Effect of Magnesium (Mg) Source on Digestibility and Buffering Capacity in Cattle

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SUMMARY

These results suggest that magnesium (Mg) supplementation has no detrimental effect on *in vitro* dry matter disappearance and depending on Mg source, may even enhance *in vitro* dry matter disappearance. Furthermore, these results indicate that different Mg sources have different buffering capacities in rumen fluid. Metabolism studies do not suggest a significant difference in Mg retention and absorption from different sources. Therefore, use of different Mg sources should have similar environmental impacts.

INTRODUCTION

Recently, there has been increasing concern about the environmental impacts of concentrated animal feeding operations. Minerals such as copper, zinc, magnesium, and cobalt are fed in excess to compensate for the decrease in feed intake observed in weaned calves arriving to the feedlot. This results in excess mineral excretion by the animal. Mineral contamination of soil and groundwater in areas of livestock concentrations are currently being monitored. The EPA may soon regulate the amounts of those minerals being fed to animals. Therefore, to minimize excretory losses of minerals, sources providing improved utilization to the animal would have value. The objective of this work was to determine the effects of magnesium source on dry matter digestibility and buffering capacity *in vitro* and to compare excretion and retention rates based on *in vivo* metabolism trials.

MATERIALS AND METHODS

Experiment 1: Two ruminally-fistulated heifers (approximate BW = 1100 lbs) were utilized in this experiment. A high roughage diet was fed for 14 d prior to initiation of *in vitro* incubations. On d 15, ruminal samples were obtained 2-h post feeding. A one liter sample of ruminal contents from each animal was collected in an Erlenmeyer flask where pH was recorded and ruminal contents strained through eight layers of cheesecloth. All collected ruminal fluid was then combined and thoroughly mixed. Anaerobic conditions were maintained by bubbling CO_2 through a buffered mineral medium (McDougall, 1948) while two volumes of ruminal fluid were added to each volume of buffer media. Urea was added to provide a final concentration of 0.05%. The suspension was mixed under a CO_2 atmosphere as 90-ml portions were added to pre-weighed 100-ml glass tubes containing 1 g of substrate (alfalfa hay). *In vitro* DM disappearance was determined using 1 g of the basal diet as substrate. Blank tubes containing no substrate were also incubated. To determine the effect of magnesium source and concentration on *in vitro* dry matter digestibility (IVDMD) magnesium from four sources: 1) MgO (MAGOX® - which contains 54% Mg from Premier Chemicals, Inc. Cleveland, Ohio), 2) $MgSO_4$ (magnesium sulfate anhydrous, reagent grade, Mallinckrodt, Inc., St. Louis, MO; 19.1% Mg), 3) Mg-hydroxide (HyMag-94™ - which contains 94%+ brucite from Applied Chemical Magnesias Corporation, Fort Collins, CO; 44.8% Mg), and 4) Mg 60/40 (MW60/40-AF™ - which contains approx. 98% brucitic marble (60% $CaCO_3$ / 40% $Mg(OH)_2$) from Applied Chemical Magnesias Corporation, Fort Collins, CO; 19.1% Mg), was suspended in deionized water and 100 µl of the Mg-water solution was added to the digestion tubes to provide 0.0, 0.10, or 0.20 % Mg/kg substrate DM. Each treatment was run in quadruplicate.

After the ruminal fluid suspension was added, tubes were gently mixed, capped with one way stoppers to keep the system anaerobic, placed in racks, and incubated in a 39 °C water bath for 48 h. Tubes were swirled every three hours to simulate G.I. tract motility. At the end of the 48 h incubation, pH was determined, and microbial activity was terminated by adding 1 ml of a saturated mercuric chloride solution to each tube. Tube contents were then centrifuged at 3000 x *g* for 30 min. The supernatant was decanted, and the digesta dried in a forced air-drying oven for 48 h at 80 °C. *In vitro* DM disappearance was determined by subtracting the mean dry matter weight that remained in the blank tube (adjusted for tube weight) from the DM weight of the tubes with substrate residue and dividing by the initial weight of the substrate added.

A second *in vitro* experiment was conducted to determine the effect of the above treatments on buffering capacity. Fistulated heifers were maintained on either control (no supplemental Mg) or 0.1% of each source of Mg (MgO, Mg-hydroxide, Mg 60/40, and $MgSO_4$) for 10 days prior to obtaining rumen fluid samples. Heifers were limit fed to 90% of their dry matter intake to assure complete consumption of feed. Buffering capacity was measured by titrating 30 ml of ruminal fluid supernatant (containing each of the Mg treatments described above) with .1 N HCl to pH 6.0. Ten replications per treatment were utilized to calculate buffering capacity. Buffering capacity was expressed as ml of 0.1N HCl /ml of ruminal fluid.

Experiment 2: Twelve Angus weaned steers (approximate weight 480 lbs) were utilized from a larger Mg study to determine the effects of Mg source on apparent digestion and absorption of Mg. Treatments consisted of: 1) Control (no supplemental Mg); 2) 0.1% as $Mg(OH)_2$, 3) 0.1% as Mg 60/40, 4) 0.1% Mg as MgO. Steers were fed an alfalfa-corn based growing diet for 56 d until they reached an approximate weight of 792 lb. Diets were fed once daily in the morning in amounts adequate to allow ad libitum access to feed throughout the day. Daily feed offerings were recorded and feed refusals were measured every 28 d. Steers were weighed on day 0, 28, and 56 of the growing phase and average daily gain, feed intake, and efficiency were determined. On d 50 of the growing phase 4 steers per treatment (from the larger Mg study) were placed in digestion crates. Steers were fed 1.25 times their maintenance requirement and given free access to water. Steers remained on the same dietary treatments as they received in the feedlot. Daily feed offerings were recorded and feed refusal was measured daily. Steers were allowed to acclimate for 7 d and then total urine and feces were collected over a 7 d period. To assure complete separation of feces and urine, a urine collection bag was strapped to each animal and connected to a vacuum pump via 9.5 mm plastic tubing. The urine was collected in a plastic carboy that contained 100 ml of HCl. Approximately 150 ml of urine was retained from each collection for Mg analysis. Fecal samples were collected daily and 10% of fecal output was composited over the 7-d collection period and analyzed for Mg. A ruminal fluid sample via stomach tube was obtained from each steer while in the metabolic crates and pH determined. All Mg analyses were determined using flame atomic absorption spectrometry (Varian Model 1275).

After the 7 d fecal and urine collection, steers were returned to their appropriate feedlot pens and switched to a high concentrate finishing diet. On days 0, 28, 56, 84, 112 and 140 d of the finishing phase, all calves were weighed and bled. Blood samples were analyzed. On d 130 of the finishing phase, the same 4 steers per treatment were placed in digestion crates and total urine and feces were collected as described previously. A ruminal fluid sample via stomach tube was also obtained from each steer while in the metabolic crate and pH determined. After the metabolism trial steers were returned to their appropriate feedlot pens.

RESULTS AND DISCUSSION

Experiment 1: Dry matter disappearance was higher ($P < 0.05$) in digestion tubes containing Mg relative to the control (Table 1). Little research has examined the effects of Mg supplementation on dry matter disappearance in ruminants. Although not directly comparable, a recent study by Coffey et al. (2000) reported trends for increased dry matter digestibility in ruminally fistulated heifers supplemented with different concentrations of magnesium mica. In this trial digestion tubes containing $MgSO_4$ ($P < 0.05$), Mg $(OH)_2$ ($P < 0.06$) and Mg 60/40 ($P < 0.08$) had higher dry matter disappearance compared to digestion tubes containing MgO.

Intakes of fistulated heifers were similar across treatments. The effects of Mg source on buffering capacity are presented in table 2. Supernatant from Mg supplemented heifers had a greater ($P < 0.01$) buffering capacity relative to the control. Thomas et al. (1984) reported a trend for a higher ruminal pH in Mg supplemented cows relative to non-supplemented controls. Magnesium oxide supernatant had a higher ($P < 0.01$) buffering capacity relative to the $MgSO_4$ supernatant and tended to have a lower ($P < 0.06$) buffering capacity relative to the $Mg(OH)_2$ supernatant.

Experiment 2: Fecal magnesium excretion (expressed as g of Mg excreted per day) for steers fed a growing diet for 56 days was similar across all Mg supplemented treatments and is comparable to previously published data (Table 3). However, urinary Mg excretion tended ($P < 0.10$) to be lower in the $Mg(OH)_2$ supplemented steers relative to the steers supplemented with similar concentrations of Mg from either Mg 60/40 or MgO. This resulted in a tendency ($P < 0.14$) for the $Mg(OH)_2$ supplemented steers to have a higher Mg retention relative to the Mg 60/40 and MgO supplemented steers. It appears that $Mg(OH)_2$ may be metabolized differently than Mg 60/40 and MgO in steers fed a growing diet for 56 d. Thomas et al. (1984) indicated that dairy cows consumed less Mg from $Mg(OH)_2$ than from MgO, but urine magnesium concentration, percent dietary Mg digested, and the percent dietary magnesium absorbed were not different between $Mg(OH)_2$ and MgO. They concluded that utilization of magnesium from $Mg(OH)_2$ may be greater than from MgO.

Table 4 shows the effects of magnesium source on apparent absorption and retention of Mg in finishing steers. By design, Mg intake was lower ($P < 0.05$) in control relative to Mg supplemented steers. Apparent absorption and retention of Mg was unaffected by treatment. The differences in apparent retention of Mg in the growing and finishing phases may be due to changes in the forage:concentrate ratio between the growing and finishing diets (high roughage vs. high concentrate).

Rumen fluid pH was not affected by treatment during the growing and finishing metabolism experiments. This is in contrast to our *in vitro* buffering capacity data. The reason for the discrepancy between the *in vivo* and *in vitro* data may be due to salivary contamination in rumen fluid samples collected via the stomach tube technique. Excess saliva in a sample could artificially elevate pH.

IMPLICATIONS

Two management factors that impact use of different magnesium sources for diet supplementation are cost and concern over the environmental impact of minerals in manure. If alternate sources of magnesium can be identified that can address either or both of these management concerns there is value in using other magnesium sources to supplement cattle diets.

LITERATURE CITED

Coffey, K.P., T.G. Nagaraja, E.G. Towne, KF. K. Brazle, and J.L. Moyer. 2000. Digestibility of prairie hay diets supplemented with different levels of magnesium-mica by beef heifers. J. Anim. Sci. 78:718-725.

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Table 1. Effects of magnesium source and concentration on in vitro dry matter disappearance

	Treatment									
	Control	MgO		$MgSO_4$		$Mg(OH)_2$		Mg 60/40		
Item	0[a]	0.1%	0.2%	0.1%	0.2%	0.1%	.2%	0.1%	0.2%	SEM
IVDMD, %	58.1	46.7	56.8	64.7	63.0	63.7	55.4	59.9	55.4	3.7

[a] Concentration of Mg added to substrate.
Control vs Mg ($P < 0.05$).
MgO vs $MgSO_4$ ($P < 0.05$).
MgO vs $Mg(OH)_2$ ($P < 0.06$).
MgO vs Mg 60/40 ($P < 0.08$).
0.1% MgO vs 0.1% $MgSO_4$ ($P < 0.04$).
0.1% MgO vs 0.1% $Mg(OH)_2$ ($P < 0.05$).
0.1% MgO vs 0.1% Mg 60/40 ($P < 0.09$).

Table 2. Effects of magnesium source on buffering capacity of ruminal supernatant[a]

Item	Control	MgO	$MgSO_4$	$Mg(OH)_2$	Mg 60/40	SEM
Buffering capacity, ml .1N Hcl/ml of ruminal fluid[b,c,d]	0.10	0.23	0.11	0.27	0.25	0.02

[a] Fistulated heifers were maintained on either control (no supplemental Mg) or 0.1% of each source of Mg for 10 days prior to obtaining rumen fluid samples.
[b] Control vs Mg ($P < 0.01$).
[c] MgO vs $MgSO_4$ ($P < 0.01$).
[d] MgO vs $Mg(OH)_2$ ($P < 0.06$).

Table 3. Effects of magnesium source on plasma magnesium concentrations and apparent absorption and retention of magnesium in growing steers.

	Treatment				
Item	Control	$Mg(OH)_2$	Mg60/40	MgO	SEM
Plasma magnesium, mg/dl					
Initial	1.5	1.5	1.5	1.6	0.1
Final[a,b]	1.4	1.5	1.7	1.5	0.05
Intake, g/d[a]	12.7	22.3	21.3	22.5	0.2
Excretion, g/d					
Fecal Mg[a]	8.8	14.7	14.6	14.8	0.8
Urinary Mg[a,c]	3.0	5.1	5.6	5.9	0.3
Apparent absorption, g/d[a]	3.9	7.6	6.7	7.7	0.9
% of intake	31.0	34.1	31.5	34.2	3.4
Retention, g/d[a,d]	0.9	2.5	1.1	1.8	0.5
% of intake	7.1	11.2	5.2	8.1	2.4
% of absorbed	23.1	32.9	16.4	24.0	9.5

[a] Control vs Mg(OH)2, Mg60/40, MgO ($P < 0.05$).
[b] Mg60/40 vs MgO ($P < 0.05$).
[c] Mg(OH)2 vs MgO ($P < 0.10$).
[d] Mg(OH)2 vs MgO ($P < 0.14$).

Table 4. Effects of magnesium source on plasma magnesium concentrations and apparent absorption and retention of magnesium in finishing steers.

	Treatment				
Item	Control	$Mg(OH)_2$	Mg60/40	MgO	SEM
Plasma magnesium, mg/dl					
Initial	1.4	1.5	1.6	1.5	0.11
Final[a]	1.2	1.6	1.6	1.6	0.08
Intake, g/d[a]	14.0	20.1	20.0	20.4	0.5
Excretion, g/d					
Fecal Mg[a]	9.8	14.7	14.6	15.1	1.1
Urinary Mg[a]	3.0	3.9	3.8	4.0	0.4
Apparent absorption, g/d	4.2	5.4	5.4	5.3	0.8
% of intake	30.0	27.0	27.1	26.0	2.1
Retention, g/d	1.2	1.5	1.6	1.3	0.5
% of intake	8.6	7.5	8.0	6.4	1.2
% of absorbed	29.0	28.0	29.6	26.0	5.6

[a] Control vs Mg(OH)2, Mg60/40, MgO ($P < 0.05$).