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Effect of source of trace minerals in either forage- or by-product–based diets fed to dairy cows: 2. Apparent absorption and retention of minerals

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ABSTRACT

Eighteen multiparous cows were used in a split-plot replicated Latin square with two 28-d periods to evaluate the effects of source of supplemental Cu, Zn, and Mn (sulfates or hydroxy) on apparent absorption of minerals when fed in either a forage- or by-product–based diet. The by-product diets were formulated to have greater concentrations of NDF and lesser concentrations of starch, and specific ingredients were chosen because they were good sources of soluble fiber and β-glucans, which bind trace minerals in nonruminants. We hypothesized that hydroxy trace minerals would interact less with digesta and have greater apparent absorption compared with sulfate minerals, and the difference in apparent absorption would be greater for the by-product diet compared with the forage-based diet. During the 56-d experiment, cows remained on the same fiber treatment but source of supplemental trace mineral was different for each 28-d period; thus, all cows were exposed to both mineral treatments. During each period cows were fed no supplemental Cu, Zn, or Mn for 16 d, followed by 12 d of feeding supplemental minerals from either sulfate 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 Cu, Zn, and Mn dietary concentrations, respectively, were approximately 19, 65, and 70 mg/kg for the forage diets and 21, 85, and 79 for the by-product diets. Treatment had no effect on dry matter intake (24.2 kg/d) or milk production (34.9 kg/d). Cows consuming the by-product diets had greater Zn (1,863 vs. 1,453 mg/d) and Mn (1,790 vs. 1,588 mg/d) intake compared with cows fed forage diets, but apparent Zn absorption was similar between treatments. Manganese apparent absorption was greater for the by-product diets compared with the forage diets (16 vs. 11%). A fiber by mineral interaction was observed for Cu apparent absorption, as cows fed hydroxy minerals with forage diets had greater apparent absorption compared with cows fed sulfate minerals; however, the opposite was observed with the by-product diets. Source of supplemental trace minerals and type of fiber in diets affected availability of Cu and Mn and should be considered in ration formulation.
Key words: mineral, fiber, by-product, digestibility

INTRODUCTION

As animal production intensifies and environmental constraints increase, chemical and physical forms of minerals and potential interactions of minerals with other feedstuffs must be considered during diet formulation. Substitution of forage fiber with nonforage fiber by-products in dairy rations has been successful (Clark and Armentano, 1993) and can be economically beneficial in certain situations. However, inclusion of small-particle by-products can decrease ruminal pH and the consistency of the rumen mat. These can decrease the rate and extent of fiber digestion and increase the rate of fiber passage (Grant, 1997). Increased flow of undigested fiber fractions increases the binding of divalent minerals, such as Cu and Zn, within the gastrointestinal tract, reducing mineral availability in nonruminants (Drews et al., 1979; van der Aar et al., 1983); however, this has not been studied in ruminants. Binding of polyvalent metal ions to fiber is enhanced in low-pH environments (Torre et al., 1991), similar to that found in the abomasum and proximal small intestine. Increased flow of undigested fiber in by-product diets could increase cationic binding with minerals to a greater extent than observed with forge-based diets.

Decreasing the disassociation of metals in the rumen limits potential antagonism with other digesta, such as fiber fractions, and could increase bioavailability of trace minerals. Hydroxy Cu and Mn (IntelliBond; Micronutrients USA LLC, Indianapolis, IN) are less soluble in the rumen compared with sulfate sources (Genther and Hansen, 2015); however, data are not consistent regarding differences in Zn solubility between

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sulfate and hydroxy sources (Cao et al., 2000; Genther and Hansen, 2015). The decreased rumen solubility of hydroxy Cu and Mn make these a good experimental model for evaluating the potential antagonistic effects of fiber on apparent mineral absorption in ruminants. The primary objective of our study was to determine whether apparent Cu, Zn, and Mn apparent absorption and retention in lactating dairy cows are affected by the interaction between forage or by-product diets and trace minerals.

MATERIALS AND METHODS

Cows and Treatments

All animal procedures were approved by The Ohio State University Institutional Animal Care Committee. Prior to the experiment, all cows used in the experiment were fed diets that contained 15 to 20 mg/kg of total Cu, 50 to 60 mg/kg of total Zn, and 40 to 50 mg/kg of total Mn for several months and should have had adequate body stores of those trace minerals.

Eighteen Holstein cows (7, 6, and 5 in second, third, and fourth lactation, respectively) were assigned to 3 groups of 6 cows based on DIM (153 ± 36 DIM at the start of the experiment). Groups consisted of 6 cows because only 6 stalls designed for total collection of feces and urine are available at our research center. Therefore, 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. Within a group, 3 cows were randomly assigned to either a forage-based diet or a by-product–based diet, and remained on the diet throughout the 56-d experiment. Then, each cow was assigned to 1 of 2 mineral treatment sequences. Hence, the experimental design is a split-plot Latin square with two 28-d periods. Each of the 28-d periods consisted of a 16-d phase where no supplemental Cu, Zn, or Mn were fed, followed by a 12-d phase of feeding either sulfate or hydroxy (IntelliBond C, Z, and M; Micronutrients USA LLC) supplemental minerals. Diet ingredients and nutrient composition are in Tables 1, 2, and 3. Forage and by-product diets were formulated to provide different concentrations of NDF and starch (Table 2). To achieve differing NDF and starch concentrations, a portion of corn silage, alfalfa silage, and all corn grain from the forage diet were replaced with rolled oats, dried corn gluten, dried beet pulp, and soy hulls in the by-product diet (Table 1). These ingredients (Table 2) were chosen to increase dietary concentrations of soluble fiber (specifically, β-glucans and pectin), which have negatively influenced mineral absorption in nonruminants (Torre et al., 1991). Supplemental trace minerals were provided in a top dress (a mix of the appropriate concentrate plus appropriate amount of either sulfate or hydroxyl Cu, Mn, and Zn) fed at 0.2 kg/d. This rate supplied dietary concentrations of 10, 35, and 30 mg/kg of diet DM of supplemental Cu, Zn, and Mn based on average DMI. Actual concentrations of supplemental minerals were similar and close to the target (Table 3). As expected, concentrations of trace minerals in basal diets differed because they were based on different ingredients. Additional information regarding materials and methods are reported in the companion paper (Faulkner and Weiss, 2017).

Cows were housed in individual tiestalls and fed once daily with a target refusal rate of 5% delivered feed. Cows were milked twice daily at approximately 0200 and 1400 h (milk yields were measured electronically). Individual feed delivery and refusal amounts were weighed and recorded daily.

Digestion Collection and Feed Samples

On d 24 of each period (d 8 of feeding supplemental minerals) cows were moved to specifically designed stalls and total output of milk, urine, and feces was measured for 4 d (Weiss et al., 2009). Urine and milk collection containers were acid-washed (50% sulfuric acid) before each collection period, and fecal and feed samples were stored in new plastic bags. Urine (not acidified), milk, orts, and feeds were sampled daily (kept refrigerated) and composited (within cow) over the 4 d. Water intake was measured and recorded daily during the collection periods by water meters connected to each individual water bowl. Silage, fecal, and refusal samples were frozen, lyophilized, and ground through a 1-mm screen (Wiley mill; Arthur H. Thomas Co., Philadelphia, PA). Concentrates were ground but not dried. Feed, orts, and fecal samples were sent to Cumberland Valley Analytical Services (Hagerstown, MD) for mineral analyses using standard wet chemistry methods (AOAC International, 2000; CVAS, 2014). Mineral samples were ashed (1 h at 535°C), digested in 15% nitric acid, diluted, and assayed by inductively coupled plasma emission spectroscopy. Methods for feed analyses were described in a companion manuscript (Faulkner and Weiss, 2017).

On d 28, blood samples were collected from the tail vein into trace mineral free vacutainers (BD Vacutainer, Franklin Lakes, NJ) for serum and into heparinized tubes for whole blood assays. Whole blood was assayed in duplicate for hemoglobin (Kit Cat. No. MAK115, Sigma-Aldrich, St. Louis, MO) and superoxide dismutase (**SOD**) activity (Ransod SD 125, Randox Laboratories, Crumlin, UK). Blood was allowed to clot;