Maximizing Milk Components and Metabolizable Protein Utilization through Amino Acid Formulation

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PRE-CONFERENCE SYMPOSIUM

71ST ANNUAL CORNELL NUTRITION CONFERENCE
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Amino acid supply and use in dairy cows

Dietary protein (RUP)
Microbial protein
Endogenous protein

Body protein
- maintenance
- growth
- fetus

Milk protein

Glucose
NH₄⁺
Urea (MUN)

AMINO ACIDS

Energy
Introduction

- When EAA are absorbed in the profile as required by the animal, the requirement for total EAA is reduced and their efficiency of use for protein synthesis is maximized (Heger and Frydrych, 1989)

- Research with lactating dairy cows has been shown many times that increasing predicted concentrations of Lys and Met in MP to recommended levels increases efficiency of use of MP for milk protein synthesis...this should not be surprising where Lys and Met are the first two limiting AA
Therefore, it is reasonable to conclude that maximizing milk components and MP utilization in lactating dairy cows requires providing a profile of AA in MP that matches the profile required for the combined functions of maintenance, reproduction, and milk production, and...that MP is provided in amounts that meet, but don’t exceed, requirements for optimal health, reproduction, and milk and milk component production

Determining the optimum/ideal profile of AA is the challenge!
**Suggested Optimum Concentrations of EAA in MP**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>4.6</td>
<td>3.1</td>
</tr>
<tr>
<td>Histidine</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>5.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Leucine</td>
<td>8.9</td>
<td>8.9</td>
</tr>
<tr>
<td>Lysine</td>
<td>7.2</td>
<td>7.3</td>
</tr>
<tr>
<td>Methionine</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Threonine</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Valine</td>
<td>6.5</td>
<td>5.3</td>
</tr>
</tbody>
</table>
## 20 Standard Amino Acids in Protein

<table>
<thead>
<tr>
<th>Indispensable</th>
<th>Dispensable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Arginine</td>
<td>1. Alanine</td>
</tr>
<tr>
<td>2. Histidine</td>
<td>2. Aspartic acid</td>
</tr>
<tr>
<td>3. Isoleucine</td>
<td>3. Asparagine</td>
</tr>
<tr>
<td>4. Leucine</td>
<td>4. Cysteine</td>
</tr>
<tr>
<td>5. Lysine</td>
<td>5. Glutamic acid</td>
</tr>
<tr>
<td>7. Phenylalanine</td>
<td>7. Glycine</td>
</tr>
<tr>
<td>8. Threonine</td>
<td>8. Proline</td>
</tr>
<tr>
<td>10. Valine</td>
<td>10. Tyrosine</td>
</tr>
</tbody>
</table>
Collectively, these observations indicate that when AA supplies approach requirements for total absorbable AA, requirements for total NEAA are met before the requirements for the most limiting EAA.

In recognition of these observations, and because Lys and Met had been shown to be the first two limiting AA for lactating dairy cows fed diets common to North America, NRC (2001) published dose-response plots that related changes in measured percentages and yields of milk protein to model-predicted changes in Lys and Met concentrations in MP.
The optimum amount of lysine in MP according to NRC (2001) is 7.2%.
The optimum amount of methionine in MP according to NRC (2001) is 2.4%
“Optimum” vs. “practical” levels of Lys and Met in MP

NRC recommendations
7.2 Lys, 2.4 Met

Practical recommendations
6.6 Lys, 2.2 Met
Purpose of Presentation

- To share the results of a recent re-evaluation of the Lys and Met dose-response plots using the “final version” of the NRC (2001) model

- To share the results of a recent effort to develop the same dose-response plots using CPM-Dairy (v.3.0.10) and AMTS.Cattle (v.2.1)

- To review our approach for maximizing milk components and MP utilization
To determine what the “requirements” for Lys and Met are when the NRC (2001) model is used to evaluate diets, the NRC committee used the indirect dose-response approach developed by Rulquin et al. (1993)

5 steps are required to develop the plots:

1. Predict concentrations of Lys and Met in MP for the control and treatment groups in experiments in which post-ruminal supplies of Lys, Met, or both, were increased
2. Identify “fixed” intermediate concentrations of Lys and Met in MP
3. Calculate a “reference production value” for each production parameter in each Lys experiment that corresponds to the “fixed” level of Lys in MP and in each Met experiment that corresponds to the “fixed” level of Met in MP
4. Calculate “production responses” (plus and minus values) for control and treatment groups relative to the “reference production values”
5. Regress the production responses on the predicted concentrations of Lys and Met in MP
Re-evaluation of NRC (2001) plots

- The approach has the “unique benefit” of allowing requirement values to be estimated using the same model as that used to predict concentrations of EAA in MP.
Development of CPM and AMTS.Cattle plots

- The indirect dose-response approach for identifying optimal concentrations of Lys and Met had not been extended to other models.

- Whitehouse et al. (2009) repeated the same steps, using the same studies as used for NRC (2001), to generate plots for CPM-Dairy and AMTS.Cattle.

- Because ration formulation and diet evaluation programs differ in approach and assumptions taken to estimate AA supply, it was expected that estimated “requirements” for Lys and Met in MP would be different from those for NRC (2001).
### The results...

<table>
<thead>
<tr>
<th></th>
<th>Requirement for maximal milk protein content</th>
<th>Lys:Met ratio</th>
<th>Requirement for maximal milk protein yield</th>
<th>Lys:Met ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NRC (2001)</strong></td>
<td>Lys</td>
<td>6.8</td>
<td>3.0:1</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Met</td>
<td>2.3</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td><strong>CPM v.3.0.10</strong></td>
<td>Lys</td>
<td>7.5</td>
<td>2.9:1</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Met</td>
<td>2.6</td>
<td></td>
<td>2.50</td>
</tr>
<tr>
<td><strong>AMTS v.2.1.1</strong></td>
<td>Lys</td>
<td>6.7</td>
<td>2.8:1</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Met</td>
<td>2.4</td>
<td></td>
<td>2.3</td>
</tr>
</tbody>
</table>
La base de données

DCAARET supplémentation Met, Lys, & Met + Lys 1976-2009 : 640

Met & Met+Lys

F1 : 505

(PDIN-PDIE)/UFL >-8

F2 : 451

Metdi<2.5

F3 : 347

- points aberrants

F4 : 336
Source de AA

- Infusion: 19,0%
- Adisseo: 15,2%
- Ajinamoto: 4,2%
- Degussa: 11,6%
- Ketionine: 6,3%
- Kodak: 43,8%
kpdi = 0,29 + 0,94 Met/ Lys

$R^2 = 0.82, s = 0.02$

essais = 148;  n = 336
vaches = 3484
Effect of NRC (2001) Predicted Percentages of Lys and Met in MP

<table>
<thead>
<tr>
<th>Predicted Lys/Met in MP (%)</th>
<th>Lys/Met ratio</th>
<th>Flows¹</th>
<th>Used for Protein Synth.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4/1.7</td>
<td>3.8/1</td>
<td>179</td>
<td>48</td>
</tr>
<tr>
<td>5.7/1.9</td>
<td>3.0/1</td>
<td>160</td>
<td>53</td>
</tr>
<tr>
<td>6.6/2.2³</td>
<td>3.0/1</td>
<td>185</td>
<td>62</td>
</tr>
</tbody>
</table>

¹ Calculations are based on a predicted MP supply of 2,800 g/d.
² Based on the assumption that the optimum Lys/Met ratio in MP is 3:1 and the understanding that any amino acid supplied in excess of need for protein synthesis is not used for protein synthesis and therefore, is catabolized and used for energy.
³ Requires feeding high-lysine protein supplements along with a ruminant Met supplement.
Benefits of Balancing for Lys and Met

1. Increased milk and milk protein production
2. Reduced need for supplemental RUP...creates space for more carbohydrates
3. Reduced N excretion
4. More predictable changes in milk and milk protein production to changes in RUP supply
5. Improved hoof health & reproduction
6. Reduced fatty livers and less change in body condition
7. INCREASED HERD PROFITABILITY
5 Steps for maximizing milk components and MP utilization through AA formulation

1) Feed a blend of forages, processed grains, and byproduct feeds to provide a blend of fermentable carbohydrates and physically fiber that maximizes feed intake, milk yield and yield of microbial protein

2) Feed adequate but not excessive levels of RDP to meet rumen bacterial requirements for AA and ammonia
RDP Balance of Consumed Diets as Predicted by NRC (2001)
Average Rumen Ammonia N Concentrations

linear, $P < 0.01$
Flow of Microbial N to the Duodenum

quadratic, $P < 0.05$
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3) Feed high-Lys protein supplements to achieve a targeted level of Lys in MP that comes as close as possible to meeting the optimal concentration
Comparison of lysine in rumen bacterial protein and feedstuffs
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4) Feed a “rumen-protected” Met supplement in the amounts needed to achieve the optimal ratio of Lys and Met in MP

5) Don’t overfeed-RUP...let the cows tell you how much they need!
Current Status of Two Herds that are Balancing for High Levels of LYS and MET in MP

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<td></td>
<td>Met 2.3</td>
<td></td>
<td>2.5</td>
<td></td>
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<td>Lys 7.5</td>
<td>2.9:1</td>
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<td>2.9:1</td>
</tr>
<tr>
<td></td>
<td>Met 2.4</td>
<td></td>
<td>2.3</td>
<td></td>
</tr>
</tbody>
</table>
A Wisconsin Holstein Herd

- 25.7% CS, 28.9% haylage, 2.5% hay, 21.7% high moisture corn, 5.4% whey perm, 3.9% fuzzy cottonseed, 4.7% roasted beans, 1.3% canola meal, 1.1% blood meal, 0.7% fishmeal, 0.7% fat, 0.1% MetaSmart, 2.3% minerals, vitamins and additives (11.0% RDP, 6.3% RUP, 26.1% NDF)
- Balanced for Lys and Met for 12 years
- MP-Lys = 6.33%, MP-Met = 2.11%, MP-His = 2.28% (NRC, 2001)
- Oct, 2009: 110 lb milk, 3.24% protein, 4.03% fat, MUN = 13.0
A New York Holstein Herd

- 40.0% CS, 20.0% haylage, 1.0% straw, 20.0% fine ground corn, 10.0% canola meal, 6.0% PROTEAM, 2.0% ProvAAI Basic, 0.6% fat, 0.08% Smartamine M, 2.3% minerals, vitamins and additives (9.5% RDP, 6.5% RUP, 30.0% NDF)
- On ProvAAI since 2003
- MP-Lys = 6.95%, MP-Met = 2.38% (CPM-Dairy)
- Oct, 2009: 95 lb milk, 3.31% protein, 3.85% fat, MUN = 8.0
- Herd average has increased from 23,000 to 30,000 and protein has increased from 2.8% to 3.3% and fat from 3.5 to 3.8%
28% corn silage, 21.8% haylage, 22.6% high moisture corn, 7.5% whey perm, 5.3% fuzzy cottonseed, 5.7% canola meal, 3.3% SoyPass, 1.1% SBM, 0.8% blood meal, 0.2% urea, 0.2% fat, 0.07% MetaSmart, 0.02% Smartamine M, 3.0% minerals, vitamins and additives (10.6% RDP, 6.5% RUP, 28.1% NDF)

MP-Lys = 6.33%, MP-Met = 2.09%, MP-His = 2.25% (NRC, 2001)

Oct, 2009: 95 lb milk, 3.24% protein, 3.91% fat, MUN = 12.4
Take-Home Messages

1. The most efficient use of MP occurs when the profile of EAA in MP matches the profile as required by the cow

2. Balancing diets for optimal Lys and Met in MP reduces requirements for RUP

3. Balancing for AA in MP should always be part of ration formulation…particularly when IOFC are low
Plots of measured milk and protein yields vs. NRC (2001) predicted flows of MP

NE milk > MP milk, and actual milk between minus 6 kg and plus 6 kg of MP-allowable milk (n = 146)

\[ y = -4 \times 10^{-6}x^2 + 0.034x - 20.56 \]
\[ R^2 = 0.65 \]

\[ y = 0.4524x - 62.063 \]
\[ R^2 = 0.74 \]
Plots of measured milk and protein yields vs. NRC (2001) predicted flows of MP–Met

Lys:Met >3.0:1, MP more limiting than energy, and MP balance between –250 g and +100 g (n = 98)
Plots of measured milk and protein yields vs. NRC (2001) predicted flows of MP–Lys.

Lys:Met <3.2:1, MP more limiting than energy, and MP balance between −250 g and +100 g (n = 28)
**Effect of NRC (2001) predicted Lys and Met in MP on predicted milk yield**

<table>
<thead>
<tr>
<th>Predicted Lys/Met in MP&lt;sup&gt;1&lt;/sup&gt; (%)</th>
<th>Milk yield&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Protein yield&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MP-Lys</td>
<td>MP-Met</td>
</tr>
<tr>
<td>6.4/1.7</td>
<td>35.6</td>
<td>38.6</td>
</tr>
<tr>
<td>5.7/1.9</td>
<td>38.9</td>
<td>40.9</td>
</tr>
<tr>
<td>6.6/2.2</td>
<td>43.5</td>
<td>42.1</td>
</tr>
</tbody>
</table>

<sup>1</sup> Calculations are based on a predicted MP supply of 2,800 g/d.

<sup>2</sup> Based on regression equations from plots of measured milk yields vs. NRC (2001) predicted MP-Lys and MP-Met flows.
Differences Between Actual and MP Allowable Milk and Lys in MP

\[ y = 5.6532x - 35.074 \]

\[ R^2 = 0.2135 \]

(n = 63 of 206)
Differences Between Actual and MP Allowable Milk and Met in MP

\[ y = 21.673x - 41.357 \]

\[ R^2 = 0.2051 \]

\[(n = 81 \text{ of } 206)\]
Benefit of balancing for Lys and Met on increasing efficiency of use of MP

40 Kg milk obtained with 2800 g of MP (containing 5.7% Lys and 1.9% Met), 159 g MP-Lys and 53 g MP-Met.

How much MP is needed to produce 40 Kg of milk if MP contains 6.6% Lys and 2.2% Met?

\[
\begin{align*}
159 \text{ g MP-Lys / 6.6% Lys (.066)} & = 2409 \text{ g MP} \\
53 \text{ g MP-Met / 2.2% Met (.022)} & = 2409 \text{ g MP}
\end{align*}
\]

How much MP is saved? \(2800 \text{ g} - 2409 \text{ g} = 391 \text{ g}\)

How much RUP is saved? \(391 \text{ g} / 0.80 = 489 \text{ g}\)
Benefit of balancing for Lys and Met on increasing efficiency of use of MP

Saving 489 g of RUP means how much less RUP in diet DM?

Assumption: A well-balanced diet containing 10.5% RDP and 7.5% RUP (i.e., 18% CP), at an intake of 25 Kg/d, with 5.7% Lys and 1.9% Met in MP will support 40 kg of milk

Original RUP intake: 25 kg DMI x 0.075 = 1.875 kg

New RUP intake = 1.875 kg – 0.489 kg = 1.386 kg

New RUP in diet DM = 1.386 kg RUP / 25 kg DMI = 5.5%

A: 2.0 percentage units less (7.5% - 5.5%)
Conclusions

- Profit margins can often be improved by increasing milk protein yield
- Increasing supply of RUP does not ensure improved milk protein production (Santos et al., 1998)
- Substitution of RDP by RUP can lead to decreased microbial protein synthesis (Santos et al., 1998)
- Over-feeding RDP can lead to decreased microbial protein synthesis (Boucher et al., 2007)
- The greatest opportunity to increase milk protein content is to increase the concentrations of the most limiting EAA in MP to “required” concentrations and avoid over-feeding RUP