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Association between chelated trace mineral supplementation and milk yield, reproductive performance, and lameness in dairy cattle

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ABSTRACT

The objective of this experiment was to evaluate the effects of feeding a ration with partial replacement of chelated trace minerals (CTM; Zn, Cu, and Mn supplied as Mintrex®) compared with a ration containing only inorganic trace minerals (ITM; supplied as sulfates, carbonates, and oxides at a commercial level) on locomotion score, milk production, and reproductive performance of dairy cows in different herds. Twenty-seven dairy herds members of a dairy cooperative (La Pirenaica, La Seu d'Urgell, Spain) that fed the same total mixed ration (TMR), were enrolled in a 6-month study. Fifteen herds continued to receive the same TMR (containing ITM), and the remaining 12 herds fed the same TMR with the only difference being a partial replacement of ITM for CTM. The ITM premix provided 57 ppm of inorganic Zn, 9 ppm of inorganic Cu, and 27 ppm of inorganic Mn, whereas the CTM premix contained 32 ppm of inorganic Zn and 25 ppm of chelated Zn, 3 ppm of inorganic Cu and 6 ppm of chelated Cu, and 17 ppm of inorganic Mn and 10 ppm of chelated Mn. The first month of study was used as a basal period, and then herds were exposed to dietary treatments for 5 months. The total number of lactating cows enrolled in the study was 2880. There were no differences in feed offered (24.1 ± 0.20 kg/d) or milk production (31.4 ± 0.23 kg/d) between treatments. The overall proportion of cows with a lameness score ≥ 3 (considered lame cows) was not different between ITM and CTM herds, but there was an interaction between treatment and month of experiment due to a numerically greater prevalence of lameness in CTM than in ITM herds during the first 2 months of study, and a lesser prevalence in the last 3 months of study. Cows in ITM herds had a greater risk of being culled due to lameness. A partial replacement of inorganic for chelated forms of Cu, Mn, and Zn (CTM) showed a greater potential for improving hoof health in herds with a relatively low prevalence of lame cows. Lastly, when considering only cows that were exposed to treatments for at least 30 days, cows in CTM herds had greater odds of becoming pregnant at first service and tended to have greater odds of becoming pregnant at second service than cows in ITM herds.

1. Introduction

Although trace minerals are included in very low levels in the diet (mg/kg), they are essential for correct performance and health, including claw integrity, fertility, milk production, and immune function (Miller et al., 1988; Smart and Cymbaluk, 1997; NRC, 2001). Trace minerals such as Cu, Mn, and Zn have important roles in protein synthesis, vitamin metabolism, formation of connective tissue, and immune function (Miller et al., 1988), and have been typically offered to cattle as inorganic compounds in the form of inorganic salts; for example, oxides, chlorides, sulfates, and carbonates. In these salts, the trace mineral dissociates from the sulfate or oxide when hydrated in the digestive tract. Dissociated minerals can interact with components of digesta and form insoluble or indigestible compounds (McDonald et al., 1996; Spears, 2003). As level of milk production has progressively increased, there has been considerable interest in the use of organic trace minerals in rations for ruminants. Organic forms of Cu, Mn, and Zn including metal amino acid chelates, metal complexes, metal methionine hydroxy-analog chelates, metal proteinates, and metal propionates have been shown to increase intestinal absorption and mineral bioavailability (Predieri et al., 2005; Wright et al., 2008). Thus, chelated forms of trace minerals could supply the same amount of available mineral at lower inclusion levels than inorganic forms, or alternatively, feeding similar levels of

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organic supplements in place of inorganic forms may result in an increased bioavailable supply of trace minerals to the animal (Nemec et al., 2012). In fact, Cope et al. (2009) reported an increased milk yield in cows supplemented with an organic form of Zn compared with cows consuming equivalent amounts of an inorganic form of Zn; however, most of the increase in milk yield was driven by a greater feed intake in cows offered organic than in those offered inorganic minerals.

Hardness of the hoof keratin has been shown to depend, in part, on the content of Ca, Cu, Zn and P, and Zn concentration has been reported to be lower in the hoof of lame animals (Baggott et al., 1988). Thus, the interruption of nutrient supply to the keratin-forming cells could result in the formation of inferior keratin tissue, potentially causing claw disorders and subsequent lameness (Tomlinson et al., 2004). Furthermore, a study (Enjalbert et al., 2006) involving more than 2000 commercial dairy and beef herds found that deficient or marginal plasma Zn concentration was associated with increased prevalence of metritis.

We hypothesized that a partial replacement of inorganic trace minerals (ITM) by homologous chelated trace minerals (CTM) would improve animal performance (especially reproduction) and hoof health. Thus, the objective of this experiment was to evaluate the effects of a partial replacement of CTM as Mintrex® (Zn, Cu, and Mn; with methionine hydroxy-analog as a ligand) compared with a ration containing only ITM (supplied as sulfates, carbonates, and oxides at a commercial level) on locomotion score, milk production, and reproductive performance of dairy cows in different herds.

Table 1
Feed and nutrient composition (g/kg of DM) of the total mixed ration.

Composition	Content
Ingredients	
Corn	241
Soybean meal	142
Corn silage	139
Oats silage	116
Barley	83
Beet pulp	78
Barley straw	57
Wheat silage	40
Molasses	34
Soybean hulls	32
Calcium carbonate	12.8
Sodium bicarbonate	7.9
Dicalcium phosphate	5.3
Sodium chloride	4.0
Urea	1.8
Vitamin–mineral premix[a]	1.8
Magnesium oxide	1.3
Nutrients	
CP	151
NDF	314
ADF	191
Ash	83
Ether extract	32
NFC[b]	420

[a] The premix composition was different depending on treatment (see Table 2).
[b] Non-fiber carbohydrates calculated as 100–CP–fat–EE–ash.

2. Materials and methods

2.1. Animals and treatments

Initially, all lactating cows from a total of 30 dairy herds, members of a dairy cooperative called 'La Pirenaica' (La Seu d'Urgell, Lleida, Spain) that were fed the same total mixed ration (TMR), were enrolled in a 6 months study. All participating herds were within a radius of 50 km and thus shared the same climatic conditions. The TMR had the same ingredients (and nutrients), which were mixed at a unique location and then distributed to each herd by truck. The first month of study was used as a basal period, and then herds were exposed to dietary treatments for five consecutive months. Reproductive data (pregnancy diagnosis) continued to be collected for 2 additional months to allow calculation of conception rates of the last month of study. Even though the same ration was fed to all cows across herds, farms differed in some aspects of management (such as stocking density, cubicle dimensions, etc.). The study started in December with a 1 month basal data collection period, and in January, herds were blocked according to production, average lactation number, lameness score, and reproductive performance, and assigned to ITM or CTM treatments. Then (day 0 of study), 15 herds continued to receive the same TMR (containing ITM), and 15 herds fed the same TMR (Table 1) with the only difference being a partial replacement of ITM for CTM. For the ITM herds, supplemental Cu, Mn, and Zn were supplied as sulfate, carbonate, and oxide salts (respectively), whereas for the CTM herds, Cu, Mn, and Zn were provided as metal methionine hydroxy-analog (2-hydroxy-4-methylthiobutanoic acid) chelates (Novus International, St. Charles, MO) partially replacing ITM. The ITM premix provided 57 ppm of inorganic Zn, 9 ppm of inorganic Cu, and 27 ppm of inorganic Mn, whereas the CTM premix contained 32 ppm of inorganic Zn and 25 ppm of chelated Zn, 3 ppm of inorganic Cu and 6 ppm of chelated Cu, and 17 ppm of inorganic Mn and 10 ppm of chelated Mn. Producers did not know whether they were feeding ITM or CTM to their cows.

Three herds from the CTM treatment fed some additional dietary supplements (top-dressing) during the course of the study and thus they were removed from the experiment. Therefore, the study included only data from 15 ITM herds and 12 CTM herds. After removing the 3 non-compliant herds, the number of lactating cows involved in the study was 2880 (1287 in ITM and 1593 in CTM herds). The median number of cows per herd was 96 (the average was 106 cows), and the median lactation number of the herds involved was 2.20 lactations, with the ITM herds having a median lactation number of 2.18 and the CTM herds a median of 2.22 lactations. Average days in milk were 208 ± 26 d (mean $\pm$ SD), with ITM herds having an average of 209 ± 23 d, and CTM herds 207 ± 29 d. All cows were Holstein–Friesian. All herds were fed the same TMR (except for the trace mineral composition) during the entire study.

2.1.1. Feed sampling, analysis, and data collection

Before starting the study, 12 samples of the common TMR were collected for 12 d to determine CP ($N \times 6.25$; method 990.03; AOAC (2000)), moisture (oven method 930.15; AOAC (2000)), NDF and ADF with the procedure of Van Soest et al. (1991), ether extract (diethyl ether extraction method 2003.05; AOAC (2000)), and mineral content (Ca, Cl, P, S, Na, K, Mg, Fe, Zn, I, Cu, Co, Mo, Se, and Mn) by dry ashing, followed by acid digestion and final analysis by inductively-coupled plasma mass spectrometry method 985.01 (AOAC, 2000). The final mineral composition of both TMRs is depicted in Table 2. Based on the results from these samples, the concentration of the experimental premix was then designed. Once the exact trace mineral composition of the common TMR was determined, the amount of chelated trace minerals that would substitute part of the inorganic forms was calculated and the study began. During the study, feed samples of about 300 g were taken fortnightly and analyzed for the same nutrients listed above.