Effect of Replacing Sulfate with Hydroxychloride Sources of Trace Minerals on Performance of Dairy Cows

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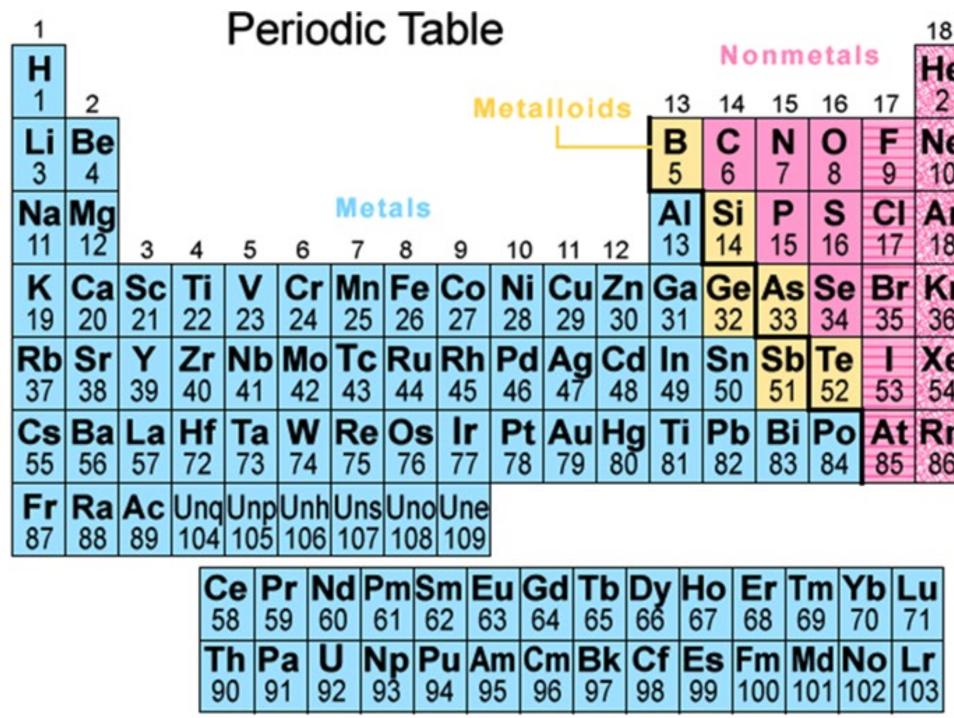

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Four-State Dairy Nutrition & Management Conference

Trace Minerals

- ✓ Inorganic trace minerals are the most commonly supplemented sources of Zn, Cu, and Mn to diets of cattle

- ✓ Of the inorganic sources, sulfates are among the most soluble
  - ✓ $ZnSO_4 \cdot H_2O$
  - ✓ $CuSO_4 \cdot 5H_2O$
  - ✓ $MnSO_4 \cdot H_2O$
  - ✓ $MnSO_4 \cdot 5H_2O$

e.g.,

$$CuSO_4 \cdot 5H_2O \xrightarrow{\text{In solution}} Cu^{2+} + SO_4^{2-} + 5H_2O$$

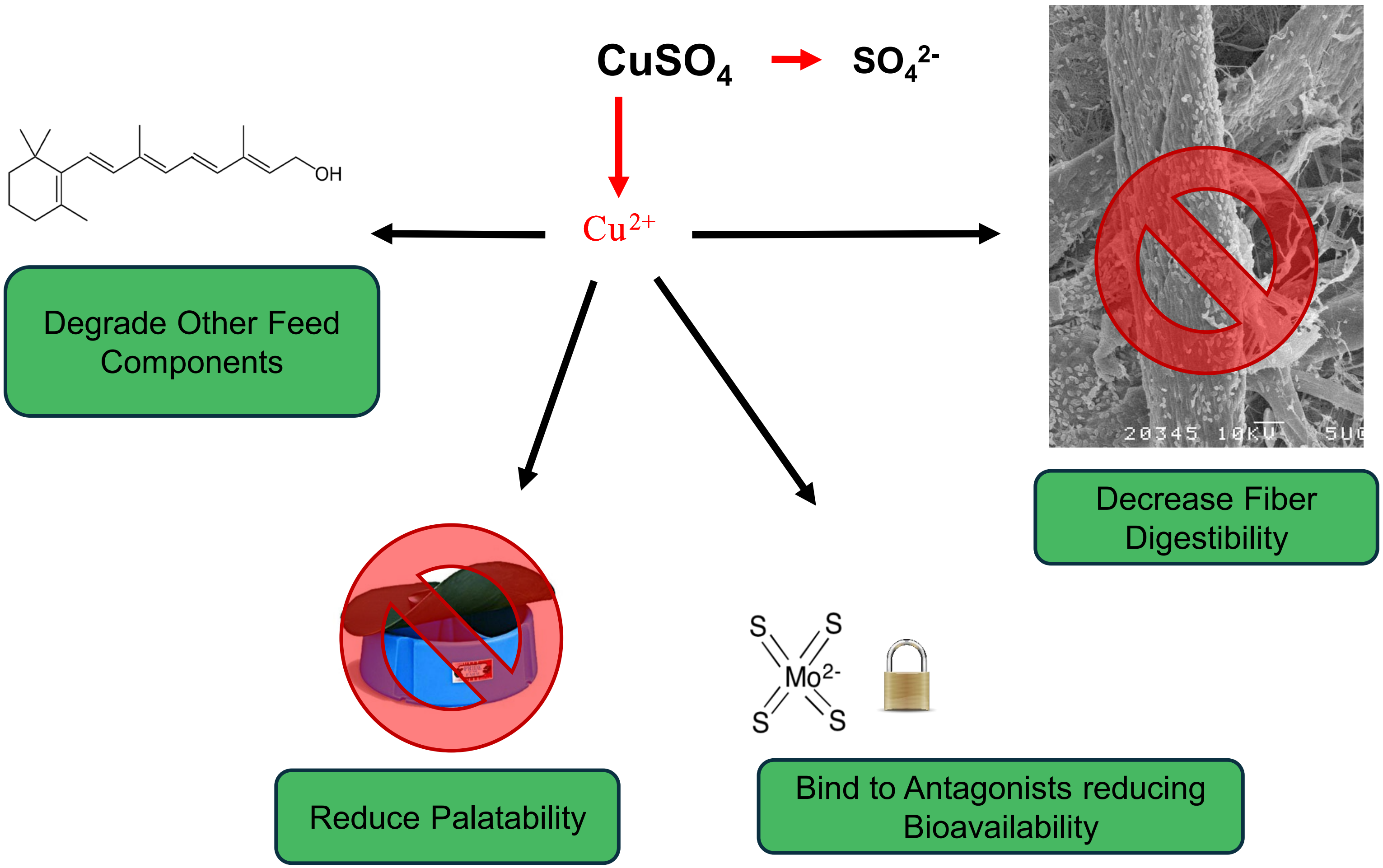
Ionic Cu^{2+} is bactericidal

e.g.,

$$ZnSO_4 \cdot H_2O \xrightarrow{\text{In solution}} Zn^{2+} + SO_4^{2-} + H_2O$$

Ionic Zn^{2+} is bactericidal

What Can Free Metal Ions Do?

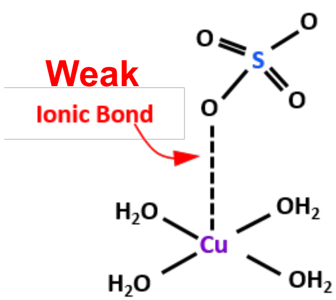


Forms of Trace Minerals

Improved Trace Mineral Sources

INORGANIC

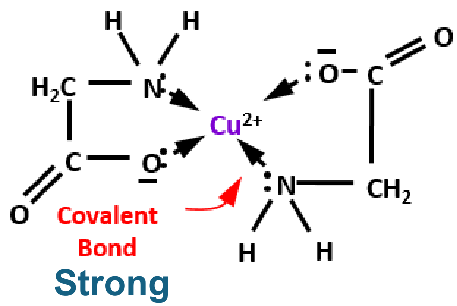
Sulfate



A specific metal bound to a non-carbon containing sulfate ligand.
Developed in the 1930's

$CuSO_4$; $ZnSO_4$; $MnSO_4$

Organic

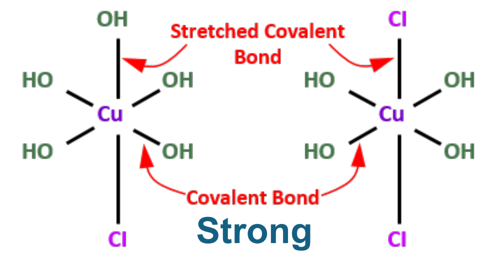


A specific metal bound to a carbon/nitrogen-containing ligand.
Developed in the 1970's

ZnAA; CuProteinate; ZnPolysaccharide

INORGANIC

Hydroxy



A specific metal bound via a coordinated covalent bond with a hydroxyl ligand.
Developed in late 1990's

IntelliBond C^{II} - $Cu_2(OH)_3Cl$

IntelliBond M - $Mn_2(OH)_3Cl$

IntelliBond Z - $Zn_5(OH)_8Cl_2 \cdot (H_2O)$

Hydroxychloride Trace Minerals

- ✓Tribasic copper chloride: $Cu_2(OH)_3Cl$

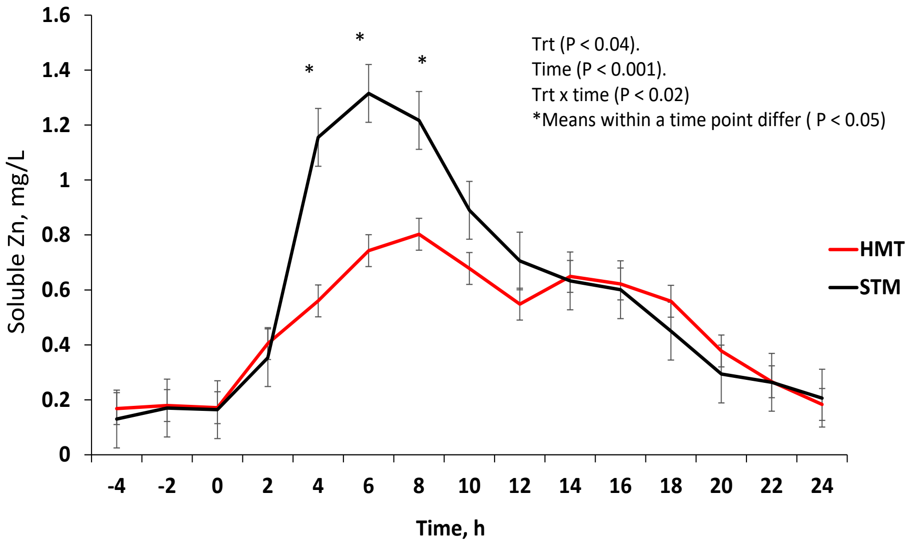
- ✓Zinc chloride hydroxide monohydrate: $Zn_5(OH)_8Cl_2 \cdot H_2O$
  - ✓Also known as tetrabasic zinc chloride hydrate

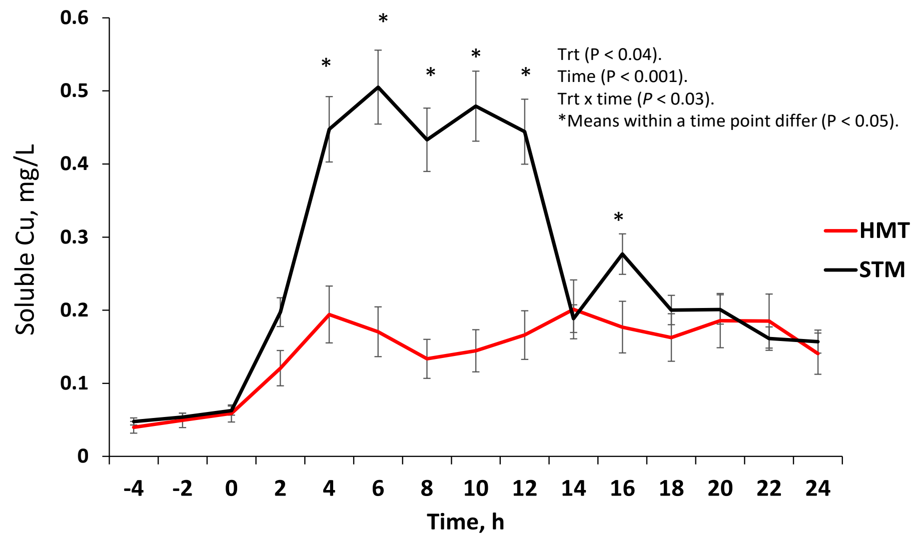
- ✓Tribasic manganese chloride: $Mn_2(OH)_3Cl$

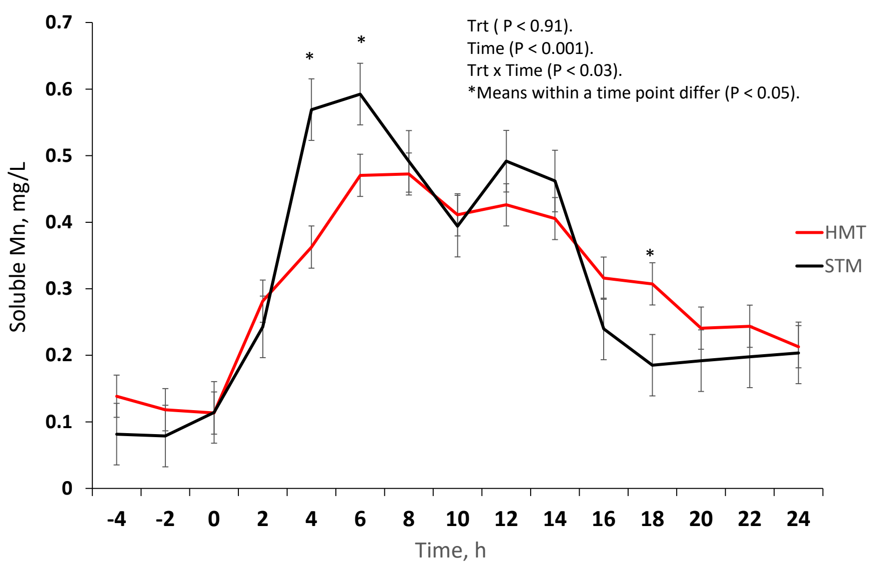
  - ✓Insoluble in pH > 5.0, making them not reactive in the rumen

  - ✓Ionize once they reach the abomasum

Solubility of Different Sources of Trace Minerals



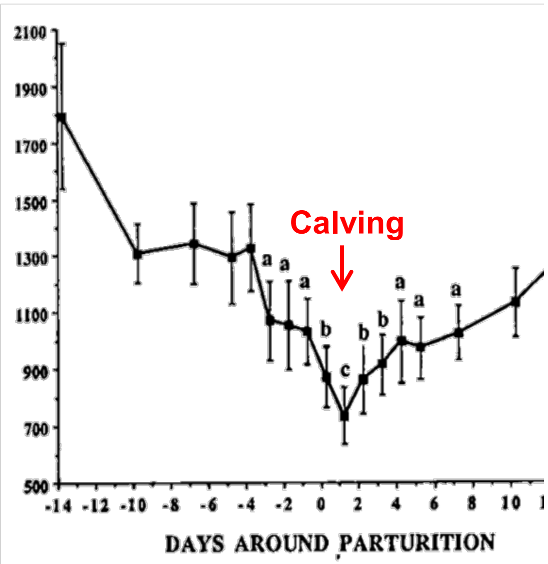




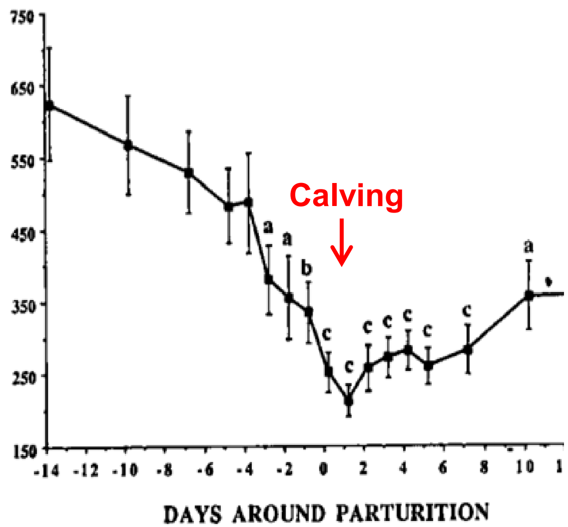
Guimarães et al. (2022) Animal 16:100500

Calving and Onset of Lactation Reduces Concentrations of Many Nutrients in Plasma

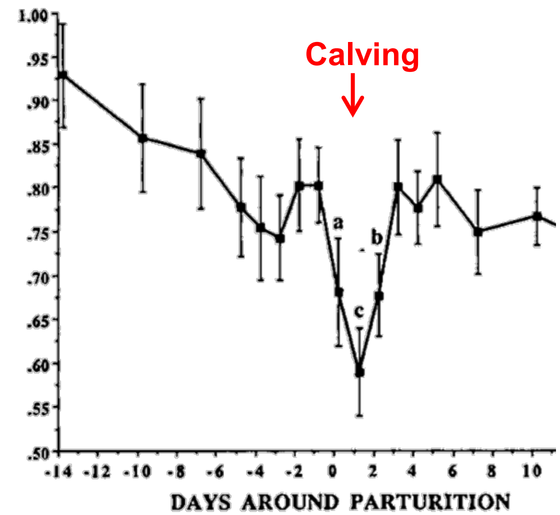
Plasma Vitamin E (ng/mL)



Plasma Vitamin A (ng/mL)



Plasma Zinc (ng/mL)



Goff and Stabel (1990) J. Dairy Sci. 73:3195

Effect of Source of TM on Production and Digestibility in Dairy Cows

Effect of trace mineral production performance in dairy cows

	Treatments					P values[1]	
Item	STM100	HTM100	STM70/OTM30	HTM70/OT30	SEM	HTM	OTM30
DMI kg/d	22.6	22.7	22.2	22.4	0.6	0.34	0.10
Yield, kg/d							
Milk	29	29.4	29.5	29.5	1.1	0.39	0.27
FPCM	31.6	32.1	32.0	32.3	1.0	0.21	0.31
Fat	1,328	1,350	1,346	1,358	43	0.25	0.36
True protein	1,068	1,087	1,083	1,091	34	0.19	0.34
MUN, mg/dL	12.6	13.1	12.9	13.1	0.3	0.04	0.49

[1]HTM = contrast (HTM100 + HTM70/OTM30) vs. (STM100 + STM70/OTM30);
OTM30 = contrast (STM100 + HTM100) vs. (STM70/OTM30 and HTM70/OTM30).

Table 3. Effect of trace mineral source on apparent total-tract digestibility (%)

	Treatment[1]					P-value[2]	
Item	STM100	HTM100	STM70/OTM30	HTM70/OTM30	SEM	HTM	OTM30
DM	68.2	68.5	68.0	68.1	0.2	0.32	0.09
OM	71.1	71.4	70.8	71.0	0.3	0.19	0.12
CP	61.3	60.5	59.9	59.8	0.4	0.14	<0.01
NDF	49.7	50.6	48.9	49.6	0.4	0.03	0.02
ADF	42.8	43.3	42.3	42.1	0.5	0.69	0.07

Daniel et al. (2020) J. Dairy Sci. 103:9081-9089

J. Dairy Sci. 106:2386–2394
https://doi.org/10.3168/jds.2022-22490

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

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[1]Department of Animal Science, Michigan State University, East Lansing 44824
[2]Micronutrients USA LLC, Indianapolis, IN 46231

- ✓ **Inclusion criteria:** Digestibility analysis, study design, cattle type, mineral intake, days on treatment, diet NDF%, etc. and the main outcomes extracted were DM digestibility, NDF digestibility, and DMI (kg/d or % of body weight).

- ✓ **Statistical analysis:** Mixed-effects model meta-analysis to estimate overall effect sizes of hydroxy versus sulfate TM.

Responses to replacing sulfate trace minerals (STM) with hydroxy trace minerals (HTM)
(Comparison: HTM – STM)

Outcome	Comparisons (n)	Mean response	SEM	*P* value
DM digestibility (% pts)	12	+0.50	0.27	0.11
NDF digestibility (% pts)	12	+1.51	0.49	0.02
DMI (kg/d)	9	+0.30	0.35	0.43
DMI (%BW)	9	+0.04	0.049	0.44

Hypotheses

✓ Replacing STM with HTM is expected to increase Zn, Cu and Mn stores in dairy cows and improve peripartum health that would benefit production in early lactation and subsequent reproduction.

Objectives

✓To evaluate the effects of two sources of trace minerals of Zn, Cu, and Mn on production, health and reproduction responses in dairy cows.

Treatments

✓ Basal diets for both treatments contained (DM basis) approximately 30 mg/kg of Zn, 6 mg/kg of Cu, and 20 mg/kg of Mn.

✓**STM (n = 70)**: Supplemented sulfate sources of Zn, Cu, and Mn to achieve approximately 65, 16, and 65 mg/kg of DM.

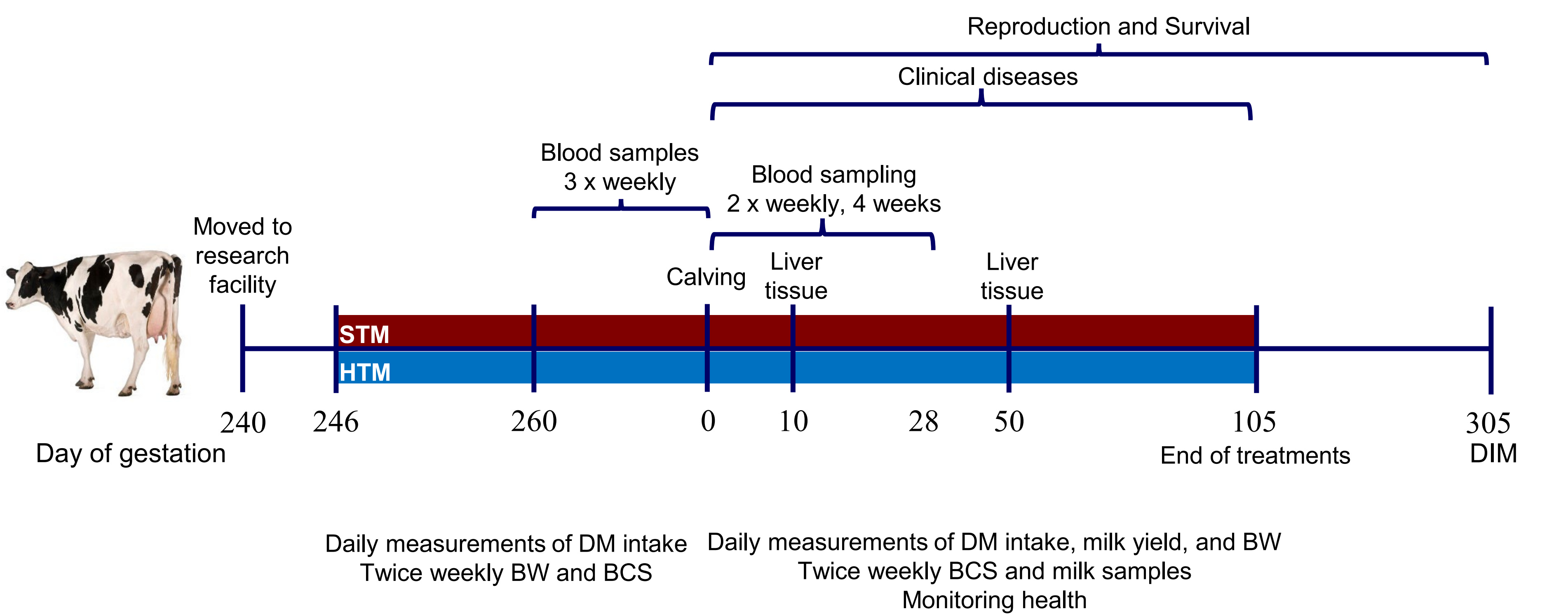
✓ **HTM (n = 71)**: Supplemented hydroxychloride sources of Zn, Cu, and Mn to achieve approximately 65, 16, and 65 mg/kg of DM.

Prepartum

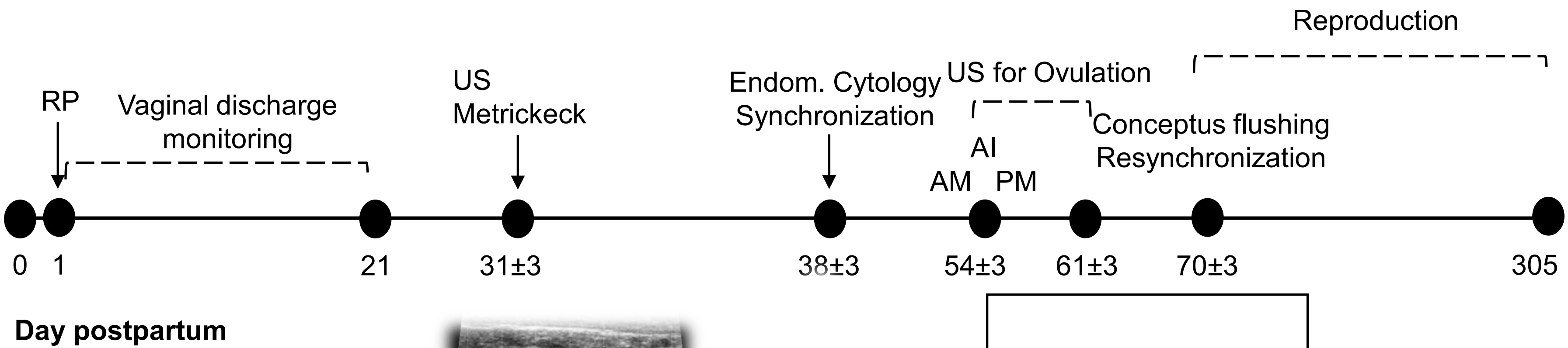
Postpartum

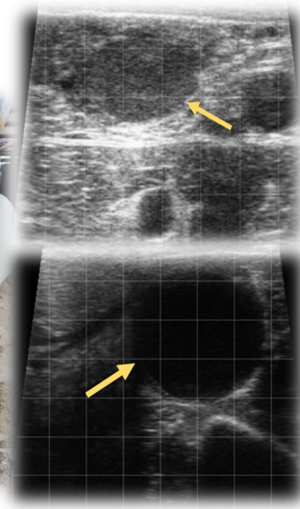
Materials and methods

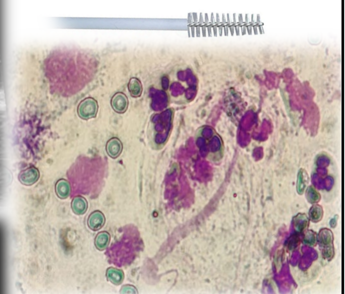
- ✓ Randomized complete block design
- ✓ 61 nulliparous and 80 parous cows at 240 d of gestation were enrolled in weekly cohorts and first blocked by parity, then:
  - ✓ Nulliparous: blocked by genomic PTA for ECM yield
  - ✓ Parous: blocked by recently completed lactation 305-d ECM yield
- ✓ Within block, cows were randomly assigned to **STM** or **HTM**



Materials and methods







Colostrum

✓ Yield of colostrum

✓Analyzed for concentrations of fat, true protein, lactose, solids-not-fat, total solids, and somatic cells

✓ Brix refractometer

✓ Radial immunodiffusion assay for IgG concentrations

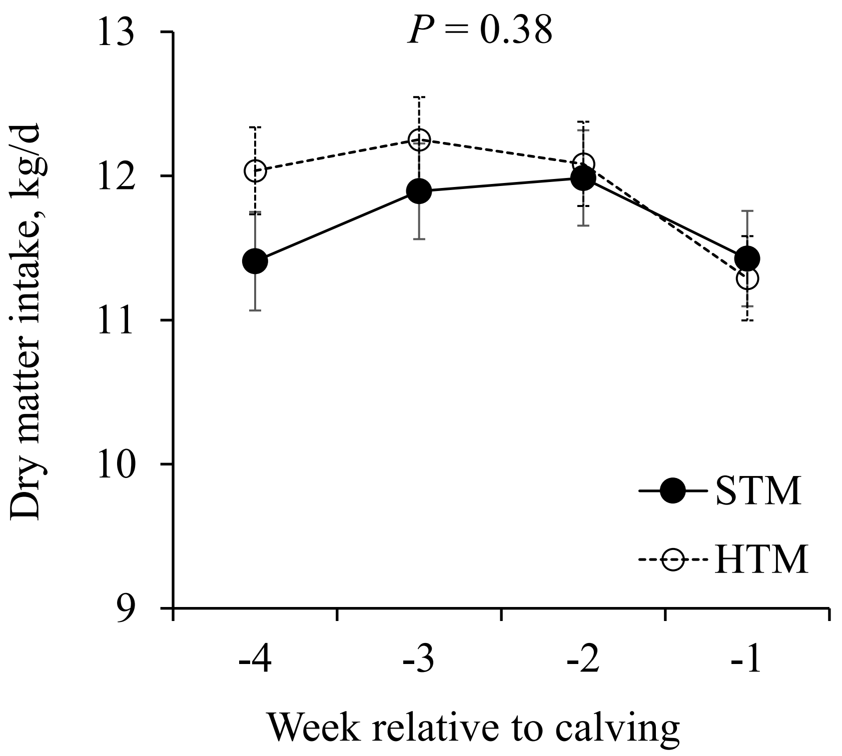
Nutrient content of trace mineral mixtures fed pre- and postpartum

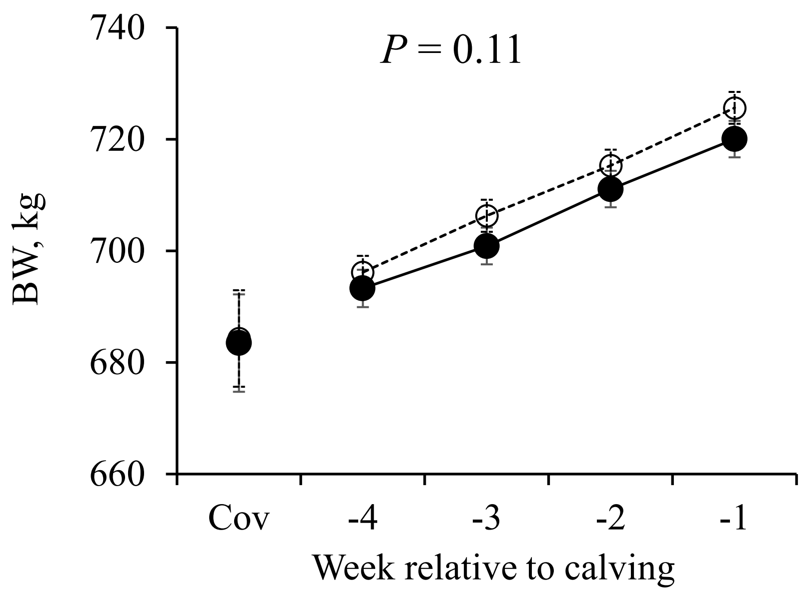
	Prepartum		Postpartum	
Nutrient, DM basis	STM	HTM	STM	HTM
Ash, %	97.2 ± 0.9	97.4 ± 0.4	97.3 ± 1.1	97.8 ± 0.7
Ca, %	31.7 ± 0.8	33.3 ± 0.5	1.16 ± 0.47	0.37 ± 0.23
Mg, %	1.18 ± 0.07	1.20 ± 0.22	0.09 ± 0.09	0.07 ± 0.05
K, %	0.55 ± 0.13	0.63 ± 0.10	32.6 ± 18.9	46.6 ± 11.2
Fe, mg/kg	780 ± 176	956 ± 201	163 ± 94	194 ± 156
Zn, mg/kg	3,212 ± 167	3,404 ± 260	7,426 ± 3,510	7,247 ± 1557
Cu, mg/kg	766 ± 46	777 ± 79	1,349 ± 622	1,413 ± 409
Mn, mg/kg	2,383 ± 229	2,482 ± 85	5,521 ± 95	6,469 ± 1634

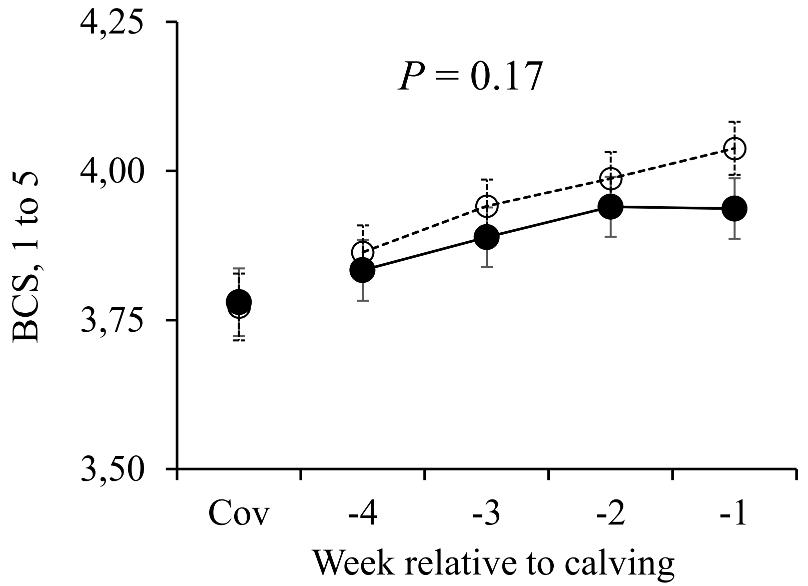
Nutrient content of diets fed pre- and postpartum (mean ± SD)

Nutrient, DM basis
NE_L, Mcal/kg
CP, %
Metabolizable
Protein, %
Methionine, % MP
Lysine, % MP
Starch, %
NDF, %
Forage NDF, %
Fatty acids, %
Ca, %
P, %
Mg, %
Zn, mg/kg
Cu, mg/kg
Mn, mg/kg
DCAD, mEq/kg

Prepartum DM intake, BW and BCS



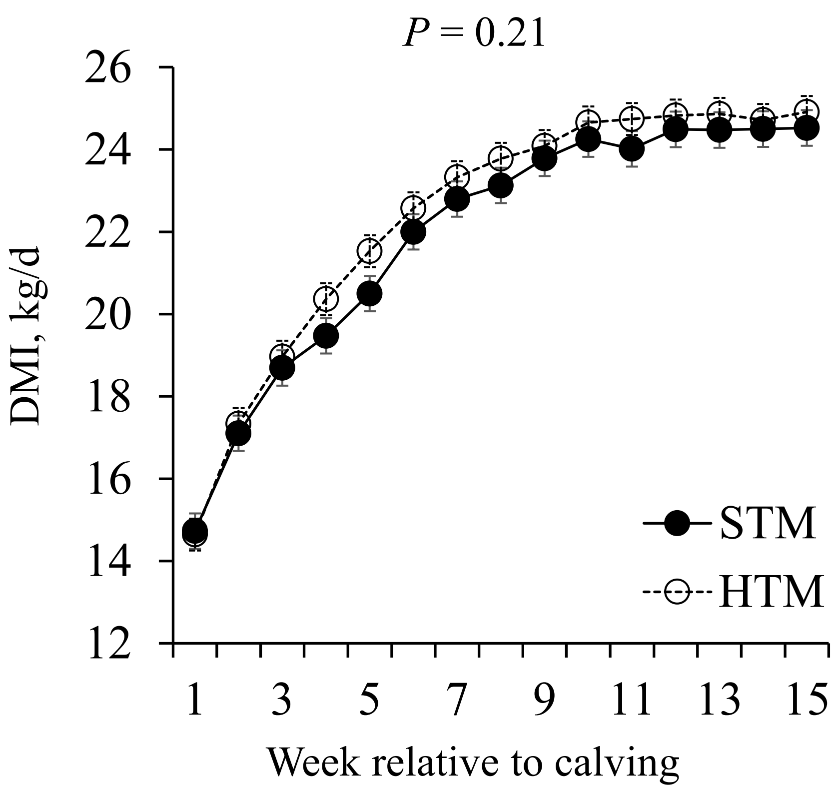


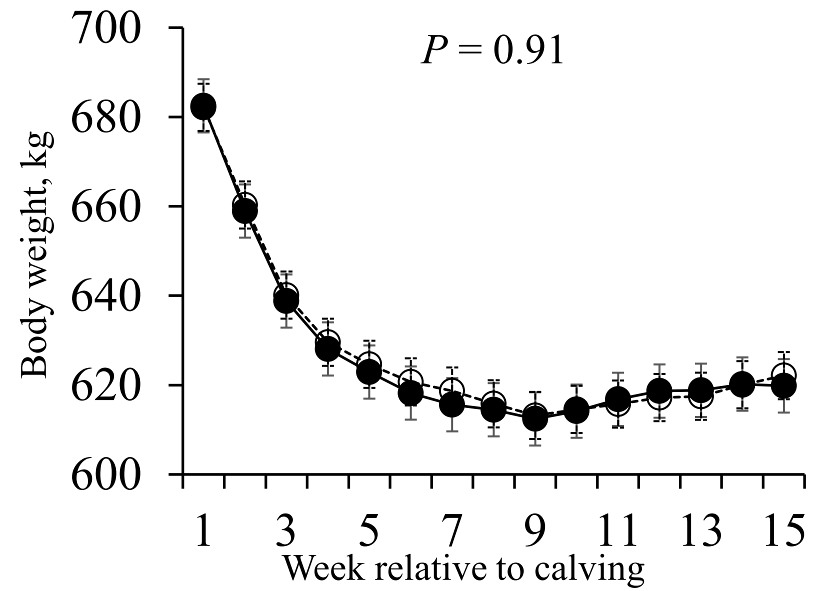


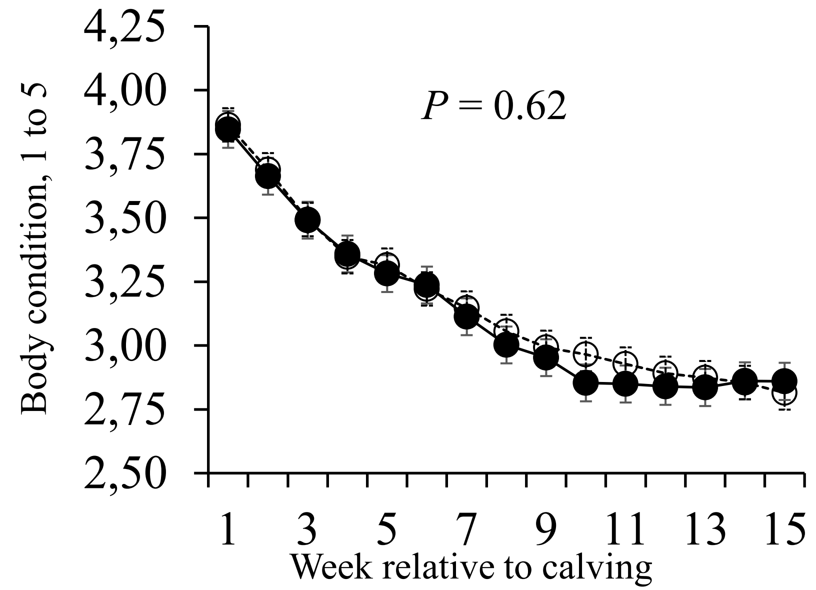
Parous cows: 14.1 ± 0.3 kg/d

Nulliparous cows: 9.5 ± 0.3 kg/d

Postpartum DM intake, BW, and BCS



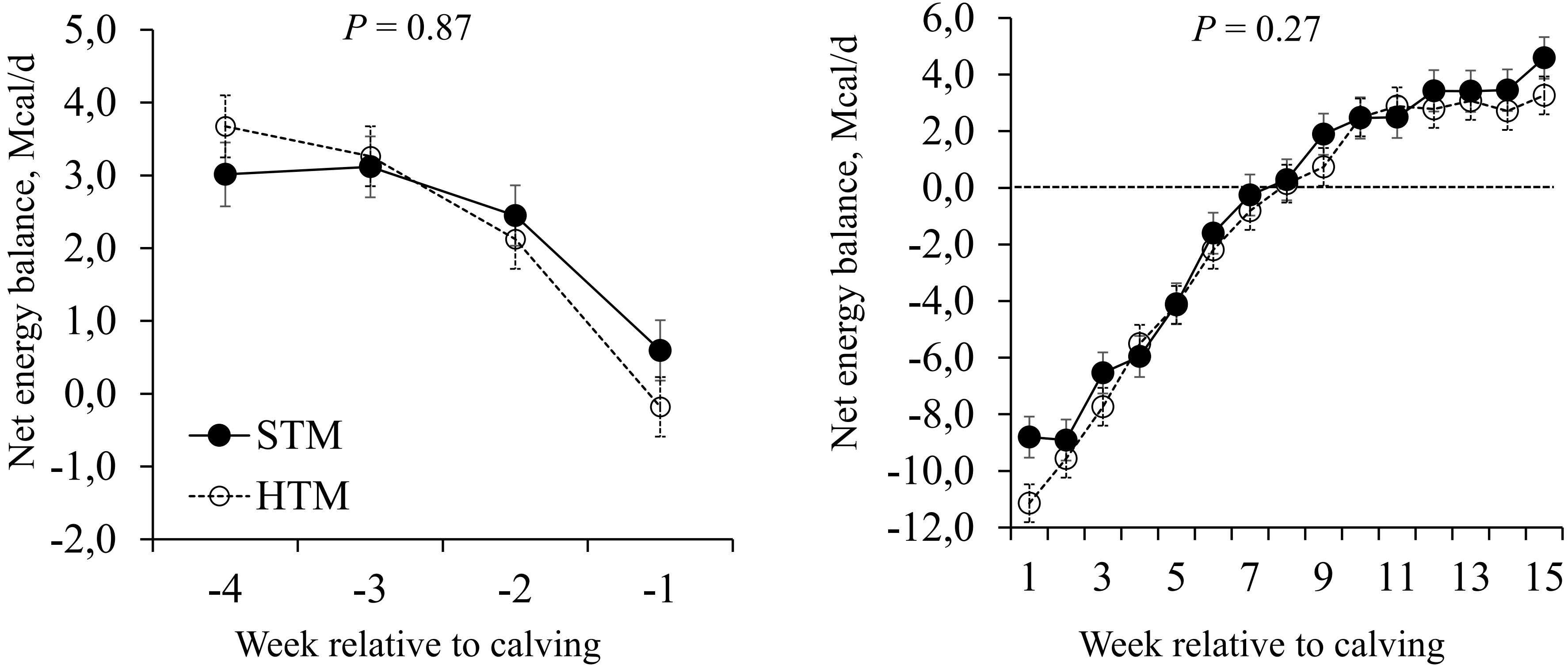




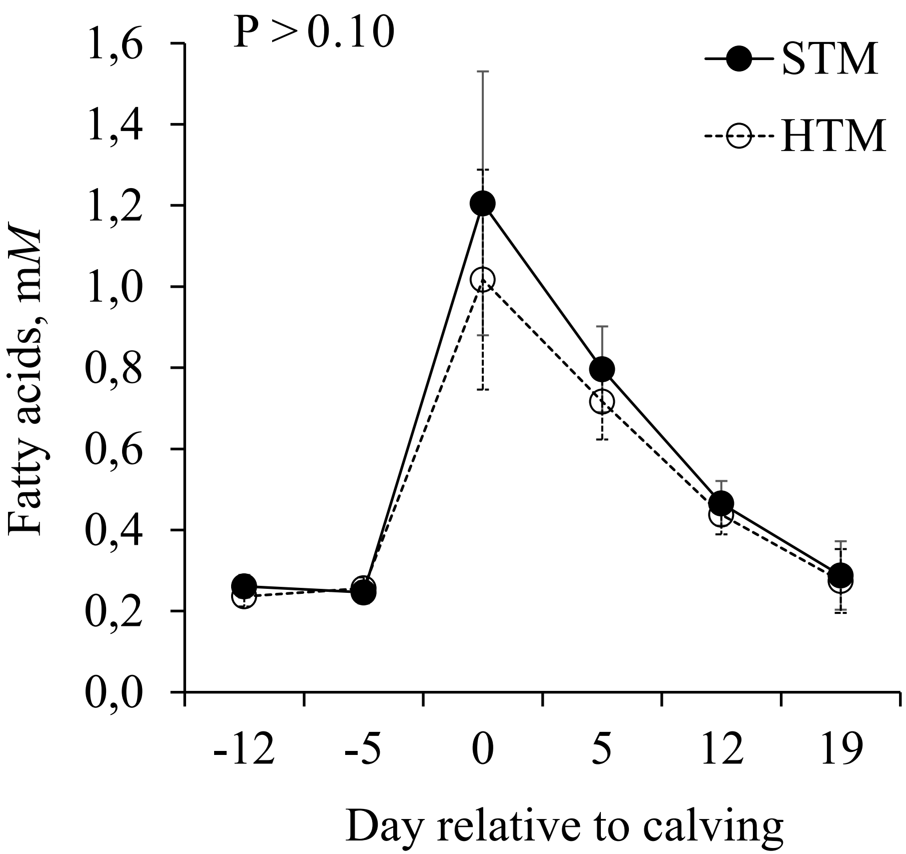
Parous cows: 24.7 ± 0.34kg/d

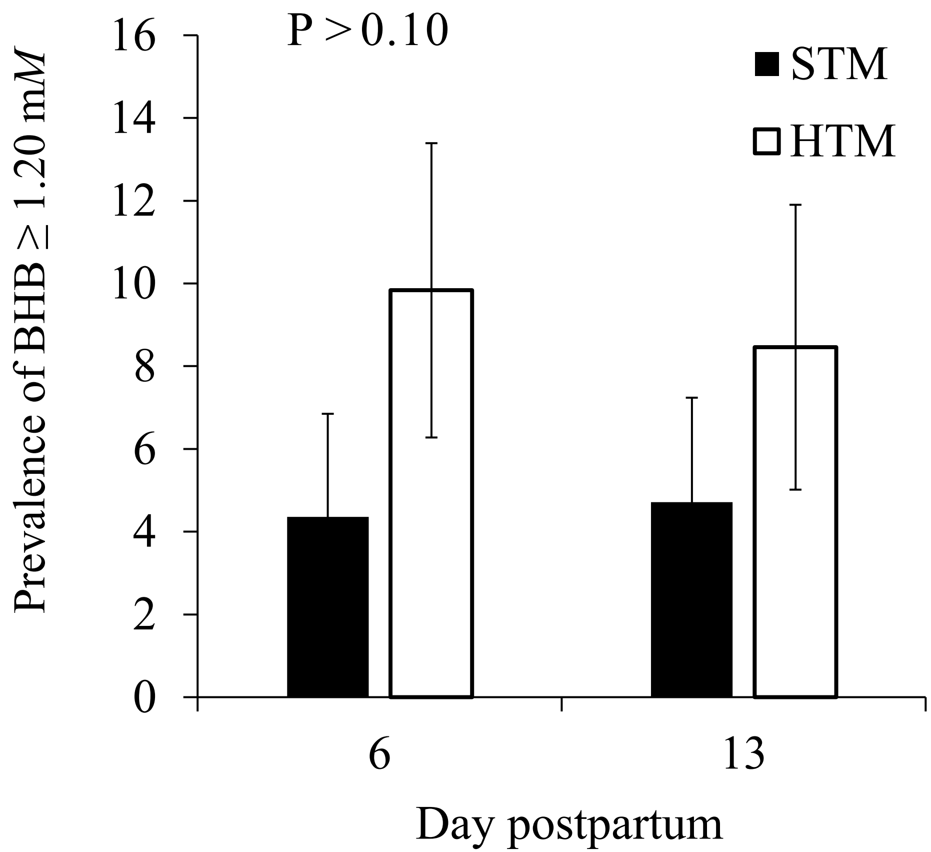
Nulliparous cows: 19.6 ± 0.4 kg/d

Pre and Postpartum NEB



Concentrations of NEFA and Prevalence of Hyperketonemia (BHB > 1.20 m*M*)





Colostrum Yield and Composition

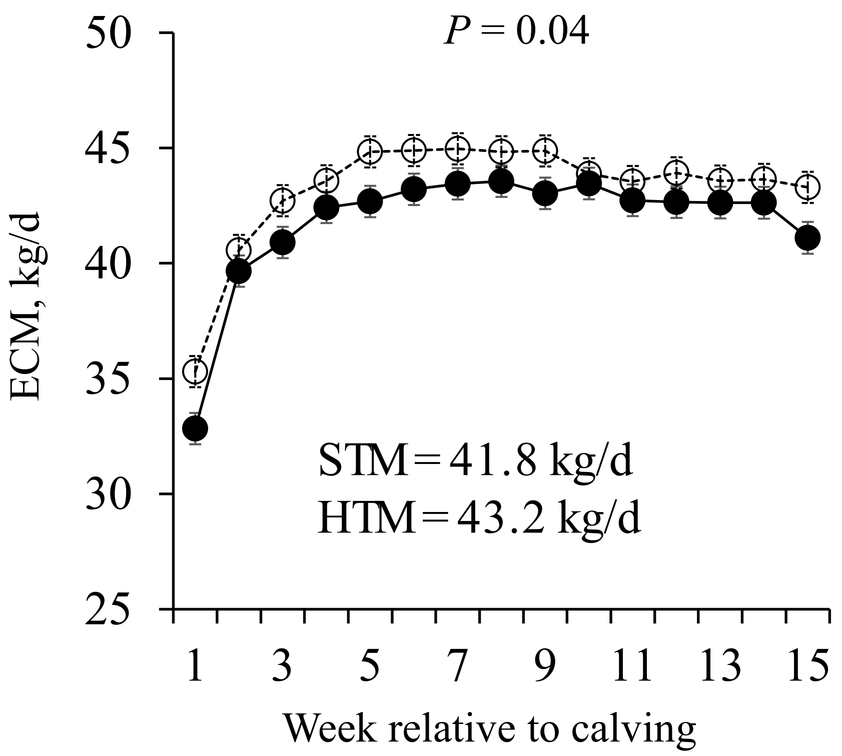
	Treatment						
	STM (n = 70)		HTM (n = 71)			*P*-value	
Item	Null	Parous	Null	Parous	SEM	TRT	TRT x parity
Yield, kg	5.54	4.89	7.07	5.47	0.81	0.08	0.50
Fat, kg	0.42	0.18	0.58	0.21	0.07	0.11	0.49
True protein, kg	0.84	0.77	1.04	0.85	0.12	0.15	0.59
Lactose, kg	0.14	0.12	0.19	0.13	0.03	0.17	0.37
Total solids, kg	1.53	1.19	1.97	1.53	0.22	0.08	0.54
Net energy							
Mcal/kg	1.67	1.33	1.69	1.40	0.05	0.29	0.64
Mcal	9.09	6.47	11.93	7.46	1.33	0.06	0.55
Somatic cell score	6.41	7.14	6.22	6.75	0.26	0.13	0.58
Brix, %	27.3	27.3	27.0	27.3	0.8	0.94	0.65
Immunoglobulin G, g	574	572	735	615	88	0.13	0.39

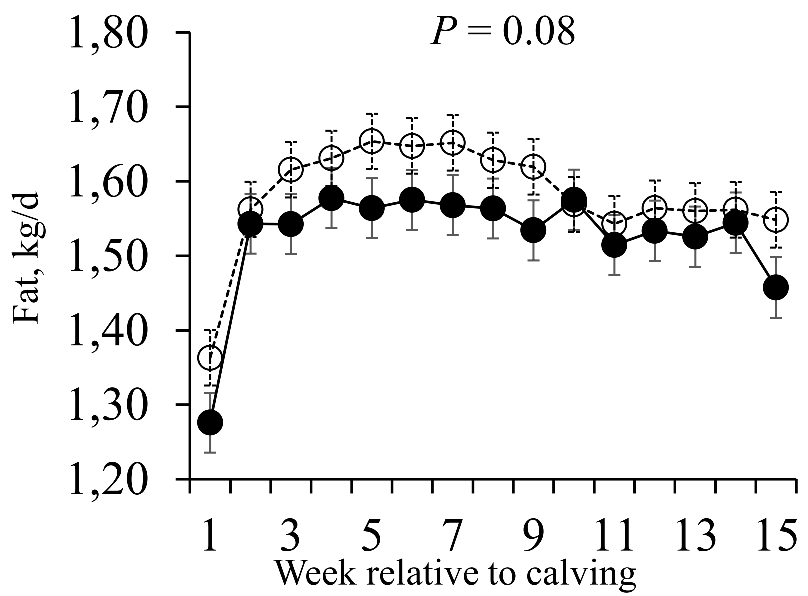
Yields of Milk, ECM, and Milk Components in the First 105 DIM

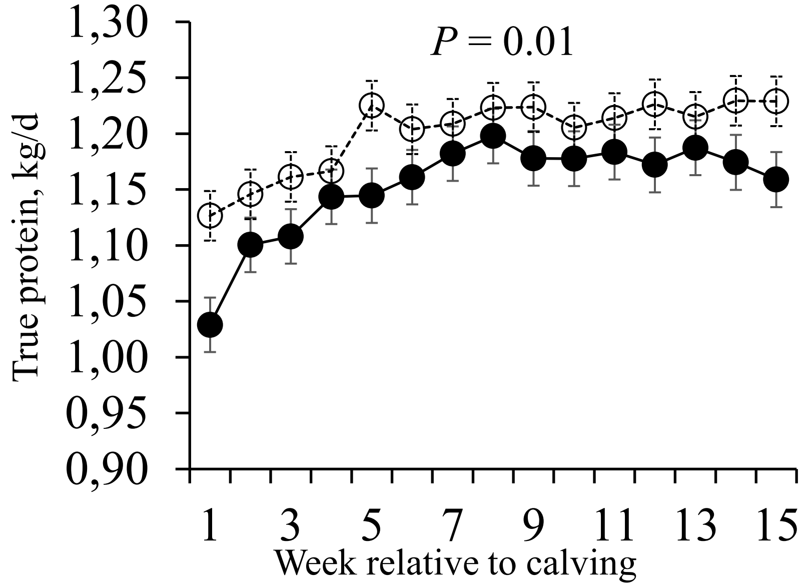
	Treatment					*P*-value		
	STM (n = 70)		HTM (n = 71)					
Item	Null	Parous	Null	Parous	SEM	TRT	TRT x parity	TRT x week
Milk, kg/d	36.1	46.8	37.3	48.0	0.8	0.08	0.96	0.31
ECM, kg/d	36.3	47.3	39.4	48.1	0.7	0.04	0.35	0.23
Fat, kg/d	1.32	1.73	1.41	1.75	0.04	0.08	0.24	0.56
True protein, kg/d	1.00	1.31	1.04	1.36	0.02	0.01	0.77	0.05
Total solids, kg/d	4.42	5.71	4.62	5.86	0.10	0.04	0.80	0.11
Fatty acids, %								
< 16 C	0.899[b]	0.927[a]	0.931[a]	0.918[ab]	0.013	0.30	0.07	0.57
16 C	1.35[b]	1.33[ab]	1.39[a]	1.31[b]	0.02	0.31	0.07	0.61
> 16 C	1.27	1.24	1.30	1.23	0.02	0.46	0.32	0.76

[a,b] Distinct superscripts in the same row denote differences among LSM ($P < 0.05$)

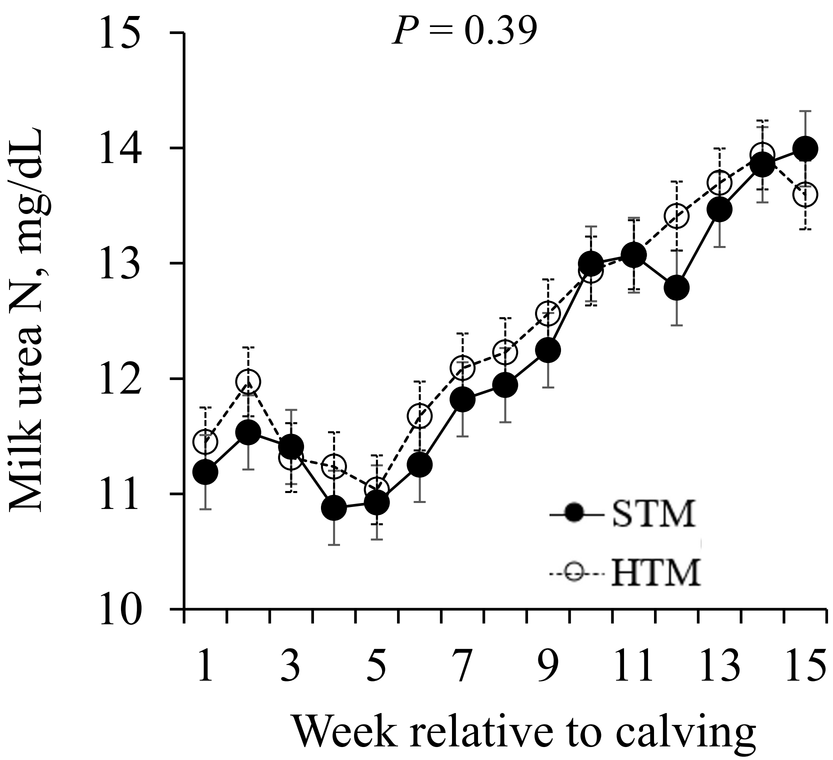
Yields of ECM, Fat and Protein

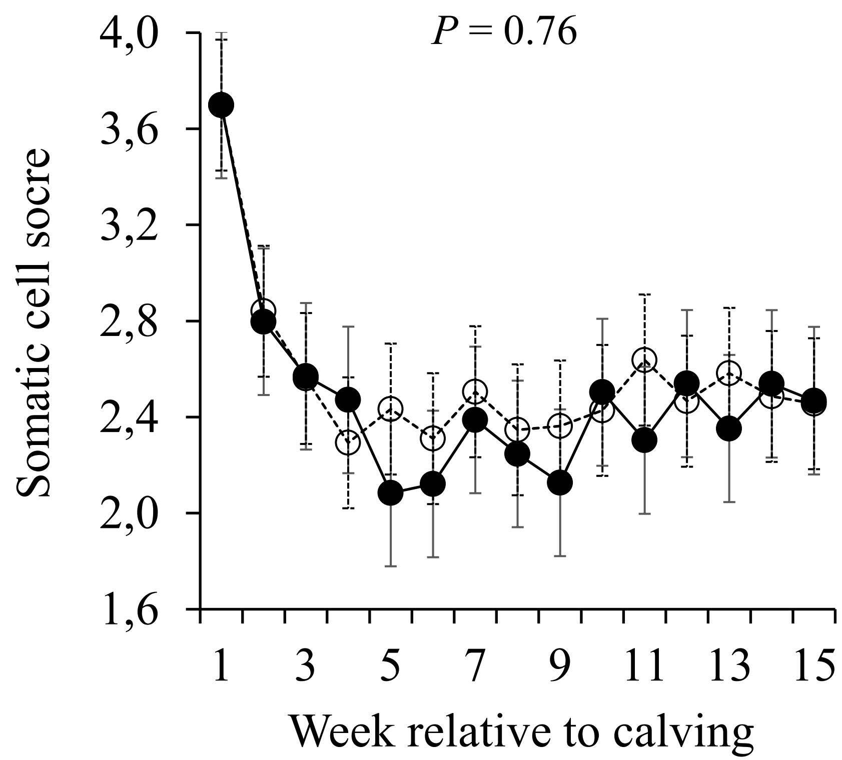






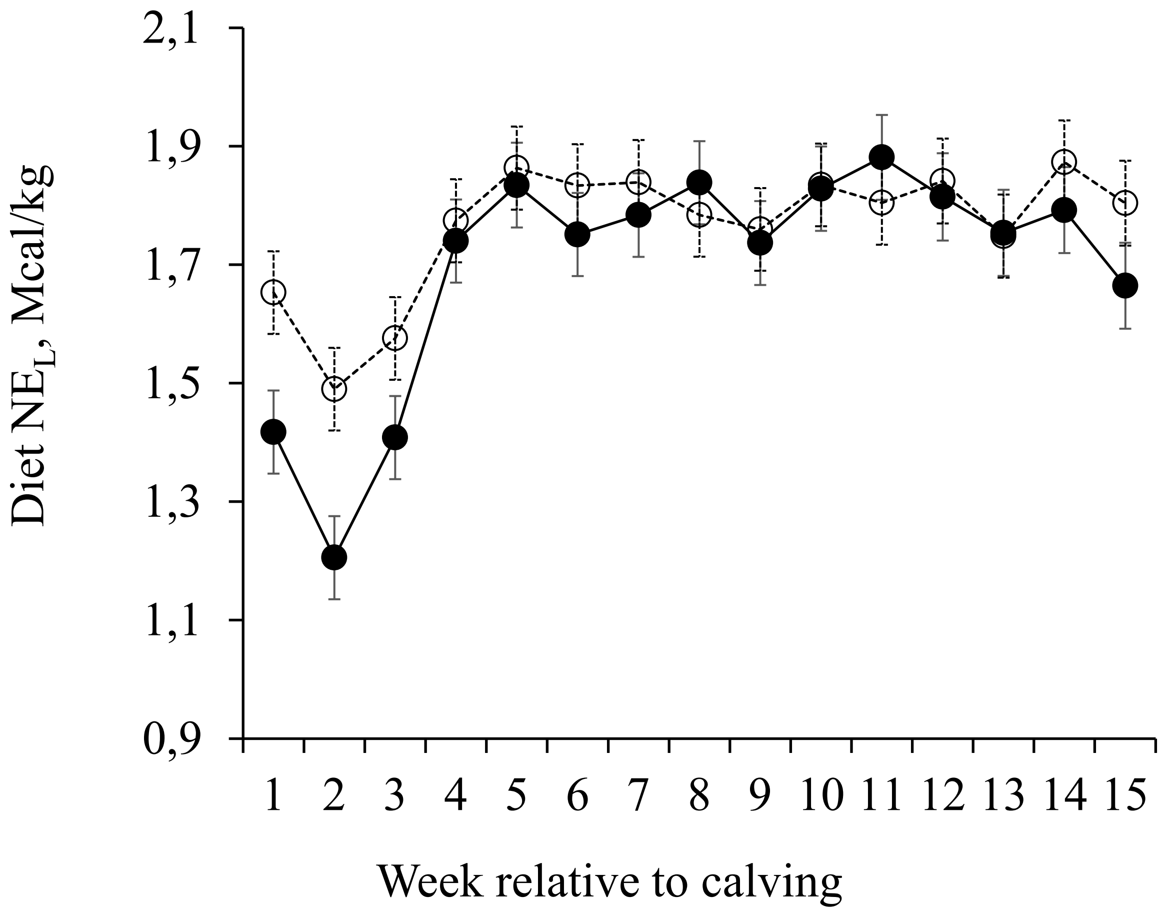
Milk urea nitrogen and SCS





Calculated NE_L of the diets in the first 105 DIM

- ✓ Estimated diet NE_L:
  - ✓ (NE_L Milk + NE_L BW Change + NE_L Maintenance) / DMI



Risk of diseases in the first 105 DIM

Item	Treatment		AOR (95% CI)[1]	*P*-value
	STM (n=70)	**HTM (n=71)**		
RFM, %	11.5 ± 6.3	3.8 ± 2.3	0.30 (0.13-0.74)	0.01
Milk fever,[2] %	1.1 ± 1.3	1.3 ± 1.3	1.12 (0.06-19.7)	0.94
Mastitis,[2] %	1.4 ± 1.0	0	---	0.49
DA,[2] %	1.4 ± 1.4	1.4 ± 1.4	0.99 (0.06-16.8)	0.99
Ketosis, %	6.4 ± 2.9	5.7 ± 2.8	0.89 (0.25-3.26)	0.86
Lameness, %	1.3 ± 1.2	6.7 ± 2.8	0.18 (0.02-1.32)	0.09

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

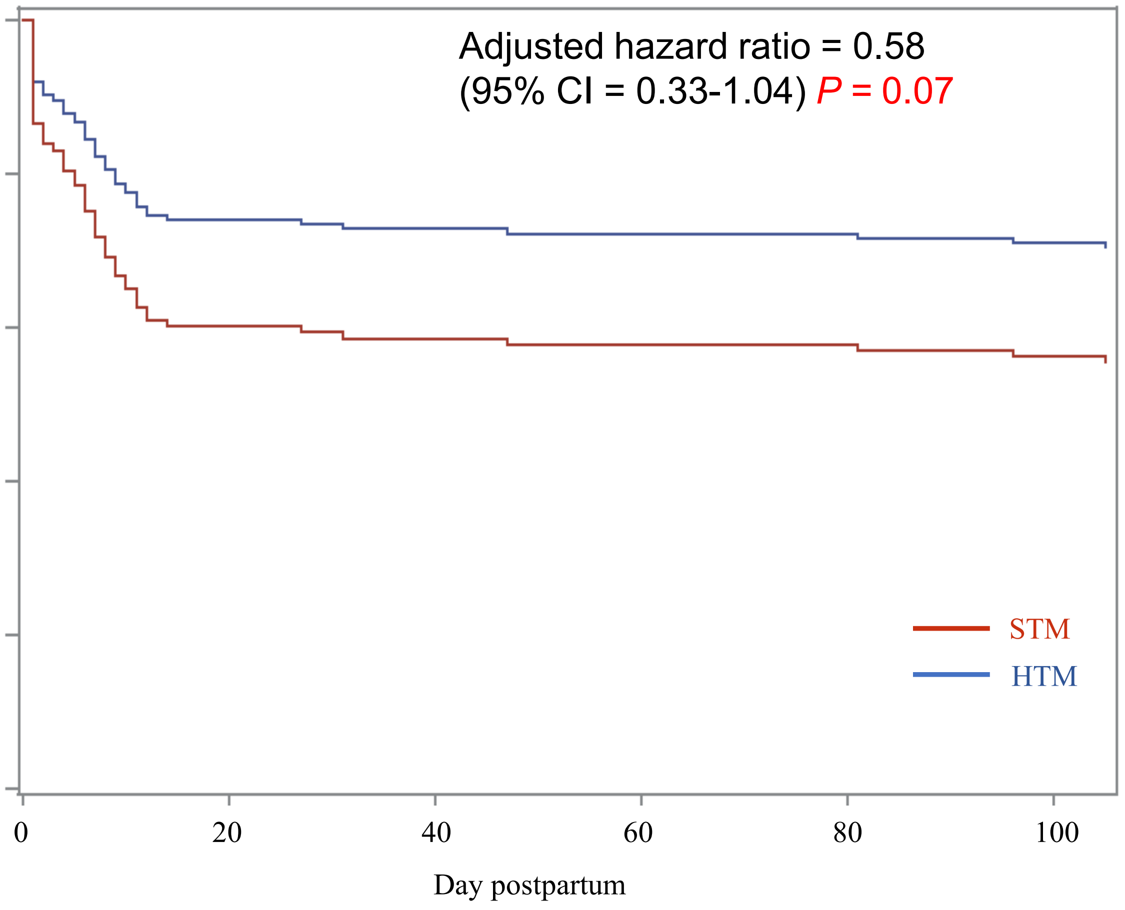
[2] Analyzed by Fisher's exact test.

Risk of diseases in the first 105 DIM

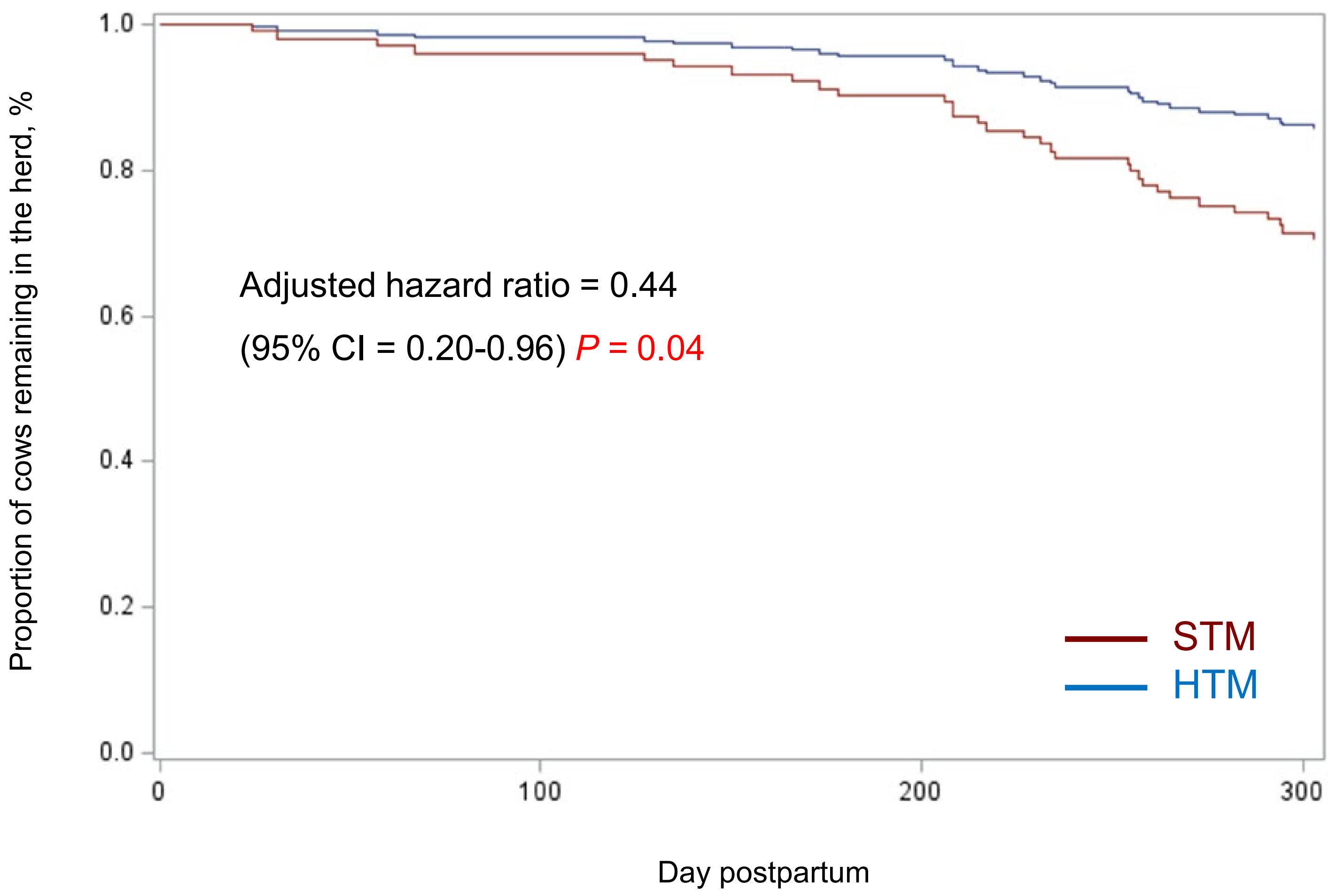
	Treatment			
Item	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
Metritis, %	34.5 ± 10.5	26.4 ± 7.2	0.68 (0.26-1.77)	0.43
Clinical endometritis, %	16.4 ± 9.6	4.0 ± 2.9	0.21 (0.03-1.31)	0.09
Subclinical endometritis, %	29.8 ± 9.1	16.4 ± 5.7	0.46 (0.19-1.12)	0.09
Endometrial PMN cells, %	3.9 ± 1.2	4.5 ± 1.2	0.14 (0.68-1.92)	0.61
Morbidity, %	52.0 ± 9.0	34.2 ± 7.2	0.48 (0.23-1.01)	0.05
Multiple diseases, %	11.7 ± 6.3	10.9 ± 4.8	0.93 (0.26-3.30)	0.90

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

Survival curves for the rate of morbidity in the first 105 d in milk



Survival curves for removal from the herd by 305 d in milk

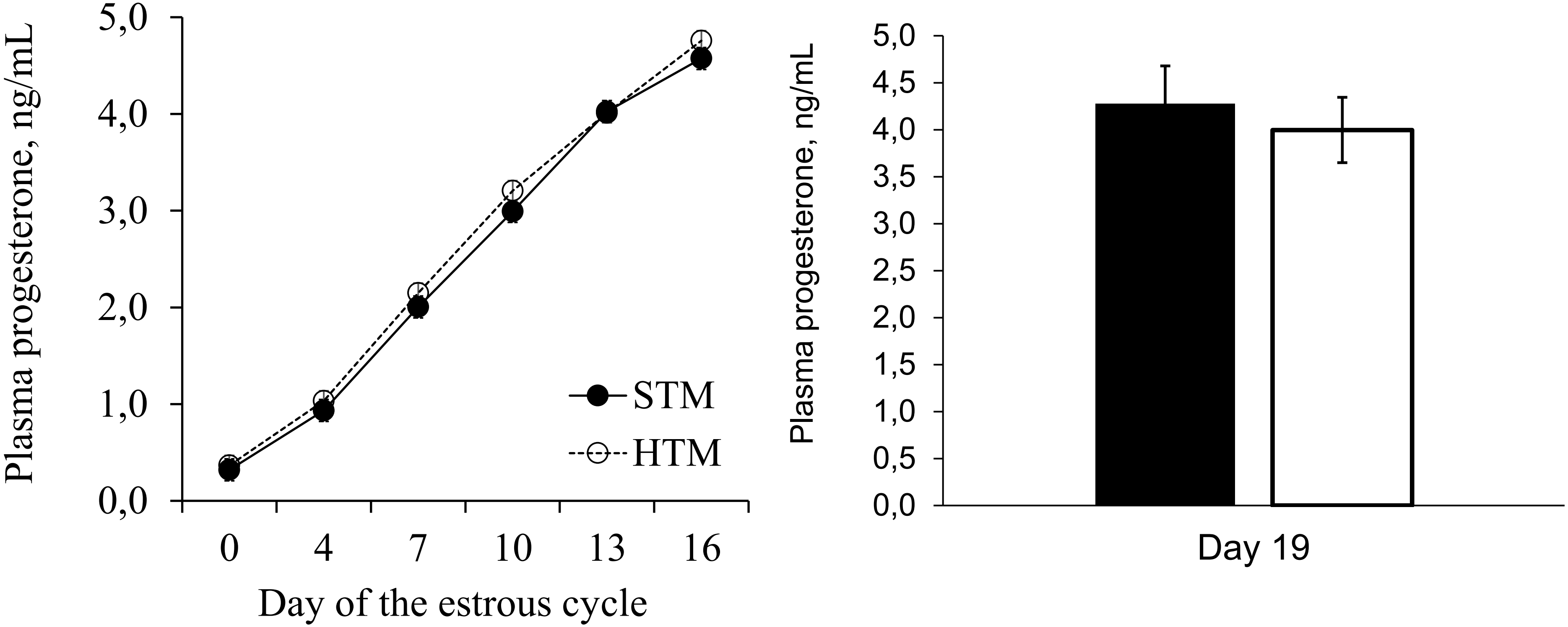


Effect of source of trace minerals on ovarian responses and conceptus development in dairy cows

Item	Treatment			
	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
Cyclic by 38 d postpartum, %	62.2 ± 9.2	59.3 ± 8.3	0.89 (0.44-1.80)	0.73
Synchronized ovulation, %	82.7 ± 4.8	93.0 ± 3.7	2.77 (0.77-9.97)	0.12
Ovulatory follicle, mm	12.7 ± 0.5	13.4 ± 0.4	---	0.18
Luteal area d 7, mm^2	344 ± 21.8	386 ± 18.7	---	0.08

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

Effect of source of trace minerals on concentrations of progesterone in dairy cows

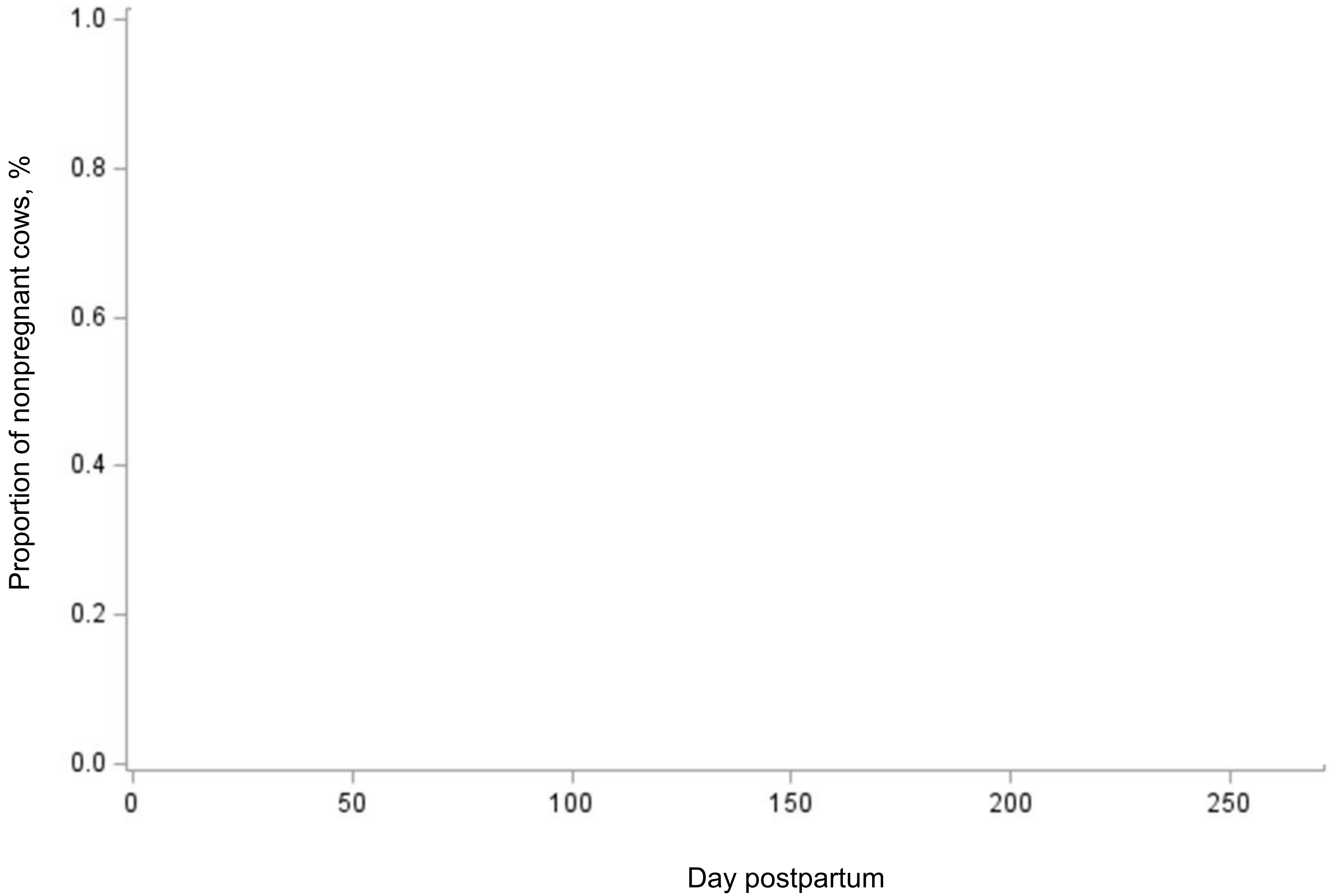


Effect of source of trace minerals on reproduction in dairy cows

Item	Treatment			
	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
DIM first AI, d	85.5 ± 0.6	86.4 ± 0.5	---	0.14
Pregnant AI, %	38.3 ± 6.2	49.3 ± 6.3	1.57 (0.78-3.17)	0.20
21-d cycle AI rate, %	72.7 ± 3.0	75.7 ± 2.4	1.17 (0.87-1.57)	0.30
21-d cycle pregnancy rate, %	18.0 ± 4.5	22.2 ± 4.5	1.30 (0.73-2.32)	0.37
Pregnant by 305 DIM, %	69.2 ± 5.7	82.1 ± 4.7	2.05 (0.92-4.56)	**0.08**

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

Survival curves for days open in the first 305 d in milk



Summary

- ✓ Replacing sulfate sources of Zn, Cu and Mn with hydroxychloride sources of the same trace minerals:
  - ✓ Tended to increase the yield of colostrum with no changes in the composition of colostrum. The increased colostrum yield resulted in increased yield of solids in colostrum
  - ✓ Increased yields of ECM in the first 15 weeks of lactation without affecting DMI postpartum.
- ✓ The diet consumed by cows receiving HTM supplied more 3.6% energy than that containing STM sources of trace minerals
  - ✓ Reduced morbidity
  - ✓ Perhaps changes in digestibility

Summary

- ✓ Replacing sulfate with hydroxychloride sources of trace minerals :
  - ✓ Reduced the risk of some uterine diseases (RFM and clinical and subclinical endometritis)
  - ✓ Reduced the risk and the rate of morbidity in the first 105 DIM
  - ✓ Increased survival of cows in the herd
  - ✓ Increased the proportion of cows pregnant at 305 DIM, although the rate of pregnancy was not affected by treatment
- ✓ Source of trace minerals did not affect the proportion of pregnant cows on day 16, conceptus size, or IFNt in the uterine flush
- ✓ Feeding HTM benefited health with some improvements in reproduction in dairy cows

Acknowledgements

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