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Effect of an injectable trace mineral supplement containing selenium, copper, zinc, and manganese on the health and production of lactating Holstein cows

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ABSTRACT

The objective of this study was to evaluate the effect of a subcutaneous injection of a multimineral preparation containing 300 mg of zinc, 50 mg of manganese, 25 mg of selenium, and 75 mg of copper at 230 and 260 days of gestation and 35 days postpartum, on the health, milk production and reproductive performance of lactating Holstein cows. A randomized field trial was conducted on three large commercial dairy farms located near Ithaca, New York, USA, with 1416 cows enrolled. All cows were housed and offered a total mixed ration consisting of approximately 55% forage and 45% concentrate on a dry matter basis of the diet, which supplied 2–6 times the NRC requirements for the supplemented elements. Dry cows and pregnant heifers were blocked by parity and randomly allocated to one of two treatments: Trace mineral supplemented (TMS) or control.

For multiparous cows, subcutaneous TMS significantly decreased linear somatic cell count scores (normalized data) as compared to control cows. The incidence of subclinical mastitis for TMS and control cows was 10.4% and 8.0%, respectively ($P = 0.005$). The main effect of treatment on clinical mastitis was not significant but the interaction of treatment and parity was significant. For primiparous cows, the incidence of clinical mastitis was 11.8% and 15.6% for control and TMS cows, respectively ($P = 0.33$); for multiparous cows, the incidence of clinical mastitis for control and TMS cows was 25.4% and 19.7%, respectively ($P = 0.03$). Additionally, control cows had increased odds of stillbirth and endometritis (odds ratios 1.69 and 1.30, respectively). The incidence of endometritis was 34.2% and 28.6% for control and TMS cows, respectively ($P = 0.039$) but treatment had no effect on reproductive performance, milk production or other health traits. Further research is required to confirm these findings and to establish whether the response seen in this study was related to the supplementation of a particular mineral.

Introduction

During the transition period, dairy cows undergo physiological stress preparing for and recovering from parturition, dramatically altering their metabolism to supply the mammary gland with nutrients necessary for milk synthesis (Goff et al., 2002), and also dealing with reduced dry matter intake (DMI), negative energy balance (Roche et al., 2009) and oxidative stress (Sordillo and Aitken, 2009).

Trace minerals play an important role in dairy cow immune function (Shankar and Prasad, 1998), fertility (Rabiee et al., 2010), and growth (Enjalbert et al., 2006). Nockels et al. (1993) reported that stressed calves reduced their trace mineral retention ability. Given that the transition period is a stressful time for the cow, a similar reduction in trace mineral retention ability could also happen in transition cows (Xin et al., 1993). The act of parturition or the beginning of lactation has been found to be associated with a reduction in plasma concentrations of calcium (Ca) and zinc (Zn) (Goff and Stabel, 1990; Goff et al., 2002), suggesting that other mineral concentrations could also be affected during the same period.

Inclusion of minerals in the diet does not ensure intake or absorption. DMI is already decreased during the transition period (Roche et al., 2009); additionally, there are dietary and animal factors contributing to DMI variation between animals (Hayirli et al., 2002) and consequently to variation in the intake of trace minerals. Dietary mineral supplements may not be absorbed properly due to interactions with other nutrients at the rumen level (Suttle, 1986). Antagonists in drinking water (e. g. iron) can also have a negative effect on trace mineral absorption from the digestive tract (Spears, 2003).

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An injectable trace mineral solution could potentially provide an alternative way of delivering extra trace minerals during the transition period. Pogge et al. (2012) reported that the use of an injectable trace mineral solution increased liver concentrations of Cu and Se for at least a 15-day period, and increased plasma Zn and Mn for several hours. Positive effects of such supplementation on cow reproductive traits have already been shown (Harrison et al., 1984; Sales et al., 2011). Additionally, Cu and Se seem to play an important role in udder health (Scaletti et al., 2003; Weiss et al., 1990). However, to the best of our knowledge, studies regarding the effect of injectable trace mineral supplementation during the transition period on health and milk production traits remain scarce. It is possible that supplementing cows with extra trace minerals twice in the dry period may help them accumulate trace minerals in stores which can be used during early lactation, while an injection during early lactation could have a positive effect on reproductive efficiency.

The objective of this study was to evaluate the effect of subcutaneous supplementation of a trace mineral supplement containing Zn, Mn, Se, and Cu (Multimin) at 230 days of gestation, 260 days of gestation and 35 days postpartum on health traits, milk production and reproductive performance of lactating Holstein cows.

Material and methods

Farms and management

One thousand, four hundred and sixteen cows kept on three dairy farms located near Ithaca, New York, USA, were enrolled from 30th August until 4th November 2010, and data were collected until 30th June 2011. Farm A milked 3700 cows, farm B 1600 cows and farm C 3500 cows. The cows on farms A and C were housed in free-stall (cubicle) barns with concrete stalls covered with mattresses and bedded with digested manure solids and waste paper–pulp, respectively. Farm B housed the cows in free-stalls with sand bedding.

All cows were offered a total mixed ration consisting of approximately 55% forage (corn silage, haylage, and wheat straw) and 45% concentrate (corn meal, soybean meal, canola, cotton seed, and citrus pulp) on a DM basis of the diet. The diets were formulated to meet or exceed the National Research Council nutrients requirements for lactating Holstein cows weighing 650 kg and producing 45 kg of 3.5% fat corrected milk. The chemical composition (mineral and vitamins) of pre-fresh and lactating cow diets for study farms A, B, and C is shown in Table 1.

Study design and treatments

Dry cows and pregnant heifers were blocked by farm and parity group (groups 1, 2, and >2, for first, second and third or greater lactation cows, respectively) and randomly allocated to one of two treatments, namely, (1) trace mineral supplemented (TMS) or (2) control. All dry cows and pregnant heifers that were available during the enrollment period were included in the study. Randomization was completed in Excel (Microsoft) using the random number function and imported into the farms' Dairy Comp 305 program (Valley Agricultural Software).

Cows that were randomly assigned to the treatment group were given three injections of trace minerals (Multimin) at approximately 230 days of gestation, 260 days of gestation, and 35 days postpartum; each injection (5 mL) contained 300 mg of zinc, 50 mg of manganese, 25 mg of selenium, and 75 mg of copper. Ethylenediamine tetra-acetate (Na_2EDTA) was used to dissolve insoluble Cu, Mn and Zn at a concentration of 450 mg/mL; 0.1% chlorocresol was added to the solution as a preservative. Control cows were not injected with a negative placebo. Body condition scores (BCS) were assessed at 230 days of gestation and at 35 ± 3 days in milk (DIM). A 5-point scale was used (Edmonson et al., 1989). Assessors were blinded to treatment status.

The project proposal was approved by the Cornell University Animal Care and Use Committee (2009-0001) and owner consent was obtained before the study was started.

Case definitions

'Stillbirth' was defined as the death of a calf occurring just prior to, during, or within 48 h of parturition. 'Retained fetal membranes' was defined as failure to release fetal membranes within 24 h of calving. Metritis and clinical mastitis were diagnosed and treated by trained farm personnel who followed a specific diagnostic protocol designed by the staff of the Ambulatory and Production Medicine Clinic, Cornell University. 'Metritis' was defined as the presence of fetid, watery, red–brown uterine discharge. 'Clinical mastitis' was defined by the diagnosis of abnormal changes in the udder and/or milk. Composite milk somatic cell count (SCC) was determined monthly by Dairy Herd Improvement Association (DHIA). 'Subclinical mastitis' was defined as a cow having a somatic cell count >200,000 and not diagnosed with clinical mastitis (Oliveira et al., 2011).

Data regarding survivability, reproduction (calving to conception interval), health traits, milk yield and SCC during the subsequent lactation were extracted from the farms' DairyComp 305 database. Displaced abomasum diagnosis made by the farm personnel was confirmed by veterinarians. Signs of uterine inflammation were evaluated at 35 ± 3 DIM by visual inspection of a uterine lavage sample as previously described (Machado et al., 2012a). Cows that had pus in the lavage sample were considered to have clinical endometritis.

Statistical analysis

Descriptive statistics analysis was undertaken in SAS using the FREQ procedure (SAS Institute). Five mixed general linear models were fitted to the data using the MIXED procedure of SAS (SAS Institute). The dependent variables evaluated in this study were: average daily milk production (kg/day), average daily fat-corrected milk (FCM) production (kg/day), milk protein (%), milk fat (%), and linear somatic cell count (SCC) score. The latter was calculated using the formula:

$$\text{Linear score} = [\ln(\text{SCC}/100,000)/0.693147] + 3$$

This formula is automatically calculated and inputted into the dairy farm software of participating dairy farms by Dairy Herd Improvement Association laboratories (Radostits, 2000). Visual evaluation of the distribution plot of the studentized residuals was used to confirm that the residuals were normally distributed.

Table 1
Chemical composition (minerals and vitamins) of pre-fresh and lactating cow diets for study farms A, B, and C.

	NRC 2001 recommendations		Farm A		Farm B		Farm C	
	Pre-fresh	Lactation	Pre-fresh	Lactation	Pre-fresh	Lactation	Pre-fresh	Lactation
Calcium (%)	0.45	0.67	1.37	0.83	1.35	0.80	1.52	0.88
Phosphorus (%)	0.23	0.36	0.30	0.36	0.31	0.42	0.34	0.38
Magnesium (%)	0.12	0.2	0.42	0.32	0.37	0.35	0.39	0.33
Potassium (%)	0.52	1.06	1.11	1.24	1.07	1.28	1.55	1.54
Sodium (%)	0.10	0.22	0.12	0.46	0.11	0.47	0.14	0.53
Chloride (%)	0.15	0.28	0.52	0.50	0.36	0.50	0.45	0.59
Sulfur (%)	0.20	0.20	0.41	0.25	0.36	0.24	0.45	0.25
Cobalt (ppm)	0.11	0.11	0.96	1.49	0.87	1.13	0.75	1.90
Copper (ppm)	13.0	11.0	19.2	20.0	16.3	21.6	16.5	25.7
Iodine (ppm)	0.40	0.44	0.96	0.99	0.18	0.69	0.92	1.08
Iron (ppm)	13.0	17.0	225	205	220	190	316	213
Manganese (ppm)	18.0	13.0	109	72.8	81.0	81.5	95.8	90.2
Selenium (ppm)	0.30	0.30	0.38	0.47	0.36	0.53	0.55	0.57
Zinc (ppm)	22.0	52.0	63.8	80.8	53.7	84.4	70.90	91.76
Vitamin A (kIU/day)	82.6	75.0	178	170	138	172	178	187
Vitamin D (kIU/day)	21.5	21.0	35	39	27	43	34	42
Vitamin E (IU/day)	1202	545	1772	726	1560	611	1760	874

Pre-fresh diets were fed from 3 weeks prepartum through parturition and lactation diets were fed from parturition through week 35 postpartum.