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Title: The Effect of Monensin on Efficiency and Production of a Brood Cow Herd

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Ninety-six mature pregnant Hereford cows were allotted to three replications with four treatments. Pregnancy was determined by rectal palpation prior to the initiation of the study. The cows were artificially inseminated the previous spring, beginning the end of May, over a period of 42 days to a single Angus sire. Hereford cleanup bulls followed for 21 days.

The cows were stratified by breeding date, weight, condition score and the previous year's adjusted weaning weights and randomly assigned to treatments. Replications were by calving date.

Monensin treatments consisted of 0, 50, 200 and 300 mg/hd/day and was provided in ground barley. Controls received .45 kg of barley/head/day with the monensin treatments receiving their doses in like amounts of barley.

The basic feed was native meadow hay containing 9.5% crude protein. Hay was weighed in daily and refusals out weekly. Throughout the study hay was adjusted to maintain equal weight gain or loss between treatments.

Initially the control cows were fed hay free choice and consumed 13.4 kg/head/day. The initial monensin treatment levels were 95% of the control's diet for the 50 mg level and 90% each for the 200 and 300 mg groups. Hay consumption for the entire confinement period was 92, 89 and 90% of the control group's diet for the 50, 200 and 300 mg groups respectively.

Rumen samples were taken twice during the study, once prior to calving and another postpartum. An esophageal hose connected to a vacuum pump was utilized on four cows per pen for a total of 48 samples. On the morning samples were taken the cows were fed at one-half hour intervals to allow ample time for sampling. All cows were sampled three to four hours after supplemental feeding. Volatile fatty acid concentration results show rumen acetic acid production was reduced and propionic increased with the 200 and 300 mg levels.

Cow weights were obtained every 28 days prior to calving and were used to adjust hay intake. Cows and calves were also weighed 24 hours postpartum, treatment termination and weaning.

Initial cow weights for the control, 50, 200 and 300 mg treatments were 455, 447, 456 and 457 kg, respectively, with prepartum gains of .34, .38, .38 and .37 kg. Weight loss during the calving and postpartum periods were similar with the exception of the 300 mg group, which lost more weight.

At or near time of calving cows were removed from their pens and taken to a calving shed. Hay fed was adjusted accordingly so the cows remaining in the pens received the proper level. Cows that lost calves or had health problems were eliminated from subsequent data.

One cow that lost a calf at birth was grafted another.

Treatments were terminated about 30 days after calving due to a lead poisoning problem brought about by the calves chewing on boards which were coated with a paint containing lead. At this time the cows were turned out on pasture.

Adjusted weaning weights for the calves were 124, 134, 129 and 133 kg respectively for the control, 50, 200 and 300 mg groups, with calves being weaned at 139 days of age. Average daily gains from calving to treatment termination and from treatment termination to weaning were similar for all treatments.

First estrus postpartum was detected by utilizing nine vasectomized bulls with chin ball markers along with visual observation. Breeding was the same as previously described. Pregnancy was determined in mid-October by rectal palpation and fetal age was estimated by breeding records and palpation results. Control cows came into estrus an average of 44 days as compared to 44, 41 and 45 days for the 50, 200 and 300 mg treatments. Conception rates were 84, 91, 100 and 86% for the control, 50, 200 and 300 mg groups respectively.

Results indicate cows can be wintered on hay with a reduction of approximately 11% hay intake, fed with 200 mg of monensin per head per day, and still maintain a productive condition. Reproductive performance was not reduced with monensin use.

The Effect of Monensin on Efficiency and Production of a Brood Cow Herd

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

THE EFFECT OF MONENSIN ON EFFICIENCY AND PRODUCTION OF A BROOD COW HERD

INTRODUCTION

Cattle producers today face an ever increasing challenge in the world of agriculture. A number of factors such as fluctuating markets and internal problems find cattlemen in a difficult situation. By attempting to keep overhead down yet produce a marketable animal in a relatively short period has resulted in a demand for increased efficiency.

In the area of ruminant nutrition much research has resulted in new products and methods to improve feed efficiency. Feed additives, growth promotants such as implants and antibiotics are readily available to the cattle producer. Many of these products require withdrawal periods prior to slaughter for protection of the consumer.

Recently a new product called monensin, trade name Rumensin, has been introduced by Eli Lilly and Company. It is orally administered and affects the rumen, altering microbial production of the volatile fatty acids, the principle energy source for the ruminant animal. More propionic acid is produced while acetic and butyric acids are decreased (Perry *et al.*, 1976; Dinius and Simpson, 1975). This results in increased feed efficiency as propionic acid is more efficient in its conversion to a useable energy source than acetic or butyric acids (Hungate, 1966).

Monensin was originally used as an anti-coccidial in poultry and recently its effectiveness in beef production was realized. Since it gained Food and Drug Administration (FDA) approval it has gained much recognition and use in the feedlot industry. One advantageous use for monensin might lie in the area of cow-calf production where it has been calculated that 65% of the total, including cow and calf, feed nutrients are required to get a calf to weaning age (Gregory, 1972). With savings up to 10% as a result of monensin use the potential is considerable, particularly since monensin can be used in combination with other products such as implants. With an additive effect of monensin and implants, efficiency may be increased by as much as 20% overall.

The objectives of this study were to determine optimum levels of monensin and whether the increased efficiency due to monensin would allow cows to be wintered on less hay. Cow reproduction and calf performance were also evaluated as to the effects monensin might have on them.

At the time of this writing monensin had not yet been approved for cow-calf operations by the FDA. This study hopefully will add needed data for its approval.

II. REVIEW OF LITERATURE

A. Physical and Chemical Properties of Monensin

Monensin Sodium, trade name Rumensin, is a feed additive produced by Eli Lilly and Company (Elanco). It is an antibiotic produced by the bacterial strain *Streptomyces cinnamonensis* (Haney and Hoehn, 1967). The empirical formula is $C_{36}H_{61}O_{11}Na$, with a molecular weight of 692.

During manufacturing monensin is exposed to sodium ions resulting in monensin sodium, the active ingredient in the Rumensin Premix, the marketable product. The color of monensin is blackish to light brown or speckled tan meal (Rumensin Tech Manual, 1975).

Monensin is used as an anticoccidial in poultry but during the last few years its potential as a possible feed additive for ruminants was realized.

B. Energy-Volatile Fatty Acid Production and Function

The ruminant is at a great advantage over many other animals due to its ability to utilize roughage containing plant fiber and cellulose. Millions of microbes work on the ingested feed which results in a number of products, some of which are the volatile fatty acids. These are the principle waste products of microbial action and represent about 50% of the ruminant animals energy source. The main energy source for the bacteria comes from carbohydrates which are fermented and chemically altered by the microbes. The fermentation consists of a rearrangement of the atoms of the carbohydrate molecule in which some carbon atoms are futher oxidized and others further reduced. The nature of each microbe determines pathways and the products formed (Hungate, 1966).

The conversion of the main VFA's, these being acetic, propionic and butyric acids, to useable energy is complex and the concentrations of each VFA is dependant on the type of feed consumed. In trials where a large amount of roughage is consumed, VFA distribution is about 70% acetic, 20% propionic and 10% butyric acids. As the concentrate level of the diet increases the proportions of propionic acid also increase while acetic and butyric acids decrease. This results in values of about 50, 40 and 10% of acetic, propionic and butyric acids, respectively.

The energy from the VFA's is brought about by a series of chemical reactions which occurs as the VFA's are absorbed through the walls of the rumen. Barcroft et al. (1944) indicated the fatty acids are directly absorbed from the rumen, reticulum, omasum and large intestine with the most absorption occurring in the rumen. Propionic and butyric acids are almost entirely metabolized in the rumen and liver. Acetic acid passes through the liver into the peripheral circulation with the main sites of its oxidation being adipose and muscular tissue.

Propionic acid is more efficient in its metabolic pathway in producing energy (Hungate, 1966). Acetic acid production results in a gross energy value of about 210 kcal/mole or a total of 420 kcal/mole, for two moles of acetic acid are formed for every mole of glucose metabolized. Efficiency is estimated to be about 62% relative to glucose which has a gross energy value of 673 kcal/mole when metabolized.

Propionic acid production yields 367 kcal/mole, or a total of 734 kcal/mole useable energy; this is 109% efficient. Butyric acid has a gross energy value of 524 kcal/mole but only one mole of butyric acid is produced for each mole of glucose metabolized. This represents an efficiency value of 77.9%. Also in the production of acetic and butyric acids carbon dioxide and methane are produced which are waste products and little energy can be recovered from them.

The heat increment or heat liberated when food is metabolized is a good measure of the efficiency of its utilization. The less the proportion of heat given off as compared to the energy taken up by the animal, the more efficient is the utilization of the food (Hungate, 1966). The heat increment of propionic acid is less than that for acetic acid. This is further evidence indicating the fact that propionic acid is more efficient than the other VFA's.

After the VFA's are absorbed into the bloodstream all three acids can be used to furnish energy through the carboxylic acid cycle. Acetic is changed to acetyl-Co-A which requires two molecules of adenosine tri-phosphate (ATP). Its complete oxidation to CO_2 and H_2O yields ten molecules of ATP. Propionic acid reacts with Co-A to form methylmalonyl Co-A which is changed to succinyl Co-A and this enters the carboxylic acid cycle. The net yield is 18 ATP's by going through this pathway. Propionic acid can also go through the glycogen pathway. Butyric acid can be changed to butyrl Co-A which is transformed to acetyl Co-A and this then goes the same route as acetic acid. The complete oxidation of one mole of glucose yields CO_2, H_2O and 27 moles of ATP (Maynard and Loosli, 1969).

C. Monensin as it Affects the Rumen

It has been demonstrated that monensin alters rumen fermentation both in vitro and in vivo (Richardson et al., 1974). It has also been shown that with the use of monensin molar percentages of the VFA's are altered, with less acetic and butyric acids being produced, but more propionic (Perry et al., 1976; Dinius and Simpson, 1975; Thornton et al., 1976). As pointed out by Hungate (1966), the metabolic pathway of propionic acid is more efficient, which then could explain the reason why monensin is effective.

Thornton et al. (1976) reported increased propionic production and a decrease in methane production. This could have been due to the decrease in acetic acid which when produced results in methane production. Propionic acid production liberates less hydrogen so less waste as methane.

Hungate (1966) points out that methane production is a valuable index as to the extent of rumen fermentation, for it is a direct measure of activity in the rumen. There is no evidence that methane is converted to other materials after it is formed, so the quantity liberated by the rumen is the amount produced.

Hale et al. (1975) and Dinius et al. (1976) in studies involving growing and finishing steers evaluated monensin and its effects on ruminal activity. It was clear that individual concentrations of the VFA's were altered in such a way as to increase the efficiency of the animal. In both studies the propionic acid production was increased while acetic and butyric acids decreased. This resulted in greater overall production by the animal and more efficient energy utilization.

D. Monensin as it Affects Feedlot Cattle

Since the introduction of monensin to the beef industry there have been numerous studies to evaluate its effect on cattle. All of the early research has been in the feedlot sector of the industry or on growing and finishing cattle. The FDA has given clearance for the use of monensin in this sector after positive results were demonstrated.

Many aspects of the feedlot industry have been studied such as: carcass composition (Richardson et al., 1974; Raun et al., 1974; Potter et al., 1976); optimum dosage levels (Linn et al., 1975; Utley, 1976); use of monensin with other feeds (Harvey et al., 1976; Summers et al., 1976; Garrett, 1976); uses with implants (Sherrod et al., 1976; Weichenthal et al., 1976; Utley et al., 1976) and the use of monensin under grazing conditions (Brethour, 1976; Oliver, 1975; Anthony et al., 1975).

All of the above studies were intended to add knowledge and to acquaint feedlot personnel to the use of monensin. Many products, which are enabling producers to mass produce cattle and still improve efficiency have been developed. Through the use of monensin, feedlots can compete more effectively and can produce cattle using less feed, therefore less feed cost because of the increased efficiency.

Average daily gain on feedlot cattle has been shown to be similar for treated and untreated cattle using monensin. Linn et al.

(1975) concluded that average daily gain for control and monensin fed steers was not significantly different. However, monensin-fed cattle consumed significantly less ration dry matter than untreated cattle, which resulted in feed costs per 100 pounds of gain being highest for the control cattle.

Wolfe and Matsushima (1975), Lofgreen (1976) and Riley et al. (1976) reported less feed intake for cattle fed monensin in feedlot trials with increased feed efficiency. Riley et al. (1976) showed feed efficiency increased by up to 12% and rumen VFA samples indicated an increase of propionic acid production.

Wolfe and Matsushima (1975) indicated average daily gain was not significantly different between control and treated cattle. At a level of 30 grams/ton, feed efficiency was at its highest as compared to treatments of 0, 10 and 20 grams/ton.

Brown et al. (1974) did a very extensive study to evaluate feedlot cattle fed monensin. Facilities varied from slatted to concrete floors, and self-feeders to fence line feed bunks. Roughages varied depending on study location, with alfalfa, hay, corn silage and corn sorghum being some of the feeds used. Results indicated increased feed efficiency, no significant difference in average daily gain, decreased feed consumption and increased rumen propionic acid production. The optimum level was at 33 ppm or 30 grams/ton.

E. Monensin as it Affects Cattle on Pasture

There are a considerable number of cattle being raised on pasture utilizing forages and roughages. This often is a preferred method of growing cattle and requires less labor and capital. Considerable savings could occur if efficiency were to be increased in this area. Research was conducted to evaluate monensin under these conditions and they proved positive. The FDA may give its approval for the use of monensin on pasture for growing and finishing cattle in the near future.

A problem that soon became evident under pasture conditions was an effective means to transport the monensin or act as a carrier, which is needed to place the premix in. Grain, such as ground barley, is commonly used along with many other means of transport. DeMuth et al. (1976) used molasses blocks treated with monensin although this too can be a problem, for it is difficult to regulate intake.

Oliver (1975) has studied monensin as it affects cattle grazing coastal bermudagrass. Monensin was mixed with a ground corn supplement and fed to the animals at levels of 25 to 200 mg/head/day. Larger weight gains were recorded for the monensin treated animals and growth rates increased as monensin levels increased.

On high roughage diets where feed is not restricted, as in pasture conditions, average daily gain has been shown to increase for monensin-treated animals. The increased efficiency associated with the monensin results in extra weight gain as compared to untreated animals.

Potter et al. (1974a) conducted studies on cattle grazing mixed legume-grass pasture of orchard grass, alfalfa brome and ladino clover. The supplement containing the monensin premix was a mixture of corn, molasses, soybean and alfalfa meal. Levels of 100 and 200 mg/head/day resulted in increased gains in the cattle relative to untreated animals. Rumen samples showed propionic acid production was increased.

Anthony et al. (1975), in a study involving cattle grazing coastal bermuda grass, reported no significant difference in average daily gain between treated and untreated animals.

Brethour (1976) and Corah et al. (1977) reported increased pasture gains on monensin-treated animals over controls when grazed on native shortgrass pasture. In the trial by Corah et al. (1977) monensin was mixed with three different carriers: a Staley commercial block, rolled corn, and a liquid supplement.

F. Monensin as it Affects Carcass Composition

The effect monensin has on carcass composition has been well documented. An extensive study on the effect of monensin on carcass quality was conducted by Potter et al. (1974b). Five hundred carcasses were evaluated with all slaughtered at the same weight. Levels of monensin used were 0, 10, 20, 30 and 40 grams/ton. Fat percentages were: 32.6, 32.5, 32.1, 31.6 and 33.0; dresssing percentages: 62.2, 62.0, 61.3, 61.0 and 61.7; marbling scores: 12.1, 12.8, 12.1, 11.4 and 12.4; cutability percentages: 46.3, 46.7, 46.2, 46.7 and 46.8, respectively, for the 0, 10, 20, 30 and 40 grams/ton groups.

The observations by Potter et al. (1974b) and a study by Sherrod et al. (1975) indicate no adverse effects associated with feeding monensin on carcass characteristics. There is no withdrawal time associated with monensin prior to slaughter.

G. Monensin as it Affects Gestating Cows

The cow-calf producer is at a level in the cattle industry that involves much labor, management and skill. Most cattle in this area of production are raised and maintained on sections of land that have an abundance of comparatively low-carrying-capacity grazing land (Neumann and Snapp, 1969). For this reason efficiency is imperative in order for maximum production. The feed required for the maintenance of a cow plus rearing her calf to weaning is great. An estimated 5.18 kg of Total Digestible Nutrients (TDN) per .45 kg of calf produced is required by the cow and calf. Added to this is an additional 2.21 kg of TDN per kg of live weight required past weaning. When the production of the edible portion is figured in, it takes 8.3 kg of TDN per .45 kg of edible beef. Thus 87.5% of the total metabolizable energy (ME) of the energy fed is used to maintain a cow and her calf. Only 12.5% of the ME was recovered in the final product (Klosterman et al., 1971). Efficiency is critical when dealing with cow-calf production. O'Mary and Dyer (1972) suggest that two animals in the breeding herd is required to produce one slaughter animal. The emphasis then should be placed at the beginning of an animal's life cycle where most of the energy expenditure occurs, in the breeding herd.

For reasons explained above, the use of monensin in a cow herd can be initiated and administered effectively. Feedlot use of monensin has increased productivity and savings, but compared to its potential in cow-calf production it may be even greater. Little work has been published on monensin use in cow-calf research but studies currently underway will add to the limited data now available.

Over two winters Turner et al. (1977) have compiled much data as it applies to the effects of monensin on brood cows. Meadow hay fed free choice and a barley supplement were provided for 48 cows each year for 2 years with monensin treatments of 0 and 200 mg/head/day provided in the supplement. Results showed less hay was consumed by the treated cows, however they also outgained the untreated animals. Analysis of rumen samples indicated an increase in propionic acid production and a decrease in acetic and butyric acids. Total VFA concentrations were not affected by the treatments.

Reproduction, lactation and calf performance are all factors associated with cow-calf production and must be studied as to the effects monensin has on them.

Randel and Rouquette (1976) evaluated the effect monensin has on lactation and efficiency. Treatment was initiated on day 256 of pregnancy so the effect of monensin on the fetus was not determined. Results indicated a reduction in butterfat content but an increase in total milk production. Feed intake was reduced while feed efficiency increased by 12.4%.

In a study by Turner (unpublished data) results show an increase in milk production by about 13% in monensin-treated cows but no difference in milk fat or protein for the treated or untreated cows.

Rindsig and Davis (1974) point out that the acetate to propionate ratio is directly related to milk fat percentage and milk volume produced. An increase in propionic acid decreases the butterfat content but increases milk production. With an increase in acetic acid just the opposite occurs. Cows on a high-grain, low-roughage diet will also decrease the milk fat content in much the same way as monensin action does. This is due to the propionate energy in the ration and the fact that blood acetate is responsible for about 40 percent of the milk fatty acids which originate in the rumen.

Little published data is available on reproductive performance of monensin-treated cows. In the study by Turner et al. (1977), they found treated cows coming back into heat an average of 30 days postpartum as compared to 42 days for the controls; conception rates were not altered.

Moseley et al. (1977), in a study on beef heifers, reported conception rates of monensin treated animals slightly higher than those of the controls. No calving losses were reported for the treated or untreated animals.

H. Deleterious Effects of Monensin

It has been reported by Wolfe and Matsushima (1975) that steers on a ration of 30 grams/ton showed some side effects due to the monensin treatments. Erratic feed consumption and loose feces in the early part of the study occurred. After about four weeks the animals adjusted and no ill effects persisted. Some time for adaptation has been suggested by Elanco representatives to give the rumen time to adjust to the feed additive. No other literature has been reported to suggest that monensin disrupts the physiological activity of the animal.

A consideration that must be anticipated is the effect monensin has on monogastric animals or animals other than ruminants. Horses are quite often in close proximity to cattle, particularly in pasture conditions.

In a study on horses, Stocker (1975) found monensin was toxic at 100 ppm, with higher levels being fatal.

III. MATERIALS AND METHODS

This study was conducted over a series of three phases with phase one commencing November 16, 1976 and continuing through the winter to March 1, 1977, just prior to calving. Phase two involved calving and went through this period to mid-May. The final phase, or postpartum period, was from mid-May when monensin treatments were terminated to the end of August when weaning took place. In mid-October pregnancy and fetal age was determined by rectal palpation and the breeding records. This accounted for an entire reproductive cycle of a brood cow.

Ninety-six mature pregnant Hereford cows ranging from three to ten years of age were allotted to three replications with four treatments and eight cows per pen. Pregnancy was determined by rectal palpation prior to the initiation of the study. The cows were artificially inseminated the previous spring beginning the end of May, and continuing 42 days, to a single Angus sire. Hereford cleanup bulls followed for 21 days. The cows were randomly stratified to respective treatments by breeding date, weight, condition score and the previous year's weaning weight. Calving date was the main determinant in assigning cows to replications, with reps being early, mid and late calvers.

A barn with access to individual feeding stalls was utilized to study one replication. Outside hay bunks were provided. The other two replications were in outside lots with sheltered hay bunks and raised feed troughs. Hay was group fed in all cases with the supplement group fed in the outside lots, but individually in the barn.

Salt, a 50:50 salt-bonemeal mix and water were provided free choice. Heated automatic waterers were used.

Monensin treatments consisted of 0, 50, 200 and 300 mg/head/day and was provided in the ground barley which acted as a carrier for the monensin. Controls received .45 kg of barley/head/day with monensin treatments receiving the same, but their respective monensin doses were added to the barley.

Monensin is used as an anticoccidial in poultry so prior to the initiation of the study it was necessary to analyze fecal samples for coccidiosis. Tests were negative.

Rumen samples for VFA analysis were taken twice during the study, once prior to calving, and another postpartum. An esophageal hose connected to a vacuum pump was utilized on four cows per pen, for a total of twelve samples per treatment. On the morning samples were taken cows were fed at one-half hour intervals to allow ample time for sampling. All cows were given a minimum of three hours from time of feeding to the time samples were taken; this was to allow for adequate rumen fermentation.

The basic feed for the cows was baled meadow hay native to the area, consisting of 80% rushes and sedges with a protein content of 9.5% crude protein. Hay was weighed in daily, with each treatment receiving a predetermined amount for that particular week. Weighback was obtained weekly to determine actual intake. Initially the control cows were fed hay free choice and consumed 13.4 kg/head/day. The initial hay levels were 50 mg receiving 95% of the controls and the 200 and 300 mg groups receiving 90%. Cow weight gains were higher than desired during the first 28 days so feed levels for all treatments were adjusted downward. Throughout the remainder of the study feed was adjusted to maintain cattle in a thrifty condition and provide equal weight gain or loss between treatments. In early March feed levels were increased to insure adequate nutrition for lactation and rebreeding. After calving and treatment termination the cows were turned out on native meadow pasture and received hay or grazed as a group.

Cow weights were obtained initially and every 28 days prior to calving and were used to adjust hay intake. Cows and calves were weighed within 24 hours postpartum, May 9 (turnout) and weaning. Calf weaning weights were adjusted to correct for age and sex. At birth, bull calves were castrated and all calves individually identified by ear tags.

At or near the time of calving cows were removed from their pens and taken to the calving shed. During this time cows were fed hay free choice and cows that were on monensin, regardless of level, received 200 mg/head/day of the monensin included in the ground barley. Cows were returned to their pens as soon after calving as possible, with no cows remaining off their treatments longer than two days. Hay fed was adjusted accordingly so the cows remaining in the pens received the proper level. Cows that lost calves were eliminated from subsequent data, as were cows that became ill or had calves that were not healthy. One cow that lost her calf at birth was grafted another.

First estrus postpartum was detected by utilizing nine vasectomized bulls with chin ball markers. Visual observations were also made at least three times daily. When the oldest calf in a pen reached seven days of age a bull was turned into that pen for two hours in the morning and evening for heat detection. Bulls were randomly assigned pens so that no bull was in the same pen for an extended number of days. Nine bulls were available and in the latter part of the study twelve pens needed to be covered. As a result an overlap occurred. Only more aggressive bulls were used to cover more than one pen and they were put in pens where the least amount of activity was expected. When the treatment phase ended and the cows were turned out to pasture, heat detection continued on a group basis. For 42 days in early June the cows were artificially inseminated to a single Angus sire and Hereford cleanup bulls followed this for 21 days. Pregnancy was determined in mid-October by rectal palpation. Fetal age was estimated by breeding records and palpation results.

Statistical analysis was determined according to Steel and Torrie (1960). A one-two factor of analysis of variance was performed using least significant difference to compare means.

IV. RESULTS AND DISCUSSION

A. Cow Gain and Hay Intake

Table 1 shows the prepartum period, November 16 to March 1, including initial and final weights and hay intake. Results indicated the monensin treatments performed equally as well or better than the control group when hay was restricted from 7 to 10% relative to the control group's diet. Feed efficiency was improved with the use of monensin during this period. This is in agreement with Turner et al. (1977) who reported similar findings with cows fed free choice.

Table 2 shows the calving period daily gains and hay intake. During this time cows were calving which resulted in negative daily gains. The 200 mg level received the least hay or 13% less than the control group. With this reduction in hay the 200 mg treatment still showed daily losses similar to the control group. The 300 mg level lost the most weight ($P>.05$) indicating this group should have received more than 89% of the control group's diet.

During the calving period a problem occurred which resulted in a number of cows being removed from the study. The cows were in a confined situation and housed in pens that were made of wooden boards coated with a paint containing lead. The pens had been painted some years before and up until this study no young or newborn calves had been housed in these pens for any length of time.

Calves, two weeks of age and older, chewed on the boards, ingesting the paint. In time, about a month, lead would reach a toxic level in the calf's body and it would become extremely sick or would

TABLE 1. COW GAIN AND HAY INTAKE FOR THE PREPARTUM PERIOD (NOVEMBER 16 TO MARCH 1)

Treatment (mg/hd/day)	No.	Initial weight[a] (kg)	Final weight[a] (kg)	ADG[a] (kg)	Hay intake: Per day (kg)	Hay intake: Percent of control
Control	24	455	490	.34	11.7	100
50	24	447	487	.38	10.9	93
200	24	456	496	.38	10.5	90
300	24	457	495	.37	10.7	92

[a]Means not significantly different at the P<.05 level between treatments.

TABLE 2. COW GAIN DATA AND HAY INTAKE FOR THE CALVING PERIOD (MARCH 1 TO MAY 9)

Treatment (mg/hd/day)	No.[b]	Initial weight[a] (kg)	Final weight[a] (kg)	ADG[a] (kg)	Hay intake: Per day (kg)	Hay intake: Percent of control
Control	21	489	437	-.75	12.9	100
50	23	486	431	-.79	11.6	90
200	19	496	442	-.78	11.2	87
300	21	491	425	-.95	11.5	89

[a]Means not significantly different at the P<.05 level between treatments.

[b]Missing values due to nine calves dying of lead poisoning, two calves dying of other causes, and one cow getting sick and being removed from the study.

die. Symptoms were disorientation, teeth grinding and convulsions. In all, 11 calves died of lead poisoning, 2 calves died of other causes and 1 cow was removed from the study due to illness. Eighty-two cows out of the original ninety-six completed the study.

Because of the lead toxicity problems, this phase of the study was terminated two weeks earlier than planned. Uneven sample sizes were also a result of the losses but this is a common problem in studies of this nature.

Average daily gain and hay intake for the entire confinement period is summarized on table 3. Overall the 200 mg level's performance was consistently the best with less weight loss on a diet 11% less than the control group's. The 300 mg level showed the greatest weight loss which means hay was not provided in sufficient amounts. For this quality of feed 300 mg may be too high.

Table 4 shows cow gain for the postpartum period when the cows and calves were on meadow pasture. Hay or pasture intake was not measured during this period. Originally the May 9 weight was to be used to adjust hay intake to bring all treatments in line with each other relative to daily gain. The 50 or 200 mg treatments hay intake would have been further reduced at this time and the 300 mg level increased in relation to the controls.

Table 5 shows a brief summary of the study from the initial to final weights. The greatest weight loss occurred for the 300 mg level with reasons explained previously. The control group came out even with the 50 and 200 mg groups showing the greatest gain but not significantly different from the other treatments.

TABLE 3. COW GAIN DATA AND HAY INTAKE FOR THE ENTIRE CONFINEMENT PERIOD (NOVEMBER 16 TO MAY 9)

Treatment (mg/hd/day)	No.[b]	Initial weight[a] (kg)	Final weight[a] (kg)	ADG[a] (kg)	Hay intake Per day (kg)	Hay intake Percent of control
Control	21	458	437	-.12	12.2	100
50	23	440	431	-.05	11.2	92
200	19	459	442	-.10	10.8	89
300	21	455	425	-.17	11.0	92

[a]Means not significantly different at the P<.05 level between treatments.

[b]Missing values due to nine calves dying of lead poisoning, two calves dying of other causes, and one cow getting sick and being removed from the study.

TABLE 4. COW GAIN FOR THE POSTPARTUM PERIOD

(MAY 9 TO AUGUST 29)*

Treatment (mg/hd/day)	No.[a]	Initial weight (kg)	Final weight (kg)	ADG[a] (kg)
Control	19	437	456	.17
50	23	428	452	.21
200	19	445	467	.20
300	21	426	444	.16

*Means not significantly different at the $P<.05$ level between treatments.

[a]Missing values due to eleven calves dying of lead poisoning, two calves dying of other causes and one cow getting sick and being removed from the study.

TABLE 5. COW GAIN DATA FROM NOVEMBER 16 TO AUGUST 29*

Treatment (mg/hd/day)	No.[a]	Initial weight (kg)	Final weight (kg)	Weight change (kg)
Control	19	457	456	-1
50	23	440	452	+12
200	19	459	467	+8
300	21	455	444	-11

*Means not significantly different at the P<.05 level between treatments

[a]Missing values due to eleven calves dying of lead poisoning, two calves dying of other causes, and one cow getting sick and being removed from the study.

This study demonstrated increased efficiency with the use of monensin for brood cows being fed native meadow hay. Hay intake was reduced by as much as 12% for the 200 mg treatment, which appeared to be the most efficient level, without adverse effects on performance. With savings of this magnitude, during the course of a 180 day wintering period a cow herd of 500 animals, consuming 12 kg/head/day, would save 129.6 metric tons of hay. This is enough hay to feed an additional 60 cows during the same period. This added production could result in a more viable economic unit and in times such as cattlemen are now experiencing, particularly the cow-calf sector, this would help considerably.

B. Volatile Fatty Acid Production

Volatile fatty acid concentrations were determined to measure the effect monensin has on rumen microbial activity. Table 6, which shows samples obtained on January 12, produced results which were highly variable and believed to be due to a laboratory problem in analysis of these data. Therefore statistical analysis was not run on these data. However, results indicated an increase in propionic acid production and a decrease in acetic and butyric acids.

The samples obtained on May 5 (table 7) show a pattern with monensin treatments. An increase in propionic acid is evident at the 200 and 300 mg levels with a reduction in butyric and acetic acids. This is in agreement with Perry *et al.* (1976), Dinius and Simpson (1975) and Thornton *et al.* (1976) who reported similar findings with monensin use.

TABLE 6. VOLATILE FATTY ACID DATA FOR SAMPLE ONE (JANUARY 12)

Treatment (mg/hd/day)	No.	Acetate	Propionate	Butyrate	Total concentration (mM/liter)
Control	12	64.7±12.3[a]	24.1± 8.25	11.3±4.17	31.9±15.5
50	12	55.2±19.8	31.8±13.6	13.0±6.27	29.9±18.8
200	12	52.0±18.1	36.2±14.0	11.8±14.0	29.7±11.1
300	12	61.1±16.9	29.2±13.8	9.8±3.34	32.5±21.4

[a]Standard error of the mean.

TABLE 7. VOLATILE FATTY ACID DATA FOR SAMPLE TWO (MAY 5) AND STANDARD ERRORS

Treatment (mg/hd/day)	No.	Molar % Acetate	Molar % Propionate	Molar % Butyrate	Total concentration (mM/liter)
Control	12	$75.8 \pm .82^{a}$	$17.3 \pm .65^{a}$	$6.8 \pm .78^{a}$	47.7 ± 1.36^{a}
50	12	$75.7 \pm .81^{a}$	$17.6 \pm .56^{a}$	$6.7 \pm .46^{a}$	41.1 ± 1.24^{b}
200	12	72.5 ± 1.88^{b}	21.1 ± 2.22^{b}	$6.4 \pm .81$	48.7 ± 1.35^{c}
300	12	72.3 ± 2.45^{b}	21.9 ± 2.59^{b}	$5.8 \pm .97^{b}$	36.1 ± 13.8^{d}

[abcd]Means with different superscripts differ at the $P<.05$ level within columns.

Acetate production was reduced when comparing the control and 50 mg levels to the 200 and 300 mg groups ($P<.05$). The 200 and 300 mg treatments increased propionic acid production ($P<.05$) as compared to the 50 mg and control groups. Butyric acid production was decreased with monensin, but was only significant on the 300 mg level.

Total VFA production was significantly different between all treatments with no clear cut pattern to monensin dosage. This is not in agreement with Turner *et al.* (1977) and Richardson *et al.* (1976) who reported little change in total VFA concentrations. Church (1976) points out that great variability can result when total VFA's are reported. Complicating factors are such things as saliva contamination, ingestion of water, changes in pH and changes in rumen volume.

C. Cow Reproductive Performance

Results for the cows reproductive performance are shown in table 8. Results for first estrus postpartum show no significant difference between treatments although the 200 mg level cows came into heat a few days earlier. Turner *et al.* (1977) reported a significant difference in first estrus postpartum during the first year of a two year study on the effects of monensin on brood cows.

The number of cows bred back is also given in table 8 and again the 200 mg monensin treatment out-performed the other groups. Only 84% of the control group's cows bred back while the monensin treatments averaged 100, 91 and 86% respectively for the 200, 50 and 300 mg groups. Conception data is of limited value, due to the small numbers involved. From the reproductive performance of the cows it seems that

TABLE 8. REPRODUCTIVE PERFORMANCE

Treatment (mg/hd/day)	No.[a]	First estrus postpartum	Bred Back	Conception %	Projected 77/78 calf interval
		Days±S.E.			Days±S.E.
Control	19[b]	44±14.1	16	84	345±17.6[c]
50	23	44±12.3	21	91	348±23.4
200	19	41±10.5	19	100	348±20.4
300	21	45±14.9	18	86	362±21.8[d]

[a]Missing values due to eleven calves dying of lead poisoning, two dying of other causes, and one cow getting sick and having to be removed from the study.

[b]One cow did not cycle and was not included in the first estrus cycle.

[cd]Menas with different superscripts differ at the $P<.05$ level within columns.

monensin does not have a deleterious effect on performance and possibly a beneficial effect.

A projected calving interval was determined by estimating the number of days from the 1977 calving to when the cows should calf in 1978. This was determined by breeding date and rectal palpation estimations. A significant difference at the P<.05 level between the control and 300 mg treatments was found but not between the other treatments. This could be due in part to the greater weight loss experienced by this group.

D. The Effect of Monensin on Calf Performance

Table 9 shows calf weights at birth, treatment termination (May 9) and weaning (August 29). Birth weights were similar between treatments. The May 9 weight shows weights ranging from 54 kg for the control group to 61 kg for the 300 mg treatment but no difference was found at P<.05.

Average daily gain, table 10, from calving to May 9 and from May 9 to weaning was computed and adjusted for sex using adjustment factors of 6.9 and 6.3%, respectively. Heifers were adjusted upwards to put them on a steer equivalence. These figures were determined by adding up the average daily gains of the steers and heifers and finding the percent difference between the two. Daily gains for both periods were not statistically significant at the P<.05 level between treatments.

Weaning weights obtained on July 29 were adjusted for age (139 day average) and sex (adjusting heifers up 6%). No difference

TABLE 9. CALF WEIGHTS*

Date	Treatment Control	50	200	300
Birth wt. (kg)	34	35	35	34
Number[a]	24	24	24	23
May 9 wt. (kg)	54	60	55	61
Number	18	21	18	21
Weaning wt. (kg)[c]	124	134	129	133
Number[d]	19	23	19	21

*Means not significantly different at the P<.05 level between treatments.

[a]Missing value due to one cow getting sick and having to be removed from the study.

[b]Missing values due to four calves not being born yet, eleven calves dying of lead poisoning, two of other causes, and one cow being removed from the study due to illness.

[c]Weaning weights were adjusted for age (139 days) and sex.

[d]Missing values due to eleven calves dying of lead poisoning, one cow being removed due to illness and two calves dying of other causes.

TABLE 10. CALF GAIN DATA FROM BIRTH TO MAY 9 AND MAY 9 TO AUGUST 29*

Period	Treatment			
	Control	50	200	300
Birth to May 9 (kg)[a]	.82	.90	.81	.86
Number[b]	18	21	18	21
May 9 to August 29 (kg)[c]	.61	.67	.64	.66
Number[d]	19	23	19	21

*Means not significantly different at the P<.05 level between treatments.

[a]Adjusted for sex with weighted means.

[b]Missing values due to four calves not being born yet, eleven calves dying of lead poisoning, two of other causes, and one cow being removed from the study due to illness.

[c]Adjusted for sex

[d]Missing values due to eleven calves dying of lead poisoning, one cow being removed due to illness, and two calves dying of other causes.

was found between treatments with the lowest weaning weights coming from the control group at 124 kg, and the highest at 134 kg from the 50 mg treatment.

The largest calf losses came from the control and 200 mg treatments. Past performance of the five cows that lost calves from the control group averaged 109% while the five from the 200 mg level averaged 102%. This is on a basis of 100 for all cows on the study. Table 11 shows the performance index of the cows that remained on the study. It is evident that of the calves lost in the control and 200 mg groups, they were from the more productive cows. So a theoretical weaning weight was determined by adjusting the actual weaning weight to an index of 100. This gives an estimate of what effect the lost calves may have had on the data.

There seems to be little effect on calf performance of cows treated with monensin. Calf weights were similar, which is in agreement with Randel and Rouquette (1976) who reported similar findings on birth weight. Average daily gain was not affected in this study by using monensin nor was weaning weight.

Increased milk production has been realized when monensin is added to a diet, as reported by Randel and Rouquette (1976) and Turner (unpublished data). Propionic acid production when increased tends to increase milk production but this results in decreased butterfat (Rindsig and Davis, 1974). The butterfat content is less on a percent basis but total butterfat is likely the same. No lactation analysis was performed in this study which would have added needed data, for this is limited and little literature is available on the subject.

TABLE 11. COW PERFORMANCE INDEX AND THEORETICAL ADJUSTMENT OF WEANING WEIGHT

Treatment (mg/hd/day)	Performance[a] index %	Weaning[b] weight (kg)	Theoretical[c] weaning weight (kg)
Control	97	124	128
50	100	134	134
200	99	129	130
300	100	133	133

[a]Performance index based on past year's weaning weights.

[b]Weaning weights were adjusted for age and sex.

[c]Theoretical values, adjusting all weaning weights to 100% performance index.

E. Summary of Results

Prepartum daily gain for all treatments was not significantly different at the $P<.05$ level, however gains for the monensin treatments were higher. This was accomplished on 7 to 10% less hay relative to the control group's diet.

During the calving period weight loss was similar for all treatments, except the 300 mg level which lost more weight. This group was fed 89% of the control group's diet which may have been too little. No significant difference at the $P<.05$ level between treatments was found, however. The 200 mg group continued to perform above the other treatments even though their diet was 13% below the control group.

Postpartum results were similar to the results for the calving period with all treatments performing similarly. Monensin treatments, however, with the exception of the 300 mg group, out-gained the control animals ($P>.05$).

Volatile fatty acid production was altered with an increase in propionic acid and a decrease in acetic and butyric acids with 200 and 300 mg levels of monensin. Total production was significantly different between treatments which is not in agreement with other studies.

Reproductive performance was not affected by the use of monensin with all treatments showing similar results. Calving interval for the 300 mg treatment, however, was longer than for the other groups. Calf performance was similar between treatments.

Overall, monensin treatments increased performance and feed efficiency compared to the control group. The 200 mg level provided the best results and can be recommended for cows wintered on meadow hay at a savings of 12% in hay requirements. A monensin level of 300 mg/head/day may be too high on high roughage diets, particularly during early lactation.

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APPENDIX

APPENDIX TABLE 1. COW GAIN FROM NOVEMBER 16 TO CALVING

Treatment mg/hd/day	No.[b]	No. of days	Initial weight[a] (kg)	Final weight[a] (kg)	ADF[ac] (kg)
Control	24	147	458	452	-.04
50	24	145	451	455	.03
200	24	144	460	469	.06
300	23	143	460	457	-.02

[a]Means not significantly different at the P<.05 level between treatments.

[b]Missing value due to one cow getting sick and having to be removed from the study.

[c]Weighted means.

APPENDIX TABLE 2. COW GAIN DATA AND HAY INTAKE FROM MARCH 1 TO CALVING

Treatment mg/hd/day	No.[b]	No. of days	Initial weight[a] (kg)	Final weight[a] (kg)	ADG[ac]	Hay intake Per day (kg)	Hay intake Percent of control
Control	24	42	488	452	-.85	12.9	100
50	24	40	487	455	-.80	11.6	90
200	24	39	501	469	-.82	11.2	87
300	23	38	498	457	-1.07	11.6	90

[a]Means not significantly different at the P<.05 level between treatments.

[b]Missing value due to one cow getting sick and having to be removed from the study.

[c]Weighted means.

APPENDIX TABLE 3. COW GAIN FROM CALVING TO MAY 9*

Treatment mg/hd/day	No.[a]	No. of days	Initial weight (kg)	Final weight (kg)	ADG[b] (kg)
Control	21	26	457	437	-.77
50	23	28	453	431	-.80
200	19	24	469	442	-1.12
300	21	32	452	425	-.83

*Means not significantly different at the P<.05 level between treatments.

[a]Missing values due to nine calves dying of lead poisoning, two calves dying of other causes and one cow getting sick and having to be removed from the study.

[b]Weighted means.

APPENDIX TABLE 4. COW GAIN FROM CALVING TO AUGUST 29*

Treatment mg/hd/day	No.[a]	No. of days	Initial weight (kg)	Final weight (kg)	ADG[b] (kg)
Control	19	137	456	456	0
50	23	140	452	452	0
200	19	136	471	467	-.03
300	21	144	451	444	-.05

*Means not significantly different at the P<.05 level between treatments.

[a]Missing values due to eleven calves dying of lead poisoning, two dying of other causes and one cow getting sick and having to be removed from the study.

[b]Weighted means.

APPENDIX TABLE 5. HAY ADJUSTMENTS BY TREATMENT PERIOD

	Treatment (mg/hd/day)							
	Control		50		200		300	
	Per day		Per day		Per day		Per day	
Week of	kg	% of C*	kg	% of C	kg	% of C	kg	% of C
11/16	13.0	100	12.4	95	11.7	90	11.7	90
12/06	13.6	100	12.9	95	12.2	90	12.2	90
12/20	11.8	100	10.7	91	10.4	88	10.4	88
02/07	10.9	100	10.3	95	9.9	91	10.3	95
03/07	12.5	100	11.1	89	10.8	86	11.1	89
03/14	12.9	100	11.5	89	11.1	86	11.5	89
03/28	13.2	100	11.7	89	11.4	86	11.7	89
04/18	13.4	100	11.9	89	11.5	86	11.9	89
05/09	---------------------Treatment Termination---------------							

*Control.

APPENDIX TABLE 6. RAW DATA - COWS (LBS)
CONTROL

Cow No.	11/16 wt.	3/1 wt.	Calving wt.	Calving date	5/9 wt.	8/29 wt.	Days to first estrus	Preg. test	Calving interval
Replication 1									
1	964	1032	932	4/15	924	944	44	X	
12	1084	1196	1144	4/30	1136	1096	37	X	
25	1006	1090	1042	4/28	994	1084	32	X	
37	836	926	940	5/12	940	854	38	X	
69	836	918	864	4/30	CD	CD	37	X	
103	1002	1124	1058	4/14	1064	1074	17	X	
151	882	958	962	4/24	880	922	51	X	
295	1050	1128	1028	4/29	990	986	NC	0	
Replication 2									
27	1082	1166	1096	4/06	1040	CD	52	X	
54	1112	1228	1066	4/03	1048	1090	47	X	
58	1034	1078	950	5/04	994	1040	30	X	
96	876	920	890	4/27	830	822	42	X	
123	846	892	826	4/25	792	886	43	X	
145	892	956	922	3/28	784	CD	51	X	
159	1050	1152	918	3/30	CD	CD	57	X	
303	980	1082	1022	3/31	954	952	61	0	
Replication 3									
30	1072	1102	972	3/17	878	1012	67	X	
91	926	1020	894	3/19	812	866	75	0	
95	1160	1240	1120	3/05	1092	1168	39	X	
105	840	876	798	3/31	718	816	59	X	
134	1134	1216	1140	4/19	1110	1190	33	X	
200	1040	1086	988	3/08	CD	CD	56	X	
272	1140	1204	1150	5/01	1070	1140	41	X	
341	1210	1314	1186	3/31	1160	1232	40	X	

CD = Calf died. X = Pregnant. 0 = Open.

APPENDIX TABLE 7. RAW DATA - COWS (LBS)
50 MG

Cow No.	11/16 wt.	3/1 wt.	Calving wt.	Calving date	5/9 wt .	8/29 wt .	Days to first estrus	Preg. test	Calving interval
Replication 1									
6	1006	1086	1008	4/23	962	1040	40	0	
64	892	1002	976	4/23	920	924	34	X	
84	1062	1202	1112	4/08	1054	1048	45	0	
98	848	886	840	4/11	764	832	52	X	
139	1140	1278	1230	5/09	1230	1272	32	X	
143	850	912	808	4/17	796	882	44	X	
144	1010	1136	1080	4/25	1026	1054	30	X	
148	924	1018	930	3/30	874	940	43	X	
Replication 2									
23	1108	1218	1210	4/02	1040	1122	48	X	
65	994	1114	1010	4/25	1020	1024	28	X	
93	920	976	924	4/04	832	946	59	X	
109	934	1002	932	4/25	926	954	37	X	
127	876	938	900	5/09	900	894	31	X	
183	1036	1158	1036	4/03	944	1038	49	X	
186	984	1084	1040	4/20	942	982	47	X	
306	914	960	878	4/01	830	910	63	X	
Replication 3									
55	880	932	840	3/20	810	894	53	X	
61	1056	1134	1032	3/11	CD	CD	84	X	
114	966	1030	990	4/25	940	1012	35	X	
124	1052	1156	1004	3/08	982	1050	40	X	
155	1100	1078	1002	3/13	876	976	78	0	
315	990	1106	1006	3/28	914	996	49	X	
319	1026	1128	1130	5/03	1058	1068	26	X	
327	1086	1216	1148	3/26	1028	1070	45	X	

CD = Calf died. X = Pregnant. 0 = Open.

APPENDIX TABLE 8. RAW DATA - COWS (LBS)
200 MG

Cow No.	11/16 wt.	3/1 wt.	Calving wt.	Calving date	5/9 wt.	8/29 wt.	Days to first estrus	Preg. test	Calving interval
Replication 1									
9	938	982	880	4/29	920	940	34	X	
21	990	1106	1052	4/21	1052	986	43	X	
39	964	1014	970	5/06	918	988	31	X	
75	890	984	972	5/01	932	910	37	X	
79	888	942	918	4/23	846	888	38	X	
80	1090	1252	1276	5/04	1196	1152	49	X	
110	1036	1188	1090	5/10	1090	1122	32	X	
125	900	926	818	4/09	806	850	45	X	
Replication 2									
20	1060	1174	1092	4/19	1042	1112	35	X	
29	1126	1260	1188	5/05	1100	1170	36	X	
81	1182	1194	1070	3/07	994	1082	53	X	
117	950	1024	1096	3/29	850	942	48	X	
173	1110	1206	1082	3/22	978	1080	59	X	
188	1116	1184	1092	3/20	984	1136	55	X	
199	924	1016	918	4/10	900	990	42	X	
279	1048	1220	1098	4/23	1004	1042	21	X	
Replication 3									
111	1024	1120	1076	3/18	CD	CD	39	0	
116	1006	1124	1016	3/08	CD	CD	89	X	
128	856	900	816	4/04	CD	CD	48	X	
146	992	1066	1006	4/27	996	1058	32	X	
169	1018	1100	1004	3/11	946	1008	60	X	
171	964	990	852	3/05	CD	CD	78	X	
251	1030	1182	1096	3/11	CD	CD	84	X	
330	1020	1064	1058	4/19	980	1046	36	X	

CD= Calf died. X = Pregnant. 0 = Open.

APPENDIX TABLE 9. RAW DATA - COWS (LBS)
300 MG

Cow No.	11/16 wt.	3/1 wt.	Calving wt.	Calving date	5/9 wt.	8/29 wt.	Days to first estrus	Preg. test	Calving interval
Replication 1									
19	958	1014	932	4/06	850	902	57	0	
57	838	912	AB	AB	AB	AB	AB	0	
73	766	810	744	4/13	718	738	58	X	
85	1222	1306	1164	4/29	1086	1178	7	0	
87	890	956	912	4/29	904	932	36	X	
92	904	1012	956	4/11	938	912	54	X	
160	902	964	932	5/05	884	898	46	X	
323	1006	1106	1088	4/28	BC	BC	47	X	
Replication 2									
12	918	990	944	3/27	890	922	48	X	
48	1056	1152	1032	4/21	976	1006	48	X	
66	994	1088	992	4/10	950	966	48	X	
89	1116	1254	1172	4/14	1124	1150	14	X	
129	1044	1088	1014	3/28	934	992	59	X	
147	1180	1294	1184	3/31	CD	CD	63	X	
196	1042	1094	970	3/23	930	1010	51	X	
300	1052	1154	1046	4/06	1014	982	35	0	
Replication 3									
13	994	1112	1010	4/17	952	1046	43	X	
16	1190	1286	1184	3/10	1054	1024	74	X	
24	984	1048	950	3/26	866	966	39	X	
88	1054	1146	1058	4/05	984	992	42	X	
150	796	862	722	4/22	724	774	45	X	
305	932	1010	906	3/17	824	872	61	X	
339	1058	1160	1072	3/18	972	1094	36	X	
352	1262	1378	1250	3/28	1152	1252	44	X	

AB = Aborted. BC = Blind calf. CD = Calf died. 0 = Open. X = Pregnant.

APPENDIX TABLE 10. RAW DATA - CALVES (LBS)
CONTROL

Cow No.	Calf No.	Sex	Breed	Birth wt.	5/9 wt.	8/29 wt.	Adjusted 8/29 wt.	Weaning age
Replication 1								
1	503	H	H	73	122	296	319	136
14	534	S	H	77	90	264	292	121
25	529	H	H	72	92	236	272	123
37	548	H	H	76	76	172	210	109
69	533	S	H	69	CD	CD	CD	CD
103	501	S	B	66	112	316	320	137
151	518	H	H	64	92	232	263	127
295	531	H	H	82	100	208	240	122
Replication 2								
27	488	S	B	81	CD	CD	CD	CD
54	481	S	B	54	126	182	174	148
58	541	S	H	93	102	238	265	117
96	526	S	H	68	86	234	254	124
123	519	S	H	77	84	196	208	126
145	462	H	B	76	CD	CD	CD	CD
159	NK	H	B	71	CD	CD	CD	CD
303	476	S	B	70	148	286	269	151
Replication 3								
30	436	H	B	75	184	378	350	165
91	440	S	B	74	158	316	280	163
95	415	S	B	80	198	376	312	177
105	474	S	B	80	136	296	279	151
134	508	H	H	84	106	242	265	132
200	NK	S	B	74	CD	CD	CD	CD
272	536	S	H	92	102	252	277	120
341	473	H	B	81	156	332	331	151

NK = Not known.
H = Heifer or Hereford.
S = Steer.
B = Black.
CD = Calf died.

APPENDIX TABLE 11. RAW DATA - CALVES (LBS)
50 MG

Cow No.	Calf No.	Sex	Breed	Birth wt.	5/9 wt.	8/29 wt.	Adjusted 8/29 wt.	Weaning age
Replication 1								
6	513	H	H	86	118	280	315	128
64	515	S	H	80	116	300	319	128
84	491	H	B	78	156	328	340	143
98	497	S	B	71	128	302	300	140
139	545	S	H	81	81	208	239	112
143	504	S	B	82	112	264	271	134
144	520	H	H	86	110	244	276	126
148	470	S	B	78	158	328	307	152
Replication 2								
23	478	S	B	80	162	326	309	149
65	522	S	H	73	96	234	251	126
93	482	H	B	64	122	266	270	147
109	523	H	H	64	84	226	258	126
127	546	S	H	73	73	244	285	112
183	479	S	B	90	174	366	349	148
186	509	S	H	83	122	310	324	131
306	477	S	B	76	134	272	258	150
Replication 3								
55	442	H	B	71	144	286	270	162
61	NK	S	B	81	CD	CD	CD	126
114	521	S	H	75	92	212	226	174
124	419	H	B	68	184	342	304	169
155	430	S	B	90	200	360	312	154
315	461	S	B	78	176	364	336	118
319	538	S	H	72	82	280	317	156
327	455	S	B	81	186	382	349	151

NK = Not known.
H = Heifer or Hereford.
S = Steer.
B = Black.
CD = Calf died.

APPENDIX 12. RAW DATA - CALVES (LBS)
200 MG

Cow No.	Calf No.	Sex	Breed	Birth wt.	5/9 wt.	8/29 wt.	Adjusted 8/29 wt.	Weaning age
Replication 1								
9	532	H	H	77	88	232	269	122
21	511	H	H	77	108	238	264	130
39	544	S	H	79	82	210	237	115
75	535	S	H	82	100	282	314	120
79	514	S	H	82	100	236	249	128
80	540	H	H	71	82	200	237	117
110	547	H	H	95	95	258	317	111
125	493	H	B	75	132	304	317	142
Replication 2								
20	507	H	B	86	136	316	348	132
29	543	H	H	93	100	254	303	116
81	416	S	B	78	182	354	297	175
117	467	S	B	75	146	328	305	153
173	447	S	B	92	178	370	333	160
188	443	H	B	80	160	324	306	162
199	496	H	B	62	94	214	225	141
279	516	H	H	78	118	266	299	128
Replication 3								
111	NK	S	B	66	CD	CD	CD	CD
116	NK	S	B	72	CD	CD	CD	CD
128	NK	H	B	76	CD	CD	CD	CD
146	525	S	H	75	92	220	238	124
169	424	H	B	74	182	344	311	171
171	NK	H	B	72	CD	CD	CD	CD
251	NK	H	B	48	CD	CD	CD	CD
330	506	H	H	68	96	220	242	132

NK = Not known.
H = Heifer or Hereford.
S = Steer.
B = Black.
CD = Calf died.

APPENDIX TABLE 13. RAW DATA - CALVES (LBS)
300 MG

Cow No.	Calf No.	Sex	Breed	Birth wt.	5/9 wt.	8/29 wt.	Adjusted 8/29 wt.	Weaning age
Replication 1								
19	490	S	B	78	160	352	341	145
57	AB	AB	AB	AB	AB	AB	AB	AB
73	500	H	B	73	116	270	287	138
85	528	S	H	80	104	232	253	122
87	530	S	H	67	84	232	255	122
92	498	H	B	59	110	232	245	140
160	542	H	H	76	84	230	277	116
323	527	H	H	59	BC	BC	BC	BC
Replication 2								
12	460	S	B	65	148	304	279	155
48	510	H	H	96	128	310	345	130
66	494	S	H	82	142	320	317	141
89	502	H	B	69	114	292	313	137
129	464	H	B	70	136	276	271	154
147	NK	S	B	59	CD	CD	CD	CD
196	449	H	B	72	144	314	301	159
300	489	S	B	77	142	282	274	145
Replication 3								
13	505	H	H	85	130	280	304	134
16	421	S	B	94	222	414	353	172
24	456	H	B	72	150	310	301	156
88	485	S	B	83	152	322	310	146
150	512	H	H	75	96	200	220	129
305	437	S	B	75	162	322	283	165
339	439	H	B	71	148	308	288	164
352	463	S	B	96	178	364	338	154

NK = Not known.
H = Heifer or Hereford.
S = Steer.
B = Black.
CD = Calf died.
AB = Aborted.
BC = Blind calf.

APPENDIX TABLE 14. CONDITION SCORES - WEIGHT (LBS) TO HIP HEIGHT (INCHES) - CONTROL

Cow No.	Ht. Hips	11/16 Cond. Score	3/1 Cond. Score	Calving Cond. Score	5/9 Cond. Score	8/29 Cond. Score
Replication 1						
1	48	20	22	19	19	20
13	50	22	24	23	23	22
25	51	20	21	20	19	21
37	47	18	20	20	20	18
69	48	17	19	18	CD	CD
103	50	20	22	21	21	21
151	48	18	20	20	18	19
295	49	21	23	21	20	20
Replication 2						
27	50	22	23	22	21	CD
54	48	23	26	22	22	23
58	49	21	22	19	20	21
96	48	18	19	19	17	17
123	47	18	19	18	17	19
145	49	18	20	19	16	CD
159	50	21	23	18	CD	CD
303	48	20	23	21	20	20
Replication 3						
30	48	22	23	20	18	21
91	48	19	21	19	17	18
95	49	24	25	23	22	24
105	47	18	19	17	15	17
134	51	22	24	22	22	23
200	50	21	22	20	CD	CD
272	51	22	24	23	21	22
341	50	24	26	24	23	25

CD = Calf died.

APPENDIX TABLE 15. CONDITION SCORES - WEIGHT (LBS) TO HIP HEIGHT (INCHES) - 50 MG

Cow No.	Ht. Hips	11/16 Cond. Score	3/1 Cond. Score	Calving Cond. Score	5/9 Cond. Score	8/29 Cond. Score
Replication 1						
6	48	21	23	21	20	22
64	49	18	20	20	19	19
84	51	21	24	22	21	21
98	48	18	18	18	16	17
139	49	23	26	25	25	26
143	47	18	19	17	17	19
144	49	21	23	22	21	22
148	48	19	21	19	18	20
Replication 2						
23	49	23	25	25	21	23
65	49	20	23	21	21	21
93	48	19	20	19	17	20
109	48	19	21	19	19	20
127	48	18	20	19	19	19
183	49	21	24	21	19	21
186	48	21	23	22	20	20
306	49	19	20	18	17	19
Replication 3						
55	48	18	19	18	17	19
61	49	22	23	21	CD	CD
114	48	20	21	21	20	21
124	48	22	24	21	20	22
155	48	23	22	21	18	20
314	48	21	23	21	19	21
319	48	21	24	24	22	22
327	50	22	24	23	21	21

CD = Calf died.

APPENDIX TABLE 16. CONDITION SCORES - WEIGHT (LBS) TO HIP HEIGHT (INCHES) - 200 MG

Cow No.	Ht. Hips	11/16 Cond. Score	3/1 Cond. Score	Calving Cond. Score	5/9 Cond. Score	8/29 Cond. Score
Replication 1						
9	48	20	20	18	19	20
21	47	21	24	22	22	21
39	48	20	21	20	19	21
75	50	18	20	19	19	18
79	48	19	20	19	18	19
80	50	22	25	26	24	23
110	49	21	24	22	22	23
125	47	19	20	17	17	18
Replication 2						
20	49	22	24	22	21	23
29	49	23	26	24	22	24
81	51	23	23	21	19	21
117	49	19	21	22	17	19
173	50	22	24	22	20	22
188	49	23	24	22	20	23
199	48	19	21	19	19	21
279	49	21	25	22	20	21
Replication 3						
111	49	21	23	22	CD	CD
116	48	21	23	21	CD	CD
128	48	18	19	17	CD	CD
146	48	21	22	21	21	22
169	49	21	22	20	19	21
171	47	21	21	18	CD	CD
251	48	21	25	23	CD	CD
330	51	20	21	21	19	21

CD = Calf died.

APPENDIX TABLE 17. CONDITION SCORES - WEIGHT (LBS) TO HIP HEIGHT (INCHES) - 300 MG

Cow No.	Ht. Hips	11/16 Cond. Score	3/1 Cond. Score	Calving Cond. Score	5/9 Cond. Score	8/29 Cond. Score
Replication 1						
19	48	20	21	19	18	19
57	46	18	20	AB	AB	AB
73	46	17	18	16	16	16
85	50	24	26	23	22	24
87	48	19	20	19	19	19
92	48	19	21	20	20	19
160	50	18	19	19	18	18
323	48	21	23	23	BC	BC
Replication 2						
12	48	19	21	20	19	19
48	49	22	24	21	20	21
66	48	21	23	21	20	20
89	49	23	26	24	23	23
129	48	22	23	21	19	21
147	49	24	26	24	CD	CD
196	46	23	24	21	20	22
300	49	21	24	21	21	20
Replication 3						
13	50	20	22	20	19	21
16	49	24	26	24	22	21
24	50	20	21	19	17	19
88	48	22	24	22	21	21
150	46	17	19	16	16	17
305	46	20	22	20	18	19
339	48	22	24	22	20	23
352	50	25	28	25	23	25

BC = Blind calf.
AB = Aborted.
CD = Calf died.

APPENDIX TABLE 18. CONDITION SCORES - WEIGHT (LBS) TO HEART GIRTH (INCHES) - CONTROL

Cow No.	11/16 Ht. girth	11/16 Cond. Score	Calving Ht. girth	Calving Cond. Score	8/29 Ht. girth	8/29 Cond. Score
Replication 1						
1	72	13	68	14	69	14
14	73	15	71	16	71	15
25	73	14	71	15	73	15
37	67	12	68	14	65	13
69	68	12	66	13	CD	CD
103	71	14	70	15	71	15
151	71	12	68	14	68	14
295	75	14	71	14	69	14
Replication 2						
27	73	15	76	14	CD	CD
54	74	15	73	15	72	15
58	74	14	67	14	68	15
96	71	12	69	13	65	13
123	71	12	70	12	69	13
145	69	13	69	13	CD	CD
159	73	14	69	13	CD	CD
303	71	14	70	15	65	15
Replication 3						
30	73	15	70	14	68	15
91	71	13	68	13	66	13
95	77	15	75	15	73	16
105	69	12	68	12	65	13
134	74	15	73	16	73	16
200	71	15	70	14	CD	CD
272	72	16	72	16	71	16
341	73	17	75	16	73	17

CD = Calf died.

APPENDIX TABLE 19. CONDITION SCORES - WEIGHT (LBS) TO HEART GIRTH (INCHES) - 50 MG

Cow No.	11/16 Ht. Girth	11/16 Cond. Score	Calving Ht. Girth	Calving Cond. Score	8/29 Ht. Girth	8/29 Cond. Score
Replication 1						
6	72	14	69	15	71	15
64	69	13	68	14	66	14
84	73	15	74	15	72	15
98	70	12	68	12	68	12
139	74	15	76	16	75	17
143	67	13	65	12	65	14
144	72	14	72	15	71	15
148	72	13	69	13	67	14
Replication 2						
23	73	15	73	17	71	16
65	72	14	70	14	71	14
93	74	12	70	13	69	14
109	69	14	66	14	66	14
127	70	13	71	13	67	13
183	72	14	71	15	69	15
186	72	14	69	15	68	14
306	67	14	67	13	65	14
Replication 3						
55	71	12	66	13	66	14
61	72	15	70	15	CD	CD
114	68	14	69	14	69	15
124	75	14	71	14	71	15
155	75	15	70	14	70	14
315	72	14	70	14	70	14
319	73	14	70	16	71	15
327	74	15	73	16	71	15

CD = Calf died.

APPENDIX TABLE 20. CONDITION SCORES - WEIGHT (LBS) TO HEART GIRTH (INCHES) - 200 MG

Cow No.	11/16 Ht. Girth	11/16 Cond. Score	Calving Ht. Girth	Calving Cond. Score	8/29 Ht. Girth	8/29 Cond. Score
Replication 1						
9	71	13	67	13	66	14
21	72	14	72	15	69	14
39	75	13	71	14	71	14
75	69	13	69	14	67	14
79	68	13	67	14	65	14
80	74	15	74	17	73	16
110	72	14	73	15	71	16
125	69	13	66	12	65	13
Replication 2						
20	74	14	72	15	71	16
29	73	15	72	17	72	16
81	74	16	73	15	72	15
117	72	13	72	15	67	14
173	75	15	72	15	70	15
188	73	15	71	15	70	16
199	69	13	67	14	69	14
279	75	14	74	15	71	15
Replication 3						
111	72	14	70	15	CD	CD
116	70	14	70	15	CD	CD
128	72	12	65	13	CD	CD
146	71	14	73	14	71	15
169	72	14	71	14	69	15
171	68	14	67	13	CD	CD
251	72	14	74	15	CD	CD
330	71	14	71	15	69	15

CD = Calf died.

APPENDIX TABLE 21. CONDITION SCORES - WEIGHT (LBS) TO HEART GIRTH (INCHES) - 300 MG

Cow No.	11/16 Ht. Girth	11/16 Cond. Score	Calving Ht. Girth	Calving Cond. Score	8/29 Ht. Girth	8/29 Cond. Score
Replication 1						
19	72	13	72	13	68	13
57	68	12	AB	AB	CD	CD
73	64	12	62	12	62	12
85	75	16	72	16	71	17
87	70	13	67	14	67	14
92	69	13	70	14	65	14
160	71	13	65	14	66	14
323	73	14	73	15	CD	CD
Replication 2						
12	72	13	76	12	68	14
48	72	15	73	14	68	15
66	72	14	67	15	68	14
89	77	14	69	17	73	16
129	72	15	70	14	68	15
147	75	16	69	17	CD	CD
196	73	14	69	14	69	15
300	72	15	70	15	71	14
Replication 3						
13	71	14	68	15	69	15
16	75	16	73	16	72	14
24	72	14	69	14	68	14
88	71	15	69	15	66	15
150	70	11	65	11	66	12
305	68	14	69	13	65	13
339	71	15	71	15	NA	NA
352	79	16	76	16	74	17

CD = Calf died.
AB = Aborted.
NA = Not available.

APPENDIX TABLE 22. VOLATILE FATTY ACID CONCENTRATIONS - RELICATION 1

Treatment	Molar % Acetate	Propionate	Butyrate	Total MM/1
Control	74.8	18.2	7.0	57.7
	76.7	16.7	6.6	18.4
	75.8	17.3	6.9	35.2
	75.8	17.6	6.6	54.9
50	75.4	18.2	6.4	45.0
	76.2	17.6	6.2	55.5
	75.9	17.1	7.0	32.2
	74.9	18.4	6.7	44.9
200	73.9	19.8	6.3	45.5
	68.9	26.5	4.6	36.8
	74.8	19.3	6.0	40.5
	76.1	17.6	6.4	51.8
300	76.5	16.5	7.0	44.1
	70.1	24.6	5.3	41.3
	66.4	27.3	6.3	51.5
	74.0	20.2	5.8	36.1

APPENDIX TABLE 23. VOLATILE FATTY ACID CONCENTRATIONS - REPLICATION 2

Treatment	Molar % Acetate	Propionate	Butyrate	Total MM/1
Control	74.8	17.5	7.7	57.8
	75.0	17.3	7.7	54.4
	75.6	16.5	7.8	26.8
	75.6	16.6	7.8	59.7
50	76.5	17.5	6.0	25.3
	76.5	17.4	6.1	19.0
	75.8	17.4	6.8	41.0
	75.3	17.7	7.1	48.4
200	73.0	21.3	5.7	71.3
	72.8	21.0	6.2	57.2
	72.4	20.8	6.8	56.6
	71.0	23.2	5.8	62.9
300	73.1	21.8	5.0	36.5
	71.9	23.1	5.0	21.1
	74.4	22.0	3.7	7.2
	71.8	22.7	5.5	23.8

APPENDIX TABLE 24. VOLATILE FATTY ACID CONCENTRATIONS - REPLICATE 3

Treatment	Molar %			Total MM/l
	Acetate	Propionate	Butyrate	
Control	76.8	17.3	5.9	53.0
	77.3	16.6	6.1	44.7
	75.8	18.6	5.9	54.1
	76.4	17.6	6.1	55.6
50	74.8	17.8	7.5	54.1
	76.8	16.7	6.6	39.3
	75.3	17.4	7.3	57.9
	74.7	18.7	6.5	30.2
200	72.4	20.6	7.1	20.8
	71.0	22.1	6.9	56.8
	72.7	19.9	7.3	42.2
	71.3	21.3	7.4	41.7
300	72.9	21.2	5.9	28.4
	72.6	20.9	6.5	42.8
	71.8	21.7	6.5	55.5
	72.5	20.6	7.0	44.6