How Much Milk or Milk Replacer Should be Fed?

Growth of Calves Fed the Same Diet

Ballard et al., 2005
Thermal Neutral Zone

• 59 to 82°F (15 to 28°C) for calf under 3 wk of age
  • Cold Stress
  • Heat Stress

• Prioritization of nutrients
  1. Maintenance
     • Thermal regulation
     • Immune system
     • Stress response
  2. Growth

Scibilia et al., 1987; NRC, 2001
Growth Rate and First Lactation Milk Decreased by Temperature at Time of Birth

Columns with different letters differ ($P < 0.05$)  
Soberon et al., 2012

Calculating Maintenance Requirements

Example with 88 lb (40 kg) calf

1. Basal maintenance requirement (Thermoneutral)

$$0.1 \text{ Mcal of } ME \times BW^{0.75} = \text{Mcal of ME}$$

$$BW^{0.75} = \text{metabolic body weight}$$

$$0.1 \times 40 \ kg^{0.75} = 1.60 \text{ Mcal of ME}$$

Van Amburgh, 2017
Calculating Maintenance Requirements

1. Basal maintenance requirement (Thermoneutral)
2. Adjustment for surface area

\[ 0.14 \text{ Mcal of ME} \times BW^{0.57} = \text{Mcal of ME} \]
\[ 0.14 \times 40 \text{ kg}^{0.57} = 1.16 \text{ (factor adjustment)} \]

Maintenance requirement for 88 lb (40 kg) calf:
\[ 1.61 \text{ Mcal of ME} \times 1.16 = \textbf{1.87 Mcal of ME} \]

***Very important for small breed calves

Brody, 1945; Van Amburgh, 2017

Calculating Maintenance Requirements

1. Basal maintenance requirement (Thermoneutral)
2. Adjustment for surface area
3. Adjustment below lower critical temperature (59°F; 15°C)

For every degree (Celsius) below 15°C energy requirement ↑ 0.0027 Mcal of ME

Ex. maintenance requirement of 40 kg calf at 0°C
\[ 0.0027 \times BW^{0.75} \times (15\text{°C} - \text{Temp}) = \text{Mcal of ME} \]
\[ 0.0027 \times 40 \text{ kg}^{0.75} \times 15\text{°C} = \textbf{0.64 Mcal of ME} \]
\[ 1.87 + 0.64 = \textbf{2.51 Mcal of ME} \]

Scibilia et al., 1987; Van Amburgh, 2017
**Nutrient Content of Milk and Milk Replacers**

<table>
<thead>
<tr>
<th>Feed</th>
<th>Protein, %</th>
<th>Fat, %</th>
<th>Mcal ME/lb</th>
<th>DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole milk</td>
<td>25</td>
<td>31</td>
<td>2.39</td>
<td></td>
</tr>
<tr>
<td>Milk replacer</td>
<td>20</td>
<td>20</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>Milk replacer</td>
<td>28</td>
<td>20</td>
<td>2.15</td>
<td></td>
</tr>
</tbody>
</table>

**Calculating Maintenance Requirements**

1. Basal maintenance requirement (Thermoneutral)
2. Adjustment for surface area
3. Adjustment below lower critical temperature (59°F; 15°C)
4. Estimate feed required for maintenance

\[
\text{DMI needed} = \frac{\text{Mcal of ME}}{\text{Mcal of ME/lb}}
\]

Ex. MR (28:20) with 2.15 Mcal of ME/lb

\[
2.51 \text{ Mcal of ME}/2.15 \text{ Mcal of ME/lb} = 1.14 \text{ lb DMI}
\]
Energy (ME) and Protein Requirements for BW Gain in a 110-lb Calf

<table>
<thead>
<tr>
<th>Rate of gain (lb/d)</th>
<th>DMI (lb/d)</th>
<th>ME (Mcal/d)</th>
<th>CP (g/d)</th>
<th>CP (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.44</td>
<td>1.21</td>
<td>2.36</td>
<td>94</td>
<td>18.0</td>
</tr>
<tr>
<td>0.88</td>
<td>1.48</td>
<td>2.89</td>
<td>150</td>
<td>22.4</td>
</tr>
<tr>
<td>1.32</td>
<td>1.76</td>
<td>3.52</td>
<td>207</td>
<td>26.6</td>
</tr>
<tr>
<td>1.76</td>
<td>2.12</td>
<td>4.36</td>
<td>253</td>
<td>27.4</td>
</tr>
<tr>
<td>2.20</td>
<td>2.47</td>
<td>4.83</td>
<td>318</td>
<td>28.6</td>
</tr>
</tbody>
</table>

1NRC (2001) Assumes milk replacer with 2.14 Mcal ME/lb DM.
*Thermoneutral conditions

Van Amburgh and Drackley, 2005

Mother Nature’s Feeding Program

- Cows’ milk: 25-26% protein (dry solids basis)
- Feeding rate: > twice the “conventional” feeding rate of MR’s (2.2-3.3 lb solids vs ~1.0 lb), spread over several meals (6-12/d)
- Feeding method: teat
- First solid feed: High-quality fresh grass (sugars, fructans, non-lignified cell walls; high butyrate fermentation)
- Weaning: gradually, at 6-10 mo vs 4-8 wk

Slide courtesy of J. K. Drackley
What Happens if You Leave a “Modern” Holstein Calf with the Cow?

- Kept with cow
- Separated at 1 day

Calves gain weight about 3 x faster

2.3 lb/d vs. 0.79 lb/d

Growth in Conventional Milk Programs Linked to Starter Intake

*Milk replacer fed at 0.45 kg/d wk 1-3, 0.23 kg/d wk 4
**Expected Growth Rates from Different Nutritional Programs Preweaning**

<table>
<thead>
<tr>
<th>Program</th>
<th>Milk replacer rate and solid feed</th>
<th>Expected growth rate lbs/d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong>, 1.43 lb/d, 1.25% of BW, ad lib starter</td>
<td></td>
<td>1.1-1.3</td>
</tr>
<tr>
<td><strong>Moderate</strong>, 1.5 lb/d, 1.75% of BW, ad lib starter</td>
<td></td>
<td>1.2-1.4</td>
</tr>
<tr>
<td><strong>Accelerated</strong>, 1.7-2.1 lb/d, 2-2.5% of BW ad lib starter</td>
<td></td>
<td>1.3-1.8</td>
</tr>
<tr>
<td><strong>Weaned calves</strong>, ad lib starter, &lt; 1.1 lb/d forage</td>
<td></td>
<td>1.9-2.1</td>
</tr>
</tbody>
</table>

Modified from Drackley, 2008

**Increasing Nutrients Capitalizes on Early Efficiency of Growth (BW and Stature)**

![Graph showing growth rates]

*Intensified Conventional*  
Stamey et al., 2012
Potential Biological and Economic Impacts of Early Nutrition

Economic Advantage for Programs Feeding Greater Milk

- Capitalize on rapid early growth potential
  - Most efficient weight and height increase
- Decrease days to breeding and first calving
- Improve health
- Improve future productivity
Milk Production Differences Due to Increased Early Nutrient Intake

<table>
<thead>
<tr>
<th>Study</th>
<th>Milk yield, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foldager and Krohn, 1994</td>
<td>3,096</td>
</tr>
<tr>
<td>Foldager et al., 1997</td>
<td>1,143</td>
</tr>
<tr>
<td>Bar-Peled et al., 1997</td>
<td>998</td>
</tr>
<tr>
<td>Ballard et al., 2005</td>
<td>1,543</td>
</tr>
<tr>
<td>Shamay et al., 2005</td>
<td>2,162</td>
</tr>
<tr>
<td>Drackley et al., 2007</td>
<td>1,840</td>
</tr>
<tr>
<td>Raeth-Knight, 2009</td>
<td>1,582</td>
</tr>
<tr>
<td>Terré et al., 2009</td>
<td>1,375</td>
</tr>
<tr>
<td>Morrison et al., 2009</td>
<td>0</td>
</tr>
<tr>
<td>Moallem et al., 2010</td>
<td>1,613</td>
</tr>
<tr>
<td>Davis-Rincker et al., 2011</td>
<td>917</td>
</tr>
<tr>
<td>Soberon et al., 2012</td>
<td>1,217</td>
</tr>
<tr>
<td>Margerison et al., 2013</td>
<td>1,311</td>
</tr>
<tr>
<td>Kiezebrink et al., 2015</td>
<td>0</td>
</tr>
</tbody>
</table>

Impact of Pre-weaning ADG on Future Milk Production

- Preweaning growth rate accounts for ~22% of the variation in first-lactation milk yield
- 2.2 lb preweaning ADG → 1st Lactation Milk
  - Research herd (Cornell) +1,874 lb
  - Commercial herd +2,454 lb
- Range in average daily gain of 0.22 to 3.48 lb in Cornell herd
Current Challenges with Higher Planes of Nutrition

The “Other” Transition Period

- Change in nutrient provision
  - Liquid and solid feed → solid feed
  - Amount of starter intake
  - Adequate rumen development
- Weaning method
- Environmental Changes
  - New housing
- Social Changes
  - Co-mingling
  - Bigger group sizes
Feed Effect on Rumen Development

Feed Type

Ruminal Development

No Papillae Development

Little Papillae Development

Proper Papillae Development

Microbial Establishment

Limited

Minimal

Optimal*

SCFA Production

Limited

Minimal

Optimal*

Higher Rates of Milk or Milk Replacer Suppress Starter Intake Preweaning

Maximum total DM intake is 2.0 to 2.5% of BW

Cowles et al., 2006
Total Dry Matter Intake

Nutrient Apparent Digestibility After Weaning

<table>
<thead>
<tr>
<th>Apparent Digestibility, %</th>
<th>1.1 lb</th>
<th>2.2 lb</th>
<th>Difference, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>77.4</td>
<td>71.8</td>
<td>5.6</td>
</tr>
<tr>
<td>OM</td>
<td>78.7</td>
<td>73.2</td>
<td>5.5</td>
</tr>
<tr>
<td>CP</td>
<td>77.1</td>
<td>71.6</td>
<td>5.5</td>
</tr>
<tr>
<td>NDF</td>
<td>34.7</td>
<td>30.2</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Also found a 6 to 9% decrease in OM digestibility

Hill et al., 2010
Solid feed intake the week before weaning (kg/d)

Daily gain the week after weaning (kg/d)

2.2 lb ADG

4.0 lb intake

Bach et al., 2017

Optimizing Starter Intake and Rumen Development

- Water management
- Do not wean too early
- Wean gradually
- Starter composition and management
- Optimize forage intake
- Avoid social stressors
Water Intake to Starter Intake Ratio (4:1)

• 1 lb starter requires 4 lb (1/2 gallon) water intake

• Without water
  • Slower rumen development
  • Reduces feed conversion rates

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Water (gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.3-2</td>
</tr>
<tr>
<td>2</td>
<td>1.5-2.0</td>
</tr>
<tr>
<td>3</td>
<td>2.1-2.6</td>
</tr>
<tr>
<td>4</td>
<td>3.0-3.6</td>
</tr>
</tbody>
</table>

Weaning Methods that Facilitate Success After Weaning
Step-Down Weaning for Higher Intakes of Milk or Milk Replacer

Khan et al., 2007

Step-Down Weaning Maintains Growth Increase

Khan et al., 2007
Milk Allowance Reduction Before Weaning

• Wean over 10-14 days

• Can be a multi-step process and combine the following methods:
  1. Reducing frequency of milk feeding
  2. Keeping frequency the same but reducing volume
  3. Increasing dilution (decrease solid content)

Bach et al., 2017; Kehoe et al., 2007; Sweeney et al., 2010

Lasting Social Impact on Calves when Grouped Postweaning

*Calves mixed at d 56 to 70

De Paula Vieira et al., 2010
What Starter do you Use?

Creating a Desirable Starter for the Calf

- Digestible and palatable ingredients
  - Corn, barley, oats, soybean meal
  - Flavors or scents
  - Minimize dustiness
  - Corn byproducts less palatable
- Provide balanced profile of absorbed nutrients
  - Neutral Detergent Fiber (NDF) >15%
  - Easily fermentable carbohydrates
  - Protein sources for the microbial protein and post-rumen digestion
    - 20% CP formulation or more for improved growth
- Avoid oilseeds and high fat

Davis and Drackley, 1998
Composition of Starter

- Starch: 20-28% (Typical to see >30% starch)
  - Needed for VFA production → Rumen development
    → Energy for growth
  - Barley and wheat ↓ rumen pH vs corn or oats
- Sugars: 15%
  - Molasses ↓ fines and ↑ palatability
  - Soluble fiber and sugar (Molasses, beet pulp)
- Crude protein: 20-25% depending on MR rate
  - ↑ DMI at weaning of calves with 25.5% CP starter
- Fat: 4-5%
  - Mixed results with inclusion levels

Impact of Fiber Content and Physical Form of Starters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fiber Content</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG, lb/d</td>
<td>Low (NDF 18.5)</td>
<td>High (NDF 28) Pellet Mash</td>
</tr>
<tr>
<td>Starter Intake, kg</td>
<td>0.75</td>
<td>0.86 0.71a 0.90b</td>
</tr>
<tr>
<td>First ruminating, wk</td>
<td>111.1</td>
<td>128.8 105.2a 134.3b</td>
</tr>
<tr>
<td>Time ruminating, %</td>
<td>5.1</td>
<td>4.6 6.0a 3.7b</td>
</tr>
<tr>
<td>NDF digestibility, %</td>
<td>15.0</td>
<td>14.8 8.7a 21.0b</td>
</tr>
</tbody>
</table>

Calves fed milk replacer (26/19) at 0.45 kg/d, weaned at 4 wk

Porter et al., 2007
Physical Form of Starter

- Physical stimulation and scraping action, rumen motility, and passage rate ↑ health of rumen
  1. Increasing expression of VFA transporters
  2. Reducing thickness of rumen epithelium
  3. Increasing passage rate
- To be successful alone, a starter must- 
  1. Have sufficient scraping ability
  2. Be consumed in a sufficient quantity

Bach et al., 2017; Castells et al., 2013; Suárez-Mena et al., 2013

Should Hay Be Provided to Calves?
Ratio of Forage to Concentrate is Small When Offered for Ad Lib Intake

<table>
<thead>
<tr>
<th>Forage Source</th>
<th>Starter (lb)</th>
<th>Forage (lb)</th>
<th>Forage:Concentrate</th>
<th>ADG (lb/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Forage</td>
<td>1.94</td>
<td>-</td>
<td>0:100</td>
<td>1.59c</td>
</tr>
<tr>
<td>Alfalfa Hay</td>
<td>1.68</td>
<td>0.26</td>
<td>14:86</td>
<td>1.68bc</td>
</tr>
<tr>
<td>Rye-grass Hay</td>
<td>2.18</td>
<td>0.10</td>
<td>5:95</td>
<td>1.85ab</td>
</tr>
<tr>
<td>Oat Hay</td>
<td>2.51</td>
<td>0.22</td>
<td>8:92</td>
<td>2.05a</td>
</tr>
<tr>
<td>Barely Straw</td>
<td>2.34</td>
<td>0.13</td>
<td>5:95</td>
<td>1.94a</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>2.58</td>
<td>0.11</td>
<td>4:96</td>
<td>1.94a</td>
</tr>
<tr>
<td>Triticale Silage</td>
<td>2.16</td>
<td>0.11</td>
<td>4:96</td>
<td>1.81ab</td>
</tr>
</tbody>
</table>

a,b,c P < 0.05

Castells et al., 2012

Should Hay Be Provided to Calves?

- It depends on the forage source
  - Alfalfa hay limits starter intake
  - Grass hay or straw could increase starter intake when chopped
- Ad libitum intake not recommended
  - Provide separate from starter to avoid sorting behavior
  - Limit to <5 to 10% of intake
  - Do not provide alfalfa hay until after weaning
- Hay is not critical for rumen development
  - May be important for “scratch” factor and rumen health
Key Management Points to Consider when Developing a Successful Program

• Colostrum
• Feeding for requirements
• Weaning time and duration
• Formulating starter to optimize intake
• Water
• Forage
• Environmental and social factors
• Replacement program does not end with weaning!

Questions?
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