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The effect of trace mineral source and concentration on ruminal digestion and mineral solubility

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ABSTRACT

The objective of this experiment was to compare the effect of sources of sulfate trace mineral (STM) and hydroxy trace mineral (HTM) at different inclusions on digestibility of dry matter (DM) and neutral detergent fiber and solubility of Cu, Mn, and Zn in the rumen and abomasum of cattle. Five ruminally cannulated steers were used in a 5 × 5 Latin square design and individually fed a corn silage–based diet on an ad libitum basis. The 5 dietary treatments were as follows: control: no supplemental Cu, Mn, or Zn, analyzed to contain 7.4 mg of Cu, 30.8 mg of Mn, and 32.1 mg of Zn per kilogram of diet DM (CON); low sulfate: 5 mg of Cu/kg of DM supplemented from $CuSO_4$, 15 mg of Mn/kg of DM from $MnSO_4$, and 30 mg of Zn/kg of DM from $ZnSO_4$; low HTM: 5 mg of Cu/kg of DM supplemented from basic copper chloride (IntelliBond C; Micronutrients Inc., Indianapolis, IN), 15 mg of Mn/kg of DM from manganese hydroxychloride (IntelliBond M; Micronutrients Inc.), and 30 mg of Zn/kg of DM from zinc hydroxychloride (IntelliBond Z; Micronutrients Inc.); high sulfate: 25 mg of Cu/kg of DM supplemented from $CuSO_4$, 60 mg of Mn/kg of DM from $MnSO_4$, and 120 mg of Zn/kg of DM from $ZnSO_4$; and high HTM: 25 mg of Cu/kg of DM supplemented from basic copper chloride, 60 mg of Mn/kg of DM from manganese hydroxychloride, and 120 mg of Zn/kg of DM from zinc hydroxychloride**.** Periods lasted for 12 d, with 10 d of diet adaptation. Dacron bags containing the CON total mixed ration were inserted on d 11 at 0 h and were removed at 6, 12, 24, and 36 h after insertion. Dry matter and neutral detergent fiber disappearances and rumen and simulated abomasal trace mineral solubilities were evaluated. Dietary treatment did not affect DM intake. Dry matter disappearance was lesser in supplemental TM treatments and greater in CON than the STM treatments, although the CON and HTM treatments did not differ. Neutral detergent fiber disappearance was not affected by treatment. Ruminally soluble Cu and Mn concentrations were least in CON and were lesser in HTM-containing treatments compared with STM treatments. However, in the abomasum, solubilities of Cu and Mn were similar across trace mineral sources. Ruminal and simulated abomasal soluble Zn was greater in the HTM treatments than in CON and STM, driven by the greater solubility of the high HTM treatment. Under the conditions of this study, supplementing trace minerals as STM decreased DM digestibility, whereas HTM did not affect DM digestibility. Additionally, Cu and Mn from HTM sources were relatively insoluble in the rumen but had similar solubility as STM at the pH found in the abomasum, suggesting that these minerals should be available for absorption in the intestine.
Key words: ruminant, trace mineral, neutral detergent fiber

INTRODUCTION

Rumen microorganisms require trace minerals (**TM**) for proper function. However, most research has shown that microorganism requirements for Cu, Mn, and Zn are minimal, much less than those typically provided by ruminant diets (Hubbert et al., 1958; Martinez and Church, 1970). Dietary concentrations of TM well beyond NRC (2000) recommendations are commonly fed in the feedlot industry (Vasconcelos and Galyean, 2007), whereas TM supplementation in the dairy industry remains uncharacterized. In vitro data also suggest that relatively small concentrations of Cu, Mn, and Zn can negatively affect cellulose digestion, whereas in vivo experimental results have been less consistent. Supplementation of Cu (20 mg of Cu/kg of diet DM) had a negative effect on finishing-cattle gain and feed efficiency (Engle and Spears, 2000a); however, the addition of similar concentrations in another study had no effect on rumen fermentation (Engle and Spears, 2000b). In vivo studies also suggest that a diet that is deficient in Zn for the animal is adequate for rumen microorganisms, although excessive dietary Zn concentrations may lessen DM digestibility (Somers and Underwood, 1969; Arelovich et al., 2000). Overall, this presents a challenge to balance TM supplementation to

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meet animal needs while avoiding negative effects on ruminal activity.

Trace mineral solubility can greatly affect the total concentration that is available to rumen microbes because only soluble minerals are available for use or interactions. Organic Zn sources are often more soluble in the rumen than inorganic sources (Spears, 2003), whereas hydroxy-TM (**HTM**) sources may be less soluble (Spears et al., 2004). IntelliBond C (basic copper chloride, Micronutrients Inc., Indianapolis, IN), IntelliBond M (manganese hydroxychloride; Micronutrients Inc.), and IntelliBond Z (zinc hydroxychloride; Micronutrients Inc.) are Cu, Mn, and Zn metal hydroxy sources, respectively, that should be less soluble in the rumen. It is anticipated that these sources will solubilize at a lesser pH, as found in the abomasum and early small intestine, where absorption occurs. Lesser ruminal solubility of these sources may prevent decreased DM digestibility from TM supplementation, while still remaining available to the animal for absorption later in the intestine. The objective of this experiment was to compare the effect of sulfate TM (**STM**) and HTM sources at different inclusions on DM disappearance, NDF disappearance, and ruminal and simulated abomasal solubilities of Cu, Mn, and Zn in cattle fed corn silage–based diets formulated for a lactating dairy cow.

Table 1. Diet composition

Item	% of diet DM
Ingredient	
Corn silage	41.0
Grass hay	19.0
Soybean meal	14.0
Dried distillers grains with solubles	15.0
Dry-rolled corn	8.5
Limestone	1.60
Vitamin A premix[1]	0.15
Salt	0.70
Trace mineral premix[2]	0.05
Treatment premix[3]	0.03
Calculated composition	
CP[4]	17.5
NDF[4]	32.7
S[5]	0.25

[1]Vitamin A premix contained 4,400,000 IU of vitamin A per kilogram.

[2]Provided the following per kilogram of diet for all treatments: 0.11 mg of Co ($CoCO_3$), 0.53 mg of I [$Ca(IO_3)_2$], 0.3 mg of Se (Na_2SeO_3).

[3]Provided the following per kilogram of diet for individual treatments: control: no supplemental Cu, Mn, or Zn; low sulfate: 5 mg of Cu ($CuSO_4$), 15 mg of Mn ($MnSO_4$), and 30 mg of Zn ($ZnSO_4$); low hydroxy trace mineral: 5 mg of Cu (basic Cu chloride), 15 mg of Mn (Mn hydroxychloride), and 30 mg of Zn (Zn hydroxychloride); high sulfate: 25 mg of Cu ($CuSO_4$), 60 mg of Mn ($MnSO_4$), and 120 mg of Zn ($ZnSO_4$); and high hydroxy trace mineral: 25 mg of Cu (basic Cu chloride), 60 mg of Mn (Mn hydroxychloride), and 120 mg of Zn (Zn hydroxychloride).

[4]Calculated based on individual ingredient analysis from Dairyland laboratories (Arcadia, WI).

[5]Calculated based on ingredient values from NRC (2000), except for dried distillers grains with solubles, which was analyzed for S by Dairyland laboratories.

MATERIALS AND METHODS

Experimental Design

Five ruminally cannulated steers (767 ± 82 kg) were used in a 5 × 5 Latin square design. Steers were individually fed a corn silage–based diet twice daily at 0700 and 1500 h, formulated to meet the needs of a lactating dairy cow (milk yield = 36 kg/d), and allowed to consume water and feed on an ad libitum basis, for approximately 5% orts (Table 1). The 5 dietary treatments were as follows: control: no supplemental Cu, Mn, or Zn, analyzed to contain 7.4 mg of Cu, 30.8 mg of Mn, and 32.1 mg of Zn per kilogram of diet DM (**CON**); low sulfate: 5 mg of Cu/kg of DM supplemented from $CuSO_4$, 15 mg of Mn/kg of DM from $MnSO_4$, and 30 mg of Zn/kg of DM from $ZnSO_4$ (**LSTM**); low HTM: 5 mg of Cu/kg of DM supplemented from basic copper chloride (IntelliBond C), 15 mg of Mn/kg of DM from manganese hydroxychloride (IntelliBond M), and 30 mg of Zn/kg of DM from zinc hydroxychloride (IntelliBond Z; **LHTM**); high sulfate: 25 mg of Cu/kg of DM supplemented from $CuSO_4$, 60 mg of Mn/kg of DM from $MnSO_4$, and 120 mg of Zn/kg of DM from $ZnSO_4$ (**HSTM**); and high HTM: 25 mg of Cu/kg of DM supplemented from basic copper chloride, 60 mg of Mn/kg of DM from manganese hydroxychloride, and 120 mg of Zn/kg of DM from zinc hydroxychloride (**HHTM**). Steers were adapted to a common diet, similar to the final diet, for 21 d before the beginning of the first period. Each 12-d period consisted of 10 d of diet adaptation, and in situ Dacron forage bags were inserted before feeding at 0600 h on d 11.

Dry matter disappearance was measured using preweighed in situ forage bags (10 × 20 cm, 50-µm porosity, Ankom Technology Corp., Macedon, NY). A TMR sample from the CON treatment (CON TMR was used as the substrate for all bags) was dried and ground through a 2-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ). A total of 4 g of CON TMR was added to each bag, and the bags were heat sealed. For each time point 6 total bags were used, 2 blank bags (not containing TMR) and 4 bags containing TMR. All bags (a total of 24 per steer) were added at 0 h, and 6 bags were removed at each of 4 time points, after 6, 12, 24, and 36 h of incubation. Once removed, bags were immediately immersed in ice water to cease fermentation and then transported to the laboratory on ice and frozen at −20°C. After bags were removed at 36 h after insertion, ruminal contents were sampled via a suction