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I am submitting herewith a thesis written by Ken J. Goddard entitled "Evaluation of Systems for Delivering Rumensin to Cattle on Pasture." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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EVALUATION OF SYSTEMS FOR DELIVERING RUMENSIN TO CATTLE ON PASTURE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Ken J. Goddard

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ABSTRACT

Two trials, involving 40 yearling steers at the University of Tennessee Blount Farm and 60 yearling heifers at Ames Plantation were conducted to evaluate two methods of delivering monensin sodium (Rumensin) to cattle grazing pasture. Salt and a salt-cottonseed meal mixture, each containing 100 mg of Rumensin per oz, were fed free-choice and salt intake, Rumensin intake and animal performance were compared to that of cattle fed salt free-choice.

Average daily consumption of Rumensin was about 70 mg per animal per day in both trials when mixed with loose salt at the rate of 100 mg per oz. Average daily consumption was 111 mg per animal when suppled at the rate of 100 mg per oz of a salt-cottonseed meal mixture (1:1) at Ames Plantation. Average daily salt and Rumensin intake (calculated on a moisutre constant basis) varied from week to week and tended to increase as elapsed days of supplementation increased.

Increasing the Rumensin level in the carriers from 100 to 200 mg per oz during the latter periods of the trial increased ($P < .05$) Rumensin intake. However, salt consumption of cattle consuming the salt-cottonseed meal Rumensin mixture was decreased. Rate of gain was similar for the control animals and the Rumensin-supplemented animals in the Blount trial ($P > .05$). However, Rumensin supplemented animals increased in weight slower ($P < .05$) than the control animals at Ames Plantation.

Two questions with respect to efficacy of these two mixtures as delivery systems for Rumensin to cattle on pasture were identified

in this study. If variation of daily Rumensin intake inhibits the ability of Rumensin to change rumen VFA proportions, this addition of Rumensin to salt as a method of delivering Rumensin to cattle on pasture may not be satisfactory. Higher levels of cottonseed-meal may result in a more palatable mixture and increased Rumensin intake, but the effect of such mixtures on salt consumption needs study.

In this study, Rumensin intake using either of the two delivery systems (salt + Rumensin and salt + cottonseed meal + Rumensin) was within the effective dosage level (50 to 200 mg per animal per day). When the Rumensin content was increased to 200 mg per oz of carrier, average daily intake was within the range of the most efficient dosage level (100 to 200 mg per animal per day) which was observed when daily intake was controlled.

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CHAPTER I

INTRODUCTION

Previous work has shown that adding monensin sodium (Rumensin), a coccidiostatic compound, to rations of cattle in feedlots has resulted in increased efficiency, and that feeding Rumensin to steers on pasture has resulted in increased rate of gain. In most preliminary studies involving cattle grazing pasture, Rumensin has been delivered to the animals in a grain mixture, generally two pounds of corn, which has been fed daily. If maximum benefit is to be obtained for the growth promoting effect of Rumensin, other, more economical methods of delivering this additive to cattle on pasture is imperative. Magnesium oxide, trace minerals and other supplements which are required in small amounts have been incorporated in salt mixtures and these mixtures have generally been relatively satisfactory carriers. It is feasible that salt may be a satisfactory and economical carrier for Rumensin when supplied in either loose or block form. The objectives of these experiments were (1) to evaluate methods of delivering Rumensin to cattle grazing pasture and (2) to evaluate the effect of Rumensin on performance of yearling cattle grazing grass-clover pasture.

CHAPTER II

LITERATURE REVIEW

Several coccidiostatic compounds have been used in attempts to control bovine coccidiosis according to Fitzgerald (1970) and Pearden et al. (1965). Monensin, an antibiotic with anticoccidial properties (Bergstrom and Maki, 1974), has been found to be effective against Elmeria bovis infections of calves.

Monensin is a biologically active compound produced by Streptomyces Cinnamonensis and, according to Oliver (1975), has been observed to increase rumen propionic acid production in both in vitro and in vivo with high grain rations. This alteration of rumen fermentation increases the efficiency of conversion of dietary energy into carcass energy (Potter et al., 1974). The exact mechanism is not completely understood, but according to Wilson et al. (1975), this improvement has been associated with an increased molar percentage of propionic acid in the rumen and the consequent change in the form of energy available for metabolism by the animal. Raun (1975) suggested that by extensive microbial fermentation of ingested feed in the reticulorumen, plant energy sources (cellulose and starch) are degraded to simple sugars and volatile fatty acids which are absorbed and utilized by the ruminant tissues. He further suggested that when acetic or butyric acid is produced from the energy source or sugar, there is a loss of carbon dioxide and hydrogen. However, when propionic acid is produced from sugar, there is no loss of carbon dioxide and the hydrogen

produced in the formation of acetic acid is utilized. The net result is that over 100 percent (109.2 percent) of the energy of the sugar molecule is recovered when two propionic acid molecules are produced from one sugar molecule (Raun,1975).

Raun (1975), Potter et al. (1974), Brown et al. (1974), Raun et al. (1974), Embry and Swan (1974), and Wilson et al. (1975) suggested that the increased feed efficiency observed when monensin was added to feedlot rations was the result of modifying the rumen fermentation and that propionic acid comprised a larger proportion of the total volatile fatty acids than was found in control animals.

I. FEEDLOT EFFICACY OF MONENSIN

Results of several experiments evaluating the effect of monensin on feed efficiency and gain in cattle fed high energy rations have been reported. In general, rates of gain were about the same for monensin supplemented animals and non-supplemented controls except for slightly lower gains at the highest level of monensin. Feed intake was reduced with increasing levels of the compound. Feed efficiency was improved from 6 to 14 percent. Trials were conducted by Burroughs et al. (1975) to evaluate the effect of adding the monensin to rations of feedlot cattle. Steer calves were used in the first trial and yearling steers were used in the second trial. Three pens of six calves (weighing 340, 410 and 475 lbs, respectively) were full-fed a control diet containing 11.2 percent protein and 70 percent TDN. for 98 days. These similar pens of calves were fed the same diet to which monensin was added at the rate of 25 parts per million (ppm) on

a dry matter basis. The second trial was a 2 x 2 factorial design involving 12 pens of 580 lb yearling Angus steers with two levels of monensin (0 and 25 ppm) and two levels of diethylstilbestrol (DES) implants (0 and 30 mg per steer). A diet similar in composition to that fed to the calves was fed to all yearling steers for 98 days.

The results indicated that feeding monensin resulted in improved feeding value of a silage ration in both calves and yearling steers and in both DES implanted and non-implanted cattle. Live weight gains at 98 days were as great or slightly greater for monensin fed cattle than for the controls. Feed dry matter intake was somewhat less for cattle consuming monensin-fortified diets and the overall result was a 12 to 13 percent improvement in feed conversion. From these data the researchers concluded that monensin was fully as effective as DES in improving feed conversion. They reported that the benefits of both materials were additive and thus resulted in greater benefits than the use of either material alone.

In a winter trial, Perry et al. (1975) fed monensin to finishing beef cattle for 133 days. Twelve lots of six steers each averaging 595 lbs received a diet of limited corn silage (15 to 20 lbs per head daily), high moisture corn (1.5 to 2 percent body weight daily), and 2 lbs of a supplement. The design of the experiment was to compare two systems of administering monensin, factorialized over two hormone treatments. The results are summarized as follows:

1. Feeding monensin at a level of 30 gm per ton of air-dry feed resulted in a change in the volatile fatty acid (VFA) pattern in the rumen. Rumen samples taken at 56 days

showed that cattle fed monensin had nearly doubled in the proportion of rumen propionic acid (38.7 vs. 22.0 percent) as cattle fed a comparable diet without monensin. Acetic acid proportion was reduced slightly, and the butyric acid was reduced nearly 50 percent.

2. Implanting with DES had no effect on the rumen VFA proportions.

3. Monensin feeding resulted in a marked depression in appetite. Since corn silage level was held relatively constant, the depression in appetite was reflected in decreased corn intake.

4. Rate of gain averaged about 7 percent less for cattle fed monensin; but due to the decreased feed intake the efficiency of feed conversion favored monensin-fed cattle. Cattle fed monensin required from 23 to 27 percent less high-moisture corn per pound of gain than those not receiving the product.

5. Since levels of silage and supplement were held constant and the cattle fed monensin were gaining slightly less, efficiency of conversion of supplement and silage favored the control cattle. Monensin improved overall feed efficiency on a dry matter basis by 8.6 to 9.3 percent.

6. The monensin effect operated independently of the DES growth-stimulatory effect. A significant improvement in daily gain and feed efficiency was obtained by implanting the steers with 36 mg of DES.

The effectiveness of different levels of monensin on feedlot performance of finishing steers was studied also by Wilson et al. (1975). Average daily gain was increased at levels of 5, 10 and 20 gm of monensin per ton of feed, but was decreased at levels of 30 to 40 gm per ton. Feed consumption decreased as the level of monensin in the ration increased. The decrease in feed consumption was accompanied by similar or improved gains in weight and resulted in an improvement in feed efficiency at all levels of monensin supplementation.

Four experiments conducted by Farlin et al. (1975) also showed that as monensin level increased, feed intake consistently decreased. Addition of monensin to the ration resulted in a consistent improvement in feed efficiency except at the 40 gm level of supplementation.

The effect of monensin on rate of gain was not consistent. Lower levels on monensin did not reduce gains but higher levels of monensin resulted in reduced feed intake which reduced rate of gain. The slight reduction in gain was offset by the significant improvement in feed efficiency.

II. EFFICACY OF MONENSIN IN CATTLE GRAZING PASTURE

A review of the efficacy of monensin in cattle fed high-roughage rations indicated a significant ($P < .05$) increase in feed efficiency with no apparent changes in weight gains. Embry and Swan (1974) reported a linear increase in feed efficiency from 0, 10, 20 and 30 gm of monensin per ton of air-dry feed in steers fed a ratio of 75 percent roughage to 25 percent concentrates. Only small differences in rate of gain (2.48 to 2.53 lb daily) were observed. Ali et al. (1975) found

that rate of gain of steers fed alfalfa haylage increased from 2.61 to 2.87 lb per day and that of steers fed a soybean meal-cottonseed hull ration increased from 2.96 to 3.17 lb per head per day when monensin levels increased from 0 to 30 gm per ton of dry matter. Similar results were reported by Hale et al. (1975).

These responses in feed efficiency of cattle fed high-roughage rations prompted investigations of the effect of monensin on the performance of cattle grazing pasture. In all studies reported to date, monensin has been added to grain or protein supplements and fed daily to cattle grazing pasture.

Three experiments were conducted by Potter et al. (1974) to determine the effect of monensin on daily gain of cattle on pasture. These experiments characterized the ruminal volatile fatty acid ratio and live weight gain responses of pasture cattle fed various dose levels of monensin. In experiment 1, six fistulated heifers were fed 907 gm of a concentrate ration at 8:00 A.M. and were then allowed to graze on mixed grass-legume pasture. After the cattle adjusted to this regime, two heifers were fed 50 mg of monensin daily with their ration, two received 200 mg and two served as controls. Experiment 2 involved 112 mixed Braham, Angus and Charolais cross cattle (steers and heifers). These cattle were allowed to graze pasture continuously and were fed 907 gm of a concentrate ration daily. The cattle were allotted according to weight and sex to four monensin treatments (0, 100, 200, 400 mg/animal/day monensin). Experiment 3 involved 120 Angus steers. This experiment continued for 168 days and was conducted the year following that in which Experiment 2 was conducted. The same

pastures and experimental procedures used in Experiment 2 were used with the following changes: monensin treatments were 0, 50, 100 and 200 mg/day. The cattle were rotated between pastures every 14 days; rumen samples for volatile fatty acid determinations were taken from all animals at the end of the experiment.

Results of these experiments with fistulated steers and growing cattle on pasture indicate that monensin increased the production of propionic acid in the ruminal fermentation of cattle and that feeding cattle 100 or 200 mg of monensin per day significantly ($P < .01$) increases rate of gain.

Anthony et al. (1975) fed monensin to yearling cattle grazing warm season perennial grasses. Yearling Hereford and Hereford x Angus steers were allotted into 12 groups of 10 animals each. The grazing area was two pastures of approximately 30 acres each established to coastal bermuda-grass. Each day during the experiment, all animals were driven into a corral, separated into individual feeding pens and fed 454 gm of cottonseed meal (CSM) or CSM to which monensin was added. Group I received no supplement (CSM or monensin). Group II received only CSM. Group III through VI received CSM with 25, 50 100 or 200 mg of monensin per 454 gm, respectively. The average daily gains for the 112 day experiment were 63. 65, 76, 69 and 70 kg for Groups I through VI, respectively. Difference among these treatment means with respect to rate of gain were not significant ($P > .05$). Also, there were no significant ($P > .05$) differences among treatment means at each of the four 28-day intervals. However, it was observed that feeding CSM, either singly or in combination with monensin,

resulted in slightly higher ($P < .05$) gains. A similar grazing trial was conducted by Oliver (1975) using steer calves and yearling steers grazing coastal bermudagrass. Ground pelleted corn fed at a rate of 908 gm/head daily was used as a carrier for the appropriate monensin levels. Cattle on all treatments grazed coastal bermudagrass at a stocking rate of 2.5 animals. The cattle were rotated among pastures at 7-day intervals. Treatments included: forage only (F), corn only (C), corn plus 25 mg monensin per head daily (C 25), corn plus 50 mg (C 50), corn plus 100 mg (C 100) and corn plus 200 mg (C 200). The total gains during the 140 day trial were 112.0 and 72.2 kg for the yearlings and calves, respectively. Treatment gains were 64.5 kg (F), 79.1 kg (C), 98.4 kg (C 25), 102.3 kg (C 50), 109.2 kg (C 100), 99.2 kg (C 200). In this trial, cattle fed monensin made significantly greater gains ($P < .05$) than either control groups. The age x treatment interaction was not significant.

III. METHOD OF DELIVERING SMALL QUANTITIES OF SUPPLEMENTS TO CATTLE GRAZING PASTURE

Supplementation of cattle grazing pasture with grain or protein supplements which serve as carriers for the desired monensin supplement is often undesirable and probably not an economical practice. Several reports have indicated that small amounts of various additives have been successfully delivered to cattle on pasture in salt, mineral blocks or other feed ingredients normally consumed by grazing cattle.

A mixture of various combinations of cottonseed meal, salt and dry molasses were used by McLaren et al. (1975), Horvath (1967) and

Murdock et al. (1975) as a carrier from various magnesium supplements for grazing cattle. In addition, satisfactory consumption of magnesium resulted when magnesium chloride was added to liquid molasses by McLaren et al. (1975).

CHAPTER III

EXPERIMENTAL PROCEDURE

Forty Angus steers purchased at feeder calf sales in East Tennessee were used at Blount Farm, and 60 Angus heifers raised in the Ames Plantation herd were used to evaluate two methods of delivering monensin sodium (Rumensin).

I. BLOUNT FARM

Four pasture groups of five compact steers (graded "x" in feeder calf sales) and four groups of five rangy steers (graded good in feeder calf sales) grazing fescue-clover pastures were available for this study. Two treatments (control with access to plain salt and a treated group with access to a mixture of salt plus 100 mg of Rumensin per oz) were included in pasture study resulting in a 2 x 2 factorial design.

Tester steers (450-550 lb) were randomly assigned to four groups of five animals each, within kind of cattle, and each group was randomly assigned to a pasture. Two groups within each kind of cattle were assigned to each Rumensin treatment. The steers grazed the respective fescue-clover pastures during the spring-summer grazing season without supplemental feed. "Put and Take" animals were added when the average pasture height of a pasture reached three inches, and they were removed when the average height of that pasture was reduced to two inches.

Salt and the salt-Rumensin mixture was fed in plastic pans inside of existing small shelters. Salt (mixture) remaining in the pans was weighed at approximately weekly intervals, and consumption was calculated on this basis. Animals were weighed at frequent intervals.

II. AMES PLANTATION

Sixty Angus heifers, weighing 450 to 575 lb, were allotted to six groups of 10 heifers each. The groups were randomly assigned to receive one of the treatments described in Table 1. Rumensin analyses are presented in Table 2. Salt-Rumensin consumption was calculated on a weekly basis, and the heifers were weighed at weekly intervals. Due to extreme variation in intake during the first period, this period was considered as an adjustment, and consumption was not included in the overall analysis.

Three of the pastures at Ames Plantation consisted primarily of a fescue and ladino clover mixture, and the other three were a mixture of common bermudagrass and ladino clover. Each of the three treatments were included in both pasture types. An abundance of high quality forage existed in each pasture throughout the season, and the groups were not rotated among pastures. Chemical analysis of pasture forage samples presented in Table 3 indicate pasture quality.

Conventional salt boxes were constructed to hold a rubber feed pan to facilitate weight of the mixtures and to minimize waste.

In both trials a sample of the salt weigh-back at the end of each period was oven-dried and allowed to equilibrate at room

TABLE 1

DESIGN OF EXPERIMENT

Treatment Number	Ames Plantation		Blount Farm		Description
	No. of animals	No. of pastures	No. of animals	No. of pastures	
1	20	2	20	4	Control no additives
2	20	2	20	4	100 mg of Rumensin per oz of salt
3	20	2			100 mg of Rumensin per oz of a salt cotton-seed meal mixture.

TABLE 2

RUMENSIN ASSAYS

Sample Number	Location[a]	Material[b]	Date Sampled	Intended Level g/t	Assay Results g/t	% of Theoretical Level
1	A & B	S	5/20	0	0	
2	B	S + R	5/20	3074	2685	87
3	B	S + R	5/20	3074	3611	117
4	A	S + R	6/8	3074	2974	97
5	A	S + C + R	6/30	3074	2656	86
6	A	S + C + R	7/24	3074	3280	107
7	A	S + R	8/20	6148	3710	60
8	A	S + R	8/20	6148	2730	44
9	B	S + R	8/20	6148	4364	71

[a]A = Ames Plantation. B = Blount Farm.

[b]S = Salt. C = Cottonseed meal. R = Rumensin.

TABLE 3

CHEMICAL ANALYSES OF PASTURE FORAGE[1]

	Treatment					
	1 Pasture		2 Pasture		3 Pasture	
	3	4	1	5	2	6
	%					
JUNE						
Crude protein	17.47	16.23	17.36	18.53	13.40	16.76
Crude fiber	26.59	23.87	25.09	25.65	31.90	26.12
Ash	9.88	8.33	7.28	10.54	8.83	9.26
Dry matter	87.99	88.60	87.99	87.31	88.40	87.77
JULY						
Crude protein	17.65	15.22	14.83	18.17	15.29	17.82
Crude fiber	25.30	28.13	25.61	27.13	30.31	27.18
Ash	13.70	9.63	7.31	11.53	7.75	8.80
Dry matter	90.11	89.37	89.84	88.44	89.28	88.91
AUGUST						
Crude protein	14.51	14.67	11.62	16.85	12.53	26.66
Crude fiber	26.21	27.75	26.08	26.58	27.36	26.66
Ash	8.39	9.25	7.62	11.62	7.97	10.18
Dry matter	84.47	87.59	86.27	85.31	85.25	84.93

[1]Grab samples were randomly collected through each pasture.

temperature. Salt (mixture) intake was calculated on a constant moisture content basis.

Statistical analyses were done according to methods described by Snedecor (1959), and separation was done by multiple range procedures.

CHAPTER IV

RESULTS AND DISCUSSION

I. CONSUMPTION OF RUMENSIN

Average daily consumption of monensin sodium (Rumensin) was about 70 mg per animal per day, in both the Ames Plantation and Blount trials, when mixed with loose salt at the rate of 100 mg Rumensin per oz (Tables 4 and 5). This level of consumption is within the suggested effective dosage range of Rumensin for grazing cattle (50 to 200 mg per animal per day). However, the greatest efficiency was observed at consumption levels of 100 to 200 mg of Rumensin per day (Anthony et al., 1975; Oliver, 1975; Potter et al., 1975). Average daily Rumensin consumption was 111 mg per animal per day when supplied at the rate of 100 mg per oz of a salt-cottonseed meal mixture (1:1) at Ames Plantation. This level of consumption was within the range of maximum efficacy reported by Anthony et al. (1975), Oliver (1975), and Potter et al. (1975). However, in the trials reported by these authors, Rumensin was delivered in either ground shelled corn or oil meals which were fed daily. Their method of delivering Rumensin to cattle on pasture resulted in uniform daily consumption of Rumensin similar to that of cattle in feedlots where Rumensin was incorporated in the total ration.

In previous pasture studies it has been assumed that uniform daily consumption of Rumensin is necessary for maximum efficiency. Average daily Rumensin intake in both the Ames Plantation and Blount

TABLE 4

EFFECTS OF ADDING 3400 PPM (100 MG) RUMENSIN TO SALT FED STEERS GRAZING PASTURE AT BLOUNT FARM, 1975

	Treatment	
	Salt	Salt & Monensin
Total Number of Steers	20	20
Average Weights & Gains (lbs)		
Initial wt (5/22/75)	664	682
Final wt (9/2/75)	758	766
Total gain	94[a]	84[a]
Daily gain	0.91[a]	0.82[a]
Average Salt & Rumensin Consumption		
Salt (oz per animal per day)	0.97[a]	0.65[b]
Rumensin (mg per animal per day)		70.0

[a,b]Means in the same row with different superscripts are significantly different ($P < .05$).

TABLE 5

EVALUATION OF METHODS OF DELIVERING RUMENSIN TO HEIFERS GRAZING PASTURE AT AMES PLANTATION, 1975

	Treatment		
	Salt	Salt & Rumensin	Salt & Rumensin plus cottonseed meal
Number of Heifers	20	20	20
Average Weights & Gains (lbs)			
Initial wt (6/16/75)	525	518	518
Final wt (9/8/75)	666	630	644
Total gain/head (84 days)	141[a]	120[b]	120[b]
Daily gain/head	1.64[a]	1.39[b]	1.39[b]
Average Salt & Rumensin Consumption[1]			
Mixture (oz per animal per day)	.70[a]	.64[a]	.98[b]
Salt (oz per animal per day)	.70[a]	.64[a]	.49[b]
Rumensin (mg per animal per day)		73.0[a]	111.0[b]

[1]Rumensin was added to the salt and salt-cottonseed meal mixture at the rate of 100 mg per oz of mixture.

[a,b]Means in the same row with different superscripts are significantly different ($P < .05$).

Farm trials varied from week to week (Tables 6 and 7). At times, the peaks and valleys in consumption were severe, and this erratic consumption could possibly be suspected of contributing to the reduced efficacy of Rumensin. An example of this fluctuation in consumption resulted in the Ames trial where one group of heifers (Pasture 2) consumed less than 50 mg per animal per day during one week and later in the season the average daily consumption by the same group was 240 mg per animal per day (Appendix Table 11). Similar consumption patterns were observed at Blount Farm.

The Rumensin level was increased from 100 to 200 mg per oz of mixture during the last period (8 days) for two of the four groups fed salt plus Rumensin at Blount Farm, and during the last two periods (19 days) Rumensin was increased at the same rate in one of the two pasture groups fed salt plus Rumensin and salt-cottonseed meal plus Rumensin at Ames Plantation. Increasing the concentration of Rumensin from 100 to 200 mg per oz of salt resulted in an increased Rumensin intake (111 vs. 172 mg/animal per day for the 100 and 200 mg per oz levels, respectively). Similar increases in Rumensin intake were observed when the concentration of Rumensin in the mixtures was increased. Intake of Rumensin was 77 and 150 mg per animal per day for groups fed salt containing 100 and 200 mg of Rumensin, respectively (Appendix Table 11). The increased intake was greater (127 vs. 213 mg per animal per day) when the Rumensin content of the salt-cottonseed meal mixture was increased from 100 to 200 mg per oz of mixture. Although the mixtures containing 200 mg of Rumensin per oz was only fed for a 19-day period, the result suggested that higher concentrations

TABLE 6

CONSUMPTION BY PERIODS AT AMES PLANTATION

	Period[a]								
	1	2	3	4	5	6	7	8	Total
Days per period	6	10	14	9	11	7	7	12	76
Total consumption of mixture,[b] oz/animal									
Tmt. 1	7	66	104	100	82	52	57	83	749
Tmt. 2	21	48	84	114	89	20	36[b]	62[b]	489
Tmt. 3	62	45	151	110	93	60	97[b]	132[b]	549
Salt consumption, oz/animal/day									
Tmt. 1	.11[c]	.66[d]	.75[ed]	1.10[f]	.75[ed]	.74[ed]	.81[e]	.69[d]	.70
Tmt. 2	.35[c]	.48[d]	.61[de]	.77[e]	.76[e]	.58[d]	.66[e]	.86[f]	.64
Tmt. 3	.52[de]	.23[c]	.54[e]	..75[f]	..43[de]	..45[d]	. .69[f]	. .48[d]	. .49
Rumensin consumption, mg/animal/day									
Tmt. 2	35[f]	48[f]	61[e]	77[g]	76[g]	58[f]	99[e]	128[d]	73
Tmt. 3	104[e]	45[g]	108[e]	150[d]	85[f]	85[f]	199[c]	142[d]	111
Mean daily maximum temperature, F	91	92	89	86	87	91	91	90	
Mean daily precipitation, in	.06	.06	.16	.16	.12	.17	0	.14	

[a]Experiment started 6/24/75 and ended 9/8/75. Values are means for 2 pastures.

[b]Rumensin was increased to 200 mg per oz in one pasture within Treatments 2 and 3.

[c,d,e,f,g]Means in the same row superscripted with the same letter are significantly different ($P < .05$).

TABLE 7

CONSUMPTION BY PERIODS AT BLOUNT FARM

	Period[a]									
	1	2	3	4	0 5	6	7	8	9	Total
Days per period	4	10	11	10	14	17	7	11	8	92
Total consumption of mixture,[b] oz/animal										
Tmt. 1	17	50	43	41	53	54	81	73	65	517
Tmt. 2	11	25	17	29	34	35	67	55	45[b]	337
Salt consumption, oz/animal/day										
Tmt. 1	.83[e]	1.01[d]	.78[e]	.81[e]	.76[e]	.64	1.15[d]	1.33[c]	1.45[c]	.97
Tmt. 2	.63[d]	.51[d]	.30[f]	.58[d]	.49[e]	.41[e]	.95[c]	1.00[c]	.99[c]	.65
Rumensin consumption, mg/animal/day										
Tmt. 2	63[f]	51[g]	30[h]	58[g]	49[g]	41	95[e]	100[e]	142[d]	70

[a]Experiment started 6/2/75 and ended 9/2/75. Values are means for 4 pastures.

[b]Rumensin was increased to 200 mg per oz in two of the four pastures in Treatment 2.

[c,d,e,f,g,h]Means in the same row superscripted with different letter are significantly different ($P < .05$).

of Rumensin in the delivery mixtures may result in increased intake of Rumensin.

Two questions need to be answered with respect to intake of Rumensin by cattle on pasture. Does variation in daily intake of Rumensin affect the efficacy of Rumensin on volatile fatty acid ratios? The second question concerns the effect of increased Rumensin concentration on salt consumption when salt is the major constituent of the mixture used as a carrier for Rumensin.

II. EFFECT OF RUMENSIN ON SALT CONSUMPTION

The addition of Rumensin to salt at the rate of 100 mg per oz significantly ($P < .05$) reduced salt consumption in the Blount Farm Trial (0.97 vs. 0.65 oz per head per day for salt alone and salt plus Rumensin, respectively). However, this reduction in salt consumption (0.70 vs. 0.64 oz per head per day) was not observed in the Ames Plantation trial. A significant reduction in salt consumption was observed between the groups consuming non-supplemented salt (0.70 oz per animal per day) and the groups consuming a mixture of salt and cottonseed meal supplemented with 100 mg of Rumensin per oz (.49 oz per animal per day). According to the National Research Council (NRC, 1970), the requirements for sodium and chlorine appear to by amply met by including 0.25 percent salt in the ration dry matter. They also suggest that growing heifers weighing 550 to 650 lb and gaining 1.65 lb per animal per day need 17 to 19 lb of dry matter per animal per day. Based on these assumptions the heifers in the Ames Plantation trial required between 0.65 and 0.80 oz of salt per day.

The addition of 100 mg of Rumensin per oz to the loose salt consumed by the heifers reduced salt intake slightly, but consumption was within the range of estimated requirements (Table 4). Salt intake of fed salt-cottonseed meal and Rumensin mixture free choice was slightly below the theoritical calculated requirements. Research results are not available to determine the effect of this reduced intake on animal performance.

III. FACTORS AFFECTING RUMENSIN INTAKE

Based on results obtained during the last 19 days of these trials, Rumensin intake increased when the concentration of Rumensin in the carriers was increased from 100 to 200 mg per oz of carrier. It appears that Rumensin intake can be increased by adding a palatable feed ingredient, such as cottonseed meal, to salt as a means for delivering Rumensin to cattle on pasture. Results of this study suggest that a higher proportion of cottonseed meal (more than 50 percent) could result in a more palatable mixture, and Rumensin intake may be increased. However, in this study the only source of salt was in the mixture consisting of salt-cottonseed meal and Rumensin and, if a higher proportion of cottonseed meal was added, salt intake should be monitered to ascertain whether intake below minimum requirements resulted.

When Rumensin is delivered to cattle in a mixture in which salt is the basic ingredient, Rumensin intake is influenced by factors which influence salt intake. In this study mean daily maximum temperature at Ames Plantation fluctuated from 87° F to 92° F, and mean daily

precipitation varied from 0 to 0.17 (Table 6). Study of the salt intake, mean maximum daily temperature and mean daily rainfall by periods suggested a relationship among these variables. However, the number of observations were too few for any conclusions.

Intake of the total mixtures of salt and Rumensin tended to increase as the number of elapsed days increased in both trials (Tables 6 and 7). Rumensin intake was significantly ($P < .05$) greater during the last four periods than during the first two periods. This is similar to results reported by Raun et al. (1974), Brown et al. (1974) and Embry and Swan (1974). They observed increased intake as elapsed days on feed increased.

IV. EFFECT OF RUMENSIN ON ANIMAL PERFORMANCE

Body weight gains of non-supplemented control steers and those supplemented with Rumensin (100 mg per oz of salt) were similar ($P > .05$) in the Blount Farm trial (Table 4 and Appendix Table 8). However, the heifers supplemented with Rumensin in the Ames trial (salt + Rumensin and salt-cottonseed meal + Rumensin) gained significantly slower ($P < .01$) than the control heifers (Tables 5 and 7). These results do not agree with those reported by Anthony et al. (1975), Oliver (1975) and Potter et al. (1975). In each of these trials, cattle fed 100 to 200 mg of Rumensin per animal per day gained significantly faster than the control animals. However, the differences in results are probably due to lower Rumensin intake by animals in these trials. Other possible explanations for these differences in results may also be due to lower salt consumption or lower forage intake if salt intake influences forage intake as suggested by NRC (1970).

CHAPTER V

SUMMARY

Two trials, involving 40 yearling steers at the University of Tennessee Blount Farm and 60 yearling heifers at Ames Plantation were conducted to evaluate two methods of delivering monensin sodium (Rumensin) to cattle grazing pasture. Salt and a salt-cottonseed meal mixture, each containing 100 mg of Rumensin per oz, were fed free-choice and salt intake, Rumensin intake and animal performance were compared to that of cattle fed salt free-choice.

Average daily consumption of Rumensin was about 70 mg per animal per day in both trials when mixed with loose salt at the rate of 100 mg per oz. Average daily consumption was 111 mg per animal when supplied at the rate of 100 mg per oz of a salt-cottonseed meal mixture (1:1) at Ames Plantation. Average daily salt and Rumensin intake calculated on a moisture constant basis varied from week to week and tended to increase as elapsed days of supplementation increased.

Increasing the Rumensin level in the carriers from 100 to 200 mg per oz during the latter periods of the trial increased ($P < .05$) Rumensin intake. However, salt consumption of cattle consuming the salt-cottonseed meal Rumensin mixture was decreased. Rate of gain was similar for the control animals and the Rumensin-supplemented animals in the Blount trial ($P > .05$). However, Rumensin supplemented animals increased in weight slower ($P < .05$) than the control animals at Ames Plantation.

Two questions with respect to efficacy of these two mixtures as delivery systems for Rumensin to cattle on pasture were identified in this study. If variation of daily Rumensin intake inhibits the ability of Rumensin to change rumen VFA proportions, this addition of Rumensin to salt as a method of delivering Rumensin to cattle on pasture may not be satisfactory. Higher levels of cottonseed-meal may result in a more palatable mixture and increased Rumensin intake, but the effect of such mixtures on salt consumption needs study.

In this study, Rumensin intake using either of the two delivery systems (salt + Rumensin and salt + cottonseed meal + Rumensin) was within the effective dosage level (50 to 200 mg per animal per day). When the Rumensin content was increased to 200 mg per oz of carrier, average daily intake was within the range of the most efficient dosage level (100 to 200 mg per animal per day) which was observed when daily intake was controlled.

LITERATURE CITED

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Ali, A., V. Lopez, D. L. Hixon, E. E. Hatfield and A. L. Neumann. 1975. The effectiveness of different levels of monensin on the feedlot performance of finishing steers. Experiment 2 (R-178) Progress Report (167 days). Illinois Beef Cattle Report.

Anthony, W. B., V. L. Brown and R. R. Harris. 1975. Monensin effect on weight gain of grazed cattle. (Abstract) J. An. Sci. 40:140.

Bergstrom, R. C., L. R. Maki. 1974. Effect of monensin in young crossbred lambs with naturally occurring coccidiosis. J. A. V. M. A., Vol. 165 No. 3.

Brown, H., L. H. Carroll, N. G. Elliston, H. P. Grueter, J. W. McAskill, R. D. Olson and R. P. Rathmacher. 1974. Field evaluation of monensin for improving feed efficiency in feedlot cattle. Proceedings, Western Section, American Society of Animal Science, Vol. 25:300.

Burroughs, W. A. Trenkle and R. L. Vetter. 1975. Two feeding trials testing the value of a new feed additive (RUMENSIN) in cattle feed-lot rations. Iowa State University A. S. R206.

Embry, L. B. and W. S. Swan. Effects of monensin of feedlot performance of growing and finishing steers. South Dakota State University, A. S. Series 74-5:19.

Farlin, S. D., D. C. Clanton, J. D. Heldt. 1975. A new feed additive for beef cattle. Nebraska Beef Cattle Report.

Fitzgerald, P. R. 1970. Chemotherapy of coccidiostats in ruminants. J Parasitol, 56:101.

Hale, W. H., Brent Theurer, J. A. Marchello, Bruce Taylor and John Kuhn. 1975. The effect of monensin on growing and finishing cattle. Arizona Cattle Feeders Day, Series P-36.

Horvath, D. J. 1967. Tetany prevention with supplemented magnesium. Feedstuffs 39:52.

McLaren, J. B. 1976. Unpublished data.

Murdock, L. W., C. W. Absher, N. Gay and J. A. Boling. 1975. Beef: Grass tetany in beef cattle. Univ. of Ky. ASC 16.

NRC. 1970. Nutrient Requirements of Beef Cattle. 4th ed. National Academy of Science, Washington, D.C.

Oliver, W. M. 1975. Effect of Rumensin on grain of steers grazed on coastal bermudagrass. (Abstract) J. An. Sci. 40:190.

Peardon, D. L., F. R. Bilkovich, A. C. Todd. 1965. Trials of candidate bovine coccidiostats: Efficiency of amprolium, lincomycin, sulfamethazine, chloroquine sulfate, and di-phenthane-70. Am J Vet Res, 26:683-687.

Perry, T. W., W. M. Beeson and M. T. Mohler. 1975. Effect of RUMENSIN on beef cattle performance. Purdue Cattle Feeders Day, pp 29-33.

Potter, E. L., C. O. Cooley, A. P. Raun, L. F. Richardson and R. P. Rathmacher. 1974. Effect of monensin on daily gain of cattle on pasture. Proceedings, Western Section, American Society of Animal Science, Vol. 25:343.

Raun, A. P., C. O. Cooley, E. L. Potter, L. F. Richardson, R. P. Rathmacher and R. W. Kennedy. 1974. Effect of monensin on feed efficiency of cattle. J. An. Sci. 39:250.

Raun, A. P. 1975. New method of improving the efficiency of cattle on various types of rations. Proceedings of Oklahoma 11th Annual Cattle Feeder Seminar.

APPENDIX

TABLE 8

ANALYSIS OF VARIANCE OF CATTLE PERFORMANCE

Source	Ames		Blount	
	df	MS(gain)	df	MS(gain)
Treatment	2	3264**	1	2873
Type of cattle			1	9272**
Treatment x type			1	43
Pastures/treatment	3	479	4	1003
Animals/pastures	54	631	32	1081

**P < .01

TABLE 9

ANALYSIS OF VARIANCE OF CATTLE INTAKE
(AMES PLANTATION)

Source	df	Mean Squares		
		Total Mixture	Salt	Rumensin
Treatment	2	0.532**	0.211**	5314
Period	7	0.257**	0.155**	2167
Treatment x period	14	0.078	0.048	779
Error	24	0.028	0.023	275

**P < .01

TABLE 10

ANALYSIS OF VARIANCE OF CATTLE INTAKE
(BLOUNT FARM)

Source	df	Mean Squares	
		Total mixture or salt	Rumensin
Treatment	1	1.875**	18753**
Period	8	0.633**	5601**
Treatment x period	8	0.032	318
Error	54	0.108	1082

**P < .01

TABLE 11

AVERAGE DAILY RUMENSIN INTAKE BY PERIOD[a] AND PASTURE (MG/ANIMAL/DAY)

Pasture No.	Tmt. No.	1	2	3	4	5	6	7	8	9	Total
Ames Plantation											
No. of days		6	10	14	9	11	7	7	12		76
2	3	106	42	111	139	74	81	240[b]	186[b]		122
3	2	55	57	52	73	100	63	132[b]	168[b]		88
4	3	102	48	105	110	95	89	157	97		100
6	2	15	38	69	80	51	53	66	88		58
Blount Farm											
No. of days		4	10	11	10	14	17	7	11	8	92
3	2	79	69	12	43	90	24	118	120	190[b]	85
4	2	83	62	17	46	21	34	100	85	154[b]	67
7	2	25	70	38	60	45	75	111	84	138	72
8	2	65	0	44	82	40	30	52	109	84	56

[a]The Ames Plantation trial started 6/24/75 and ended 9/8/75. The Blount Farm trial started 6/2/75 and ended 9/2/75.

[b]Rumensin level was increased to 200 mg per oz of carrier during these periods.

VITA

Ken J. Goddard was born August 26, 1948 in Fayette County, Tennessee. He received his elementary education at Grand Junction, and in 1966 graduated from Fayette County High School, Somerville, Tennessee.

In August, 1966 he entered the University of Tennessee, Knoxville, in the College of Agriculture and received his Bachelor of Science degree in Agricultural Economics in June, 1970. While attending the University, Mr. Goddard was a member of Alpha Gamma Rho Fraternity and served as House Manager, Historian, and Secretary for that organization. As a Senior, he received the Man of the Year Award, which is presented to an outstanding Senior annually by Alpha Gamma Rho.

He was also a member of the Agricultural Economics and Business Club and the Block and Bridle Club serving on the Executive Council in both organizations. He received the Sophomore Merit Scholarship Award and Senior Scholarship Award while serving in the Block and Bridle Club and was Co-Chairman of Ag Round-Up in 1969.

Following graduation, he was employed by the University of Tennessee Agricultural Extension Service and is presently working in Hardeman County. Mr. Goddard enrolled in the University of Tennessee Graduate School in 1973 and in March, 1976 received the Master of Science degree majoring in Animal Science.