

Recent advances in trace mineral nutrition for beef cattle in grazing and feedlot production



Nelore Cattle – Butler Farms Inc.



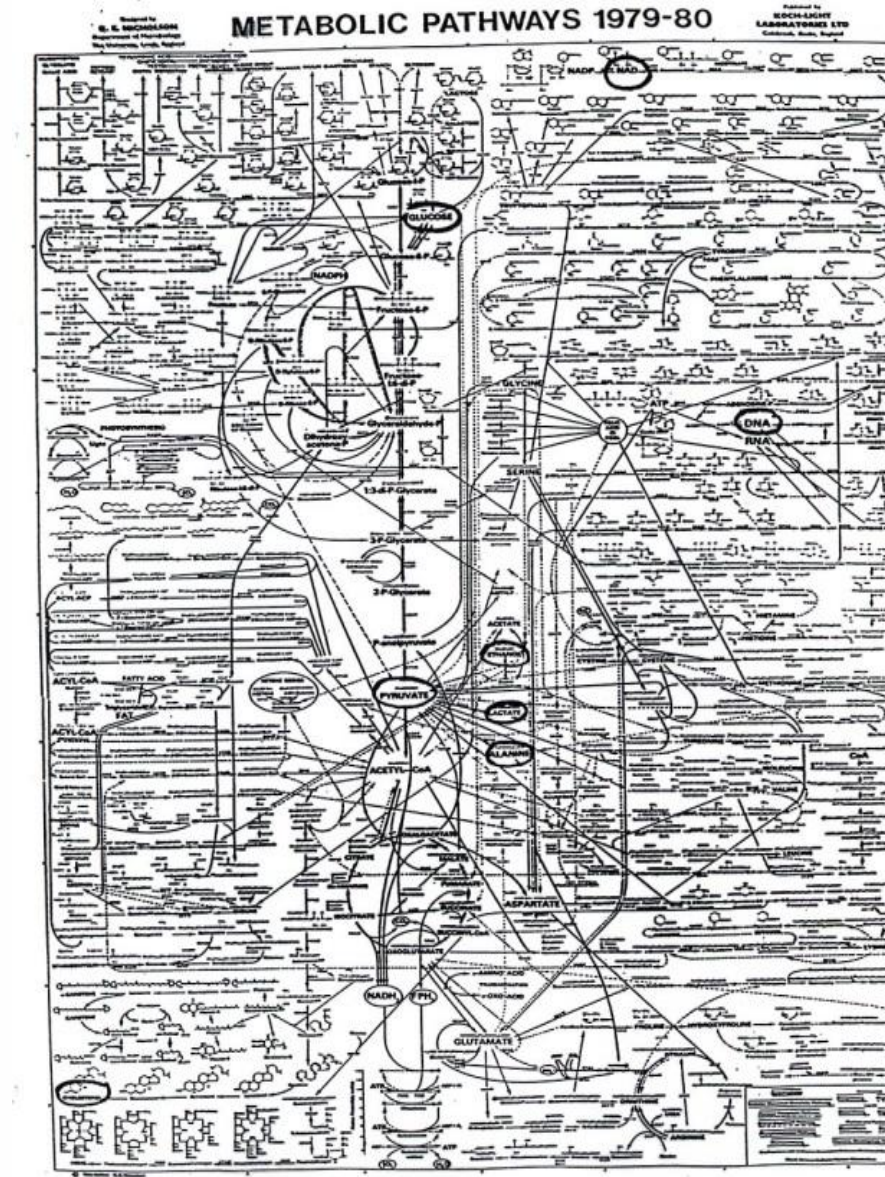
Terry Engle
Colorado State University

Outline

- ✓ General functions of trace minerals (Cu, Mn, Zn, and Cr)
- ✓ Requirement estimates
- ✓ What we think we know vs. what we actually do
- ✓ Challenges
- ✓ Homeostasis of trace minerals/current research
- ✓ Production data (feedlot and cow-calf)
- ✓ Future direction

General functions of minerals:

- Structural (bone, cytoskeleton, connective tissue)
- Maintenance of homeostasis
 - acid base balance (RBC and kidney)
- Enzyme activity
 - metalloenzymes
 - metal activated enzymes
- Components or regulators of hormones - Iodine
- Lipid metabolism
- Gene expression
- Hormone (production, storage, and secretion)
- Vitamin metabolism
- Component of Vitamin B₁₂ (prop. → succ.-CoA; methyltransferase)
- Reproduction
- Membrane stability
- Immunity



http://mcb.berkeley.edu/courses/mcb100fall/past/2003/assets/metabolic_pathways.jpg

Requirement Estimates: Data Comparison

- **AFRC** – Agriculture and Food Research Council (Report 6).
- **ARC**: Agricultural Research Council: The Nutrient Requirements for Ruminant Livestock.
- **BR CORTE** (2016/23) – Nutrient requirements for Zebu beef cattle. Valadares Filho et al., (2016/23).
- **CSIRO** – Commonwealth Scientific and Industrial Research Organization
- **Costa e Silva** (2016) Macrominerals and Trace Element Requirements for Beef Cattle
- **NASEM/NRC** (2016) – National Research Council Nutrient Requirements for Beef/Dairy Cattle

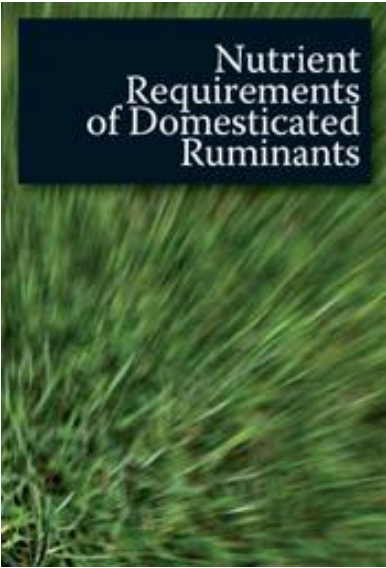
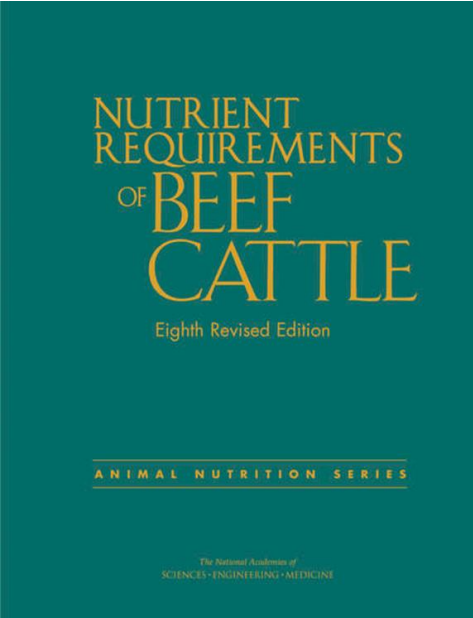
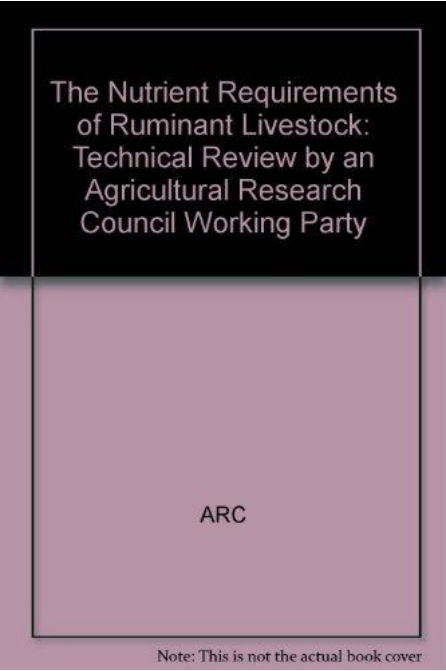


Trace Element Requirements for Beef Cattle

Dietary Requirements

Item	mg/kg dry matter intake					
	Cu	Fe	Mn	Se	Zn	Co
NASEM (2016)	10.0	50.0	20.0	0.10	30.0	0.15
CSIRO (2007)	---	---	---	0.05	11.6	---
ARC (1980)	7.1	---	---	---	27.0	---
Costa E Silva (2015)	9.5	218.0	9.5	0.57	61.0	2.78
BR-Corte (2016/23)	7.9	207.3	23.1	0.56	56.8	0.78

Costa e Silva et al. (2015); Absorption coefficients, where reported, are highly variable: Cu 6-84%; Mn 1-75%; Se 30-50%; Zn 5-80%.



Feedlot diets: What we say we should do and what we actually do can be different.

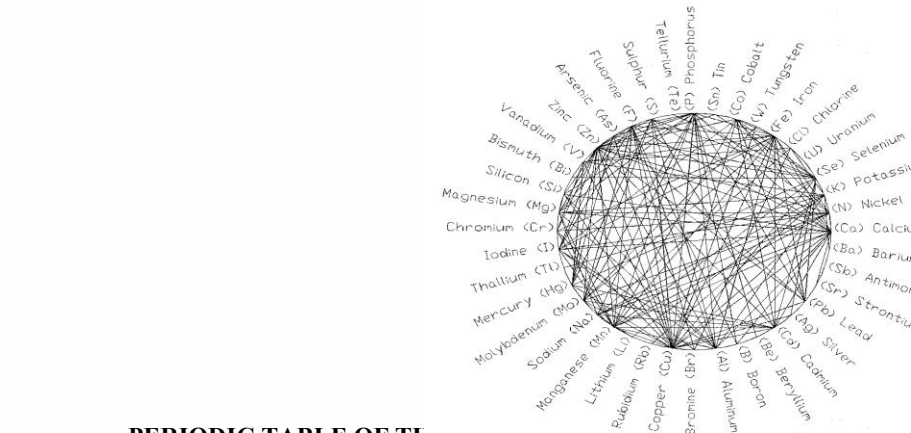
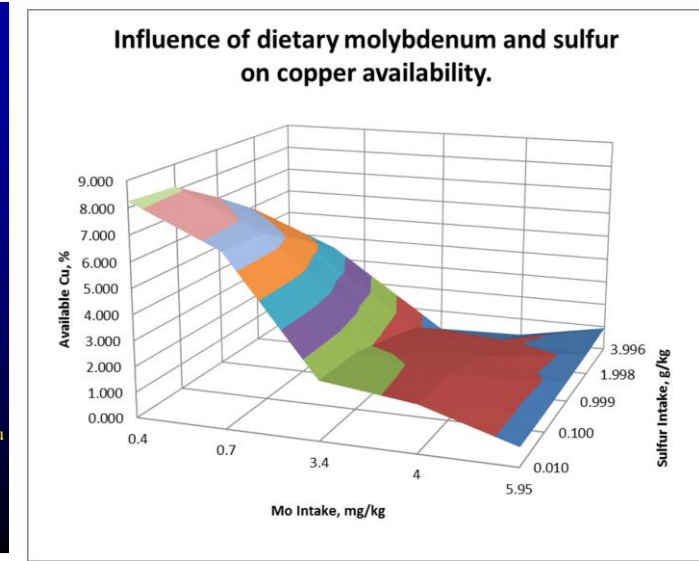
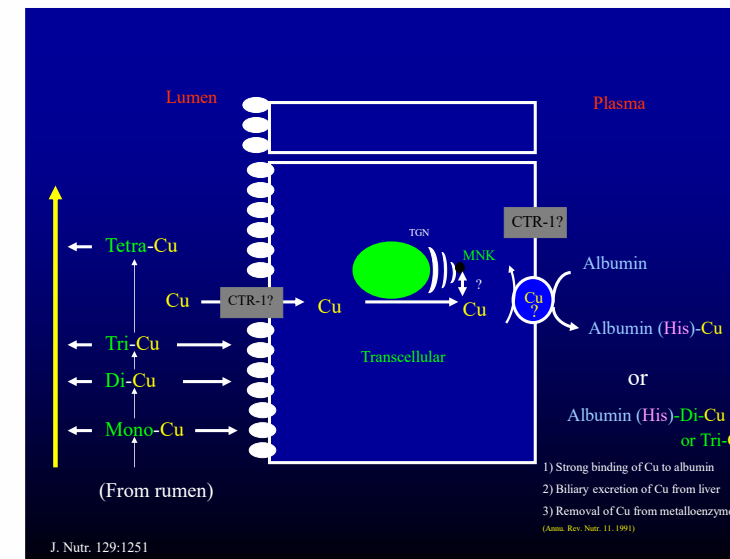
- **Vasconcelos and Galyean (2007) and Samuelson et al. (2016):** Surveys of consulting feedlot nutritionists in the US indicate that most industry supplemental mineral zinc concentrations are 2 to 3 times (mode: 100 mg of supplemental Zn/kg DM) the total concentrations recommended by the NASEM (2016; 30 mg Zn/kg DM).
- **Silvestre and Millen (2019).** The 2019 Brazilian survey on nutritional practices of feedlot cattle consulting nutritionists. Mean/mode for Zn supplementation was 55.1/40.0 mg/kg DM and Cu 15.5/15.0 (similar to BR-CORTE 2016/23 recommendations).

Why the Variation?

- Contamination
- **Analytical Methods (e.g., Cr, Mn)**
- Absorption coefficient adjustment
- Treatment/experimental design
- Environment
- **Breed**
- **Antagonists**
- **Stress**
- Diet type
- Mineral sources
- Examine experiments thoroughly.

Interactions with other elements

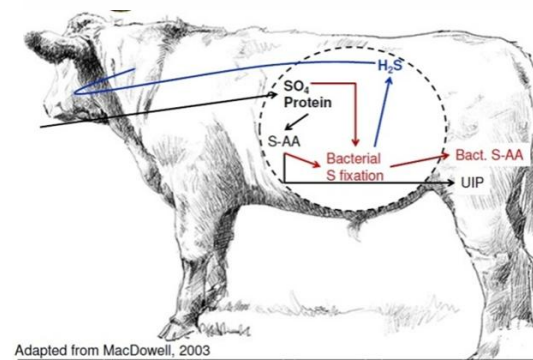
- Cu-Mo-S (thiomolybdates; mono, di, tri, tetra) High concentrations of Mo (10 mg Mo/kg DM) may not affect Cu status of cattle any more than moderate concentrations of Mo (5 mg Mo/kg DM).
 - Mo in water – does not appear to have the same influence on Cu metabolism relative to Mo in the feed/diet. (Kincaid, 1980 calves; Kistner et al., 2017 feedlot steers: Thorndyke, et. al., 2020, 2021, 2023 Cows, calves, and steers).
- Fe and Cu
 - Synergistic (Enzymes)
 - Antagonistic (Gut)
- High Zn can decrease Cu absorption -
 - Molecular adaptation of the intestinal cells.
- Rumen microorganism interaction with trace minerals?



PERIODIC TABLE OF THE ELEMENTS

Adapted from Sargent-Welch Scientific Company

Puls, 1994



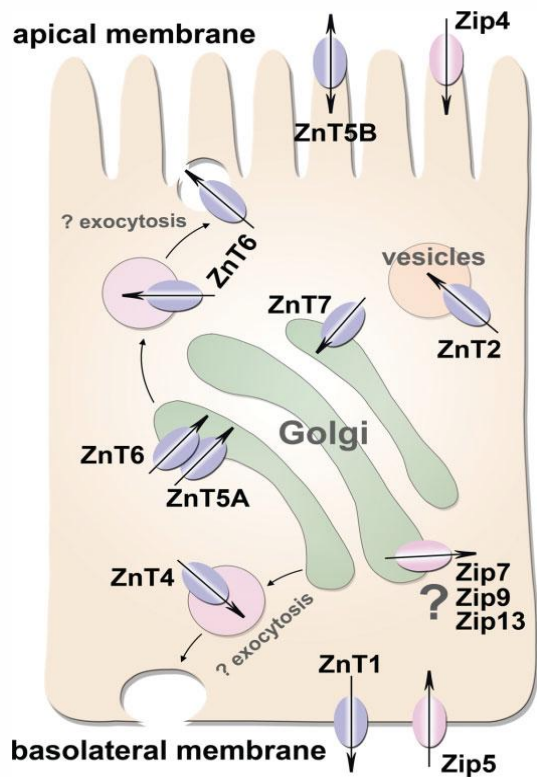
Adapted from MacDowell, 2003

Challenges to increased trace mineral supplementation

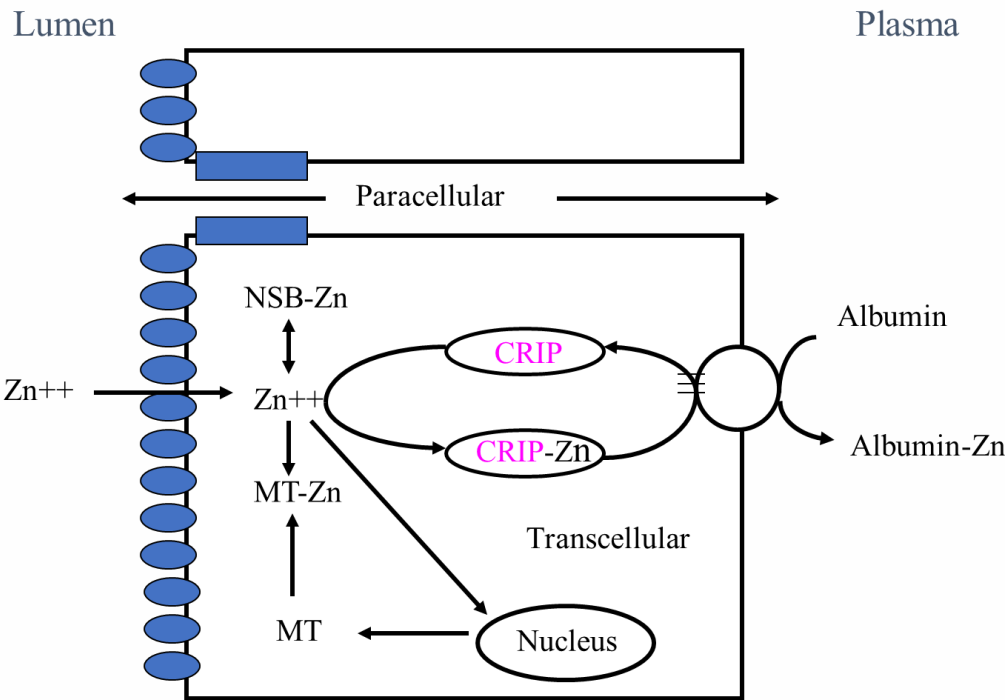
- **Trace mineral homeostasis**
 - Intake (palatability), gastrointestinal tract, excretion
 - Animal demand (Huerta et al. 2002; Genther-Schroder et al., 2016; Carmichael et al. 2018)
- **Waste management**
 - Absorption vs. excretion
 - Estimates are most commonly accomplished with total fecal and urine collection.
 - Challenge: often observe reduced feed and water intake in digestion stalls.
 - Contamination
 - Negative apparent absorption values for certain trace elements can happen (Wang et al., 2013; Hejna et al., 2019; Marchande et al. 2024).
 - Mass balance experiments? Not sensitive enough for trace mineral experiments.
- **Rumen environment**
 - Microbial requirements
 - Redox potential

Trace mineral homeostasis - Zinc

- If Zn is involved in protein metabolism and growth should more be supplemented?
- More is not always better.
- Homeostatic control of Zn absorption.
 - Absorption and retention (endogenous excretion) are controlled.



Wang and Zhou. 2010. IUBMB Life. 62:176-182



J. Nutr. 122:89

Homeostatic control of zinc in lactating dairy cattle^a

	Dietary zinc (mg/kg)	
	39.5	16.6
Zn consumed, mg/d	695 ^c	295 ^d
Net ⁶⁵ Zn absorption ^b	34.8 ^c	53.4 ^d
Milk zinc		
⁶⁵ Zn ^b	6.3 ^c	14.4 ^d
mg Zn/d	60	52
Net ⁶⁵ Zn retention ^b	28.5 ^c	39.0 ^d

^aCows were fed diets for 6 weeks. ⁶⁵Zn was given orally on week 5 and followed for 14 days.

^b% of ⁶⁵Zn dose.

^{c,d}(P < 0.01).

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Effect of zinc status on zinc absorption

- Lactating cows depleted of zinc for 6 weeks (6 mg Zn/kg DM).
- Apparent zinc absorption
 - Initial: 21%
 - 1 week of depletion: 51%
 - 6 weeks of depletion: 64%
 - 1 week of repletion: 33%

Zinc absorption and retention in beef cattle

Effects of gestational status on apparent absorption and retention of copper and zinc in cattle

Item	Pregnant	Non-pregnant	P <
Copper			
Intake, mg/d (6.8 mg Cu/kg DM)	88.9	88.9	---
Apparent absorption, mg/d	7.9	2.9	0.06
Apparent retention, mg/d	6.8	1.7	0.05
Zinc			
Intake, mg/d (17 mg Zn/kg DM)	220.3	220.3	---
Apparent absorption , mg/d	21.9	12.0	0.04
Apparent retention , mg/d	17.3	7.8	0.06

- Increasing total dietary Zn above requirements decreased the amount of Zn absorbed and retained in other ruminants (1973; Suttle et al, 1982; VanValin et al., 2018).

Increasing Zn in feedlot diets

Summary of feedlot research data investigating zinc dose on feedlot cattle growth and carcass characteristics (2000-2024).

Author	Animal	N (trt)	EU/trt	Days on feed	Study type	Approximate [Zn] in basal diet, mg Zn/kg DM	Zn dose + total diet, mg Zn/kg DM	Response to increased dietary Zn		
								Overall ADG	DMI	Marb.
Francis et al., 2024	Steers	68 (4)	8	144	Rec/Fin.	88.0	88-310	↑/↔	↔/↔	↔
Heiderscheit and Hansen 2022	Steers	54 (3)	18	52	Receiving	54.0	54 - 174	↔	↑	---
Budde et al 2019	Steers	400 (5)	8	182	Grow/Fin.	28.2	28.2 - 118.2	↔	↔	↔
Van Bibber-Krueger et al., 2019	Heifers	480	6	144	Fin	51.35	51-141	↔	↔	↔
Montano et al 2018	Holstein steers	168 (4)	7	336	Grow/Fin.	27.0	27.0 - 67.2	↔	↔	↔
Nunnery et al 2007	Heifers	97 (4)	3	168	Rec./Fin.	52.5/44.1	44.1 - 90.9	↔/↔	↔/↔	↔
Kessler et al 2003	Bulls	60 (4)	15	284	Grow/Fin.	34.1	34.1 - 79.0	↔	↔	↔
Spears and Kegley 2002	Steers	60 (4)	15	182	Grow/Fin.	33.0/26.0	26.0 - 55.0	↑/↔	↔	↑
Malcolm-Callis et al 2000	Steers	108 (3)	2	112	Fin.	70.0	70.0 - 280.3	↔	↔	↔

Challenges

- Waste management
 - Fecal excretion of Cu, Mn, and Zn



Courtesy of Jim Ippolito



Trace mineral fecal excretions in lactating Holstein cows receiving diets differing by their sulfate trace mineral supply.

Item	NRC (2001)	Increased Mn and Zn (2X NRC; sulfate)
Intake, mg/d (mg/kg DM)		
Cu	473 (18.9)	461 (18.4)
Mn	882 (35.2)	2,934 (116.9)
Zn	2,245 (90.2)	4,331 (172.5)
Fecal excretion, mg/d		
Cu	516	553
Mn	1,041	3,101
Zn	1,995	3,500

Marchland et al. 2024.

- Elevated Mn and Zn had no impact on animal performance
- Limited research in feedlot cattle.
- Rough estimate: Apparent absorption of Cu, Mn, and Zn ≈ 5-30% (Nockels et al. 1993; Ward and Spears, 1995; Pogge et al. 2014; Charmichael et al. 2016).
- Should this be expressed on a per unit of animal production?
- Future research is needed.

Can increasing dietary trace minerals alter rumen fermentation?

Rumen microorganism trace mineral requirements?

- Trace minerals required by rumen microorganisms.
 - Iron
 - **Zinc**
 - **Copper**
 - Cobalt
 - Molybdenum
 - Nickel
 - Manganese?

Rumen Fermentation

- The role that Cu and Zn play in rumen microbial fermentation is not well understood.
- The majority of research determining microbial trace mineral requirements has been conducted *in vitro*.
- Early *in vitro* rumen simulated experiments indicate that low concentrations of Cu and Zn in artificial rumen fluid were adequate to optimize fiber digestion (Cheng et al, 1955; Hubbert et al, 1958; Durand and Kawashima, 1980).
- Requirements of the host ruminant for zinc and copper are much higher than those needed by rumen microorganisms (≈ 0.1 mg Cu/l; Zn 0.2 mg/l).

Ruminal disappearance of copper and zinc from forages from dacron bags incubated for 0 or 72 hours in the rumen of cattle

Ruminal disappearance of copper and zinc from forages and corn from dacron bags incubated for 0 or 72 hours in the rumen of cattle

Item	Copper		Zinc	
	0 ^a	72 h	0 ^a	72 h
	----- % of total -----			
Alfalfa	88.9	92.9	25.8	79.4
Rhizoma peanut	50.6	89.6	18.1	80.5
Dwarf elephantgrass	84.4	94.3	7.3	75.5
Bermudagrass	69.9	75.8	43.1	62.1
Bahiagrass	63.1	81.7	33.8	53.0
Limpograss	70.0	69.5	26.6	67.2
Ground corn ^b	77.0	84.3	18.0	58.8

^aAmount disappearing following washing with water.
 Emanuele and Staples, 1990

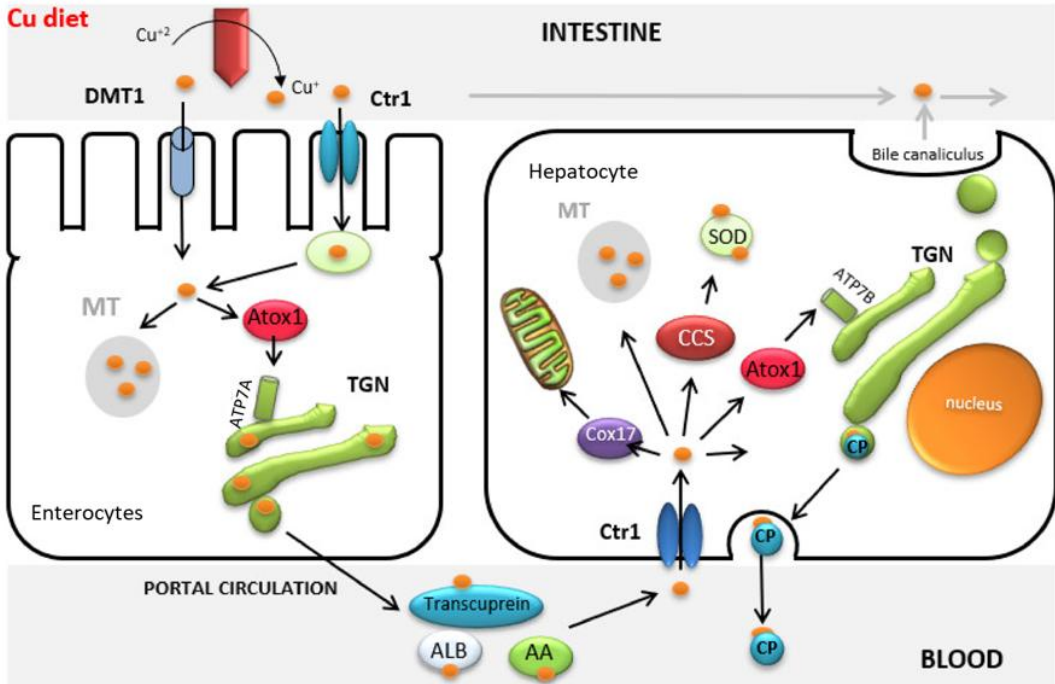
^bCalculated from Zanetti et al. (2017).

- A high proportion of Cu and Zn is released relatively quickly.
- Cu and Zn may be sequestered in the plant material differently.

***Note: Microenvironments within the rumen are exposed to high concentrations of Cu and Zn.

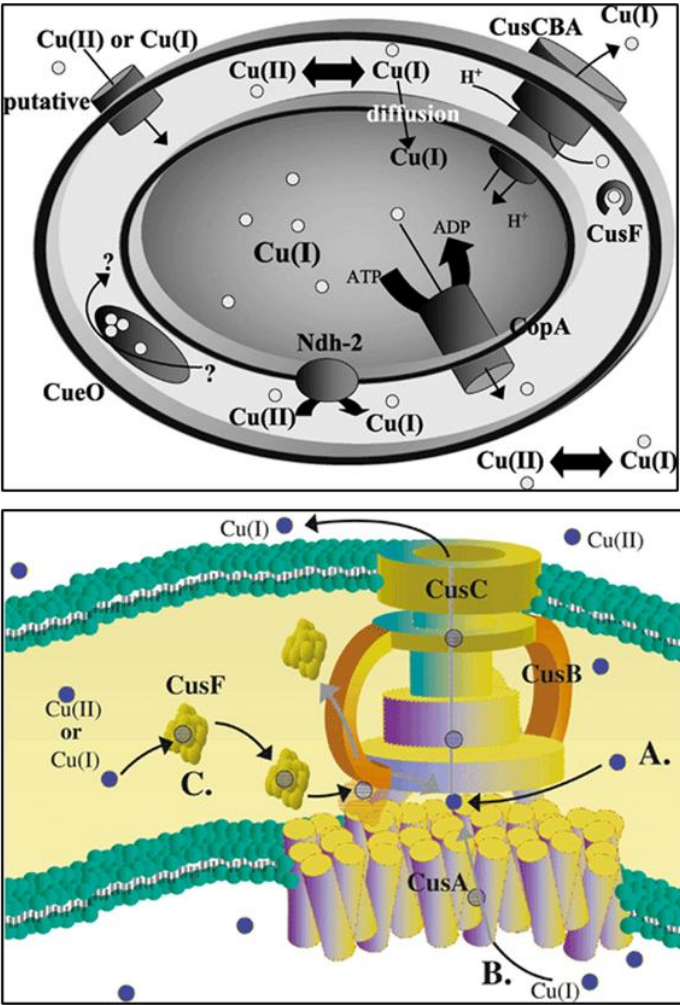
Copper homeostasis

Animals



López-Alonso, M., and M. Miranda. 2020. Copper Supplementation, A Challenge in Cattle. Animals 10:1890.

Bacteria



Trace minerals, mineral solubility, digestibility, and rumen fermentation

- Reduction in total-tract digestibility of NDF and CP in crossbred steers fed a medium quality hay receiving an intraruminal bolus with 12.5 g of copper oxide (Arthington 2005).

Effect of trace mineral source on fiber digestion in lactating dairy cows^a

Item	Sulfate ^a	Hydroxy ^a
NDF digestion, % ^b		
Forage diet ^c	43.0	45.9
By-product diet ^d	49.8	51.2

^aCopper, zinc, and manganese were supplemented at 10, 32, and 30 mg/kg, respectively.

^bTrace mineral source effect ($P < 0.02$).

^c44% corn silage, 20% alfalfa silage.

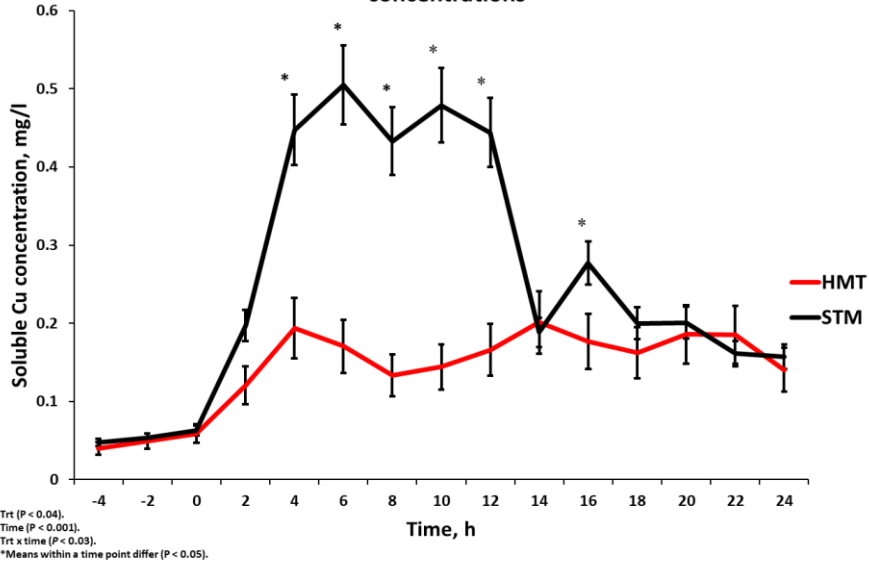
^d11% corn gluten feed, 15% beet pulp, 14.1% soy hulls.

Faulkner and Weiss, 2017



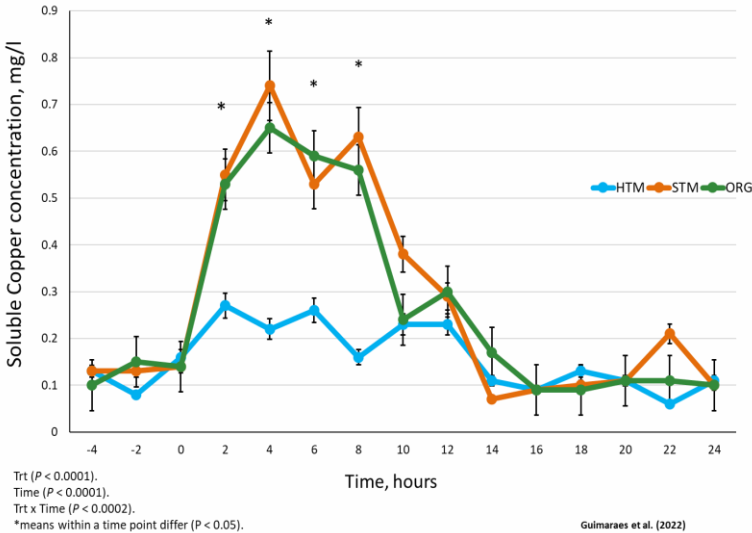
Low quality forage diet

Figure 1a. Influence of trace mineral source on rumen soluble Cu concentrations

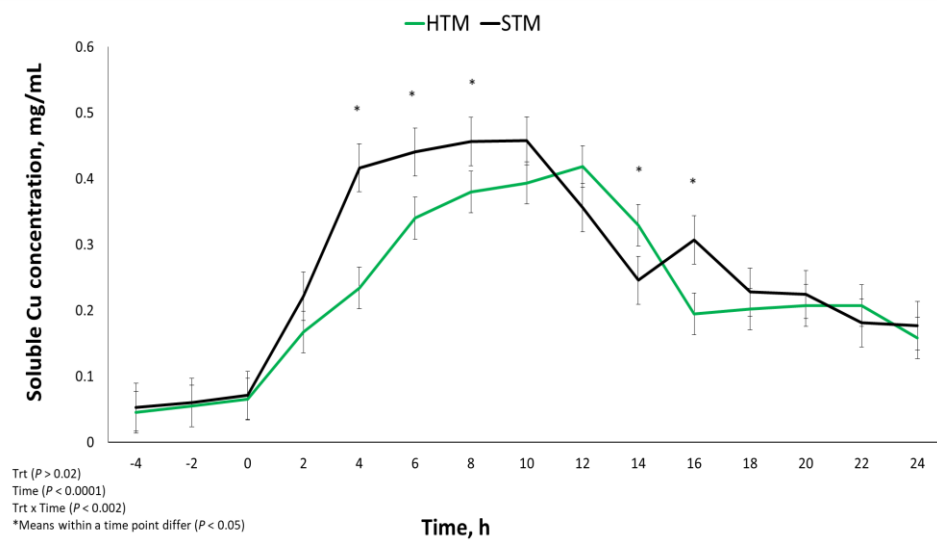


Dairy diet

Influence of trace mineral source on rumen soluble Copper concentrations



Feedlot diet



Digestibility and fermentation characteristics

Effect of trace mineral source on digestibility in steers fed a low-quality hay supplemented with protein^a

	Sulfate	Hydroxy	P<
DMI, kg/d	7.4	7.4	-----
DM digestibility, %	51.9	53.4	0.07
NDF digestibility, %	40.4	42.7	0.04
ADF digestibility, %	32.4	34.1	0.05
CP digestibility, %	51.2	54.3	0.06
Total SCFA, mM	59.8	72.3	0.05

^aCopper, manganese, and zinc were supplemented at 20, 40, and 60 mg/kg, respectively.

Effect of Trace Mineral Source on Digestibility and Ruminal VFA in Steers Fed a Diet Formulated to Meet the Requirements of a Lactating Dairy Cow^a

Item	Sulfate	Hydroxy	P<
DMI, kg/d	8.2	8.2	-----
DM digestibility, %	64.6	66.5	0.05
NDF digestibility, %	43.0	47.6	0.05
ADF digestibility, %	29.8	32.4	0.05
Total ruminal VFA, mmol/L	73.3	77.4	0.05

^aZinc, copper and manganese were supplemented at 60, 10, and 40 mg/kg, respectively.

Feedlot diet

Influence of trace mineral source on fermentation characteristics

Item	STM ¹	HTM ¹	SEM	P-value ³
Ruminal pH	5.72	5.73	0.06	0.93
Total VFA ² , mmol/L	117.1	118.1	2.74	0.61
Acetate ⁴	31.4	29.5	2.59	0.47
Propionate ⁴	35.7	45.7	3.12	0.05
Butyrate ⁴	17.4	11.6	1.77	0.05

Treatment means are different (*P*<0.05).

¹ Treatments are: sulfate trace minerals (STM) and hydroxychloride traces minerals (HTM)

² Volatile fatty acid

³ Treatment interaction

⁴ Individual volatile fatty acid are represented in mmol/100 mmol unit.

***No impact on fiber or starch digestibility.



Meta-analysis of the effects of sulfate versus hydroxy trace mineral source on nutrient digestibility in dairy and beef cattle

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¹Department of Animal Science, Michigan State University, East Lansing 48824

²Micronutrients USA LLC, Indianapolis, IN 46231

Table 1. List of studies, comparisons, and explanatory variables included in the meta-analysis

Reference	Study type	Design code	Observations per treatment	Method ¹	Top dress or TMR	Beef or dairy
Caldera et al., 2019	Randomized block	RCBD	4	Total collection	Top dress	Beef
Daniel et al., 2020	Latin square	LS	13	uNDF ₂₄₀	TMR	Dairy
Faulkner and Weiss, 2017 (byproduct)	Split-plot replicated Latin square	LS	18	Total collection	Top dress	Dairy
Faulkner and Weiss, 2017 (forage)	Split-plot replicated Latin square	LS	18	Total collection	Top dress	Dairy
Genther and Hansen, 2015 (low level)	5 × 5 Latin square	LS	5	In situ 24 h	TMR	Beef
Genther and Hansen, 2015 (high level)	5 × 5 Latin square	LS	5	In situ 24 h	TMR	Beef
Guimaraes et al., 2021	Randomized block	RCBD	6	Total collection	TMR	Beef
Guimaraes et al., 2022	Randomized block	RCBD	4	Total collection	TMR	Beef
Miller et al., 2020 (conventional)	Replicated 4 × 4 Latin square	LS	14	uNDF ₂₄₀	TMR	Dairy
Miller et al., 2020 (brown mid-rib)	Replicated 4 × 4 Latin square	LS	14	uNDF ₂₄₀	TMR	Dairy
Micronutrients trial 2017D123USCZM	Crossover	LS	14	uNDF ₂₄₀	TMR	Dairy
Micronutrients trial 2017D103CACZM	Split-plot replicated Latin square	LS	6	In situ 24 h	TMR	Dairy

¹uNDF = undigested NDF after incubation in rumen fluid for either 336 or 240 h.

Summary:

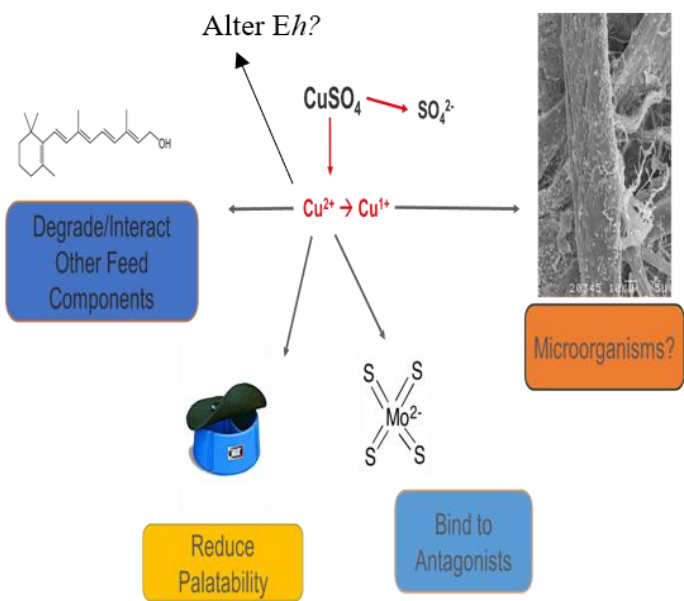
- Dry matter digestibility: HTM supplementation increased DMD by 1.64 ± 0.35 units in beef cattle studies compared to STM. No impact on DMD in dairy cattle studies.
- NDF digestibility: Increased (2.68 units) in HTM compared to STM supplemented cattle but was also impacted by method (total collection/marker vs in situ incubation).
- DMI was not impacted by TM source.

Ruminal impact?

- Ruminal trace mineral solubility may impact ruminal fermentation possibly through impacting rumen microbiota function.

Can soluble ions of **copper** impact rumen redox potential?

- Solubility of Cu vs. free ion solubility are different.
- Inclusion of mineral salts (Cu, Mn, and Zn) have been reported to reduce nutrient digestibility in cattle (5 - 25 mg Cu/kg DM; Genther and Hansen, 2015; Faulkner and Weiss, 2017; Caldera et al., 2019) → soluble ruminal Cu concentrations ranging from 0.2 to 0.6 mg Cu/l (Caldera et al., 2019).
- Other elements? DCAD/EB in the rumen and redox potential in soil can influence mineral availability.



Influence of copper dose on rumen fermentation characteristics in fistulated steers receiving a finishing diet (13.7% CP, NEg, mcal/kg 1.53)

Item	Supplemental Cu, mg/kg DM			P<
	0 ¹	10	20	
Ruminal pH	5.61	5.58	5.62	0.85
Ruminal soluble Cu, mg/L	0.08 ^c	0.21 ^b	0.30 ^a	0.04
Cu ⁺⁺ , % ²	63%	48%	29%	0.02
Redox potential, mV	-182.3	-180.7	-150.2	0.10
Total VFA ³ , mmol/L	114.8	117.4	112.8	0.67
Acetate ³	52.4	53.2	54.1	0.47
Propionate ⁴	32.2 ^a	33.3 ^a	27.2 ^b	0.05
Butyrate ⁴	12.4	10.4	14.3	0.09

¹Basal diet contained 4.8 mg Cu/kg DM.
²Calculated as Cu⁺⁺/ruminal soluble Cu.
³Volatile fatty acid.
⁴Individual volatile fatty acid are represented in mmol/100 mmol.

- Data indicate a possible impact on Eh and rumen fermentation.
- Is this reduction in propionate enough to reduce animal performance?

Production impacts?

Effect of trace mineral source on performance of finishing steers

	Sulfate	Hydroxy	P-value
n=	200	200	
ADG, kg/d	1.72	1.77	0.12
DM intake, kg/d	9.9	10.1	0.27
Gain:feed	0.174	0.176	0.59
Hot carcass wt, kg	402.1	411.1	0.04
Dressing, percentage	62.4	63.3	0.01
Longissimus muscle area, cm ²	89.4	91.3	0.03
Yield grade	2.53	2.70	0.04

Spears et al., 2024

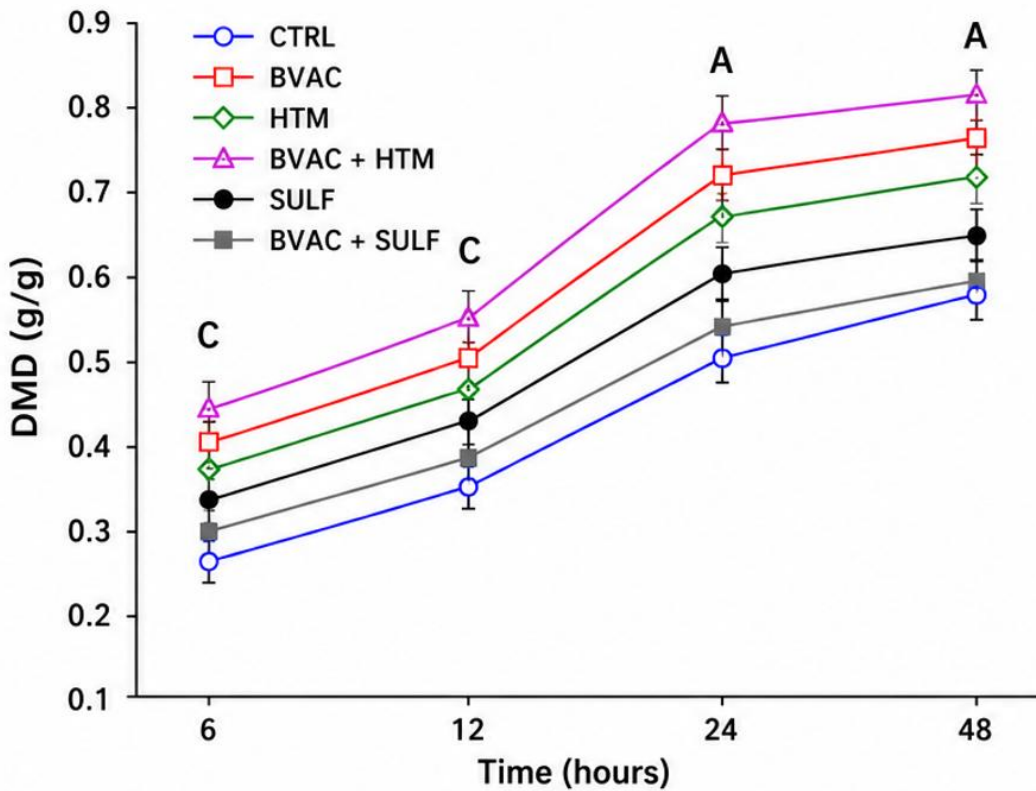
PSXII-17 Trace minerals source influences the performance of Nellore cattle in the growing phase during the transition between dry to rainy season in Brazil 🇧🇷

[Iorrano A Cidrini](#), [Josiane F Lage](#), [Igor Ferreira](#), [Karla Oliveira](#), [Laura F Prados](#), [Gustavo R Siqueira](#), [Flávio D Resende](#)

Journal of Animal Science, Volume 98, Issue Supplement_4, November 2020, Pages 445–

Effect of trace mineral source on performance of Nellore cattle grazing pasture and supplemented with limited concentrate.

	Inorganic	Hydroxy	P-value
Body weight, kg			
Initial	348.7	350.7	0.28
Final (day 90)	392.0	397.1	0.03
Average daily gain, kg	0.47	0.51	0.01



In vitro rumen fermentation data:
Indicates possible synergism between trace mineral source and DFM.

Leonel et al., 2026

Gut Barrier Function

Loss of gut barrier integrity:

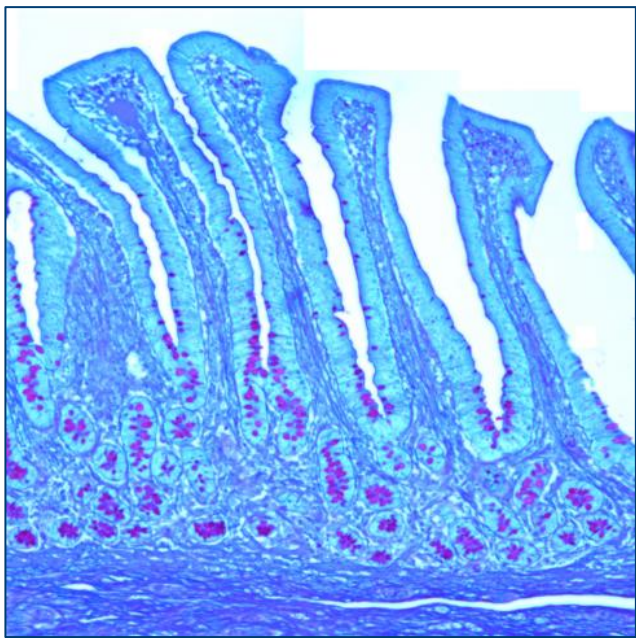
- Allows for passage of pathogens into circulation which initiates a systemic immune response.
- Factors that can cause gut barrier dysfunction
 - ✓ Feed restriction
 - ✓ Weaning
 - ✓ Heat stress

Effect of zinc source and feed restriction on gut barrier integrity

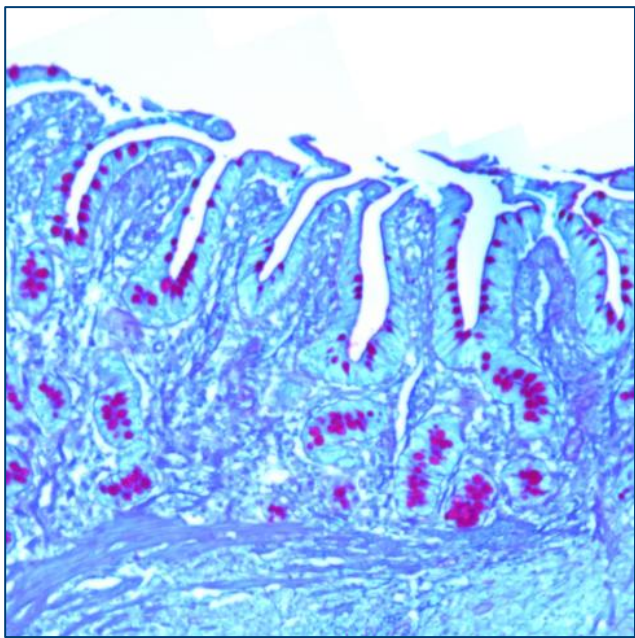
24 Holstein cows; 159 DIM

2×2 factorial:

- 1. Ad-libitum fed or feed restricted
- 2. ZnSO₄ or Hydroxy Zn



FR-HYD



FR-SO₄



J. Dairy Sci. 108:7800–7814
<https://doi.org/10.3168/jds.2025-26261>

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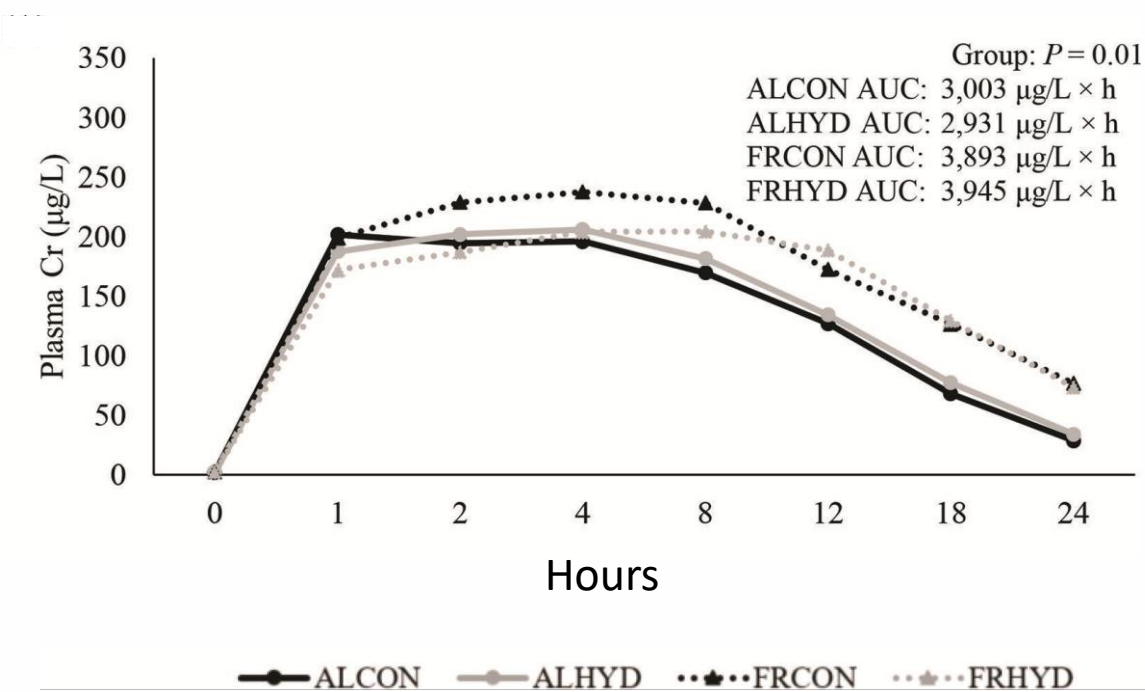
Evaluating the effects of zinc hydroxychloride on intestinal barrier permeability and biomarkers of inflammation and metabolism during and following heat stress

S. Rodriguez-Jimenez,¹ E. J. Mayorga,¹ M. A. Abeyta,¹ B. M. Goetz,¹ J. Opgenorth,¹ S. K. Kvidera,² M. M. McCarthy,² K. E. Griswold,² and L. H. Baumgard^{1*}

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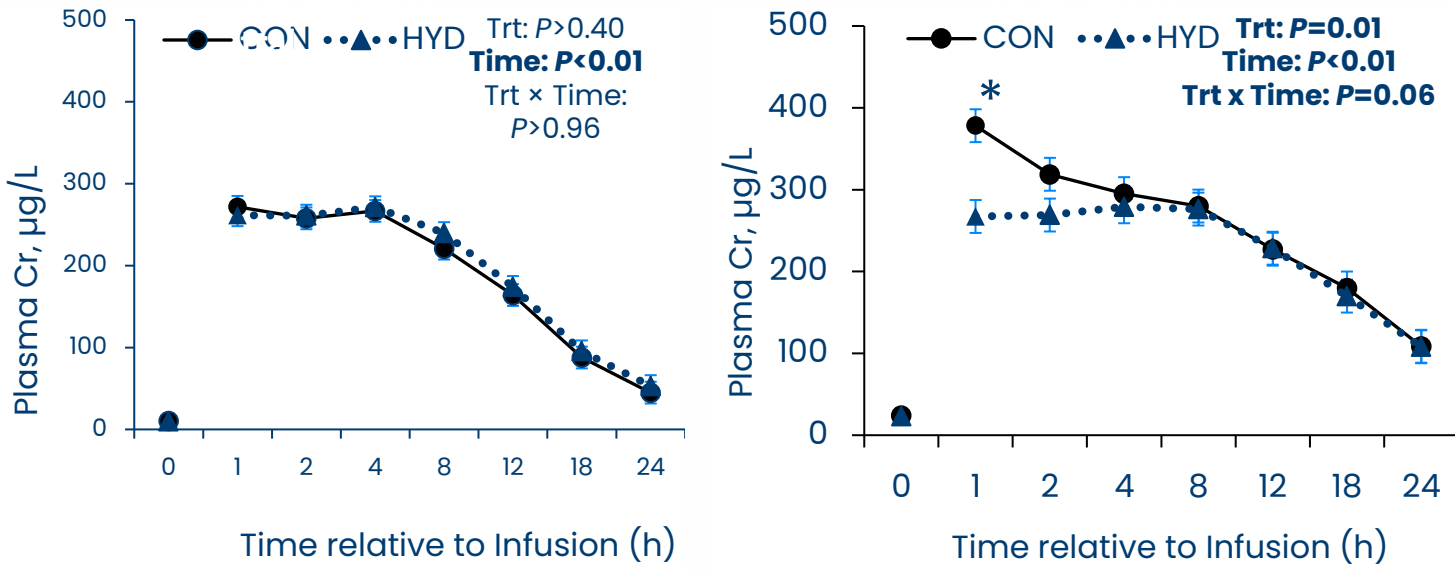
²Selko USA, Indianapolis, IN 46241

Gut barrier integrity measured using chromium-EDTA

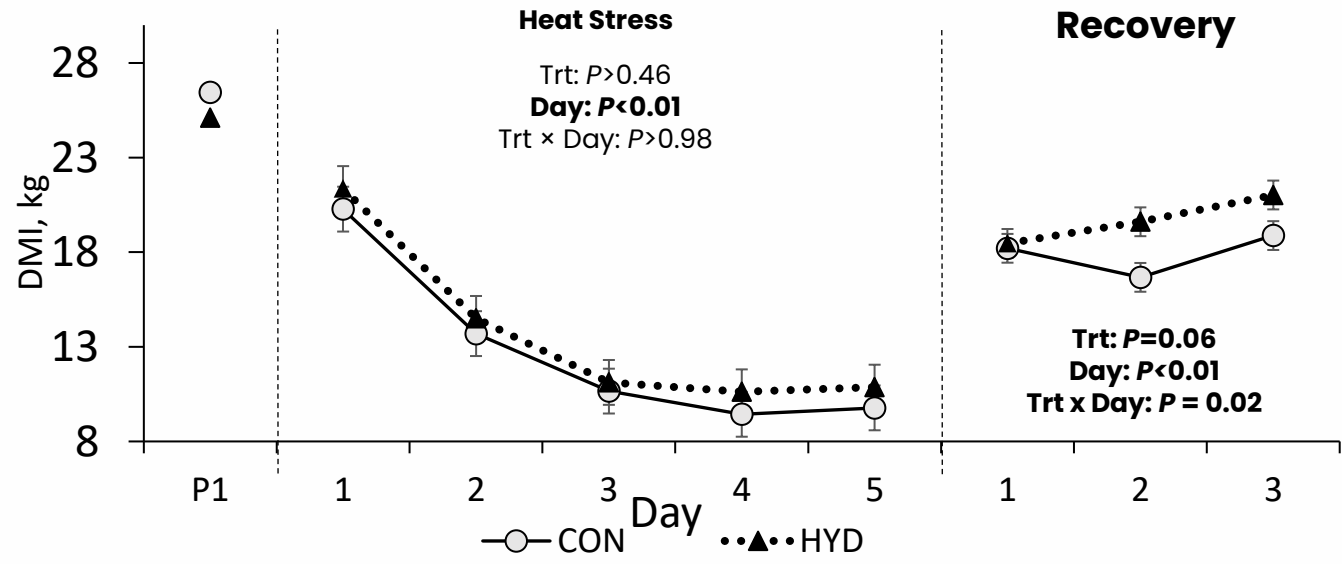


Effect of zinc source on response to heat stress

- Treatments:
- 1. control (CON;Zn sulfate; n=12)
 - 2. IntelliBond Z (HYD: Zn from zinc-hydroxychloride; n=12)



Effect of zinc source and heat stress on feed intake

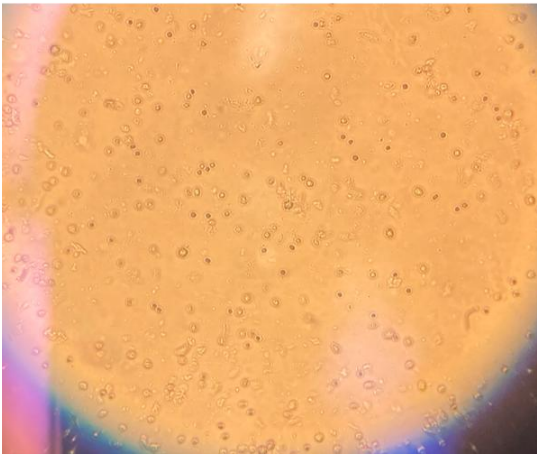


- Take home message:**
- ✓ Heat stress increased gut permeability and inflammation.
 - ✓ Supplementing HYD-Zn:
 - ✓ Improved gut barrier function.
 - ✓ Modified metabolism and inflammation.
 - ✓ Increased DMI during heat stress recovery.
 - ✓ Why/how?

Rodríguez Jiménez et al. 2025

Current research

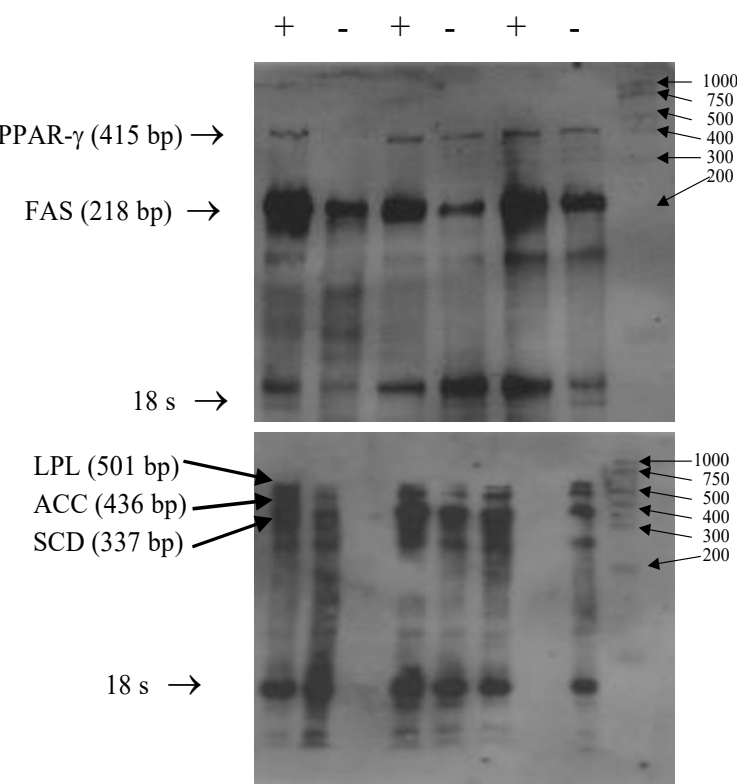
Enterocyte and hepatocyte cell lines



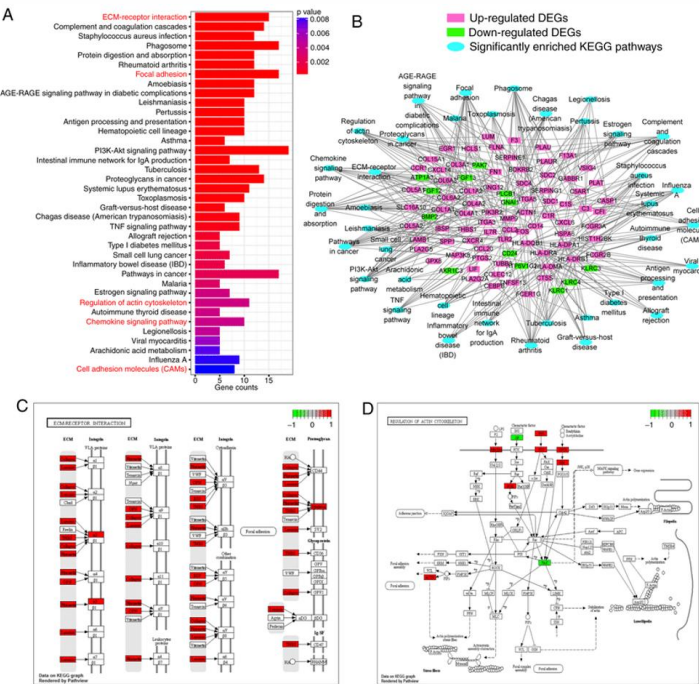
Water quality



Impacts of trace elements and vitamins on lipid and muscle protein metabolism.



Influence of minerals and vitamins on disease resistance, gut inflammation, oxidative stress, and fetal programming → potential postnatal outcomes



Chromium

- Why the interest in chromium?
- Chromium has been shown to enhance the function of insulin, alter lipid metabolism, and improve immunity in beef cattle.
- Responses to Cr supplementation of finishing cattle have been variable.
 - Supplementation of 0.25 mg Cr/kg DM, from Cr, to finishing diets increased ADG, final BW, and HCW in Angus crossbred steers (Budde et al., 2019; Hallmark et al., 2020).
 - The addition of 0.45 mg Cr/kg DM, from Cr, increased ADG, final BW, and HCW in continental crossbred steers (Baggerman et al., 2020).
 - In other studies Cr supplementation of 0.45 (Smock et al., 2020), 0.50 (Trojan et al., 2023) or 0.54 mg Cr/kg diet (Kneeskern et al., 2016) has not improved feedlot performance.
 - Factors that affect responses of finishing cattle to Cr supplementation have not been defined.
- **No established requirement or recommended inclusion level for Cr in the current NASEM (2016) publication for beef cattle. Costa e Silva et al., (2015) BR-Corte 2016/23 estimated Cr to be 2.53 mg/kg DM.**

Hot carcass weights (kg) of finishing steers supplemented with sulfate or hydroxychloride trace minerals

Reference	n	Length of study	Sulfate	Hydroxychloride
Wagner et al., 2016	64	174 days	372.1	374.4
Caldera et al., 2017	80	145-159 days	416.6	418.9
Budde et al., 2019	80	162-211 days	362.5	367.8

(Kneeskern et al., 2016; Budde et al., 2019; Smock et al., 2020;; Hallmark et al., 2020; Baggerman et al., 2020; Trojan et al., 2023)

Trace mineral source and chromium propionate supplementation affect performance and carcass characteristics in feedlot steers

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- n = 400 steers
- Cattle were blocked by initial body weight (4 blocks; randomized block design).
- 20 pen replicates per treatment with 10 steers per pen; EU = pen.
- Finishing diet fed for 154 d.
 - Treatments:
 - 0 or 0.25 mg Cr/kg DM

Main effects of chromium supplementation on performance of feedlot steers.

	Cr, mg/kg DM		SEM	P<
	0.250	0.0		Trt
Initial number of animals	200	200	---	---
Final number of animals	198	198	---	---
Initial BW, kg	369.9	369.6	7.61	0.97
Final BW, kg	678.8	670.3	4.68	0.34
ADG, kg/d	1.78	1.71	0.03	0.03
DM intake, kg/d	9.98	9.97	0.13	0.96
Gain:feed	0.179	0.171	0.002	0.02

Main effects of chromium supplementation on carcass characteristics of feedlot steers

	Cr, mg/kg DM		SEM	P<
	0.250	0.0		Trt
HCW, kg	410.8	402.4	3.13	0.06
DP	63.2	62.5	0.15	0.01
LM area, cm ²	91.3	89.4	0.81	0.04
Fat thickness, cm	1.23	1.12	0.03	0.58
Marbling score	632.7	628.8	8.90	0.69
YG	2.64	2.59	0.06	0.50

Basal diet contained 0.097 mg Cr/kg DM.
Observation: Cattle supplemented with 0.25 mg Cr/kg DM seem to respond differently that cattle supplemented with 0.50 mg Cr/kg DM.

- Summary:**
Cr supplementation at 0.25 mg Cr/kg DM improved:
- ADG
 - Gain:feed
 - Dressing percentage
 - Longissimus muscle area
 - Glucose metabolism
 - Note-basal diet was low in [Cr]

Spears et al, 2024

Cow-calf production:

Influence of supplemental copper, manganese, and zinc source on reproduction, mineral status, and performance in a grazing beef cow-calf herd over a four-year period.



Experiment:

- 180 Angus x Hereford cows (3 years old)
- 9 pastures with 20 cow per pasture (rotated monthly across 18 pastures).
- Replicates: 3 pasture replicates per treatment.
- 3 free-choice trace mineral treatments.



• Free-choice trace mineral treatments

Table 1. Free-choice mineral supplement ingredient composition (DM basis).

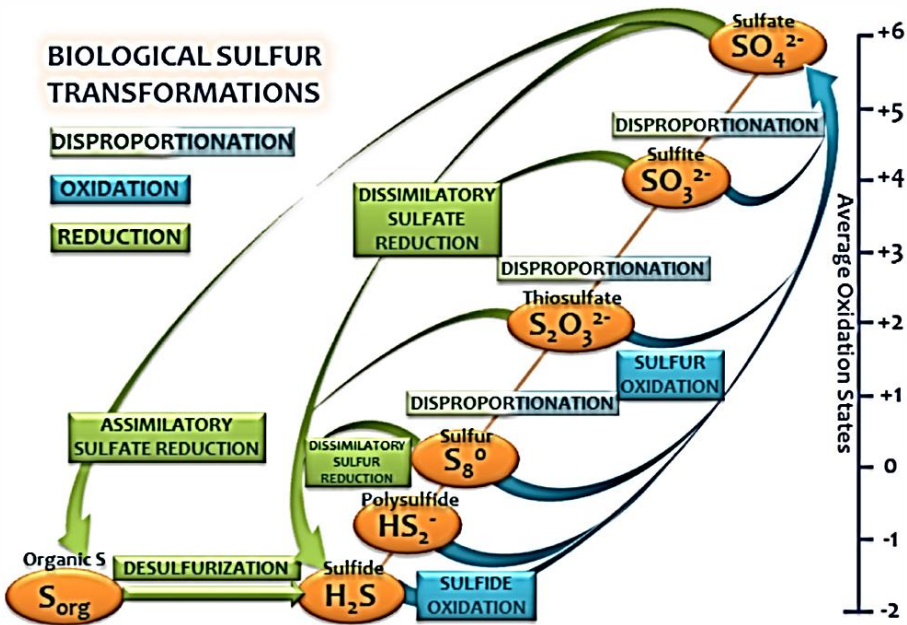
Item, %*	Treatment		
	Sulfate ¹	Hydroxy 1X ²	Hydroxy 0.5X ³
Monocalcium Phosphate (21% P)	29.51	29.89	29.68
Salt (NaCl) ⁴	30.00	30.00	30.00
Calcium Carbonate (39.4% Ca)	18.42	18.42	18.43
Elemental sulfur (98% S)	12.00	12.31	12.31
Corn Distillers Dried Grains	4.01	4.01	4.81
Magnesium Oxide (56% Mg)	2.38	2.38	2.38
Selenium (0.40% Se)	0.66	0.66	0.66
Soybean Oil	1.00	1.00	1.00
Copper Sulfate (25% Cu)	0.40	-	-
Zinc Sulfate (36% Zn)	0.85	-	-
Manganese sulfate (32% Mn)	0.63	-	-
Intellibond Cu (56% Cu)	-	0.18	0.09
Intellibond Mn (44% Mn)	-	0.46	0.23
Intellibond Zn (55% Zn)	-	0.55	0.27
Cobalt Carbonate (46% Co)	0.001	0.001	0.001
Calcium Iodate (63% I)	0.01	0.01	0.01
Vitamin A (65,000 IU/g)	0.05	0.05	0.05
Vitamin D ₃ (500,000 IU/g)	0.01	0.01	0.01
Vitamin E (500 IU/g)	0.07	0.07	0.07

¹Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.

²Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN) .

³Hydroxy 0.5X= 0.5 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 500, 1,000, and 1,500 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).

⁴On month 10 of the experiment, an additional 16.6% salt was added to each free-choice mineral feeder at the time of mineral delivery and thoroughly mixed by hand for the remainder of the experiment.



- $\text{MoO}_4^- + \text{H}^+ + \text{HS}^- \leftrightarrow \text{H}_2\text{O} + \text{MoO}_3\text{S}^-$ (monothiomolybdate)
- $\text{MoO}_3\text{S}^- + \text{H}^+ + \text{HS}^- \leftrightarrow \text{H}_2\text{O} + \text{MoO}_2\text{S}_2^-$ (dithiomolybdate)
- $\text{MoO}_2\text{S}_2^- + \text{H}^+ + \text{HS}^- \leftrightarrow \text{H}_2\text{O} + \text{MoOS}_3^-$ (trithiomolybdate)
- $\text{MoOS}_2^- + \text{H}^+ + \text{HS}^- \leftrightarrow \text{H}_2\text{O} + \text{MoS}_4^-$ (tetrathiomolybdate)

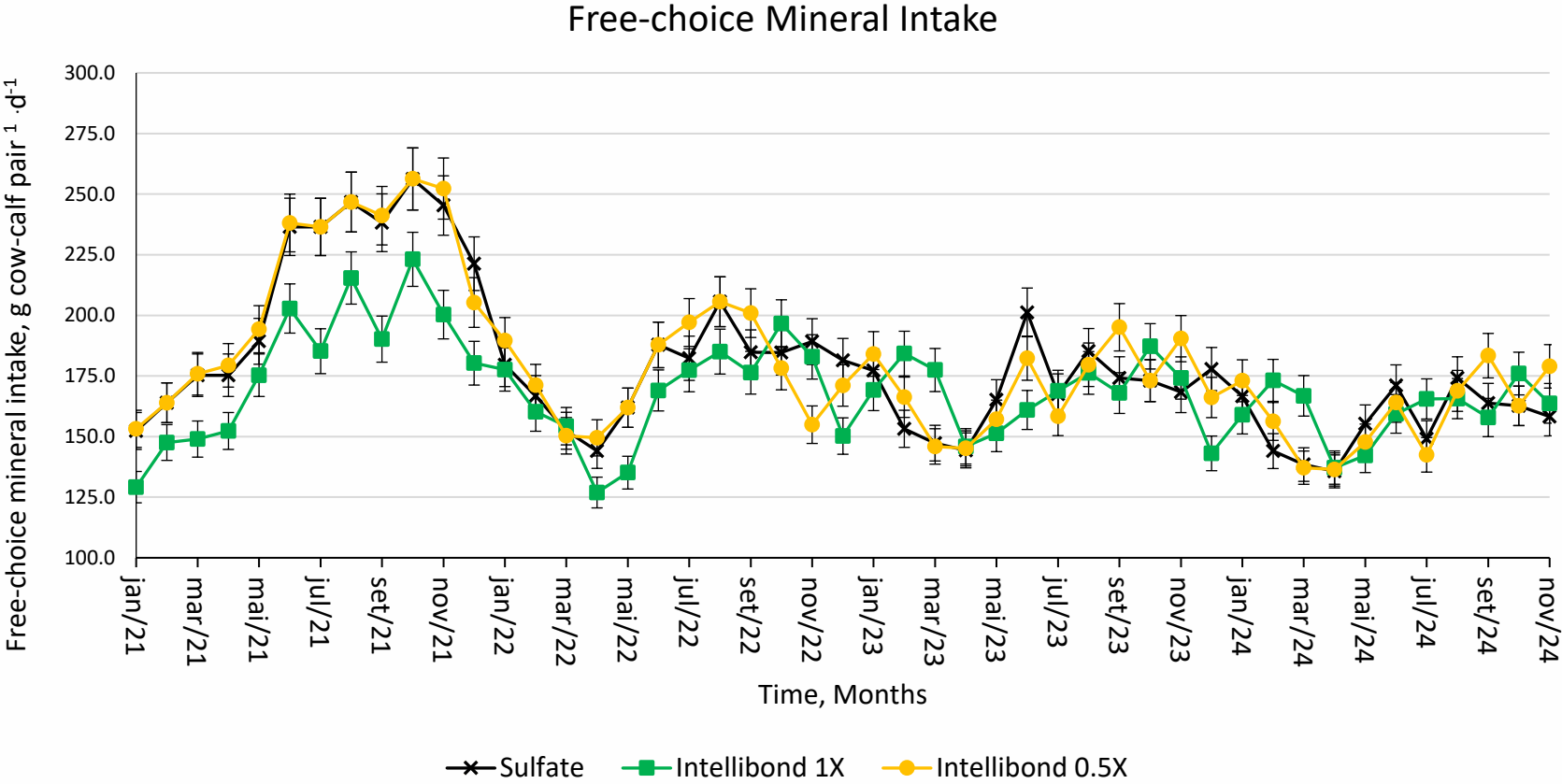
***Main objective: does ruminal solubility of minerals under elevated dietary S, over a 4-year period, impact cow-calf production parameters ($\approx$ 3.0 mg Mo/kg DM and 0.31% S).

Data Collection

- BW, BCS, weaning weights.
- Monthly forage and water samples.
- Blood and liver biopsies were collected at the end of each year.
- Weaning weights, reproductive performance, offspring feedlot performance and carcass characteristics.
- Monitored monthly free-choice mineral intake.



Free-choice trace mineral intakes



Calving: Feb/Mar
Breeding: July
Weaning: October

Effects of trace mineral supplement on cow BW and BCS (Years 1-4).

Item	Treatment			SEM	Contrast	
	Sulfate ¹	Intellibond 1x ²	Intellibond 0.5x ³		Sulfate vs. Intellibond 1x	Intellibond 1x vs. Intellibond 0.5x
BW, kg						
d 0	562.6	568.0	569.2	14.2	0.94	0.87
d 314, yr. 1	607.5	616.0	613.1	17.8	0.89	0.94
d 659, yr. 2	618.9	621.3	622.4	18.0	0.90	0.91
d 984, yr. 3	622.3	624.1	625.3	19.7	0.84	0.92
d 1332, yr. 4	628.1	631.2	630.7	21.3	0.83	0.94
BCS ⁴						
d 0	5.9	5.9	5.9	0.08	0.88	0.91
d 314, yr. 1	5.7	5.8	5.8	0.04	0.91	0.92
d 659, yr. 2	5.4	5.5	5.5	0.06	0.94	0.94
d 984, yr. 3	5.1	5.4	5.3	0.05	0.91	0.94
d 1332, yr. 4	5.0	5.3	5.2	0.04	0.81	0.90

¹ Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.

²Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN) .

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⁴1=emaciated, 9= obese; Richards eat al., 1986.

⁵Artificial insemination.

⁶Adjusted for sex.

Effects of trace mineral supplement on cow reproductive performance and actual weaning weights (Year 1, 2, 3, and 4; Preliminary Data).

Item	Treatment			SEM	Contrast	
	Sulfate ¹	Intellibond 1x ²	Intellibond 0.5x ³		Sulfate vs. Intellibond 1x	Intellibond 1x vs. Intellibond 0.5x
<u>Pregnancy rate to AI⁵, %</u>						
Year 1	63.5	63.3	56.7	5.1	0.64	0.63
Year 2	30.0	57.5	51.7	6.2	0.05	0.41
Year 3	40.4	60.9	57.3	5.3	0.07	0.40
Year 4	43.1	61.2	59.3	4.9	0.05	0.07
<u>Overall Pregnancy Rate, %</u>						
Year 1	91.7	93.3	93.1	2.3	0.86	0.92
Year 2	95.0	95.0	96.7	5.9	0.98	0.87
Year 3	94.8	95.0	96.1	6.3	0.97	0.83
Year 4	95.1	94.8	98.3	4.2	0.99	0.96
<u>Actual WW, kg⁶</u>						
Year 1	236.4	240.1	235.9	6.1	0.79	0.91
Year 2	242.2	249.9	244.2	3.8	0.08	0.29
Year 3	242.1	248.3	250.3	4.9	0.05	0.17
Year 4	241.9	250.3	248.9	4.3	0.06	0.16

¹ Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.

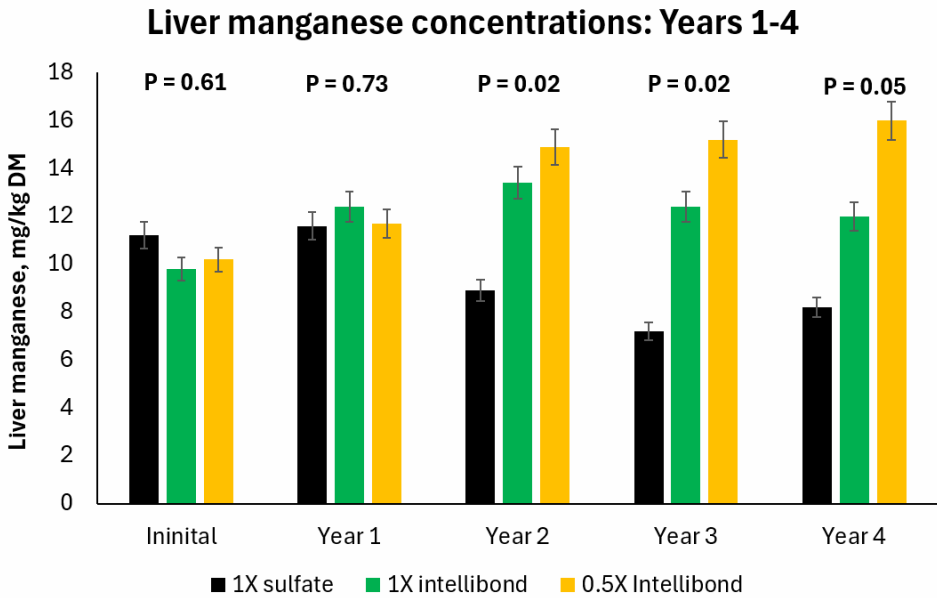
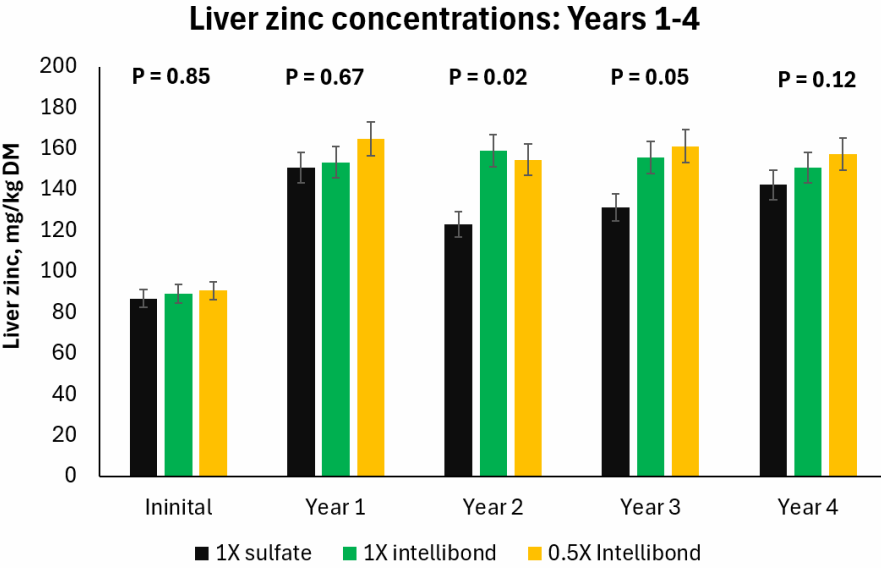
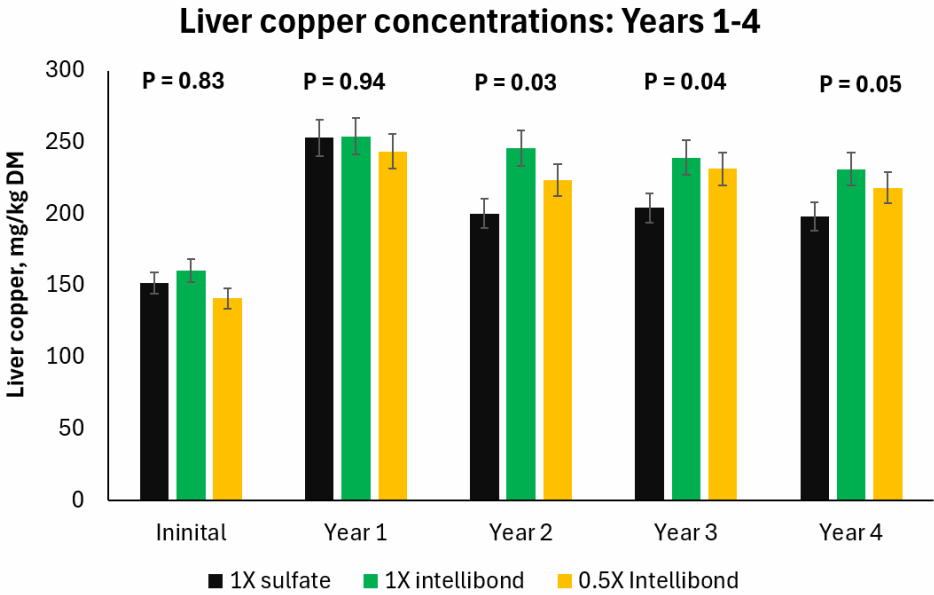
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⁴ 1=emaciated, 9= obese; Richards eat al., 1986.

⁵ Artificial insemination.

⁶ Adjusted for sex.



Feedlot

At weaning: All offspring were commingled and fed a group until reaching a target slaughter weight.



Summary:

Supplementing HTM under elevated dietary sulfur conditions increased:

- Overall pregnancy rates to AI.
- Liver Cu, Zn, and Mn.
- Actual weaning weights but not 205 d adjusted weaning weights.
- No impact on offspring feedlot performance.

Future Challenges/Opportunities:

- Mineral availability from basal feed ingredients.
- Mineral solubility throughout the gastrointestinal tract.
- Rumen pH, reducing potential, and abomasal retention time.
- Minerals and growth (Zn, Cr, Cu, etc.).
- Cow production efficiency (TM source influence conception rates to AI and mineral status of cows). Manganese? Breed? Thiomolybdates?
- Trace minerals (and vitamins?) and heat/cold stress?
- Over supplementation of trace minerals? Homeostasis, environment, etc.?



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Novel supplemental guidelines for zinc, copper, and manganese in bovines, integrating net requirements, native dietary occurrence, and the boundaries of homeostatic regulation

Jean-Baptiste Daniel*  and Javier Martín-Tereso 
Trouw Nutrition R&D, 3800 AG, Amersfoort, the Netherlands

➤ Considering the dynamic range of absorptive regulation: maximum uptake rates achievable during upregulation and minimum uptake rates attainable during down regulation, instead of assuming fixed absorption coefficients.

Obrigado!

