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HYPOMAGNESEMIA EFFECTS ON MAGNESIUM, CALCIUM AND POTASSIUM BALANCE IN LACTATING BEEF COWS

A Thesis

Presented for the

Master of Science

Degree

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ABSTRACT

The major objectives of this experiment were to determine the daily balance of magnesium, calcium and potassium in lactating beef cows under conditions of hypomagnesemia.

Three balance trials were conducted using lactating cows. Three dietary regimes were imposed: tetany-prone hay, good-quality hay and heavily fertilized fescue pasture (Treatments 1, 2 and 3, respectively). The tetany-prone hay was from pastures heavily fertilized with N and K which had produced hypomagnesemic tetany. Treatments 1 and 2 were conducted in metabolism stalls, and Treatment 3 cows were allowed to graze the tetany-prone pasture. Total collections were made in the stalls. The internal (acid-detergent lignin)-external (Cr_2O_3) indicator technqiue was used to determine fecal dry matter output and dry matter consumption of the pasture cows. Urine volume was estimated on the pasture cows using creatinine ratios. Milk production (calf-suckle technique) was estimated and sampled for cows on all treatments.

Pasture cows were found to have consumed less magnesium than the cows on tetany-prone hay or the control hay. Urinary excretion of magnesium was very low for cows on the tetany-prone hay and pasture. Excretion of magnesium in the milk remained the same regardless of treatment. Fecal excretion of magnesium was higher for cows on the two hay treatments than for cows on tetany-prone pasture. Magnesium balance was negative for both tetany-prone hay and pasture cows.

No differences were found between plasma magnesium levels of the tetany-prone hay and pasture cows, but plasma levels of control cows

were significantly higher. Treatment had no effect on plasma calcium or plasma potassium levels of the cows.

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CHAPTER I

INTRODUCTION

Magnesium is one of the critical mineral elements for ruminants. Wilson (1964) reported that 50% of the magnesium in the body is stored in bone. The remainder of the magnesium is located in soft tissues and is essential for normal neuromuscular activity and as an activator of enzymes involved in carbohydrate, protein and lipid metabolism (Rook and Storry, 1962). Hypomagnesemic tetany is a disorder of cattle and sheep caused by an abnormally low serum magnesium level and is known as grass tetany, grass staggers, lactation tetany, wheat pasture poisoning and winter tetany (Fontenot et al., 1973). "Grass tetany" was first related to low serum magnesium by Sjollema (1932).

Although a rather small percentage of the population is affected by hypomagnesemic tetany, it causes major economic losses in those herds where it is encountered. Grass tetany occurs mainly in mature lactating ruminants turned into lush, rapidly growing spring pastures according to a review by Grunes et al. (1970). The physical symptoms of grass tetany are excitability, incoordination, loss of appetite, viciousness, muscular tremors, excess salivation, grinding of teeth, general tetanic contractions, labored breathing, pounding heartbeat, coma, convulsion and death (Sims and Crookshank, 1956; Sjollema, 1932; Aikawa, 1971).

The lowered serum magnesium levels usually observed in animals suffering from hypomagnesemic tetany indicate that the disturbance is associated with a metabolic deficiency of magnesium. Either inadequate magnesium in the diet or the presence of agents or factors that interfere with the utilization of the magnesium in the diet of ruminants is the cause(s) of grass tetany.

Much research has been conducted concerning hypomagnesemia of ruminants, yet many questions are still unanswered as to the control and etiology of this syndrome. Absorption and excretion data of lactating beef cattle are very limited in the literature. Knowledge of the balance of magnesium and related minerals may provide insight into the cause of grass tetany.

The objective of this experiment was to determine the daily balance of calcium, magnesium and potassium in lactating beef cows under conditions of hypomagnesemia.

CHAPTER II

REVIEW OF LITERATURE

I. ABSORPTION OF MAGNESIUM

Much research has been conducted on the sites and methods of magnesium absorption in the ruminant. The exact location and method of uptake of magnesium is still not well delineated. Care and van't Klooster (1965) found that no net absorption of magnesium occurs in the abomasum and duodenum. This agrees with work of Tomas and Potter (1976) who found magnesium infused into either the abomasum or omasum was completely recovered at the duodenum, indicating a lack of net absorption of magnesium from these compartments. This is contrary to other research by Ben-Ghedalia et al. (1975) whose results demonstrated that a substantial amount of ingested magnesium was absorbed before the duodenum. They found that the greatest fall in the level of soluble calcium occurred after the first 3 m of the intestine, while a significant decrease in soluble magnesium was found only at 15 and 25 m from the pylorus. In the duodenum, 84, 78 and 62% of the total calcium, magnesium and phosphorus, respectively, were soluble, whereas in the digesta flowing through the terminal ileum, the corresponding values were 3.2, 7.2 and 19% for calcium, magnesium and phosphorus. The forestomach and the colon were found to be the main sites of magnesium net absorption; 1.12 mmol/hr was apparently absorped from the stomach and 1.05 mmol/hr from the colon. The rise of pH as the digesta advances along the intestine is accompanied by a concomitant decrease in magnesium solubility. Stevenson and Unsworth (1978) reported net absorption of magnesium occurred before the proximal duodenum and also lower down the alimentary tract. Kay et al. (1978) working with calves before and after weaning found magnesium net absorption occurred mainly in the large intestine. After weaning, they also found that absorption of magnesium before the ileum declined. Perry et al. (1967) and Pfeffer et al. (1970) found a net secretion of calcium, magnesium and potassium occurred in the upper small intestine. Absorption of these constituents was greatest in passage through the small intestines. Few changes occurred in the intestinal concentration of calcium and magnesium in passage through the cecum and large intestine.

Contrasting data are available on the absorption of magnesium from the rumen. Although the rumen mucosa has been found to be permeable to magnesium at very high concentrations in the rumen field, the average magnesium concentrations normally found are considered to be less than those required to overcome the electrochemical gradient, and measured uptakes from the rumen contents have indicated magnesium absorption from this site to be negligible (Care and van't Klooster, 1965). This is contrary to Tomas and Potter (1976), who concluded that no significant absorption of magnesium occurs from either the omasum or abomasum in sheep and that the reticulo-rumen is the principal site of magnesium absorption before the pylorus. They also stated that the absorption of magnesium postruminally is insufficient to maintain normal magnesium status in the animal. This agrees with work of Field and Munro (1977) who found that absorption in the stomach region was primarily in the rumen. They showed that magnesium can be absorbed from the stomach, and the rate of transport of magnesium from the rumen to blood is not proportional to ruminal concentration but approaches a limiting value with increasing concentration.

The dietary regime and state of nutrition also markedly affect the absorption of magnesium. Dietary calcium and phosphate have a marked effect on absorption. Toothill (1963) reported the apparent absorption of magnesium was significantly reduced by an increase in the dietary calcium level from 0.34 to 0.68% or of phosphorus from 0.39 to 0.79% and was further reduced when calcium and phosphorus were simultaneously increased to levels of 0.65 and 0.78%, respectively. Grace and Macrae (1972) found that protein supplementation had no effect on the extent or sites of magnesium absorption, but altering the feeding regime changed the proportion of the net absorption of magnesium occurring in the stomach and intestinal regions. McAleese et al. (1961) studying the absorption of ^{28}Mg by magnesium-deficient lambs found uptake of magnesium was much greater and urinary excretion was much less than by control lambs. Smith (1959a) working with calves found that 25-40% of the dietary magnesium intake was absorbed by the large intestines.

Ruminants absorb dietary magnesium inefficiently, but why this is so is not clear. The weight of evidence suggests that the rate limiting factor is not the amount of ultrafilterable magnesium in the liquid phase of the gut contents but the actual transport of magnesium across the gut wall (Field and Munro, 1977).

II. BALANCE OF MAGNESIUM

In considering the factors related to grass tetany, the balance of magnesium is very important. Three main factors seem to interplay in the cause of hypomagnesemia. They are intake, excretion and the blood plasma level of magnesium.

Intake

Kemp et al. (1961) found that the daily intake of Mg of cows on freshly cut grass from pastures was 16.62 g/day. The mean availability of the herbage magnesium in these trials was 17% within a range of 7 to 33%. This is close to the reported amounts of magnesium intake of cows on spring pasture by Rook and Blach (1958). They found the intake of magnesium to vary from 9.5 to 12.2 g/day. O'Kelley and Fontenot (1969) using regression equations obtained at each stage of lactation for the effect of dietary magnesium on serum magnesium predicted magnesium intake of 20.9, 22.1 and 18.0 g/day would be required to maintain serum magnesium levels of 2.0 mg/100 ml during early, mid and late lactation, respectively. Another factor reported by Field (1967b) is that the increased susceptibility to grass tetany with age has been attributed to a reduction in the magnesium reserves of ruminants with age. But their results with grazing ewes suggest that a reduction with age in the intake of magnesium may be an additional factor. In one study by Lomba et al. (1968) the magnesium absorption is enhanced by increasing magnesium and calcium intake, while nitrogen and to a lesser extent fat, giving higher fecal losses, had an opposite effect. The urinary losses of magnesium are not related to magnesium intake and digestibility, and the balance is thus directly proportional to the digestible amounts.

Excretion

In three experiments with dairy cattle by Rook and Balch (1958), the mean proportion of the ingested herbage magnesium excreted in the feces was 82.3, 83.0 and 82.4% with wide variations between individual animals in their utilization of herbage magnesium. Lomba et al. (1968) also reported that fecal endogenous losses of magnesium can be highly variable. In two trials with lambs, Fontenot et al. (1960) fed a high protein, high potassium ration which resulted in a significant increase in fecal magnesium excretion when compared with feeding a control ration. The increased fecal excretion of magnesium was associated with a decreased plasma level. Their findings are consistent with the view that rations high in protein or potassium may induce tetany by interfering with the absorption or retention of magnesium. Kemp et al. (1961) reported on an average 83% of the magnesium ingested was excreted in the feces within a range of 67 to 93%. In other work on fecal magnesium excretion, House and Van Campen (1971) found that increased intake of potassium chloride significantly depressed magnesium absorption, reduced urinary excretion and lowered endogenous fecal magnesium excretion but elevated total fecal magnesium output. Smith (1959b) found that subcutaneous injections of magnesium sulfate had no apparent effect on the endogenous fecal excretion although urine excretion was enormously increased and plasma magnesium was maintained in calves.

Urine is another means by which animals excrete magnesium. In one study by Rook et al. (1958), the excretion of magnesium in the urine varied from 0.06 to 7.92 g/day. The very high excretion which occurred on a ration providing 31 g of magnesium a day suggests that the urine is a major route for the excretion of magnesium absorbed in excess of the requirements. These results suggest that the renal threshold for magnesium is of the order of 2.0 mg/100 ml of blood serum (Rook et al., 1958). Fisher et al. (1978) reported results that indicated urinary magnesium level may be a more accurate and sensitive measure of magnesium status than blood serum magnesium. They found the species of forage greatly influenced blood serum and urinary magnesium levels. Orchard grass tended to lower serum and urinary magnesium, while tall fescue seemed to maintain the magnesium levels. Similar work by Kemp et al. (1961) found a close correlation between the serum magnesium levels and the excretion of magnesium in urine by lactating cows. They reported that urinary excretion of magnesium fluctuated from 0.40 to 4.24 g of magnesium a day with a mean value of 1.77 g of magnesium a day. A change from winter rations to cut young grass was invariably followed by an immediate fall in urinary magnesium excretion, and in animals in which the excretion of urinary magnesium fell virtually to zero, there was also a progressive development of hypomagnesemia (Rook and Balch, 1958). Field (1967a) working with sheep found there was a highly significant rectilinear relationship between the amount of magnesium in the urine and the magnesium intake. Garces and Evans (1971) with growing cattle found the excretion of magnesium in urine was high when compared with calcium. They found the average excretion of magnesium into the urine was 14% of the ingested magnesium.

Cow's milk generally contains the same magnesium content regardless of a decline in magnesium intake or if hypomagnesemia occurs according to Rook and Storry (1962). Many researchers have reported cow's milk normally contains approximately 120 ppm of magnesium with a range of 70-180 ppm (Kemp et al., 1961; Grunes et al., 1970).

Plasma

Ross and Halliday (1975) surveyed 200,000 cows in Scotland and found a mean serum magnesium level of 2.1 mg/100 ml. The lower limit of the normal range for serum magnesium is 1.8 mg/100 ml; when serum magnesium falls below this level, the excretion of magnesium in the urine is greatly reduced (Kemp et al., 1961). Forbes (1972) analyzed plasma samples of 25 cases of grass tetany and found that 88% of all cases of hypomagnesemic tetany were also hypocalcemic. Several other trends have been noted on plasma magnesium. Wise et al. (1963) found serum magnesium levels were decreased with high levels of dietary phosphorus when dietary calcium levels were low. Diets with high calcium levels resulted in a normal serum magnesium level even at the highest phosphorus level. Another interesting factor of serum magnesium levels is that older cows tend to have lower levels of serum magnesium (Fisher et al., 1978). This may be partially explained by the fact that 30% of skeletal magnesium in young animals can be mobilized and translocated under conditions of magnesium deprivation, while in adult animals only 2% of bone magnesium can be used for physiological needs (Rook and Storry, 1962).

III. FACTORS AFFECTING MAGNESIUM UTILIZATION

Many factors have been reported to affect the utilization of magnesium by the ruminant. Some of the factors are: nitrogen, other minerals, energy level, organic acids and many other factors.

Nitrogen

The incidence and severity of hypomagnesemia appears to be increased by the application of heavy dressings of nitrogen (Bartlett et al., 1957). They found blood pH and the concentration of blood serum calcium, sodium and potassium in cattle were unaffected by a change from winter feed to spring grazing. But they found a marked increase in blood serum nonprotein and urea nitrogen and blood ammonia nitrogen on spring pastures that had received a heavy dressing of nitrogen fertilizer and had a high nitrogen content. Their results reflect a high ammonia production in the gut, which may be responsible for the disturbance in magnesium metabolism which produces hypomagnesemia. This work by Bartlett et al. (1957) seems to be in agreement with a hypothesis by Wilcox and Hoff (1974). Their hypothesis suggests that grass tetany is caused by the peculiar growing conditions during early spring resulting in unique compositional characteristics of spring forages. Winter leaching, low soil temperature and application of ammonium-containing fertilizer make the ammonium ion the principal source of nitrogen available to plants during this period. Absorption of ammonium by the plant results in greatly reduced intake of magnesium and calcium with little effect on potassium and produces high amide concentration in the plant with depletion of carbohydrates. These factors combine in the animal to create a high concentration in the rumen of free ammonia and an increased pH, depletion of the remaining carbohydrate and a further reduction in the availability of the already low magnesium and calcium (Wilcox and Hoff, 1974). Moore et al. (1972) presented results contradicting to these. Their results with wether lambs indicated that high levels of dietary nitrogen do not interfere with magnesium absorption but appear to result in a small increase in urinary magnesium. Other workers have reported that the overall utilization, as evaluated in balance trials, was less for the high nitrogen-containing forages (Stillings et al., 1964). They found the average apparent availability of magnesium in the low nitrogen-containing forages ranged from 18 to 24%, while the high nitrogen-containing forages ranged from 11 to 16%. The decreased apparent availability of magnesium in the high nitrogen-containing forages was reflected by decreased urinary magnesium excretions and in most cases by decreased magnesium balance.

Kemp et al. (1966) suggested that the unfavorable influence of nitrogen fertilization of grassland may be at least partly due to an increase in the fat content in the herbage, resulting in insoluble magnesium soaps in the feces. This work agrees with the work of Mayland et al. (1974) who found a rapid increase in the ratio of nitrogen to total water-soluble carbohydrates coincided with the onset of tetany and is thought to be the primary factor which indirectly decreases magnesium availability and precipitates tetany.

Potassium

Many researchers have observed an association between high potassium levels in the grass or diet and grass tetany. Newton et al. (1972) found high potassium intake decreased the average apparent magnesium absorption by 46%. Fecal magnesium excretion was increased and urinary magnesium was much lower for lambs fed high-potassium diets. It appears that high-potassium intake, which generally occurs when ruminants are first allowed access to lush pastures, could have a detrimental effect on the absorption and utilization of magnesium. Similar results were reported by Suttle and Field (1967) and House and Van Campen (1971). Kunkel et al. (1953) included 5% of potassium as the bicarbonate in the rations of sheep and found a significant lowering of serum magnesium content. This hypomagnesemia was without clinical symptoms. Two explanations have been expressed on the effect of high potassium on magnesium utilization. House and Van Campen (1971) suggest that the high levels of potassium inhibit alimentary absorption of magnesium and increase retention of magnesium by the body cells is a possible mechanism for the development of hypomagnesemia. Lentz et al. (1976) stated that elevation of insulin levels caused by abruptly increased potassium increased glucagon secretion and could eventually lead to depletion of gluconeogenic precursors and subsequent ketosis. Uncontrolled ketosis in turn could lower blood pH, triggering onset of grass tetany coma. Other workers report no effect on blood serum magnesium of sheep fed high levels of potassium (Pearson et al., 1949; Daniel et al., 1952).

Energy Level

Another factor that appears to be important in magnesium utilization is energy level. Madsen et al. (1976) supplemented hay rations with varying levels of glucose and found an increased apparent magnesium absorption and urinary magnesium output in wethers. Glucose added to vegetative grass did not change magnesium absorption, but plasma magnesium concentrations were higher than controls. This study suggests that supplementation with a readily available carbohydrate during periods of dietary magnesium deficiency may reduce the rate of plasma magnesium decline characteristic of ruminants grazing spring grass. House and Mayland (1976b) working with wethers reported similar results that support the view that supplemental energy may enhance the availability of magnesium.

Organic Acids

Some research indicates that high levels of the organic acids, citric and trans-aconitic, may influence the utilization of magnesium. Bohman et al. (1969) reported a tetany that resembles field cases of grass tetany has been experimentally induced in cattle by orally administering potassium chloride plus either citric or trans-aconitic acid. These two acids or potassium chloride administered separately did not produce tetany. Administration of potassium chloride alone lowered plasma magnesium in 24 hours to 1 week. Citric and trans-aconitic acid are thought to complex with magnesium thus reducing the availability to the ruminant. Other work by House and Van Campen (1971) found little effect on magnesium metabolism from feeding various levels of citric acid.

Other Factors

Many other factors are thought to be involved in the utilization of magnesium. One factor that appears to affect magnesium utilization is age. Chicco et al. (1973) studied the relationship in ruminants between plasma magnesium and voluntary feed intake as influenced by age and dietary magnesium. He found mature animals have a more rapid decrease in feed consumption and plasma magnesium because of a limited ability of the older animals to mobilize skeletal magnesium. Fasting appears to affect magnesium utilization also. Herd (1966) found a significant drop in serum magnesium levels occurred after a 24-hour fast, and a significant drop in both serum calcium and magnesium levels occurred after a 48-hour fast. He considered that short fasts occur in practice due to estrus, severe weather and other reasons and may play an important role in precipitating symptoms in susceptible animals. Suttle and Field (1967) reported that increasing the water intake increased the urinary outputs of magnesium by 33%, and the retention of magnesium was significantly reduced by 0.2 g/day. Other research by Powley and Johnson (1976) using sheep in metabolism stalls concluded that artificially drying grass causes a reduction in magnesium availability. Another important factor reported to affect magnesium utilization is vitamin D. Stillings et al. (1964) reported the supplemental vitamin D_2 increased the apparent availability and retention of calcium and magnesium in animals consuming low nitrogen-containing forage but had no effect when given to animals consuming high nitrogen-containing forage. In contrast to this, Boling et al. (1979) found that an injection of cholecalciferol(D_3) decreased serum magnesium for 3 days postinjection. Another theory suggests that the parathyroid may control magnesium action in cattle. Todd et al. (1962) administered parathyroid extract to dairy cattle and found no effect on plasma levels of magnesium.

IV. SUPPLEMENTAL SOURCES OF MAGNESIUM

Much research has been conducted trying to determine an effective and economical procedure for supplying supplemental magnesium to grazing cows. Many methods have been tried with various responses. Allcroft (1954) used an oral supplement of calcined magnesite and found it to be effective in preventing tetany. This agrees with work by Line et al. (1958) who gave a daily supplement of 2 oz calcined magnesite in a premix or drench and found it to give adequate protection against the development of hypomagnesemia. They reported a supplement of 3.5-4 lb of linseed cake and 12,000 I.U. of vitamin D gave only partial protection. Storry and Rook (1963) determined the availability of the magnesium of various salts by giving them as supplements to a basal diet and measuring the increase in urinary excretion of magnesium. The availabilities of the oxide, nitrate, acetate and lactate were similar, but the citrate gave a markedly higher value. The sulfate and in one cow the chloride gave a lower value. Gerken and Fontenot (1967) and Moore et al. (1971) both compared magnesium oxide and dolomitic limestone and found magnesium absorption was significantly greater for the magnesium oxide supplemented ration. They also found that feeding dolomitic limestone depressed the digestibility of the carbohydrate fractions and energy of the ration. Magnesium phosphate as a dietary supplement was fed to lactating cattle and found to give significant improvements in plasma magnesium and reduced the incidence of individual cows with low values (Ritchie and Fishwick, 1977). Another method for supplying magnesium to cattle is in their water supply. Rogers and Poole (1976) compared magnesium oxide in the feed at a rate of 22.3 g magnesium/cow/day and magnesium acetate in the drinking water at a rate of 15.5 g magnesium/cow/day against a control group that received no supplemental magnesium. Plasma levels were increased .21 and .39 mg/100 ml for magnesium oxide and magnesium acetate, respectively. McLaren et al. (1975) compared supplemental magnesium in the form of a magnesium oxide-salt-dry molasses-cottonseed meal mixture and a magnesium chloride-liquid molasses mixture and found both forms reduced the incidence of grass tetany. Their data suggested that early initiation of magnesium supplementation and continuous monitoring of intake to assure adequate consumption of supplemental magnesium is vital to successful prevention of grass tetany by this means. Another way of supplementing magnesium is with magnesium rumen bullets. House and Mayland (1976a) reported that magnesium rumen bullets can provide substantial amounts of magnesium, but the rate of decomposition in the reticulo-rumen was highly variable.

Another means of supplying magnesium has been to apply various magnesium compounds to the pastures. McConaghy et al. (1963) reported applications of calcined magnesite and dolomitic limestone as soil treatments raised the magnesium contents of herbage slightly but not to levels judged safe. Low blood serum magnesium levels were recorded for cows grazing this herbage. Magnesium sulfate applied as a spray temporarily raised the apparent magnesium content of the herbage but was easily washed off by rain. Rogers and Poole (1971) found foliar dusting was highly effective in reducing the incidence of hypomagnesemia and maintained a normal mean level of magnesium in serum for at least 3 weeks. Other work shows that 6.6 g of magnesium oxide given as a daily drench did not increase plasma magnesium values at 24 hours (Ritchie and Hemingway, 1963). They did get an increase in plasma magnesium of 0.5 mg/100 ml 4 hours after drenching. According to Smith et al. (1975), the daily feeding of 5 lb corn and 2 oz magnesium per cow is a very effective method of maintaining normal blood magnesium level and preventing grass tetany.

V. RECOMMENDED DIETARY LEVEL FOR MAGNESIUM

Magnesium is the fourth most abundant cation in the body and second most abundant intercullular cation (Care, 1967). It is involved in many enzyme systems particularly those involving the transfer of energy (Wilson, 1964). Mature lactating beef cows require 12-30 mg per kilograms of body weight per day. Most cattle feeds appear to contain adequate amounts of magnesium except certain pastures in early spring (N.R.C., 1976). N.R.C. (1976) recommends .18% of the diet dry matter as magnesium is adequate to maintain normal body function. This is slightly higher than a review by Emery (1976) that recommended .15% of the ration dry matter as magnesium being adequate.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. GENERAL DESIGN OF EXPERIMENT

A balance trial was conducted using 18 lactating Angus cows. Three dietary regimes were imposed: tetany-prone hay, control hay and heavily fertilized fescue pastures (Treatments 1, 2 and 3, respectively). The tetany-prone hay was from pastures heavily fertilized with N and K which had produced hypomagnesemic tetany. The fescue pasture had been heavily fertilized with N and K and the pasture stockpiled for winter grazing. The balance trials were conducted in February and March, 1978. Treatments 1 and 2 were conducted in metabolism stalls, and Treatment 3 cows were allowed to graze the tetany-prone pasture. Forage, feces, urine, milk and blood samples were collected. These data collected in 1978 were combined with similar data from the two previous years. In 1976 the balance trials were conducted imposing Treatments 1 and 2, tetany-prone hay from Highland Rim Experiment Station and control hay, respectively. Then, in 1977 a balance trial was conducted imposing Treatment 3.

II. MANAGEMENT AND PROCEDURE

Animals

Thirty Angus cows bred to calve in late January were selected from the herd at Holston farm. Ten cows were allotted to each treatment according to weight, age and plasma magnesium. The average weight for all cows was 435 kg, and the average age was 10 years. Cows were placed on their respective treatments November 7, 1977. Cows fed hay diets were housed inside a barn at Holston farm and fed ad libitum tetany-prone and control hay, respectively, and NaCl free choice. Treatment 3 cows were maintained on the tetany-prone pasture at Holston farm. All cows were weighed and bled via jugular veinipuncture monthly until January and then biweekly until collection trials began in mid-February. Cows on Treatments 1 and 2 were fed in dairy stanchions at Holston to adapt them for metabolism trials.

Treatments

Six cows per treatment were chosen for the collection trials. Cows were selected according to plasma magnesium and the age of their calves. The cows on Treatments 1 and 2 were placed in metabolism stalls similar to those described by Hobbs et al. (1950), except they had dairy free stall rails for sides and were lower to the floor. The cows were in the stalls for 14 days with their calves in individual crates along side. Calves were allowed to nurse twice daily. Cows were fed and watered twice a day while in the stalls. Total collection of feces and urine were made for 7 days and milk production estimated and sampled using the calf-suckle technique every 12 hours during the 7-day collection period. Since total collections of feces and urine are impractical on grazing animals, the total dry matter consumed and total fecal dry matter output was estimated for Treatment 3 cows by the Cr_2O_3 dilution and internal indicator method of Linkous et al. (1955) for a 7-day preliminary and a 7-day collection period. Creatinine ratios were used to determine urinary excretion (Albin and Clanton, 1966; Field, 1964).

Data Collected

The daily forage consumption of each cow on Treatments 1 and 2 was measured and recorded. Total feces were collected, weighed and recorded. Approximately 2% of the forage and feces samples were dried, ground and stored until analyses of magnesium, calcium and potassium were conducted. Total urine volume was collected on each cow via a 22 gauge Foley catheter. Samples of approximately 100 ml of milk from each cow were taken when the calf was half through nursing. Milk and urine samples were stored at -4°C until they were thawed for analysis. Each cow on all treatments was fed 250 g of a pelleted feed containing 9.5 g Cr_2O_3 twice a day for 14 days. Grab samples of feces and urine were collected twice daily for the second 7 days from the pasture cows on Treatment 3. Fecal DM output and forage DM intake were estimated using equation 1 and 2, respectively. The formulas are from Crampton and Harris (1969):

$$\text{Fecal DM output (g/day)} = 19 \text{ g } Cr_2O_3 \text{ in feed} \times 100 \; / \; \% \; Cr_2O_3 \text{ in feces grab sample DM} \qquad (1)$$

$$\text{Forage DM intake (g/day)} = (\text{Fecal DM output} \times \text{Fecal ADL}) \; / \; (\% \text{ ADL in forage}) \qquad (2)$$

Urine volume on pasture cows was estimated using:

$$\text{Urine volume (ml/day)} = 50.9 \times \text{WT (kg)} \; / \; \text{Concentration of creatinine in grab urine sample} \qquad (3)$$

(50.9 mg of creatinine/kg BW was a constant determined using data from Treatments 1 and 2 where total collections were made.)

Milk production was estimated and sampled as in Treatments 1 and 2. Grab pasture samples were collected to determine the mineral content of the forage consumed by Treatment 3 cows. Blood samples were taken twice on all cows during the collection periods. Blood was taken via jugular veinipuncture using heparinized syringes and tubes. The blood was centrifuged and plasma separated and frozen for subsequent analysis.

III. CHEMICAL ANALYSIS

Plasma

Plasma samples were diluted to a known volume for stable mineral analysis of magnesium, calcium and potassium. All mineral analyses were run using a Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer, observing the standard procedure for the preparation of different samples.

Forage and Feces

Dry matter determinations (A.O.A.C., 1975) were made on forage and feces. Approximately 2 g of forage and fecal samples were taken and ashed at 600°C for 4 hours and put into solution with 5 ml of 6NHCL. All samples were then diluted to a known volume for stable mineral analysis. Forage and feces were also analyzed for acid detergent fiber and acid detergent lignin by the method of Van Soest and Vine (1967). Feces were analyzed for chromium according to the method of Williams et al. (1962). Forages were also analyzed for crude protein by the Kjeldahl method (A.O.A.C., 1975).

Urine and Milk

Urine and milk samples were frozen until analysis could be conducted. Five milliliters of each urine sample were ashed at 600°C for 4 hours, then put into solution with 3 ml of 6N HCl and diluted to a known volume. Creatinine determinations were made using the Hycel Creatinine Test.[1]

Milk samples were thawed in warm water and shaken to redisperse sample. It was then treated exactly as urine.

All samples were analyzed for stable magnesium, calcium and potassium using the above-prescribed methods. To prevent phosphate interference in magnesium and calcium analysis, .1% Lanthanum Trioxide was added.

IV. STATISTICAL ANALYSIS

The data were analyzed statistically with programs prepared by Barr et al. (1976). Analyses of variance were used to determine if any independent variables explained any variation in the dependent variable. The model used was:

$$Y_{ij} = u + t_i + k_j + e_{ij}$$

where:

Y_{ij} = dependent variables.

u = theoretical population mean.

t_i = effect of treatment, $i = 1 - 3$.

[1]Hycel, Inc., Houston, Texas.

k_j = effect of year, j = 1 - 3.

e_{ij} = random error.

If differences were determined by F test, least square means were separated using the Student Neuman-Keuls test (Sokal and Rohlf, 1969). In addition to this, plasma mineral levels obtained from November to March were fitted to a trinomial regression on day. The regression equation used was:

$$\hat{Y} = a + b_1(\text{day}) + b_2(\text{day}^2) + b_3(\text{day}^3)$$

where:

$\hat{Y}$ = dependent variables.

a = intercept.

day = day of trial.

b_1, b_2, b_3 = the partial regression coefficients for each dependent variable on the independent variable = day, day^2, day^3.

Plasma mineral levels were also fitted to a trinomial regression on day with calving date held constant. Duncan's Multiple Range Test was used to separate mean plasma mineral values.

CHAPTER IV

RESULTS AND DISCUSSION

I. BALANCE DATA

The forage analyses during collection periods are presented in Table 1. The control hay averaged higher in magnesium content than tetany-prone hay or tetany-prone pasture. The calcium content was lowest for tetany-prone pasture. Nitrogen content was higher for tetany-prone pasture than the two types of hay.

Daily magnesium balances for cows on each treatment are presented in Table 2. Magnesium intake was higher ($\underline{p} < .05$) for cows on the control and tetany-prone hays than for tetany-prone pasture cows. No significant difference was found between magnesium intake for the cows on the control and tetany-prone hay, although the cows on the control hay averaged higher. Fecal magnesium excretion was higher ($\underline{p} < .05$) for cows on tetany-prone and control hays than the tetany-prone pasture cows. Fecal magnesium excretion was higher for the cows on tetany-prone hay than the control-hay cows but was not statistically significant. Urinary magnesium values were highest ($\underline{p} < .05$) for the cows fed control hay. Milk magnesium was not significantly different for any of the treatments. The cows on the tetany-prone pasture and tetany-prone hay both had a negative magnesium balance, and the control-hay cows maintained a positive balance. Differences among the magnesium balance least square means were not statistically significant. The feces was the main route of magnesium excretion for cows on all treatments.

Table 1. Forage analysis during collection periods.

Variable	Treatment: Tetany-Prone Hay 1976	Tetany-Prone Hay 1978	Control Hay 1976	Control Hay 1978	Tetany-Prone Pasture 1977	Tetany-Prone Pasture 1978
Mg[a]	1.28	2.82	1.66	2.95	1.97	1.82
Ca[a]	7.97	4.43	4.04	9.69	3.22	4.91
K[a]	20.99	41.61	25.27	26.88	28.86	24.34
CP[b]	13.5	12.5	10.2	11.2	19.5	13.5
ADF[b]	43.30	43.25	42.40	39.64	26.07	32.31
ADL[b]	7.10	6.76	6.55	7.18	3.54	7.95

[a]Expressed as mg/g DM basis.

[b]Expressed as percent of DM.

Table 2. Least square means of daily magnesium balance in grams (±S.E.M.).

Item	Treatment[a]		
	Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
No. of animals	10	10	12
Intake	$16.24^{b} \pm 1.18$ (13.53)	$18.36^{b} \pm 1.14$ (16.48)	$6.75^{c} \pm 1.03$ (9.76)
Excretion			
Fecal	$16.86^{b} \pm 1.71$ (12.90)	$13.24^{b} \pm 1.66$ (9.36)	$8.40^{c} \pm 1.49$ (10.53)
Urinary	$.83^{c} \pm .28$ (.27)	$1.79^{b} \pm .25$ (1.47)	$-.32^{d} \pm .22$ (.21)
Milk	$.58^{b} \pm .06$ (.49)	$.64^{b} \pm .60$ (.54)	$.53^{b} \pm .05$ (.56)
Balance	$-.70^{b} \pm 2.02$ (-.13)	$2.89^{b} \pm 1.84$ (5.10)	$-2.26^{b} \pm 1.67$ (-1.53)

[a]Values in parentheses are raw means across year; least square means calculated from individual observations.

[b,c,d]Least square means within a row superscripted with different letters are significantly different ($p < .05$).

Daily calcium balance for cows on each treatment is presented in Table 3. Calcium intake was highest ($p < .05$) for cows on the control hay and lowest ($p < .05$) for cows on the tetany-prone pasture. Fecal excretion of calcium was higher ($p < .05$) for the control-hay cows than the tetany-prone pasture cows. Fecal excretion of calcium by the tetany-prone hay cows was not significantly different from those on the other two treatments. Fecal excretion of calcium showed more variation than the calcium intake as evidenced by the standard error of the means. Urinary calcium excretion was not different from control and tetany-prone hay cows but was higher ($p < .05$) for the tetany-prone pasture cows. Excretion of calcium in the milk was not statistically different among cow treatments. Cows on the control hay maintained a positive balance of calcium that was higher ($p < .05$) than both the tetany-prone hay and tetany-prone pasture cows. The tetany-prone hay and tetany-prone pasture cows were in a negative calcium balance but were not significantly different. The main excretory pathway for calcium was also the feces.

Daily potassium balance data are shown in Table 4. Potassium intakes were different ($p < .05$) from each other for all treatments. Potassium intake was highest ($p < .05$) for cows on the tetany-prone hay and lowest ($p < .05$) for cows on the tetany-prone pasture with the control cows intermediate between the two other treatments. No differences were found in the fecal excretion of potassium between cow treatments. Urinary potassium excretion was not different for the tetany-prone or control-hay cows and was lower ($p < .05$) for the tetany-prone pasture cows. Excretion of potassium via the milk was similar for cows on all treatments. Means for cows on all treatments showed negative potassium balances.

Table 3. Least square means of daily calcium balance in grams (±S.E.M.).

Item	Treatment[a]		
	Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
No. of animals	10	10	12
Intake	$27.52^{c} \pm 3.69$ (25.69)	$58.64^{b} \pm 3.58$ (58.61)	$17.52^{d} \pm 3.21$ (22.02)
Excretion			
Fecal	$28.13^{bc} \pm 5.05$ (20.83)	$36.64^{b} \pm 4.90$ (30.44)	$19.16^{c} \pm 4.40$ (25.02)
Urinary	$.13^{c} \pm .07$ (.07)	$.16^{c} \pm .06$ (.12)	$.51^{b} \pm .51$ (.57)
Milk	$6.90^{b} \pm .87$ (6.40)	$7.42^{b} \pm .84$ (6.85)	$6.45^{b} \pm .76$ (6.54)
Balance	$-5.79^{c} \pm 5.92$ (-1.61)	$14.70^{b} \pm 5.39$ (21.19)	$-9.17^{c} \pm 4.88$ (-10.11)

[a]Values in parentheses are raw means across year; least square means calculated from individual observations.

[b,c,d]Least square means within a row superscripted with different letters are significantly different ($p < .05$).

Table 4. Least square means of daily potassium balance in grams (±S.E.M.).

Item	Treatment[a]		
	Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
No. of animals	10	10	12
Intake	218.77^{b} ± 10.61 (179.30)	180.41^{c} ± 10.30 (151.10)	99.04^{d} ± 9.25 (139.01)
Excretion			
Fecal	63.50^{b} ± 8.77 (24.20)	59.95^{b} ± 8.51 (21.24)	66.23^{b} ± 7.65 (87.05)
Urinary	165.96^{b} ± 11.77 (106.49)	157.02^{b} ± 10.71 (117.02)	24.47^{c} ± 9.70 (73.68)
Milk	6.71^{b} ± .71 (6.43)	7.42^{b} ± .69 (7.27)	6.06^{b} ± .62 (6.46)
Balance	-7.59^{b} ± 13.99 (42.18)	-45.84^{c} ± 13.01 (5.57)	-1.74^{b} ± 11.55 (-28.18)

[a] Values in parentheses are raw means across year; least square means calculated from individual observations.

[b,c,d] Least square means within a row superscripted with different letters are significantly different ($p < .05$).

The mean magnesium intake of the cows on tetany-prone pasture (Table 2) is within the range reported by Rook and Balch (1958). The intake of magnesium by the tetany-prone hay cows and control-hay cows are in general agreement with the work of Kemp et al. (1961). Lomba et al. (1968) reported that fecal endogenous losses of magnesium are highly variable which could explain some of the variation in fecal magnesium loss among treatments. Another possible explanation of the high fecal excretion is an error in the collection of fecal samples. Crampton and Harris (1969) stated that at least 50 grab fecal samples should be taken from each animal to keep the error below 5%. He also states that the chromic oxide should be fed for at least 10 days before the start of sampling. In this study only 14 samples per cow were taken and Cr_2O_3 fed 7 days prior to collection. Another possible explanation of the high fecal magnesium is that the cows were depleting their bone stores of magnesium. Beckmann (1977) reported a decrease in bone magnesium with mature sheep that suggests some magnesium is being mobilized from the bones. Another factor that could have introduced error into the magnesium balance of the pasture cows was the underestimation of the pasture ADL. Grab samples of pasture were taken at random and may not represent the actual grazing of the cows. The high excretion of magnesium by the tetany-prone hay cows could be related to the high intake of potassium. This is in agreement with work by House and Van Campen (1971) who found that increased intake of potassium significantly depressed magnesium absorption. Lomba et al. (1968) reported that magnesium absorption is enhanced by increasing magnesium and calcium intake in dry and in lactating cows. The calcium intake was lower (p < .05) for the tetany-prone hay cows than the control cows which could account for the depressed absorption of magnesium. The same relationship is evident in the cows on pasture. Bartlett et al. (1957) reported increased intake of nitrogen reduced the availability of magnesium. This could explain poor absorption of magnesium by the pasture cows.

Urinary excretion of magnesium is within the range reported by Rook et al. (1958) with dairy cows. These same workers reported urine was a major route for the excretion of magnesium absorbed in excess of requirements which suggests the cows fed control hay were closer to meeting magnesium requirements than the tetany-prone hay and pasture cows.

Milk magnesium remained constant across treatments and agrees with values reported by Grunes et al. (1970). This is consistent with work by Rook et al. (1958) who found cows to invariably meet the magnesium requirements for milk production.

Rook et al. (1958) found the body retention of magnesium ranged from -1.5 to 5.6 g/day. This agrees with these balance data. Rook et al. (1958) reported body retention of magnesium appeared to be independent of the dietary supply of available magnesium but dependent on the rate of retention of calcium. In these data the control-hay cows retained more (p < .05) calcium which could account for the increased retention of magnesium by the cows fed control hay.

II. PLASMA DATA

Plasma data presented is from 1978 only. Plots of the treatment regression curves for plasma magnesium levels are illustrated in Figure 1. Day 1 corresponds to November 7, 1977, and day 144 to April 6, 1978. Analysis of variance showed treatment had a significant effect on plasma magnesium. Mean plasma magnesium levels are presented in Table 5. The loss in weight of the cows on all treatments was not significantly correlated to the plasma magnesium, calcium or potassium. Plasma magnesium and plasma calcium were found to be significantly ($\underline{p} < .01$) correlated. Plasma magnesium values of the control cows were higher at the start of the trial and remained significantly higher ($\underline{p} < .05$) than the tetany-prone pasture cows throughout the trial except on day 138 when no difference was found. The plasma magnesium of the control cows compared with the tetany-prone hay cows was the same at the start of the trial but greater ($\underline{p} < .05$) until day 96 when they were the same again. There were no differences found between the plasma magnesium of the tetany-prone hay and tetany-prone pasture cows. All cows had a similar pattern in plasma magnesium values. All values dropped slightly at the start and then increased until approximately day 100, then dropped sharply. No differences were found for the mean plasma magnesium within the control-hay cows except between day 1 and day 124 ($\underline{p} < .05$). Within tetany-prone pasture cows and within tetany-prone hay cows, no differences were found for plasma magnesium. Plasma magnesium of the tetany-prone pasture cows at the end of the trial averaged 1.06 mg/100 ml within a range of 1.27-.23 mg/100 ml. The lowest values recorded were among the tetany-prone pasture cows by cows 188 and 845, .35 and

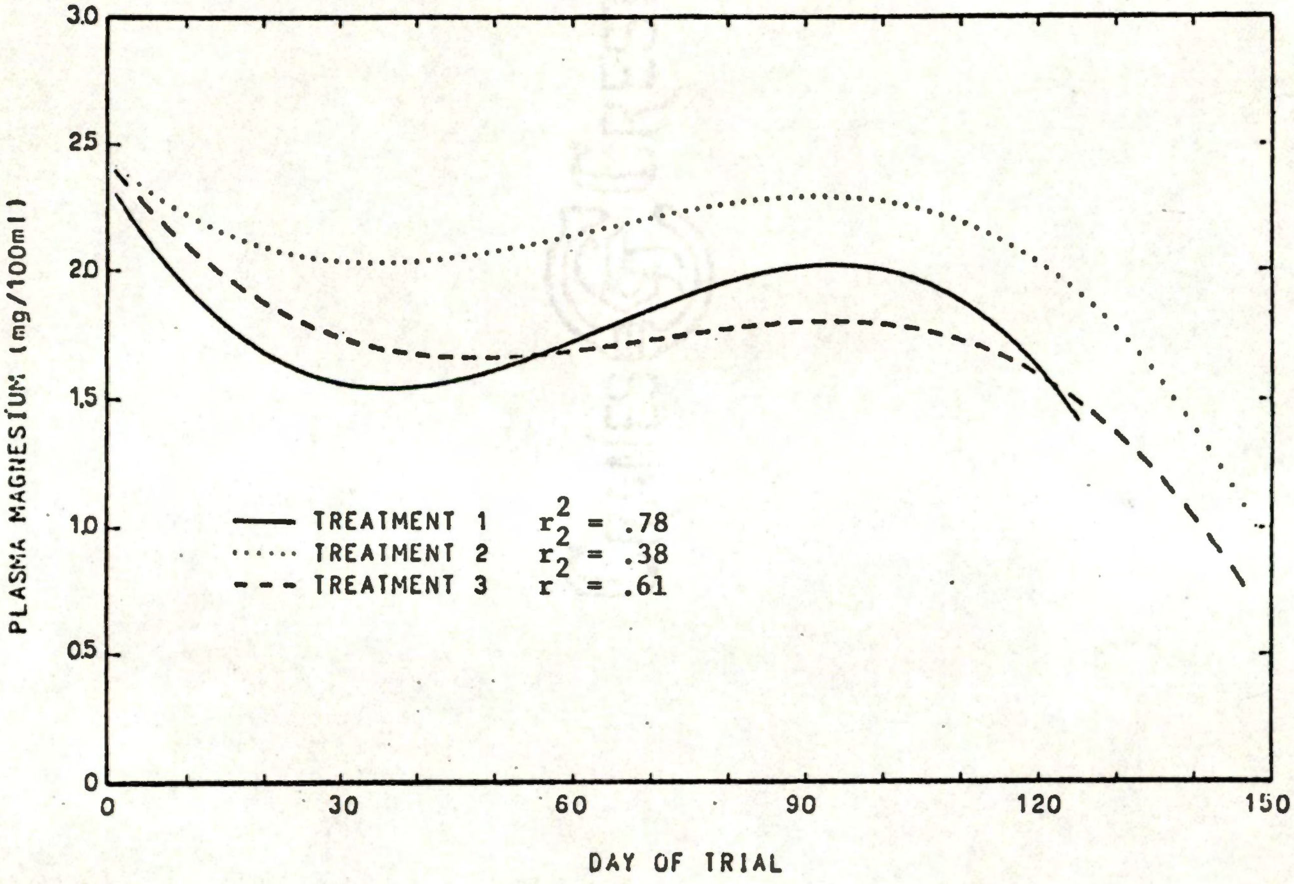

Figure 1. Trinomial regression curves for plasma magnesium.

Table 5. Mean plasma magnesium level (mg/100 ml) (±S.E.M.).

Day of Trial	Treatment: Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
1	$2.05^{ab} \pm .08$	$2.33^{a} \pm .07$	$1.84^{b} \pm .18$
31	$1.61^{b} \pm .10$	$2.14^{a} \pm .09$	$1.51^{b} \pm .15$
54	$1.57^{b} \pm .15$	$1.99^{a} \pm .08$	$1.50^{b} \pm .13$
68	$1.69^{b} \pm .14$	$2.26^{a} \pm .12$	$1.72^{b} \pm .19$
82	$1.59^{b} \pm .17$	$2.23^{a} \pm .08$	$1.74^{b} \pm .14$
96	$1.93^{ab} \pm .11$	$2.04^{a} \pm .10$	$1.64^{b} \pm .12$
110	$1.91^{ab} \pm .15$	$2.03^{a} \pm .05$	$1.64^{b} \pm .15$
124	$1.74^{a} \pm .13$	$1.78^{a} \pm .12$	
138		$2.28^{a} \pm .13$	$1.49^{a} \pm .34$
144		$2.40^{a} \pm .25$	$1.06^{b} \pm .24$

[a,b]Means superscripted with the same letter within a row are not significantly different ($\underline{p} < .05$).

.23 mg/100 ml, respectively. These two cows had calves that were approximately 8 weeks old at the time of the lowest values.

Trinomial regression plots for plasma calcium are presented in Figure 2. Analysis of variance showed treatment did not significantly affect the plasma calcium levels of the cows. Mean plasma calcium levels are presented in Table 6. No differences were found between treatments except on day 82 when the plasma calcium of the control cows was higher ($p < .05$) than the other two treatments. Analysis of variance did show that the day of the trial significantly ($p < .05$) affected the plasma calcium values of the cows.

Mean plasma potassium levels are presented in Table 7. Tetany-prone pasture cows were lower ($p < .05$) than the other two treatments on day 1 of the trial. No other differences were found except on day 68 when the plasma potassium of the control cows was lower ($p < .05$) than the cows on the other two treatments and on day 82 when the tetany-prone hay cows were lower ($p < .05$) than the control-hay cows. Plots of the regression curves for plasma potassium are presented in Figure 3. Analysis of variance showed treatment had no effect on the plasma potassium of the cows. Day of the trial affected ($p < .01$) the plasma potassium values of the cows.

Trinomial regression curves for plasma magnesium with calving date constant are presented in Figure 4. Significant ($p < .01$) differences due to treatment were observed for plasma magnesium. Control cows maintained a higher plasma magnesium level than cows on the other two treatments. Tetany-prone hay and tetany-prone pasture cows had similar depletion rates of plasma magnesium until approximately 45 days prepartum

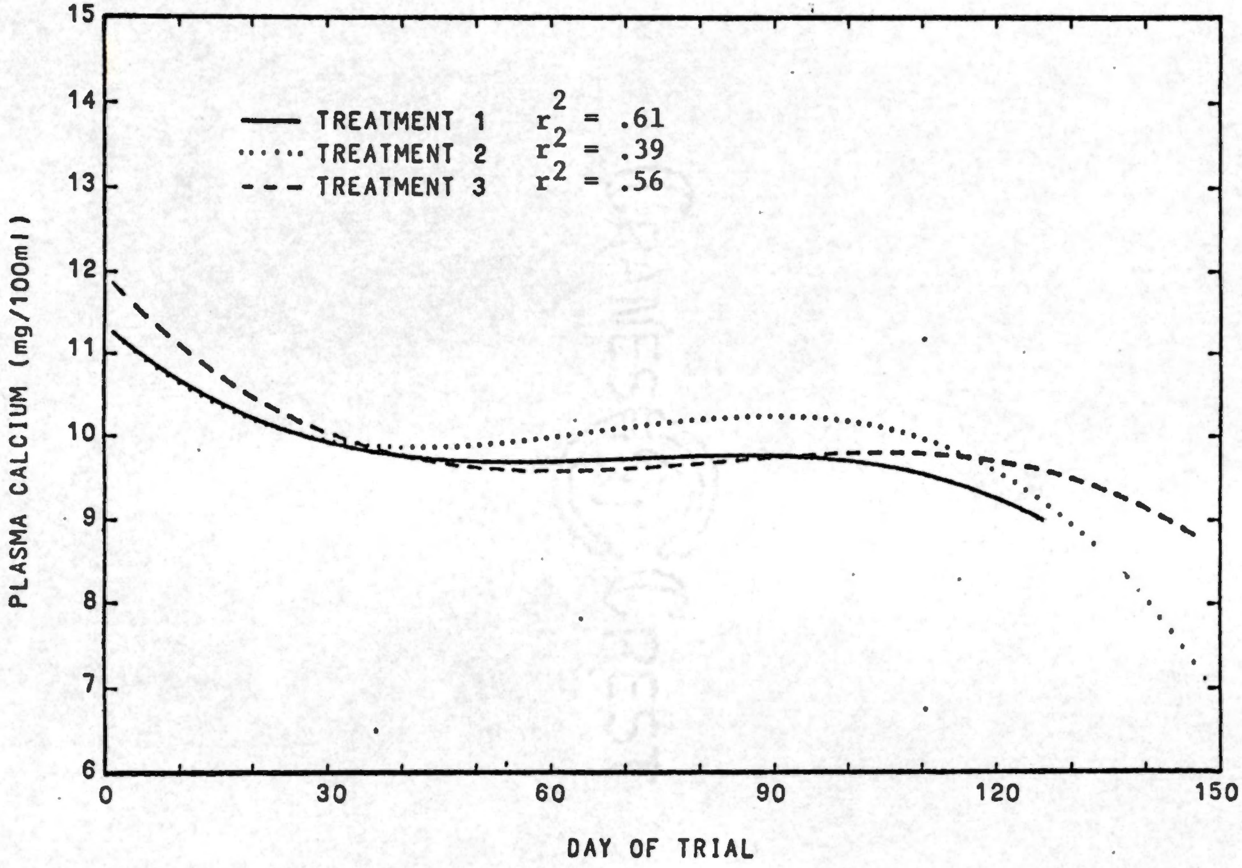

Figure 2. Trinomial regression curves for plasma calcium.

Table 6. Mean plasma calcium level (mg/100 ml) (±S.E.M.).

Day of Trial	Treatment		
	Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
1	10.94 ± .31	11.19 ± .26	10.49 ± .39
31	9.79 ± .11	9.46 ± .13	9.65 ± .16
54	9.94 ± .21	10.01 ± .14	9.51 ± .21
68	10.33 ± .19	10.73 ± .29	9.88 ± .45
82	9.51[b] ± .21	10.36[a] ± .17	9.83[b] ± .10
96	9.77 ± .21	10.13 ± .30	9.89 ± .23
110	9.61 ± .28	10.29 ± .23	9.77 ± .16
124	9.34 ± .02	9.52 ± .10	
138		11.29 ± .04	9.88 ± .43
144		9.93 ± .08	9.23 ± .14

[a,b]Means superscripted with the same letter within a row are not significantly different ($p < .05$).

Table 7. Mean plasma potassium level (mg/100 ml) (±S.E.M.).

Day of Trial	Treatment		
	Tetany-Prone Hay	Control Hay	Tetany-Prone Pasture
1	$16.26^{a} \pm .47$	$16.15^{a} \pm .43$	$14.78^{b} \pm .38$
31	15.69 ± .48	15.64 ± .31	15.12 ± .53
54	15.33 ± .54	15.52 ± .32	15.77 ± .38
68	$15.01^{a} \pm .35$	$13.45^{b} \pm .46$	$15.06^{a} \pm .32$
82	$14.72^{b} \pm .54$	$16.12^{a} \pm .28$	$15.31^{ab} \pm .32$
96	15.83 ± .53	15.94 ± .73	14.88 ± .42
110	15.78 ± .60	14.79 ± .51	15.45 ± .36
124	17.52 ± .03	14.46 ±1.17	
138		14.50 ± .01	15.65 ± .48
144		13.79 ± .06	15.45 ±1.02

[a,b]Means superscripted with the same letter within a row are not significantly different (p < .05).

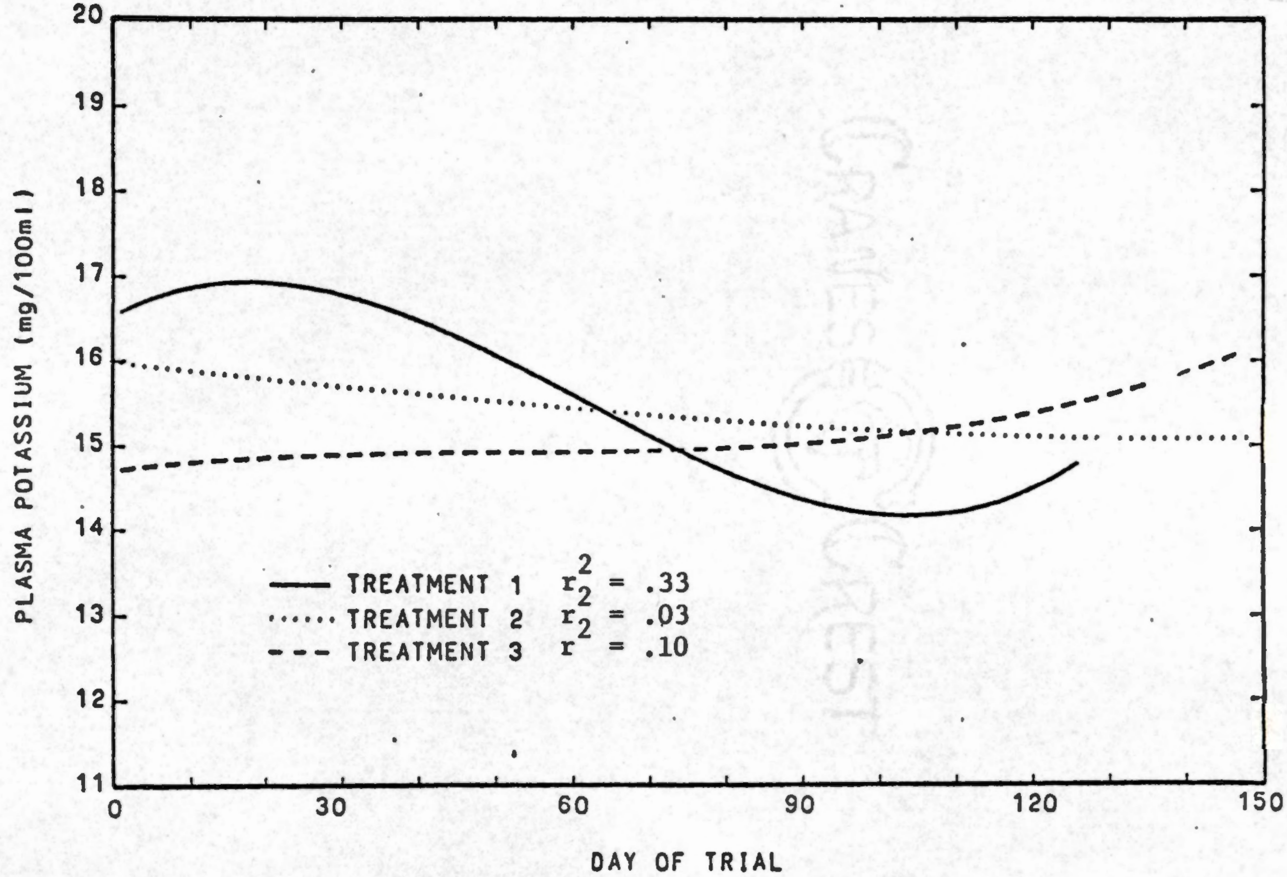

Figure 3. Trinomial regression curves for plasma potassium.

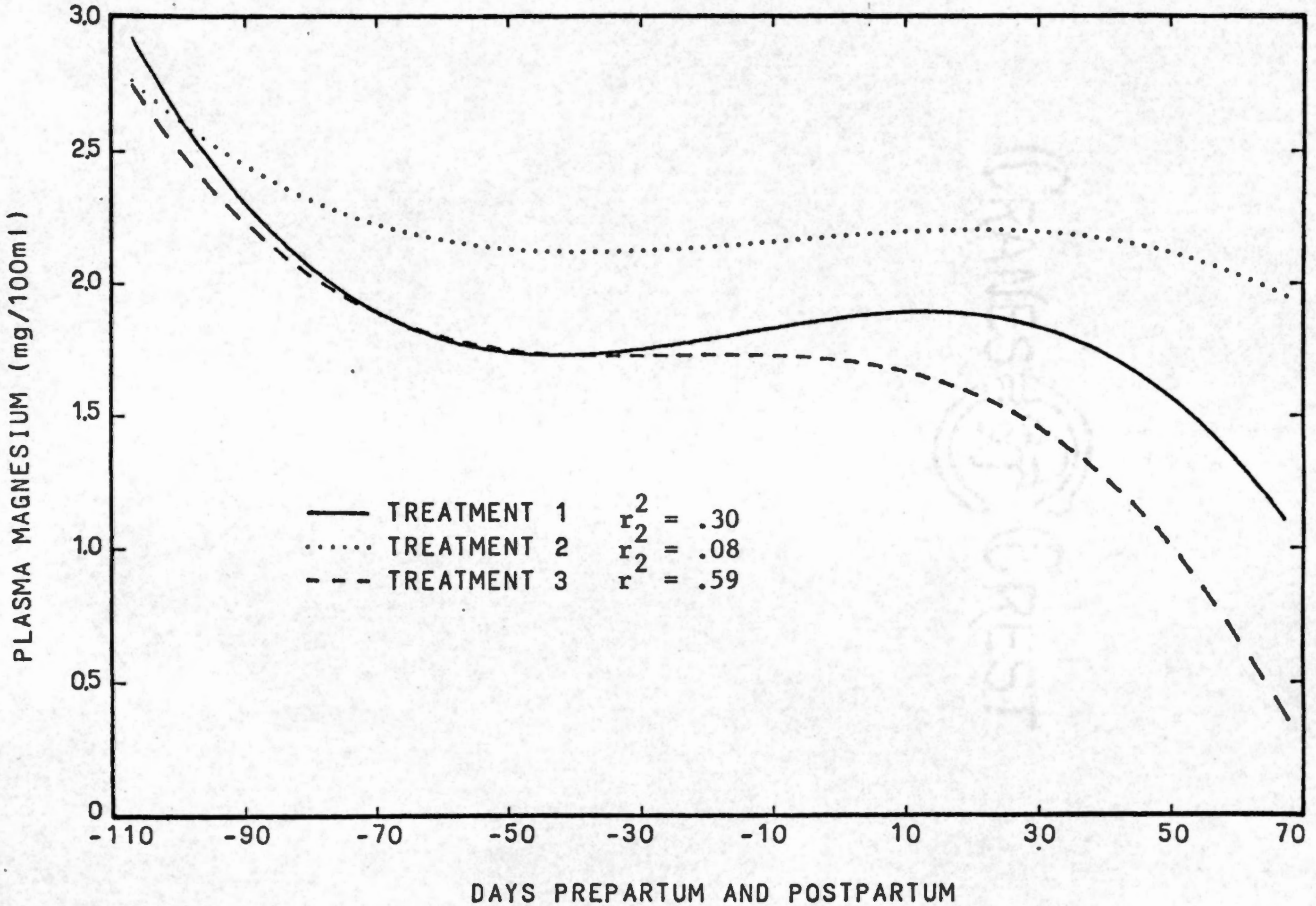

Figure 4. Trinomial regression curves for plasma magnesium, with calving date constant.

when the plasma magnesium of the tetany-prone pasture cows decreased more sharply.

Plots of plasma calcium regression curves with calving date constant are shown in Figure 5. Treatment had no effect on plasma calcium and all treatments had similar plasma calcium values throughout the trial.

Trinomial regression curves for plasma potassium with calving date constant are illustrated in Figure 6. Tetany-prone pasture cows showed a gradual increasing trend of plasma potassium, while the control and tetany-prone hay cows increased in plasma potassium until approximately 60 days prepartum then decreased until 25 days postpartum. Treatment did not significantly affect plasma potassium of the cows.

The plasma magnesium depletion which occurred with the cows on tetany-prone hay and pasture is primarily a result of the cows consuming forage low in magnesium. Rook (1961) using lactating cows depleted their plasma magnesium by feeding a ration deficient in magnesium. Beckmann (1977) reported similar results using sheep. No clinical symptoms of tetany were observed in the cows in 1978. Bohman et al. (1969) reported that symptoms of tetany generally do not occur unless the plasma magnesium falls below 1.0 mg/100 ml. Although several individual cows had plasma magnesium values below this level, the lowest mean level of plasma magnesium was 1.06 mg/100 ml. Forbes (1972) found 88% of all cases of hypomagnesemia he studied to also be hypocalcemic. This agrees with this data which showed that as plasma magnesium decreased so did plasma calcium. Cow 845 had the lowest plasma magnesium and also the lowest plasma calcium value, .23 and 6.48 mg/100 ml,

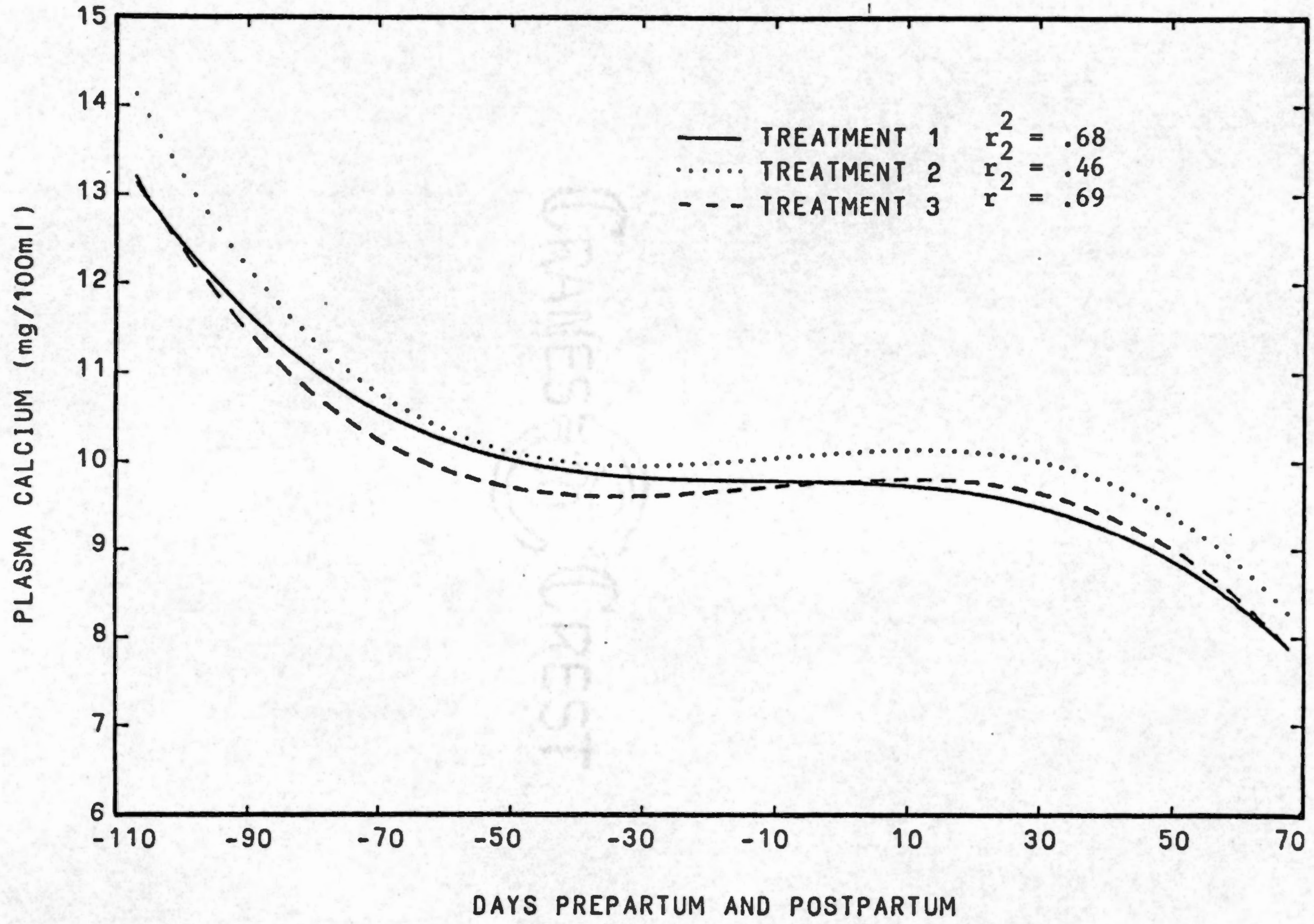

Figure 5. Trinomial regression curves for plasma calcium, with calving date constant.

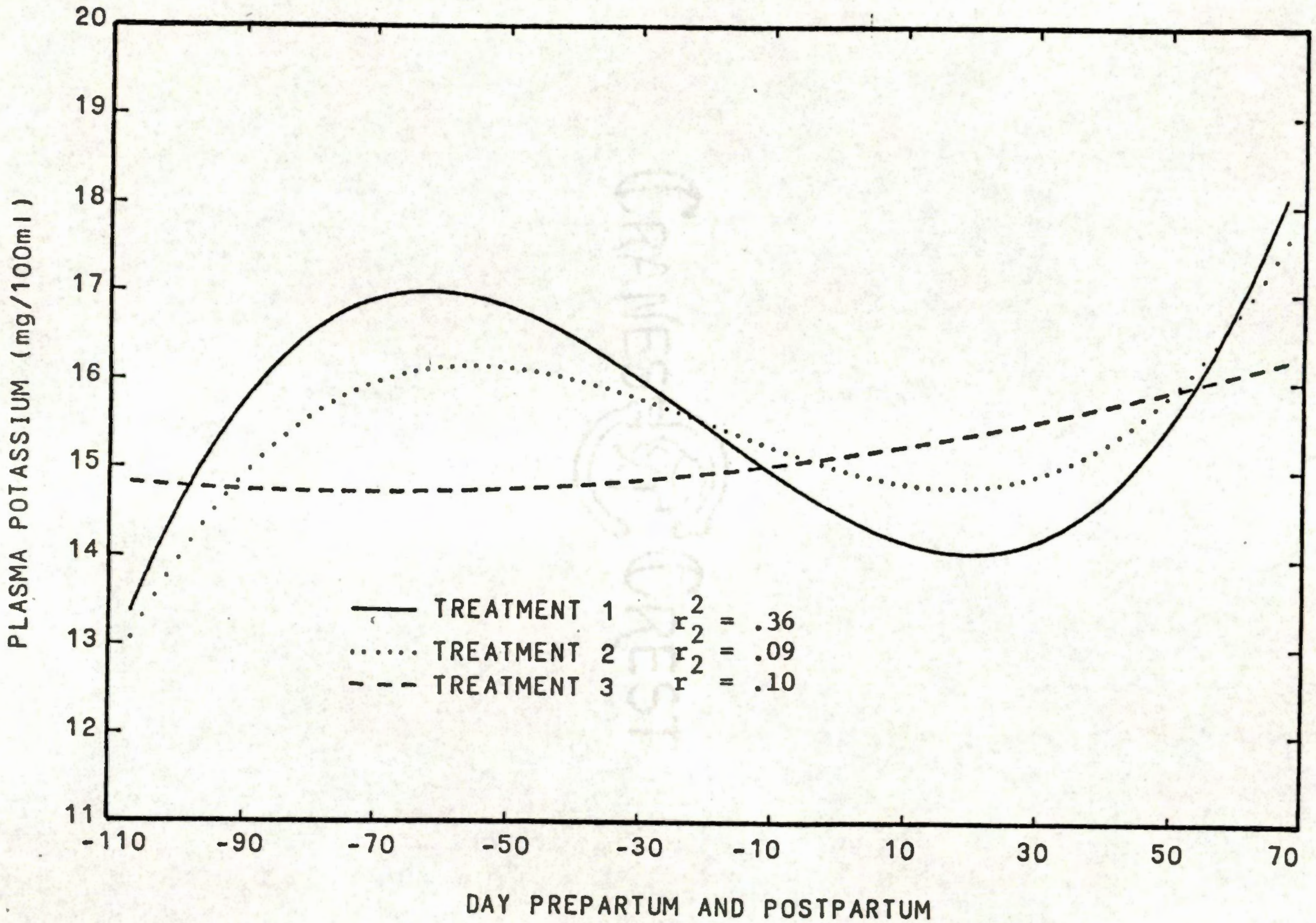

Figure 6. Trinomial regression curves for plasma potassium, with calving date constant.

respectively. This level of plasma calcium is considered subnormal according to Grunes et al. (1970). Rook and Storry (1962) also observed this relationship between plasma magnesium and plasma calcium. Sims and Crookshank (1956) established normal serum calcium to be 11.08 mg/100 ml. These data are slightly lower than this value.

All plasma potassium values are within the range reported by Grunes et al. (1970). Plasma potassium values showed more variation than did the plasma magnesium and calcium. The gradual increase in plasma potassium of the tetany-prone pasture cows is possibly related to the increase in the potassium content of the pasture during the stage of rapid spring growth. No logical assumption could be made as to the different relationships of the plasma potassium of the pasture cows with the cows on the two hays. Beckmann (1977) showed similar results to the two hay groups of cows. He reported a decrease in plasma potassium with wethers on a control diet adequate in potassium.

CHAPTER V

SUMMARY

Balance trials were conducted 3 years to study the daily balance of magnesium, calcium and potassium in lactating beef cows under conditions of hypomagnesemia. Samples of forage, feces, milk and urine were collected and analyzed. Blood was also collected to study the plasma mineral values of the cows.

Magnesium intake was higher ($p < .05$) for cows on the control and tetany-prone hays than the tetany-prone pasture cows. Tetany-prone hay cows excreted more magnesium in the feces than the control cows and also significantly ($p < .05$) less magnesium in the urine than the controls. These results seem to indicate something else is involved other than intake of magnesium being inadequate. Results indicate possibly calcium retention has an effect on availability of magnesium. Magnesium balance was negative for cows on both tetany-prone hay and pasture treatments. The control cows maintained a positive balance of magnesium.

Cows on the control hay maintained a positive balance of calcium that was higher ($p < .05$) than both the tetany-prone hay and tetany-prone pasture cows. The tetany-prone hay and tetany-prone pasture cows were in a negative calcium balance. Potassium balance data were highly variable. No differences were found in the fecal potassium excretion. Milk maintained constant levels for magnesium, calcium and potassium across treatments. This suggests cows have some mechanism for maintaining their milk's composition even under conditions of deprivation.

Plasma magnesium values of the tetany-prone hay cows and tetany-prone pasture cows were the same, and plasma magnesium of the control-hay cows were found to be greater ($\underline{p} < .05$) than plasma magnesium values of the cows on the other two treatments. This indicates the tetany-prone hay is as likely to produce conditions of hypomagnesemia as the tetany-prone pasture. Both the tetany-prone hay and pasture cows had similar depletion patterns of plasma magnesium. No differences were found between treatments for plasma calcium. Treatments did not significantly affect plasma potassium. Plasma potassium levels of the tetany-prone pasture cows showed an increasing trend similar to the increase in plant potassium as the rapid spring growth occurred. But no significant differences were found among the mean plasma potassium levels within the pasture cows.

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APPENDIX

Table 8. Mean squares for balance variables.

Variable	Mean Squares: Treatment	Year	Error
Magnesium			
Intake	215.8[b]	171.9[b]	9.21
Fecal	107.3[b]	191.5[b]	19.3
Urinary	7.4[b]	5.2[b]	.44
Milk	.02	.16	.02
Balance	54.	278.8[b]	23.7
Calcium			
Intake	3737.3[b]	905.6[b]	89.7
Fecal	517.0	554.9[a]	168.3
Urinary	.24[b]	.04	.03
Milk	1.7	8.2	5.0
Balance	1415.5[b]	1062.4[b]	202.9
Potassium			
Intake	21063.2[b]	27204.9[b]	742.7
Fecal	70.9	19304.4[b]	507.9
Urinary	31844.9[b]	36407.9[b]	801.7
Milk	3.2	4.1	3.4
Balance	4646.5[b]	28508.5[b]	1121.2

[a] $p < .05$

[b] $p < .01$

Table 9. Intercept and regression coefficients for plasma mineral levels, with calving date constant.

Mineral	Treatment[a]	Intercept	B_1[b]	B_2	B_3
	1	1.87069645	.00311948	-.00008514	-.00000193
Mg^{++}	2	2.18083475	.00196335	-.00002164	-.00000085
	3	1.71159346	-.00285108	-.00013089	-.00000182
	1	9.77557001	-.00205080	-.00012762	-.00000375
Ca^{++}	2	10.11340420	.00548447	-.00013865	-.00000505
	3	9.78414692	.00498188	-.00016452	-.00000476
	1	14.51257659	-.03947620	.00066545	.00001059
K^{+}	2	15.01067502	-.02043536	.00039639	.00000707
	3	15.14833830	.01140478	.00007566	-.00000003

[a]Treatment 1 = Tetany-Prone Hay

Treatment 2 = Control Hay

Treatment 3 = Pasture

[b]B_1 = Linear regression coefficient for day of calving.

B_2 = Quadratic regression coefficient for day of calving.

B_3 = Cubic regression coefficient for day of calving.

Table 10. Intercept and regression coefficients for plasma mineral levels.

Mineral	Treatment[a]	Intercept	B_1[b]	B_2	B_3
	1	2.35442783	-.05147275	.05147275	-.00000507
Mg	2	2.44236084	-.02720661	.00054001	-.00000285
	3	2.43582104	-.03929601	.00062417	-.00000296
Ca	1	11.33878027	-.07647661	.00114419	-.00000542
	2	11.32493307	-.08175520	.00141995	-.00000716
	3	11.96809517	-.09791184	.00127947	-.00000517
K	1	16.53538036	.04768802	-.00157094	.00000860
	2	15.98451535	-.00969999	.00000092	.00000016
	3	14.72432729	.01063579	-.00019304	.00000125

[a]Treatment 1 = Tetany-Prone Hay

Treatment 2 = Control Hay

Treatment 3 = Pasture

[b]B_1 = Linear regression coefficient for day.

B_2 = Quadratic regression coefficient for day.

B_3 = Cubic regression coefficient for day.

VITA

Richard Sebastian Ritter, son of Gerald F. and Jane Ritter, was born in Nashville, Tennessee, on January 1, 1955. He grew up and attended elementary and secondary schools in Nashville. He entered Tennessee Technological University in September 1973 and received the Bachelor of Science degree in Animal Science in August 1977. He immediately entered graduate school at The University of Tennessee, Knoxville, to study ruminant nutrition and received the Master of Science degree in Animal Science in June 1979.