Improving Overall N Efficiency through Better Protein and Amino Acid Formulation

Mike Van Amburgh, Debbie Ross, Marcelo Gutierrez-Botero, Larry Chase, Tom Overton, Andres Ortega, and Andrew LaPierre

Dept. Of Animal Science, Ithaca, NY
mev1@cornell.edu

Today’s discussion

• What are the opportunities for protein and AA balancing?
  - what are we capable of now?

• Deciding what is first limiting and why?
• Basic biology around amino acids
• Feed chemistry is important
• Feed ingredient options and formulation challenges
• Formulating for metabolizable protein and refining formulations with amino acids

• Summary
Improving Efficiency of Use of Intake Nitrogen

- Opportunities exist – need refining
- On farm N efficiencies (milk N:feed N)
  - 20 to 32%
- Theoretical efficiency limit 40 to 45% in lactating dairy cattle (Van Vuuren and Meijs, 1987; Hvelplund and Madsen, 1995; Dijkstra, 2013)
- Practical limit is ~ 38 to 40% and groups are achieving this
- Requires refinement of current ration formulation models – balancing for rumen N and post-ruminal amino acids
- Requires refinement of feeding management – reduce variation associated with feed, management

There are cows within herds/groups approaching the theoretical limits of protein efficiency

Walnut Ridge Dairy, Lansing NY
High group average production: 120 ± 35 lb/d
Average DMI: 60.1 lb/d, 15.8% CP
Average N efficiency: 38% (productive N:intake N)
Studied group for 4 months and modeled individual cows within the entire group

Cows at high end of production: ~169 lb/d milk
At estimated intake, N efficiency: 41%
Milk Yield and Milk Protein Synthesis

• Are energy driven events
  – Relies on an adequate supply of amino acids
  – Driven by propionate production in the rumen
    • Propionate converted to glucose in the liver – which in turn stimulates insulin and IGF-I secretion
    • Intestinal glucose absorption also supplies energy substrate but there is a discount on energy for lactose synthesis – based on the data of Reynolds et al. and others, about an 18% discount due to tissue use prior to mammary availability

Effects of insulin on milk protein

• Hyperinsulinemic-Euglycemic clamps
  – Clamp alone
    • 15% increase in milk protein yield (Mackle et al., 1999)
  – Clamp w/ abomasal infusion of casein
    • 28% increase in milk protein yield (Griinari et al., 1997)
  – Clamp w/ abomasal infusion of BCAA & casein
    • 25% increase in milk protein yield (Mackle et al., 1999)
  – Clamp w/ IV infusion of AA (casein profile)
    • Insulin and insulin plus AA increased milk by 13 to 18% and protein by 10 to 21% in goats
      – (Bequette et al, 2001)
Long-acting insulins and milk protein

- 30 multiparous Holstein cows
  - 52 to 130 DIM, avg. 88 +/- 25
- 3 treatments given at 12-h intervals for 10 d
  - Control
  - 0.2 IU/kg of BW Humulin-N (Eli Lilly and Co.), 2X/d
  - 0.2 IU/kg of BW Insulin glargine (Sanofi-Aventis), 2X/d
- Blood samples
  - Twice daily from coccygeal vein
  - Before morning injections, 6 hours later
- Milk samples every other day, 2x/d


Effect of long-acting insulins on milk protein yield

![Graph showing protein yield over days with significance levels]

Where to Start – Cow has Two Different Requirements

- Need to separate crude protein from true or metabolizable protein and amino acids
- The cow doesn’t understand crude protein
  - The rumen has requirements for rumen N, mostly in the form of ammonia and some AA and peptides
  - Post-ruminally the requirements are for digestible amino acids – from undegraded feed and microbes

Impacts of source and amounts of CP on intestinal supply of N and performance of cows

What is first limiting, energy or protein, and how can we figure it out?

And is rumen N adequate and MP limiting or is MP adequate and rumen N limiting?

Ipharraguerre and Clark, 2005
Protein/CHO Balance

[Diagram of protein and carbohydrate balance]

Really important for the fiber digesting bacteria

Making AA Balancing Work – feed chemistry and digestibility

- From modeling exercises, the most important variable in predicting AA supply is digestible NDF
  - This incorporates three outcomes – better feed intake, good rumen health and more microbial yield due to better digestibility

- The second most important variable is the digestibility of the protein source
Improving Efficiency of Nitrogen Use

- Milk protein output and overall protein efficiency is a function of energy supply
- Amino acid balance enhances efficiency of energy use and sometimes N use – not always direct
- Urine N is variable and is a function of excess nitrogen intake and recycling
- Urine N is most volatile form – so reducing it will reduce the environmental impact and improve efficiency
- Can use monitoring tools like milk urea nitrogen to diagnose independent of production responses or predict it with formulation

Urinary N is main form of excreted N Fecal N is fairly constant

<table>
<thead>
<tr>
<th>Reference</th>
<th>Intake N (g/d)</th>
<th>Fecal N (g/d)</th>
<th>Urinary N (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauffman and St-Pierre, 2001</td>
<td>429</td>
<td>178</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>460</td>
<td>184</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>572</td>
<td>198</td>
<td>190</td>
</tr>
<tr>
<td>Hristov and Ropp, 2003</td>
<td>658</td>
<td>208</td>
<td>233</td>
</tr>
<tr>
<td></td>
<td>754</td>
<td>176</td>
<td>279</td>
</tr>
</tbody>
</table>
Nitrogen excretion in milk, feces and urine based on N intake in lactating dairy cattle – under controlled conditions of energy as first limiting:

40 kg milk/d @24 kg DMI range in CP intake 14 to 18.7%

Van Amburgh et al. 2015 J. Dairy Sci

Productive N to Urinary N ratio

<table>
<thead>
<tr>
<th>Excretion</th>
<th>Fecal (kg)</th>
<th>Urine (kg)</th>
<th>Total Manure (kg)</th>
<th>Fecal N (g)</th>
<th>Urine N (g)</th>
<th>Total Manure N (g)</th>
<th>Productive N:Total N</th>
<th>Productive N:Urinary N</th>
<th>Manure N:Total N</th>
<th>NH3 Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>48</td>
<td>21</td>
<td>69</td>
<td>286</td>
<td>181</td>
<td>447</td>
<td>0.38:1</td>
<td>1.46:1</td>
<td>0.62:1</td>
<td>101.23</td>
</tr>
</tbody>
</table>

Productive N: Urine N

Average ratio 0.7:1
Acceptable 1:1
Outstanding 1.25:1
Predicting AA Balance – Four Pieces To The Nitrogen/AA Part of the Puzzle

What is most limiting?

Total amino acid requirements → Digestibility in the small intestine → Nitrogen components at the duodenum → profile of each component

IN RUMINANTS INTESTINAL DIGESTIBILITY IS A CALCULATION

Intestinal digestibility = 1 – [indigestible N/ rumen un-degraded protein]
Procedure in a single flask

Output
1. Total feed N
2. uN – unavailable Nitrogen

Comparison of ADIN and Ross in-vitro indigestible N (uN) assay

<table>
<thead>
<tr>
<th>Feed N (% DM)</th>
<th>ADIN (%N)</th>
<th>Ross In-vitro indigestible N (% N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular blood meal</td>
<td>16.2 4.7</td>
<td>16</td>
</tr>
<tr>
<td>Heat damaged blood meal</td>
<td>16.1 1.8</td>
<td>93</td>
</tr>
<tr>
<td>Soybean meal solvent extracted</td>
<td>7.6 6.7</td>
<td>8</td>
</tr>
<tr>
<td>Soybean meal heat treated</td>
<td>7.3 7.9</td>
<td>11</td>
</tr>
</tbody>
</table>
Treatment Diets

- Diets designed to iso-energetic and iso-nitrogenous
- Treatment difference was created by using two different blood meals
- One blood meal was highly digestible (9% uN), the other had average digestibility (34% uN)
- The calculated difference in N digestibility between the two treatments was 38 g N – cattle were consuming ~667 g N (5.8% of intake)

Chemical Composition of Diets Fed

<table>
<thead>
<tr>
<th>Item,</th>
<th>Treatment¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOW uN</td>
<td>HIGH uN</td>
</tr>
<tr>
<td>DM, % as fed</td>
<td>50.0</td>
<td>50.5</td>
</tr>
<tr>
<td>CP, % DM</td>
<td>15.2</td>
<td>15.2</td>
</tr>
<tr>
<td>NDF, % DM</td>
<td>31.9</td>
<td>32.3</td>
</tr>
<tr>
<td>ADF, % DM</td>
<td>21.3</td>
<td>20.5</td>
</tr>
<tr>
<td>EE, % DM</td>
<td>4.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Starch, % DM</td>
<td>30.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Sugar, % DM</td>
<td>3.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Ca, % DM</td>
<td>0.65</td>
<td>0.60</td>
</tr>
<tr>
<td>P, % DM</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>ME*, Mcal/kg DM</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Lys:Met*, % MP</td>
<td>3.21</td>
<td>2.89</td>
</tr>
</tbody>
</table>

¹ uN = unknown nitrogen
Nitrogen Intake

Blue line is high digestibility
Red line is low digestibility

Energy Corrected Milk (LS Means)

High digestibility
Low digestibility

(P<0.01)
<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>LOW uN</th>
<th>HIGH uN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual milk, kg</td>
<td></td>
<td>42.0</td>
<td>40.4</td>
</tr>
<tr>
<td>Predicted ME allowable milk, kg</td>
<td></td>
<td>46.2</td>
<td>46.0</td>
</tr>
<tr>
<td>Predicted MP allowable milk, kg</td>
<td></td>
<td>44.9</td>
<td>45.1</td>
</tr>
<tr>
<td>Predicted MP supply, g</td>
<td></td>
<td>3,105</td>
<td>3,144</td>
</tr>
<tr>
<td>Using ADIN and NDIN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted MP allowable milk, kg</td>
<td></td>
<td>42.6</td>
<td>39.3</td>
</tr>
<tr>
<td>Predicted MP Supply, g</td>
<td></td>
<td>3,036</td>
<td>2,835</td>
</tr>
</tbody>
</table>
Intestinal digestibility study – 96 cows
(HID) diet formulated with 2.7 lb blood meal, low intestinal digestibility
(LID) diet formulated with 2.9 lb blend of 82.8% feather meal and 17.2% of the
blood meal.
MP allowable milk of 101 lb/d and 95 lb/d, respectively.

<table>
<thead>
<tr>
<th></th>
<th>HID</th>
<th>LID</th>
<th>s.e.</th>
<th>P</th>
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<tbody>
<tr>
<td>N</td>
<td>48</td>
<td>48</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Body weight, lb</td>
<td>1,638</td>
<td>1,641</td>
<td>4</td>
<td>0.4</td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>57.7</td>
<td>56.6</td>
<td>2.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Milk, lb/d</td>
<td>101</td>
<td>99</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>Energy corr. milk, lb/d</td>
<td>109</td>
<td>102</td>
<td>3.8</td>
<td>0.04</td>
</tr>
<tr>
<td>Fat, %</td>
<td>4.08</td>
<td>3.81</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Prot, %</td>
<td>3.03</td>
<td>2.93</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>Fat, lb/d</td>
<td>4.14</td>
<td>3.74</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Protein, lb/d</td>
<td>3.07</td>
<td>2.88</td>
<td>0.01</td>
<td>0.008</td>
</tr>
</tbody>
</table>

C. Hoff, 2018 unpublished

Limiting amino acids in lactating dairy cows

1. Met, Lys, and His identified most often as first limiting

1. Met: when most RUP is provided by oilseed meals, animal-derived proteins, or a combination of the two

2. Lys: when corn or feeds of corn origin provide most or all dietary RUP

3. His: when grass silage, barley and oat diets are fed without supplemental RUP