Weaning Biology and Strategies

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The Investment of Raising Replacements

Feed Efficiency and Feed Costs by Age

$2,500 investment

Outline

- Pre-Weaning Nutrition
  - Transition
  - Post-Weaning Nutrition

Early Life Nutrition

- Dietary regimes in early life influence lifetime productivity

- 1kg of pre-weaning ADG = 1,540kg 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>1,409</td>
</tr>
<tr>
<td>Bar-Peled et al., 1998</td>
<td>453</td>
</tr>
<tr>
<td>Foldager et al., 1997</td>
<td>519</td>
</tr>
<tr>
<td>Ballard et al., 2005 (@ 200 DIM)</td>
<td>700</td>
</tr>
<tr>
<td>Shamay et al., 2005 (post-weaning protein)</td>
<td>981</td>
</tr>
<tr>
<td>Davis-Rincker et al., 2011</td>
<td>416</td>
</tr>
<tr>
<td>Drackley et al., 2007</td>
<td>835</td>
</tr>
<tr>
<td>Raith-Knight et al., 2009</td>
<td>718</td>
</tr>
<tr>
<td>Terre et al., 2009</td>
<td>624</td>
</tr>
<tr>
<td>Morrison et al., 2009 (no diff. calf growth)</td>
<td>0</td>
</tr>
<tr>
<td>Moallem et al., 2010 (post-weaning protein)</td>
<td>732</td>
</tr>
<tr>
<td>Soberon et al., 2012</td>
<td>552</td>
</tr>
</tbody>
</table>

Outline

- Pre-Weaning Nutrition
  - Transition
  - Post-Weaning Nutrition
The most dramatic physiological challenge in the young ruminant (Baldwin et al., 2004)

A smooth transition from a monogastric to a ruminant
- Decreases morbidity and mortality and increases gain (Khan et al., 2012)
- Requires adequate size and function of the rumen (Baldwin, 2004)

Limited rumen capacity, papillae growth and muscular development
- Esophageal groove effectively shunts milk directly to the abomasum (Orskov et al., 1970)

Ruminant calves produces and absorbs VFA which is the primary energy source
- Liver function
  - Glucose synthesis increases, predominately from propionate
  - Urea synthesis increases
  - Metabolic activity increases

Pre-ruminant calf is completely dependent on glucose absorbed from intestine
- Liver function
  - Primary site of ketone body synthesis
  - Not much glucose being synthesized

Consumption of solid feed (Khan et al., 2011)
- Volatile fatty acids
  - Cellular growth
  - Blood flow (Baldwin and McLeod, 2000)
- The age of the calf (Lane et al., 2002)
Rumen Development

- **The Machinery to Absorb VFA**
  - Rumen Epithelial Development

- **The Employees to Make VFA**
  - Rumen Microbial Development

Prenatal Rumen Development

- Distinguishable areas of stomach compartments are present in the third week of embryonic development

- All rumen compartments have been formed by the third month (Warner, 1958)

Prenatal Rumen Development

- Microvasculature of the epithelial layer
- 3-8 months of gestation (Church, 1988)

Rumen at Birth

- No rumen papillae visible
- Very smooth surface
- Thin and transparent

Rumen Papillae - Birth

- 200 µm

- 300 µm
Rapid Rumen Development

Hodgson, 1974

Weaning

Papillae Protrude from Polyps

Rumen Papillae - Transition

Rumen Papillae - Ruminant

Rumen Development

- The Machinery to Absorb VFA
  - Rumen Epithelial Development

- The Employees to Make VFA
  - Rumen Microbial Development
Sterile at Birth

Rumen Microbial Development
- After birth aerobic bacteria colonize
- Anaerobic bacteria soon predominate
  - Cellulolytic and methanogenic first
    - (Fonty et al., 1989)

Pre-ruminant to Ruminant
- Lactate-fermenting bacteria exceed adult values then decline
- Protozoa are introduced via contact with mature ruminants

Lower Gut at Weaning
- Elevated starch levels in fecal matter during weaning (Eckert et al., 2015; Steele et al., 2015- ADSA)
- Starter feeding in calves decreased the expression of tight junctions (Malmuthuge et al., 2013)

Factors Impacting Weaning
I. Plane of Nutrition
II. Age
III. Step-Down
IV. Water
V. Forage
I. Plane of Nutrition

Jasper and Werry, 2002

II. Age at Weaning

Miller-Cushon et al., 2013

DeVries et al., 2013

II. Age at Weaning

- Early weaning has been strongly promoted in the past
- No difference between early and late weaning when calves fed low plane of nutrition (Quigley et al., 1988).
- What about high planes of nutrition?

Longer Transition in Nature

Beef Weaned at 6-8 Months
II. Age and Bodyweight Gain

In both treatments, weaning increased ($P<0.01$) ruminal SCFA, blood BHBA and fecal starch. Yet, the differences between the week before and after weaning were greater ($P<0.01$) in calves weaned at six weeks.

III. Step-Down Weaning

- Approximately 20% BW
- Approximately 10% BW

(Eckert et al., 2015)

Weaning Age – ME Intake

- In both treatments, weaning increased ($P<0.01$) ruminal SCFA, blood BHBA and fecal starch
- Yet, the differences between the week before and after weaning were greater ($P<0.01$) in calves weaned at six weeks.
III. Step-Down Weaning – Starter Intake

Khan et al., 2007

III. Step-Down Weaning – Bodyweight

Khan et al., 2007

III. Step-Down Weaning - Duration

Sweeney et al., 2010

Duration of Step-Down

Sweeney et al., 2010

III. Step-Down Weaning

Steele et al., 2015

Bodyweight Response

Steele et al., 2015
**Dissection Results**

<table>
<thead>
<tr>
<th>Step-Down</th>
<th>Abrupt</th>
<th>SE</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Anatomy [kg]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW</td>
<td>94.1</td>
<td>94.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Forestomach</td>
<td>11.0</td>
<td>9.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Lower Gut</td>
<td>6.8</td>
<td>6.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Rumen Full</td>
<td>8.2</td>
<td>7.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Rumen Empty</td>
<td>1.7</td>
<td>1.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Rumen Morphology**
- Rumen Papillae Length (cm): 1.8 vs 1.7 (SE 0.5, P = 0.14)
- Rumen Papillae Width (cm): 0.4 vs 0.4 (SE 0.1, P = 0.24)
- Surface Area (mm²): 684 vs 602 (SE 34.0, P = 0.22)

- No differences in omasum, abomasum, small intestine, cecum or large intestine gross anatomy

**Steele et al., 2015**

- No correlation between length or width and surface area
- Greater papillae size ≠ a greater surface area

**3D Morphology with Micro-CT**

- No correlation between length or width and surface area
- Greater papillae size ≠ a greater surface area

**Steele et al., 2014**

**IV Water Intake**

- Providing water to calves is recommended but little data available
- Water intake is associated with higher ADG (Kertz et al., 1980)
  - May aid in the development of the rumen
**Forage Intake**

- Roughage increases rumen musculature, motility and volume (Baldwin et al., 2004)

- Starter
  - VFA production
  - High in energy
  - Palatable

- Forages
  - Low in energy
  - Ruminal abrasion
  - Bulk
  - Rumination

**New Zealand – No starters...only grass**

**Forage and Starter Mix**

- Calves fed starter with 7.5% and 15% hay performed better than 0% hay

- Finding the delicate balance between the forage and concentrate is key

Coverdale et al., 2004

![Ruminal pH During Weaning](image)

![Water Intake – Age at Weaning](image)

![Water and Starter Intake](image)
Outline

- Pre-Weaning Nutrition
- Transition
  - Post-Weaning Nutrition

Post-Weaning Factors

- Calf research has been focused on the pre-weaning phase
  - Very little is known about post weaning efficiency and feeding strategies
    - The next frontier

Why is immediately after weaning intriguing?

- Can we take advantage of their high efficiency?
- How much can they each and does forage limit intake?
- Chopped forage
  - Consistency of forage intake
  - Ruminal abrasion
  - Convenience
Dry TMR - Dry Matter Intake

Dry TMR – Average Daily Gain

Post-Weaning and Beyond
- An area that has not been studied
- Need to integrate pre and post weaning planes of nutrition with lifetime performance
- The Next Frontier in Calf Nutrition

Take Home Messages
- Accelerated programs require accelerated rumen development
- Step-down weaning improves performance
- Offering water is essential
- Forage may play a key role in rumen development and health
- Post-weaning nutrition is a new frontier