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Effect of source of trace minerals in either forage- or by-product–based diets fed to dairy cows: 1. Production and macronutrient digestibility

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ABSTRACT

Excess rumen-soluble Cu and Zn can alter rumen microbial populations and reduce fiber digestibility. Because of differences in particle size and chemical composition, ruminal and total-tract digestibility of fiber from forage- and by-product–based diets can differ. We hypothesized that, because of differences in mineral solubility, diets with hydroxy rather than sulfate trace minerals would have greater fiber digestibility, but the effect may depend on source of fiber. Eighteen multiparous cows were used in a split-plot replicated Latin square with two 28-d periods to evaluate the effects of Cu, Zn, and Mn source (sulfates or hydroxy; Micronutrients USA LLC, Indianapolis, IN) and neutral detergent fiber (NDF) source (forage diet = 26% NDF vs. by-product = 36%) on total-tract nutrient digestibility. During the entire experiment (56 d) cows remained on the same fiber treatment, but source of supplemental trace mineral was different for each 28-d period so that all cows were exposed to both mineral treatments. During each of the two 28-d periods, cows were fed no supplemental Cu, Zn, or Mn for 16 d followed by 12 d of feeding supplemental Cu, Zn, and Mn from either sulfates or hydroxy sources. Supplemental minerals for each of the mineral sources fed provided approximately 10, 35, and 32 mg/kg of supplemental Cu, Zn, and Mn, respectively, for both fiber treatments. Total dietary concentrations of Cu, Zn, and Mn were approximately 19, 65, and 70 mg/kg for the forage diets and 21, 85, and 79 mg/kg for the by-product diets, respectively. Treatment had no effect on dry matter intake (24.2 kg/d) or milk production (34.9 kg/d). Milk fatty acid profiles were altered by fiber source, mineral source, and their interaction. Cows fed the by-product diets had lower dry matter (65.9 vs. 70.2%), organic matter (67.4 vs. 71.7%), and crude protein digestibility (58.8 vs. 62.1%) but greater starch (97.5 vs. 96.3%) and NDF digestibility (50.5 vs. 44.4%) compared with cows fed the forage treatment. Feeding increased concentrations of by-products decreased total digestible nutrients regardless of mineral source. Feeding hydroxy Cu, Zn, and Mn increased NDF digestibility (48.5 vs. 46.4%) but had no effect on total digestible nutrients.
Key words: trace mineral, fiber, digestibility

INTRODUCTION

Source and amounts of trace minerals can affect ruminal fermentation. Organic trace minerals (Cu, Zn, Mn, Se, and Co) had no effect on nutrient digestibility by dairy heifers but increased total VFA production compared with sulfate minerals (Pino and Heinrichs, 2016). Excessive in vitro Cu (Durand and Kawashima, 1980) and Zn (Arelovich et al., 2000; Eryavuz and Dehority, 2009) supplementation negatively affects microbial populations and rumen fermentation. Ruminal solubility of trace minerals is likely a factor that influences how trace minerals affect rumen fermentation and microbial populations, which may in turn affect nutrient digestibility. Hydroxy Cu and Mn are less soluble in the rumen compared with sulfate sources, whereas differences in solubility of hydroxy Zn and Zn sulfate are inconsistent (Cao et al., 2000; Genther and Hansen, 2015). Reducing the concentration of soluble trace minerals, particularly Cu, by feeding hydroxy minerals may increase ruminal digestibility.

Substitution of forage fiber with nonforage fiber sources (i.e., by-products) in dairy rations is a common field practice; however, the source and physical characteristics of dietary fiber affects ruminal fermentation and extent and site of nutrient digestibility (Allen and Mertens, 1988; Firkins, 1997; Varga and Kolver, 1997). By-product–based diets often have less starch than forage-based diets, and starch can inhibit fiber digestibility (Ferraretto et al., 2013). Because of the numerous differences between forage- and by-product–based diets, trace mineral source (i.e., solubility) may affect diets differently depending on carbohydrate sources and concentrations.

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Table 1. Ingredient composition of the diet[1] (% of DM)

	Forage		By-product	
Ingredient	Sulfate	Hydroxy	Sulfate	Hydroxy
Corn silage	44.0	44.0	20.0	20.0
Alfalfa silage	20.0	20.0	15.0	15.0
Ground corn	18.5	18.5	—	—
Soybean meal, 48% CP	14.9	14.9	8.5	8.5
Rolled oats	—	—	14.1	14.6
Dried corn gluten feed	—	—	11.0	11.0
Dried beet pulp	—	—	15.0	15.0
Soy hulls	—	—	14.1	14.1
Animal/vegetable fat	0.51	0.51	0.65	0.65
Limestone	0.69	0.69	0.47	0.47
Magnesium oxide	0.16	0.16	0.07	0.07
Dicalcium phosphate	0.25	0.25	0.13	0.13
Iodized salt	0.48	0.48	0.42	0.42
Selenium premix[2]	0.15	0.15	0.15	0.15
Vitamin mix[3]	0.37	0.37	0.37	0.37
Cu sulfate	0.0003	—	0.0003	—
Zn sulfate	0.0008	—	0.0008	—
Mn sulfate	0.0008	—	0.0008	—
Hydroxy Cu[4]	—	0.0001	—	0.0001
Hydroxy Zn	—	0.0005	—	0.0005
Hydroxy Mn	—	0.0006	—	0.0006

[1]Forage- or by-product–based diets with Cu, Zn, and Mn from sulfate or hydroxy mineral sources.

[2]Sodium selenate, 200 mg/kg.

[3]Contained 735 kIU of vitamin A/kg, 270 kIU of vitamin D/kg, 4,400 IU of vitamin E/kg, and 135 mg of biotin (Rovimix Biotin, DSM Nutritional Products, Heerleen, the Netherlands)/kg.

[4]IntelliBond C, Z, M (IntelliBond; Micronutrients USA LLC, Indianapolis, IN). Based on assays, the products contained approximately 59, 57, and 45% Cu, Zn, and Mn, respectively.

Few published data exist detailing the interaction of dietary mineral and fiber sources on nutrient digestibility in ruminants. We hypothesized that because of differences in rumen solubility, source of trace mineral would affect fiber digestibility (i.e., sulfate source would negatively affect digestibility) and the difference would be greater for diets with greater concentrations of fiber (e.g., by-product–based diets). Furthermore, because milk fatty acid (**FA**) profile can change in response to changes in ruminal fermentation, treatments and interactions could also affect milk FA profile. The objectives of our study were to investigate the effects of trace mineral source on nutrient digestibility and subsequent changes in milk FA composition when fed in forage- or by-product–based diets.

MATERIALS AND METHODS

Cows and Treatments

All animal procedures were approved by The Ohio State University Institutional Animal Care and Use Committee. Eighteen multiparous Holstein cows were placed into 3 groups of 6 cows based on DIM (153 ± 36 DIM at the start of the experiment) and used in a split-plot experiment. Within each group, 3 cows were randomly assigned to 1 of 2 fiber treatments (whole-plot treatment) and remained on that treatment throughout the entire experiment. Whole-plot diets were based on forage or by-product fiber sources (Tables 1 and 2). The split-plot treatments (source of supplemental mineral) were arranged as a 2 × 2 Latin square (2 cows and 2 periods per square). Groups were limited to 6 cows because only 6 digestion stalls were available at our facility. Within a group and period, treatment replications were not balanced (i.e., within each period, 2 treatments were fed to 2 cows each and 2 treatments were applied to only 1 cow each); however, over the entire experiment, replication was balanced.

Following NRC (2001) guidelines, the by-product diets were formulated to have greater concentrations of total NDF and lesser concentrations of starch compared with the forage-based diets. In addition by-products were chosen to specifically increase concentrations of β-glucans, and neutral detergent-soluble fiber because these may bind minerals. Within the whole-plot treatment, each cow was assigned to 1 of 2 supplemental mineral treatment (split-plot treatment) sequences. The experiment had two 28-d periods that consisted of a 16-d phase when no supplemental Cu, Zn, or Mn were fed followed by a 12-d phase of feeding supplemental minerals as sulfates or hydroxy forms (IntelliBond C,