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Abstract

Calcium addition is necessary in order to balance the high phosphorus concentrations that are characteristic of high-concentrate ruminant diets. However, calcium sources differ in their bioavailability. Our objective was to determine apparent calcium and magnesium absorption and retention in goats offered diets containing different sources of calcium. Spanish-Boer goats (n = 18; 19.6 ± 1.88 kg) were stratified by body weight (BW) and sex and randomized to dietary treatments consisting of Purina Antlermax 16 containing either calcium carbonate (CC), Calmin (CM) or Milk Cal (MC). Goats were adapted to a control, corn-based high-concentrate diet on pasture and then moved to individual 1.0 × 1.5-m pens with plastic coated expanded metal floors, and adjusted to their respective diets along with removal of hay from the diet over a 7-d period. Goats were then offered their respective diets at a total of 2% of BW in equal feedings at 8:30 AM and 5:00 PM for an additional 14-d adaption period to diet and facilities followed by a 7-d collection of total urine and feces. Data were analyzed using PROC MIXED of SAS. Calcium and magnesium intake were not different ($P \geq 0.12$) among diets. Calcium and magnesium apparent absorption and retention (g/d and % of intake) were greatest ($P < 0.05$) in goats offered CC and did not differ ($P \geq 0.20$) between goats offered the CM and MC diets. Therefore, calcium and magnesium were more available for goats from the diet containing calcium carbonate compared with diets containing Calmin and Milk Cal.

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Meet the Student-Author

Jennifer Long

I am from St. Louis, Missouri and graduated from Cor Jesu Academy in 2012. I graduated in May 2016 with a Bachelor of Science in Animal Science and minors in Wildlife Habitat and Environmental, Soil and Water Science. During my undergraduate career I served as the Vice-President of the University of Arkansas Wildlife Society student chapter. I have completed internships at the Saint Louis Zoo, Endangered Wolf Center and worked at the Beaver Watershed Alliance as a Microsoft Word - Long_Table 1 GAIL REV.docx.pdf Conservation Intern. In June 2016, I plan to move to Logan, Utah to pursue a master's degree in Agricultural Extension and Education at Utah State University.

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Introduction

Calcium is essential for growth and maintenance of bones and teeth and is the most abundant mineral in the body (Soares, 1995). Ninety-nine percent of the body's calcium is located in the skeleton and the remaining 1% is crucial for cellular metabolism, blood clotting, enzyme activation, and neuromuscular action (Soares, 1995). Calcium bioavailability is greatly affected by the calcium-to-phosphorus ratio in the diet (Kim et al., 1985; Albanese et al., 1986; Lopes and Perry, 1986). In high-concentrate diets, calcium addition is required to balance the excessive levels of phosphorus in the diet. The optimal calcium-to-phosphorus ratio is 2:1, but ruminants can tolerate relatively large calcium-to-phosphorus ratios if magnesium concentration in the diet is not great (Chester-Jones et al., 1990).

Calcium carbonate is commonly used as a supplemental calcium source because it is inexpensive and because of its buffering capacity. When the availability of calcium from dried skim milk was rated at 100, Greger et al. (1987) estimated the availability of calcium carbonate at 102% in comparison. Other sources of calcium are available that have potential value as supplements for which little information is available. Therefore, the objective of this study was to determine the bioavailability of calcium and magnesium in growing goats offered different calcium sources.

Materials and Methods

The University of Arkansas Animal Care and Use Committee approved all procedures (IACUC #15062). Spanish × Boer crossbred goats (n = 18; 19.6 ± 1.88 kg) were purchased from a single source, vaccinated against eight clostridial strains (Covexin 8®; Merck Animal Health, Intervet, Inc., Madison, N.J.), dewormed with levamisole hydrochloride (Prohibit® Soluble Drench Power Anthelmintic, Agri Laboratories, Ltd., St. Joseph, Mo.), and co-mingled on a predominantly bermudagrass (*Cynodon dactylon* L.) pasture. Goats were offered increasing amounts of a control, corn-based high-concentrate diet on the pasture until they were consuming the diet at 2% of body weight (BW). They were then stratified by BW and sex and allocated randomly to dietary treatments consisting of a commercially available pelleted diet containing either calcium carbonate (CC), Calmin (CM) or Milk Cal (MC). Calmin is sourced from red algae off of the coasts of Ireland and Iceland. Milk Cal is calcium sourced from milk. Diets were formulated to contain 16% crude protein (CP), 0.6% calcium, 0.48% phosphorus, 0.5% magnesium and 1.4% potassium. However, in the actual diets, calcium composition was slightly greater in CC in comparison to MC and CM (Table 1) with no difference in calcium composition between MC and CM. Magnesium and K composition was similar among the three diets.

Goats were moved to individual 1.0 × 1.5-m pens with plastic-coated expanded metal floors located in an insulated metal barn with exhaust ventilation and adjusted to their respective diets along with removal of hay from the diet over a 7-d period. Goats were then offered their respective diets at 8:30 AM and 5:00 PM for an additional 14-d adaption period to diet and facilities followed by a 7-d collection of total urine, feces and orts. Orts and fecal samples were collected at 8:30 AM daily, weighed, and dried to a constant weight at 50 °C in brown paper bags. Total urine for each goat was collected daily at 8:00 AM, weighed, mixed thoroughly, and a 10% aliquot by volume was placed in individual plastic containers and stored frozen (-20 °C). Forty mL of HCL (50% v/v) were added prior to each daily urine collection to prevent ammonia volatilization by microbial action. Urine samples were composited across days within goat.

Representative samples of feed were taken daily as feed was weighed for the goats and dried to a constant weight at 50 °C in brown paper bags. After drying, feed and fecal samples were allowed to equilibrate to atmospheric moisture in a temperature-controlled room (20 °C) and ground to pass a 1-mm screen in a Wiley mill (Author H. Thomas, Philadelphia, Pa.).

Concentrations of calcium and magnesium were determined using inductively coupled plasma emission spectroscopy after wet ashing with concentrated trace mineral grade nitric acid (ICP-OES; Method 985.01; AOAC, 2000). All laboratory analyses were corrected to a dry matter (DM) basis (Method 934.01; AOAC, 2000).

Data were analyzed using PROC MIXED of SAS with animal considered the experimental unit and treatment as the fixed effect. Sex and the sex × treatment interaction were included in the original model but the interaction was not significant ($P \geq 0.63$) for any of the variables measured. Therefore, these effects were removed from the final model. One goat on the CC diet and one goat on the MC diet did not consume their diets and their data were therefore excluded from the data analyses. Treatment means were compared using an F-protected *t*-test. All data are reported as least-squares means.

Results and Discussion

Dry matter intake (g/d) and apparent digestibility (%) did not differ ($P = 0.97$ and 0.14, respectively) among the three diets (Table 2). Calcium intake (g/d) did not differ ($P = 0.12$) among the three diets (Table 3). Calcium apparent absorption and retention (g/d and % of Ca intake) were greatest ($P < 0.05$) from CC, but did not differ ($P \geq 0.20$) between MC and CM.

Magnesium intake (g/d) did not differ ($P \geq 0.12$) among the three diets (Table 4). Magnesium apparent absorption and retention (g/d and % of Mg intake) were greatest ($P < 0.05$) from CC and did not differ ($P \geq 0.69$) between CC and MC.

In this study we compared the bioavailability of calcium carbonate, Calmin, and Milk Cal from the commercial pellet Antlermax 16. Antlermax 16 is a high-concentrate diet formulated to contain 16% crude protein and is

Table 1. Calcium, magnesium, and potassium composition of Antlermax 16 diets with different calcium sources that were offered to growing goats.

	Diets[†]		
Composition	Calcium Carbonate	Calmin	Milk Cal
Calcium, %	0.77	0.59	0.60
Magnesium, %	0.50	0.46	0.46
Potassium, %	1.36	1.36	1.43

[†] Calmin is calcium extracted from red algae; milk calcium is calcium extracted from milk.

Table 2. Dry matter (DM) intake and digestibility by growing goats offered Antlermax 16 with different calcium sources.[†]

	Diets[‡]			
Item	Calcium Carbonate	Calmin	Milk Cal	SEM[§]
DM intake, g/d	368	372	372	1.87
DM digestibility, %	75.5	72.2	72.9	32.97

[†] Means among treatments were not different ($P \geq 0.14$).

[‡] Calmin is calcium extracted from red algae; milk calcium is calcium extracted from milk.

[§] SEM = Standard error of the mean.

intended as a complete diet for growing deer to help support antler growth. However, goats were the experimental model instead of deer, because goats have similar digestive tracts (Van Soest, 1994) and are easier to collect fecal and urine samples from within metabolism crates than deer. Knowing the absorption and retention of calcium from Calmin, Milk Cal, and calcium carbonate is useful for determining the appropriate source and amount that should be added to the diet in order to maintain optimal horn growth and strength in deer.

Calcium source did not affect diet digestibility in the present study. Digestibility of cattle feedlot diets was not affected by substituting dolomitic limestone—a calcium source with demonstrated lower availability of calcium and magnesium—for calcium carbonate (Crawford et al., 2008). Growing pigs offered diets with calcium carbonate consumed more feed than those offered diets with a number of other calcium sources, but feed conversion efficiency was not affected by calcium source (Ross et al., 1984). In this study, diet intake was restricted, which also potentially limited differences in digestibility due to calcium source. Other data pertaining to the impacts of different sources of calcium on digestibility of high-concentrate diets for ruminants is limited.

The diets in this study were formulated to contain 0.6% calcium but the CC diet actually contained more calcium (0.77%) compared with MC (0.6%) and CM (0.59%). Although not different statistically ($P = 0.12$), this differential calcium concentration along with offering all diets at 2% of BW resulted in goats that were offered CC consuming 0.61 and 0.58 g/d more calcium than goats offered CM and MC, respectively. The calcium from the CC diet was the most bioavailable in comparison to MC and CM. However, this was likely not a result of the numerical increase in calcium intake because the proportion of calcium absorbed from diets is generally inversely proportional to diet calcium concentrations (Pond et al., 2005).

In a summary across a number of mammal species, calcium carbonate had equivalent Ca absorption to a number of other calcium sources including nonfat dry milk and dried skim milk (Soares, 1995). Ross et al.

Table 3. Calcium balance by goats offered Antlermax 16 with different sources of supplemental calcium.

Item	Diets†			SEM‡
	Calcium carbonate	Calmin	Milk Cal	
Intake, g/d	2.82	2.21	2.24	0.878
Apparent absorption, g/d	0.97[a]	0.27[b]	0.22[b]	0.170
Apparent absorption, %	32.4[a]	11.6[b]	10.1[b]	5.71
Retained, g/d	0.91[a]	0.24[b]	0.18[b]	0.172
Retained, % of intake	30.1[a]	10.1[b]	8.1[b]	5.85
Retained, mg/kg body wt.	43.7[a]	11.4[b]	9.2[b]	7.11

[a,b] Means within a row without a common superscript letter differ ($P < 0.05$).

† Calmin is calcium extracted from red algae; milk calcium is calcium extracted from milk.

‡ SEM = standard error of the mean.

Table 4. Magnesium balance by goats offered Antlermax 16 with different sources of supplemental calcium

Item	Diets†			SEM‡
	Calcium carbonate	Calmin	Milk Cal	
Intake, g/d	1.85	1.71	1.71	0.155
Apparent absorption, g/d	0.93[a]	0.52[b]	0.48[b]	0.088
Apparent absorption, %	49.2[a]	31.1[b]	29.9[b]	4.00
Urine Mg, g/d	0.47	0.47	0.41	0.058
Retained, g/d	0.46[a]	0.05[b]	0.08[b]	0.073
Retained, % of intake	24.1[a]	2.9[b]	5.2[b]	4.12
Retained, mg/kg body wt.	23.1[a]	2.5[b]	4.5[b]	3.74

[a,b] Means within a row without a common superscript letter differ ($P < 0.05$).

† Calmin is calcium extracted from red algae; milk calcium is calcium extracted from milk.

‡ SEM = standard error of the mean.

(1984) reported that growing pigs fed diets with calcium carbonate consumed more feed compared with pigs fed diets with a number of other calcium sources but calcium source did not affect other measurements including femur strength and relative calcium bioavailability. Human subjects showed no effect of calcium carbonate versus milk on urinary calcium concentrations (Martini and Wood, 2002). Therefore, calcium carbonate appears to be comparable to other more expensive calcium sources in its value as a calcium source for small ruminants.

The only supplemental magnesium source used in these diets was magnesium oxide, which is considered the standard magnesium source in livestock diets. Since calcium and magnesium can potentially affect the absorption of each other (Pond et al., 2005), it was also necessary to determine the impacts of calcium source on magnesium absorption. The CC diet had the greatest apparent absorption and retention of magnesium compared with the diets with CM and MC. Therefore, calcium carbonate does not appear to have a negative impact on magnesium bioavailability compared with other supplemental calcium sources.

Summary and Conclusions

Calcium and magnesium were more available for goats consuming the diet containing calcium carbonate compared with the diets containing Calmin and Milk Cal. Calcium carbonate is also less expensive typically than the other sources evaluated in this study. Therefore, it is not necessary to include these more expensive sources in order to improve calcium and magnesium bioavailability.

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