Effect of Monensin or Salinomycin Supplementation in a 50% Concentrate Diet on Mineral Utilization of Growing Goats

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ABSTRACT: An experiment was conducted to clarify the effects of dietary supplementation of monensin or salinomycin on mineral utilization of growing goats. Six goats weighing 10.54 kg initially were randomly assigned to treatments in a replicated 3 × 3 Latin square design. Treatments were a basal diet, basal plus 30 ppm monensin and basal plus 20 ppm salinomycin on a DM basis. The basal diet was a mixture of Italian ryegrass wafer, soybean meal, ground maize and $CaCO_3$ with DM proportions of 50, 13.76, 36 and 0.24%, respectively. Each period lasted for 21 days, and the apparent absorption and retention of minerals were measured during the last 7 days of each period. Salinomycin supplementation improved NDF digestibility and plasma glucose. The apparent absorption and retention of Ca, P, Mg, Na and K were not influenced by the treatments. The concentrations of plasma Ca, P, Mg, Na, K and Cl were similar in all treatments. The ionophore supplementation had no significant effect on acid excretion. The results suggest that 30 ppm monensin or 20 ppm salinomycin supplementation is not effective in improving the utilization of Ca, P, Mg, Na and K in growing goats fed a diet composed of the 50% concentrate.

(**Key Words**: Monensin, Salinomycin, Mineral Retention, Growing Goat)

INTRODUCTION

Carboxylic ionophores such as monensin and salinomycin have been used as feed additives for ruminants. Improved feed efficiency of growing ruminants has been reported when monensin (Fontenot and Huchette, 1993) or salinomycin (Bergen and Bates, 1984) were supplemented. The effectiveness of ionophores in improving feed utilization was related to the reduced methane production and increased proportion of propionate in the rumen (Schelling, 1984). The primary role of the ionophores is to form lipid-soluble complexes with certain cations and alter their flow across cell membranes (Pressman, 1976).

Ionophores have been proved to influence mineral metabolism in cattle and sheep, although the relationship between mineral utilization and productivity has not been elucidated clearly. Armstrong and Spears (1988) reported that monensin administration affected the metabolism of P, Mg and K, being independent of alterations in ruminal metabolism. Dietary supplementation of monensin increased Ca retention in cattle fed a forage-based diet (Spears et al., 1989b). Also, supplemental monensin increased retention of P and Mg in lambs (Kirk et al., 1985b) and growing steers (Starnes et al., 1984) fed concentrate-based diets.

The effect of supplemental ionophore on mineral utilization has been studied mostly in sheep and cattle either fed high-concentrate or high-forage diets. The beneficial effects of ionophore supplementation on the productivity of ruminants may encourage the application of ionophores in diets composed of various ranges of concentrate level. This experiment was designed to clarify the effect of 30 ppm monensin or 20 ppm salinomycin supplementation, which seemed to be appropriate amounts for ruminants, on mineral utilization of growing goats fed a diet composed of 50% concentrate.

MATERIALS AND METHODS

Animal and feed

Six castrated-growing native Japaness goats weighing 10.54 ± 2.96 kg (mean ± S.D.) initially were allocated to control, monensin and salinomycin treatments in a replicated 3 × 3 Latin square design. Treatments consisted of: 1) basal diet, 2) basal diet containing 30 ppm monensin, and 3) basal diet containing 20 ppm

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salinomycin on a DM basis. The basal diet was a mixture of first cutting Italian ryegrass wafer, soybean meal, ground maize and $CaCO_3$ in the proportion of 50, 13.76, 36 and 0.24% on a DM basis, respectively. The chemical composition of the basal diet is shown in table 1. The diet was formulated to meet requirement for TDN, protein and minerals (NRC, 1981) and was offered in two equal amounts at 09:00 and 15:00 hours each day. One gram of vitamins was mixed thoroughly with the feed immediately before feeding.

Table 1. Chemical composition of basal diet offered to growing goats

Constituent	Diet[1]
	.... % ....
Dry matter	88.08
Organic matter	93.94
Crude protein	15.23
Crude fat	3.46
NDF	35.29
ADF	21.35
Ca	0.45
P	0.36
Mg	0.21
Na	0.07
K	2.05

[1] All values are expressed on a DM basis except for DM.

The goats were placed in the metabolism stalls located in a controlled-temperature room kept at 20℃. The animals were adapted to the experimental conditions for 2 weeks before the start of the experiment. Each 21-day experimental period consisted of a 14-day preliminary period and a 7-day total collection period.

Sample collection

During the total collection period, feed, feed refusal, fecal and urine samples were collected daily and composited. Total fecal output was dried at 60℃ in a forced-air oven for 24 hours. Urine was collected non-acidified in plastic bottles immersed in crushed ice, weighed and sampled (Fredeen et al., 1988). At the end of experiment, the frozen-urinary samples were thawed, composited proportionally according to daily output and filtered through ashless filter paper.

Ten milliliters of blood samples were obtained by jugular puncture into heparinized vacuum tubes before feeding and 3 hours after feeding on the last day of each experimental period. Blood was centrifuged immediately at 1,870 × g for 10 minutes at 4℃ and plasma samples were stored at −20℃ until they were analyzed.

Chemical analysis

Dried feed, feed refusals and fecal samples were ground in a stainless steel mill through a 1-mm screen. Samples were analyzed for ash, fat and nitrogen, NDF and ADF. The concentrations of Ca, Mg, Na and K were determined by atomic absorption spectrophotometry and P was determined by a colorimetry procedure. The composited-samples of urine were analyzed for titratable acid, ammonium (NH_4^+) (Chan, 1972), nitrogen and mineral. Urine samples for mineral determination were wet oxidized, and Ca, P, Mg, Na and K contents were determined as described above.

Plasma glucose and Cl were determined using commercial kits (Wako Pure Chemical Industries, Ltd., Japan) and plasma inorganic phosphorus (Pi) was determined by the procedure of Taussky and Shorr (1953). Plasma Ca, Mg, Na and K were determined by atomic absorption spectrophotometry after dilution with deionized water.

Statistical analysis

Analysis of variance of a replicated Latin square was used to analyze the effect of monensin or salinomycin supplementation. Treatment means were compared by LSD and the significance was declared at $p < 0.05$.

RESULTS AND DISCUSSION

Nitrogen and NDF utilization

There were no significant differences in DM intake, weight gain and nitrogen retention. In goats fed the basal diet, basal diet plus monensin and salinomycin, the DM intake were 29.2, 28.5, and 28.3 g/day/kg body weight and the weight gain were 48, 44 and 58 g/day, respectively. Nitrogen retention was 0.15 g/day/kg body weight in all treatments.

There was no significant difference in protein digestibility among treatments (table 2). The beneficial effect of ionophore supplementation on protein utilization is likely dependent on the concentrate level in the diets. It was reported that supplemental ionophore tended to increase nitrogen retention in cattle fed a forage-based diet (Spears et al., 1989a), but the effect was not observed in cattle fed a concentrate-based diet (Reffett-Stabel et al., 1989). Thus, protein utilization may not be influenced by the supplemental ionophore in a diet with 50% of concentrate as well as a concentrate-based diet.

The digestibility of ADF was not affected by monensin or salinomycin supplementation in the basal diet (table 2). The digestibility of NDF and plasma glucose measured three hours after feeding were significantly higher in goats fed the basal diet plus salinomycin than in the goats fed the basal diet only. Plasma glucose in goats fed the basal diet, basal diets plus monensin and salinomycin were as follows; 61.8, 64.3 and 64.3 mg/dl (before feeding) and 64.9, 69.2 and 71.0 mg/dl (three hours after feeding), respectively.

Table 2. Nutrient digestibility in growing goats fed a 50 % concentrate diet with monensin or salinomycin supplementation

Item	Treatment			SEM
	Basal	Basal + Monensin	Basal + Salinomycin	
	.... %			
DM	70.7	71.2	71.8	0.5
Crude protein	66.7	69.3	69.2	1.0
NDF	52.8[b]	54.1[ab]	55.3[a]	0.6
ADF	48.7	51.2	52.6	1.7

Means within same row with different superscript letters differ ($p < 0.05$).

Fiber digestibility has been increased by supplemental ionophore in ruminants fed either high or low concentrate diets (Spears, 1990). Schelling (1984) reported that supplemental ionophore increased the proportion of propionate, a glucose precursor, in the rumen. The higher NDF digestibility in salinomycin treatment is likely accompanied by a shifted synthesis of acetate to propionate in the rumen which may account for the increase in plasma glucose. The results suggest that salinomycin supplementation in a diet with 50% concentrate may have similar effect on NDF digestibility with high or low concentrate diets.

Metabolism of Ca, P and Mg

Daily intakes of Ca, P and Mg, which met the requirement for 10.5 kg goats gaining 50 g/day (NRC, 1981), were not affected by the treatment (table 3). No differences were observed in either apparent absorption or retention of Ca, P and Mg in goats fed a basal diet, basal diets with monensin or salinomycin. Plasma Ca, Pi and Mg were similar in all treatments (table 4).

Previous studies suggest that supplemental ionophore increased Ca absorption and retention in cattle fed a forage-based diet (Spears et al., 1989b), but this was not observed in ruminants fed concentrate-based diets (Starnes et al., 1984; Kirk et al., 1985b). On the other hand, the retention of P and Mg was not influenced by monensin in cattle fed a forage-based diet (Spears et al., 1989b), but increased in concentrate-based diets (Starnes et al., 1984; Kirk et al., 1985b).

Table 3. Mineral utilization in growing goats fed a 50% concentrate diet with monensin or salinomycin supplementation

Item	Treatment			SEM
	Basal	Basal + Monensin	Basal + Salinomycin	
	...... mg/day/kg body weight			
Calcium :				
Intake	131.6	128.4	127.6	1.6
Apparent absorption	31.5	38.7	39.2	4.5
Retention	31.2	38.5	39.0	4.5
Phosphorus :				
Intake	106.7	104.5	103.4	1.2
Apparent absorption	29.6	32.8	34.9	3.9
Retention	28.8	31.7	33.8	3.8
Magnesium :				
Intake	61.6	60.0	59.3	0.9
Apparent absorption	26.3	25.5	26.3	1.0
Retention	−0.4	2.0	1.4	1.6
Sodium :				
Intake	21.0	20.4	20.4	0.3
Apparent absorption	16.6	15.7	16.2	0.6
Retention	−4.4	−2.9	0.1	2.5
Potassium :				
Intake	598	585	574	8
Apparent absorption	533	527	516	9
Retention	−36	−19	−5	21

Supplemental monensin or salinomycin in growing goats fed a 50% concentrate diet had no effect on the utilization of Ca, P or Mg. Although the utilization of Ca, P and Mg in ruminants fed an ionophore may be influenced by a high level of concentrate or roughage, further study is needed to clarify the relationship between dietary concentrate level and ionophore in connection with Ca, P and Mg utilization.

Metabolism of Na and K

The intake, absorption and retention of Na and K were similar in all treatments (table 3). The retention of K was negative in all treatments. Compared with dietary requirements, according to NRC (1981), dietary Na intake was too low, but K intake was more than sufficient in the present experiment. Excreted-ammonium, net acid and total acid in urine were not influenced by the supplementation of monensin or salinomycin (table 5).

Table 4. Plasma mineral concentrations of growing goats fed a 50% concentrate diet with monensin or salinomycin supplementation

Item	Treatment			SEM
	Basal	Basal + Monensin	Basal + Salino-mycin	
Before feeding :				
Ca (mg/dl)	9.7	9.9	9.8	0.1
P (mg/dl)	8.2	9.1	9.1	0.5
Mg (mg/dl)	2.3	2.3	2.3	0.1
Na (mg/dl)	310	305	307	2
K (mg/dl)	18.5	19.2	19.8	1.0
Cl (meq/l)	119	121	119	1
Three hours after feeding :				
Ca (mg/dl)	10.3	10.3	10.2	0.1
P (mg/dl)	8.0	8.9	8.4	0.5
Mg (mg/dl)	2.7	2.7	2.7	0.1
Na (mg/dl)	306	309	306	3
K (mg/dl)	19.4	19.0	19.2	0.8
Cl (meq/l)	121	124	120	2

Table 5. Excretion of urinary acid-base metabolites in growing goats fed a 50% concentrate with monensin or salinomycin supplementation

Item	Treatment			SEM
	Basal	Basal + Monensin	Basal + Salino-mycin	
	······ mmol/day/kg body weight ······			
Total NH_4^+	0.56	0.51	0.55	0.07
Net acids	−4.17	−4.10	−4.18	0.11
Total acids	−4.61	−4.49	−4.65	0.14

Previous studies have shown that the absorption and retention of Na and K are inconsistently influenced by ionophore supplementation. In steers fed a concentrate-based diet, Na absorption was increased by supplemental monensin (Starnes et al., 1984), and K retention was increased by supplemental salinomycin (Reffett-Stabel et al., 1989). In lambs fed a concentrate-based diet, monensin supplementation reduced Na retention (Kirk et al., 1985a).

Monensin has a strong affinity for Na (Presman, 1976) and salinomycin for K (Mitani et al., 1975). The acid-base balance in biological fluids is influenced by dietary Na and K (Block, 1991). However, the utilization rates of Na and K as well as the acid-base status of goats fed a 50% concentrate diet were not influenced by dietary supplementation of monensin or salinomycin. It is not clear whether the effectiveness of supplemental monensin or salinomycin on Na or K utilization is related to the level of concentrate in the diet. Further study is necessary to identify factors affecting Na and K utilization in ruminants fed ionophores.

REFERENCES

Armstrong, J. D. and J. W. Spears. 1988. Intravenous administration of ionophores in ruminants: effects on metabolism independent of the rumen. J. Anim. Sci. 66:1807-1817.

Bergen, W. G. and D. B. Bates. 1984. Ionophores: Their effect on production efficiency and mode of action. J. Anim. Sci. 58:1465-1483.

Block, E. 1991. Anion-cation balance and its effect on the performance of ruminants. In: Recent Advances in Animal Nutrition. (Eds. W. Haresign and D. J. A. Cole). Butterworth-Heinemann, Ltd. Oxford. pp. 163-179.

Chan, J. C. M. 1972. The rapid determination of urinary titratable acid and ammonium and evaluation of freezing as a method of preservation. Clin. Biochem. 5:94-98.

Fredeen, A. H., E. J. DePeters, and R. L. Baldwin. 1988. Characterization of acid-base disturbances and effects on calcium and phosphorus balances of dietary fixed ions in pregnant or lactating does. J. Anim. Sci. 66:159-173.

Fontenot, J. P. and H. M. Huchette. 1993. Feeding sorbitol alone or in combination with monensin the finishing cattle. J. Anim. Sci. 71:545-551.

Kirk, D. J., L. W. Greene, G. T. Schelling and F. M. Byers. 1985a. Effects of monensin on monovalent ion metabolism and tissue concentrations in lambs. J. Anim. Sci. 60:1479-1484.

Kirk, D. J., L. W. Greene, G. T. Schelling and F. M. Byers. 1985b. Effects of monensin on Mg, Ca, P, and Zn metabolism and tissue concentrations in lambs. J. Anim. Sci. 60:1485-1490.

Mitani, M., T. Yamanishi and Y. Miyazaki. 1975. Salinomycin : A new monovalent cation ionophore. Biochem. Biophys. Res. Commun. 66:1231-1236.

National Research Council. 1981. Nutrient Requirements of Goats : Angora, dairy and meat goats in temperate and tropical countries. National Academy Press, Washington, D. C.

Pressman, B. C. 1976. Biological applications of ionophores. Annu. Rev. Biochem. 45:501-530.

Reffett-Stabel, J., J. W. Spears, R. W. Harvey and D. M. Lucas. 1989. Salinomycin and lasalocid effects on growth rate, mineral metabolism and ruminal fermentation in steers. J. Anim. Sci. 67:2735-2742.

Schelling, G. T. 1984. Monensin mode of action in the rumen. J. Anim. Sci. 58:1518-1527.

Spears, J. W. 1990. Ionophores and nutrient digestion and absorption in ruminants. J. Nutr. 120:632-638.

Spears, J. W., J. C. Burns and G. W. Wolfrom. 1989a. Lysocellin effects on growth performance, ruminal fermentation, nutrient digestibility and nitrogen metabolism in steers fed forage diets. J. Anim. Sci. 67:547-556.

Spears, J. W., B. R. Schricker and J. C. Burns. 1989b. Influence of lysocellin and monensin on mineral metabolism of steers fed forage-based diets. J. Anim. Sci. 67:2140-2149.

Starnes, S. R., J. W. Spears, M. A. Froetschel and W. J. Croom, Jr. 1984. Influence of monensin and lasalocid on mineral metabolism and ruminal urease activity in steers. J. Nutr. 114:518-525.

Taussky, H. H. and E. Shorr. 1953. A microcolorimetric method for the determination of inorganic phosphorus. J. Biol. Chem. 202:675-685.