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Effects of magnesium source and monensin on nutrient digestibility and mineral balance in lactating dairy cows

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ABSTRACT

The interaction of monensin and 2 supplemental Mg sources (MgO and $MgSO_4$) on total-tract digestion of minerals and organic nutrients and milk production was evaluated in lactating dairy cattle. Eighteen multiparous Holstein cows (139 ± 35 DIM) were used in a split-plot experiment with 0 or 14 mg/kg diet DM of monensin as the whole-plot treatments and Mg source as split-plot treatments. During the entire experiment (42 d), cows remained on the same monensin treatment but received a different Mg source in each period (21 d) of the Latin square. Diets were formulated to contain 0.35% Mg with about 40% of that provided by MgO or $MgSO_4$. Diets were formulated to have similar concentrations of major nutrients and K concentrations were elevated (2.1% of DM) with K_2CO_3 to create antagonism to Mg absorption. Apparent digestibility was measured by total collection of urine and feces. Supplemental $MgSO_4$ decreased DMI (26.9 vs. 25.7 kg/d) and tended to decrease milk yield (40.2 vs. 39.3 kg/d), but increased the digestibility of OM (68.3 vs. 69.2%) and starch (91.9 vs. 94.4%) compared with MgO. Feeding $MgSO_4$ with monensin decreased NDF digestibility compared with other treatments (46.7 vs. 50.2%). That diet also had decreased apparent absorption of Mg compared with diets without monensin (15.6 vs. 19.2%), whereas MgO with monensin had greater apparent absorption of Mg (23.0%) than other treatments. Cows consuming $MgSO_4$ had increased apparent Ca absorption (32.2 vs. 28.1%) and balance. A diet with $MgSO_4$ without monensin increased the concentration of long-chain fatty acids in milk, suggesting increased mobilization of body fat or decreased de novo fatty acid synthesis in the mammary gland. Overall, when dietary Mg was similar, MgO was the superior Mg source for lactating dairy cattle, but inclusion of monensin in diets should be considered when evaluating Mg sources.

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INTRODUCTION

Relative to daily requirements, lactating dairy cows have small reservoirs of labile Mg (Blaxter and McGill, 1956); therefore, rations must consistently provide adequate absorbable Mg. Absorption of Mg does not appear to be under homeostatic regulation (Schweigel and Martens, 2000), which means that apparent absorption reflects availability of dietary Mg, and apparent absorption varies widely (−4 to 30% of intake; Weiss, 2004). Major factors affecting availability of Mg are dietary K concentration and source of Mg. Apparent absorption of Mg from $MgSO_4$ averaged about twice as great as Mg from MgO when fed to sheep (Van Ravenswaay et al., 1989). This likely reflects greater ruminal solubility of Mg from sulfate than from MgO. Rumen microbes require ionized Mg for fiber degradation (Morales and Dehority, 2014), and increased Mg supply may improve total-tract NDF digestibility in lactating cows (Erdman et al., 1982).

Monensin is a feed additive used to improve feed efficiency by depleting cells and select microbes of intracellular K and altering rumen ecology (Bergen and Bates, 1984). Monensin may also improve digestibility, absorption and retention of nutrients in cattle (Spears, 1990). Feeding monensin has improved Mg apparent absorption 15 to 25% in ruminants by decreasing the antagonistic effect of K on Mg absorption (Greene et al., 1986), but the effects may be dependent on the source of Mg. In gestating beef cattle, monensin with $MgSO_4$ increased plasma glucose and decreased blood urea and ruminal butyrate concentrations in early lactation compared with diets with $MgSO_4$ but without monensin or MgO with monensin (Grings and Males, 1988), suggesting altered energy metabolism and digestibility.

Supplementing diets with a more soluble Mg source and monensin may be beneficial to the high producing dairy cow, especially when subject to K antagonism.

The objective of this research was to investigate the interaction of supplementing 2 different Mg sources and monensin on the digestion and balance of nutrients in lactating dairy cattle. We hypothesized a more soluble source of Mg (i.e., $MgSO_4$) combined with monensin would increase Mg apparent absorption and improve the digestibility of other nutrients in lactating cattle compared with diets without monensin or with MgO.

MATERIALS AND METHODS

Cows and Treatments

All procedures involving animals were approved by The Ohio State University Institutional Animal Care and Use Committee. Eighteen multiparous Holstein cows (139 ± 35 DIM) were used in a split-plot experiment with subplot treatments in a Latin square design. Because our facility only has 6 stalls designed for total collection of urine and feces, cows were placed into 3 groups of 6 based on 10-d average milk yield (range in average group yields: 42.6 to 46.8 kg/d). Whole plot treatments were 0 or 14 mg/kg of DM of monensin (Rumensin 90, Elanco Animal Health, Greenfield, IN). The split-plot design allowed monensin treatments to be fed for the entire 42 d of the experiment without possibilities of carryover effects. Cows were also not fed monensin for at least 3 mo before the experiment. Split-plot treatments (arranged as a 2 × 2 Latin square) were Mg either from MgO (Animag Prilled 30/100, Martin Marietta Magnesia Specialties LLC, Baltimore, MD) or $MgSO_4$ (Magriculture, Giles Chemical, Waynesville, NC). Each Latin square consisted of two 21-d periods with total collection of urine and feces on d 16 to 20 of each period. Diets were formulated to contain about 40% Mg from supplemental Mg sources and have similar concentrations of total dietary Mg (target: 0.35% of DM; Table 1). All diets were formulated to contain similar concentrations of nutrients and have elevated K concentrations (basal diet was 1.3% K plus 0.8% K from K_2CO_3) to create antagonism on Mg absorption.

Cows were housed in individual tie stalls and fed once daily at a refusal rate of 3 to 5%. Individual feed delivery and refusal amounts were weighed and recorded daily. Cows were milked twice daily at 0200 and 1400 h, and milk yields were measured electronically (Afimilk, Kibbutz Afikim, Israel). Cows were weighed on consecutive mornings (values were averaged within a cow) at the beginning and end of each period. Silages were sampled weekly, analyzed for DM (100°C for 48 h), and used to adjust diets. One refusal sample was taken on d 10 of each period, analyzed for DM (100°C for 48 h), and used to calculate DMI when in the tiestalls.

Digestion Collection Samples

For the measurement of apparent nutrient digestibility and balance, cows were moved from tiestalls to digestion stalls, and total output of urine and feces was measured for 4 d (Weiss et al., 2009). Urine (acidified with 50% sulfuric acid and nonacidified), feces, milk, refusals, and feeds were sampled daily (refrigerated between days) and composited by wet weight for each cow. Water intake was measured and recorded daily by water meters connected to each individual water bowl. One water sample from the inlet feeding the water bowl was taken during each digestion period and analyzed for minerals.

Milk, acidified urine, and wet feces composite samples were analyzed for N by the Kjeldahl method (AOAC International, 2000; 984.13.4.09) immediately following each digestion period. Subsamples of feed, refusal and fecal composites were analyzed for DM (100°C for 48 h). The remaining silage, fecal, and refusal composite samples were frozen, lyophilized, and ground through a 1-mm screen (Wiley mill, Arthur A. Thomas Co., Philadelphia, PA). Concentrates and dried, ground samples of silages, feces, and refusals were assayed for DM (100°C for 24 h), ash (muffle oven at 600°C

Table 1. Ingredient composition of the diets

	Diet[1]	
Ingredient, % of DM	MgO	$MgSO_4$
Corn silage	34.2	34.2
Alfalfa silage	22.0	22.0
Ground corn	18.4	17.5
Soybean meal, 48% CP	12.9	13.0
Soy hulls	8.7	8.0
Animal/vegetable fat	0.49	0.48
Potassium carbonate[2]	1.51	1.49
Dicalcium phosphate	0.35	0.35
Magnesium oxide[3]	0.19	—
Magnesium sulfate[4]	—	1.65
Trace-mineralized salt[5]	0.70	0.70
Mineral-vitamin premix[6]	0.62	0.62

[1]198 g/kg of monensin (Rumensin, Elanco Animal Health, Greenfield, IN) added to the diet of each Mg source at 14 mg/kg of the DM by replacing ground corn.

[2]56% K (DCAD Plus, Church & Dwight Co. Inc., Piscataway, NJ).

[3]58% Mg, mean particle size: 923 ± 20.3 μm (Animag Prilled 30/100, Martin Marietta Magnesia Specialties LLC, Baltimore, MD).

[4]9.8% Mg (Magriculture, Giles Chemical, Waynesville, NC).

[5]Contained 95% NaCl, 3,500 mg/kg of Zn, 2,800 mg/kg of Mn, 1,750 mg/kg of Fe, 400 mg/kg of Cu, 70 mg/kg of I, and 70 mg/kg of Co (trace-mineralized salt, Morton Salt Inc., Chicago, IL).

[6]Premix contained 60 mg/kg of Se (sodium selenate), 111 mg/kg of biotin, 3.8 g/kg of Zn (Zinpro 120, Zinpro Corp., Eden Prairie, MN), 800 mg/kg of Cu (copper sulfate), 500 kIU/kg of vitamin A, 200 kIU/kg of vitamin D, and 3,600 IU/kg of vitamin E.

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