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Effects of Trace Mineral Supplementation on Cow-Calf Performance, Reproduction, and Immune Function

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Abstract

Three-hundred Angus cows were used in a randomized design to evaluate trace mineral supplementation over a 209-d trial on cow and calf performance, liver trace mineral content, and immune function. Treatments included the following supplemental trace minerals: 1) inorganic trace minerals—low level; 2) inorganic trace minerals—high level; and 3) organic trace minerals—high level. Cows fed the high level of inorganic trace minerals lost more weight ($P<0.05$) than cows fed the other treatments. Cow condition score was not affected by treatment. Calf average daily gain on the organic high level of trace minerals was higher ($P<0.05$) from birth to May 13 and May 13 to September 24 compared with the other treatments. Pregnancy rate to artificial insemination was higher ($P<0.05$) when cows were fed the organic high level of trace minerals compared with the other treatments. Trace mineral supplementation had an equivocal impact on liver trace minerals over time. Cell-mediated immune function was not affected by type or level of trace mineral supplementation.

(Key Words: Trace Minerals, Cow-Calf Performance, Immune Function, Reproduction.)

Introduction

Trace mineral supplementation has been shown to enhance performance and immune function in transported feedlot cattle (2). When an antagonist is present, such as Mo, S, or Fe, supplementing Cu in an organic form to avoid the antagonist is advantageous. The superior absorption of organic elemental complexes over ionic elemental forms in the gastrointentinal tract of calves has been documented (8, 10, 12). It may also be possible to feed a higher level of the inorganic form to offset the deficiency. The objectives of this study were to evaluate the effects of supplemental trace minerals on liver trace mineral content of cows and calves, cow weight and condition score change, reproductive performance, and calf growth and immune function.

Materials and Methods

Three-hundred Angus cows were used in a randomized design to evaluate trace mineral supplementation on cow and calf weight change, cow condition score change, reproductive performance, liver trace mineral content, and calf immune function. Cows were allotted to treatment based on body weight, body condition score, and expected calving date. The three treatments included the following: 1) inorganic trace minerals—low level; 2) inorganic trace minerals—high level; and 3) organic trace minerals—high level. Trace mineral composition is presented in Table 1. Copper concentration was increased 2.1 times from low to high levels. The Zn and Mn concentrations were increased 1.44 times, whereas Co was increased 10 times from low to high levels. Experimental procedures were reviewed and approved by the University Animal Care Committee.

Cows and calves were maintained at the Colorado State University Beef Improvement Center, Saratoga, WY. The study started on March 12, 1997 and ended on September 29, 1997. Cows were maintained in three treatment groups during calving. All cows were put in one group for the 25-d period (May 15 to June 10) on

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TABLE 1. Trace mineral mixes fed to cows (% as fed).

Ingredient	Inorganic low level	Inorganic high level	Organic high level
Biofos dicalcium phosphate	37.74	37.77	37.95
Magox magnesium oxide	16.75	16.50	16.75
Limestone	15.12	15.12	14.85
Salt	14.00	14.00	14.00
Wheat midds	5.20	4.72	
Dried molasses	5.00	5.00	5.00
Cottonseed meal	2.50	2.50	2.50
Tallow	1.00	1.00	1.00
Vitamin A 30,000	0.67	0.67	0.67
Zinc sulfate	0.60	0.86	
Iron oxide	0.50	0.50	0.50
Selenium	0.27	0.27	0.27
Ranch-O-Dine[a]	0.25	0.34	0.34
Copper sulfate	0.20	0.43	
Manganous oxide	0.20	0.29	
Cobalt carbonate	0.0025	0.024	
Availa-4[b]			6.17
Calculated analysis (% DM basis)		(ppm)	
Copper	501	1086	1086
Zinc	2160	3113	3113
Manganese	1225	1764	1767
Cobalt	11	110	110

[a]EDDI 4.4%; salt 95.6%.

[b]Availa-4 contains 51 mg Zn/g, 28.5 mg Mn/g, 17.8 mg Cu/g, and 1.7 mg Co/g from an amino acid complex.

Bureau of Land Management (BLM) pasture. At this time they were given a mineral mix (Table 1) that contained the same levels of inorganic Cu, Mn, Zn, and Co as Treatment 1. On June 11, cow-calf pairs were split into replicated pastures. The inorganic low-level treatment was given to two replicated pastures of 48 and 51 pairs. The cows fed the inorganic high-level treatment were split into three replicated groups of 32, 34, and 34 pairs, respectively. The cows fed the organic high-level treatment were split into three groups of 35, 33, and 32 pairs. Cow-calf pairs remained in the pastures until the end of the trial. Cow-calf pairs were stocked at approximately 5.4 pairs per hectare, and the pastures were irrigated.

TABLE 2. Analysis of hay (DM basis) fed to cows.

Item	Native hay	Alfalfa
Dry matter	87.4	85.8
Crude protein, %	8.4	15.5
ADF, %	32.6	25.7
TDN, %	66	71
Calcium, %	0.34	1.22
Phosphorus, %	0.13	0.26
Potassium, %	1.2	2.0
Magnesium, %	0.10	0.18
Sulfur, %	0.18	0.29
Iron, ppm	467 (66–1387)[a]	
Manganese, ppm	81	34
Zinc, ppm	24	46
Copper, ppm	6.1	7.4
Molybdenum, ppm	0.44	0

[a]Range of four values.

Cows were fed native meadow hay and alfalfa over the 61-d period from March 12 to May 12 (Table 2). Alfalfa was fed at a rate of 2.6 kg per cow per day, whereas native hay was fed at a rate of 13.2 kg per cow per day. Water sources were analyzed for trace mineral content (Table 3).

In vivo cellular immune response to phytohemagglutinin antigen (PHA) injection was evaluated on September 29 through October 1 on 15 calves per treatment. Hair on the right side of the animal in the area of the 10th intercostal space just behind the front shoulder was clipped, and 0.75 µg of PHA (lectin from *Phaseous vulgaris* red kidney bean, Sigma Chemical, St. Louis, MO) in 0.1 ml of PBS buffer at a pH of 7.4 was injected intradermally at two separate sites (1) approximately 2.0 cm apart as an assessment of in vivo cell-mediated immune function. Inflammatory response was measured in millimeters as a change from the steers' skin thickness prior to injection with PHA and after 8, 24, and 48 h post-injection using skin fold calipers (Slim Guide, Creative Health Products, Plymouth, MI).

Differences were calculated by subtracting the time 0 measurements from each time measurement and averaging the two observations according to the following formula:

$$Mt = \{(M1t - M1I) + (M2t - M2I)\}/2$$

where M1t = skin thickness at site 1 at time t; M1I = initial skin thickness at site 1; M2t = skin thickness at site 2 at time t; M2I = initial skin thickness at site 2; and Mt = average skin swelling response at time t.

TABLE 3. Water analysis (mg/L).

Item	Stream	Well
pH	7.2	7.0
Calcium	25.2	60
Magnesium	6.0	17.6
Sodium	4.1	10.2
Potassium	6.6	1.2
Alkalinity	77	170
Hardness	88	222
Carbonate	<0.1	<0.1
Bicarbonate	94.2	207.7
Chloride	3.4	4.5
Sulfate	25.0	68.5
Nitrate	<0.1	2.9
TDS	165	373
Boron	0.01	0.03
Iron	0.19	0.07
Manganese	0.02	0.03
Copper	0.03	0.01
Zinc	0.01	0.45
Molybdenum	<0.01	0.01
Conductivity (μmhos/cm)	215	495

TABLE 4. Effect of trace mineral supplementation on cow-calf performance (least squares means).

Item	Inorganic low level	Inorganic high level	Organic high level	SEM
Head, no.	99	100	100	
Initial wt, kg 3/12	586	587	582	5.8
5/13 wt	496	492	495	5.8
6/13 wt	531	520	522	5.6
Off test wt (kg)	596	580	587	5.8
Cow wt change, kg				
3/12–5/13[c]	–90[ab]	–95[a]	–86[b]	2.4
5/14–6/10	35[a]	29[ab]	27[b]	2.4
6/11–9/24	65	60	65	2.5
3/12–9/24	10[a]	–7[b]	5[a]	2.8
Condition score				
3/12	5.5	5.5	5.6	0.07
5/13	6.0	6.0	6.1	0.06
9/24	5.5	5.4	5.6	0.07
Calf (no.)	94	100	98	
Birth wt, kg[d]	37	36	37	0.4
Birth – 5/13, kg	0.69[b]	0.68[b]	0.75[a]	0.02
134 d – ADG, kg/d (5/14-9/24)	1.08[b]	106[b]	1.11[a]	0.02
Birth – 9/24, kg	0.84	0.84	0.88	0.01
5/13 Calf wt, kg	64	62	65	2.49
Weaning wt – 9/24, kg	209[a]	204[b]	214[a]	2.89
Reproduction				
No. Open	12	19	12	
No. Pregnant to natural service	27	25	13	
No. Pregnant to AI	60	56	75	
Head, no.	99	100	100	
Pregnant to AI, %	61[b]	56[b]	75[a]	4.7
Pregnant overall, %	88	81	88	3.5

[a,b]Means in a row with different superscripts differ ($P<0.05$).
[c]Cows calved during this period.
[d]Average calf birth date was April 4.

Twenty cows were selected on March 13 at random within each of the three treatment groups for liver biopsy. Fifteen calves were also selected for liver sampling on May 13 from the group of 20 cows that had been identified as liver biopsy cows.

Liver biopsies were obtained on May 13 and September 29 on the same 45 calves and on March 12, May 13, and September 29 on the same 60 cows. Calves were restrained using a calf table; cows were restrained in a squeeze chute. The incision site location was on the right side of the animal in the area of the 10th intercostal space (just cranial to the 11th rib) at a point intersecting a line drawn from the tuber coxae (point of the hip) to the humeroscapular joint (point of the shoulder). Hair was clipped from an approximately 1.6 x 1.6-cm area over the identified site. The area was then thoroughly cleaned using a betadine solution followed by isopropyl alcohol. Five milliliters of 2% lidocaine hydrochloride solution was injected as a local anesthetic. A small stab incision was made using a #15 scalpel blade.

With the insertion stylet in place, a modified bone marrow biopsy instrument was passed through the peritoneum and "popped" through the diaphragm and into the liver. The liver had a characteristic "gritty" feel. The insertion stylet was then removed, and the free end of an intravenous transfer extension set with a 20-ml syringe attached was connected to the exposed end of the biopsy punch. A sample was collected by inserting the stylet two or three times into the liver while applying negative pressure (suction) to the syringe. The sample was then

TABLE 5. Mineral fed to cows and calves (g/d per head).

Period	Inorganic low level	Inorganic high level	Organic high level
61 d, 3/12 to 5/13	86	60	56
103 d, 6/13 to 9/24	49	66	60
164 d over the 209-d study	62	63	59

TABLE 6. Liver trace mineral content of cows (DM, ppm).

Item	Inorganic low level	Inorganic high level	Organic high level	SEM
Head, no.	20	20	20	
Magnesium				
3/12	568	585	588	
5/13	469	464	477	0.39
9/29	458[b]	469[ab]	489[a]	9.25
Zinc				
3/12	114	119	118	
5/13	89	87	90	3.4
9/29	90	89	97	3.5
Copper				
3/12	6.7	7.6	6.2	
5/13	11.4[a]	21.0[b]	25.0[b]	2.57
9/29	11.9	24.5	21.8	4.92
Molybdenum				
3/12	3.3	3.6	3.5	
5/13	4.0	4.0	4.0	0.13
9/29	3.2	3.0	3.0	0.10
Iron				
3/12	410	369	382	
5/13	551	526	566	78.4
9/29	456	406	428	25.0
Calcium				
3/12	357	284	285	
5/13	292[a]	262[b]	290[a]	
9/29	243	255	240	14.8
Manganese				
3/12	10	7.3	7.3	
5/13	8.5	8.4	8.4	0.28
9/29	8.2	8.9	8.7	0.26
Sulfur				
3/12	7247	7338	7424	
5/13	6863[a]	6413[b]	6773[a]	111.9
9/29	6919	6928	7072	91.0
Phosphorus				
3/12	10,160	10,635	10,766	
5/13	9486	9246	9625	617
9/29	8416[a]	8574[ab]	8886[b]	135

[a,b]Means in a row with different superscripts differ ($P<0.05$).

expelled into a petri dish. The liver core sample (approximately 1 g) was transferred into a labeled 3-cc falcon tube for transport and submission for analysis. Liver trace mineral analysis was performed by the Animal Health Diagnostic Laboratory (Lansing, MI 48909). Liver biopsies were analyzed by ICP-AES using the method of Braselton (1). ICP-AES analyses were carried out on a Polyscan 61E thermo (Jarrell Ash Corp., Franklin, MA). Cow condition score was based on a 1-to-9 scoring system, with 1 being thinnest and 9 being fattest (3). Cow body condition was not affected by trace mineral treatment throughout the trial.

Pregnancy was determined by rectal palpation of the reproductive tract 65 to 66 d following a timed insemination of all cows. Approximately equal numbers of cows from each treatment were inseminated by each of two technicians. Pregnancies were confirmed by a second palpation conducted 103 to 104 d following the timed insemination. The same technician performed all palpations. Palpations were performed blind to treatment and previous pregnancy diagnosis.

Calves were vaccinated on September 25, 1997 with Cattlemaster 4®, Ultrabac7/Sombac®, and One Shot® (Pfizer, Inc., Exton, PA 19341). Blood samples were drawn from 45 calves on September 29, 1997 via vena puncture for infectious bovine rhinotracheitis and PI_3 titer analysis.

Data were analyzed with least squares ANOVA for a completely randomized design using the Proc GLM procedures of SAS (9). Treatment least squares means were tested with a protected F-test at the $P<0.05$ level. Differences in pregnancy rate were determined using Chi square (9).

Results and Discussion

Cow weight was not affected by treatment at the four weighing times (Table 4). However, cow weight loss was greater ($P<0.05$) from March 12 to May 13 for cows fed the high level of inorganic trace minerals than for cows fed the other trace mineral treatments. Cows were pastured together (not separated by treatment) from May 13 to June 10 to facilitate a BLM grazing permit. During this period, a mineral mix was fed that was formulated to be isomineral to the inorganic low-level treatment. Cows fed the inorganic low-level treatment prior to turn-out on BLM pasture gained more ($P<0.05$) weight while on BLM than cows fed the organic high-level treatment prior to turn-out on BLM pasture.

Cow weight change from June 10 through September 24 was not affected by treatment. Throughout the trial, cows fed the high-level treatment of inorganic trace minerals lost more ($P<0.05$) weight than cows fed the other treatments. Cow condition score was based on a 1-to-9 scoring system, with 1 being thinnest and 9 being fattest (4). Cow body condition was not affected by trace mineral treatment throughout the trial.

Calf birth weight was not affected by trace mineral treatment; however,

TABLE 7. Liver trace mineral levels (DM, ppm) for calves.

Item	Inorganic low level	Inorganic high level	Organic high level	SEM
Calves, no.	12	11	15	
Magnesium				
5/13	494	476	435	26.7
9/29	507	505	508	8.14
Zinc				
5/13	114	103	89	12.14
9/29	175	166	160	8.12
Copper				
5/13	75[a]	60[ab]	33[b]	12.5
9/29	20.7	27	21.8	3.91
Molybdenum				
5/13	1.58[a]	1.0[b]	0.87[b]	0.14
9/29	2.56[a]	2.17[b]	2.25[ab]	0.12
Iron				
5/13	590	491	627	78.4
9/29	404	399	378	21.4
Manganese				
5/13	4.75	3.45	3.20	0.64
9/29	6.25	6.55	6.55	0.17
Hematology ($x10^3/\mu L$)				
Nucleated cells	10	11.55	11.72	0.78
Neutrophils				
Band	2.38	2.89	3.27	0.55
SEG	7.50	8.22	7.91	0.69
Lymphocytes	0.37	0.44	0.55	0.20
Monocytes	1.60	2.38	2.57	1.1
Eosinophils	2.5	5.5	6.5	1.63
Basophils	3.1	4.0	3.7	1.10
Titers (log_2)				
IBR	1.47	1.79	1.55	0.25
PI_3	2.07	2.32	2.32	0.30

[ab]Means in a row with different superscripts differ ($P<0.05$).

TABLE 8. Correlation coefficients of liver trace minerals for 38 cows and calves.

Item	Cow 3/12, Calf 5/13[c]	Cow 5/13, Calf 5/13	Cow 9/29, Calf 9/29
Magnesium	0.03	–0.41[a]	–0.04
Zinc	0.08	0.14	0.31[a]
Manganese	0.09	–0.09	0.10
Copper	0.26	–0.31[b]	0.38[a]
Molybdenum	–0.11	0.08	0.08
Sulfur	0.26	–0.02	–0.14
Iron	–0.16	0.04	–0.03
Phosphorus	0.08	–0.26[b]	–0.04
Potassium	0.08	–0.32[a]	0.08

[a]$P<0.05$.
[b]$P<0.10$.
[c]Date cows and/or calves were biopsied.

calf average daily gain from birth until May 13 (approximately 39 d) was higher ($P<0.05$) for calves fed the high level of organic trace minerals than calves fed the other treatments. The higher ($P<0.05$) rate of gain for calves with access to the high level of organic trace minerals compared with calves fed the other trace mineral treatments continued from May 13 until September 24. Average daily gain for calves with access to the organic high-level treatment tended to be higher from birth until the end of the trial, compared with calves fed the other treatments. Weaning weight was lower ($P<0.05$) for calves fed the inorganic high level of trace minerals compared with calves fed the other treatments. Feeding higher levels of inorganic trace minerals when an antagonist such as Fe was present appeared to have negative consequences on cow weight change and calf weaning weight.

Pregnancy rate to artificial insemination was higher ($P<0.05$) for cows fed the organic high level of trace minerals compared with cows fed the other treatments. Improving pregnancy rate early in the breeding season results in older and heavier calves at weaning, and therefore has the potential to improve the economics of cow-calf production dramatically. However, overall pregnancy rate was not influenced by trace mineral treatment (Table 4).

The native hay fed to cows (Table 2) from March 12 to May 12 contained higher than anticipated levels of Fe, which has been an antagonist of Cu. Copper levels in both native hay and alfalfa were below the NRC (6) level of 10 ppm. Water analysis did not reveal any dramatic challenges to trace mineral adequacy (Table 3) and appeared to be satisfactory.

Mineral consumption was slightly lower than targeted (Table 5) from March 12 through May 13. The high level of trace minerals (either organic or inorganic) appeared to limit intake. This may have been caused by the substitution of trace minerals for wheat midds in the mixtures

(Table 1). In order to stimulate intake of the mineral mixes, Solulac (distillers dried solubles; Grain Processing Corp., Muscatine, IA) was hand-mixed at rate of 2.5% for the inorganic high-level treatment and 5.0% for the organic high-level treatment. This adjustment appeared to alleviate the lower intake of these mineral mixes as indicated by the comparable intake (60 to 62 g per animal per day) over the 209-d study.

Liver trace mineral analysis for cows is reported in Table 6. Mineral analysis of liver tissue for the initial sampling (March 12) was not different for the majority of macro and micro minerals. However, liver Mg and P were lower ($P<0.05$) in cows fed the inorganic low-level treatment than in cows fed other treatments because of random allotment.

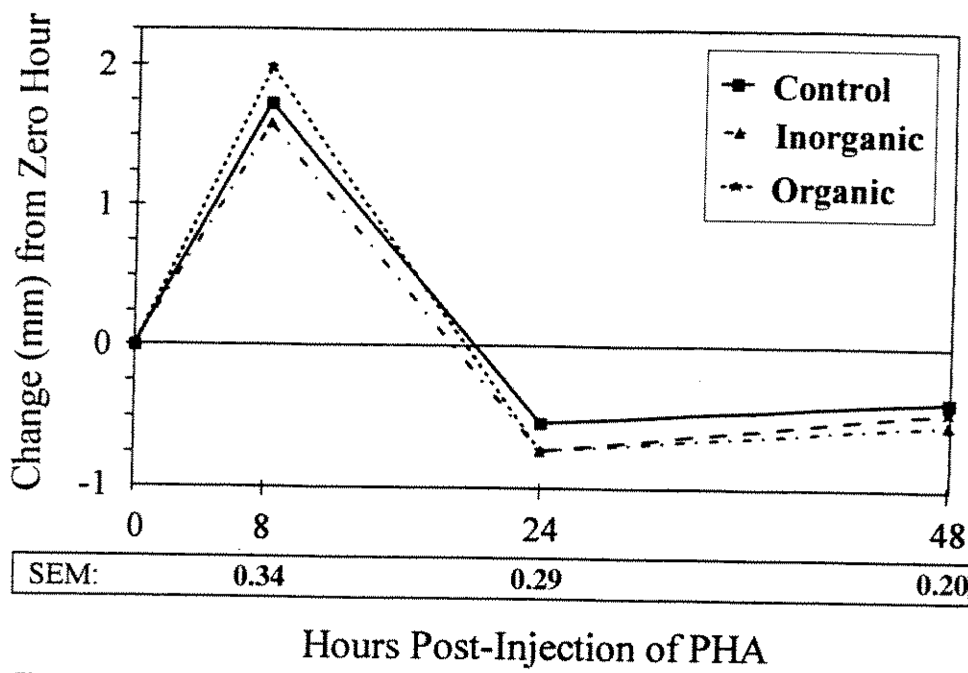


Figure 1. PHA skin swelling change (mm).

Liver Cu was higher ($P<0.05$) at the May 13 sampling for cows fed the high-level treatment of either organic or inorganic trace minerals compared with cows fed the low-level treatment of trace minerals. Copper levels were extremely low across all sampling times, with highest mean of 25 ppm. These results agree with the study by Olsen et al. (7) concerning the dietary level of trace mineral supplementation influence on liver Cu. However, liver Cu levels reported by Olsen et al. (7) were three to five times higher. Recommended levels of liver Cu exceed 90 ppm. By the end of the study, the cows that were fed high levels of trace minerals increased liver Cu threefold. Liver Ca and S were lower ($P<0.05$) on the May 13 sampling for cows fed the high-level treatment of inorganic trace minerals compared with cows fed the other treatments. Cow liver Mn levels did not differ between treatments and were within a normal range.

Liver Zn was highest upon initial sampling and decreased substantially at the May and September sampling times. This trend was also observed by Olsen et al. (7). Zinc is stored in other tissues, such as the pancreas, at higher levels than the liver, which may explain why there were no observed differences between treatments. Liver mineral analysis on September 29 revealed lower ($P<0.05$) Mg and P levels for cows fed the low-level treatment of inorganic trace minerals compared with cows fed the organic high-level treatment.

Liver trace mineral levels for calves are reported in Table 7. Liver Cu obtained on May 13 was higher ($P<0.05$) for calves from cows fed the inorganic low-level treatment of trace minerals compared with calves from cows fed the organic high-level treatment of trace minerals. This difference may have been caused by lower trace mineral consumption of the organic high-level treatment from March 12 through May 13 (Table 5). Liver Mo levels were higher ($P<0.05$) on May 13 for calves from cows fed the inorganic low-level treatment of trace minerals compared with the other treatments. Calf liver Cu was dramatically reduced from the initial sampling (May 13) until the final sampling (September 29). Liver Cu was reduced twofold to threefold from initial to final sampling for calves fed the inorganic treatments, whereas liver Cu for calves fed the organic treatment was reduced approximately 12 ppm. Copper levels in this study were dramatically lower than those reported by Johnson et al. (5; an average of 216 ppm, compared with 23 ppm in this study). Liver Zn and Mn were comparable between studies. Molybdenum levels remained elevated ($P<0.05$) on September 29 in calf liver from calves fed the inorganic low-level treatment compared with those fed the inorganic high-level treatment.

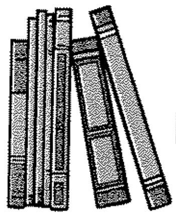
Calf hematology was not affected by trace mineral type or level (Table 7). Antibody titers were not influenced by trace mineral type or level. Titers appeared to be lower than other observations (11), possibly because of the short period of time from vaccination until blood collection (4 d).

Liver mineral content was correlated between cows and their calves (Table 8). Correlation coefficients were not significant when the March 12 cow liver analysis was correlated with the calf liver samples obtained on May 13. When cow and calf liver mineral samples from May 13 were correlated, Mg and K concentrations were observed to have a correlation coefficient ($P<0.05$) of –0.41 and –0.32, respectively, between cow and calf liver content. This suggests that there may be a large transfer of Mg and K from cow to calf during late gestation and early lactation. The Cu and P concentrations also tended to be ($P<0.10$) negatively correlated at the May 13 sampling ((0.31 and (0.26, respectively) between cows and calves. A positive correlation coefficient ($P<0.05$) was observed between cows and calves at the September 29 sampling for Zn and Cu (0.31 and 0.38, respectively). This may suggest that the calves consumed some mineral supplement during the summer grazing period.

The cell-mediated immune response (Figure 1), as measured by injection with PHA, was not affected ($P>0.05$) by trace mineral type or level. The greatest relative skin swelling change occurred at the 8-h measurement, compared with the 24- or 48-h measurement.

Implications

Supplementing elevated levels of trace minerals to deficient cows (based on liver biopsies) appeared to have little impact on cow body weight and condition score change. Organic trace mineral supplementation enhanced early reproductive performance and calf average daily gain, compared with inorganic trace mineral supplementation.



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