Native Corn Starch Versus Either Cellulose or Glucose in the Diet and the Effects on Apparent Magnesium Absorption in Goats[1]

J. T. SCHONEWILLE,[2] L. RAM, A. T. VAN'T KLOOSTER, H. WOUTERSE, and A. C. BEYNEN

Department of Large Animal Medicine and Nutrition, Faculty of Veterinary Medicine, Utrecht University, PO Box 80.152, 3508 TD Utrecht, The Netherlands

ABSTRACT

The objective of this study was to determine whether dietary glucose or starch would reduce the inhibitory effect of high K intake on Mg absorption in ruminants. In a 6 × 6 Latin square design, six goats were fed diets with or without added $KHCO_3$ containing either cellulose, glucose, or native corn starch. The K concentrations of the diets were 7.8 or 34.0 g of K/kg of dry matter, and carbohydrates were incorporated so that their concentrations were identical on a glucose equivalent basis (331 g of glucose/kg of dry matter). The intake of extra K significantly reduced apparent Mg absorption from 29.8 to 22.1% on average. Glucose, instead of cellulose, in the diet did not affect Mg absorption. Replacement of dietary cellulose by corn starch enhanced the mean efficiency of Mg absorption from 21.8 to 30.9%. Starch versus glucose increased Mg absorption by 5.8 percentage units. No statistically significant interaction was observed between the type of carbohydrate and the amount of K in the diet with regard to Mg absorption. This study showed that the inhibitory effect of dietary $KHCO_3$ on Mg absorption in goats was fully counteracted by the replacement of cellulose with starch in the diet. Possible changes in the pH of ruminal fluid might have mediated the dietary effects on Mg absorption.

(**Key words**: magnesium absorption, potassium, starch, ruminants)

INTRODUCTION

In areas with intensive livestock production, such as British Columbia, Canada (5) and The Netherlands (24), grass silages are generally high in K. Concentrations of K that are >30 g/kg of DM are common. High K intakes inhibit Mg absorption in cattle (6); therefore, forages that are rich in K create the risk of hypomagnesemia. Supplementation of dairy rations with Mg to prevent hypomagnesemia has proved to be quite useful, but excessive supplementation is undesirable because it raises feed costs, reduces palatability, and can induce diarrhea. Furthermore, diets supplemented with MgO to attain 2 and 6 g of Mg/kg of DM showed a reduction of nutrient utilization in ruminants that was induced by Mg (2). Thus, it seems more appropriate to improve Mg absorption than to supplement the diets of dairy cows with large amounts of Mg to safeguard the Mg status of dairy cows.

Wilson et al. (27) demonstrated that plasma Mg concentration was maintained within the normal range when cows were offered supplemental starch when grazing a tetany-prone pasture. Pfeffer et al. (19) showed that replacement of hay by rolled barley, which raised the starch content of the diet, increased apparent Mg absorption in sheep. Absorption of Mg might have been improved because of the ingested starch. Indeed, in a controlled study, Giduck and Fontenot (7) observed a significant increase in Mg absorption in sheep when the diet consisting of hay was supplemented with starch. Similarly, the intake of supplemental soluble carbohydrates, such as glucose, sucrose, and lactose, has also been shown to increase Mg absorption in sheep (7, 15, 22). In those studies, the carbohydrates were added to the basal diet so that the test and control diets contained different concentrations of all nutrients, which might have interfered with a valid interpretation of the data. In the studies of Giduck and Fontenot (7) and Madsen et al. (15), the K concentrations in the diet were relatively low (<20 g/kg of DM). Thus, whether the stimulatory effect of glucose and starch on Mg absorption would also occur at high K intakes was unknown. We measured apparent Mg absorption in goats fed diets that were either low or high in $KHCO_3$ and contained either cellulose, glucose, or native corn

Received March 27, 1996.
Accepted December 10, 1996.
[1]This study was supported by the Commodity Board for Feedingstuffs (Produktschap voor Veevoeder), The Hague, The Netherlands.
[2]Correspondence and reprint requests.

starch. The dairy goat was used as a model for the dairy cow because the two species are similar in terms of digestive physiology and metabolism. However, goats are easier to handle and house and are less expensive to purchase and maintain. It was anticipated that the outcome of the present study could be useful when designing further studies using dairy cows. The three carbohydrate sources were incorporated into the low and high K diets so that their amounts were identical on a glucose equivalent basis. This approach allowed a direct comparison of the three carbohydrate sources and also addressed the question of whether glucose or starch would reduce the influence of supplemental $KHCO_3$ on Mg absorption.

MATERIALS AND METHODS

Goats and Experimental Design

Six nonpregnant, nonlactating, Dutch White dairy goats with a preliminary BW of 56.1 kg (SE = 1.69) were used. The trial had a 6 × 6 Latin square design in which the dietary treatments were three types of carbohydrate supplements (cellulose, glucose, or starch) and two K concentrations. The trial was preceded by a 14-d preexperimental period that allowed the goats to become adapted to the straw-based diets. Each experimental period lasted 28 d. The goats were randomly assigned to each sequence of feeding on the six experimental diets. The goats were weighed before the morning meal on the last day of each dietary period. During the experiment, the goats were either housed individually in pens with a layer of wood shavings as bedding or in metabolism cages with slatted floors.

Diets

All diets contained MgO, which was added to attain 2 g of Mg/kg of DM. The diets contained either 5.5 or 61.3 g of $KHCO_3$/kg of DM. The variable carbohydrate sources, i.e., cellulose, glucose, and native corn starch, were added to the diets on a glucose equivalent basis. Corrections were made for the different water contents of the carbohydrate preparations and for the water excluded during formation of glycosidic bounds in the two polysaccharides. The composition of the experimental feeds, which were in pelleted form (diameter = 10 mm), is shown in Table 1. During the preexperimental period, the goats were offered the low K diet with additional cellulose. Goats were then fed one of the six experimental diets, which included the diet fed during the preexperimental period. During the trial, the goats were fed a restricted amount of feed (1.1 kg of the low K and 1.17 kg of the high K diets/d per goat) to maintain energy balance. The diets were offered twice daily in two equal portions at 0800 and 1600 h. Orts, if any, were recorded.

Collection of Samples

The experimental feeds were sampled at two different intervals during each experimental period. The feed samples were ground and stored in a sealed jar at room temperature (18°C).

Blood samples were taken on the last day of each experimental period. Between 0700 and 0730 h, before the morning meal, blood was sampled from the jugular vein into evacuated heparinized tubes. The heparinized blood samples were centrifuged for 10 to 15 min at approximately 2700 × *g*, and the plasma was collected and stored at –18°C.

On d 18 of each experimental period, the goats were placed in metabolism cages. During the last 8 d of each experimental period, urine and feces were collected quantitatively from each goat. The 24-h urine collections were weighed, and 10% was collected and stored at –18°C in a plastic bottle that contained 50 ml of 6*N* HCl. The 24-h fecal collections from each goat were stored at –18°C in plastic bags. At the end of each experimental period, the total feces produced by each goat was weighed and mixed thoroughly; 10% was dried for 5 d at 60°C. The dried feces was ground, sampled, and stored in a sealed jar at room temperature (18°C).

Chemical Analyses

Nitrogen concentrations of the feedstuffs were determined by the macro-Kjeldahl method (12); a factor of 6.25 was used to convert N to CP. Ether extracts of the feedstuffs were prepared according to the AOAC (1); the solvent was evaporated, and the crude fat residue was weighed. The ADF content of the feedstuffs was estimated after treatment with neutral detergent reagent according to the method described by Goering and Van Soest (8) using the Fibertec System M2 (Tecator, Stockholm, Sweden). To determine the starch content of the feedstuffs, they were enzymatically treated with amyloglucosidase from *Aspergillus niger* (EC 3.2.1.3) to hydrolyze all starch to glucose (13). Subsequently, glucose was measured enzymatically with a test combination (Boehringer Mannheim GmbH Diagnostica, Mannheim, Germany) and a computerized autoanalyzer (Beckman Synchron CX® Systems; Beckman, Mijdrecht, The

Netherlands). The free glucose content of the feedstuffs was measured directly. Starch was calculated as total glucose minus free glucose. Prior to the determination of the selected minerals in feedstuffs and feces, the samples were ashed (480°C for 6 h) and dissolved in 4 *M* HCl. Magnesium, Ca, and K were estimated by atomic absorption spectroscopy, and Na was estimated by atomic emission spectroscopy (Perkin Elmer 3110 PC; Perkin-Elmer Corp., Norwalk, CT). Total P in feedstuffs was determined by the method of Quinlan and DeSesa (21). Magnesium in plasma and urine was measured directly by atomic absorption spectroscopy (Perkin Elmer 3110 PC). The accuracy of each assay was monitored using a commercially available reference sample (hay powder, CRM 129; Community Bureau of Reference, Brussels, Belgium) and in-house reference samples and was found to be within 5% deviation from the target values. The precision of the determinations was ≤3.0% (coefficient of variation) for combined measures within and between runs.

Statistical Analysis

All data for each dietary treatment were checked for normal distribution using the Kolmogorov-Smirnov test (26) and then were subjected to ANOVA. Goat, experimental period, dietary K, type of carbohydrate, and the interaction term for K concentration and type of carbohydrate were factors (26). Because of orts, Mg intake was somewhat lower for the high K and glucose diet; therefore, it was necessary to perform ANOVA using Mg intake as a covariate (26). When the influence of a dietary factor reached statistical significance, Tukey's *t* test was used to identify diets with different effects on the variable involved. Throughout, significance was set at $P < 0.05$.

RESULTS

Feed Intake and BW

During the period of excreta collection of the last three experimental periods, the goats did not fully consume the diets that were rich in glucose. Orts were approximately 5 and 20% for goats fed the low and high K diets, respectively. Moldiness probability contributed to loss of palatability of the diets that were rich in glucose. The diets containing cellulose and starch were consumed completely.

TABLE 1. Composition of the experimental diets.

	Low K			High K		
	Cellulose	Glucose	Starch	Cellulose	Glucose	Starch
Constant components,[1] g	640.0	640.0	640.0	640.0	640.0	640.0
Cellulose, g	322.6	. . .	. . .	322.6	. . .	. . .
Glucose, g	. . .	360.0	. . .	. . .	360.0	. . .
Corn starch, g	. . .	. . .	342.2	. . .	. . .	342.2
Demineralized water, g	37.4	. . .	17.8	37.4	. . .	17.8
$KHCO_3$,[2] g	. . .	. . .	. . .	59.5	59.5	59.5
Total, g	1000.0	1000.0	1000.0	1059.5	1059.5	1059.5
Chemical analysis						
DM, g/kg	912	916	902	915	865	908
CP, g/kg of DM	119	114	119	113	113	113
Crude fat, g/kg of DM	21	20	25	22	25	25
ADF, g/kg of DM	537	251	247	503	237	248
Starch, g/kg of DM	5	0	299	0	4	297
Glucose, g/kg of DM	3	354	5	2	290	4
Mg, g/kg of DM	2.13	2.02	2.21	1.99	1.87	2.07
Ca, g/kg of DM	6.09	5.87	6.45	6.15	5.87	5.86
P, g/kg of DM	4.01	3.93	4.20	3.85	3.69	3.83
K, g/kg of DM	8.09	6.66	8.61	33.94	34.78	33.36
Na, g/kg of DM	2.62	2.44	2.69	2.61	2.29	2.56

[1]The constant components consisted of 475 g of barley straw, 25 g of low sugar beet molasses, 92 g of casein, 20 g of soybean oil, 4 g of NaCl, 11 g of $CaHPO_4$, 2.5 g of MgO, 5.5 g of $KHCO_3$, and 5 g of premix. The premix consisted of 3195.5 mg of $CaCO_3$, 1.0 mg of $CoSO_4 \cdot 7H_2O$, 0.5 mg of $Na_2SeO_3 \cdot 5H_2O$, 0.8 mg of KIO_3, 123.0 mg of $MnSO_4 \cdot H_2O$, 1493.5 mg of $FeSO_4 \cdot 7H_2O$, 59.0 mg of $CuSO_4 \cdot 5H_2O$, 110.0 mg of $ZnSO_4 \cdot H_2O$, 1.7 mg (5000 IU) of retinylacetate, 0.025 mg (1000 IU) of cholecalciferol, and 15.0 mg (15 IU) of dl-α-tocopherylacetate.

[2]The experimental diets that were low in K were prepared first. Then, the feeds were each divided into two parts, one of which was supplemented with $KHCO_3$.

TABLE 2. Balance of Mg in goats (n = 6) fed the experimental diets.[1]

	Low K			High K			Pooled	*P*		
	Cellulose	Glucose	Starch	Cellulose	Glucose	Starch	SED	$KHCO_3$	Carbohydrate	Interaction
Intake, g/d	2.13	2.00	2.19	2.12	1.75	2.18	ND[2]	ND	ND	ND
Feces, g/d	1.62^{ab}	1.42^{bc}	1.39^{c}	1.70^{a}	1.36^{c}	1.63^{ab}	0.068	0.040	<0.001	0.018
Apparent absorption										
g/d	0.51^{bc}	0.58^{b}	0.80^{a}	0.42^{bc}	0.38^{c}	0.55^{bc}	0.058	<0.001	<0.001	0.183
% of Intake	24.1^{bc}	28.7^{b}	36.6^{a}	19.5^{c}	21.5^{bc}	25.1^{bc}	2.765	<0.001	0.001	0.229
Urine, g/d	0.42^{bcd}	0.52^{ab}	0.66^{a}	0.30^{d}	0.37^{cd}	0.45^{bc}	0.045	<0.001	<0.001	0.436
Balance, g/d	0.09^{ab}	0.06^{ab}	0.14^{a}	0.12^{ab}	0.01^{b}	0.10^{ab}	0.041	0.429	0.023	0.358

[a,b,c,d]Means in the same row with different superscripts differ ($P < 0.05$; Tukey's t test).

[1]Magnesium intakes were not identical for the six treatments; therefore, Mg intake was incorporated as a covariate to correct for the influence of Mg intake, if any, on the variables. Only Mg excretion in feces appeared to be influenced ($P = 0.003$) by Mg intake. The interaction effect on Mg excretion in feces was not significant ($P = 0.109$) after introduction of Mg intake as a covariate in the statistical analysis. The probability values presented in the table are derived from statistical analyses without Mg intake as a covariate.

[2]Not determined because goats were offered a restricted amount of feed.

The mean BW across all treatments was 55.3 kg (SE = 2.09; n = 6). Dietary treatments did not influence BW.

Mg Balance

Magnesium intake was similar for all treatments except for the high K diet that was rich in glucose (Table 2). The high K and glucose diet was associated with an 18% lower Mg intake because of the orts and the relatively low Mg content associated with this diet. The Mg balance, as affected by the diet, was statistically analyzed with or without Mg intake as a covariate. The amount of K and the type of carbohydrate in the diet influenced fecal excretion of Mg. The addition of $KHCO_3$ to the diet that was rich in starch raised fecal excretion of Mg. Starch, instead of glucose, in the low K diet reduced fecal excretion of Mg. Magnesium balances were similar for all treatments (Table 2).

Urinary excretion of Mg and apparent Mg absorption were positively related (Pearson's r = 0.808 and 0.791, respectively, for absolute and relative values; $P < 0.001$; n = 36). Magnesium absorption, expressed as a percentage of intake, was affected by supplemental $KHCO_3$ and the type of carbohydrate, but there was no significant interaction between the two dietary variables.

To enhance clarity, values for Mg absorption were either pooled according to the amount of K or the type of carbohydrate in the diet. The pooling was justified because of the lack of interaction between the treatments. Figure 1 shows that the addition of $KHCO_3$ to the diets decreased ($P < 0.001$) apparent Mg absorption by almost 8 percentage units. When cellulose was replaced by either glucose or starch, mean Mg absorption increased by about 3 and 9 percentage units, respectively (Figure 2). The difference in Mg absorption between the diets containing cellulose and glucose did not reach significance ($P = 0.240$). Magnesium absorption differed between diets containing cellulose and starch ($P = 0.001$) and between diets containing glucose and starch ($P = 0.021$).

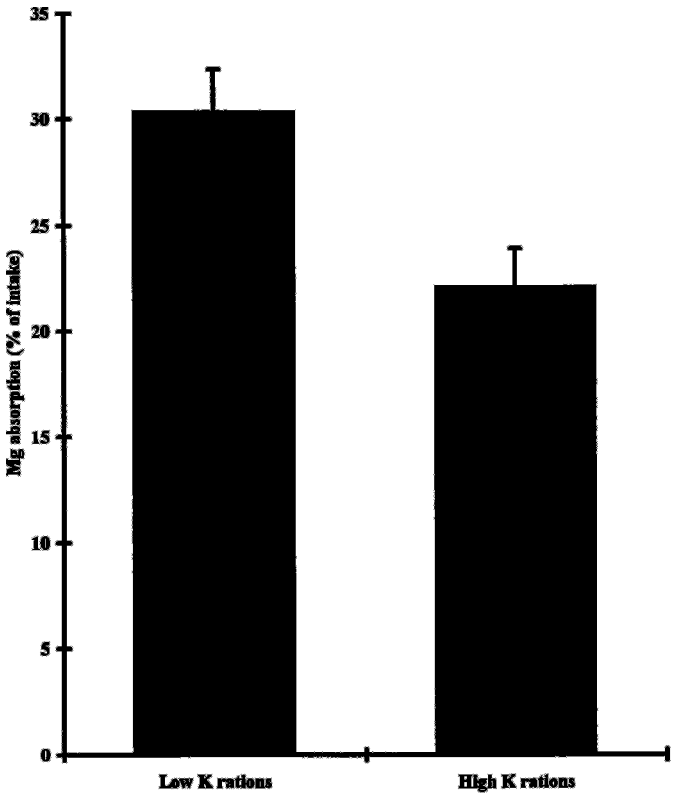

Figure 1. Apparent Mg absorption at two concentrations of dietary K (error bar = SE).

Plasma Mg

The dietary treatments did not affect plasma Mg concentrations. For all treatments combined, mean plasma Mg concentration was 0.90 mmol/L (SE = 0.016; n = 6).

DISCUSSION

This study confirms earlier work (10, 18, 20) that showed that the addition of $KHCO_3$ to the diets of ruminants inhibited apparent Mg absorption. High versus low K intake by the goats reduced mean Mg absorption by 8 percentage units. Substitution of glucose for an identical amount of glucose equivalent units in the form of cellulose did not significantly affect Mg absorption. Replacement of cellulose and glucose by starch significantly increased Mg absorption by 9 and 6 percentage units, respectively. There was no interaction between the amount of K and the type of carbohydrate in the diet. However, replacement of cellulose by starch counteracted the inhibitory effect of extra K intake on Mg absorption. The stimulatory effect of supplemental starch on Mg absorption had been shown earlier in sheep (7), but this study showed for the first time that starch stimulated Mg absorption when compared with cellulose and also that ingestion of starch may reduce the inhibitory influence of K.

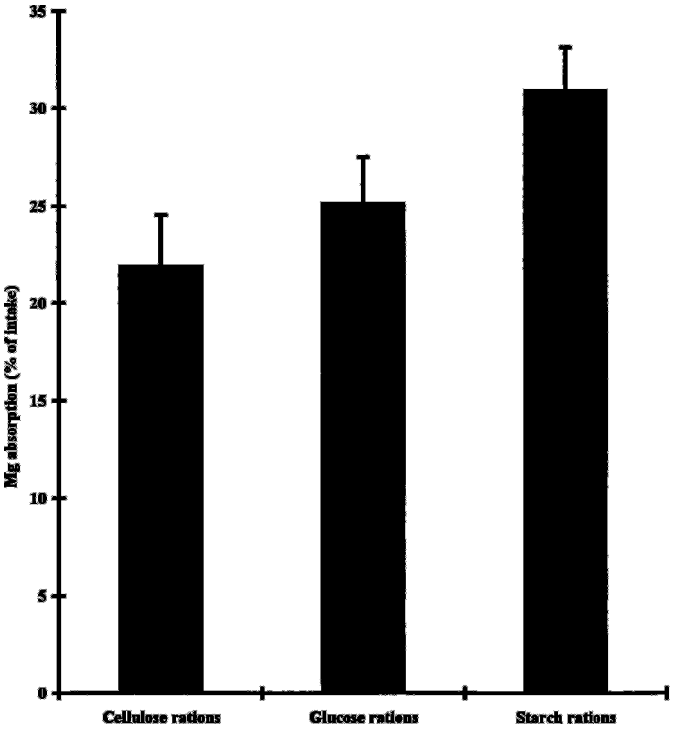

Figure 2. Apparent Mg absorption for three types of dietary carbohydrates (error bar = SE).

The differential effects of cellulose, glucose, and starch on Mg absorption in ruminants may relate to their different patterns of ruminal fermentation. The intake of increased amounts of soluble carbohydrates (4) or rapidly fermentable carbohydrates (3, 16) may lower ruminal pH. A decrease in pH may increase the solubility of Mg (9, 25), which in turn could enhance the availability of Mg for absorption across the ruminal epithelium (11). At 2 h postfeeding, supplemental glucose had reduced the pH in the ruminal fluid more than did starch (7). We found that glucose was less effective than starch in stimulating Mg absorption. Thus, it is difficult to see that a lowering of the pH of ruminal fluid would result in the observed stimulation of Mg absorption as induced by starch. However, Mg absorption might have been determined by the ruminal pH when expressed as the area under the curve rather than as the peak value postfeeding. Alternatively, the short-chain fatty acids produced during ruminal fermentation of dietary carbohydrates might stimulate Mg absorption by the delivery of protons to Mg^{2+}/H^+ exchangers located in the apical membrane of the epithelium (23).

The observation that starch ingestion counteracted the inhibitory effect of extra K intake on Mg absorption is not easy to reconcile with the proposed mechanisms underlying the effect of K. The process of Mg absorption hypothetically consists of two components, one sensitive and one insensitive to K (14). The transport component that is sensitive to K depends on the potential difference across the ruminal wall; increased K concentrations caused greater differences (17). The transport component that is insensitive to K corresponds to electroneutral Mg transport across the ruminal epithelium (14). How starch intake could enhance either component of Mg absorption is difficult to understand. The lack of a significant interaction between type of carbohydrate and amount of K in the diet does not provide further clues.

Caution is warranted in generalizing the outcome of this study to mean that dietary native corn starch reduces the inhibitory effect of extra K intake on Mg absorption. In this study, we used $KHCO_3$ to increase the K content of the diet. There is evidence suggesting that identical amounts of K in the form of either $KHCO_3$ or KCl and also of K intrinsically present in feedstuffs could have different effects on Mg absorption (24). Possibly, the degree to which starch coun-

teracts the effect of K depends on the type of anion in the dietary K salt. Nevertheless, the present observations could have important practical implications if and when the stimulatory effect of starch on Mg absorption in dairy cows is confirmed. Then, it might be possible to reduce the inhibitory influence of K not by raising the amount of Mg in the diet, but by incorporating starch, preferably derived from a commercially attractive source.

ACKNOWLEDGMENTS

Wim Lensing is thanked for his biotechnical assistance as is Jan Van der Kuilen for chemical analysis.

REFERENCES

1 Association of Official Analytical Chemists. 1984. Official Methods of Analysis. 14th ed. AOAC, Arlington, VA.
2 Chester-Jones, H., J. P. Fontenot, H. P. Veit, and K. E. Webb, Jr. 1989. Physiological effects of feeding high levels of magnesium to sheep. J. Anim. Sci. 67:1070.
3 Cone, J. W., and M. Vlot. 1990. Comparison of degradability of starch in concentrates by enzymes and rumen fluid. J. Anim. Physiol. Nutr. 63:142.
4 Fenner, H., F. N. Dickinson, and H. D. Barnes. 1967. Relationship of digestibility and certain rumen fluid components to level of feed intake and time of sampling after feeding. J. Dairy Sci. 50:334.
5 Fisher, L. J., N. Dinn, R. M. Tait, and J. A. Shelford. 1994. Effect of level of dietary potassium on the absorption and excretion of calcium and magnesium by lactating cows. Can. J. Anim. Sci. 74:503.
6 Fontenot, J. P., V. G. Allen, G. E. Bunce, and J. P. Goff. 1989. Factors influencing magnesium absorption and metabolism in ruminants. J. Anim. Sci. 67:3445.
7 Giduck, S. A., and J. P. Fontenot. 1987. Utilization of magnesium and other macrominerals in sheep supplemented with different readily-fermentable carbohydrates. J. Anim. Sci. 65: 1667.
8 Goering, H. K., and P. J. Van Soest. 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures, and Some Applications). Agric. Handbook No. 379. ARS-USDA, Washington, DC.
9 Grace, N. D., E. Davies, and J. Monro. 1977. Association of Mg, Ca, P, and K with various fractions in the diet, digesta, and faeces of sheep fed fresh pasture. N.Z. J. Agric. Res. 20:441.
10 Greene, L. W., J. P. Fontenot, and K. E. Webb, Jr. 1983. Effect of potassium level on site of absorption of magnesium and other macroelements in sheep. J. Anim. Sci. 56:1214.
11 Horn, J. P., and R. H. Smith. 1978. Absorption of magnesium by the young steer. Br. J. Nutr. 40:473.
12 International Dairy Federation. 1986. IDF Standard 20A. Int. Dairy Fed., Brussels, Belgium.
13 Keppler, D., and K. Decker. 1974. Methods of Enzymatic Analysis. 2nd ed. H. U. Bergmeyer, ed. Acad. Press, New York, NY.
14 Leonhard, S., H. Martens, and G. Gäbel. 1989. New aspects of magnesium transport in ruminants. Acta Vet. Scand. 86(Suppl.):146.(Abstr.)
15 Madsen, F. C., D. E. Lentz, J. K. Miller, D. Lowrey-Harnden, and S. L. Hansard. 1976. Dietary carbohydrate effects upon magnesium metabolism in sheep. J. Anim. Sci. 42:1316.
16 Malestein, A., A. T. Van't Klooster, and J. W. Cone. 1988. Degradability of various types of starch by incubation with rumen fluid or with bacterial α-amylase. J. Anim. Physiol. Nutr. 59:225.
17 Martens, H., and I. Blume. 1986. Effect of intraruminal sodium and potassium concentrations and of the transmural potential difference on magnesium absorption from the temporarily isolated rumen of sheep. Q. J. Exp. Physiol. 71:409.
18 Newton, G. L., J. P. Fontenot, R. E. Tucker, and C. E. Polan. 1972. Effects of high dietary potassium intake on the metabolism of magnesium by sheep. J. Anim. Sci. 35:440.
19 Pfeffer, E., A. Thompson, and D. G. Armstrong. 1970. Studies on intestinal digestion in the sheep. 3. Net movement of certain inorganic elements in the digestive tract on rations containing different proportions of hay and rolled barley. Br. J. Nutr. 24: 197.
20 Poe, J. H., L. W. Greene, G. T. Schelling, F. M. Beyers, and W. C. Ellis. 1985. Effects of dietary potassium and sodium on magnesium utilization in sheep. J. Anim. Sci. 60:578.
21 Quinlan, K. P., and M. A. DeSesa. 1955. Spectrophotometric determination of phosphorus as molybdovanadophosphoric acid. Anal. Chem. 27:1626.
22 Rayssiguer, Y., and C. Poncet. 1980. Effect of lactose supplement on digestion of lucerne hay by sheep. II. Absorption of magnesium and calcium in the stomach. J. Anim. Sci. 51:186.
23 Scharrer, E., and T. Lutz. 1990. Effects of short chain fatty acids and K on absorption of Mg and other cations by the colon and caecum. Z. Ernaehrwiss. 29:162.
24 Schonewille, J. T., L. Ram, A. T. Van't Klooster, H. Wouterse, and A. C. Beynen. 1997. Intrinsic potassium in grass silage and magnesium absorption in dry cows. Livest. Prod. Sci. 48:99.
25 Terashima, Y., S. N. Terashita, N. Tohrai, and H. Itoh. 1976. Effects of intraruminal administration of lactic acid on mineral concentrations in rumen fluid of steers. Jpn. J. Zootech. Sci. 47: 166.
26 Wilkinson, L. 1990. SYSTAT: The System for Statistics. SYSTAT Inc., Evanston, IL.
27 Wilson, G. F., C.S.W. Reid, A. J. Metson, and G. W. Butler. 1969. Influence of starch and peanut oil on plasma magnesium in grazing dairy cows. N.Z. J. Agric. Res. 12:467.