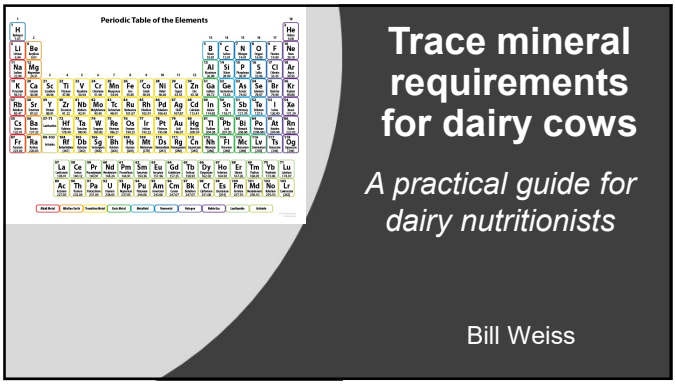



1

## Required Trace minerals for dairy cows

- ✓ Required in milligram or microgram amounts per day
- ✓ Diet concentrations expressed in mg/kg (or ppm)
- ✓ No known 'stand-alone' function
- ✓ Only known functions are as essential components of:
  - **Enzymes/proteins:** **Cu**, Fe, **Mn, Se, Zn**
  - **Hormones:** I (0.5 mg/kg)
  - **Vitamins:** Co (0.2 to 0.5 mg/kg supplemental)
  - **Non-enzyme polypeptide:** Cr (0.5 mg/kg supplemental)

2

## Diet formulation for TM (also Mg)

Cu Zn Se Mn

Meet basic requirements
↓
Adjust for risks
↓
Adjust for antagonism
↓
Consider extra-requirement responses
↓
Consider source effects

3

## NASEM Requirement System

Diet Reqt = (Maint + Milk + Growth + Fetal)
**mg/d** Absorption Coefficient

For trace nutrients may not be best approach

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]**
[1]Department of Animal Sciences, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, OH 44691
[2]Department of Animal Science, Iowa State University, Ames, IA 50011

4

## 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

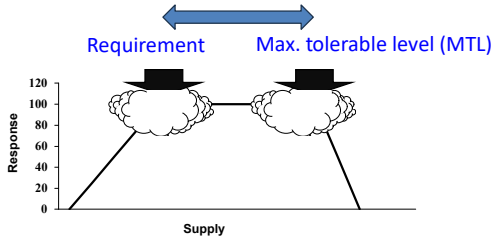
5

## Diet formulation for TM

Meet basic requirements
↓
**Adjust for risks**
↓
Adjust for antagonism
↓
Consider extra-requirement responses
↓
Consider source effects

6

## Reducing risk of deficiency increase risk of 'toxicity' and vice versa




7

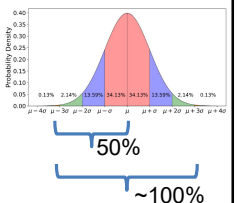
## Sources of 'risk'

1. Variability of diet composition
2. Variability of requirements within a pen
3. Accuracy of requirement equations
4. Accuracy of absorption coefficients
5. Toxicity risk
6. Cost

8

## 1 'Standard' safety factor

- Requirements meet needs of 50% of population
- Assuming normal distributions; Mean plus 2 **SD** = 98% of population
- Assuming basal heat production = 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

9

## Should forage TM be discounted to mitigate risk?

Forages have extremely high SD for TM

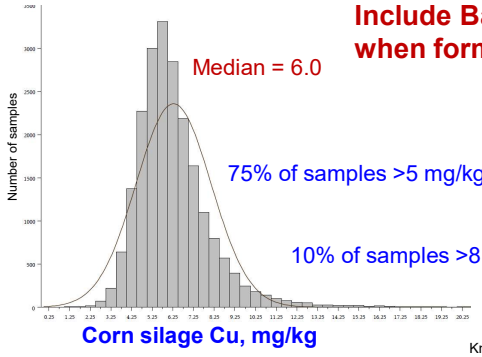
**High variation is not a reason to enter 0 for feed minerals**

- Much of the variation is sampling
- Use data from multiple samples
- Book values for TM often better than sample value

**Entering 0 is usually more wrong than using the mean**

10

## Include Basal TM when formulating




Knapp and Weiss, 2015

11

## *"But* TM in feeds are not available" WRONG !

**TM availability: Equal to or lower than supplements**

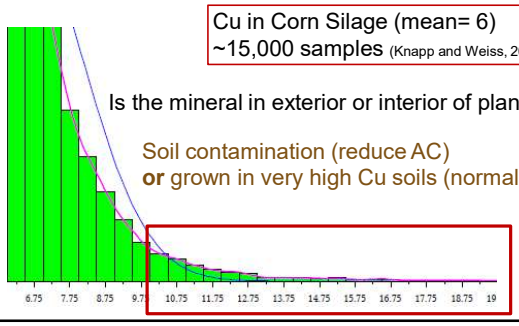
- In humans and lab animals, usually equal or better
- In ruminant feeds, dependent on soil contamination

**Metals in soil are mostly oxides**

12

## May need to adjust TM for soil contamination

Cu in Corn Silage (mean= 6)
~15,000 samples (Knapp and Weiss, 2016)




Is the mineral in exterior or interior of plant?

Soil contamination (reduce AC)
**or** grown in very high Cu soils (normal AC)

13

## 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

14

## 2 Accuracy of equations/variables

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

15

## 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

16

## Relative availability

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

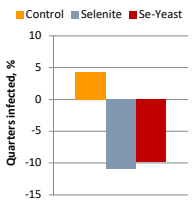
17

## What response value should you use?

Se-Yeast vs selenite

| | |
|---|---|
| Absorption: | ~1.5X |
| Whole blood Se: | 1.3X |
| WB GSHpx: | 1.2X |
| Calf blood Se: (Se fed to dam) | 1.4X |
| Milk/colostrum | 1.8X |

Se-Y = selenite

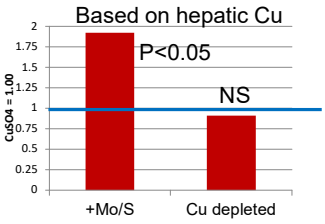



Malbe et al., 1995

18

## Relative availability has limitations

Hydroxy Cu chloride vs. Cu sulfate




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 ?

19

## How do you use relative availability data?

If data show product X is twice as good as sulfate, *should I feed half as much* ?

1. **Cu**: Maybe but usually not
2. **Se**: Don't adjust
3. **Mn:** Probably doesn't matter
4. **Zn:** Don't adjust

20

## 3 Toxicity risk and severity

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

21

## Diet formulation for TM and vitamins

Meet basic requirements

↓

Adjust for risks

↓

**Adjust for antagonism**

↓

Consider extra-requirement responses

↓

Consider source effects

22

## Many metals share an intestinal mechanisms

Excessively high concentrations of can antagonize others

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

Keep dietary concentrations of TM reasonable!

23

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

1. Mostly (all?) occurs within rumen
2. Mode of action not completely understood but probably via sulfide production (insoluble, binds metals)
3. Diet S (including water) > 0.25% may antagonize
4. Cu is most sensitive to increasing diet S

24

## Remember Water

Assumed typical intakes for dry and lactating cows

Water with 300 mg/L **Sulfate-S**
= +0.1% dietary S

Water with 750 mg/L Sulfate-S
= +0.3% dietary S

Sulfate-S = Sulfate*0.33

**Take water samples occasionally**

25

## 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

26

## Diet formulation for TM and vitamins

Meet basic requirements
↓
Adjust for risks
↓
Adjust for antagonism
↓
**Consider extra-requirement responses**
↓
**Consider source effects**

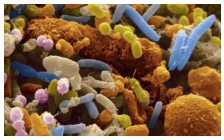
27

## Do minerals have to be absorbed to affect cow?

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

28

## Source of TM affect ruminal/intestinal microbiome



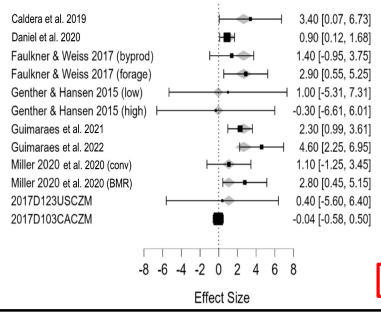
Compared with sulfates

- 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

29

## Hydroxy vs sulfate: NDF Digestibility




**Meta-analysis**

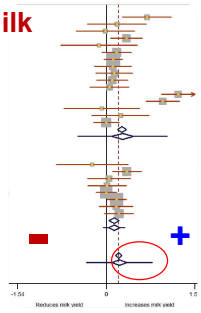
Ibraheem et al., 2023

**+1.5% units (P < 0.02)**

NEL in about 1 lb of milk

30

## 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

31

## Recommendations

**Use high quality alternatives to sulfates**

- Increased diet energy
- Potentially enhanced immune function/health

32

## Recommendations:

## Selenium (0.3 mg/kg)


**Only question is source:**

- Lactating: Majority from selenite usually is fine
- Lactating with high S diets: Mix of selenite:yeast
- Dry and prefresh: Majority yeast

33

## Use standard safety factor (1.2X) for Zinc


- Modest toxicity risk
- Low uncertainty

**Total Diet!**

- **NASEM**
  - Lactating: ~ 60 mg/kg
  - Dry: ~30 mg/kg (dry)
- **Formulation goals**
  - Lactating: 75 to 80 mg/kg
  - Dry: ~ 45 mg/kg

Adjust for elevated S

34

## Use standard safety factor (1.2X) for copper


- High toxicity risk
- Moderate uncertainty
- High antagonism risk

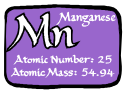
**Total Diet!**

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

Adjust for elevated S and Mo

35

## 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

36

## Recommended TOTAL dietary concentrations (mg/kg) assuming typical intakes

| Mineral | NASEM | Recommended |
|---|---|---|
| Cu | 10 | 12 to14* |
| Mn | 30 | 60 to 80* |
| Se | 0.3 | 0.3 |
| Zn | 60 | 70 to 80*† |

* Increase when diet has >0.25% S

† Include some HQ organic

37

## Summary

- ✓ Current estimates are usually close to correct
  - Feed **modest** excess to ensure adequacy
  - Base safety factor on variability, antagonism, accuracy, and toxicity risk
- ✓ Sulfate TM are usually good sources of mineral *but* reduce digestibility and energy

- TM source effects are more than just increased absorption (which may not even be that different)

38


39