EFFECT OF SUPPLEMENTAL POTASSIUM AND MONENSIN ON RUMINAL DIGESTION AND PASSAGE RATES

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Story in Brief

Four ruminally cannulated cattle (1005 lb) were fed 63 percent milo diets to determine the effects of potassium and monensin on ruminal digestion and in situ disappearance of corn and soybean meal. Treatments included two levels of potassium (.64 or .86 percent) and monensin (0 or 27 ppm). Ruminal buffering capacity and concentrations of sodium, potassium and total volatile fatty acids were not affected by treatment. Potassium supplementation depressed ruminal isobutyrate and increased ruminal liquid passage rates by 15 percent. Monensin depressed ruminal ammonia-nitrogen, and acetate, butyrate and valerate while increasing propionate and isovalerate. Passage rates of milo and prairie hay tended to be faster when monensin was fed. Added monensin did not alter ruminal dry matter disappearance of corn but tended to increase ruminal disappearance of dry matter and nitrogen from soybean meal. This may have been due to a higher ruminal pH with monensin supplementation. As ruminal pH increased, digestion rates of soybean meal dry matter and nitrogen increased. No interactions between potassium and monensin were detected. Results indicate that potassium supplementation does not alter effects of monensin on digestion.

(Key Words: In Situ, Potassium Chloride, Monensin, Feedlot, Rate of Passage.)

Introduction

Monensin is widely used in feedlot diets. Monensin generally improves feed efficiency, depresses feed intake and has little effect on the daily gain of feedlot cattle. Monensin increases the proportion of propionate produced in the rumen and often increases the quantity of dietary protein that escapes degradation in the rumen by forming complexes with certain minerals [potassium (K) and sodium (Na)]. Hence, monensin feeding modifies protein and mineral availability (NRC, 1984). Interactions between dietary mineral levels and monensin have been detected in microbiological and mineral balance studies, but interactions in the rumen and in feedlot performance have not been reported.

This study was designed to detect effects and interactions of K and monensin on ruminal digestion and passage rate of ruminal fluid and particles.

Materials and Methods

Two Angus-Hereford heifers (1043 lb) and two Brahman-Hereford cross steers (968 lb) fitted with large ruminal cannulas were fed each of 4 diets to determine the impact of K and monensin on digestion of a

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70 percent concentrate, complete mixed diet. The four diets (Table 1) were: the basal (B) diet (calculated to provide .57 percent endogenous K); the basal diet plus 27 ppm monensin (M); the basal diet plus supplemental potassium (K) from potassium chloride to provide .95 percent K; and the basal ration supplemented with both K and monensin (KM) (with .95 percent K and 27 ppm monensin). The K contents analyzed .65, .87, .62 and .85 percent K for the B, K, M and KM diets. Daily dry matter intake of each animal was restricted to 1.25 percent of the animal's initial shrunk weight.

Periods, during which each diet was fed, lasted 21 days with sampling of rumen contents on days 19 through 21 of each of the 4 periods. Feed samples were collected on days 19 through 21, composited within each diet and period, and analyzed for dry matter, ash, nitrogen (N), starch, K and Na.

On day 19, rumen samples were obtained before feeding and 1, 3, 6 and 9 hours later. Ruminal samples were analyzed for pH, ammonia-N (NH_3-N), volatile fatty acids (VFA), buffering capacity, K and Na.

To determine diet effects on ruminal digestion rate, beginning on day 19, dacron bags containing 1.5 g of soybean meal or ground corn were suspended in the rumen for 4, 12 or 24 h for each of the diets. Upon removal from the rumen, the bags were washed, dried, weighed and nitrogen content was determined.

Animals were stalled in metabolism crates and fed twice daily at 0800 and 2000 h. For estimating passage rates from the rumen, whole rumen fluid was sampled at 0800 on day 20, and 150 g of milo labeled with ytterbium and 100 g of prairie hay labeled with dysprosium were added to the diet for each animal, and a fluid marker (100 ml of CoEDTA plus 150 ml distilled water) was dosed into the rumen. Rumen fluid samples were withdrawn 6, 12, 18, 24, 30 and 36 hours after the dosing meal and dried, ground, and analyzed for dry matter, ash, cobalt (Co), ytterbium (Yb) and dysprosium (Dy) concentrations.

Table 1. Composition of finishing diets with varying amounts of dietary potassium and monensin.

Item	Diets [ab]			
	B	K	M	KM
Dry rolled sorghum	63.43	62.70	63.41	62.68
Sun-cured prairie hay	15.00	15.00	15.00	15.00
Cottonseed hulls	15.00	15.00	15.00	15.00
Cottonseed meal	5.50	5.50	5.50	5.50
Trace mineralized salt	.50	.50	.50	.50
Limestone	.57	.57	.57	.57
Potassium chloride	.00	.73	.00	.73
Monensin	.00	.00	.02	.02

[a]Basal (B) = .65% K analyzed.
Potassium (K) = .87% K analyzed.
Monensin (M) = .62% K analyzed and 27 ppm monensin.
[b]Potassium and monensin (KM) = .85% K analyzed and 27 ppm monensin.
[b]Diets analyzed 32.6% starch, and 10.2% crude protein.

Results and Discussion

Intakes of various nutrients are presented in Table 2. Analyzed sodium intake was 30 percent greater (P<.05) with the K or K-monensin diets. This is due partly to the fact that monensin was added in the form of monensin sodium but mainly because the commercial KCl added contained between 1.5 and 2.5 percent Na.

Ruminal fluid K and Na concentrations averaged over 5 sampling times did not differ significantly with diet though ruminal K tended to be greater with elevated K intake. The consistency in ruminal concentrations of K and Na across all treatments was surprising and probably reflects recycling of Na and K to the rumen. Recycling of Na and K to the rumen in another study was 19 to 26 g Na and 3 to 10 g K daily (Doran et al.,1985). In this trial, K recycling into the rumen, calculated from K concentration and liquid passage rate, was from 65 to 88 g daily.

Table 2. Dietary intake and ruminal measurements.

Item	Diets			
	B	K	M	KM
Dietary intake				
Organic matter, g/d	5284	5257	5286	5266
Starch, g/d	1850	1854	1776	1671
Nitrogen, g/d	88.7	90.8	88.7	89.3
Potassium, g/d	35.60	47.30	33.94	46.43
Sodium, g/d	5.50	7.28	5.93	7.58
Dietary K:Na ratio	6.59	6.66	5.72	7.49
Ruminal fluid				
Potassium, ppm	2447	2551	2283	2747
Sodium, ppm	2018	2050	2394	1848
Potassium:Na ratio	1.51	1.62	1.15	1.70
Ruminal passage rate				
Liquid, (Co) %/h	2.95	3.39	2.87	3.32
Solids				
Milo, (Yb) %/h	1.73	1.96	1.98	2.24
Prairie hay, (Dy) %/h	2.48	2.22	2.50	2.57
Rumen volume, liter[a]	71.7	65.8	62.0	60.8
Rumen outflow, liter/h	2.1	2.2	1.8	2.0
Ammonia-N, mg/dl	6.59[b]	5.55[b]	4.25[c]	4.02[c]
pH	6.26	6.13	6.39	6.32
Buffering capacity (ml HCl needed to change 40 ml strained rumen fluid from pH 7.0 to pH 5.0)	45.9	48.6	46.8	45.2

[a]Rumen volumes were estimated from relative zero time intercepts of Co.

[bc]Means in a row with different superscripts differ (P<.05).

Monensin supplementation did not alter (P>.05) ruminal concentrations of either K or Na. Previously, monensin supplementation has had conflicting effects on ruminal fluid K and has not altered ruminal Na. In one trial at a lower K intake (35 percent of this trial) monensin supplementation increased ruminal fluid K levels by 21.6 percent. In a second trial (at a similar K level to our trial) monensin supplementation decreased the ruminal fluid K level. In a third trial at a K level similar to the current trial, monensin supplementation did not alter ruminal fluid K concentration.

The ruminal K:Na ratio did not differ significantly among treatments, but as the ruminal K levels increased, ruminal Na levels tended to decrease. Ruminal fluid concentrations of K and Na were inversely related (r=-.96; P<.0001) as has been suggested from other studies. Possibly osmotic pressure regulates absorption or outflow of both ions. Prior research has indicated that dietary K added in the presence of lasalocid will reduce ruminal fluid Na concentrations. This tendency was apparent with monensin in our study.

Liquid passage rate was 15 percent faster (P<.07) with K supplementation, agreeing with other research reports. Ruminal outflow was correlated positively with the ruminal ratio of K:Na (r=.47; P<.07) tending to increase as K increased. Fluid dilution rate and particulate passage rate for Yb-labeled milo tended to increase together (r=.59; P<.02). Presumably, higher potassium intakes increased urinary K excretion which in turn increased water intake and rumen fluid dilution rate. Higher ruminal K:Na ratios also increased ruminal volume (r=.52; P<.04). In this study, ruminal outflow of liquid (Figure 1) and ruminal liquid volume increased together (r=.53; P<.03), possibly due to increased water consumption.

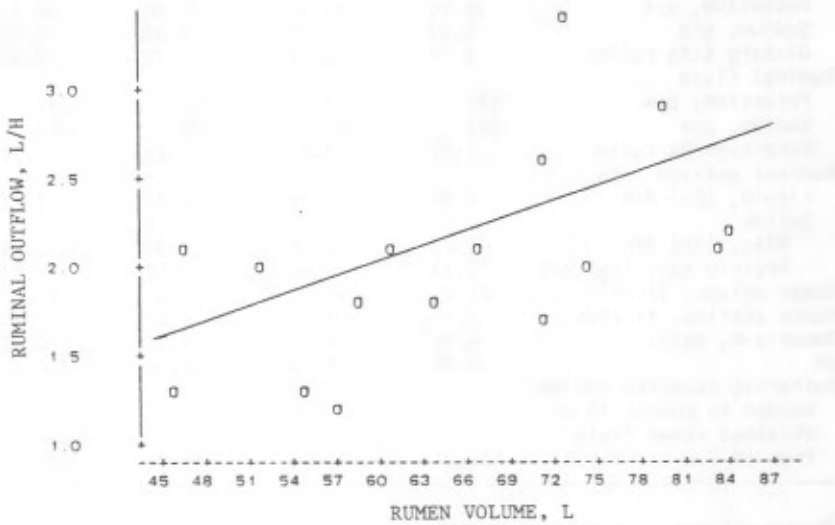

Figure 1. Ruminal outflow (O) vs ruminal volume.

Passage rate of both milo and prairie hay from the rumen tended to increase with K supplementation with the fastest passage with the K-monensin diet. Solids passage rate also tended to increase with added monensin. This contradicts results of previous reports in which monensin has decreased passage rates of both the liquids and solids. Differences in passage rates among these trials may be due to differences in rumen volume or K:Na ratios in the rumen. Passage rate of milo from the rumen and the ruminal K:Na ratio were negatively related ($r=-.52$; $P<.04$).

Estimated rumen volumes in this trial tended to be reduced with monensin supplementation ($P<.12$). This effect has been noted in other trials at similar feed intake levels. In the current trial, as rumen volume tended to increase (Figure 2) the passage rates of milo and prairie hay tended to decrease ($r=-.45$; $P<.08$ and $r=-.29$; $P<.28$). The relation between fluid passage rate and rumen volume was low ($r=-.16$; $P<.56$). Volatile fatty acid concentration changes discussed below could be partly attributed to changes in ruminal volume.

With all four diets, the passage rate for milo was slower than for prairie hay. This is inconsistent with the theory that smaller particles leave the rumen rapidly. Possibly, milo particles became lodged in the ruminal raft which reduced their passage rate.

Ruminal ammonia-N levels were lower ($P<.03$) with the monensin-supplemented diets as is often reported. Ruminal ammonia decreases are consistent with the suggestion that monensin depresses protein breakdown in the rumen. No K by monensin interaction was evident ($P>.05$) for ruminal ammonia, which agrees with other trials. Ruminal ammonia-N levels and ruminal pH were negatively correlated ($r=-.47$; $P<.07$). At higher pH levels, as occurred with monensin supplementation, ruminal ammonia-N is more rapidly absorbed from the rumen which reduces the ruminal ammonia-N level.

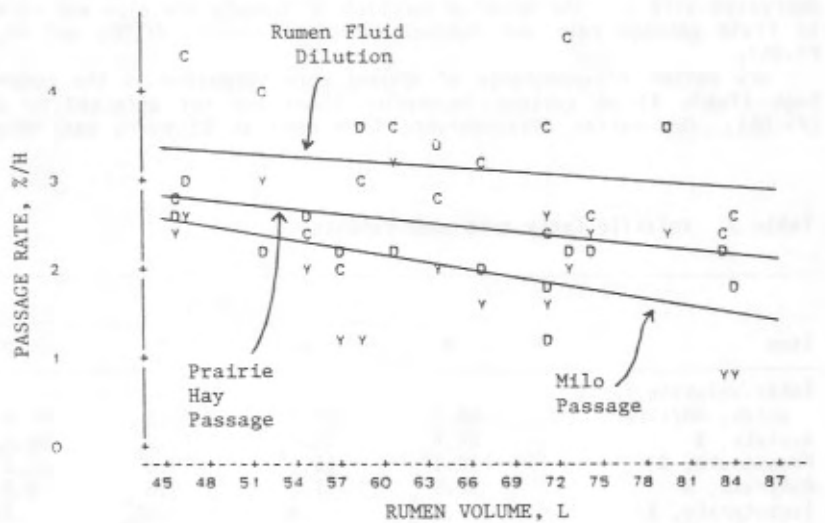

Figure 2. Rumen fluid dilution (C), milo passage rate (Y), and prairie hay passage rate (D) vs ruminal volume.

Ruminal pH tended to be higher with monensin supplementation ($P<.11$), possibly due to decreased production of volatile fatty acids or lactate. Increases with monensin are common but usually slight. All pH values in this experiment were higher than would be expected for a 70 percent concentrate diet which may be due to the low feed intakes used.

Buffering capacity was not altered by treatment ($P>.05$). Treatments with a higher initial pH and lower volatile fatty acid concentrations tended to have the lower buffering capacities. Mean ruminal pH and buffering capacity were negatively related ($r=-.56$; $P<.02$) while total volatile fatty acid concentration and buffering capacity were positively related ($r=.49$; $P<.05$). This tends to refute the theory that added KCl acts to buffer ruminal contents. Though KCl like $CaCl_2$ tended to reduce ruminal pH, potassium acetate or carbonate should have greater impact on buffering capacity. Ruminal pH and buffering capacity in this study appeared attributable primarily to VFA concentrations.

Total volatile fatty acid concentration (Table 3) was similar ($P>.05$) across treatments. However, ratios were altered with monensin supplementation. Monensin increased the molar proportion of propionate ($P<.01$) by 31.3 percent but tended to decrease ($P<.06$) molar proportions of acetate and butyrate (4.6 percent and 18.3 percent). These results agree with previous reports.

Addition of K did not significantly alter ($P>.05$) the ruminal acetate:propionate ratio similar to other reports. However, K supplementation decreased the molar percentage of isobutyrate, and monensin supplementation decreased the molar proportion of valerate ($P<.01$) and increased isovalerate ($P<.05$). A K by monensin interaction further depressed the proportion of valerate ($P<.04$). Reductions in isovalerate reflect reduced protein degradation differences suggesting that protein catabolism in the rumen was increased with monensin but decreased with K. The molar proportion of isobutyrate also was related to fluid passage rate and ruminal ammonia-N ($r=.45$; $P<.08$; and $r=.50$; $P<.05$).

Dry matter disappearance of ground corn suspended in the rumen in bags (Table 4) at various incubation times was not affected by diet ($P>.05$). Dry matter disappearance from corn at 12 hours was related

Table 3. Volatile fatty acid measurements.

Item	Diets			
	B	K	M	KM
Total volatile fatty acids, mM/liter	96.1	110.8	98.5	95.4
Acetate, %	67.6	70.0	65.2	66.0
Propionate, %	16.1[a]	15.9[a]	20.8[b]	21.1[b]
Butyrate, %	12.9	11.0	9.8	9.8
Isobutyrate, %	.51[b]	.43[a]	.52[b]	.23[a]
Valerate, %	.92[a]	.97[a]	.86[b]	.70[c]
Isovalerate, %	1.93[b]	1.76[b]	2.85[a]	2.07[a]

[abc]Means in a row with different superscripts differ ($P<.05$).

Table 4. Effect of potassium and monensin on rate of in situ dry matter and nitrogen disappearance.

Item	Diets			
	B	K	M	KM
Digestible corn DM available, %	76.5	74.7	75.1	75.2
Digestion rate of corn DM, %/h	1.41	1.25	1.32	1.49
Digestible soybean meal DM available, %	68.8	69.0	63.9	64.2
Digestion rate of soybean meal DM, %/h	1.72	1.87	2.12	1.82
Digestible soybean meal N available, %	89.7	84.7	79.0	86.2
Digestion rate of soybean meal N, %/h	2.00	1.65	2.53	2.61

positively with liquid and solids passage rates ($r=.57$; $P<.02$; and $r=.46$; $P<.07$). Possibly increased water intake or water movement into the rumen with added K tended to remove the soluble corn residues at a faster rate. Disappearance of corn at 24 hours of incubation remained weakly related with solids passage rate ($r=.25$; $P<.36$). The zero time intercept was about 25 percent (Figure 3) suggesting that about 25 percent of the corn dry matter was lost from bags as soluble residues and small particles during the first few hours of incubation. Only the less soluble, larger particles remained to be digested thereafter.

Dry matter disappearance from dacron bags should be a relative index of dry matter digestibility. Previous trials have detected no effect of K on in vivo dry matter digestibility. In contrast, some previous research suggests that monensin increases in vivo dry matter digestibility. The discrepancy in digestion rates between in situ disappearance of this trial and previous in vivo trials may be due to several factors. First, in vivo dry matter digestion encompasses all diet components including starch, nitrogen and ADF. In contrast, corn is primarily starch, so in situ disappearance primarily reflects starch digestion. Secondly, previous trials have primarily reported total tract dry matter digestibility while this trial relates only to ruminal dry matter digestibility. Earlier trials with monensin have yielded contradictory results of ruminal dry matter digestibility.

Dry matter (Figure 4) and nitrogen disappearance (Table 4) of soybean meal were not significantly altered by diet ($P>.05$), though ruminal digestion of nitrogen (Figure 5) tended to be increased with addition of monensin to the diet ($P<.07$). This result contradicts most earlier research in which monensin has been reported to reduce ruminal digestion of dietary protein and increase protein escape. Usually, however, total flow of N from the rumen is not increased with monensin as microbial protein flow generally decreases in an amount similar to the increase in feed N passage. If monensin changed composition of

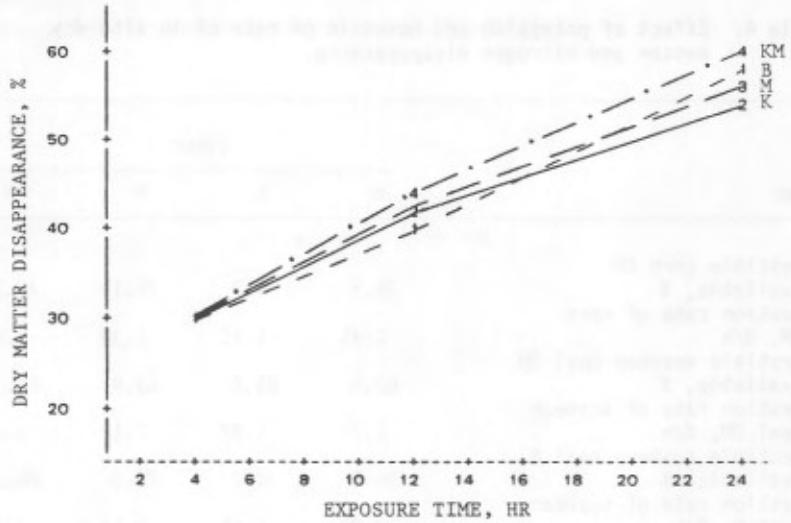

Figure 3. Dry matter disappearance of ground corn from dacron bags suspended in the rumen of cattle for 4, 12 or 24 hours.

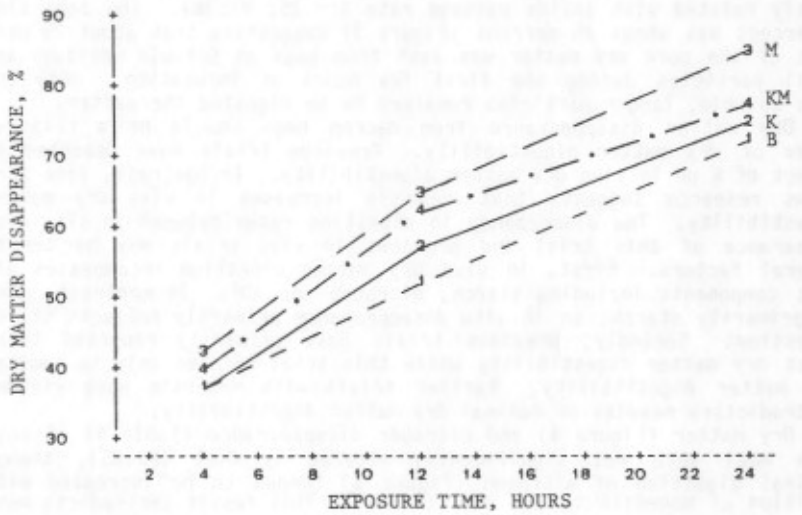

Figure 4. Dry matter disappearance of soybean meal from dacron bags suspended in the rumen of cattle for 4, 12 or 24 hours.

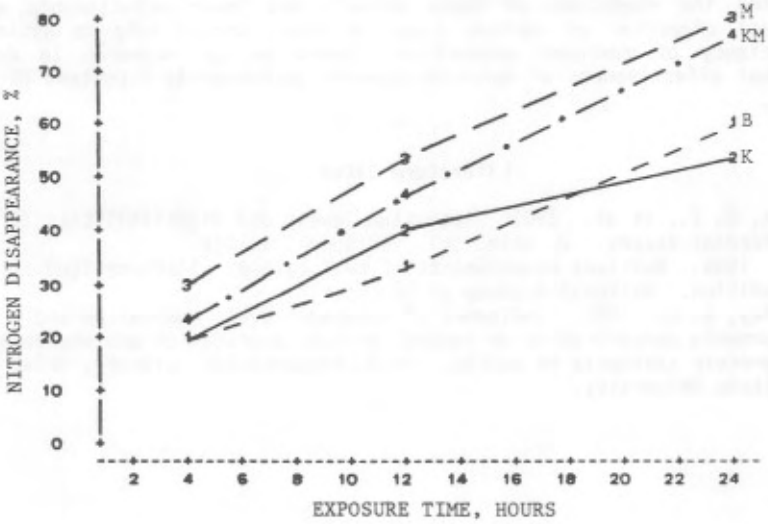

Figure 5. Nitrogen disappearance of soybean meal from dacron bags suspended in the rumen of cattle for 4, 12 or 24 hours.

ruminal microbes, microbial flow would be underestimated while ruminal escape of feed protein would be overestimated in vivo.

Increased disappearance of soybean meal nitrogen with monensin supplementation could be due to increased ruminal pH. Ruminal pH was related positively with dry matter and nitrogen disappearance of the soybean meal at 24 hour ruminal incubation ($r=.63$; $P<.009$ and $r=.71$; $P<.002$). Whether the interaction of pH with protein degradation is due to (a) altered solubility of the feed protein, (b) reproportioning of microbial species, or (c) altered proteolytic activity of existing species remains undetermined (Weakley, 1983). A second explanation for increased escape of soybean meal nitrogen with monensin supplementation relates to ruminal retention time. Passage rates of particles increased with monensin supplementation. If particulate passage rate is increased, escape in vivo could increase, despite an increased rate of N digestion in the rumen. In situ nitrogen digestibility at 24 hours was related positively to passage rate of Yb-labeled milo and Dy-labeled prairie hay ($r=.53$; $P<.04$ and $r=.45$; $P<.08$).

In conclusion, results from this study indicate that K did not alter the effect of monensin on measured ruminal factors. Though some researchers have shown that K can alter effects of ionophores on mineral levels and retention and on viability of ruminal microbes, added K generally does not alter effects of ionophores on feed efficiency in feeding studies. An interaction would be expected if all the effects of monensin relate to alteration in ion transport but ionophores have a number of effects, some of which can be enhanced or countered by added K. In this study, these changes include ruminal pH (increased with monensin, possibly reduced by K), ruminal fluid dilution rate (increased by K and reduced by monensin) and particulate passage rate (increased by both K and monensin). Further research to

examine the magnitude of these effects and their relationship with ruminal digestion of various types of diets should help to optimize efficiency of ruminant production. Based on our research to date, ruminal effectiveness of monensin appears unchanged by K content of the diet.

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