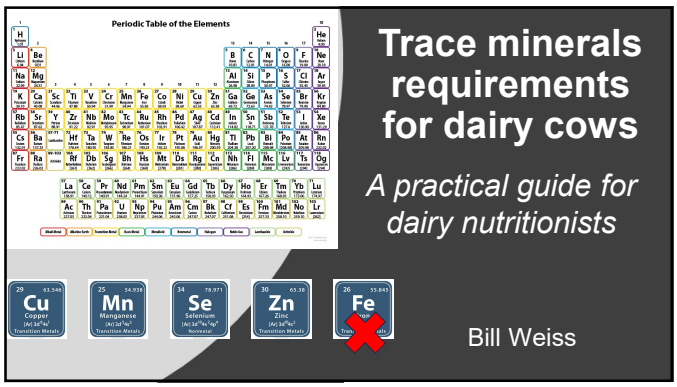

1

Diet formulation for TM

- Meet basic requirements
- Adjust for risks
- Adjust for antagonism
- Consider non-factorial responses
- Consider source effects

2

NASEM Mineral Report

This is the start

Item	Diet Density	Req Density	Absorb Req (TAR)	Diff TAS- TAR
Micro Mineral	mg/kg	mg/kg	mg/d	**mg/d**
Co	0.00	0.20	5	**-5**
Cr	0.16	N/A	N/A	**N/A**
Cu	7.10	8.95	12	**-2**
Fe	151.56	17.74	47	**351**
I	0.00	0.43	11	**-11**
Mn	31.06	30.03	3	**0**
Se	0.17	0.30	8	**-3**
Zn	37.07	59.71	314	**-119**

3

Why you should not supplement Fe

1. NASEM Adequate intake (reqt): 15 to 20 mg/kg
   - Typical diets: >50 mg/kg
2. Two studies with dairy (+30 mg/kg organic Fe)
   - One study: no effect
   - One study: substantial negative effects

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NASEM Requirement System

$$\text{Diet Reqt (mg/d)} = \frac{(\text{Maint} + \text{Milk} + \text{Growth} + \text{Fetal})}{\text{Absorption Coefficient}}$$

Is this appropriate for TM ?

J. Dairy Sci. 107:10099–10114
https://doi.org/10.3168/jds.2024-25150

Invited review: **Limitations to current mineral requirement systems for cattle and potential improvements**

W. P. Weiss[1]* and S. L. Hansen[2]
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[2]Department of Animal Science, Iowa State University, Ames, IA 50011

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Concerns with NASEM TM Factorial System

1. **Ignores potential concentration effects**
   - Absorption
   - Potential effects on rumen and intestinal microbiome
2. **Very limited AC data**
3. **Some requirements may be circular**
   - Milk concentration can increase with increased TM
   - Maintenance may increase with increased TM

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Diet formulation for TM

Meet basic requirements

↓

Adjust for risks

↓

Adjust for antagonism

↓

Consider non-factorial responses

↓

Consider source effects

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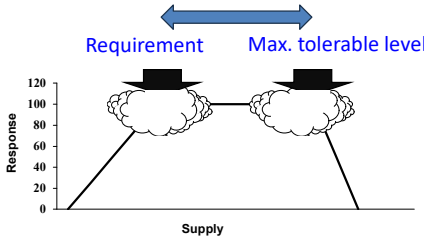
If you ↓ risk of deficiency, ↑ risk of 'toxicity' and vice versa



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Sources of 'risk'

1

1. Variability of diet composition
2. Variability of requirements within a pen

2

3. Accuracy of requirement equations
4. Accuracy of absorption coefficients

3

5. Toxicity risk
6. Cost

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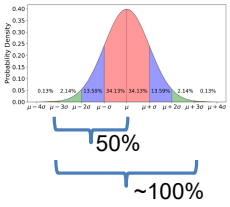
1 'Standard' safety factor

- Req't meet needs of 50% of population
- With normal distributions; Mean + 2 **SD** = 98% of population
- Assuming BMR = variation in mineral reqt: Mean X 1.2 = 98% of population



For **many** minerals: **~1.2 X NASEM requirement** will meet requirements of ~100% of animals in a pen

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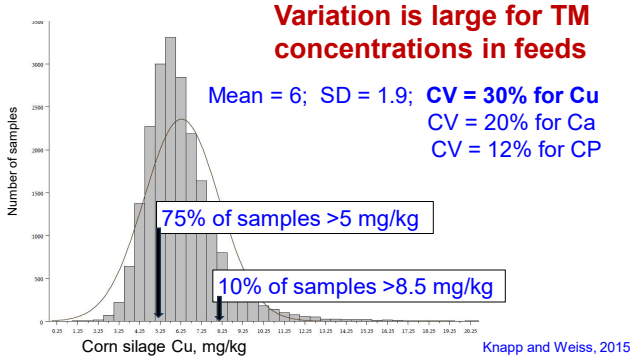
Variation is large for TM concentrations in feeds



Mean = 6; SD = 1.9; **CV = 30% for Cu**
CV = 20% for Ca
CV = 12% for CP

75% of samples >5 mg/kg

10% of samples >8.5 mg/kg

Knapp and Weiss, 2015

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Should forage TM be discounted to mitigate risk ?

Forages have extremely high SD for TM

High variation is not a reason to enter 0 for feed minerals

- Much of the variation is sampling
- SD are inflated because of long tails
- Use data from multiple samples
- Book values for TM often better than sample value

Entering 0 is usually more wrong than using the mean

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"But TM in feeds are not available"

WRONG !

TM availability: Equal to or lower than supplements

- In humans and lab animals, usually equal or better
- In ruminant feeds, dependent on soil contamination

TM in soils are often poorly absorbed

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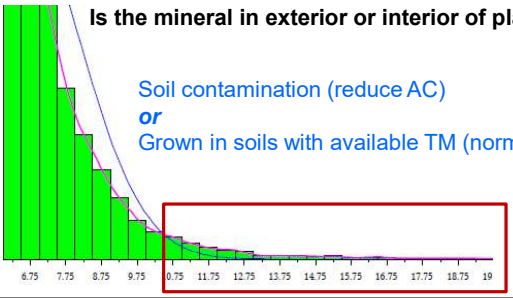
May need to adjust TM for soil contamination

Is the mineral in exterior or interior of plant?

Soil contamination (reduce AC)
or
Grown in soils with available TM (normal AC)



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High TM in Basal Feeds

With high ash/and Fe
- likely soil contamination
- availability probably low
- use population mean, not sample value

Without high ash
- could be interior metals
- availability may be similar to inorganic supplements
- use good local mean

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2 Accuracy of equations/variables

1. **Requirements**
   - Cu: probably ok
   - Mn: probably poor
   - Zn: good
   - Se: no equation
2. **Absorption**
   - ?????

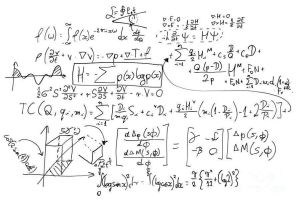

Image: Michal Bednarek

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Most AC are based on relative availability

1. Feed a reference mineral (e.g., $CuSO_4$) and test mineral (same amount of supplemental mineral
2. Measure **response (?)** and report ratio

$$\frac{\text{Liver Cu when fed source X}}{\text{Liver Cu when fed Cu sulfate}}$$

3. Multiply reference AC by ratio to get test AC

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Relative absorption

1. Need a response variable
2. Diet specific
3. Need accurate value for reference minerals

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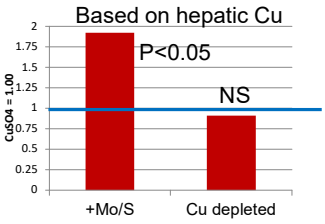
Relative availability has limitations

Hydroxy Cu chloride vs. Cu sulfate (with steers)



Spears et al., 2004

Everything is relative!

If CuSul AC = 0.05 is HyCu = ~0.10 ?

or

is CuSulf = 0.025 and HyCu = 0.05 ?

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Should AC be adjusted for relative availability?

In my humble opinion, NO

1. Experimental conditions limit extrapolation
2. Concentration can affect AC and other things
3. Questionable or no RA data for many TM

Diets with 'specialty TM' vs. sulfate TM

1. Keep total diet concentrations about the same
2. Maybe reduce the safety factor/ antagonism adjustment

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3 Toxicity risk and severity

- Cu: High
- Mn: Very low
- Se: Moderate to high (only specific forms)
- Zn: Low to moderate

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Diet formulation for TM and vitamins

Meet basic requirements

↓

Adjust for risks

↓

Adjust for antagonism

↓

Consider non-factorial responses

↓

Consider source effects

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Many metals share intestinal transport mechanisms

Excessively high concentrations of can antagonize others

- Fe and Mn
- Cu and Zn
- Fe and Cu
- Etc.

Keep dietary concentrations of TM reasonable!

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Sulfur (sulfate) antagonizes Cu, Mn, Zn,and Se

1. Mostly (all?) occurs within rumen
2. Mode of action not understood but probably via sulfide production (insoluble, binds metals)
3. Diet S (including water) > 0.25% may antagonize

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Remember Water

Water with 250 mg/L **Sulfate-S**
= +0.1% dietary S

Water with 700 mg/L **Sulfate-S**
= +0.3% dietary S

Sulfate-S = Sulfate*0.33

Take water samples occasionally

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Weiss adjustments for high S: Supplemental minerals from sulfates

- Suggested additional adjustments to **Cu, Mn, Zn** for high S (Includes the 1.2 X adjustment for variability)

≤0.2%S:	1.2X
0.3% S:	1.4X
0.4% S:	1.5X
0.5% S:	1.6X

Include the S in water

If also > ~3 ppm Mo: Add 0.2 to above values for **Cu**

Almost all diets: Cu: 13 to 20 mg/kg total diet

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Diet formulation for TM and vitamins

Meet basic requirements
↓
Adjust for risks
↓
Adjust for antagonism
↓
Consider non-factorial responses
↓
Consider source effects

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Do minerals have to be absorbed to affect cow ?

Mineral requirements:	**Absorbed ?**
▪ Maintains body stores	✓
▪ Supports productive functions - growth - lactation - reproduction	✓
▪ Support immunity and health	Yes and no
▪ GI function/ nutrient digestion	Yes and no

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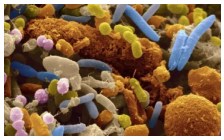
Source of TM affect ruminal/intestinal microbiome



Compared with sulfates

- Organic Zn reduced the pathogen associated with digital dermatitis in feces (Faulkner et al., 2017)
- Hydroxy Zn reduced the pathogen in feces (Wenner et al., 2022)

Probably a concentration effect not a mg/d effect

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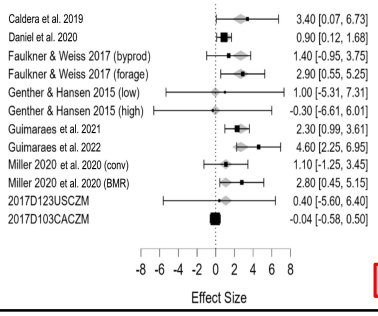
Hydroxy vs sulfate: NDF Digestibility



Meta-analysis

Ibraheem et al., 2023

+1.5% units (P < 0.02)

NEL in about 1 lb of milk

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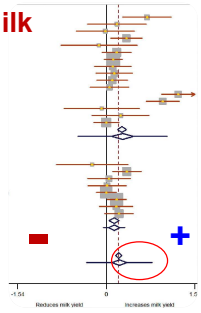
Milk



OTM cocktail (Cu, Co, Mn, Zn) increased production

- **Milk:** +0.9 kg/d
- **Prot:** +30 g/d
- **Fat:** +40 g/d

Rabiee et al., 2010, JDS

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Recommendations

Use high quality alternatives to sulfates and chlorides

- Increased diet energy
- Potentially enhanced immune function/health

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Recommendations:

Selenium (0.3 mg/kg)

Only question is source:

- Lactating: Majority from selenite (or selenate) is usually fine
- Lactating with high S diets: Mix of selenite:(yeast or Se-met)
- Dry and prefresh: Majority (not all) from yeast or Se-met

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Use standard safety factor (1.2X) for Zinc

- Low to modest toxicity risk
- Low uncertainty

Total Diet!

- **NASEM**
  - Lactating: ~ 60 mg/kg
  - Dry: ~30 mg/kg
- **Formulation goals**
  - Lactating: 70 to 80 mg/kg
  - Dry: ~ 40 mg/kg

Adjust for high S

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Use standard safety factor (1.2X) for copper

- High toxicity risk
- Moderate uncertainty
- High antagonism risk

Total Diet!

- **NASEM**
  - Lactating: ~ 10 mg/kg
  - Dry: ~15 mg/kg
- **Formulation goals**
  - Lactating: 12 mg/kg
  - Dry: ~ 18 mg/kg

Adjust for high S and Mo

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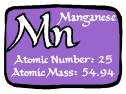
Manganese needs greater SF



Low toxicity risk
High uncertainty

Suggest: ~2X NASEM

- NASEM:
  - Lactating: **~30 mg/kg**
  - Dry: **~40 mg/kg**

Total Diet!

- **Formulation goals**
  - Lactating: **~ 60 mg/kg**
  - Dry: **~80 mg/kg**

Adjust for elevated S

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Summary

A profound conclusion:
Feed enough but not too much!

- Current estimates are mostly close to correct
  - Feed **modest** excess to ensure adequacy
  - Base safety factor on variability, antagonism, accuracy, and toxicity risk
- TM source effects are more, probably a lot more, than just increased absorption

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