The Practical Application of Balancing Lactating Cow Rations for Amino Acids

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Background

Nature has made the protein and AA nutrition of the cow complicated:

Feeding 2 systems:
1. A bacterial that requires ammonia but can use AA
2. A mammalian that requires AA and must detoxify ammonia

It is the interdependency of these two systems, as well as the inability to know exactly what each is contributing, that causes the problems with determining supply and requirements.
Background

The cow is poor at utilizing nitrogen: only about 25-30% of intake nitrogen is used for producing milk, meat or offspring.

Most of the remaining is excreted in urine and contributes to environmental pollution—and more stringent regulation is coming.

Studies are lacking:

There are 100's of studies on AA nutrition, but they are almost all of a Latin square design. Short term lots of things can be masked—long term has devastating effects on production.

Goals for today:
1. Talk about new knowledge of AA use supply
2. Discuss some studies
3. Make some balancing recommendations

➢ Need long term studies to determine real effects of AA balance and supplementation

➢ Right now we have ideas of what is correct, not many real studies.
The Essential AA

- For dairy cattle there are 9 EAA: His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val
- Arg can be synthesized by the cow, but perhaps not in sufficient quantities under high production and disease (?)
  - more properly called provisionally essential

The cow as well as the microbes can make non-essential AA from EAA
- The total of NEAA + EAA = MP

The Essential AA

- We need to supply both the total AA (MP) and the EAA to supply the metabolic demands of the cow:
  - Maintenance
  - Growth
  - Reproduction
  - Milk production—dominant drain of AA in lactating cow

Microbial Protein

- Rumen bacteria can make all AA that the cow needs: both EAA and NEAA
- Rumen microbes normally make up about 50-75% of total AA arriving at duodenum
  - 45-60% bacteria
  - 10-15% protozoa
Microbial Protein

<table>
<thead>
<tr>
<th>Item</th>
<th>Arg</th>
<th>His</th>
<th>Ile</th>
<th>Leu</th>
<th>Lys</th>
<th>Met</th>
<th>Phe</th>
<th>Thr</th>
<th>Trp</th>
<th>Vol</th>
<th>EAA</th>
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<td>Milk</td>
<td>3.3</td>
<td>2.8</td>
<td>5.7</td>
<td>9.9</td>
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<td>5.0</td>
<td>4.1</td>
<td>1.4</td>
<td>6.6</td>
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</tr>
<tr>
<td>R. Bact</td>
<td>5.1</td>
<td>2.6</td>
<td>5.7</td>
<td>8.1</td>
<td>7.9</td>
<td>2.6</td>
<td>5.1</td>
<td>5.8</td>
<td>-</td>
<td>6.2</td>
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<tr>
<td>R. Prot</td>
<td>3.5</td>
<td>1.5</td>
<td>5.5</td>
<td>6.7</td>
<td>8.2</td>
<td>1.7</td>
<td>4.7</td>
<td>4.4</td>
<td>-</td>
<td>5.2</td>
<td>42.7</td>
</tr>
</tbody>
</table>

Rumen bacterial protein is most like milk protein
- lacks only His and Met, perhaps a bit of Leu

The goal of every ration should be to optimize the amount of microbial protein.

Because producing more microbial protein entails adding more feed for an ever decreasing amount of microbial protein, maximizing microbial protein may not be economically viable.

RUP

The portion of true protein that escapes degradation by rumen microbes (RUP) is the second greatest source of AA for the cow.

Normally 25-35% of total AA

<table>
<thead>
<tr>
<th>Item</th>
<th>Arg</th>
<th>His</th>
<th>Ile</th>
<th>Leu</th>
<th>Lys</th>
<th>Met</th>
<th>Phe</th>
<th>Thr</th>
<th>Trp</th>
<th>Vol</th>
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<td>2.6</td>
<td>5.1</td>
<td>5.8</td>
<td>-</td>
<td>6.2</td>
<td>49.8</td>
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<td>8.2</td>
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<td>-</td>
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<tr>
<td>DOG</td>
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<td>2.7</td>
<td>3.7</td>
<td>7.7</td>
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<td>4.9</td>
<td>3.7</td>
<td>0.8</td>
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<td>2.1</td>
<td>4.2</td>
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<td>5.4</td>
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<td>4.5</td>
<td>7.6</td>
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<td>1.3</td>
<td>5.1</td>
<td>3.9</td>
<td>1.3</td>
<td>4.7</td>
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<td>4.3</td>
<td>5.9</td>
<td>1.1</td>
<td>12.3</td>
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<td>1.2</td>
<td>6.8</td>
<td>4.6</td>
<td>1.4</td>
<td>6.2</td>
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<td>2.7</td>
<td>4.0</td>
<td>7.1</td>
<td>7.3</td>
<td>2.7</td>
<td>3.9</td>
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<td>2.2</td>
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<td>44.6</td>
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<tr>
<td>Pork</td>
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<td>2.9</td>
<td>2.8</td>
<td>5.8</td>
<td>5.1</td>
<td>1.4</td>
<td>3.3</td>
<td>3.1</td>
<td>0.7</td>
<td>4.0</td>
<td>34.7</td>
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<td>3.8</td>
<td>7.0</td>
<td>5.5</td>
<td>1.9</td>
<td>3.9</td>
<td>3.9</td>
<td>1.8</td>
<td>4.7</td>
<td>41.0</td>
</tr>
</tbody>
</table>
**RUP**

Are the AA of RUP the same as intact protein?

For most feeds, the answer is yes. For animal protein meals, the answer may be different. For poorly fermented silages, the answer may be different - needs a significant amount of research.

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**RUP**

Do all AA in RUP have the same digestibility?

Answer is clearly NO. But every model uses 80% because that is global average - does not do bad, but we can do better.

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**Endogenous protein**

General agreement that the rest of protein is endogenous protein. Scarf protein and digestive secretions - really not "new" AA, as most are secreted and then absorbed.

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**Endogenous protein**

How big a contribution? estimates from 1 to 15%

How long can this level be maintained?

Need a lot of research here!
AA Supply

The really good news is that models built on NRC, AminoCow and newer versions of CNCPS do a reasonably good job of predicting AA flow over a wide range of rations and management conditions.

Not perfect, but good

<table>
<thead>
<tr>
<th>Flow</th>
<th>Overall</th>
<th>Grass</th>
<th>Alfalfa</th>
<th>Corn silage</th>
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</thead>
<tbody>
<tr>
<td>MCP</td>
<td>None</td>
<td>None</td>
<td>AMT, NRC</td>
<td>NRC</td>
</tr>
<tr>
<td>RUP</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Arg</td>
<td>AC, NRC</td>
<td>AMT</td>
<td>AC, NRC</td>
<td>None</td>
</tr>
<tr>
<td>His</td>
<td>AC</td>
<td>None</td>
<td>AC</td>
<td>None</td>
</tr>
<tr>
<td>lle</td>
<td>NRC</td>
<td>AC, AMT</td>
<td>NRC</td>
<td>NRC</td>
</tr>
<tr>
<td>Leu</td>
<td>All</td>
<td>All</td>
<td>None</td>
<td>NRC</td>
</tr>
<tr>
<td>Lys</td>
<td>AC, AMT</td>
<td>AC, NRC</td>
<td>AC, NRC</td>
<td>AC, NRC</td>
</tr>
<tr>
<td>Met</td>
<td>AC, NRC</td>
<td>None</td>
<td>None</td>
<td>AC, NRC</td>
</tr>
<tr>
<td>Phe</td>
<td>AC, AMT</td>
<td>AC, AMT</td>
<td>AC, AMT, CPM</td>
<td>AMT, CPM</td>
</tr>
<tr>
<td>Thr</td>
<td>All</td>
<td>NRC</td>
<td>AMT, CPM</td>
<td>ALL</td>
</tr>
<tr>
<td>Val</td>
<td>AC, AMT</td>
<td>NRC</td>
<td>AC, AMT</td>
<td>NRC</td>
</tr>
</tbody>
</table>

Pacheco et al., 2012

Requirements

➢ This means we have a reasonably good idea about the amount of AA arriving at the small intestine.

➢ What we really do not know is the requirements, especially the requirements for lactation

- not so unusual, lactation requirements for all species are ‘guestimates’

Requirements

How could this be so?

1. We know that the intestine uses AA for energy, especially branched chains (Ile, Leu and Val)
   - Is it required, variable, or luxury consumption?
Requirements

2. We know when a cow is in negative energy balance (transition, early lactation) up to 50% of glucose is from AA.
   - Do we need to feed for this?

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Ratio</th>
<th>sd</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk true protein yield, g/d</td>
<td>784</td>
<td>155</td>
<td>370</td>
<td>1,076</td>
</tr>
<tr>
<td>Metabolizable protein, g/d</td>
<td>1,794</td>
<td>485</td>
<td>747</td>
<td>3,619</td>
</tr>
<tr>
<td>Arg U:O</td>
<td>2.45</td>
<td>0.60</td>
<td>0.88</td>
<td>4.18</td>
</tr>
<tr>
<td>His U:O</td>
<td>1.08</td>
<td>0.25</td>
<td>0.46</td>
<td>1.80</td>
</tr>
<tr>
<td>Ile U:O</td>
<td>1.41</td>
<td>0.20</td>
<td>1.01</td>
<td>1.96</td>
</tr>
<tr>
<td>Leu U:O</td>
<td>1.31</td>
<td>0.24</td>
<td>0.98</td>
<td>2.37</td>
</tr>
<tr>
<td>Lys U:O</td>
<td>1.33</td>
<td>0.25</td>
<td>0.60</td>
<td>2.09</td>
</tr>
<tr>
<td>Met U:O</td>
<td>0.96</td>
<td>0.11</td>
<td>0.59</td>
<td>1.18</td>
</tr>
<tr>
<td>Phe U:O</td>
<td>1.07</td>
<td>0.08</td>
<td>0.82</td>
<td>1.20</td>
</tr>
<tr>
<td>Thr U:O</td>
<td>1.19</td>
<td>0.18</td>
<td>0.87</td>
<td>1.58</td>
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<tr>
<td>Val U:O</td>
<td>1.49</td>
<td>0.27</td>
<td>0.85</td>
<td>2.22</td>
</tr>
<tr>
<td>Mammary plasma flow L/d</td>
<td>14,160</td>
<td>2,784</td>
<td>9,384</td>
<td>23,076</td>
</tr>
</tbody>
</table>

After Lapierre et al., 2012

Requirements

3. We already know milk protein is 50% EAA.
   - This indicates EAA must be between 70-85% of total milk protein.
   - Does this indicate a requirement?
   - Would the gland prefer to use EAA?
   - Luxury consumption?

Both Patton (2010) and Pacheco et al. (2012) found that fully 1/3 of study were MP deficient when entered into the NRC model.
   - Suggests that NRC requirement is too high.
   - Is this because the AA composition of the protein is not accounted for?
We found that for milk protein % use of g/d EAA was as well correlated as AA%MP
(adjR² = 0.811 and 0.810, RMSE = 0.14 and 0.14, for g/d and AA%MP, respectively).
For milk protein yield, use of g EAA/d was a better measure
(adjR² = 0.952 and 0.937, RMSE = 0.04 and 0.05 for g/d and AA%MP, respectively).

Who is ‘right’?
While they are surely all incorrect, none of them are wrong.
The authors have simply evaluated the available data differently.
None have been challenged like they should be!
Requirements

Because of the differences between lactation and growth, as well as the ability of the mammary gland to control blood flow and extraction %, we may never have exact requirements.

Rather we may have ranges for AA at a given production level.

Studies

Classic study of Schwab et al., 1992a, b

- Infusion of 4 L of AA in liquid
- Based on corn silage, grass silage and corn grain
- Protein a mix of DDG and SBM
- 10-day periods
- Looked at 4 stages of lactation to find Met and Lys requirements
- Reasonably high microbial protein %
**Studies**

*Benefield et al., 2009*
- Fed 2 different RPMet products; 1 at 2 rates
- 2-wk periods, data reported each week
- Based on corn silage, alfalfa hay, and corn
- Protein mixture of soybean meal and expeller soybean meal

<table>
<thead>
<tr>
<th>Item</th>
<th>Week</th>
<th>Control</th>
<th>RPM6</th>
<th>RPM12</th>
<th>RPM12</th>
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<tbody>
<tr>
<td>Milk</td>
<td>1</td>
<td>84.5</td>
<td>81.0</td>
<td>79.6</td>
<td>81.4</td>
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<td></td>
<td>2</td>
<td>81.4</td>
<td>79.0</td>
<td>78.6</td>
<td>81.4</td>
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<tr>
<td>Average</td>
<td></td>
<td>82.9</td>
<td>80.1</td>
<td>81.0</td>
<td>82.5</td>
</tr>
<tr>
<td>MTP, %</td>
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<td>2.90a</td>
<td>3.02b</td>
<td>3.02b</td>
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<td></td>
<td>2</td>
<td>2.97</td>
<td>2.99</td>
<td>3.03</td>
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<tr>
<td>Average</td>
<td></td>
<td>2.94a</td>
<td>3.00b</td>
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<tr>
<td>Average</td>
<td></td>
<td>1100</td>
<td>1090</td>
<td>1110</td>
<td>1120</td>
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</tbody>
</table>

16.4% CP basal diet

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*Broderick et al., 2008*
- Became apparent when there was lots of MP, there was no response to RPMet
- Wanted to look at RPMet with reduced protein
- Corn silage, alfalfa silage, HMSC based diets
- Protein mixture of WRS and SM
- periods of 4 wks

**Exp1**

<table>
<thead>
<tr>
<th>Item</th>
<th>18.6 CP, 0 DLM</th>
<th>17.3 CP, 5 DLM</th>
<th>16.1 CP, 10 DLM</th>
<th>14.8 CP, 15 DLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>87.3^a</td>
<td>81.5^a</td>
<td>81.5^a</td>
<td>87.3^a</td>
</tr>
<tr>
<td>MTP, %</td>
<td>3.02</td>
<td>2.98</td>
<td>2.97</td>
<td>3.04</td>
</tr>
<tr>
<td>MTP, g/d</td>
<td>1150^a</td>
<td>1230^a</td>
<td>1230^a</td>
<td>1200^b</td>
</tr>
</tbody>
</table>

**Exp2**

<table>
<thead>
<tr>
<th>Item</th>
<th>17.3 CP, 0 DLM</th>
<th>17.3 CP, 10 DLM</th>
<th>16.1 CP, 0 DLM</th>
<th>16.1 CP, 10 DLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>87.6</td>
<td>88.2</td>
<td>86.2</td>
<td>85.1</td>
</tr>
<tr>
<td>MTP, %</td>
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<tr>
<td>MTP, g/d</td>
<td>1210</td>
<td>1230</td>
<td>1190</td>
<td>1170</td>
</tr>
</tbody>
</table>

Broderick et al., 2008
Studies
Lee et al., 2012a
-corn silage, alfalfa haylage, corn based
-Protein mix WRSB and SBM
-Period of 10 weeks
-MP adequate diet, MP deficient diet, and MP deficient diet plus RPLys and RPMet

<table>
<thead>
<tr>
<th>Item</th>
<th>Ad-MP</th>
<th>Def MP</th>
<th>Def MP + Lys</th>
<th>Def MP + Met</th>
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<tbody>
<tr>
<td>Milk</td>
<td>79.6</td>
<td>76.1</td>
<td>74.8</td>
<td>74.8</td>
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<tr>
<td>MTP, %</td>
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<td>2.92b</td>
<td>2.95ab</td>
<td>2.95ab</td>
</tr>
<tr>
<td>MTP, kg</td>
<td>1190a</td>
<td>1120b</td>
<td>1120b</td>
<td>1120b</td>
</tr>
</tbody>
</table>

15% CP

Studies
Lee et al., 2012b
-Corn silage, alfalfa silage, corn grain base
-Protein Mix, WRSB, canola meal, expeller soybean meal
-12 weeks
-MP adequate, MP Deficient, MPdef +Lys+Met, MPdef +Lys+Met+His

<table>
<thead>
<tr>
<th>Item</th>
<th>Ad-MP</th>
<th>Def MP</th>
<th>Def MP + Lys+ Met+ His</th>
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<tbody>
<tr>
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<td>81.2ab</td>
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<tr>
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<td>2.98</td>
<td>2.94</td>
<td>2.99</td>
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<tr>
<td>MTP, kg</td>
<td>1130a</td>
<td>1100a</td>
<td>1100a</td>
</tr>
</tbody>
</table>

15.7% CP
Limiting Amino Acids

Since Rulquin and his co-workers, Schwab and his co-workers, Met is thought of as most likely to be limiting.

In a big meta-analysis, we proved that is more or less correct.
- Most studies with high MP and short time-still an effect

Limiting Amino Acids

Same people assumed Lys is second limiting
Robinson (2010) in meta-analysis found no effect of added Lys; we found no effect of Lys on Met response.
- High MP; short time

Limiting Amino Acids

- Lys (continued)
- Because of microbial protein synthesis, probably less likely to be limiting than His or perhaps others, but still important—especially in early lactation.

Limiting Amino Acids

Much speculation because of Leu effect on mTor, adding Leu should affect protein response.
- Has not been shown to date
  - Suggest that trials be held for longer periods and with lower MP
As microbial protein becomes greater percent, more likely to be limiting
Limiting Amino Acids

Studies with other EAA (Ile, Phe, Thr, Trp, and Val) have really not been looked at especially for the longer term.

For the ruminant, any EAA can become limiting, (1) if MP is not high, (2) there is not a great amount of RUP, and (3) as the animal depends on greater percent of microbial protein.

In summary, for what we know right now:

1. Met because it is low in both microbes and in most RUP sources, is probably most limiting.
2. Other EAA are hard to be limiting if MP is high.
3. If MP is reduced, then His probably becomes second limiting.
4. Lys appears to be 2nd or 3rd limiting in early lactation; after this it is pretty hard to find a deficiency.

Beyond that we really do not know.

Why reduce MP?

1. If MP is reduced, then get less N into the environment.
2. Protein is EXPENSIVE.
   - At today’s prices that means we can lower costs from $0.25-$0.50 per day.
   - If we do not lose production (either milk or milk protein yield), it’s a no brainer.
The Big Question:

In a practical sense, what do we do with all of this?

Balancing for Amino Acids

1. Commit to balancing for AA!

Understand that it is:
(a) more than a Lys:Met ratio
(b) more than Lys or Met as % MP
(c) an on-going process –we do not have good requirements yet

2. Select a model and stick with it.

As indicated, every model except old CPM is okay until we know more.

Learn the assumptions and how to use the model.

Make sure it has some evaluations.

How should I begin to balance amino acids for dairy cattle?
Balancing for Amino Acids

3. Collect the information needed to make the model run:
   A. Body weight
   B. Know what to ask the feed laboratory to provide.
   C. Do not assume the RUP and AA numbers for one model will work in another.

4. Measure the DMI for each group
   We found the best model predicted with 3.5 lb of actual DMI only 60% of the time.
   3.5 lb of DM is a lot of microbial protein
   -Do you really want to feed 1 TMR to the whole herd and use AA balance?

5. Optimize for microbial protein.
   For all the reasons we have talked about-
   Balance NDF and fiber mat first
   Balance NFC and RDP
   Maximizing may be too expensive.

6. Meet projected deficits
   A. MP by adding RUP
   B. EAA by adding RPAA—if unavailable, then add best RUP source
   C. Satisfy on the basis of grams
      Cows do not eat ratios.
Balancing for Amino Acids

6. Meet projected deficits (continued)
   Balance the g for the model you are using.
   After you are comfortable, then you can fine tune it for what the cows are telling you.

7. If group is less than 16 DIM, add 12% more MP to cover most of the need for gluconeogenesis
   AC, NC already added, the rest need to be added

8. Believe in the cow.
   If the model says that the diet you are feeding lacks an AA, and the cow is producing that amount of milk and milk protein, the chances are the model is incorrect and not the cow.
   The chances are that it is the requirement and not the flow of AA to the duodenum.

9. Monitor the situation.
   If the MP is lowered and RPAA is added:
   If more RPAA is added:
   If more MP is added:
   Keep a close eye on production and keep fine tuning it until you have optimized the situation for the dairyman—both long and short term.
Balancing for Amino Acids

In our experience, if your clients know DMI, if they have forages and byproducts of consistent quality, levels of 90-95 lb of milk per day on a whole herd basis can be maintained on 15.6-15.8% CP. Have seen a 15.2% for 8 months.

If not, protein will have to be raised.

The Challenge is Yours

Like other important advancements, the expertise in AA balance will come from the field.

This is your chance to really impact on your client’s economic health and on the science of nutrition.

Thank you for your attention.

Any questions?