Impact of Trace Mineral Variation with Forages on the Ration Formulation Process

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Questions to be answered

- Does Cu, Zn, Fe & Mn content of forages vary by season and location?
- Are some minerals present at high enough concentrations in forages that they could interfere with or antagonize the digestion and absorption of others?
- What is the extent of soil contamination in forages?
- What are the best approaches to address TM concentrations and availability in formulation?

What are excessive mineral levels in forages?

- Forage Cu > 30 mg/kg and ration Cu > 20 mg/kg could result in liver Cu accumulation and chronic toxicity
  - Based on 8 mg/kg from non-forage feed ingredients and absorption coefficient = 0.04
- Forage Fe > 500 mg/kg and ration Fe > 300 mg/kg could result in Cu depletion
  - Based on 125 mg/kg from non-forage feed ingredients and drinking water at 0.3 – 2.0 mg/L
  - NRC 2001; Bremner et al., 1987; Phillips et al., 1987
  - High Fe may also interfere with Zn absorption
- Excess intake of Mn and Zn from forages not an issue under practical U.S. dairy feeding conditions

Data overview

- Data generously provided by Ralph Ward, Cumberland Valley Analytical Services
- 10 forage data sets from crop years 2009-2014 with more than 60,000 samples from 44 states in the combined sets
  - corn silage
  - grass, MMG, MML, and legume hays and haylages
  - small grain silages
  - sorghum and sudan silages
- Macronutrients (DM, CP, NDF, ADF, lignin, starch, EE, ash)
- Macrominerals (Ca, P, Na, K, Cl, S, Mg)
- Microminerals (Fe, Cu, Mn, Zn)
### Data Sets

<table>
<thead>
<tr>
<th></th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>20,654</td>
</tr>
<tr>
<td>Legume hay</td>
<td>8,856</td>
</tr>
<tr>
<td>MMIL silage</td>
<td>8,631</td>
</tr>
<tr>
<td>MMSG silage</td>
<td>2,914</td>
</tr>
</tbody>
</table>

### Samples cover major dairy regions

### TM concentrations are not normal and are skewed high

~5% of samples are more than 2 SD greater than the median, while almost none are >2 SD on the low side.

### Home grown forages have more skewed distributions

Extreme samples
Mineral concentrations are more consistent in corn silage

Geographical variation

Cu Variation -- Regional Hot Spots

Areas on maps correspond to mailing centers, not counties.

Knapp et al., 2015a
Areas on maps correspond to mailing centers, not counties.

Knapp et al., 2015a

soil contamination

You might have a soil contamination problem...
Soil contamination is higher in western regions

Soil contamination, ash, and iron concentrations

<table>
<thead>
<tr>
<th>Level of Soil Contamination</th>
<th>Com Silage</th>
<th>Legume Hay</th>
<th>MML Silage</th>
<th>MMG Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>63.5</td>
<td>18.3</td>
<td>8.3</td>
<td>19.3</td>
</tr>
<tr>
<td>Total Ash</td>
<td>0.47</td>
<td>9.29 ± 1.24</td>
<td>9.21</td>
<td>6.38</td>
</tr>
<tr>
<td>Fe</td>
<td>131 ± 0.03</td>
<td>312.7 ± 1.32</td>
<td>295.1 ± 1.15</td>
<td>719.4 ± 1.76</td>
</tr>
</tbody>
</table>

1-4%:

| Percentage                  | 98.0       | 71.9       | 78.1       | 97.4       |
| Total Ash                   | 0.94       | 19.09      | 10.09      | 6.41       |
| Fe                          | 214 ± 1.98 | 355 ± 2.45 | 423 ± 2.61 | 555 ± 2.95 |

> 4%:

| Percentage                  | 9.5        | 8.9        | 11.6       | 22.5       |
| Total Ash                   | 0.05 ± 2   | 13 ± 2.5   | 15.5 ± 1.86| 12 ± 0.77  |
| Fe                          | 555 ± 3.75 | 872 ± 5.53 | 1150 ± 7.56| 850 ± 6.01 |

Knapp et al., 2015b
Total Ash (% DM), Fe concentrations (mg/kg), given as mean ± SD.
MML= Mixed Mostly Legume, MMG = Mixed Mostly Grass.
Note that ash and Fe concentrations are not normally distributed within a forage type.

managing TM variation in formulation
Are your dairies in an area that has a high average AND high variation?

Recommendations for sampling frequency & supplementing differ by region

- More testing → More supplementation
- Less testing → Less supplementation

TM Variation in TMRs

- Simulated variation in forages and other basal feed ingredients
- Forages
  - Used actual data from Cumberland Valley Analytical Services for a given region
  - Accounted for mean, variation, AND correlations between TMs in forages
- Used NRC 2001 data for grains, protein meals, and other byproducts.
Forages: different averages + different variation

Feed mixing and supplementation hits target with reduced variation

3 scenarios

1) Basal ingredients + no supplementation: 50:50 forages, concentrate (flaked corn, DDGS, CGF, SBM
2) Basal ingredients + 1x supplementation: 11 Cu, 52 Zn, 40 Mn, 17 Fe mg/kg added
   - Equivalent of supplementing at NRC 2001 levels without considering endogenous minerals in feed ingredients
3) Basal ingredients + 1.5 x supplementation: 17 Cu, 78 Zn, 60 Mn, 25.5 Fe mg/kg added

Requirements: Mins & Maxes

- Cu min = 11 mg/kg
- Cu max = 30 mg/kg
- Fe min = 17 mg/kg
- Mn = 40 mg/kg
- Zn = 52 mg/kg
TMR Results: 3 scenarios

<table>
<thead>
<tr>
<th></th>
<th>Basal ingredients</th>
<th>Basal + 1x supplementation</th>
<th>basal + 1.5x supplementation</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu ave</td>
<td>6.0</td>
<td>17.0</td>
<td>23.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Cu &lt; 11 mg/kg</td>
<td>99.58</td>
<td>0.05</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Cu &gt; 30 mg/kg</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Zn ave</td>
<td>33.2</td>
<td>85.2</td>
<td>111.2</td>
<td>8.5</td>
</tr>
<tr>
<td>Zn &lt; 52 mg/kg</td>
<td>98.75</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Mn ave</td>
<td>35.1</td>
<td>75.1</td>
<td>98.1</td>
<td>10.0</td>
</tr>
<tr>
<td>Mn &lt; 40 mg/kg</td>
<td>69.02</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Fe ave</td>
<td>204</td>
<td>221</td>
<td>230</td>
<td>86.2</td>
</tr>
<tr>
<td>Fe &lt; 17 mg/kg</td>
<td>0.06</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Basal ingredients: forages, concentrate (flaked corn, DDGS, CGF, SBM with no mineral supplementation)

1x supplementation (mg/kg): 11 Cu, 52 Zn, 40 Mn, 17 Fe added
1.5x supplementation (mg/kg): 17 Cu, 78 Zn, 60 Mn, 25.5 Fe added

How do the 3 scenarios compare?
Basal diet is copper deficient in >99% of mixes

How do the 3 scenarios compare?
At basal +1x supplementation, no deficiencies

Green – Basal ingrds
Blue – 1x suppl.

How do the 3 scenarios compare?
1.5x supplementation could lead to excess Cu

Green – Basal ingreds
Blue – 1x suppl.
Red – 1.5x suppl.
Results & Caveats

- Mixing feeds together substantially reduces the TM variation in the TMR compared to the individual forages.
- It also reduces the correlation between TM concentrations (data not shown).
- This analysis assumed that the TM levels in one forage are independent of TM levels in other forages going into the TMR.
- This may not be true for home-grown forages. In forages grown on the same soils, the mineral concentrations may be correlated.

Sulfur & thiomolydates

- Excess S (>0.40) in the feed is not expected to be an issue with Cu availability in rations...
  - Unless a lot of sulfates are added and the ration contains > 5 lbs. DDGS. Basal ingredients provided between 0.08 and 0.30%S in the TMR.
  - 5 lbs. DDGS containing 1%S would add 0.10% S to the TMR if DMI=50 lbs.
  - Does not consider S in drinking water!

TM formulation

- TM concentrations in basal ingredients DO contribute significant amounts of TMs to the ration.
- Amount of mineral supplementation should be a function of the TM levels in the basal ingredients and the animals’ requirements.

Summary

- Trace mineral concentrations in forages can exceed 5 S.D. above the median on the HIGH SIDE.
- Using “book values” rather than analytical values can result in rations having insufficient or excess trace minerals.
  - Book values represent the national average, not necessarily what’s in forages in a given region.
  - In some regions, excesses may put cows at risk of copper toxicity.
- Forages in certain regions have higher levels of soil contamination than others.
  - Fe associated with the soil contamination may interfere with the absorption of other minerals.
- Sampling & analysis is key!
  - The average in a given region provides a more appropriate reference value than book values.
  - Testing frequency will be determined by the variation.
Thanks!