Apparent Magnesium Absorption in Dry Cows Fed at 3 Levels of Potassium and 2 Levels of Magnesium Intake*

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ABSTRACT

In vitro experiments with isolated rumen epithelium have shown that the relationship between the ruminal K concentration and either the apical membrane potential difference or the mucosal-to-serosal Mg flux reach plateau values at high ruminal K concentrations. Hence, it may be hypothesized that the inhibitory effect of supplemental K on Mg absorption becomes smaller at high initial K intakes. To test our hypothesis, 6 ruminally fistulated, nonpregnant dry cows were fed 6 experimental diets in a 6×6 Latin square design with a 2×3 factorial arrangement of treatments. Four cows were of a Friesian-Holstein $\times$ Holstein-Friesian cross, and the 2 remaining cows were of a Meuse-Rhine-IJssel $\times$ Holstein-Friesian cross. The diets provided either 40.6 or 69.1 g of Mg per day and contained 20.7, 48.0, or 75.5 g of K per kilogram of dry matter. The dietary variables were obtained by mixing KHCO_3 and MgO into the basal concentrate. Absorption of Mg and the urinary Mg excretion was significantly decreased by supplemental K and significantly increased after the intake of supplemental Mg. In contrast to apparent Mg absorption, the urinary excretion of Mg was not affected by the dietary K $\times$ Mg interaction. Postfeeding ruminal K and Mg concentrations were increased with increasing K and Mg intakes. Postfeeding ruminal K concentrations and the urinary excretion of Mg showed a linear negative correlation; the slope was not significantly affected by Mg intake. Therefore, our hypothesis was rejected. Furthermore, these data indicate that supplemental Mg can effectively counteract the suppressant effect of K on Mg absorption in cows.

(**Key words:** magnesium, potassium, absorption, cow)

INTRODUCTION

Hypomagnesemic tetany is prevalent in early lactating cows grazing on pastures with a high K content

(Kemp, 1960; Littledike et al., 1983). A common approach to prevent hypomagnesaemia is to increase Mg intake by supplementing the concentrate with MgO to oppose the inhibitory effect of K on Mg absorption (Bell, 1983; Ram et al., 1998). Because the inhibitory effect of K on Mg absorption is not well quantified (Schonewille, 1999), Mg is supplemented on the basis of subjective considerations and practical experience rather than assessment formulas.

In ruminants, Mg absorption essentially takes place in the rumen (Tomas and Potter, 1976; Greene et al., 1983), and there are many controlled feeding trials showing the negative relationship between K intake and Mg absorption (Newton et al., 1972; Poe et al., 1985; Wylie et al., 1985). However, under in vitro conditions with isolated sheep rumen epithelium, Leonhard-Marek and Martens (1996) have shown that at luminal K concentrations higher than about 80 mM, Mg fluxes across the rumen epithelium become independent from the luminal K concentrations. Thus, it may be hypothesized that the inhibitory effect of supplemental dietary K on absolute Mg absorption (g/d) is not constant but becomes smaller at higher initial K intakes. Furthermore, whether supplemental Mg would effectively counteract the inhibitory effect of supplemental dietary K on Mg absorption was checked.

To test our hypothesis, Mg absorption was measured in 6 nonpregnant, dry cows that were fed rations containing 20, 48, or 76 g of K/kg of DM. Potassium intake was increased by supplementing the basal concentrate with KHCO_3 , which has been proven to be equally effective to intrinsic K-salts in depressing Mg absorption (Schonewille et al., 1999b). The installed range of dietary K concentrations is beyond the practical range (Schonewille et al., 1997), but it was anticipated that this would enhance the interpretation of the data.

MATERIALS AND METHODS

The experimental protocol was approved by the animal experiments committee of the Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands.

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Table 1. Compositions of the experimental concentrates in grams.

	Low Mg			High Mg		
	Low K	Medium K	High K	Low K	Medium K	High K
Constant components ¹	988.6	988.6	988.6	988.6	988.6	988.6
MgO	11.4	11.4	11.4	23.6	23.6	23.6
KHCO ₃	...	120.0	258.0	...	120.0	258.0
Total	1000.0	1120.0	1258.0	1012.2	1132.2	1270.2

¹The constant components consisted of 420.0 g of sugar beet pulp, 130.0 g of soybean meal, 25.0 g of sugarcane molasses, 90.0 g of cassava meal, 150.0 g of rape seed meal, 100.0 g of corn gluten feed, 50.0 g of corn meal, 7.4 g of soya oil, 2.2 g of NaCl, 5.0 g of lime stone, 7.0 g of mono-calcium phosphate, 2.0 g of premix. The premix consisted of (per gram): 67.5 mg of ZnSO₄·H₂O, 57.5 mg of MnSO₄·H₂O, 25.0 mg of CuSO₄·H₂O, 0.6 mg of KIO₃, 0.4 mg of CoSO₄·7H₂O, 0.4 mg of Na₂SeO₃·H₂O, 0.9 mg of vitamin A (450 IU), 4.2 mg of vitamin D (424 IU), 25.0 mg of vitamin E (12.5 IU), and 818.5 mg of CaCO₃.

Animals and Experimental Design

Six nonpregnant, nonlactating, multiparous cows (age 6.3 ± 0.6 yr; mean $\pm$ SE) with a mean BW of 792 kg (SE $\pm$ 24.6) were used. The cows were fitted with a rumen cannula. Four cows were of a Friesian-Holstein $\times$ Holstein-Friesian cross, whereas the 2 remaining cows were of a Meuse-Rhine-IJssel $\times$ Holstein-Friesian cross. During the experiment, they were housed indoors in a stanchion barn in tie-up stalls, on a soft rubber mat (1.2×1.85 m²), and a layer of sawdust as bedding.

The trial had a 6×6 Latin square design with a 2×3 factorial arrangement of treatments, and it was preceded by a 14-d preexperimental period that allowed the cows to become adapted to the experimental rations. Rations were based on artificially dried grass and concentrate, with a roughage-to-concentrate ratio of 50/50 (DM). Each experimental period lasted 28 d. The animals were randomly assigned to each sequence of feeding on the 6 experimental rations and had free access to water.

Experimental Rations

Appropriate dietary concentrations of Mg and K were attained by the addition of MgO and KHCO₃ to the basal concentrate. The ingredient composition of the experimental concentrates is shown in Table 1. The ingredient and analyzed compositions of the complete experimental diets are shown in Table 2.

The cows were fed a restricted amount of the experimental diets to ensure constant intakes of nonvariable nutrients and to maintain energy balance (CVB, 2002). The diets were offered $2 \times$ d in 2 equal portions at 0800 and 1700 h. The cows consumed all feed supplied.

Collection of Samples

The experimental concentrates, artificially dried grass and hay, were sampled from d 19 to 28 of each

period, were ground, and were subsequently stored in a sealed jar at room temperature (18°C). On d 19 of each period, blood was taken between 1400 to 1500 h from the coccygeal vein into evacuated heparinized tubes and centrifuged immediately for 10 min at $2700 \times g$, and the plasma was collected and stored in plastic tubes at -18°C . From d 20 to 27 of each experimental period, urine and feces were collected quantitatively from each cow. Urine was collected by using urine collectors attached to the cows with leather harnesses. Urine coursed down into 2 vessels so that approximately 80% was collected in one vessel. The remaining urine was collected in the other vessel that contained Na-azide as a preservative. Total urine collections from each 24-h interval were weighed, and 0.5% (wt/wt) of the total urine was sampled and stored at -18°C in a plastic bucket that contained 100 ml of 6 M HCl. The daily feces production of each cow was weighed and homogenized thoroughly, and 3% of the wet weight was stored at -18°C . At the end of each collection period, the day samples of feces of each cow were combined, mixed thoroughly, and sampled. The samples were dried for 5 d at 60°C , ground, and stored in a sealed jar at room temperature (18°C) until analysis.

On d 28 of each period, prior to the morning meal, 500 mL of Cr-EDTA solution (100 g of Cr-EDTA/L, pH 6.5 to 6.7) were introduced into the rumen via the cannula as a marker to assess rumen volume and passage rate of the rumen liquid phase. Rumen fluid samples were taken (approximately 30 mL) at 0745, 0900, 1000, 1100, 1300, 1500, and 1700 h. Immediately after collection, pH of ruminal fluid was recorded, the rumen fluid samples were centrifuged at room temperature (18°C) at $2700 \times g$ for 15 min, and the supernatant was stored in plastic tubes at -18°C . An aliquot of the supernatant was centrifuged at 20°C at $30,000 \times g$ for 30 min, and the supernatant was stored in plastic tubes at -18°C ; this was not done for the rumen fluid sample taken at 1000 h. Ultracentrifugation is required to isolate free

Table 2. Intake and analyzed compositions of the experimental diets.

	Low Mg			High Mg		
	Low K	Medium K	High K	Low K	Medium K	High K
Intake	(kg DM/cow/d)					
Experimental concentrate ¹	3.75	4.16	4.63	3.78	4.19	4.71
Artificially dried grass ²	3.03	3.03	3.03	3.03	3.03	3.03
Hay ³	0.30	0.30	0.30	0.30	0.30	0.30
Total DIM	7.08	7.50	7.96	7.11	7.52	8.04
Nutrient composition of total diets	(g/kg of DM)					
CP	130.86	122.65	115.17	126.45	124.21	113.57
Crude fat	23.56	23.97	23.51	23.02	23.55	22.86
Crude fiber	174.36	166.13	156.10	174.46	164.37	153.68
Mg	5.80	5.47	5.02	9.69	9.25	8.55
K	20.48	48.21	75.56	20.86	47.84	75.46
Ca	6.98	6.94	6.44	7.17	6.87	6.39
P	4.79	4.77	4.27	4.70	4.51	4.18

¹The analyzed composition of the concentrates were as follows: low Mg/low K: 892 g of DM/kg; Mg, 9.50; K, 15.04; Ca, 10.08; P, 6.40 g/kg of DM. Low Mg/medium K: 886 g of DM/kg; Mg, 8.52; K, 65.51; Ca, 9.70; P, 6.20 g/kg of DM. Low Mg/high K: 877 g of DM/kg; Mg, 7.45; K, 110.75; Ca, 8.55; P, 5.19 g/kg of DM. High Mg/low K: 890 g of DM/kg; Mg, 16.77; K, 15.78; Ca, 10.40; P, 6.21 g/kg of DM. High Mg/medium K: 881 g of DM/kg; Mg, 15.29; K, 64.71; Ca, 9.56; P, 5.73 g/kg of DM. High Mg/high K: 884 g of DM/kg; Mg, 13.43; K, 110.00; Ca, 8.43; P, 5.03 g/kg of DM.

²The analyzed composition of artificially dried grass: 918.05 g of DM/kg; other components were expressed in terms of (g/kg of DM): CP, 97.29; crude fat, 24.78; crude fiber, 255.63; Mg, 1.71; K, 27.42; Ca, 3.55; P, 3.07.

³The analyzed composition of hay: 916.10 g of DM/kg; other components were expressed in terms of (g/kg of DM): CP, 63.24; crude fat, 12.43; crude fiber, 324.20; Mg, 1.09; K, 18.56; Ca, 2.96; P, 2.09.

Mg associated with low molecular weight fractions in rumen fluid (Grace et al., 1988).

Chemical Analyses

Nitrogen contents were determined by the macro-Kjeldahl method (International Dairy Federation, 1986); a factor of 6.25 was used to convert nitrogen mass into CP. Ether extracts of the feedstuffs were prepared according to the Association of Official Analytical Chemists (AOAC) (1984), the solvent was evaporated, and the crude fat residue was weighed. The crude fiber content of feedstuffs was estimated according to the AOAC (1984) method. Prior to the determination of selected minerals in feedstuffs and feces, the samples were ashed at 480°C for 6 h. The ashed samples were dissolved in 15 mL of 4 M HCl, and the acidified solution was analyzed for Mg, Ca, and K by atomic absorption spectroscopy. Total P in feedstuffs was measured using a spectrophotometer following the method of Quinlan and DeSesa (1955). The concentrations of Mg and K in rumen fluid were determined directly by the atomic absorption spectroscopy. Concentration of Cr in rumen fluid was analyzed by atomic emission spectroscopy. Magnesium concentrations in plasma and urine were measured by atomic absorption spectroscopy. The accuracy of each assay run was found to be within 3% deviation from the target value of a commercial hay powder

(CRM 129, Community Bureau of Reference, Brussels, Belgium) and from that of in-house reference samples. The combined within- and between-run precision of the determinations was <3% (coefficient of variation).

Calculations and Statistical Analysis

The calculations of rumen volume and the passage rate of rumen fluid content were described previously by Schonewille et al. (1999b). Prior to statistical analysis, geometrical means of 5 postfeeding values of rumen pH and concentrations of Mg and K, based on samples taken at 0900, 1100, 1300, 1500, and 1700 h, were calculated. The means can be considered as estimates of the areas under the curve (Wolever and Jenkins, 1986). Then, all data were subjected to ANOVA. The total variation was divided into cow, experimental period, dietary treatment, and the interaction of dietary Mg and K (K × Mg). When the influence of the dietary treatments reached statistical significance, Tukey's *t* test was used to distinguish the dietary treatments that had different effects on the variable involved. For the data from each cow (*n* = 6) and for each diet (*n* = 6), linear correlations were calculated between ruminal variables and Mg absorption. The calculations were done under the assumption that the 36 data points could be considered independent. To detect rumen variables that were related to Mg absorption, multiple re-

Table 3. Balance of Mg (g/d) in dry cows fed the experimental diets.

	Low Mg			High Mg			Pooled SEM	P-value		
	Low K	Medium K	High K	Low K	Medium K	High K		K	Mg	K × Mg
Intake	41.1	41.0	40.0	68.9	69.6	68.7	ND ¹	ND	ND	ND
Feces	35.9 ^e	35.7 ^e	39.1 ^d	56.1 ^c	60.7 ^b	63.9 ^a	0.541	<0.001	<0.001	<0.001
Absorption	5.2 ^c	5.3 ^c	0.8 ^d	12.8 ^a	8.9 ^b	4.8 ^c	0.541	<0.001	<0.000	<0.002
Urine	6.8 ^b	3.9 ^{cd}	1.6 ^e	9.5 ^a	5.7 ^{bc}	3.1 ^{de}	0.451	<0.000	<0.000	0.433
Balance	-1.6 ^c	1.4 ^{ab}	-0.8 ^{bc}	3.3 ^a	3.2 ^a	1.7 ^{ab}	0.584	0.014	<0.000	0.028

^{a,b,c,d,e}Values in the same row with different superscript differ significantly ($P < 0.05$; Tukey's t test).

¹ND = Not determined because the cows were fed restricted feed.

gression analysis was performed with animal and period as factors. Urinary Mg excretion (g/d) was used as a dependent variable. Rumen fluid concentrations of Mg and K, ruminal pH, rumen volume, passage rate of rumen liquid, and an interaction term of Mg and K concentrations in rumen fluid were used as independent variables. Forward, stepwise regression was performed by incorporating into the model the rumen variable showing the highest significant, partial correlation coefficient for its relation with the residual variance in urinary Mg excretion. Throughout, statistical significance was preset at $P < 0.05$.

RESULTS

Body Weight

Mean BW at the end of the experiment was 786 kg (SE $\pm$ 23.4; $n = 6$), which is almost identical to preexperimental values.

Mg Balance and Plasma Mg

Absolute Mg absorption (g/d) and Mg absorption expressed as a percentage of intake were significantly increased after the intake of supplemental Mg and were significantly decreased after the intake of supplemental K (Table 3). However, when the dietary K concentration increased from low to medium (from 20.5 to 48.2 g/kg of DM), the depressant effect of additional K on Mg absorption was not observed at Mg intakes of 41 g/d (low-Mg rations). Absolute Mg absorption (g/d) and Mg absorption expressed as a percentage of intake were positively correlated (Pearson's $r = 0.827$, $P < 0.001$, $n = 36$). Urinary Mg excretions were positively related to the absolute amount of Mg absorbed (Pearson's $r = 0.817$; $P < 0.001$, $n = 36$), and a significant K $\times$ Mg interaction with regard to the urinary excretion of Mg was not observed. Magnesium balance was positively related to the amount of Mg absorbed (Pearson's $r = 0.745$; $P < 0.001$, $n = 36$) and all values that were within 5% of the intake of Mg.

Plasma Mg concentrations were not significantly influenced ($P = 0.226$) by dietary treatments. For all treatments combined, mean plasma Mg concentration was 0.92 mM (SE $\pm$ 0.01, $n = 6$), which is in the normal range (Kemp, 1960).

Ruminal Mg and K Concentrations and pH

The ruminal concentrations of Mg and K, both before and mean postfeeding values, were significantly increased after the intake of supplemental Mg and K, respectively (Table 4). There was no significant effect of Mg intake on the ruminal concentrations of K, and K intake did not influence ruminal Mg concentrations either.

The pH of rumen fluid prior to the morning meal did not differ significantly between dietary treatments, but postfeeding values were significantly influenced by both dietary Mg and K (Table 4). Generally, the ruminal pH decreased after the ingestion of feed, which is related to ruminal fermentation and the production of VFA. The postfeeding decrease in ruminal pH was significant ($P < 0.007$, Student's paired t test) for all but the high Mg, high K treatment ($P = 0.222$, Student's paired t test). Apparently, the amounts of KHCO_3 and MgO ingested after feeding the high-K, high-Mg ration counteracted the fermentation-induced lowering of ruminal pH.

Rumen Volume and Passage Rate

Rumen volume (L), absolute (L/h), and fractional outflow (%/h) of liquid phase were not affected ($P \geq 0.152$) by dietary treatment, the mean values for the combined treatments ($n = 6$) being 53.3 L (SE $\pm$ 0.84), 5.2 L/h (SE $\pm$ 0.27), and 9.9%/h (SE $\pm$ 0.46), respectively.

Multiple Regression Analysis

After forward, stepwise regression, it appeared that the factors, animal, and experimental period, and the ruminal Mg and K concentrations contributed signifi-

Table 4. Ruminal pH, Mg, and K concentrations in rumen fluid in dry cows fed the experimental diets.

	Low Mg			High Mg			Pooled SEM	<i>P</i> -value		
	Low K	Medium K	High K	Low K	Medium K	High K		K	Mg	K × Mg
Mg (mM)										
0745 h	4.22 ^c	4.44 ^c	4.29 ^c	6.73 ^b	7.30 ^b	8.84 ^a	0.522	0.449	<0.000	0.462
Postfeeding ¹	7.39 ^b	6.78 ^b	6.86 ^b	13.09 ^a	11.83 ^a	12.53 ^a	0.497	0.195	<0.000	0.765
P (mM)										
0745 h	21.40 ^c	43.91 ^b	63.34 ^a	23.24 ^c	42.67 ^b	63.80 ^a	1.123	<0.000	0.814	0.699
Postfeeding ¹	29.75 ^c	66.24 ^b	103.85 ^a	31.56 ^c	65.06 ^b	102.78 ^a	1.972	<0.000	0.927	0.696
Ruminal pH										
0745 h	6.93	6.94	6.93	6.92	6.98	6.91	0.034	0.432	0.810	0.619
Postfeeding ¹	6.59 ^d	6.73 ^{bc}	6.80 ^{ab}	6.67 ^c	6.80 ^{ab}	6.84 ^a	0.026	<0.000	0.011	0.659

^{a,b,c}Values in the same row with different superscript differ significantly ($P < 0.05$; Tukey's t test).

¹Geometrical mean of 5 samples postfeeding taken at 0900, 1100, 1300, 1500, and 1700 h.

cantly to the explained variance in urinary Mg excretion (Table 5). Furthermore, the interaction term of rumen fluid Mg and K concentrations did not significantly contribute to the explained variance in urinary Mg excretion (g/d); the partial correlation (R_{partial}) with the residual variance in urinary Mg excretion was 0.252 ($P = 0.235$) when rumen fluid Mg and K concentrations were already incorporated into the regression model.

DISCUSSION

This study confirms earlier work showing that the addition of K to the ration of ruminants inhibits Mg absorption (Ram et al., 1998; Schonewille et al., 1999a, 1999b). Upon ANOVA, Mg absorption (g/d) was significantly affected by a K × Mg interaction (Table 3). Under the assumption of 0 Mg balance, apparent Mg absorption and urinary Mg excretion should be identical. Thus, it is difficult to explain why Mg absorption but not urinary Mg excretion was significantly affected by a K × Mg interaction. However, it may be suggested that Mg absorption was underestimated after the feeding of the low-Mg, low-K ration. Indeed, urinary Mg excretion

was 1.5 g/d higher than apparent Mg absorption, which resulted in a negative Mg balance that differed significantly from zero ($P = 0.001$, Student's paired t test). However, plasma Mg values were found to be 0.91 ± 0.027 mmol/L (mean ± SE) after feeding of the low Mg, low-K ration. Because the renal threshold for plasma Mg was found to be around 0.75 mmol/L (Rook and Balch, 1958; Storry and Rook, 1963), it is difficult to see that a negative Mg balance would occur after feeding the low Mg, low-K ration. Thus, it may be concluded that the observed dietary K × Mg interaction was due to the aberrantly low value of Mg absorption after feeding the low Mg, low-K ration. Therefore, urinary Mg excretion was considered as a more reliable index of Mg absorption than the difference between Mg intake and fecal Mg excretion.

The inhibitory action of K on Mg absorption can be explained by the depolarizing action of high luminal K concentrations on the apical membrane potential of rumen epithelial cells, F1 which reduces the driving force for Mg uptake by these cells (Martens et al., 1987). Furthermore, in vitro studies with isolated sheep rumen epithelium (Leonhard-Marek and Martens, 1996)

Table 5. Multiple regression models accounting for 83.9% of the observed variance in urinary Mg excretion.¹

Independent variable	Unit	Regression coefficient ± SE ²	<i>P</i> -value
Constant	g/d	8.9 ± 1.13	<0.001
Animal	Rank order (2–6)	NG ³	0.001
Experimental period	Rank order (2–6)	NG ³	0.029
Ruminal K ⁴	mM	−0.08 ± 0.007	<0.001
Ruminal Mg ⁴	mM	0.33 ± 0.068	<0.001

¹ $P < 0.001$, $n = 36$.

²The regression coefficient equals the change in average response of urinary Mg excretion (g/d) if the independent variable increases by one unit.

³NG = not given, because the values are not of interest, and there were 3 regression coefficients for the factor period.

⁴Values are geometrical means of 5 postfeeding values of rumen samples taken at 0900, 1100, 1300, 1500, and 1700 h.

Figure 1. Urinary Mg excretion in individual cows in relation to the mean postfeeding ruminal K concentrations. Cows were fed experimental rations containing 3 concentrations of K (20.7, 48.0, and 75.5 g K per kilogram of DM) and were fed at 2 levels of Mg intake (40.6 and 69.1 g/d). The linear correlation coefficients and regression formulas were: low-Mg intake, $r = -0.785$, $y = 8.3 - 0.06 \times$ ($P < 0.001$, $n = 18$); high-Mg intake, $r = -0.844$, $y = 11.6 - 0.08 \times$ ($P < 0.001$, $n = 18$). Symbols: ■, Low Mg/low K; ▲, Low Mg/medium K; ●, Low Mg/high K; □, High Mg/low K; △, High Mg/medium K; ○, High Mg/high K.

have demonstrated that Mg absorption became independent from the luminal K concentration at levels higher than 80 mM. In this study, it was found that the mean postfeeding ruminal K concentrations responded in linear, dose-dependent fashion to the level of K intake, whereas Mg intake had no effect on the ruminal K concentrations (Table 4). Figure 1 shows the relationships between the mean postfeeding ruminal K concentrations and the urinary Mg excretion at the 2 levels of Mg intake. It is difficult to see that the urinary Mg excretion becomes marginally depressed when the dietary K content is increased from medium to high level (from 48.0 to 75.5 g K/kg of DM). Apparently, such an effect, if any, may occur under feeding conditions only when ruminal K concentrations are higher than those in this study.

Furthermore, the outcome of multiple regression analysis (Table 5) indicates that the T5 slopes of the regression lines, as shown in Figure 1, are essentially similar because the partial correlation for the ruminal K $\times$ Mg interaction appeared to be nonsignificant. Indeed, the observed increase in rumen Mg concentrations after supplementing the rations with Mg effectively increased urinary Mg excretion, thereby counteracting the inhibitory effect of supplemental K on the urinary Mg excretion. This observation is corroborated by the outcome of studies in sheep (Dalley et al., 1997a; Ram et al., 1998).

In addition to the electrogenic component of Mg uptake by rumen epithelial cells, the chemical gradient of soluble Mg between the lumen and cell content is

also of importance. From in vitro studies by Dalley et al., (1997b), it follows that the solubility of Mg in ruminal fluid decreases abruptly when rumen pH is > 6.0 . Thus, at higher pH values, the soluble Mg concentration becomes unrelated to the pH. In our study, ruminal pH was significantly influenced by the additional intake of K and Mg (Table 4). However, mean postfeeding Mg concentrations in ultracentrifuged rumen fluid were not correlated with mean postfeeding pH values (Pearson's $r = 0.047$, $P = 0.785$). Probably, the impact of ingested KHCO_3 and MgO on ruminal pH was not sufficient to substantially decrease the solubility of Mg in rumen fluid and thereby affect Mg uptake by rumen epithelial cells. Indeed, rumen Mg concentrations were not significantly influenced by the additional intake of K (Table 4). Rumen Mg concentration can be affected by rumen volume and passage rate of rumen fluid (Van't Klooster, 1967). However, based on stepwise regression, the variance in rumen and passage rate of rumen fluid did not significantly contribute to the explained variance in Mg absorption. Thus, in this study rumen pH, rumen volume, and fractional outflow were not related to Mg absorption.

CONCLUSIONS

This feeding trial highlights that supplemental K in the diet diminishes apparent Mg absorption equally for low- and high-Mg rations. There was a negative linear correlation between rumen K concentrations and urinary Mg excretion. It is concluded that under practical feeding conditions, the inhibitory effect of supplemental K on Mg absorption is constant and not related to the initial level of K intake. This implies that the diet formulations for cows fed tetany-prone grass (20 to 75 g of K/kg of DM) need to contain supplemental Mg in order to avoid the risk of hypomagnesaemia due to the depressant effect of K on Mg absorption.

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