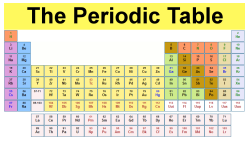
Assessing Mineral Availability and Real-World Implications



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Most formulation systems in US are based on factorial approach and absorbed minerals

- Replace inevitable losses via feces and urine (i.e., maint.)
- Replace minerals secreted in milk
- Replace minerals accreted in new tissue (growth)
- Replace minerals accreted in fetus

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Most formulation systems in US are based on factorial approach and absorbed minerals

Feed enough **absorbable** minerals to maintain **adequate** labile body stores and fluid concentrations

- Replace … nt.)
- Replace …
- Replace minerals accreted in new tissue (growth)
- Replace minerals accreted in fetus

Must know what is absorbed

Must know what's adequate
Is adequacy constant?

Must know concentrations

?

3

Issues with factorial system: *Efficiency of use of absorbed mineral*

- Milk averages 0.04 mg Cu/kg
- Cow produces 35 kg of milk
- Lactation requirement for absorbed Cu = 35*0.04 = 1.4 mg/d

- Are minerals required to make milk (or body or fetal tissue) ?
- Are these included in maintenance (constant not related to production) ?

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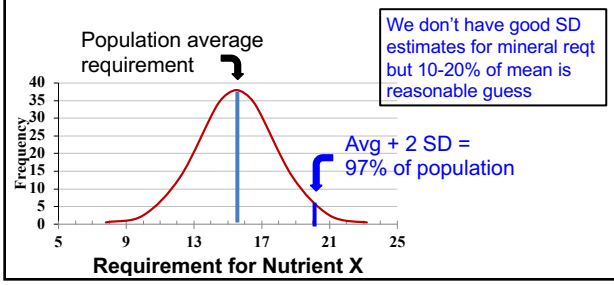
Issues with factorial system: *Requirement vs Recommendation*



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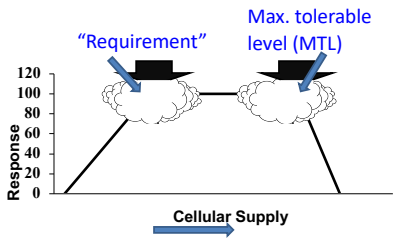
Don't forget the uncertainty regarding MTL (build in a 20% buffer ?)



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Absorbed Factorial Mineral Approach

Inputs

Feedstuffs
Mineral concentration

Absorption coefficients

A huge black box in mineral nutrition

g or mg/d of mineral available for use

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Mineral Availability via Mass Balance

- Measure amounts and mineral composition of:
  - Feed
  - Feces
  - Milk
  - Urine

Apparent Absorption = $\frac{(\text{Intake} - \text{Feces})}{\text{Intake}}$

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Apparent absorption ≠ Absorption coefficient

- Fecal mineral losses :
  - Unabsorbed dietary
  - Endogenous (Metabolic) Fecal ⟸ Part of maint. reqt
  - Homeostatic excretion

"True" Availability = $\frac{\text{Intake} - (\text{Feces} - \textbf{Met. Fecal})}{\text{Intake}}$

AC = True availability measured when cows fed approximately at requirement

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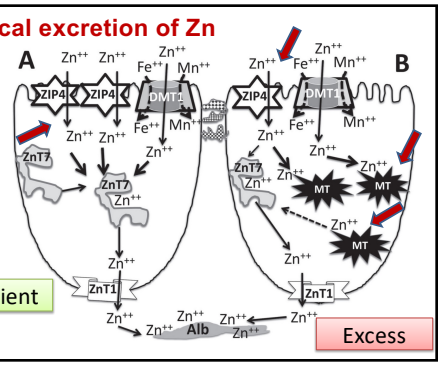
Homeostatic fecal excretion of Zn

Enterocytes



Goff, 2018 JDS

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So how are mineral AC measured?

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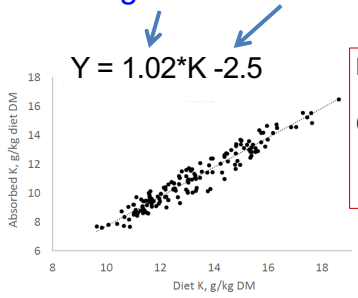
Obtaining AC and endo. fecal (Lucas plot)



EF: *f*(BW) (NRC 2001)

Correct: EF= *f*(DMI)

- Dry cow vs lact

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Estimating True Availability

Absorbed K, g/kg DM = 1.02(+ 0.06) x Diet K - 2.48(+ 0.74)

True Absorption

Metabolic Fecal K (implied maintenance)
Error is large (CV = 30%)

- Approach works well if:
  - Absorption rate is not regulated (and high)
  - Surplus mineral is excreted in the urine
  - Sources/diets have similar availability
- Used for the strong ions: K, Na, and Cl
- Can be used with Mg (source adjustment)

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Isotope method to measure AC

- Stable or radioactive isotopes of minerals
- Very good
- Very expensive
- Radioactive waste for some isotopes
- Most data are 50-60 years old

We have and into foreseeable future will have limited data on AC of most minerals

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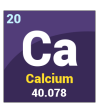
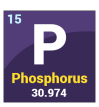
Macrominerals

- AC are getting more accurate
  - ✓ More data
  - ✓ Reanalysis of old data





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Absorption of Calcium

- AC for $CaCl_2$ = 0.95 (NRC 2001) (calf data)
- AC actually ~0.6 in older cattle
- Other sources were relative to $CaCl_2$
- Based on newer data, EF loss too high

Estimated AC and EF loss are often correlated (lower AC often = lower EF loss)

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Absorption of Phosphorus

- Form of P matters (Feng et al: 2015)
  - Inorganic P = 0.84
  - Organic P (including phytate) = 0.68
  - Labs could offer assay

Grass hay: 67% Inorganic; 33% organic:
AC = 0.67*.84 + .33*0.68 = **0.79**
SBM: 7% Inorganic; 93% organic: AC = **0.69**

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Magnesium

1. Absorbed from rumen
2. Absorption does not appear to be regulated
3. Real world antagonists
   - K (linear)
   - LCFA (-10 to 20%)
   - Soluble CP (must be very high)
4. Endo fecal Mg = ~0.3 mg/kg DMI (apparent absorption can be used to estimate AC)

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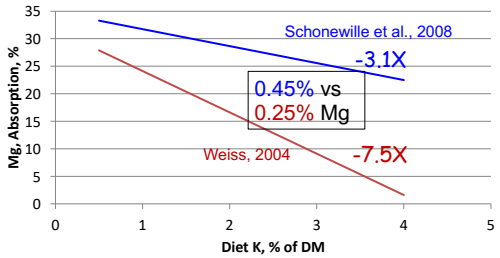
K and Mg Absorption in Dairy Cows



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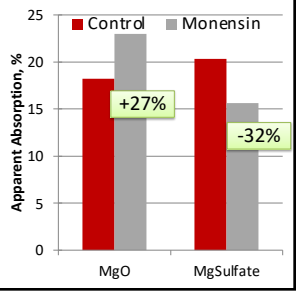
Monensin ⬆ and ⬇ Mg absorption

- All diets 2.1% K (0.8 from K carb)
- 0.35% Mg (0.2 basal)
- Treatments
  - MgO or $MgSO_4$
  - 0.2 vs 0.4% S
  - 0 or 14 mg/kg monensin

Tebbe et al., 2018



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Mg AC in NRC (2001) needs revised

	NRC, 2001	Revised
Basal feeds	0.16	0.30* (± 0.16)
Good MgO	0.70	0.20* to 0.25
$MgSO_4$	0.90	0.35* to 0.40

* Standardized to 1.2% K

Feeds are better, supplements are worse than we thought

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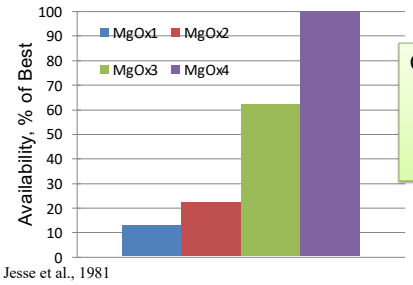
Mg Availability from 4 sources of MgO



Jesse et al., 1981

Can lab test **rank** these ?

Can lab test **quantify** these ?

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Measuring AC of TM is extremely difficult

- Very low AC (large measurement errors)
- Numerous antagonists
- Likely source x antagonist interactions
- Homeostatic fecal excretion
- 'Tightly' regulated absorption

Diet may have greater effect on AC than mineral source

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Small change in AC of TM can have big effect on diet

Cu TAR (35 kg milk): 10 mg/day
DMI = 24 kg, Basal diet 8 mg/kg DM

Basal AC = **0.03** vs. **0.05** $CuSO_4$ AC = **0.04** vs **0.06**

	Diet conc.	$CuSO_4$ needed
High basal+**high** $CuSO_4$	9 ppm	49 mg/cow/d
Low basal+**Low** $CuSO_4$	13 ppm	445 mg/cow/d

+ ~400 mg/d

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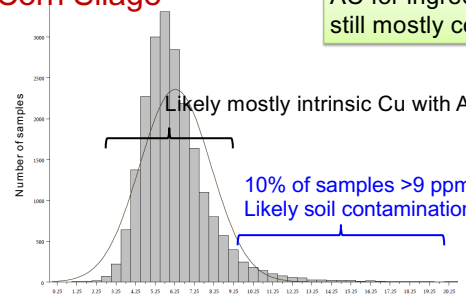
Corn Silage

AC for ingredients are still mostly constants



Knapp and Weiss, 2016

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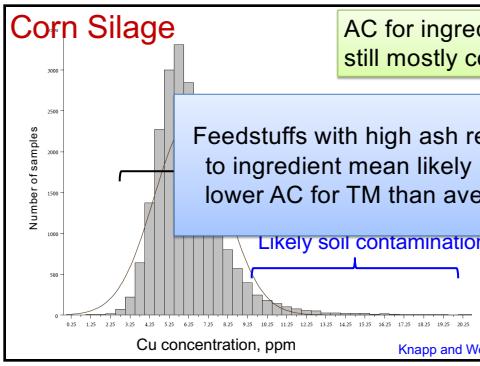
Corn Silage

AC for ingredients are still mostly constants



Knapp and Weiss, 2016

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Known and potential antagonists for TM

Cu (0 to 0.1)
- S
- Soil (clay)
- Mo+S
- Fe
- Zn (?)
- Fiber

Mn (0 to 0.01)
- P
- S
- Ca (?)
- K (?)
- Fe

Zn (0.05 to 0.2)
- S
- Cu (?)
- Phytate (?)
- Fiber

Se
- S
- Ca
- Met (yeast)

Can't quantify yet, but qualitative adjustment may be needed

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Relative Availability (often used for commercial TM)

1. Feed a standard mineral (e.g., $CuSO_4$)
2. Feed test mineral X (same amount)
3. Measure **appropriate response** and report ratio

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

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

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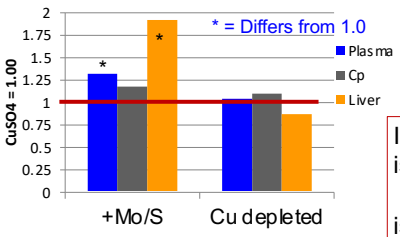
Relative Availability Coefficients

Relative availability of Cu from Tribasic Cu



Spears et al., 2004

If CuSul AC = 0.05
is TBC = ~0.10 ?
or
is CuSulf = 0.025
and TBC = 0.05 ?

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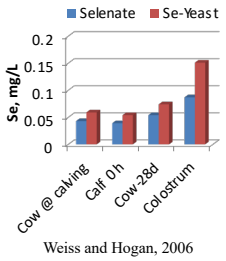
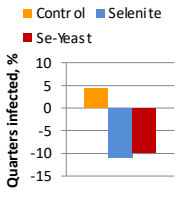
Does the response measure have value ?

Se-Y: 1.2 to 2X better



Weiss and Hogan, 2006

Se-Y = selenite



Malbe et al., 1995

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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: Yes, adjust for availability
2. Se: Don't adjust
3. Mn: Probably doesn't matter
4. Zn: Don't adjust (microbiome effects?)

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Revised Ingredient AC

Macrominerals

Ca: 0.4 to 0.6
P: 0.7 to 0.9*
Mg: 0.2 to 0.35
K, Na, Cl: ~1.0

* Adjust based on lab tests?

Trace Minerals

Cu: ~0 to 0.1
Fe: 0.05 to 0.15
Mn: ~0 to 0.01
Se: 0.5 to 0.85
Zn: 0.05 to 0.20

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What would revised AC do to average* diets?

- If lots of Mg supplement fed; ⬆Mg%
- If lots of Ca supplement fed: ⬆Ca%
- P concentration may change depending on basal ingredients
- ⬆Mn

* Minimal antagonists

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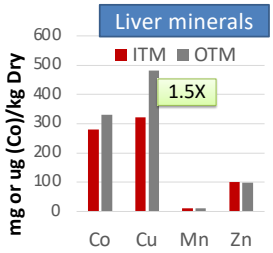
Are OTM more available ? Yes

- -30 to 30 DIM
- Sulfate or AA-complex Cu, Mn, Zn (Co only in AA)
- TMR (mg/kg PF/ Fresh):
  - Zn 83 or 70
  - Mn 76 or 70
  - Cu 14 or 12



Osorio et al., 2016

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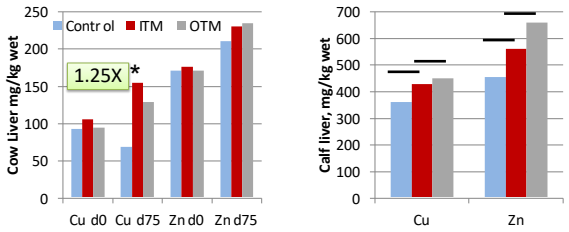
Are OTM more available? Not always

Late gestation beef cows



Marques et al., 2016

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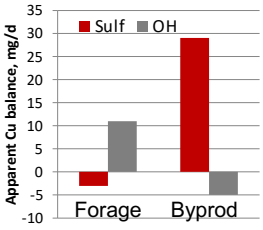
Numerous interactions: concluding sulfate consistently < available is incorrect

- High forage vs high byproduct NDF diets
- Ca. 50% of Zn, Cu, Mn from sulfate or hydroxy
- Source x fiber NS for Mn and Zn but P < 0.05 for Cu



Faulkner et al., 2016

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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	✓
▪ Maintains good health	?
▪ GI function/ nutrient digestion	?

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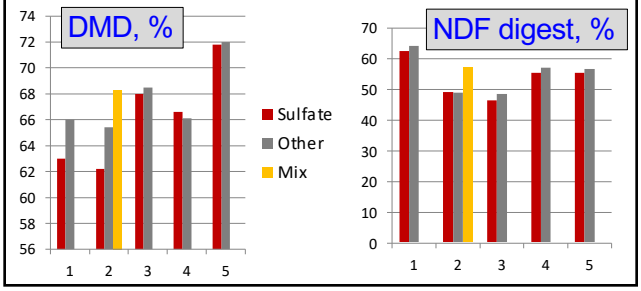
TM Sulfates may reduce digestibility

ElAshry et al.,2012;Wang et al.,2012;Faulkner&Weiss, 2017;Pino&Heinrich,2016; Miller et al.,2020



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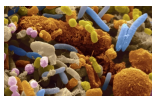
Are differences between organic and inorganic TM only bioavailability?

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

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Conclusions

- ✓ Factorial approach = 50% of population
- ✓ Reqt *1.1 to 1.2 = ~97% of population
- ✓ Need to incorporate more sources of variation into AC
- ✓ Remember interactions

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Conclusions

- ✓ Mg sources AC very different from 2001
- ✓ AC for TM are still poorly defined but better than using only concentrations
- ✓ Minerals don't have to be absorbed to affect cows

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