixed mostly grass), and between 36 and 55% corn silage (either brown midrib 3 or conventional) in ration DM (Cotanch et al., 2014).
- **Study 3**: approximately 42 to 60% corn silage (brown midrib 3 or conventional) and 2 to 7% wheat straw (finely or coarsely chopped) in ration DM (Miller et al., 2017).

Details of ration formulation may be found in the references for each study. Importantly, all of the diets fed in these three experiments were based heavily on corn silage, contained some combination of haycrop silage and chopped straw, and in Study 1 (the
current study) two of the diets also contained substantial pelleted beet pulp to formulate the lower uNDF240, lower forage diet.

Figures 1 and 2 illustrate the relationships that we observed when we combined the data from these three studies. For these types of diets, both uNDF240 and especially peuNDF240 appear to be usefully related with DMI and ECM production.

At the moment, it is important to restrict these inferences to similar diets (corn silage with hay and fibrous byproducts) because more research is required with varying forage types and sources of uNDF (forage versus non-forage) to determine the robustness of the relationships shown in Figures 1 and 2. In particular, legumes such as alfalfa contain more lignin and uNDF240, but have faster NDF digestion rates than grasses, and we might expect different relationships between dietary uNDF240 and DMI for legume- versus grass-based rations. In fact, research has shown that very high levels of uNDF240 intake may be achieved when lactating cows are fed finely chopped alfalfa hay (Fustini et al., 2017) in part because alfalfa contains more uNDF240 than grasses (Palmonari et al., 2014; Cotanch et al., 2014).
Figure 1. Relationship from three studies between dietary uNDF240 and DMI and ECM yield for cows fed diets based on corn silage, haycrop silage, and chopped wheat straw.

Figure 2. Relationship from three studies between dietary peuNDF240 and DMI and ECM yield for cows fed diets based on corn silage, haycrop silage, and chopped wheat straw (peuNDF240 = physically effective undigested NDF measured at 240 h of in vitro fermentation).

SUMMARY AND PERSPECTIVES:
A TALE OF TWO FIBERS

The calculated “physically effective uNDF240” (pef x uNDF240) appears to be a useful concept when interpreting cow response to the diets fed in this study and studies with similar types of diets. Our goal is not to coin yet another nutritional acronym, but to
focus on a potentially useful concept. We were able to elicit the same response by the cow whether we fed lower uNDF240 in the diet with greater peNDF, or whether we fed higher uNDF240, but chopped the dry hay more finely. In other words, the peuNDF240, or integration of pef and uNDF240, was highly related to DMI and ECM yield.

If future research confirms this relationship between dietary uNDF240 and DMI, it suggests that when forage fiber digestibility is lower than desired, then a finer forage chop length will boost feed intake and lactational response. In addition to investigating potential and probable differences between legumes and grasses, we also must understand the potential responses to forage and non-forage sources of fiber.

As Charles Dickens wrote in his classic novel *Tale of Two Cities* “It was the best of times, it was the worst of times.” When it comes to fiber, it looks like we can have the best of times when we are able to integrate two measures of fiber – uNDF240 and peNDF - when formulating rations (Grant, 2018). Research is needed to test this relationship in alfalfa-based diets, pasture systems, and other feeding scenarios that differ markedly from a typical Northeastern and upper Midwestern US diet based primarily on corn silage.

REFERENCES


Harper, K. J., and D. M. McNeill. 2015. The role of iNDF in the regulation of feed intake and the importance of its assessment in subtropical ruminant systems (the role of iNDF in the regulation of forage intake). Agric. 5:778-790.


Non-Immunoglobulin Factors in Colostrum:
Communication from the Dam to the Calf

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Email: mev1@cornell.edu; cell: 607-592-1212

Overview of today’s talk
• Introduction
• Effects of colostrum on growth and nutrient use
• Role of colostrum in gastrointestinal tract development
• Colostrum components and the immune system
• Colostrum components and changes in metabolism
• Summary

Goal of The Replacement Program
The primary goal of all heifer programs is to raise the highest quality heifer that can maximize profits when the animal enters the lactating herd.

A quality heifer is an animal carrying no limitations – nothing that detracts from her ability to produce milk under the farm’s management system.

Optimize profits by obtaining the highest quality heifer at the lowest possible cost usually in the least amount of time.

Snapshot Evaluation of the Potential Quality of The Replacement
• 1st Calf Heifers “Treated” as Calf/Heifer* ≤30%
  24 hrs. → 3 mos. ____, 4 mos. → fresh ____
• DOAs in first calf heifers ≤7%
  Male DOAs ____, Female DOAs ____
• 1st Calf avg. peak ≥80% of Mature
  1st Calf lactation total yield ≥80% of Mature
• 1st Calf Culls ≤60 Days in Milk ≤5%
• 1st Calf ME’s ≥Mature ≥15%
• 1st Calf “Treated” in Lactation* 85% retention (any herd) to 2nd lactation ≥85%
• Lower #1 reason for 1st lact. culls(continuous improvement)

Colostrum by Bottle or Tube Feeder – 3 L

M.Desjardins-Morrissette et al, JDS

The lactation cycle and the opportunity to provide bioactive factors to the offspring

Blum and Baumrucker, 2002
Relatively new definition related to the topic of epigenetic programming in neonates:

- Lactocrine hypothesis (Bartol, Wiley and Bagnell, 2009)

  - Maternal programming extended beyond the uterine environment through ingestion of milk-borne morphological factors - milk in this case can include colostrum
  - In neonatal pigs, maternal relaxin from colostrum stimulates development and differentiation of the uterus (15 vs 30 ml colostrum)
  - Mediates the expression of estrogen receptors – stimulates on differentiation of stroma and epithelial cells and then proliferation

Role of colostrum Relaxin in female piglets on expression of estrogen receptors and development

What Does Mom Want for Her Calf?

She wants them to grow and be healthy –

Anabolism!

With or without the steroids?

Importance of Colostrum Supply for the Neonate

- Colostrum provides immunoglobulins for establishing passive immunity
- Colostrum contains high amounts of nutrients, but also non-nutrient factors that support gut maturation
- Colostrum borne growth factors such as IGF-1 or hormones like insulin might act through specific receptors in the gut mucosa of the neonate to stimulate cell proliferation, cell differentiation, and protein synthesis
- Colostrum is a communication tool of the dam to direct calf development at the beginning of extra-uterine life

Components Units Colostrum Mature Milk
Gross Energy MJ/L 6 2.8
Immunoglobulin G g/L 81 <2
Lactoferrin g/L 1.84 Undetectable
Insulin µg/L 65 1
Glucagon µg/L 0.16 0.001
Prolactin µg/dL 280 15
Growth hormone µg/dL 1.4 <1
IGF-1 µg/dL 310 <1
Leptin µg/dL 30 4.4
TGF-α µg/dL 210 <1
Cortisol pg/ml 1,500-4,400 710
17βEstradiol pg/ml 1,000-2000 10-20

Foley and Otterby, 1978; Hammon et al., 2000; Blum and Baumrucker, 2008
Inadequate Colostrum Intake Reduces Long Term Performance

Effects of Colostrum Ingestion on Lactational Performance, Prof. Anim. Scientist, 2005

Brown Swiss calves were fed 2 L or 4 L of colostrum and colostrum over another 6 to 8 feedings

<table>
<thead>
<tr>
<th></th>
<th>2 L</th>
<th>4 L</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>37</td>
<td>31</td>
</tr>
<tr>
<td>Daily gain, lb/d</td>
<td>1.76</td>
<td>2.2</td>
</tr>
<tr>
<td>Age at conception, mo</td>
<td>14.0</td>
<td>13.5</td>
</tr>
<tr>
<td>Survival through 2nd lact.</td>
<td>75.3</td>
<td>87.1</td>
</tr>
<tr>
<td>Milk yield through 2nd lact., lb</td>
<td>35,297</td>
<td>37,558</td>
</tr>
</tbody>
</table>

Source of Colostrum Replacement Important for Feed Efficiency – observable over first 29 days of life
Calves fed colostrum or a serum derived colostrum replacement demonstrated differences in feed efficiency - no differences in IgG status

<table>
<thead>
<tr>
<th>Variable</th>
<th>Colostrum</th>
<th>Colostrum Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Total DMI, lb</td>
<td>34.5</td>
<td>33.1</td>
</tr>
<tr>
<td>Milk replacer DMI, lb</td>
<td>23.5</td>
<td>24.3</td>
</tr>
<tr>
<td>Starter DMI, lb</td>
<td>10.9</td>
<td>8.7</td>
</tr>
<tr>
<td>Feed efficiency,(gain:feed)</td>
<td>0.43</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Effect of Colostrum level on Growth and Feed Efficiency

Soberon, 2011

<table>
<thead>
<tr>
<th>Treatment</th>
<th>HH</th>
<th>LH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std dev</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IgG concen. mg/dl*</td>
<td>2,746</td>
<td>1,466</td>
</tr>
<tr>
<td>Birth wt, lb</td>
<td>97</td>
<td>92</td>
</tr>
<tr>
<td>Weaning wt, lb</td>
<td>172</td>
<td>159</td>
</tr>
<tr>
<td>ADG pre-weaning, lb</td>
<td>1.74</td>
<td>1.48</td>
</tr>
</tbody>
</table>

Effect of High (4+2 L) or Low (2 L) Colostrum and Ad-lib (H) Milk Replacer Intake on Feed Efficiency and Feed Intake in Pre and Post-Weaned calves (Soberon Ph.D. diss., 2011)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>HH</th>
<th>LH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG birth to 80 d, lb</td>
<td>1.72</td>
<td>1.45</td>
</tr>
<tr>
<td>Hip height gain, birth to 80 d, cm/d</td>
<td>0.214</td>
<td>0.184</td>
</tr>
<tr>
<td>Total milk replacer intake, lb DMI*</td>
<td>97.8</td>
<td>90.1</td>
</tr>
<tr>
<td>Grain intake pre-weaning, lb*</td>
<td>4.8</td>
<td>4.6</td>
</tr>
<tr>
<td>ADG/DMI, pre-weaning**</td>
<td>0.60</td>
<td>0.67</td>
</tr>
<tr>
<td>ADG post-weaning*, lb</td>
<td>2.4</td>
<td>1.76</td>
</tr>
<tr>
<td>DMI post-weaning*, lb/d</td>
<td>6.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Effect of Colostrum level on Growth and Feed Efficiency

• Calves fed 4 L (+2L @12 hrs) or 2 L of pooled colostrum within one hour of birth
• Half of calves on each colostrum treatment assigned to “ad libitum” feeding regimen
• All calves are housed in a co-mingled pen and fed with an automatic feeder
• Daily intakes of milk replacer and weekly measures of body weight and hip heights
• Weekly blood samples

Colostrum status impacts feed efficiency but varies by level of nutrient intake

Conventional: 1.25 lb/d, 22:20
Intensified: 1.75 lb/d 7 days, 2.5 lb/d to 42 days 28:20
23% CP starter

Ig status Poor Good Poor Good
n 21 20 17 25
Mean serum IgG, mg/dL 558a 1,793b 609a 2,036b
Average daily gain, lb/d 1.17a 1.09a 1.39b 1.63c

*means in same row with different letters are differ P<0.10
Colostrum components and gastrointestinal tract development

- Many studies have been conducted that demonstrate short term responses to hormones and growth factors found in colostrum
- General response is enhanced protein synthesis, increased enzyme expression, greater GIT development
- This development suggests:
  - The GIT is a stronger barrier to infection
  - Has more surface area for digestion and absorption
  - More capacity to digest more nutrients due to higher enzyme secretion

Feeding of a Colostrum Extract in Calves: Effects on Small Intestinal Villus Growth

<table>
<thead>
<tr>
<th>Trait</th>
<th>Colostrum Extract</th>
<th>Colostrum 1st Milking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross energy, MJ/kg DM</td>
<td>19.7</td>
<td>24.9</td>
</tr>
<tr>
<td>Crude protein, g/kg DM</td>
<td>690</td>
<td>555</td>
</tr>
<tr>
<td>Immunoglobulin G, g/kg DM</td>
<td>44.2</td>
<td>159</td>
</tr>
<tr>
<td>Whey protein, g/kg DM</td>
<td>656</td>
<td>410</td>
</tr>
<tr>
<td>Crude fat, g/kg DM</td>
<td>3.2</td>
<td>265</td>
</tr>
<tr>
<td>N-free extracts, g/kg DM</td>
<td>173</td>
<td>104</td>
</tr>
<tr>
<td>Crude ash, g/kg DM</td>
<td>61.8</td>
<td>75</td>
</tr>
<tr>
<td>IGF-I, mg/kg DM</td>
<td>23</td>
<td>1.1</td>
</tr>
<tr>
<td>Insulin, µg/kg DM</td>
<td>365</td>
<td>67</td>
</tr>
<tr>
<td>Lactoferrin, g/kg DM</td>
<td>1.6</td>
<td>7.5</td>
</tr>
</tbody>
</table>

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<th>Trait</th>
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</tr>
<tr>
<td>Lactoferrin, g/kg DM</td>
<td>1.6</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Influence on Villus Height in Neonatal Calves

Roffler et al., 2003

Colostrum versus Formula Feeding: Crypt Cell Proliferation in Neonatal Calves

Blättler et al., 2001

Influence on Crypt Cell Proliferation in Neonatal Calves

Milk replacer with and without a colostrum extract

Roffler et al., 2003

Colostrum Extract Feeding: Crypt Cell Proliferation in Neonatal Calves

Blättler et al., 2001
Colostrum versus Formula Feeding: Xylose Absorption in Neonatal Calves

Plasma Xylose

Colostrum

Rauprich et al., 2000

Colostrum Feeding and Glucose Uptake in Neonatal Calves

Composition of Colostrum and Formula

<table>
<thead>
<tr>
<th></th>
<th>Dry Matter</th>
<th>Ash</th>
<th>OM</th>
<th>Lactose</th>
<th>Crude Protein</th>
<th>Crude Fat</th>
<th>Crude Energy</th>
<th>IGF-I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>DM</td>
<td>g/kg DM</td>
<td>g/kg DM</td>
<td>MJ/kg DM</td>
<td>µg/l</td>
</tr>
<tr>
<td>Colostrum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>239</td>
<td>10.7</td>
<td>228.2</td>
<td>200.9</td>
<td>523.2</td>
<td>194.6</td>
<td>22.1</td>
<td>173.4</td>
</tr>
<tr>
<td>Day 2</td>
<td>179</td>
<td>9.1</td>
<td>170.0</td>
<td>259.6</td>
<td>395.9</td>
<td>269.1</td>
<td>23.6</td>
<td>192.4</td>
</tr>
<tr>
<td>Day 3/4</td>
<td>151</td>
<td>8.1</td>
<td>143.2</td>
<td>341.0</td>
<td>296.8</td>
<td>292.8</td>
<td>23.3</td>
<td>85.6</td>
</tr>
<tr>
<td>Formula</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>240</td>
<td>20.9</td>
<td>219.0</td>
<td>200.9</td>
<td>514.0</td>
<td>173.4</td>
<td>22.5</td>
<td>n.m.</td>
</tr>
<tr>
<td>Day 2</td>
<td>179</td>
<td>12.9</td>
<td>165.7</td>
<td>259.8</td>
<td>409.3</td>
<td>246.4</td>
<td>23.8</td>
<td>n.m.</td>
</tr>
<tr>
<td>Day 3/4</td>
<td>153</td>
<td>10.5</td>
<td>142.6</td>
<td>338.3</td>
<td>338.3</td>
<td>246.2</td>
<td>23.5</td>
<td>n.m.</td>
</tr>
</tbody>
</table>

n. m. = not measurable

Colostrum Feeding and Glucose Uptake in Neonatal Calves

Effect of Colostrum Intake over 4 days on Glucose Metabolism and Energy Status

• 7 calves fed colostrum versus 7 calves fed milk-based formula 4 hrs on average after birth
• Comparable in macronutrients
• Basal blood samples were drawn before morning feed and 2 hours after intake on day 1 to day 4
• Glucose absorption into blood using isotopes

Steinhoff-Wagner et al., 2011

Plasma Glucose: Postnatal Concentrations and Changes after Feed Intake

Postnatal Concentrations before Feed Intake

Plasma Glucose, mmol/l

Statistics
Main Effects:
Diet $P < 0.001$
Time $P < 0.05$
Diet $x$ Time $P < 0.7$

Steinhoff-Wagner et al., 2011

Changes on Day 4 after Feed Intake

Plasma Glucose, mmol/l

Statistics
Main Effects:
Diet $P < 0.001$
Time $P < 0.001$
Diet $x$ Time $P < 0.001$
*: Sig. Diet Effect at Time Point

Steinhoff-Wagner et al., 2011

Plasma Insulin Concentration of Calves Fed Colostrum or Colostrum like formula from Birth – Day 4 of Life

Insulin, pmol/L

Statistics
Main Effects:
Diet $P < 0.001$
Time $P < 0.001$
Diet $x$ Time $P < 0.001$
*: Sig. Diet Effect at Time Point

Steinhoff-Wagner et al., 2011
Plasma Glucose Concentration of Calves Fed Colostrum or Milk Replacer from Birth – Day 4 of Life

[Graph showing plasma glucose concentrations for calves fed colostrum vs. milk replacer.]

Dark bars are colostrum fed calves, white bars are control calves.

Steinhoff-Wagner et al., 2010

**Feeding Effects on Villus Maturation and Lactase Activity in Neonatal Calves**

[Graph showing villus height/crypt depth ratio and lactase activity across different gut segments for calves fed colostrum vs. milk replacer.]

Statistics:
- **Main Effects**:
  - Diet: \( P < 0.001 \)
  - Segment: \( P < 0.001 \)
  - Diet x Segment: \( P < 0.16 \)

- **Statistics**:
  - Lactase activity:
    - Diet: \( P < 0.06 \)
    - Segment: \( P < 0.001 \)
    - Diet x Segment: \( P < 0.7 \)

Steinhoff-Wagner et al., unpublished

**Colostrum vs Milk Replacer for first 4 days of life - summary**

Glucose uptake increased – similar nutrient supply
- Colostrum enhanced glucose uptake via insulin or enhanced enzyme activity in gut or simply maturation of gut
- Plasma glucagon higher – better glucose status, indication of higher reserve capacity
- Plasma protein levels higher – more protein available for growth, higher protein synthesis, less protein for glucose
- Plasma urea lower – less protein turnover and lower protein utilization for glucose production

Steinhoff-Wagner et al., 2011

**Sampling**

- Samples were obtained every 30 minutes for the first 4 hours from the catheter following first feeding
- Calves were fed their second feeding (colostrum replacer) 12 hours post first feeding
- Final samples were obtained immediately before and 1-hour after second feeding

Lopez, unpubl. 2012

Effect of Insulin Supplementation of a Colostrum Supplement on Insulin Absorption and Glucose Uptake

- 6 bulls and 6 heifers were obtained from the Teaching and Research Dairy in Harford New York.
- Calves were dried, weighed, and received IV catheters before first feeding and a blood sample was taken immediately prior to first feeding
- Land O’ Lakes Colostrum Replacer was used as colostrum, and calves were fed on average 1.25 hr after birth.
- 1000 IU of human insulin (Novolin) was added to the treatment group 1st feeding

Lopez, unpubl. 2012
Plasma Glucose and Insulin of Calves Provided Supraphysiologic levels of Insulin in a Colostrum Replacer

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment</th>
<th>S.E.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin, uU/ml</td>
<td>56.75</td>
<td>85.45</td>
<td>7.99</td>
<td>0.01</td>
</tr>
<tr>
<td>Glucose, mg/dL</td>
<td>69.81</td>
<td>81.74</td>
<td>3.56</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Lopez, unpubl. 2012

What happens to immune cells in colostrum?

- Data generated over the last 15-20 years demonstrates that leukocytes and other immune related cells in colostrum are “trafficked” into circulation in the calf
- Does this have any impact on the activity of the neonatal immune system?
- Other implications for the calf?

Immune cell transfer from colostrum to circulation

- Maternal leukocytes can be detected in calf circulation within 12 hr, peak at 24 hr and disappear by 48 hr. (Reber et al. 2008)
- Cells appear to be sequestered into tissues and lymph nodes after 48hr (Tuboly and Bernath, 2002; Williams, 1993).
- However, cells have been measured up to 5 wks after colostrum administration (Reber, et al. 2005)
- Long-term there appears to be greater cellular immunity in calves that received the whole colostrum compared to cell free colostrum (Reber et al. 2005; 2008)

Immune cell transfer from colostrum to circulation

- Calves fed whole colostrum have greater cellular immunity as defined the activation markers CD25 and CD26 by 7 days after birth
- Also greater antigen presenting capacity on cell surfaces
- Calves fed whole colostrum have greater cellular immune responsiveness to vaccinations

Effect of maternal cells transferred with colostrum on cellular responses to pathogen antigens in neonatal calves

- Calves were fed whole colostrum, frozen colostrum, or cell-free colostrum within 4 hours after birth.
- Leukocytes were obtained from calves before feeding colostrum and 1, 2, 7, 14, 21, and 28 days after ingestion.
- Proliferative responses against bovine viral diarrhea virus (BVDV) and mycobacterial purified protein derivatives were evaluated.
- Dams received a vaccine containing inactivated BVDV, but were not vaccinated against mycobacterial antigens

**Effect of maternal cells transferred with colostrum on cellular responses to pathogen antigens in neonatal calves**

- All calves had essentially no IgG in circulation at birth, but comparable and substantial concentrations by day 1.
- Calves that received whole colostrum had enhanced responses to BVDV antigen 1 and 2 days after ingestion of colostrum.
- Calves that received frozen colostrum or cell-free colostrum did not respond to BVDV.
- No difference in mycobacterium challenge in all treatments

**Take home:** uptake of cells from colostrum enhance cellular immunity in calves by providing mature, programmed cells from the dam


---

**Take home for colostrum management**

Colostrum feeding for 4 days…

- First milking colostrum within 6 hr of birth – 4 qt for large breeds
- First milking colostrum at 12 hr
- Second milking colostrum for day 2
- Third and fourth milking colostrum for days 3 and 4

---

**Summary**

- Mom is trying to send information to the calf via mammary secretions – some of our management approaches have short circuited this “information flow”
- Colostrum contains factors that impact intestinal development and nutrient supply independent of nutrient consumption
- Colostrum can positively impact pre and post weaning feed efficiency (from 12 to over 50%)
- The dam makes colostrum for more than one day, and this has additional impacts on calf development

---

**Thank you for your attention**
Herd Level Dynamics and Management: Impact on Production and Profit

Mike Van Arnum
Dept. of Animal Science
Email: mev1@cornell.edu; cell: 607-592-1212

Overview of today’s discussion

• Identifying disruptors…. All the best biology in the world will not overcome a lack of monitoring and feedback of the system
• What are the major management disruptors that impact heifer profitability at the farm level and what is their value?
• Benchmarking
• Inventory
• Age at first calving
• Summary

Herd Replacement Objectives

• Focus on return on investment – over their productive life
• Minimize non-completion (animals that are born and never enter lactation)
• Optimize the productivity of the animal (manage them for their genetic potential starting at birth)

Key Areas

• Quality
  – Outstanding growth, few to no treatments, high quality environment, good airflow, low ammonia, minimize organic material contamination, meet all the growth benchmarks for optimum milk yield

• Costs: 20 to 30% of costs to operate the business
  – Total costs ($1,900 - $2,400 depending on region)
  – Feed (53% if total heifer costs; $1.42-$2.05/d)
  – Labor
  – Non-completion/performance (10% or higher)
• Number raised
• Capturing value of excess heifers

Growth Benchmarks to Optimize First and Subsequent Lactation Milk Yield

Birth to weaning: double body weight
Puberty: 45% mature weight
Breeding and Pregnancy: 55-60% mature weight
First lact. post-calving BW: 82 to 85% mature weight
Mature weight determined at middle of 3rd and 4th lactation – 80 to 200 days in milk on healthy cows, not cull cows

STUDY GOAL

TO IDENTIFY SPECIFIC DAIRY PRODUCTION MEASURES THAT ARE CORRELATED WITH THE FINANCIAL HEALTH OF A DAIRY
THE DATA

- 425 farm-year records from clients in upper Midwest
- 90 total variables, 54 numeric
- 85 farms represented (not counting censored)
- 10 calendar years
- 5.0 year-end records per farm (avg.)
- 1071 average lactating cows per farm (range from 95 to 4700 )

RELATIONSHIP BETWEEN NFI AND KEY MEASURES

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CORRELATION w/NFI</th>
<th>KEY LEARNINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 day pregnancy risk</td>
<td>0.17</td>
<td>Increased days open is expensive (small sample)</td>
</tr>
<tr>
<td>ECM shipped, lb./cow/day</td>
<td>0.15</td>
<td>More milk per cow is profitable – effect of marginal milk</td>
</tr>
<tr>
<td>Heifer survival rate, %</td>
<td>0.15</td>
<td>Keeping calves healthy is beneficial</td>
</tr>
<tr>
<td>Number heifers</td>
<td>0.07</td>
<td>Heifer inventory not related to profitability – supports culling strategy</td>
</tr>
<tr>
<td>Milk shipped, herd total, cwt</td>
<td>0.05</td>
<td>Profitability not related to total lb. shipped</td>
</tr>
<tr>
<td>Herd size, lactating</td>
<td>-0.03</td>
<td>Herd size not related to profit</td>
</tr>
<tr>
<td>Labor cost*</td>
<td>-0.06</td>
<td>Labor cost is unrelated to profitability</td>
</tr>
<tr>
<td>Death loss (%)</td>
<td>-0.10</td>
<td>Death losses negatively impact profitability</td>
</tr>
<tr>
<td>Somatic cell count</td>
<td>-0.14</td>
<td>Investing to produce high quality milk is profitable</td>
</tr>
<tr>
<td>Net herd replacement cost**</td>
<td>-0.30</td>
<td>Lowering replacement costs helps profitability, value of cull cows</td>
</tr>
</tbody>
</table>

RELATIONSHIPS BETWEEN NET HERD REPLACEMENT COSTS AND OTHER MEASURES

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CORRELATION w/ NHRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cull + death rate, %</td>
<td>0.38</td>
</tr>
<tr>
<td>SCC x 1000</td>
<td>0.35</td>
</tr>
<tr>
<td>Profitability (NFI, $/cwt ECM/day)</td>
<td>-0.32</td>
</tr>
<tr>
<td>ECM/cow/day, lb./day</td>
<td>-0.46</td>
</tr>
</tbody>
</table>

DIFFERENCE IN PROFIT BETWEEN HIGHEST 1/3 AND LOWEST 1/3 (BASED ON NHRC, $/cwt ECM, COP) ~$633 K/year for 1071 cow herd*

* Top third (NHRC = $0.88/cwt) produced 88.5 lb. ECM/cow/day; bottom third (NHRC = $2.02/cwt) produced 76.4 lb. ECM/cow/day

LONGEVITY - DRIVEN PROFIT

- Performance and Percent of Herd by Parity
- Cows >100DIM

PLOT MILK BY LACT

- Peak ~ 69% mature cows
- Overall lactation ~ 69% of mature cows
- 18/21 case studies in last 5 yr – same problem

Fetal growth and requirements

Do you have a pregnant heifer group?

Do you have a late pregnant heifer group?
191 days pregnant - beginning of third trimester

Fetal weight (lb)

Month of pregnancy

Growth rate = 0.92 lb/d
Birth weight = 103 lb

Growth rate = 1.01 lb/d
Birth weight = 108 lb

Requirements of ME and MP for pregnancy

- Calculated based upon expected birth weight of calf and day of gestation
- Become meaningful beginning on day 191 of pregnancy
- Efficiency of ME use for pregnancy is 14%
- Efficiency of MP use for pregnancy is 33%

Pregnant heifers – 1,212 lb, 1,770 lb mature BW

180 days pregnant – at the end of the 2nd trimester

Target gain: 3.15 lb/d
ME allowable: 3.2 lb/d
MP allowable: 4.3 lb/d
Pregnant heifers – 1,278 lb; 1,770 lb mature BW

200 days pregnant – into the 3rd trimester

Target gain: 3.63 lb/d
ME allowable: 2.65 lb/d
MP allowable: 2.06 lb/d

Growth Benchmarks to Optimize First and Subsequent Lactation Milk Yield

Birth to weaning: double body weight
Puberty: 45% mature weight
Breeding and Pregnancy: 55-60% mature weight

First lact. post-calving BW: 82 to 85% mature weight
Goal is to achieve 82% of mature size to achieve 80% of mature cow milk yield

Mature weight determined at middle of 3rd and 4th lactation – 80 to 200 days in milk on healthy cows, not cull cows

Location

• Pen study ---16 cows in 12 pens (192 total)
  – Random allocation of cow to pen, pen to diet
  – 12 multiparous, 4 primiparous animals per pen

Body weight and BCS

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactation</td>
<td>2.4</td>
<td>1-6</td>
</tr>
<tr>
<td>DIM at trial start</td>
<td>115</td>
<td>50-180</td>
</tr>
<tr>
<td>Mature weight, lb</td>
<td>1,712</td>
<td>1,351-2,200</td>
</tr>
<tr>
<td>2+ lactation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight, lb</td>
<td>1,677</td>
<td>1,322-2,200</td>
</tr>
<tr>
<td>BCS</td>
<td>2.95</td>
<td>2.2-3.6</td>
</tr>
<tr>
<td>1st lactation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight, lb</td>
<td>1,351</td>
<td>1,051-1,578</td>
</tr>
<tr>
<td>BCS</td>
<td>3.1</td>
<td>2.87-3.5</td>
</tr>
</tbody>
</table>
Growth in the First Lactation and Loss of Milk due to Partitioning

- Need to look at distribution
- 1,351 lb 1st lact/1,712 lb mature BW = 0.79 ~ 79% mature size
- 1,051 lb 1st lact/1,322 lb MBW = 0.79 ~ 79%
- 1,578 lb 1st lact/2,200 lb MBW = ~ 0.72 ~ 72%
- In this herd, heifers at the bottom of the distribution curve are close to the benchmark, whereas heifers at the top of the distribution curve are too light

Cornell Research Dairy

1993 – mature body weight = 1,474 ± 125 lb (668 kg)
2016 – mature body weight = 1,777 ± 160 lb (803 kg)

Body weight by week

- 79% of mature

Milk production

20 yr of farm level observations suggest milk yield is nearly always within a couple units of the percent mature BW unless there is another constraint

Discussion Group Heifer Project
Benchmarking performance to optimize milk yield

<table>
<thead>
<tr>
<th>Herd</th>
<th>% Mature Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>85 – false positive</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>82 – good herd</td>
</tr>
<tr>
<td>5</td>
<td>79 – acceptable</td>
</tr>
<tr>
<td>6</td>
<td>79 - acceptable</td>
</tr>
<tr>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td>8</td>
<td>77</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>10</td>
<td>76</td>
</tr>
<tr>
<td>11</td>
<td>75</td>
</tr>
<tr>
<td>12</td>
<td>72</td>
</tr>
</tbody>
</table>
PLOT MILK BY LACTGRP – Fellows Case Study
last spring - heifers producing at 82% of mature cows. 2x herd averaging 87 lb

The target growth system (Fox et al., 1999, NRC, 2001) was used to develop the growth, breeding, and post-calving body weight goals

Cornell Dairy Herd
Mature size ～ 1,474 ± 120 lb
Target AFC ～ 22 months
Target post-calving BW (82% of mature weight ～ 1,209 lb)

Therefore the target pregnant weight was 55% of the mature size (811 lb) – breeding was initiated at 750 lb to achieve the target - independent of age

Lactation Study Design
- Post-hoc analysis of pre-pubertal growth rate, AFC, BW at calving, days in milk and 3.5% FCM yield of Holstein heifers fed a control diet or diet containing a FA supplement

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Sunflower oil</th>
<th>EnerGII</th>
<th>CaCLA</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Pre-pubertal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lb</td>
<td>1.90</td>
<td>1.92</td>
<td>1.96</td>
<td>1.87</td>
<td>0.15</td>
</tr>
<tr>
<td>AFC, mo</td>
<td>21.8</td>
<td>21.6</td>
<td>22.3</td>
<td>22.3</td>
<td>1.5</td>
</tr>
<tr>
<td>BW at calving, lb</td>
<td>1,227</td>
<td>1,199</td>
<td>1,241</td>
<td>1,267</td>
<td>76</td>
</tr>
<tr>
<td>Days in milk</td>
<td>299</td>
<td>294</td>
<td>294</td>
<td>290</td>
<td>10</td>
</tr>
<tr>
<td>Milk yield, 3.5% FCM, lb</td>
<td>25,057</td>
<td>24,599</td>
<td>25,538</td>
<td>25,344</td>
<td>2,450</td>
</tr>
</tbody>
</table>

Smith and Van Amburgh, 2003

Management scenario for many herds – value of monitoring

2014-2015 – Milk price was high for most of those two years

- Cull cow prices were also high for same period
- Cull value was almost equal to heifer rearing costs

Many herds now have more than 35% first lactation animals – upwards of 45% 1st lactation in some herds

Little to no monitoring once pregnant – calving in at weights below the benchmark of 82% mature body weight

Current scenario for many herds – value of monitoring for case study herd at 69% of lactation milk

Expected milk if target met: ～ 90 lb (40 kg) at peak

Assume ～225 lb (102 kg) for every pound at peak

11.5 lb (5.2 kg) greater peak * 225 = 2,583 lb (532 kg)
unrealized milk due to not meeting the 82% mature size benchmark

Net milk: $16.80/CWT

$8.33 IOFC margin (Net milk – feed cost per CWT)

$8.33 * 25.8 CWT = $215.20 per 1st lactation heifer IOFC

800 cow herd * 40% 1st lactation heifers = 320 heifers *
$215.20 IOFC =$68,852 IOFC not realized ($86/lact. cow)
**Value of monitoring – $20 milk**

Net milk: $20.80/CWT

- $8.33 IOFC margin (Net milk – feed cost per CWT)
- $12.33 * 25.8 CWT = $318.11 per 1st lactation heifer
- IOFC
- 800 cow herd * 40% 1st lactation heifers = 320 heifers *
- $318.11 IOFC = $101,795.20 IOFC not realized
  ($127/ lact. cow)

**Case study herd demographics**

- Extremely Young Herd
  - Average Lactations: 1.7

**Why this outcome?**

- Sexed semen
- Low NCR
- Reasonable cull cow value
- Little long-term, systems thinking

**Impact of Young Herd Demographics and Lack of Benchmaks**

1st lactation heifers are not paying for themselves

- Cost of Raising a heifer $3.35/day
- Average age at first calving = 22.9 months
- $2,301 to rear a heifer
- 26,400 M365 first lactation
- $20.20 milk price/cwt
- $4,336 milk income first lactation
- 50 lbs /day predicted DMI at $0.12/lb DM = $6/day
- calving interval = 381 - 59 avg days dry = 322 DIM
- $1,886/cow feed cost for first lactation
- Hoof trimming expense = $30/cow
- Breeding expense = $55/cow
- Veterinary service expense = $11/cow
- Medicine expense = $102/cow
- $198/cow additional operating expense

**Average total costs to raise heifers – 17 farms in NY 2012**

**Labor up about 10% feed down about 10% so similar average**

- Cost, Per Day per Animal
  - **Feed**: $1.598 53.3% $1.296 $2.051
  - **Labor**: $0.358 12.0% $0.215 $0.509
  - **Bedding**: $0.131 4.4% $0.028 $0.293
  - **Health**: $0.060 2.0% $0.028 $0.127
  - **Breeding**: $0.069 2.3% $0.036 $0.107
  - **Machinery, Operation & Ownership**: $0.123 4.1% $0.056 $0.225
  - **Building, Operation & Ownership**: $0.171 5.7% $0.070 $0.300
  - **Manure, Storage & Spreading**: $0.073 2.4% $0.024 $0.150
  - **Non-Performance Expense**: $0.114 3.8% $0.034 $0.179
  - **Interest on Daily Investment**: $0.205 6.8% $125.3
  - **All other Costs**: $0.094 3.1% $0.183 $0.677

- **Total Cost per day per Animal**: $2.996 $2.66 $3.43
- **Total Cost per Pound of Gain**: $1.72 $1.53 $1.89
- **Total Cost per Animal Completing System**: $2,090 $1,876 $2,263
- **Total Investment in Animal**: $2,238 $2,026 $2,413

1 Trucking, Insurance, Custom Boarding, Professional Services

**Wisconsin data: $2,377 in 2013**

**Jason Karszes**

**Impact of Herd Demographics – especially when benchmarks not met**

- $ 4,336 milk income
- $ 2,301 cost to rear
- $ 1,932 1st lactation feed cost
- $ 198 operating expenses
- $ 963 labor expense
- $ 402 repairs expense
- $ 180 bedding and supplies
- $ 396 milk marketing
- $ 923 overhead expense

- $-1896 loss/1st lactation animal

**Heifer Breakeven and Profitability**

- Heifer Payback
- Cull value
- 41.3 mo

- Average Lactations = 1.7
- Average Herd Life = 45 months
- Breakeven Point = 46 months
What happens to Net Farm Income if we modify culling behavior to reduce inventory?

Total heifer cost $2,300

Reduction in heifer inventory due to lower turnover:
- 391 heifers
  $899,300 in reduced costs for the herd

In this example, assuming 2,927 milking cows, that’s $155 increase in net farm income per cow

The Hidden Value of Inventory
1,000 cows milking and dry with 8% non-completion rate

Assume $2,200 replacement cost

With AFC 22 months and 33% cull rate – requires 631 Heifers
$1,388,200 heifer program cost

With AFC 24 months and 42% cull rate – requires 877
$1,929,400 heifer program cost

$541,000 difference over 2 years

850 milking cattle = $318 net farm income per cow

How Early Should Heifers Calve to Optimize Lifetime Productivity?
Within Herd Analysis of AFC on Productive Days, Milk Yield, Longevity

- Lactation records from
  - 2,519,232 first lactation cows
  - 937 herds in the Northeast and California
- Within herd analysis
  - Accounts for management, environment, and genetic differences among farms

Within Herd Analysis of AFC on Productive Days, Milk Yield, Longevity

- Retrospective assignment to AFC treatment groups
  - Herd avg. AFC was calculated each year
  - Heifers were assigned to one of 5 AFC age groups:
    1) Less than -63 days from herd avg. AFC
    2) -22 to -63 days from herd avg. AFC
    3) -21 to 21 days from herd avg. AFC
    4) 22 to 63 days from herd avg. AFC
    5) Greater than 63 days from herd avg. AFC

Study from Wisconsin – field/farm data from DHIA records evaluation of heifer calving in 2005

>69,000 heifers analyzed

Stratified herds by level of production –
3x milking high – 28,100 lb RHA,
3x milking medium -24,795 lb RHA,
2x medium – 24,795 lb RHA,
2x low – 20,387 lb RHA

Curran et al. Prof. Anim. Sci., 2013
Curran et al., 2013

**Exit age (total days) by AFC and 2x or 3x milking stratified by herd milk yield**

**Herd life (days milked) by AFC and 2x or 3x milking stratified by herd milk yield**

**Lifetime milk (lb) by AFC and 2x or 3x milking stratified by herd milk yield**

**Herd Life, UK data 2011**

**Table 3. Measures of longevity (mean ± SEM) for 211 Holstein-Friesian cows killed before third calving**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Rearing period</th>
<th>Lactation 1</th>
<th>Lactation 2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at calving (d)</td>
<td>450 ± 56</td>
<td>1,187 ± 16</td>
<td>831 ± 14</td>
<td>831 ± 11</td>
</tr>
<tr>
<td>Age at first calving (d)</td>
<td>1,059 ± 29</td>
<td>710 ± 35</td>
<td>538 ± 24</td>
<td>538 ± 24</td>
</tr>
<tr>
<td>Herd life from first calving (d)</td>
<td>0</td>
<td>322 ± 29</td>
<td>367 ± 15</td>
<td>345 ± 16</td>
</tr>
<tr>
<td>DIM lactation 1 (d)</td>
<td>0</td>
<td>260 ± 21</td>
<td>260 ± 21</td>
<td>260 ± 21</td>
</tr>
<tr>
<td>DIM lactation 2 (d)</td>
<td>0</td>
<td>24 ± 2</td>
<td>40 ± 1</td>
<td>32 ± 1</td>
</tr>
<tr>
<td>Total lifetime DIM (d)</td>
<td>0</td>
<td>563 ± 27</td>
<td>474 ± 23</td>
<td>474 ± 23</td>
</tr>
<tr>
<td>Longevity index* (d)</td>
<td>0</td>
<td>0.24 ± 0.4</td>
<td>0.40 ± 0.4</td>
<td>0.32 ± 0.3</td>
</tr>
</tbody>
</table>

*Longevity index was defined as the proportion of days alive spent in milk production (lifetime DIM divided by age in days at calving).

Brickell and Wathes, JDS, 2011

**LSM of Milk, Fat and Protein by AFC using 24 mo as a base**

**Lifetime Milk, Fat and Protein Yield for Holsteins, Jerseys and Brown Swiss**

Figure 1. Least squares means of each age at first calving (AFC) group compared with a baseline of 24 mo for actual first-lactation (A) milk yield, (B) fat yield, and (C) protein yield in Holsteins, Jerseys, and Brown Swiss cattle. Standard errors are represented as bars extending from each data point.

Figure 2. Least squares means of each age at first calving (AFC) group compared with a baseline of 24 mo for lifetime (A) milk yield, (B) fat yield, (C) protein yield, (D) DIM, and (E) lifetime days spent in Holsteins, Jerseys, and Brown Swiss cattle. Standard errors are represented as bars extending from each data point.
Summary

- Disruptors to dairy profitability are found in the heifer rearing program
- The heifer program is a cost center and the only way to reduce the impact is to lower the time to calving and optimize lactation yield and productivity over the lifetime
- Non-completion rate, inventory and age at first calving account for a large percentage of total Net Farm Income
- Lowering the cost requires feedback and information and systems thinking
The Next Step in Corn Silage Hybrid Evaluation: Fiber and Starch Yields

Michael Miller, MS
Miner Institute

Corn silage
- Large proportion of dairy cow’s diet
- Provides energy from digestible fiber and starch
- Varies in yield and quality depending on growing environment, genetics, and harvest management

(Cherney et al., 1991; Johnson et al., 2003; Kung et al., 2008)

Measures of fiber
- Neutral detergent fiber (NDF)
  - Cellulose, hemicellulose, and lignin
  - Measure of total fiber and related to intake and chewing activity
- Undigested NDF (uNDF)
  - remaining fiber fraction after a 240-h in vitro incubation (indigestible fraction)
  - Related to physical effectiveness and gut fill

Brown mid-rib (BMR) corn silage
- Brown mid-rib mutation (BM1 or BM3)
  - Reduced lignin concentrations
  - Increased NDF digestibility
- Biggest hurdles for widespread adoption
  - Reduced yield
  - Increased seed cost

Measures of fiber
- Potentially digestible NDF (pdNDF)
  - Measure of fiber that can be degraded
- NDF digestibility (NDFd) in vitro or in situ
  - 12, 24, 30, 48, 72, 120, and 240 hours
  - \( \frac{(\text{Initial NDF} - \text{Remaining NDF fraction})}{\text{Initial NDF}} \times 100 \)
  - Affected by weather and environment

Oba and Allen, 1999

Corn silage hybrid evaluation using fiber fractions
Northern New York Corn Hybrid Trial

- Five hybrids were used in a randomized complete block design study and assigned randomly to plots within each block in a 14-acre tile-drained research field.
- All plots were harvested by chopping individual strips into dump trucks and weighing on truck scales and a composite sample was taken from each load.
- Relatively little research has evaluated performance among bm1, bm3, and non-BMR hybrids with respect to yield and forage quality across growing seasons.

Table 1. Hybrids and planting information for Miner Institute

<table>
<thead>
<tr>
<th>Item</th>
<th>Hybrid 1 (company and number)</th>
<th>Hybrid 2 (company and number)</th>
<th>Hybrid 3 (company and number)</th>
<th>Hybrid 4 (company and number)</th>
<th>Hybrid 5 (company and number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting date</td>
<td>5/21/15</td>
<td>5/21/15</td>
<td>5/21/15</td>
<td>5/21/15</td>
<td>5/21/15</td>
</tr>
<tr>
<td>Harvest date</td>
<td>10/2/15</td>
<td>10/2/15</td>
<td>10/2/15</td>
<td>10/2/15</td>
<td>10/2/15</td>
</tr>
<tr>
<td>2015</td>
<td>Mycogen F2F379 (bm3)</td>
<td>Mycogen F2F499 (bm3)</td>
<td>Pioneer PO238XR (bm1)</td>
<td>Pioneer PO533AM1 (non-BMR)</td>
<td>Mycogen TMF2Q419 (non-BMR)</td>
</tr>
</tbody>
</table>

Fresh chop corn forage quality measures for hybrids grown at Miner Institute

<table>
<thead>
<tr>
<th>Item (% of DM, unless otherwise noted)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>A-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM3</td>
<td>BM3</td>
<td>BM3</td>
<td>BM3</td>
<td>BM3</td>
<td>BM3</td>
<td></td>
</tr>
<tr>
<td>Neutral detergent fiber (aNDFom)</td>
<td>38.1±</td>
<td>38.1±</td>
<td>38.1±</td>
<td>38.1±</td>
<td>38.1±</td>
<td></td>
</tr>
<tr>
<td>30-h aNDF digestibility, % of aNDFom</td>
<td>60.1±</td>
<td>60.1±</td>
<td>60.1±</td>
<td>57.2±</td>
<td>57.2±</td>
<td>0.01</td>
</tr>
<tr>
<td>Undigested NDF 30-h</td>
<td>12.5±</td>
<td>12.5±</td>
<td>12.5±</td>
<td>16.6±</td>
<td>16.6±</td>
<td>0.01</td>
</tr>
<tr>
<td>Undigested NDF 120-h</td>
<td>7.9±</td>
<td>7.9±</td>
<td>10.2±</td>
<td>11.4±</td>
<td>11.4±</td>
<td>0.15</td>
</tr>
<tr>
<td>Potentially digestible NDF (pdNDF)</td>
<td>31.4±</td>
<td>30.7±</td>
<td>27.6±</td>
<td>27.0±</td>
<td>29.6±</td>
<td>0.05</td>
</tr>
</tbody>
</table>

abcd Least squares means within a row without a common superscript differ (P ≤ 0.05).
Brown midrib-3 hybrids had higher NDF digestibility and lower undigested neutral detergent fiber at 240-h than BM1 and non-BMR hybrids, though yield of pdNDF was similar.

Neutral detergent fiber and pdNDF yields may be useful metrics for corn silage hybrid evaluation.

**Fiber and Starch yield calculator**

- [http://www.whminer.org/dairy/](http://www.whminer.org/dairy/)
  - On the right side under "Dairy Management Tools"
  - Excel file that can calculate fiber and starch yields
  - Just input yield and quality data

**Fiber and Starch yield calculator**

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  - On the right side under "Dairy Management Tools"
  - Excel file that can calculate fiber and starch yields
  - Just input yield and quality data
By this time you’re either finishing chopping the last of the corn silage or have already finished. Hopefully the corn silage was chopped and processed well and stored with optimal packing density, received inoculants to drive good fermentation, and has an oxygen barrier to prevent spoilage. Now is the time to evaluate how the corn silage hybrids performed and to choose hybrids for next year’s crops. Some of the metrics commonly used are yields expressed as tons per acre, starch content, starch digestibility, neutral detergent fiber (NDF) content, and NDF digestibility (NDFd) at 30 hours. These are important because corn silage provides energy to the cow from fiber and starch. In the last few years NDF has been better defined using in vitro fermentation at multiple points, usually 30, 120, and 240 hours, and is called undigested NDF (uNDF). Undigested NDF at 240 hours (uNDF at 240-h) is the measure of the indigestible portion of the fiber and has been related to gut fill. With uNDF at 240-h and NDF we then can calculate the potentially digestible NDF by subtracting uNDF at 240-h from NDF. Better differentiation of fiber has given enhanced understanding of how the cow is able to utilize it. So in order to compare corn silage hybrids these measure should be included.

High quality forage starts with the seed choice which makes corn silage hybrid selection vital to meeting the production goals of the farm. Using data from the hybrids grown on your farm and local hybrid trials can help make this decision. Brown midrib (BMR) corn silage has a mutation (bm1 or bm3) that produces less lignin and has increased NDFd.

### Table 1. Hybrids and planting information for Miner Institute, Chazy, NY

<table>
<thead>
<tr>
<th>Year</th>
<th>Hybrid 1</th>
<th>Hybrid 2</th>
<th>Hybrid 3</th>
<th>Hybrid 4</th>
<th>Hybrid 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>Mycogen F2F379 (bm3)</td>
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<td>Mycogen F2F379 (bm3)</td>
<td>Mycogen F2F499 (bm3)</td>
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</tr>
</tbody>
</table>

### Table 2. Fresh chop corn forage quality and yield measures for hybrids grown at Miner Institute, Chazy, NY, 2015-2017

<table>
<thead>
<tr>
<th>Item</th>
<th>Hybrid 1</th>
<th>Hybrid 2</th>
<th>Hybrid 3</th>
<th>Hybrid 4</th>
<th>Hybrid 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield, ton/ac (35% DM)</td>
<td>17.0 b</td>
<td>17.3 ab</td>
<td>17.5 ab</td>
<td>18.2 ab</td>
<td>19.2 a</td>
</tr>
<tr>
<td>Starch, % of DM</td>
<td>33.5 ab</td>
<td>32.3 b</td>
<td>35.2 a</td>
<td>35.5 a</td>
<td>34.7 ab</td>
</tr>
<tr>
<td>NDF, % of DM</td>
<td>38.1 ac</td>
<td>36.9 ac</td>
<td>36.6 b</td>
<td>38.0 ac</td>
<td>39.3 a</td>
</tr>
<tr>
<td>pdNDF, % of DM</td>
<td>67.1 a</td>
<td>66.2 a</td>
<td>60.1 b</td>
<td>56.1 c</td>
<td>57.2 c</td>
</tr>
<tr>
<td>uNDF 240-h, % of NDF</td>
<td>6.7 c</td>
<td>6.2 c</td>
<td>9.2 b</td>
<td>10.0 a</td>
<td>9.8 ab</td>
</tr>
<tr>
<td>pdNDF, % of DM</td>
<td>31.4 a</td>
<td>30.7 b</td>
<td>27.4 c</td>
<td>27.9 c</td>
<td>29.6 c</td>
</tr>
<tr>
<td>NDF yield, ton/ac (35% DM)</td>
<td>6.4 b</td>
<td>6.2 b</td>
<td>6.3 b</td>
<td>6.9 b</td>
<td>7.5 a</td>
</tr>
<tr>
<td>uNDF 240-h yield, ton/ac (35% DM)</td>
<td>1.1 c</td>
<td>1.1 c</td>
<td>1.6 b</td>
<td>1.8 ab</td>
<td>1.9 a</td>
</tr>
<tr>
<td>pdNDF yield, ton/ac (35% DM)</td>
<td>5.3 ab</td>
<td>5.2 ab</td>
<td>4.7 b</td>
<td>5.1 ab</td>
<td>5.6 a</td>
</tr>
<tr>
<td>Starch yield, ton/ac (35% DM)</td>
<td>5.7 b</td>
<td>5.7 b</td>
<td>6.2 b</td>
<td>6.5 b</td>
<td>6.7 a</td>
</tr>
</tbody>
</table>
This allows for greater intakes but adoption has been slow due to seed cost and lower yields. A corn silage hybrid trial conducted at Miner Institute for 3 years (2015-2017) compared bm3, bm1, and non-bmr hybrids. The hybrid and planting information is in Table 1 while fresh chop forage quality and yield are in Table 2. The non-bmr (hybrid 5) had higher yield than the bm3 (hybrid 1). This wasn’t a surprise, but the other bm3 and bm1 (hybrids 2 and 3) were not different from non-bmr hybrids (hybrids 4 and 5) which was a surprise. Brown midrib-1 and non-bmr hybrids (hybrids 3 and 4) had higher starch content than bm3 hybrid (hybrid 2). Brown midrib-3 hybrids (hybrid 1 and 2) had higher NDFd at 30-h than bm1 and non-bmr hybrids (hybrids 3, 4, and 5) and the bm1 (hybrid 3) had a higher NDFd at 30-h than the non-bmr hybrids (hybrids 4 and 5). Brown midrib-3 hybrids (hybrid 1 and 2) had lower uNDF at 240-h than bm1 and non-bmr hybrids (hybrids 3, 4, and 5). Potentially digestible NDF (pdNDF) content was higher for bm3 hybrid (hybrid 1) than bm1 and non-bmr hybrids (hybrids 3, 4, and 5) and bm3 (hybrid 2) and non-bmr (hybrid 5) hybrids had higher pdNDF than bm1 and non-bmr hybrids (hybrids 3 and 4). Based on the quality measures the bm3 hybrids have higher NDFd 30-h with lower uNDF 240-h than the other hybrids.

Going one step further by calculating fiber and starch yields will allow better differentiation of corn silage hybrids. The fiber and starch yields are calculated by multiplying the yield by the nutrient fraction (NDF, uNDF 240-h, pdNDF, and starch) and presented on 35% dry matter basis. Non-bmr hybrid (hybrid 5) had higher NDF yield than bm3 and bm1 hybrids (hybrids 1, 2, and 3). The bm3 hybrids (hybrids 1 and 2) had lower uNDF 240-h yield than bm1 and non-bmr hybrids (hybrids 3, 4 and 5) and the bm1 hybrids had a lower uNDF 240-h yield than non-bmr hybrid (hybrid 5). The pdNDF yield was higher for non-bmr hybrid (hybrid 5) than the bm1 hybrid (hybrid 3). The starch yield was higher for non-bmr hybrid (hybrid 5) than the bm3 hybrids (hybrids 1 and 2). Based on the yield measures, the bm3 hybrids provided similar pdNDF yields as the other hybrids by having less indigestible fiber. Using quality and yield measures will help when making corn silage hybrid selection.

Miner Institute has created a spreadsheet to help with calculating fiber and starch yields that’s available online http://whminer.org/dairy/ under “Dairy Management Tools” called “Corn Silage Hybrid Fiber and Starch Yields Calculator”. There are 3 sheets: “Instructions”, “Insert data”, and “Yields”. To calculate the fiber and starch yields insert yield and forage analysis in the “Insert data” sheet, but make sure that the units are same as the column headings. Once the data is inserted then go to the “Yields” sheet and the fiber and starch yields are calculated and to sort hybrids based on one of the measures use the little drop down box next to the measures name shown in Figure 1. These instructions are also on the first sheet.

Corn silage is a major feed component in dairy cow diets, so making the best choice for which hybrids to plant is a big decision for a farm. Since corn silage provides energy to the cow from the fiber and starch fractions these should be used in evaluating different hybrids. To better evaluate the hybrids, the quality measures should be on a yield basis and these can be easily calculated using the “Corn Silage Hybrid Fiber and Starch Yields Calculator” located on our website.

— Michael Miller
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Milk Fatty Acid Testing – Useful for the Herd, the Group, and the Cow

H. M. Dann, D. M. Barbano, A. Pape, & R. J. Grant
2018 Dairy Day at Miner Institute

Federal Milk Order Component Prices

Milk Fat and Protein Yield are Key Drivers of Profitability

Pounds of Fat and Protein: A Combination of Milk Yield and Fat and Protein Content

Milk Fat Composition

Most Variable Component of Milk

- 98% triglycerides
- More than 400 unique fatty acids (FA) in milk (GC analysis)
- About 20 FA make up the majority
  – Broadly grouped into 3 subcategories

Howland and Karszes, 2015 Pro-Dairy

Jensen et al., 2002; Palmquist, 2006; Moate et al., 2007
Milk Fatty Acid (FA) Groups

- **De novo FA - < C16**
  - Made in the mammary gland
  - Influenced by rumen fermentation/function
  - 18-30 relative % (21-26)

- **Preformed FA - > C16**
  - From fat the diet
  - From body fat mobilization
  - 32-42 relative % (35-42)

- **Mixed origin FA - C16**
  - Made in the mammary gland (de novo)
  - 30-40 relative % (35-42)

Milk Fatty Acid Profile Provides Insight: Performance and Health of the Cow

- **Diet and dietary changes**
  - Forage quality, CHO fermentability, RUFAL, ...

- **Feeding and management practices**
  - Behavioral...rumen pH
  - Risk of milk fat depression

- **Physiological state of cow**
  - Stage of lactation
  - Energy balance
  - Health

Testing Facilities For Milk Fatty Acids

(MIR Spectroscopy)

- Sterns County
  - Zumbrota MN
  - DHIA Labs
- ADM DHIA Lab
- Texas Federal Milk Market Lab
- Cornell University
  - Miner Institute
- St. Albans Coop
  - Agrimark Coop
  - Cayuga Marketing Coop

Common Ways to Use the Milk Fatty Acid Metrics for Bulk Tank Milk

- **Monitoring while looking for opportunities and reacting to changes over time**
- **Herd “snapshot” and troubleshooting**
  - “My milk fat % is too low”

Troubleshooting Herds

Milk Samples over Multiple Days, Herd Average Plotted
Troubleshooting Herds
Milk Samples over Multiple Days, Herd Average Plotted

Prediction of Fat % (Y) From Milk Fatty Acid Metrics (X)

De Novo FA, g/100 g milk | Mixed Origin FA, g/100 g milk | Preformed FA, g/100 g milk | Unsaturation, DB/FA
--- | --- | --- | ---
40 Holstein Herds (St. Albans 2013) | Y = 2.297X + 1.844 | Y = 1.540X + 1.586 | Y = 0.793X + 2.774 | Y = -0.583X + 6.421 | R² = 0.80 | R² = 0.86 | R² = 0.07 | R² = 0.69
167 Holstein Herds (US 2016-2017) | Y = 2.233X + 1.830 | Y = 1.892X + 1.179 | Y = 1.289X + 1.911 | Y = -0.408X + 5.971 | R² = 0.61 | R² = 0.79 | R² = 0.15 | R² = 0.31

Every 0.1 g/100 g milk ↑ in de novo FA is a 0.2% ↑ in fat %
Barbano et al., 2017; Barbano et al., unpublished

167 Holstein Herds (US 2016-2017)

1. Fat, %
2. Fat, lb/d
3. De Novo FA, g/100 g milk

167 Holstein Herds (US 2016-2017)

1. Herd Milk, lb/d
2. De Novo FA, g/100 g milk

High de novo herds tend to be...
5x more likely to deliver feed 2x/d in freestall
11x more likely to deliver feed 5x/d in tiestalls
Woolpert et al., 2016; Woolpert et al., 2017

High de novo herds feed...
Less ether extract (≤3.5%) 
More physically effective fiber (≥21%)
Woolpert et al., 2016; Woolpert et al., 2017
High de novo herds tend to be... 10x more likely to provide ≥18 in bunk space/cow 5x more likely to stock stalls at ≤110%  

Herd Level Risk Factors for Milk Fat Depression: Relationship with TMR Composition

- 4 factors together (starch content, monensin, PUFA, and MUFA) only accounted for 32% of the variation in herd milk fat percentage
- Particle size of TMR
  - Herds that had >49.3% of the TMR particles on the middle screen of the Penn State particle separator had higher milk fat percentage than those with ≤49.3%,
  - Herds with >54.0% of TMR particles in the bottom pan had lower milk fat percentage than herds with ≤54.0%
- Indicates many variables contribute to low milk fat and herds experiencing low milk fat will need to examine many potential risk factors when working to troubleshoot milk fat depression

Factors Associated with Milk Fat and Fatty Acids

Diet Factors
- Diet-induced milk fat depression
  - Specific inhibition of milk fat by bioactive fatty acids
- Fermentable carbohydrates
  - Starch
  - Forage fiber (acetate)
  - pNDF
- Fats
  - RUFAL: C18:1 + C18:2 + C18:3
  - Palmitic acid
  - Contribution of forages
- Feed additives
- Wild yeasts/molds

Cow/Environment/Management Factors
- Genetics
- Parity
- Days in milk
- Season
- Time budget (behavior)
  - Stocking density
- Feeding strategy
  - TMR vs. PMR vs. component
  - Frequency of feed delivery/push up

Jenkins, 2013; Harvatine, 2017; Bauman, 2017 AMTS webinar

Monthly Averages for Bulk Tanks from a Holstein Herd

De novo FA, g/100g milk

Mixed FA, g/100g milk

Woolpert et al., 2017

McCarthy et al., 2018

McCarthy et al., 2018

McCarthy et al., 2018
Monthly Averages for Bulk Tanks from a Holstein Herd

Going Beyond Bulk Tank Sampling...

Commercial Herds – Group Samples
Use of Biomarkers for Negative Energy Balance and Ketosis

- Milk beta hydroxybutyrate (BHB) and acetone – most researched to date
  - Fast, low-cost, noninvasive relative to blood

- Milk BHB for screening of subclinical ketosis
  - MIR prediction better for BHB (80% sensitivity) than fat to protein (66% sensitivity) (van Knegsel et al., 2010)

- Threshold of ≥ 0.2 mmol/L – detect ketosis in cow, proposed in herd-level surveillance programs (Denis-Robichaud et al., 2014)
Milk Predicted Blood NEFA – Highest in Early Lactation

Fresh Pen NEFA from NE and MW Herds

Milk Predicted Blood NEFA for Fresh Cows

Milk Predicted Blood NEFA – Fresh Period

Milk Predicted Blood NEFA: Deviation from Expected Herd Pattern

Milk Composition Changes for a Cow Before and After DA Surgery
**MIR Methodology and Implementation of Machine Learning Models May Allow for Early Detection of Health Issues**

- Data: 1436 observations for ketosis dataset and 1240 observations for DA, with at least 10 healthy samples for every sick sample
- Predictors:
  - Milk-estimated blood NEFA (μEq/L)
  - De novo fatty acid (g/100 g FA)
  - Preformed fatty acid (g/100 g FA)
  - Ratio of fat to protein
  - BHB
- Response: occurrence of ketosis or DA
- Model type: random forests, logistic regression
- Evaluation: AUC from 10 replicates of 10-fold cross-validation

**Milk Composition Predicts Clinical Ketosis with Moderate Accuracy**

**Real-Time Predication of Health Issues: Pilot System for Miner Herd**

- Objective: provide general-purpose alerts for health issues in fresh cows to farm staff
- Approach:
  - Collect and analyze milk samples (M1) from cows in fresh pen
  - Use machine learning models based on milk composition to predict health issues (e.g. ketosis, DA, metritis, mastitis...)
  - Provide information to farm staff

**General Purpose Health Alert – Model Performance**

**Frequency of Milk Testing**

- Monthly DHI milk-testing program
  - Prevalence of hyperketonemia at the herd level
- Need a higher frequency for detection and treatment of individual cows
- Development of on-farm MIR milk analyzers is needed
Milk Fatty Acid Profile – Another Tool for Your Toolbox

• Milk components are an important part of the milk check
• Knowing the milk fatty acid profile and making decisions based on it may help improve performance and health of cows and affect profitability