Feeding Strategies To Achieve High Money Corrected Milk

Kevin Harvatine, Ph.D.
Associate Professor of Nutritional Physiology
Penn State University
kjh182@psu.edu

GPS Consulting
November 15th, 2017
Milk fat is a big contributor to cash flow ($/hd/d @80 lb of 3.7 fat & 3.05 protein)

<table>
<thead>
<tr>
<th>Date</th>
<th>Milk Value, $/hd/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>Protein</td>
</tr>
<tr>
<td>Other solids</td>
<td></td>
</tr>
</tbody>
</table>

[Graph showing milk value trends over time]
**Milk fat is valuable $$**

Value of 0.1 units of milk fat at $2.42/lb

<table>
<thead>
<tr>
<th>Cows</th>
<th>65 lb/d</th>
<th>80 lb/d</th>
<th>95 lb/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$57</td>
<td>$71</td>
<td>$84</td>
</tr>
<tr>
<td>100</td>
<td>$5,741</td>
<td>$7,065</td>
<td>$8,390</td>
</tr>
<tr>
<td>1000</td>
<td>$57,406</td>
<td>$70,653</td>
<td>$83,900</td>
</tr>
<tr>
<td>9 million</td>
<td>$517 million</td>
<td>$636 million</td>
<td>$755 million</td>
</tr>
</tbody>
</table>

Dr. Normand St. Pierre would argue is also the most profitable component because of cheaper nutrients required to make it!
Milk fat has value to consumers!

- Taste!
- No longer “bad” fat
- “Natural” for “clean” labels
- Stable and good manufacturing characteristics

Many potential bioactive nutrients

Over 400 different fatty acids

- ”Good” trans-11 fatty acids and conjugated linoleic acid
- Odd and branch chain FA of microbial origin
- “Milk fat globular membrane proteins”
What is milk fat?

- Lipid droplet coated with phospholipids and “Milk fat globular membrane proteins”

- Two sources: De novo and Preformed

![Fatty acid content chart]

- De novo synthesis
- Preformed

**Fatty acid**

- 4:0
- 6:0
- 10:0
- 12:0
- 14:0
- 16:0
- 16:1
- 18:0
- 18:1
- 18:2
What should you be thinking about

1. Set your goal
   - Seasonal pattern
   - Genetics

2. Balance the diet
   - Unsaturated fat
   - Fermentability
   - Acetate supply
   - Palmitic acid
   - Additives

3. Manage the feeding system
   - Reduce slug feeding
What should milk fat concentration be?

Based on 222,468 DHIA test days from PA, MN, TX, and FL from 2010 to 2016

Average 3.75
31% < 3.6%
11.6 < 3.4%
Milk fat is affected by many factors

**Nutritional Factors**
- Inhibited by milk fat depression
  - Unsaturated fat
  - Fermentability
  - Acidosis
  - Feeding strategies
  - Ionophores
- Increase by additional substrate
  - Acetate
  - Palmitic acid

**Non-nutritional Factors**
- Genetics
- Season
- Stage of lactation
- Parity

**Diet-Induced Milk Fat Depression (MFD) = Specific inhibition of milk fat by bioactive fatty acids**
Milk fat is the most heritable production trait and DGAT1 SNP explains a large part of the genetic variation.
PTA Fat gives an indication of genetic potential

Fig. 2. The effect of sire predicted transmitting ability (PTA) for milk fat percentage quartile on milk fat percentage for the first 10 months of lactation. Data were analyzed using repeated measures ANOVA and the effect of animal nested within farm was controlled in the model as a random effect. Parity was also kept in the model as a fixed effect. Error bars represent 95% confidence interval of the mean.

Bicalho et al. 2014. Theriogenology. 81:257-265
There is a seasonal pattern of milk fat & protein: Mid East US Milk Market

- **Fat**: 
  - Occurs in all milk markets
  - Concentration: ~0.25 Units

- **Protein**: 
  - Concentration: ~0.20 Units
There is also a seasonal rhythm in milk fat YIELD

<table>
<thead>
<tr>
<th>State</th>
<th>Mean</th>
<th>Amplitude</th>
<th>Peak</th>
<th>Rhythm Fit*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN</td>
<td>2.19</td>
<td>0.116a</td>
<td>Feb 21a</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>PA</td>
<td>2.18</td>
<td>0.138b</td>
<td>Feb 24b</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Salfer et al. ADSA 2017
Let's talk about nutrition:
Milk fat can be decreased by Diet-Induced Milk Fat Depression (MFD)

- Bioactive fatty acids are made in the rumen that decrease milk fat were identified 20 years ago
- Diet and management risk factors result in a change in the rumen microbes that produces these bioactive “trans-10” FA intermediates
- Up to a 50% reduction in milk fat
- Specific decrease in lipid synthesis in the mammary gland
- Greater decrease in fatty acids made by the mammary gland (de novo)

This is a very common cause of reduced milk fat yield, but is not meant to explain every change in milk fat!!!
Unsaturated fatty acids are “biohydrogenated” in the rumen, but the pathway depends on the microbes present.

Linoleic acid
\((cis-9, \, cis-12 \, C_{18:2})\)

→ Rumenic acid
\((cis-9, \, trans-11 \, CLA)\)

→ Vaccenic acid
\((trans-11 \, C_{18:1})\)

→ Stearic acid \((C_{18:0})\)

Alternate pathways

Alternate CLA isomers
\(trans-10, \, cis-12 \, CLA\)

\(trans-10, \, cis-12 \, CLA\)

→ \(trans-10 \, C_{18:1}\) isomers

→ Stearic acid \((C_{18:0})\)

Griinari and Bauman, 1999
We know this bioactive FA decreases specific transcription factors in the mammary gland that regulate milk fat synthesis.
Risk factors cause BH-induced milk fat depression

- Rarely is low milk fat caused by a single factor on a farm

- We can’t eliminate all the risk factors

- We don’t want to eliminate all the risk factors!!!
Risk Factors for “Diet-Induced MFD”

- Dietary fatty acid level and profile
- Availability of fatty acids
- Rumen modifiers- ionophore
- Ruminal acidosis
- Dietary carbohydrate profile
- Rate and extent of fermentation
- Effective fiber
- Ruminal N balance
- Feeding strategies/management
- Silage fermentation/quality
- Forage types
- Individual cow effect (level of intake etc)

RUFAL: Rumen Unsaturated Fatty Acid Load (but C18:2 most important)

High producing cows normally most susceptible
There is a Continuum From "High" to "Low" Milk Fat

Each herd and each cow is somewhere on this continuum!!
Can fatty acids be used to troubleshoot milk fat problems?

**Milk trans-10 18:1 & MILK FAT %**

- **trans-10 C18:1**
  - 0.3 to 0.5% = normal fat
  - 0.6 to 1.0% = 3.2 to 3.5% fat
  - >1% = < 3.2% fat

- Also expect decrease in de novo synthesized FA

Harvatine, unpublished
What is the time-course of induction of and recovery from diet-induced milk fat depression?

- When MFD occurs........when did the problem originate?

- When correcting the diet......when do we expect to see improvements???
Diet-induced MFD occurs in 7 to 10 d

Rico and Harvatine, 2013

**Normal Pathway**
cis-9, trans-11 CLA

**Alternative Pathway**
trans-10, cis-12 CLA
Recovery from diet-induced MFD takes 14 to 18 d, but moving up in 7 to 10 d

Alternative Pathway
trans-10, cis-12 CLA

Rico and Harvatine, 2013
Rapid changes in rumen microbes during diet-induced MFD

**Total Fungi**

<table>
<thead>
<tr>
<th></th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trt</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Trt x time</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SEM</td>
<td>1.18</td>
</tr>
</tbody>
</table>

I, R = P < 0.05

Milk fat depression increases as milk yield increases: 900 cow herd with MFD

Overall Mean = 3.24%
< 75 lbs = 3.8%
75 to 95 lbs = 3.2%
>95 = 2.9%
**Milk fat concentration**

<table>
<thead>
<tr>
<th></th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trt</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Level</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Trt x level</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>SE</td>
<td>0.23</td>
</tr>
</tbody>
</table>

**Milk fat, %**

- **High**: 92 lbs
- **Low**: 64 lbs

**Alternative Pathway**

**trans-10 C18:1**

<table>
<thead>
<tr>
<th></th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trt</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Level</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Trt x level</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SE</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Con vs. PA, 1 = $P<0.05$; 1$^+$ = $P<0.1$

PA vs Cal-salts, 2 = $P<0.05$; 2$^+$ = $P<0.1$
Unsaturated fatty acids are a big risk factor

1. Amount of unsaturated fatty acids
   - Fatty acid concentration and profile
   - 18:2 more important than 18:1 and 18:3
   - Grain and oilseeds generally high in 18:2 and forages high in 18:3

2. Rate of availability of the fatty acids
   - Cottonseed vs distillers grains with solubles
Why are high corn silage diets higher risk for diet-induced milk fat depression??

- More rapidly fermented starch?
- Lower effective fiber?
- Difference in fiber digestibility/rates?

- Level and rate of C18:2 availability??
- Low in fat, but cows eat a large amount

- Corn genetics is more important than environment
67 Corn Silages from Two Test Plots (2013)

~60 to 90 g/d difference in C18:2 intake just in the corn silage
Oilseeds FA profile has been modified by selection

<table>
<thead>
<tr>
<th>Feedstuffs (% FA)</th>
<th>16:0</th>
<th>18:0</th>
<th>18:1</th>
<th>18:2</th>
<th>18:3</th>
<th>20:1</th>
<th>22:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapeseed</td>
<td>3</td>
<td>1</td>
<td>17</td>
<td>13</td>
<td>6</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>Canola</td>
<td>5</td>
<td>2</td>
<td>60</td>
<td>20</td>
<td>9</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Low Poly Canola</td>
<td>4</td>
<td>3</td>
<td>76</td>
<td>10</td>
<td>4</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Soybean</td>
<td>11</td>
<td>4</td>
<td>23</td>
<td>54</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High Oleic Soy</td>
<td>6.5</td>
<td>4</td>
<td>75</td>
<td>7</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- High oleic soybeans should be lower risk for milk fat depression!
Processing is important as increases rate of availability in the rumen.

Mohamed et al. 1998. JDS 71:2677-2688

- Grinding oilseeds make them more like free oils.
What is effect of feeding management? 1x vs 4x per day feeding

** P< 0.01; *** P< 0.001

Rottman et al. 2014
Rate of feed intake is variable over the day

- Very hard to change this.
- Fresh feed delivery is strong stimulus to feeding

Ying et al. JDS 2015
The daily pattern of intake creates huge changes in the rumen over the day.
Interesting Call From the Field

• One pen of cows on a large farm consistently 0.3 to 0.5 units lower in milk fat

• Moved fifteen cows from the pen to another pen and they increased milk fat

• Normal MFD troubleshooting did not help

• Cows being fed later in the day (11:30 AM)

• Switched milking and feeding order so feed delivered earlier and before milking.

• Milk fat increased equal to peer pen
Example of feed additive that reduces risk of MFD: HMTBa (Alimet)

Low Cows

High Cows

<table>
<thead>
<tr>
<th>Milk Fat (%)</th>
<th>Time, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>28</td>
</tr>
<tr>
<td>High</td>
<td>42</td>
</tr>
</tbody>
</table>

Risk of MFD

Low Cows

High Cows

Risk of MFD

HMTBa = + 0.73

Baldin et al., JDS In Press
HMTBa prevented increase of trans-10 C18:1 in milk

Baldin et al., JDS In Press
Other dietary effects with smaller impacts

- Absorbed fat
  - Palmitic acid

- Acetate supply
  - Forage digestibility and rumen function

- Excess propionate stimulating insulin
  - High grain and rapid fermentation
  - Preformed fatty acids go to fat stores
  - *Not milk fat depression, but can be a 0.1 to 0.2 unit decrease in milk fat*
Palmitic Acid and Milk Fat Response

- Generally an increase in milk fat, but is variable
  - No change to 0.6 unit (300 g) increase (Mosley et al. 2007)
  - May depend on concentration of FA in the basal diet, diet type, etc.
  - Apparent palmitic acid transfer ~15-20%
  - Average ~90 g/d increase in milk fat with 1 lb/d

Need to consider:
- Price of fat vs. return in milk fat
- Would expect less BCS gain because increased energy going towards milk fat
Increasing acetate increases milk fat under normal conditions

<table>
<thead>
<tr>
<th>Acetate (g/d)</th>
<th>0</th>
<th>300</th>
<th>600</th>
<th>900</th>
<th>SE</th>
<th>Linear</th>
<th>Quad.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lbs</td>
<td>59.9</td>
<td>62.2</td>
<td>60.0</td>
<td>59.5</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk, lbs</td>
<td>84.9</td>
<td>86.3</td>
<td>88.9</td>
<td>85.6</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>1382</td>
<td>1468</td>
<td>1582</td>
<td>1577</td>
<td>59</td>
<td>&lt;0.001</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>3.64</td>
<td>3.87</td>
<td>4.03</td>
<td>4.10</td>
<td>0.20</td>
<td>&lt;0.001</td>
<td>-</td>
</tr>
</tbody>
</table>

- 600 g/d of acetate increased milk fat by 200 g/d
- Mostly increase in de novo synthesized FA

How do we get more acetate?
Forage quality and good rumen fermentation!

Urrutia et al. J. Nutr. 2017
Nutrition is best practiced as an “Experiment in Progress”!!

- When milk fat is **Acceptable**
  - Inclusion of risk factors is probably advantageous to feed cost, production, and efficiency

- When milk fat is **Low**: Look For a Reason
  - When did it start and what happened ~7-10 d prior?
  - Is it a certain string or group of cows?
    - High producing cows are normally more susceptible
  - What season is it?
  - Is the sample a daily average?
The experiment in progress

1. Diet Polyunsaturated Fatty Acids
   - Concentration of C18:2

   - Source of C18:2
     - Very different rates of rumen release
     - Ca Salts are more slowly released, but are not inert

   - Fish oil is very potent (EPA and DHA)

   - Lowest risk to losing milk yield!
2. Diet Fermentability

- Analyze carbohydrate profiles and effective fiber
- Experience with similar diets in the region is important
- Sugars may be beneficial

- Start to titrate down starch and increase fiber
- Switch rapidly fermentable sources for less rapidly fermentable sources
- Increase forage NDF and effective fiber

**Careful..... May Lose Milk!!**
3. Rumen Modifiers

- **Rumensin**
  - Risk factor, but does not cause MFD by itself
  - Can be synergistic with other risk factors for induction

- **DCAD**
  - Increasing DCAD decreases MFD (both Na and K)

- **HMTBa**
  - Reduces the risk of MFD

- **Yeast & Direct Fed Microbials**
  - May reduce incidence of MFD in some cases
  - Have not tested their effect on recovery

**Remember we are dealing with many interactions!**
4. Feeding Strategies
   – Number of feeding times per day
   – Slick bunks before feeding?
   – Feeding times
* You can slug feed TMR!

5. Saturated Fat Supplements
   - No risk for induction of milk fat depression
   - High palmitic acid (C16:0) supplements may increase milk fat in some cases
   - Milk fat depression will reduce the effectiveness of high palm supplements

Monitor milk yield and milk fat over time!!!

**Set Expectations for the Time Required**
Key Opportunities

• Manage feeding times and coordinate with milking times to manage feeding behavior and reduce slug feeding

• Could we (should we) group cows based on milk fat concentration or potential?

• In the future we will probably monitor de novo fatty acid concentration and \textit{trans-10 C18:1}

• Is milk fat value a long-term trend?
  – Select cows for higher milk fat
He didn’t talk about milk protein!

- Milk protein is much less responsive to nutrition and management

- Most of the things we just talked about will improve microbial protein yield and energy intake, which will also benefit milk protein

Also- did I mention that these things also make a healthy rumen and a healthier cow!
Let's review

Rumen environment is critical to milk fat yield and involves interactions of numerous dietary, cow, and environmental factors.

1. Set your goal
2. Balance your diet
3. Manage feeding

Constant “Experiment in Progress” to maximize energy intake, milk yield, and milk fat yield.
Lab Members:
Isaac Salfer, Richie Shepardson, Cesar Matamoros, Elle Andreen, Elaine Brown, Beckie Bomberger

Previous Lab Members:
Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Mutian Niu, Dr. Natalie Urrutia, Andrew Clark, Dr. Liying Ma, and Jackie Ying

Disclosures
K.J. Harvatine’s research in the past 8 years were partially supported by the Agriculture and Food Research Initiative Competitive Grant No. 2010-65206-20723 and 2015-67015-23358 from the USDA National Institute of Food and Agriculture [PI Harvatine], USDA Special Grant 2009-34281-20116 [PI Harvatine], Berg-Schmidt, ELANCO Animal Health, BASF, Novus International, PA Soybean Board, Phode Laboratories, Kemin International, Milk Specialties Global, Adisseo, Micronutrients Inc., and Penn State University. Harvatine has consulted for Milk Specialties Global, a manufacturer of prilled saturated fat supplements, as a member of their science advisory board (~3 days per year) and Micronutrients Inc. Harvatine has also received speaking honorariums from ELANCO Animal Health, Novus International, Cargill, Virtus Nutrition, Chr Hansen, NDS, Nutreco, and Milk Specialties Global in the past three years.