Update on Mineral Nutrition of Dairy Cows

Establishing Mineral “Requirements”

NRC 2001 Factorial Approach

Maintenance Requirements (~30-50% of total req’t)

1. Amount of nutrient that is inevitably lost that must be replaced (nonlactating, not growing, not pregnant)

2. Minimum amount of a nutrient needed to maintain body functions and health without reducing body stores
Main Concerns with current factorial method

1. Maintenance requirement (optimal health?)
2. Milk secretion vs milk synthesis
3. Non-nutrient effects?

Likely error
Under
Under

Use of Mineral balance to estimate total requirement (diet, not TAR)

\[ Mn \text{ bal} = -151 + 0.26 \times X \]

Weiss and Socha, 2005

'Requirement' estimated by balance method*

~625 kg cow, 35 kg milk

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Balance method</th>
<th>NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu:</td>
<td>360 mg</td>
<td>250 mg</td>
</tr>
<tr>
<td>Mn:</td>
<td>580 mg</td>
<td>310 mg</td>
</tr>
<tr>
<td>Zn:</td>
<td>840 mg</td>
<td>870 mg</td>
</tr>
</tbody>
</table>

* Data from digestibility studies by OSU

NRC 2001 Factorial Approach

Inputs
Feedstuffs
Mineral concentration
Absorption coefficients

TAS
mg/d of mineral that is available for use
The AC is a weak link in formulating for available TM

1. Very difficult to measure
2. Diet and source dependent
   - e.g., high S diet and Cu
   - e.g., organic vs inorganic
3. Animal status dependent

Uncertainty increases risk
Formulation must consider risk

For Minerals (and vitamins) substantial uncertainty exists
- requirements
- absorption

You must evaluate: risk/reward
If you are wrong does it cost more to over or underfeed???

Trace Minerals Recommendations

Think mg/day, not ppm

<table>
<thead>
<tr>
<th></th>
<th>Dry cow</th>
<th>80 lbs milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu reqt</td>
<td>175 mg</td>
<td>250 mg</td>
</tr>
<tr>
<td>Diet conc</td>
<td>14 ppm</td>
<td>10 ppm</td>
</tr>
</tbody>
</table>

45 vs 60 lbs DMI: 410 vs 550 mg/d (20 ppm)

Concentrations may be higher for dry cows but lower for high yielding cows

Trace Minerals Recommendations

Basal feeds provide TM

Problems with the data
- Variable
- High sampling error
- Non-normal distribution

Get enough samples
Use median

Problems do not justify ignoring basal supply
Cu concentration, ppm

Number of samples

Mean = 6.3
Median = 6.0

75% of samples >5 ppm

10% of samples >8.5 ppm

High TM in Basal Feeds

With high ash and Fe
- likely soil contamination
- availability probably low

Without high ash
- could be interior metals
- availability may be similar to inorganic supplements

Trace Minerals Recommendations

Capture value from high availability TMs

Need 6 mg absorbed Cu to meet req

Copper sulfate = 25% Cu; AC = 0.05
Product X® = 25% Cu; Relative AC = 2X

\[
\frac{6}{0.05} \times 0.25 = 480 \text{ mg CuSO}_4 \quad \text{or} \quad \frac{6}{(0.05 \times 2)} \div 0.25 = 240 \text{ mg of Product X®}
\]
Relative Availability

1. Feed a standard mineral (e.g., CuSO₄)
2. Feed test mineral (same amount)
3. Measure response and report ratio

Liver Cu when fed source Y
Liver Cu when fed Cu sulfate

1. Diet specific
2. Animal specific
3. Everything is relative

Are differences between organic and inorganic TM due to bioavailability?

Organic Zn reduced the pathogen associated with digital dermatitis in feces (inorganic did not)
Faulkner et al., 2017

Intestine is a very important immune organ
Microbiome affects immunity

Potassium (NRC = ~1.1%)

The Good
1. Can improves milk fat (DCAD, not K)
2. Helps with heat stress (K)
3. Some data: optimal is >NRC

The Bad
1. Reduces Mg absorption (K)
2. Increases manure and manure (K)

Higher K (DCAD) improves fat and FE

Diet K% (DCAD)
Cont: 1.3 (32)
K carb: 2.1 (53)

Both diets
34% forage
6% DDG
Early lact. cows
Harrison et al., 2012

Harrison et al., 2012
Higher K (DCAD) improves fat and FE

Diet K% (DCAD)
Cont: 1.2 (2)
K carb: 2.2 (30)

All diets
27% DDG
4.2 or 5.8% Fat

No K x fat INT

Lamar and Weiss, 2013

Higher Diet K = More Manure

0.45 vs 0.25% Mg

K and Mg Absorption in Dairy Cows

1. Absorbed from rumen
2. Real world antagonists
   - K (linear)
   - LCFA (probably not big)
   - Rumen ammonia (RDP)
   Acute vs. chronic
3. Minimal homeostatic control of absorption

Weiss et al., 2009

Weiss, 2004

Schonewille et al., 2008
**Magnesium**

<table>
<thead>
<tr>
<th>Source</th>
<th>Magnesium Availability (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal feeds</td>
<td>0.16</td>
</tr>
<tr>
<td>Good MgO</td>
<td>0.7 or 0.5</td>
</tr>
<tr>
<td>MgSO(_4)</td>
<td>0.9 or 0.7</td>
</tr>
</tbody>
</table>

*Correct* values based on NRC 2001:
- Good MgO: 0.30 to 0.25
- MgSO\(_4\): 0.35 to 0.40

* @1.2%K

Feeds are better than we thought
Supplements are worse than we thought

**Mg Availability from 4 sources of MgO**

- MgO\(_1\)
- MgO\(_2\)
- MgO\(_3\)
- MgO\(_4\)

Jesse et al., 1981

Uncertainty increases risk
Formulation must consider risk

**Sulfur (NRC = 0.2%)**

No reason to exceed NRC
1. Reduces copper availability
2. Reduces selenium availability
3. Reduces DCAD (milk and DMI)

Higher S diets may be cheaper ($/lb) because of DDG inclusion

**High S forage = Reduced Copper Stores**

- Grass fertilized with Nothing
- NH\(_3\)-Sulfate
- Forage S
  - 0.2%
  - 0.5%

Arthington et al., 2004
Se and Sulfur

-3% units/0.1% added S

![Graph showing Se absorption with different S levels](graph.png)

Ivancic and Weiss, 2001

Remember Water

Water with 250 ppm Sulfate-S = +0.1% dietary S
Water with 700 ppm Sulfate-S = +0.3% dietary S

Take water samples occasionally

Sulfur (NRC = 0.2%)

Watch total S (diet + water)
1. Reduces copper availability
2. Reduces selenium availability
3. Reduces DCAD (milk and DMI)

Absorbed Cu = ~9-12 mg/d
Total Cu*: 200 to 270 mg/d

Feed Enough!
- Reduced mastitis
- Improved immunity
- Reduced RP

Don’t feed too much!
- Real world toxicity (i.e., death)
- Accumulation of liver Cu
Copper: Lots of Real World Antagonists

1. High Sulfur (Forage, DDG, water)
2. High reduced Fe (water)
3. Grazing (soil ingestion)
4. High Mo

NRC assumes minimal antagonism:
Real world situations justify increased Cu

Liver Cu continues to accumulate (diet = ~20 ppm)

Balemi et al., 2010 (NZVJ)

Cu Recommendations

No DDG, good water:
- 1.2 to 1.5X NRC (12 to 17 ppm TOTAL Cu when using CuSO₄)
- If using high bioavailability sources, feed less (i.e., no safety factor)

Lifetime moderate overfeeding of Cu may be causing problems!

Cu Recommendations

With Antagonists (eg. DDG, bad water ...)
- Maybe 2 to 3X NRC (20 to 30 ppm)
- Use proven 'High available' Cu
- Evaluate status (liver Cu from cull cows, biopsies)

Lifetime moderate overfeeding of Cu may be causing problems!
**Se: All animals: 0.3 ppm added**

Lactating cows, normal situation
- all or predominantly inorganic

Lactating cows, antagonists (e.g. S)
- substantial amount from Se-yeast

Late gestation cows and heifers
- mix of inorganic and Se-yeast

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**Selenium Yeast**

Benefits:
- 1.2 to 1.3 X more available
- Builds up body Se reserves
- Increases milk Se (humans)
- Transfer to fetus and colostrum
- Limited absorption antagonists

Disadvantage: Cost

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**Probability of Disease vs Blood Se**

![Graph showing probability of disease vs blood selenium levels]

Whole blood = 0.16 – 0.18 µg/ml

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**Relative Response: Selenite vs Se-yeast**

![Graph comparing relative response of selenite and Se-yeast]

Weiss and Hogan, 2006

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**Legends**
- Control
- Selenite
- Se-Yeast

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**Mastitis**
- Retained placenta
- Cystic ovaries
NRC (2001): ~14 - 18 ppm

Beef cows fed 18 ppm produced calves with signs of clinical Mn deficiency (Hansen et al., 2006)

Dairy cow balance data suggests 30-40 ppm

Use of Mineral balance to estimate maintenance requirement (diet, not TAR)

\[
\text{Mn bal} = -151 + 0.26 \times X
\]

580 mg/d = 0 balance: At mean DMI; 28 ppm

Faulkner and Weiss (2016): 33 to 38 ppm

Weiss and Socha, 2005

Chromium (No NRC requirement, FDA max = 0.5 ppm from Cr prop)

- Part of Glucose Tolerance Factor (GTF)
- Enhances insulin sensitivity (early lactation cows are insulin resistant)
- Reduces lipolysis and lowers NEFA which can stimulate DMI in early lactation
- Enhances cellular immunity (cortisol?)

Production Responses

12 studies, 30 trt

Typical rate:
~1 ppm dry
0.5 ppm lactating

Typical duration
-3 wk to +4 WOL

Multiple Cr sources

~2/3 of trt comp.
>3 lb/d increase
Summary

1. Uncertainty and risk management justifies moderate overfeeding of MANY minerals
   Moderate = +20 to 50% of NRC

2. Safety factors should be farm, mineral, and mineral source specific

3. Consider long term effects of overfeeding

4. Do not ignore minerals in basal ingredients (use means or medians for TM)

5. Supplemental Mg is not as good as you thing but feed Mg is better than you think

http://dairy.osu.edu