Nutritional Regulation of Gut Function: Pre-weaning

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Nutritional Regulation of Gut Function: Pre-weaning

I. Calf Management Trends

II. Pre-weaning
   - Colostrum feeding
   - Colostrum transition
   - Milk feeding in the first weeks
Dietary regimes in early life influence lifetime productivity

1 lb of pre-weaning ADG = 1,540 lbs of milk in first lactation

(Soberon et al., 2012)
**Early Life Nutrition: Future Milk**

<table>
<thead>
<tr>
<th>Study</th>
<th>Milk yield, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foldager and Krohn, 1991</td>
<td>1,405&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bar-Peled et al., 1998</td>
<td>453&lt;sup&gt;t&lt;/sup&gt;</td>
</tr>
<tr>
<td>Foldager et al., 1997</td>
<td>519&lt;sup&gt;t&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ballard et al., 2005 (@ 200 DIM)</td>
<td>700&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
<tr>
<td>Shamay et al., 2005 (post-weaning protein)</td>
<td>981&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
<tr>
<td>Davis-Rincker et al., 2011</td>
<td>416&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>Drackley et al., 2007</td>
<td>835&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
<tr>
<td>Raith-Knight et al., 2009</td>
<td>718&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>Terre et al., 2009</td>
<td>624&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>Morrison et al., 2009 (no diff. calf growth)</td>
<td>0&lt;sup&gt;ns&lt;/sup&gt;</td>
</tr>
<tr>
<td>Moallem et al., 2010 (post-weaning protein)</td>
<td>732&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
<tr>
<td>Soberon et al., 2012</td>
<td>552&lt;sup&gt;s&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
“Nutritional Programming”

“...early adaptation to a stress or stimuli that permanently changes the physiology and metabolism of the organism and continues to be expressed even in the absence of the stimulus/stress that initiated them...”

(Patel and Srinivansan, 2002)
Gut Health and Dairy Calves

- 10% mortality and over 50% of morbidity is related to calf diarrhea (NAHMS, 2007)

- 19% of calves fail passive transfer of Ig and 24% of calves have calf diarrhea in the first month (NAHMS, 2007)

- Antibiotic use pre-weaning has been associated with decreased lifetime milk production (Soberon et al., 2012)
Knowledge Gaps

Industry Concerns

Colostrum

Plane of Nutrition

Maternal

Antimicrobial
Colostrum Feeding Method

Bottle

Tube

(Sharifi et al., 2009)
Colostrum Feeding Method

**IgG**

- Mean IgG Conc. (mg/ml)
- Time Relative to Colostrum Feeding (minutes)

**Acetaminophen**

- Concentration (mg/L)
- Time Relative to Colostrum Feeding (minutes)

(Desjardins-Morrissette et al., 2018)
Delayed Colostrum Feeding

(Fischer et al., 2018)
Delayed Colostrum Feeding

- Delaying the first colostrum meal may delay the colonization of beneficial bacteria to the calf intestine

(Fischer et al., 2018)
Heat Treatment of Colostrum

- Heat-treated colostrum increases *Bifidobacterium* and reduced the colonization of *E. coli* in the small intestine (Malmuthuge et al., 2015)

NC = No Colostrum
FC = Fresh Colostrum
HC = Heated Colostrum
Heat Treatment of Colostrum

Bovine Colostrum Oligosaccharide (Fischer et al., 2018)

- Heat-treatment may cleave prebiotic oligosaccharides from colostral proteins and lipids
Bovine colostrum oligosaccharides (bCOs) produced in higher concentrations immediately after parturition (Fischer et al., 2018)
From Colostrum to Milk

First Feeding

Colostrum

Milk

Wk 1

First Feeding

Colostrum

Transition

Milk

Wk 1
### From Colostrum to Milk

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mature Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>%</td>
<td>24.5</td>
<td>19.0</td>
<td>16.0</td>
<td>15.5</td>
<td>15.3</td>
<td>12.2</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>6.4</td>
<td>5.6</td>
<td>4.6</td>
<td>5.0</td>
<td>5.0</td>
<td>3.9</td>
</tr>
<tr>
<td>Protein</td>
<td>%</td>
<td>13.3</td>
<td>8.5</td>
<td>6.2</td>
<td>5.4</td>
<td>4.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Essential Amino Acids</td>
<td>mM</td>
<td>390</td>
<td>230</td>
<td>190</td>
<td>140</td>
<td>115</td>
<td>ND</td>
</tr>
<tr>
<td>Lactoferrin</td>
<td>g/L</td>
<td>1.84</td>
<td>0.86</td>
<td>0.46</td>
<td>0.36</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Insulin</td>
<td>μg/L</td>
<td>65</td>
<td>35</td>
<td>16</td>
<td>8</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Growth Hormone</td>
<td>μg/L</td>
<td>1.5</td>
<td>0.5</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Insulin-like growth factor I</td>
<td>μg/L</td>
<td>310</td>
<td>195</td>
<td>105</td>
<td>62</td>
<td>49</td>
<td>ND</td>
</tr>
</tbody>
</table>

- Improved health status in calves fed transition milk
  (Conneely et al., 2014)
From Colostrum to Milk

- All calves fed one meal of colostrum followed by:
  - Milk
  - 50% milk/ 50% colostrum (Transition)
  - Colostrum

(Pyo et al., 2018)
From Colostrum to Milk

IgG mg/ml vs Hours after birth

- Milk
- 50%/50%
- Colostrum

First Meal
Second Meal

(Pletts et al., 2018)
Passive Transfer

- Trancytosis of immunoglobulins (Jochims et al., 1997)
- Receptor mediated and highly regulated
  - Trancytosis (to blood)
  - Recycling (back to lumen)
  - Metabolism (endosome)
- Regulation of these pathways in calves is unclear
Normal Pre-Weaning Milk Intake

d_4 of life

(de Passille et al., 2016) (Jasper and Weary, 2002)
Feeding Large Meals

- Calves typically nurse 6-12 times per day in the first weeks of life (Jensen, 2004)

- Larger meals fed less frequently increase the risk of:
  - Abomasal inflammation & lesions
  - Milk overflow into the rumen
  - Ruminal acidosis, decreased passage rate and digestion

  (Berends et al., 2012; 2015)
Abomasal Capacity

- Young calves fed 2 litres of milk per meal (3 x)
- Offered ad libitum meal of milk with barium sulfate
- Most calves drank more than 5 litres with no evidence or ruminal overflow

(Ellingsen et al., 2016)
Larger Meal Size and Insulin Sensitivity

- Compared calves fed elevated (8L/d) vs low (4L/d) plane of milk 2x per day
  - No evidence of post-prandial hyperglycemia and hyperinsulinemia
  - No difference in glucose tolerance
  - Slower (41% reduction, \( P = 0.02 \)) abomasal emptying rates during the pre-weaning phase (MacPherson et al., 2016)
Gastric Emptying and Glucose-Insulin Dynamics

Acetaminophen (mg/ml) vs. Time (min)

Glucose (Mm) and Insulin (ng/ml)

Glucose (blue line, squares)
Insulin (yellow line, triangles)

0 100 200 300 400
Gastric emptying rate will influence glucose appearance in blood (Stahel et al., 2016)
Take Home Messages

- There are still some basic concepts in calf biology and nutrition that we do not understand.
- No difference between tube vs. bottle feeding colostrum for passive transfer.
- Delaying colostrum by six hours can impact passive transfer and gut microbiology.
- Pasteurizing colostrum may help to improve calf gut health if managed properly.
Take Home Messages

- An abrupt transition from colostrum to milk can compromise gut development
- Elevated planes of milk can be fed early in life
- Elevated planes of milk can be fed with 2x/day feeding schemes