Management and Feeding Practices for Fresh Cows

- Can have a substantial impact on a cow’s well-being and a farm’s profitability
- Many recommendations are based on field experience and limited research (Drackley, 1998; Block, 2010; Overton and Boomer, 2010)

Components of Successful Fresh Cow Programs

- Implementation of management practices that focus on...
  - Prevention of transition disorders
  - Optimization of nutrient intake
  - Removal of stressors
  - Real time monitoring and use of the information

Use of a Designated Fresh Cow Pen

- Allows dairies to facilitate monitoring of health problems, minimize social stress, and provide a diet specifically formulated for fresh cows
- Use increased with herd size (Houwieser et al., 2010)
- Competition at the feed area increased feeding rate and altered feeding behavior (Kraeuzel et al., 2009; Proudfoot et al., 2009)

Use of a Designated Fresh Cow Pen

- The optimal duration of stay in a fresh pen is unknown...it most likely varies among farms and cows
- Cows housed as a separate group for 1 mo after calving with stocking density ≤100% vs. comingling with herd (Østergaard et al., 2010)
  - Primiparous: ~230 kg (506 lb) more ECM during 1st 305 DIM & less ketosis treatments (HR = 0.33)
  - Multiparous: not affected
- Did not use a “fresh cow diet”...probably see more benefits of separate groups
Time Budgets are Restricted in Early Lactation

- Milking frequency
- Time spent in lock-up for fresh cow checks and other management tasks
- Limit to <2 h/d with fresh feed delivery

Fresh Cow Pen Size Determined by...

- Ability to detect sick cows in a group of fresh cows
- Target stocking density of feed bunk and stalls
- Target duration of stay in the pen
- Rate of calving

Use of High-Risk and Low-Risk Fresh Cow Pens

- Opportunity for large dairies
- Target specialized management time to cows that need it
- Decrease lock-up time for exam and treatment
- Decrease time away from stalls
- Rest for lame and sick cows
- Milking frequency adjustment (2x vs. 3x)

Thin Cows Have a Greater Risk of Becoming Lame

- Thickness of the digital cushion of the hoof was a strong predictor of lameness (Bicalho and Machado, 2009)
- Decreased milking frequency (2x vs. 3x) accelerated the recovery of lame cows (score >2, 1-5) (Caixeta and Bicalho, 2011)
- 36% lower probability of lameness
- Improved BCS (2.98 vs. 2.93)
- No effect on milk (90.2 vs 92.2 lb/d)

http://thedaylandinitiative.vetmed.wisc.edu/tdi/ac_group_size.htm
**Lameness and Transition Cow Behavior and Health**

- Moderate and severely lame cows (score 3, 1-3)
- Longer lying times throughout transition period
- Greater number of lying bouts per day for 3 d before and after calving
- Discomfort and hypersensitivity to pain
- Greater risk for ketosis (elevated BHBA)

Calderon and Cook, 2011; J. Dairy Sci. 94:2883

**Pain Management is an Emerging Issue**

- Types of pain at calving
  - Visceral: dilation phase with pain stimuli coming from cervical dilation and distention of the lower uterine segment
  - Somatic (musculoskeletal): due to distention and traction on pelvic structures surrounding the vagina and distention of the pelvic floor
- Assessment of pain
  - General indices
  - Physiological indicators
  - Measures of behavior
  - Dystocia

Wenning et al., 2016; Mainau and Manteca, 2011

**Limited Work on the Impact of Pain Relief During and After Calving**

- Hypoalgesia - decreased sensitivity to painful stimuli
- Occurs during late pregnancy and parturition via endogenous opioids
- Placental opioid-enhancing factor in amniotic fluid
- Drugs not labeled for pain reduction in cattle
- Pain physiology, immunology, and metabolism are interrelated
- Relationships are very difficult to understand and predict outcomes with NSAID administration

Mainau and Manteca, 2011

**Administration of Ketoprofen at Calving on the Milk Yield and Fertility of Holstein-Friesian Cattle**

- Ketoprofen (NSAID) treatment at calving and +24 h
  - Tended to lower incidence of retained fetal membranes
  - 1.7 times less likely to develop condition
- No effect
  - Endometritis score
  - Presence of CL at 20-25 DIM
  - Time to 1st insemination
  - Inseminations per pregnancy
  - Milk yield
- No measure of inflammatory mediators, behavior, comfort, early intake and performance

Richards et al., 2009; Veterinary Record 165:102

**Inflammation is Common During Early Lactation and is Stimulated by Several Pathways**

- Sources
  - Infection
  - Inflammatory cytokines
  - Oxidative stress (Cordoba and Allen, 2006)
  - Lipid peroxides during negative energy balance
  - Ruminal acidosis (Guzha et al., 2017)

- Problems
  - Negative effects on lipid and glucose metabolism (Bradford et al., 2006; Bradford, 2012)

Flunixin Meglumine (Banamine) Administration the 1st 3 Days of Lactation Shows No Benefit

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Banamine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 7 DIM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectal temp, °F</td>
<td>101.8</td>
<td>102.2</td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>41.4</td>
<td>32.6</td>
</tr>
<tr>
<td>Milk, lb/d</td>
<td>63.4</td>
<td>56.1</td>
</tr>
<tr>
<td>1st 35 DIM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>48.4</td>
<td>42.9</td>
</tr>
<tr>
<td>Milk, lb/d</td>
<td>79.4</td>
<td>75.2</td>
</tr>
</tbody>
</table>

*P < 0.05; Shewetz et al., 2009*
Milk Yield is Related to Inflammation
Liver Activity Index (LAI) Based on Plasma Acute Phase Proteins

Health and Fertility are Related to Inflammation
Liver Activity Index (LAI) Based on Plasma Acute Phase Proteins

Health problems, frequency

<table>
<thead>
<tr>
<th>Item</th>
<th>Low</th>
<th>Int. Low</th>
<th>Int. High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metritis</td>
<td>0.0a</td>
<td>5.0a</td>
<td>5.3a</td>
<td>26.3a</td>
</tr>
<tr>
<td>Cows with ≥ 1 problems</td>
<td>5.3a</td>
<td>26.3a</td>
<td>45.0a</td>
<td>42.1a</td>
</tr>
</tbody>
</table>

Fertility indices

| Days open, d              | 92.9a | 132.5b  | 138.8b    | 110.5b|
| Conception rate (1st service), % | 52.6  | 45.0    | 21.0      | 36.8  |
| Services per pregnancy, #  | 1.65  | 2.04    | 2.68      | 2.01  |

Practical Considerations when Feeding for Immunity

- Feeding management – diet on paper vs. consumed, imbalances
  - Antioxidants and trace elements
    - Vitamin E, selenium (organic), l-carotene/vitamin A, copper, zinc, chromium, commercial products
  - Metabolic modifiers
    - Choline, agonists for peroxisome proliferator-activated receptors (PPAR) such as 2,4-thiazolidinedione (not approved for use on dairies)
  - Anti-inflammatory agents (NSAIDs)
    - Aspirin, flunixin meglumine (Banamine)

Nutrition for the Fresh Cow

- Should feed diets that
  - Provide nutrients to accelerate the postpartum increase in intake and milk
  - Support noncompromised lipid mobilization
  - Minimize health problems
  - Prepare cows for conception

Strategies for Feeding Early Lactation Cows

- Increasing the dietary nutrient (energy/protein) density
  - Increase starch, protein or fat components at expense of forage
  - Implications for rumen function, milk composition, nutrient partitioning, and metabolic hormones
- Altering the source of fermentable carbohydrates
  - Implications for acidosis risk and intake
- Changing the availability of glucogenic nutrients relative to lipogenic nutrients
  - Implications for reproductive performance
- Targeting use of specific fatty acids
  - Implications for immunity and reproductive performance
- Changing amount and source of metabolizable protein and amino acids

Eating Behavior and Feed Intake are the Result of Neural Integration of Numerous Signals

Physiological State of Cow → Diet Characteristics → Management Environment
Mechanism of Intake Regulation by the Hepatic Oxidation Theory

- Propionate: end product of ruminal fermentation
- Stimulates oxidation in the liver
- Meal terminates - oxidative fuel metabolism by liver exceeds liver energy requirement, brain is signaled to intake
- Propionate flux affected by starch fermentability

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- Propionate flux affected by starch fermentability

Recommending for Fresh Cows
(Low insulin, insulin resistant, high NEFA)

- Maintain rumen fill during transition period
- Forages with low ruminal retention time (grass, straw)
- Avoid feeding highly fermentable diets to fresh cows (may be ~7 to 21 d)
- Rapid production and absorption of propionate will suppress intake
- Ground corn is good choice...moderate ruminal fermentability, high small intestinal digestibility
- Use of nonforage fiber sources

Miner Study

- 72 multiparous Holstein cows
- 40-d dry period
- Controlled-energy, high-straw diet
- 91-d lactation period
- 21% (low), 23% (medium), and 26% starch diets

Treatment 1-21 DIM 22-91 DIM

Low (LL) Low Low
Medium-High (MH) Medium High
High (HH) High High

Recommendations for Fresh Cows
(Low insulin, insulin resistant, high NEFA)

- Maintain rumen fill during transition period
- Forages with long ruminal retention time (grass, straw)
- Avoid feeding highly fermentable diets to fresh cows (may be ~7 to 21 d)
- Rapid production and absorption of propionate will suppress intake
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Ingredient Composition of Diets (% of Dry Matter)

<table>
<thead>
<tr>
<th>Item</th>
<th>Dry</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>30.7</td>
<td>34.6</td>
<td>34.6</td>
<td>34.6</td>
</tr>
<tr>
<td>Haylage</td>
<td>11.0</td>
<td>11.4</td>
<td>11.7</td>
<td>11.4</td>
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<tr>
<td>Wheat straw</td>
<td>24.9</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Corn meal</td>
<td>-</td>
<td>6.9</td>
<td>11.1</td>
<td>16.7</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>8.6</td>
<td>11.4</td>
<td>11.9</td>
<td>11.9</td>
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<tr>
<td>Soybean hulls</td>
<td>9.3</td>
<td>9.7</td>
<td>6.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>6.1</td>
<td>3.9</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Canola meal</td>
<td>3.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>DDGS</td>
<td>3.2</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>AminoPlus</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>15.5</td>
<td>7.0</td>
<td>6.9</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Analyzed Chemical Composition of Diets (% of Dry Matter)

<table>
<thead>
<tr>
<th>Item</th>
<th>Dry</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>52.9</td>
<td>49.5</td>
<td>50.1</td>
<td>49.6</td>
</tr>
<tr>
<td>CP, %</td>
<td>13.4</td>
<td>17.3</td>
<td>17.0</td>
<td>16.7</td>
</tr>
<tr>
<td>ADF, %</td>
<td>34.2</td>
<td>22.9</td>
<td>21.8</td>
<td>20.3</td>
</tr>
<tr>
<td>NDF, %</td>
<td>50.7</td>
<td>35.7</td>
<td>33.9</td>
<td>31.9</td>
</tr>
<tr>
<td>Starch, %</td>
<td>13.5</td>
<td>21.0</td>
<td>23.2</td>
<td>25.5</td>
</tr>
<tr>
<td>RFS, %</td>
<td>11.5</td>
<td>16.8</td>
<td>18.9</td>
<td>20.2</td>
</tr>
<tr>
<td>Sugar, %</td>
<td>4.5</td>
<td>6.1</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Fat, %</td>
<td>2.6</td>
<td>4.0</td>
<td>4.1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

RFS = rumen fermentable starch

Dry Matter Intake (DMI)

Trt: P = 0.06
Time: P < 0.001
Trt x Time: P = 0.09
LL > HH: P ≤ 0.10

n = 72 cows
**Starch Intake**

Trt: $P < 0.001$
Time: $P < 0.001$
Trt x Time: $P < 0.001$
LL < MH, HH: $P < 0.05$

**Neutral Detergent Fiber (NDF) Intake**

Trt: $P < 0.001$
Time: $P < 0.001$
LL > MH, HH: $P < 0.05$

**Milk Yield and Composition for 13 wk of Lactation**

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>$P$-value</th>
<th>$SE$</th>
<th>$TRT$</th>
<th>$Time$</th>
<th>$TRT \times Time$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5% FCM, kg/d</td>
<td>LL</td>
<td>51.9</td>
<td>47.4</td>
<td>1.7</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>52.2</td>
<td>47.4</td>
<td>1.7</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>47.4</td>
<td>43.5</td>
<td>1.5</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SCM, kg/d</td>
<td>LL</td>
<td>47.4</td>
<td>47.9</td>
<td>1.5</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>47.9</td>
<td>43.5</td>
<td>1.5</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>47.9</td>
<td>43.5</td>
<td>1.5</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fat, %</td>
<td>LL</td>
<td>3.88a</td>
<td>3.64y</td>
<td>0.08</td>
<td>0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>3.64y</td>
<td>3.79xy</td>
<td>0.08</td>
<td>0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>3.79xy</td>
<td>3.79xy</td>
<td>0.08</td>
<td>0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fat, kg/d</td>
<td>LL</td>
<td>1.93x</td>
<td>1.86xy</td>
<td>0.06</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>1.86xy</td>
<td>1.77y</td>
<td>0.06</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>1.77y</td>
<td>1.77y</td>
<td>0.06</td>
<td>0.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>True protein, %</td>
<td>LL</td>
<td>2.90</td>
<td>2.92</td>
<td>0.04</td>
<td>0.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>2.92</td>
<td>2.97</td>
<td>0.04</td>
<td>0.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>2.97</td>
<td>2.97</td>
<td>0.04</td>
<td>0.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>True protein, kg/d</td>
<td>LL</td>
<td>1.42ab</td>
<td>1.50a</td>
<td>0.04</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>1.50a</td>
<td>1.34+</td>
<td>0.04</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>1.34+</td>
<td>1.34+</td>
<td>0.04</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MUN, mg/dL</td>
<td>LL</td>
<td>15.2</td>
<td>12.7+</td>
<td>11.9+</td>
<td>0.3</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>12.7+</td>
<td>11.9+</td>
<td>0.3</td>
<td>&lt;0.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>11.9+</td>
<td>11.9+</td>
<td>0.3</td>
<td>&lt;0.01</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Serum NEFA and BHBA During First 21 DIM**

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>$P$-value</th>
<th>$SE$</th>
<th>$TRT$</th>
<th>$Time$</th>
<th>$TRT \times Time$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEFA, uEq/L</td>
<td>LL</td>
<td>452+</td>
<td>431+</td>
<td>43</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>577+</td>
<td>431+</td>
<td>43</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>431+</td>
<td>431+</td>
<td>43</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BHBA, mg/dL</td>
<td>LL</td>
<td>9.3</td>
<td>8.8</td>
<td>7.8</td>
<td>0.15</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>8.8</td>
<td>7.8</td>
<td>7.8</td>
<td>0.15</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>0.15</td>
<td>0.46</td>
</tr>
</tbody>
</table>

**Body Weight and Body Condition Score**

Trt: $P = 0.99$
Time: $P < 0.001$
Trt x Time: $P = 0.59$
Energy Balance

-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
0 5 10 15
EB, Mcal/d

Week Relative to Parturition

LL
MH
HH

EB, %

Week Relative to Parturition

LL
MH
HH

Trt: P = 0.56
Time: P < 0.001
Trt x Time: P = 0.04

Trt: P = 0.41
Time: P < 0.001
Trt x Time: P = 0.01

n = 72 cows

Fresh Cow Feeding Guidelines for Carbohydrates

- Group fresh cows separately and use a fresh cow diet
- Balanced carbohydrate blend
  - 21-24% starch
  - 4-6% sugar
  - 9-10% soluble fiber
  - 34-38% NFC
  - 28-34% NDF
- Ensure adequate perND
- Formulate in the context of the dry and high group diets

Just a starting point... adjust for digestibility and particle size

Cows Experience Negative Protein Balance in Early Lactation

Calculated metabolizable protein (MP) balance of cows fed 17.8% CP

Potential Deficiencies in Metabolizable Protein (CPM v. 3)

Protein Recommendations for Fresh Cows

- Maximize MP balance and quality
- Optimize ruminal fermentation and microbial protein synthesis
  - Sufficient RDP and fermentable carbohydrates
- Use high quality RUP to provide digestible amino acids
- Use ruminally protected amino acids
  - Especially for lower CP diets
- Feed dry cows adequate MP

Amino Acid Supply in Early Lactation

- Few studies focus on fresh period
- Lysine and methionine limiting in wk 4 (Schwab et al., 1992)
- Factor in regulating milk yield and milk protein production1 (Schei et al., 2005)
- Lysine supplementation is preferentially used to support body protein turnover then milk protein synthesis in early lactation (Robinson et al., 2013)

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Reduced Dietary Crude Protein Diets in Early Lactation

- Modification of diet to reduce CP by ~1% by removing soluble CP and replacing with RP Lys and Met
- 1 to 42 DIM
  - Maintained productivity (76 lb/d)
  - Increased proportion of dietary N captured in milk protein (37.6 vs 34.2%)

Robinson et al., 2004

Approaches of Targeted Feeding of Fat to Affect Performance and Fertility

- Feeding by-pass fat supplements to increase energy density
- Sequential feeding of high carbohydrate/insulin-stimulating to high fat/insulin-depressing diets
- Feeding specific fatty acids that exert pro- or anti-inflammatory effects

Thatcher et al., 2010; Reprod. Dom. Anim. 45(Suppl. 3): 2

Essential Fatty Acids

- Requirement
  - Linoleic acid (C18:2 n-6)
    - Precursor for the biosynthesis of prostaglandins of the 2 series that exert a proinflammatory effect
    - May benefit postpartum health of cow
  - Linolenic acid (C18:3 n-3)/ Eicosapentaenoic acid (EPA, C20:5 n-3)
    - Suppression of inflammatory molecules
    - Reduce inflammatory response in uterus associated with carry-over effects of subclinical endometritis
    - Reduce potential luteolytic peaks at time that the conceptus is suppressing PGF2α secretion to maintain the CL for pregnancy maintenance
    - Feed after period of immunosuppression and uterine involution

Thatcher et al., 2010; Reprod. Dom. Anim. 45(Suppl. 3): 2

Fatty Acid Supplementation (1.5% of DM) During the Transition and Breeding Periods on Fertility of Dairy Cows

Sat = palm oil: EnerGII, 47% C16:0
n6 = safflower oil: Prequel 21, 64% C18:2 n-6
n3 = fish oil: StrataG, 11% C20:5 n-3 + C22:6 n-3

Silvers et al., 2011; J. Dairy Sci. 94 189

Sequential Feeding of Specific Fatty Acids

- During the transition period
  - Feed diets rich in linoleic acid (n-6)
- During the breeding period
  - Diets rich in EPA and DHA (n-3)
- Probably n-6 and n-3 needed all the time
- Impacts fatty acid composition of tissues and alters immune response...overall benefit to cow performance and fertility

Thatcher, 2010; Block, 2011

How Much Fat or Specific Fatty Acid Should be Fed and When to Improve Reproduction?

- Feed supplemental fat sources with key fatty acids at a minimum of 1.5% of dry matter (~1% for fish oil)...effective for reproduction and avoids negative effects on performance, intake, ruminal carbohydrate digestibility, milk fat depression
  - Base diet without fat supplement ~3-4%
  - Adequate pEnDF
  - Watch rumen unsaturated fatty acid load (RUFAL; sum of oleic (C18:1), linoleic (C18:2) and linolenic (C18:3) acids)
    - UFC entering reticulo-rumen from feeds, especially with DDGS and whole cottonseed
  - Feed fat long enough before fatty acids are needed for restoring reproductive tissues to a new fertile state
  - 21 days...maybe 40 days before desired physiological response

Staples et al., 2007
Conclusions
- No “one size fits all” approach
- Interactions of nutrition, environment, & management

Conclusions
- Use a fresh cow group and diet
  - Minimize stress
  - Focused labor
  - Targeted nutrition
- Formulate within the context of the dry and high group diets

Conclusions
- Immediately after calving, limit use of highly fermentable starch sources and provide adequate peNDF to maximize DMI and minimize ruminal acidosis
- When NEFA and BHBA decrease, provide highly digestible carbohydrates to maximize DMI and milk production

Conclusions
- Improve metabolizable protein supply and quality through optimal ruminal fermentation, feeding high quality RUP sources, and supplementing with RPAA
- Supplement with polyunsaturated fatty acids (n-6, n-3) during key physiological periods to improve postpartum immune response and reproductive performance

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