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Long-term effect of organic trace minerals on growth, reproductive performance, and first lactation in dairy heifers

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ABSTRACT

The effect of trace mineral nutrition in utero and during growth and first lactation was evaluated using 64 multiparous dry cows supplemented with organic (OTM) or inorganic trace minerals (ITM) for 60 d before calving. At calving each calf was alternately assigned to OTM or ITM, to obtain 32 calves in each treatment. Calves received OTM or ITM treatments in colostrum (from treatment mothers), milk replacer, and starter, and then as heifers they received treatment in a TMR until 100 DIM. Growth, reproductive, and lactation performances until 100 DIM were evaluated. Age at calving was compared by treatment. Body weight, hip height, withers height, and heart girth were not affected by the trace mineral form received before calving ($P > 0.05$) except near calving, when these traits were affected by some heifers leaving the study as they calved. Heifers fed OTM tended to calve earlier than those supplemented with ITM ($P = 0.07$). Overall milk yield until 100 DIM was greater in OTM supplemented heifers ($P = 0.09$); however, trace mineral form did not affect milk quality. Overall, in the long term, OTM appeared to improve age at calving and early-lactation milk production of dairy heifers, which may affect their future productive life.

Key words: heifer, trace minerals, growth, reproduction, lactation

INTRODUCTION

Many studies have shown that nutrition from birth through puberty affects lactation performance later in life (Le Cozler et al., 2008). The amount and bioavailability of trace minerals (**TM**) such as Zn, Mn, Cu, and Co are examples of such an interaction. Trace minerals are required for structural proteins, enzymes, coenzymes, and cellular proteins (Nocek et al., 2006) and are important for immune function and health. Also, TM are cofactors for metabolic and chemical reactions in cells and tissues.

Cobalt is a cofactor for vitamin B_{12} synthesis in the rumen, and vitamin B_{12} is required in many metabolic reactions for transfer of methyl groups (Herdt and Hoff, 2011). Animals with Co deficiency have low appetite and poor growth (Heinrichs, 1996). Zinc is highly abundant in the cell, where it is structurally and functionally important (e.g., enzymatic and cell cycle regulation). Also, Zn plays a role in appetite regulation, immune function, and growth in calves and heifers (Herdt and Hoff, 2011), increasing ADG before and after weaning (Spears, 1996). Zinc deficiencies are associated with reduced intake and poor growth in calves and heifers, decreased fertility, and high susceptibility to infection (Heinrichs, 1996; Spears, 1996; Herdt and Hoff, 2011). Copper is a structural component of molecules in several tissues and a component of enzymes and coenzymes necessary for ATP and melatonin synthesis, formation of connective tissue, and maintenance of adequate antioxidative status (cytochrome oxidase, superoxide dismutase, tyrosinase, and lysyl oxidase, among others). Copper deficiencies are often associated with low BW, reproductive cycle abnormalities (anestrous, embryonic loss, polycystic ovaries), and greater incidence of diseases due to depressed immune function (Herdt and Hoff, 2011). Iodine and Mn are very important during puberty in heifers, and deficiencies are expressed as failure in estrus expression or absence of estrous, reduced conception rates, retained placentas, and fetal resorption (Heinrichs, 1996).

Reproductive performance in ruminants is highly dependent on their nutritional status, and TM are involved in synthesis of reproductive hormones, reduction of free radicals, improvement of the uterine micro-environment for embryonic implantation, and fetal growth and development (Smith and Akinbamijo, 2000). Moreover, maternal nutrition affects offspring performance and can affect the health and productive life of progeny (Rhind, 2004).

Trace minerals traditionally have been supplemented as inorganic salts, but organic forms are increasingly used in dairy diets. Chelated organic TM are more stable in the gastrointestinal environment and do not form complexes with other minerals or dietary components; hence, intestinal absorption is increased. Also, this form of presentation is more similar to the form of TM in the body in comparison with free inorganic ions (Spears, 1996).

Authors declare no conflict of interest.

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The aim of this study was to investigate the effect of TM form on growth, reproduction, and first-lactation performance in dairy heifers exposed to inorganic or organic TM in utero through 100 DIM under controlled feeding management.

MATERIALS AND METHODS

Experimental Design

All procedures involving the use of animals were approved by the Pennsylvania State University Institutional Animal Care and Use Committee (#41063). Sixty-four dry cows of second or greater parity were supplemented with organic (**OTM**) or inorganic (**ITM**) trace minerals (n = 32 per treatment) for 60 d before calving in winter and spring of 2013. At calving, each calf was alternately assigned to either OTM or ITM (n = 32). Thus, calves received OTM or ITM treatments beginning in the last 60 d of gestation and continuing into their first lactation. The combination of in utero and postnatal feeding resulted in 4 treatment groups: inorganic heifer-inorganic cow (**IH-IC**); inorganic heifer-organic cow (**IH-OC**); organic heifer-inorganic cow (**OH-IC**), and organic heifer-organic cow (**OH-OC**; Gelsinger et al., 2016).

Calves received 2 L of colostrum immediately after birth and 2 L more between 8 and 10 h after birth. Colostrum was provided by cows fed OTM or ITM. Calves were placed in individual pens and fed the same amount of milk replacer (20% CP, 20% fat) containing OTM or ITM twice a day. Decoquinate (DECCOX; Zoetis, Florham Park, NJ) was added daily in the milk replacer at 8.6 mg/g of DM to control possible coccidiosis. Also, calves received the same starter (except for the TM treatment) with a maximum of 2.3 kg/d until weaning. Calves were weaned at 7 wk and kept in the calf barn until wk 12, where they were fed 2.3 kg/d OTM or ITM starter plus ad libitum second-cutting grass hay and water. Then, heifers were group housed in a naturally ventilated free-stall barn with free access to water. Until breeding, heifers were allocated to pens (12 m^2 per heifer) with sawdust beds that were changed weekly. After breeding, heifers were moved to a different pen in the same barn with sand bedding. During all times, both groups of heifers received the same silage-based TMR but with different TM (OTM or ITM) under a precision feeding system, where the amount feed offered was adjusted weekly based on BW. Dry matter intakes were increased according to age and BW; therefore, no refusals were observed. Heifers were bred based on observed estrus only. Close to calving (±60 d), heifers were transferred to a prepartum pen where they were fed a TMR with the respective TM (OTM or ITM). Proteinate TM (Co, Cu, Mn, Zn) and selenium yeast were supplied by Alltech (BioPlex and Sel-Plex, Nicholasville, KY) for the entire study. Inorganic forms were sulfated minerals, and organic forms were proteinates. Chemical composition of the diets is presented in Table 1. Composition of the TM supplemented for each period is in Table 2.

Calves were weighed and measured at birth, at weaning, and every 2 mo until calving; these periods will be referred to as the growth part of the trial. Growth measurements included BW, hip height, withers height, and heart girth. After calving, first-lactation heifers were milked twice a day (0500 and 1700 h), and milk yield was recorded daily until 100 DIM by an Afifarm system (S.A.E. Afikim, Kibbutz Afikim, Israel; United States distributor: Germania Dairy Automation, Waunakee, WI). Milk samples were collected a.m. and p.m. 30, 60, and 90 d after parturition. Milk subsamples were stored at 4°C with preservative (Bronolab-WII; D&F Control Systems Inc., Dublin, CA) until analyzed for fat, protein, lactose, total solids, and SCC by infrared spectroscopy [Fossomatic 4000 Milko-Scan and 400 Fossomatic, Foss Electric, Hillerød, Den-

Table 1. Chemical composition of the diets[1] at different stages of growth in heifers supplemented with organic (OTM) or inorganic (ITM) trace minerals

Chemical composition	4 to 6 mo[2]		6 to 10 mo		10 to 16 mo		16 to 20 mo		20 mo to calving		First lactation	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DM, %	55.65	±6.1	50.14	±5.4	60.25	±4.8	55.82	±5.2	46.13	±4.9	53.92	±5.6
CP, %	18.02	±4.1	16.01	±2.5	15.82	±2.2	16.74	±2.1	13.07	±3.1	17.70	±2.5
NDF, %	38.26	±7.1	40.70	±5.2	38.47	±4.6	41.77	±4.1	45.63	±4.8	32.04	±4.2
ADF, %	28.25	±5.2	31.64	±3.8	29.61	±3.6	34.13	±3.1	30.24	±3.5	24.9	±3.1
Ca, %	0.63	±0.1	0.53	±0.2	0.50	±0.2	0.56	±0.3	0.61	±0.4	0.58	±0.5
P, %	0.31	±0.1	0.22	±0.1	0.29	±0.2	0.28	±0.3	0.26	±0.3	0.25	±0.2
ME,[3] Mcal/kg	2.31	±0.1	2.25	±0.3	2.32	±0.2	2.18	±0.1	2.32	±0.1	2.52	±0.2

[1] Chemical compositions (DM basis) are means of the diets received by group during the entire trial.

[2] From weaning to 4 mo, heifers received ad libitum grass hay and 2.5 kg of starter.

[3] ME calculated as TDN × 0.04409 × 0.82 (NRC, 2001).

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