AVAILABILITY AND UTILIZATION OF MAGNESIUM FROM DOLOMITIC LIMESTONE AND MAGNESIUM OXIDE IN STEERS

by

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INTRODUCTION

Hypomagnesemic tetany occurs in beef cows fed conventional rations or grazing native pastures early in the spring. This disturbance results in considerable mortality in some beef cow herds and the ensuing financial loss is of serious consequence to cattlemen. It appears that the problem is widespread in Virginia and neighboring states. The incidence of the disturbance has appeared to be on the increase during recent years. Thus, there is need for effective preventive measures that can be economically employed by cattlemen.

Field observations and research in Virginia, and a review of the literature indicate that insufficient intake of magnesium at times of relatively high requirement may be a major predisposing factor. The disturbance is reported to occur most often in lactating beef cows. It is most prevalent from parturition to about 2 months postpartum, but occasionally is reported in cows in advanced pregnancy. It has been observed that the usual feeds consumed by beef cows during the winter and early pasture herbage may be low in magnesium content. Factors decreasing the availability of feed magnesium may also play a part. These conditions suggest the use of supplemental dietary magnesium during the winter and spring months.

Supplemental feeding of dolomitic limestone, containing approximately 12% magnesium, and magnesium oxide, containing 60% magnesium, has been recommended in Virginia to increase the magnesium intake of beef cattle. Force feeding either

75 gm. of dolomitic limestone or 15 gm. of magnesium oxide has been recommended. An alternate means of supplying magnesium was suggested consisting of providing access to a 1:1 mixture of salt and magnesium oxide, on the assumption that cattle would consume about 30 gm. of this mixture per day. The objective of these recommendations was to increase the daily magnesium intake by 9 gm. per day. Due to lack of research data it was assumed that additional magnesium from either source would be equally available to the animal. Research to determine the availability of the supplemental magnesium from these sources is needed to properly evaluate the effectiveness of each.

A series of metabolism trials were conducted with beef steers to determine the utilization of the supplemental magnesium from dolomitic limestone and magnesium oxide, when fed at such levels as to supply approximately 9 gm. of magnesium per day.

REVIEW OF LITERATURE

Hypomagnesemia: Symptoms and Occurrence

Grass tetany, grass staggers, hypomagnesemic tetany, winter tetany and wheat pasture poisoning are all terms that appear in the literature to describe a disturbance occurring in ruminants. A characteristic symptom of the disturbance is a lowered blood magnesium level.

Detailed descriptions of the symptoms of the disturbance in cattle were published by Sjollema (1932), Sims and Crookshank (1956) and Doza (1959). Herd and Peebles (1962) reported the symptoms in sheep. The symptoms usually reported are nervousness, restlessness, lack of appetite, muscle twitching, an unsteady gait, staggering and falling, a wild look, gnashing of the teeth and abundant salivation. General tetanic contractions occur as the disturbance progresses. The animal is unable to rise, but strikes out with the limbs and makes unsuccessful attempts to rise. During this period of intense excitement a pounding heart beat audible some distance from the animal has been reported. Later a paretic comatose state develops during which the muscles may be rigid and the mouth may be opened and closed spasmodically. Mucous membranes may be hyperemic. Blood serum magnesium levels below 1 mg. per 100 ml. are commonly reported. Normal levels are usually above 2.0 mg. per 100 ml. Lowered blood serum calcium levels are also frequently noted.

Sjollema (1932) reported the usual serum calcium level in affected animals at 6.5 mg. per 100 ml., in contrast to a normal range of 9.5 to 11 mg. Inorganic phosphorus levels of 2 to 8 mg. per 100 ml. have been reported. Thus the inorganic phosphorus level may be either above or below the normal level of 4.5 mg. per 100 ml. given by Sjollema (1932).

Without treatment, death of affected animals usually occurs within a few hours after the onset of the visible symptoms.

The disturbance, affecting both cattle and sheep, is known in many countries of the world. Sjollema (1932) reported that it had been known in Holland for more than half a century and was on the increase due to alterations in methods of feeding and fertilizing. The occurence of the disturbance in Norway during World War II was attributed to a dietary lack of magnesium due to feed shortages, and the use of fodder cellulose and herring meal instead of more conventional feeds (Blaxter and McGill, 1956).

In Europe, hypomagnesemia usually occurs during the first few weeks of the grazing season (Bartlett et al, 1957; Storry, 1961). According to Hemingway et al. (1961), it occurs in both hill and lowland flocks on poor or restricted diets, and may be influenced by adverse weather conditions. It also occurs in sheep receiving an ample supply of improved herbage, including cereal forages.

Herd and Peebles (1962) reported on the incidence of the syndrome in sheep in Australia, and stated that deaths were confined to the period of peak milk production after lambing. Swan and Jamieson (1956) implicated factors resulting in reduced feed intake in the onset of clinical tetany among dairy cows in New Zealand. Results of a survey of beef cow herds in one area of New Zealand indicated that substantial losses occurred during the spring of 1961, and that certain areas had a higher incidence of the disturbance than others (Cairney, 1964). A possible relationship between soil type and the occurrence of the disturbance was suggested, since it was much more prevalent in inland than in coastal regions of the area surveyed.

Until recently, the disturbance had been of major importance in the United States only in ruminants grazing cereal forages. In the winter wheat grazing areas, primarily the Texas and Oklahoma Panhandles, it occurs in mature cows in late pregnancy or early lactation grazing lush wheat pastures and is known as "wheat pasture poisoning" (Sims and Crookshank, 1956). The disturbance has been reported in Georgia by Beardsley et al. (1963). It occurs primarily in lactating beef cows grazing temporary winter pastures of oats or rye. Hjerpe (1964) estimated the death loss in California from grass tetany at 4,000 to 6,000 head during the winter of 1963-64. These losses occurred in cattle wintered on native grass pastures which were more lush than usual for that time of year. He stated that no explanation could be given for the fact that pastures had been equally good the previous year and only sporradic losses had been reported.

In the United States, a similar syndrome to that occurring in cattle has been reported in sheep grazing cereal forages (Barrentine and Morrison, 1953). The condition was observed in grazing ewes about 1 to 3 weeks after parturition. Only ewes with suckling lambs were affected and those with twins were more susceptible.

Hypomagnesemia has been reported in beef cows fed conventional winter rations in Pennsylvania (Stillings et al., 1962, Maryland (Leffel and Mason, 1959), West Virginia (Horvath, 1959), and Virginia (Fontenot et al., 1965). It has been reported as early as November in fall calving cows, but is most prevalent in late winter and early spring. It declines rapidly after pasture appears. From analysis of feeds used by affected herds, it appears that a dietary deficiency of magnesium is a primary cause of the so called "winter tetany". Other factors which have been suggested to play a role in its occurrence are poor utilization of dietary magnesium, low nutrient intake, and lactation stress (Inglis, 1960, Beardsley et al., 1963).

Magnesium Metabolism and Utilization in Ruminants

The indispensable role of magnesium has been established. It is absorbed from the gastro-intestinal tract, and an excess is rapidly excreted in the urine (White et al., 1954). Most of the magnesium in the body is in bone from which it can be mobilized to some extent. The ability to mobilize bone magnesium decreases with increasing age (Hemingway et al., 1963; Smith and Field, 1963). The normal blood serum magnesium level in pigs, cattle, sheep and goats is 1.2 to 3.8 mg. per 100 ml. (Rook and Storry, 1962). Recent estimates indicate that 65 to 80% of the serum magnesium is ultrafilterable. The magnesium content of soft tissue varies widely from .06 to .13% of the dry matter (Rook and Storry, 1962).

Magnesium serves as a co-factor for many enzymatic reactions, particularly those involved in carbohydrate metabolism (Wacker, 1965).

Magnesium deficiency symptoms have been observed in many species, in addition to cattle and sheep. Hyperirritability is a common symptom. It has been suggested that the magnesium ion plays an important part in the transmission of impulses at the neuromuscular junction. A low concentration of magnesium relative to calcium could result in the release of acetyl choline and the transmission of nerve impulses (Blaxter et al., 1954). These workers also suggested that low concentrations of magnesium in the extracellular fluid may produce tetany in this way. In support of this view, O'dell (1960) points out that magnesium has a depressing effect on the neuromuscular system. He also mentions that it is the only known metallic ion which produces anesthesia and this effect is counteracted by calcium.

Stewart and Moodie (1956) found that when heavy doses of magnesium sulfate were administered orally, absorption of magnesium from the rumen, abomasum, duodenum, small intestine and cecum resulted. Magnesium nitrate was found to be more quickly absorbed than magnesium sulfate, when given orally. Smith (1959) found that young calves could absorb considerable magnesium from the large intestine (25 to 40% of intake from a milk diet), but this ability was lost rapidly with increasing age and by 12 weeks of age no appreciable magnesium was absorbed from the large intestine.

Care and Van't Klooster (1964) reported that at low magnesium concentration in the small intestine of an adult sheep, there was a net secretion of magnesium into the lumen of the intestine. Net absorption of magnesium increased as the concentration in the small intestine increased until maximum absorptive capacity was reached. Magnesium absorption appeared to be at a minimum at either end of the small intestine, with most of the absorption taking place in the middle part.

Storry (1961a) suggested that conditions favoring net uptake of magnesium from the gut are most favorable in the abomasum and duodenum. Reduction of the acidity of abomasal digesta _in vitro_ resulted in a decrease in the concentration of ultrafilterable calcium and magnesium, due to the binding of these ions on the suspended material in the digesta (Storry, 1961b).

Appreciable quantities of magnesium are secreted into the digestive tract in saliva and other digestive juices. Unless reabsorbed from the digestive tract, this magnesium is lost to the animal as endogenous fecal magnesium. Several attempts have been made to estimate the endogenous loss of magnesium. Smith (1959) estimated the endogenous loss in calves at 0.5 mg. per kg. of bodyweight per day at 2 to 5 weeks of age. At 26 to 32 weeks of age the endogenous loss had risen to 2.2 mg. per kg. However, he suggested that this increase did not fully account for the decreased utilization of dietary magnesium that accompanies increasing age in calves, and suggested that decreased absorption was of greater significance.

Hemingway et al. (1960) estimated the endogenous fecal magnesium of sheep at 225 mg. per day. Storry and Rook (1963) fed a diet providing 0.5 gm. of magnesium per day to two non-lactating cows. Fecal magnesium excretion continued at 1.0 gm. per day indicating an endogenous fecal magnesium excretion of at least 0.5 gm. per day.

Excretion of magnesium in the urine is the major route for the disposal from the body of the amount absorbed in excess of requirements (Rook _et al._, 1958). In periods of magnesium deficiency urinary excretion virtually ceases in the conservation of available magnesium. However, there is a continual loss in feces and in the milk of the lactating animal (Storry and Rook, 1963; Rook _et al._, 1964).

Several workers have attempted to estimate the renal "threshold" for magnesium, which may be defined as the serum or plasma magnesium concentration at which urinary excretion ceases. Rook _et_ _al_. (1958) estimated the renal magnesium threshold in dairy cows at 2.15 to 2.20 mg. per 100 ml. of serum. Storry and Rook (1963) estimated the renal threshold in two dairy cows by regression analysis. They found that these values were 1.46 and 1.76 mg. per 100 ml. of serum. respectively. L'Estrange and Axford (1964) found the renal threshold in two lactating ewes to be 1.37 and 1.94 mg. per 100 ml.; this difference in serum magnesium levels was significant and is further evidence that the threshold value is subject to considerable individual variation.

In a metabolism trial with dairy cows, Rook _et_ _al_. (1958) found the magnesium requirement for milk production to be 0.132 gm. per liter of milk. A similar value was obtained by Rook _et_ _al_. (1964) in metabolism trials involving very low intakes of dietary magnesium from artificial diets. On a basal diet providing only 3 gm. of magnesium per day there was no urinary loss, blood serum magnesium levels dropped sharply, but there was no alteration of magnesium concentration in the milk. Thus more rapid development of hypomagnesemia in the lactating animal may be due to the high requirement for milk production. Similar results were obtained with ewes by L'Estrange and Axford (1964). They found that ewes on a semi-purified diet, *low in magnesium, maintained a relatively constant milk magnesium* concentration although acute hypomagnesemia, hypocalcemia, loss of appetite and tetany occurred within 3 days after removal of supplementary magnesium from the diet.

The degree of absorption of magnesium from feed and magnesium supplements varies considerably. Blaxter and McGill (1956), in a review of balance trials, reported from 30 to 50% "availability" for magnesium in feedstuffs. They suggest a value of 33% for use in estimating dietary needs. Rook et al. (1958) reported that 66 to 77% of the magnesium ingested by dairy cows on a variety of stall rations was excreted in the feces. When these cows were fed cut grass in metabolism stalls, fecal excretion rose to 80 to 83% of dietary intake. Ferrando et al. (1963) reported that only 59 to 62% of the magnesium in alfalfa hay was recovered in the feces, indicating considerably higher absorption of magnesium from this feedstuff than from fresh grass.

Rook et al. (1964) found the "available" magnesium (urinary magnesium plus milk magnesium/dietary magnesium X 100) in some partially purified diets low in magnesium to be approximately 25 to 35%. Basal diets providing either 9 or 13 gm. of magnesium per day adequately met the needs of lactating cows, as indicated by the maintenance of normal blood magnesium levels and continued measurable urinary excretion.

McAleese et al. (1961), in studies with magnesium^{28}, found that lambs on a magnesium deficient diet absorbed considerably more magnesium in the form of magnesium chloride than did controls. After 60 hours, 50 to 52% of the magnesium had been excreted in the feces of the controls, while only 25 to 30% was recovered in the feces of the deficient lambs.

Storry and Rook (1963) measured the magnesium availability in various salts of magnesium by measuring the increase in urine excretion when the salts were fed to two non-lactating dairy cows. The mean values for the two cows were 26 and 34.5%, indicating considerable individual difference. This difference was statistically significant. Magnesium availability was similar for magnesium oxide, lactate, acetate and nitrate, but was higher for citrate. Magnesium sulfate, silicate and chloride were found to be somewhat lower in availability. Thomas and Okamoto (1958) found that magnesium in grain and hay was better utilized by young calves than magnesium from magnesium sulfate, although the apparent difference was not statistically significant.

The work of McAleese <u>et al</u>. (1961), in which magnesium^{28} was used, provides added information on the metabolism of magnesium in deficient and control lambs. In that experiment, magnesium deficient and control lambs were given magnesium^{28} either orally or intravenously. When given intravenously, magnesium^{28} activity dropped rapidly and had largely disappeared in 8 to 10 hours. There was little uptake of magnesium^{28} in the red blood cells. Plasma magnesium^{28} activity reached a maximum in 12 to 14 hours after oral dosing and then declined rapidly. The levels reached in the deficient lambs were less than those of the control lambs. due to greater tissue uptake in the deficient lambs. This suggests that prolonged elevation of blood magnesium values is not likely to be achieved by either intravenous or oral additions of magnesium. The fact that the deficient lambs absorbed more of the oral magnesium^{28} has already been mentioned. The urinary excretion of the deficient lambs was much less than that of controls, amounting to less than 1% of the amount ingested. In the control group, urinary excretion was 20% of the amount ingested. Summation of these observations leads to the conclusion that there is considerable tissue uptake before blood levels are elevated in animals which have been on a low magnesium intake.

Prevention of Hypomagnesemia by Supplementation

A large number of factors have been investigated in an attempt to define the conditions under which hypomagnesemia may develop. Although it seems that insufficient intake of magnesium is responsible for the "winter" tetany found in beef cows (Fontenot et al., 1965), the relationship is not so definite in the case of dairy cows on early spring pasture in Europe or in beef cattle and sheep grazing wheat pasture in the Great Plains. Under these conditions, hypomagnesemia develops suddenly in animals which, theoretically, at least, received sufficient dietary magnesium to meet their requirements. Dietary potassium levels (Storry, 1961), dietary citrate (Burt and Thomas 1961), dietary phytate (Roberts and Yudkin, 1960; Evered, 1961), calcium and phosphorus intake and metabolism (O'Dell, 1960) and other factors have all been suggested as being involved in the occurrence of hypomagnesmia, particularly that occurring in the grazing animal.

The possibility that one or more of the above factors or unknown factors may play an active role in bringing about hypomagnesemia cannot be overlooked. However, Thomas (1964) states that "the most likely mechanisms causing grass tetany are a decrease in magnesium intake caused by low magnesium concentrations in the feed, and/or low forage intake, coupled with comparatively high requirement".

Increasing dietary intake of magnesium at critical times has proven beneficial. Most of the research in this area has been done in recent years. Line _et al._, (1958) reported that relatively little effort had been made to develop suitable preventive measures for hypomagnesemia. These workers found that 56.7 gm. of calcined magnesite given as a drench or in feed was effective in preventing hypomagnesemia in a group of 56 dairy cows during the critical early grazing period. Of the cows receiving the magnesium supplement, only 14 had serum magnesium levels below 1.8 mg. per 100 ml. No serum magnesium levels below 1.1 mg. per 100 ml. were recorded in the treated group. This level was above the critical range of

0.5 to 0.7 mg. per 100 ml., the level at which these workers stated that tetany is likely to occir. In the control group receiving no supplemental magnesium, 14 of 28 cows had serum levels below 1.0 mg. per 100 ml., and two cows had serum values as low as 0.5 mg. per 100 ml. In that experiment neither supplemental vitamin D no linseed was effective in maintaining normal serum magnesium levels.

Alcroft (1961) pointed out the futility of attempting to build up within the animal a supply of readily available magnesium for emergency use. He concluded that supplementary magnesium must be provided regularly during critical periods and recommended 56 gm. of magnesium oxide as the minimum daily amount for lactating dairy cattle. Rook et al. (1964) found that supplemehtal feeding of magnesium oxide to lactating dairy cows on an artificial diet containing 3 gm. of magnesium per day was effective in the prevention of hypomagnesemia. They used three levels of supplementation resulting in total daily magnesium intakes of 6, 15 and 33 gm. Measurable urinary excretion was evident at both the 15 and 33 gm. per day levels indicating that both levels adequately met the magnesium requirements under these conditions.

Fontenot et al. (1965), in field studies involving more than 400 beef cows in three herds, found that supplemental magnesium oxide or dolomitic limestone was effective in preventing tetany. Providing supplemental magnesium at the level of approximately 9 gm. per day was attempted, but not always achieved due to low consumption of the supplemental mixtures. The supplemental magnesium did not consistently maintain blood serum magnesium levels in these herds, but was apparently effective in preventing the occurrence of tetany.

Barrentine and Morrison (1953) found that hypomagnesemia in ewes grazing cereal forages could be controlled by feeding magnesium carbonate or legume hay. Ritchie et al., (1962) reported that the general recommendation for the control of hypomagnesemia in sheep in Scotland was calcined magnesite supplying 4 to 8 gm. of magnesium per head per day. These workers found that this supplemental level maintained normal serum magnesium levels of non-pregnant, not-lactating Cheviot ewes on a low magnesium winter ration. When magnesium "bullets" were given, blood serum magnesium levels were maintained when the release rate of magnesium was as little as 75 mg. per day (Ritchie et al., 1962). However, when these "bullets" were given to sheep on "tetany prone" rye grass pasture they failed to maintain serum magnesium levels (McGuire and Wilson, 1961; Wilson et al., 1962).

Ritchie and Hemingway (1963a) found that 4 gm. of magnesium per day as a drench did not increase serum magnesium levels in ewes when measured 24 hours after drenching. Magnesium absorption did take place, however, since serum magnesium levels were elevated by 0.5 mg. per 100 ml. 4 hours after drenching. At 10 hours this effect had largely disappeared. In a second experiment (Ritchie and Hemingway, 1963b) similar results were obtained from feeding 6.6 gm. of magnesium oxide per day (4 gm. of magnesium). This level did not elevate serum values 24 hours after treatment, but did increase serum concentration by 0.5 mg. per 100 ml. of serum 4 hours after treatment. It was found that the ewes in that experiment had substantially lower serum magnesium levels after lambing than prior to lambing, and that supplementation was ineffective in returning the serum concentration to pre-lambing levels. They attributed the drop in serum magnesium to lactation requirements. These workers concluded that only a trivial part of the supplemental magnesium was utilized by the animal, and that the frequency of intake of magnesium was more important than the absolute amount administered.

Wolton (1960) reported on the seasonal patterns of magnesium content in pasture herbage. Lowest levels were recorded in April, legumes were higher in magnesium than grasses, and there were differences between grass species.

A number of workers have attempted to control hypomagnesemia in grazing animals through applications of magnesium to the pasture. Two approaches to the problem have been studied. One is the application of magnesium-containing materials (fertilization) considerably ahead of grazing so that the additional magnesium can be taken up from the soil by the pasture herbage. The increased magnesium content within the plant would result in increased magnesium intake by the grazing animal. The other approach is the application of additional magnesium as a dust or spray just prior to grazing so that the animal ingests the additional magnesium along with the pasture herbage.

Smith et al. (1958) found that fertilizer applications of magnesium totaling 365 kg. per hectare resulted in maintenance of normal serum magnesium levels, while animals grazing on untreated pastures experienced sharply lowered serum magnesium levels and tetany. McConaghy et al. (1963) found that fertilization with calcined magnesite and dolomitic limestone raised the magnesium content of herbage slightly, but not to levels they considered safe. However, no tetany was experienced in animals grazing treated pastures although some low blood serum magnesium levels were recorded. These workers found that magnesium sulfate sprayed on pasture herbage was only of temporary benefit. Finely powdered magnesite applied as a dust to pasture herbage before grazing was suggested as a method of controlling tetany.

Kemp and Geurink (1962) found it possible to increase the magnesium content of pasture herbage with magnesium fertilization. They found that the potash status of the soil was an important factor, since a higher potash level lowered the effectiveness of the magnesium application. Wolton (1960) suggested that at least 674 kg. of magnesium should be applied per hectare as fertilizer in order to effectively raise the magnesium content of the forage. Frequent treatments were thought to be more beneficial than larger amounts designed to be effective for a longer period of time.

Birch and Wolton (1961) fertilized pastures with magnesium oxide at two levels, 56 and 1123 kg. per hectare. They found both levels to be effective in preventing the drop in serum magnesium levels which occurred in cattle grazing untreated pastures. Cows switched from treated to untreated pastures exhibited a decline in serum magnesium levels and those transferred from untreated to treated pastures exhibited a corresponding elevation in serum magnesium levels.

Jones (1963) found that magnesium sulfate fertilization was of little effectiveness after the first year. In contrast, fertilization with magnesium limestone had only a small effect the first year, but resulted in a 55 percent increase in herbage magnesium in the third year. Maximum increase was achieved in the fourth year after application of magnesium limestone.

Todd and Morrison (1964) found that hypomagnesemia could be prevented by dusting pasture herbage with 31.5 kg. of calcined magnesite per hectare just prior to the beginning of grazing. The magnesium content of the dusted herbage was 0.31% compared to 0.16% for the undusted forage. Hypomagnesemia and tetany (one death) occurred in the cows grazing undusted pasture but not in those grazing dusted pastures.

In summarizing the literature reviewed, hypomagnesemia, commonly known as grass tetany, is a disturbance of ruminants characterized by a lowered blood magnesium level. It occurs most frequently in the lactating animal shortly after parturition. Hyperirritability followed by tetanic convulsions which subside into a comatose condition are common symptoms. Without treatment, death usually occurs within a few hours after the onset of symptoms. Blood serum magnesium levels below 1 mg. per 100 ml. are usually reported when tetany occurs.

The disturbance has been reported in many parts of the world. In Europe it is most prevalent in dairy cows on spring grass. It occurs in beef cows and sheep grazing cereal forages in several sections of the United States. In Virginia the problem has been most prevalent in beef cows wintered on conventional forages. An insufficeint intake of magnesium due to low magnesium levels in forages is indicated as a major cause of the hypomagnesemia occuring in Virginia.

Magnesium is an essential element found in all parts of the animal body. It serves as a co-factor for many enzymatic reactions and is thought to have a role in the transmission of nervous impulses at the neuromuscular junction. It is absorbed primarily from the small intestine and the excess above body requirements is excreted in the urine. The degree of absorption from various feeds and supplemental sources has been shown to be quite variable; only limited work was conducted with supplemental sources of magnesium.

Supplementation with a number of sources of magnesium has been attempted as a preventive measure for hypomagnesemia. In general, these have been helpful but information on the relative value of different supplements is lacking. In particular, there has been little research on the relative value of dolomitic limestone and magnesium oxide as sources of supplemental magnesium.

OBJECTIVE

The objective of this experiment was to determine the degree of availability and utilization of supplemental magnesium by beef steers when supplied as dolomitic limestone and magnesium oxide.

EXPERIMENTAL PROCEDURE

Six yearling steers, three Hereford and three Angus, were fed a basal ration alone and supplemented with dolomitic limestone and magnesium oxide in a series of three metabolism trials lasting from April 10 to June 25, 1965. The experimental design consisted of two randomly selected 3 x 3 Latin squares. The Hereford steers were randomly alloted to one Latin square and the Angus steers to the other square. Random allotment was made to metabolism stalls. The steers were kept in false-bottom metabolism stalls which are modifications of the stall described by Nelson et al., (1954).

The steers were tamed, and placed in the metabolism stalls on March 17, thus allowing several weeks for adjustment to the stalls before the first trial began. At the end of each of trials 1 and 2 the steers were removed from the stalls for about one week. During these periods, the steers were confined in a small dry lot adjacent to the building housing the metabolism stalls. All steers were fed the basal ration during these periods. The steers were weighed individually at the beginning and end of each metabolism trial.

The basal mixture consisted of corn cobs, shelled yellow corn, corn gluten meal, defluorinated rock phosphate and vitamins A and D. The corn cobs and shelled corn were ground in a hammer mill through a 1.905 cm. screen. A sufficient amount of feed was ground and mixed just prior to the beginning of each trial. The ingredient composition of the basal mixture is shown in Table 1. The chemical composition of the mixture by trials is shown in Table 2.

TABLE 1. INGREDIENT COMPOSITION OF THE BASAL MIXTURE

Feeds	Kg./100 kg. final ration
Shelled corn	19.46
Corn cobs	58.35
Corn gluten meal	22.04
Defluorinated phosphate	0.15
Vitamins A and D [a]	+

a 3,168 U.S.P. units vitamin A and 396 U.S.P. units vitamin D per kg. of feed.

TABLE 2. CHEMICAL COMPOSITION OF THE BASAL MIXTURE BY TRIALS

	Percent composition by trial		
Component	1	2	3
Dry matter	90.65	90.84	88.80
Crude protein	14.37	14.22	13.94
Ether extract	1.66	1.89	1.31
Crude fiber	19.30	20.86	21.30
Nitrogen free extract	53.56	52.16	51.04
Organic matter	88.89	89.13	87.59
Ash	1.76	1.71	2.21
Calcium	0.09	0.07	0.08
Phosphorus	0.26	0.24	0.25
Magnesium	0.11	0.12	0.10

All rations consisted of 5.0 kg. of basal mixture and 30 gm. of trace-mineralized salt. The control ration (A) contained 40 gm. calcium carbonate, in addition. Ration B contained 76 gm. dolomitic limestone, and ration C contained 15 gm. of magnesium oxide and 40 gm. of calcium carbonate, in addition. An attempt was made to equalize the daily intake of all nutrients except magnesium. Rations B and C were supplemented with approximately 9 gm. of magnesium per day. The composition of the three rations is in Table 3.

TABLE 3. COMPOSITION OF RATIONS (GM. PER HEAD DAILY).

Component	Ration A	Ration B	Ration C
Basal mixture	5000	5000	5000
Trace-mineralized salt	30	30	30
Dolomitic limestone		76	
Magnesium oxide			15
Calcium carbonate	40		40
Total	5070	5106	5085

One half of the daily ration was fed at 6:30 a.m. and the remainder at 5:00 p.m. Water was available at all times except during the feeding period (2 hours at each feeding).

Each trial consisted of a 10-day preliminary period followed by a 10-day collection period. The feces were collected in metal pans, picked up several times each day and placed in covered metal cans. A metal funnel, placed under a metal grid on the floor of the metabolism stall, directed the urine into plastic jugs from which it was collected daily. The feces were weighed once daily, thoroughly mixed and a 5% sample taken.

The urine was diluted to a definite minimum weight of 15 kg. daily and a 1% sample, by volume was taken. Some of the steers excreted more than 15 kg. of urine daily. Therefore, the total weight was recorded and a 1% sample was taken. Feces were preserved with thymol, and sufficient hydrochloric acid (diluted 1 to 1 by weight with water) was added to the urine samples to maintain a slightly acid pH. The fecal and urine samples were kept under refrigeration until analyzed.

Feed and feces were analyzed for magnesium by the method of Bradfield (1961). Calcium in feed and feces was determined by the method of the A.O.A.C. (1960) and phosphorus was determined by the volumetric molybdate method of Fiske and Subbarow (1925) after wet ashing. Crude fiber in feed and feces was determined by the method of Whitehouse et al., (1945). Urine was analyzed for nitrogen and feeds and feces were analyzed for dry matter, crude protein, ether extract, and ash according to the methods of the A.O.A.C. (1960).

Samples of venous blood were taken by jugular puncture immediately after each weighing. These were allowed to coagulate and serum was separated by centrifugation. Serum samples were stored under refrigeration until analyzed. Serum magnesium was determined by the method of Orange and Rhein (1951). Serum calcium was determined by the Clark and Collip (1925) modification of the Tisdall (1923) procedure. The Fiske and Subbarow (1925) method was used in analyzing for serum inorganic phosphorus.

The urine was analyzed for magnesium by the method of Orange and Rhein (1951). Urine calcium was determined by the method outlined by Hawk et al., (1954) and urine phosphorus was determined by the method of Fiske and Subbarow (1925).

The data were analyzed by analysis of variance, and Duncan's (1955) multiple range test was used to test for difference between treatment means.

RESULTS

Data on magnesium utilization are given in Table 4. Individual data are presented in Table 1 in the appendix.

TABLE 4. UTILIZATION OF MAGNESIUM BY STEERS FED A BASAL RATION ALONE AND WITH DIFFERENT MAGNESIUM SUPPLEMENTS.

Ration Mg supplement	A None	B Dolomitic limestone	C Magnesium oxide
Mg intake, gm.	4.85	14.38	13.47
Mg excretion, gm.			
Fecal	2.28	10.46	6.50
Urinary	1.56 [a]	0.97 [a]	4.92 [b]
Mg absorption, gm.	2.57 [a]	3.92 [b]	6.97 [c]
Mg absorption, %	52.91 [a]	27.33 [b]	51.53 [a]
Mg availability in supp.,%			
Calculated from fecal [d]		14.27 [a]	51.08 [b]
Calculated from urinary [e]	32.92 [a]	6.73 [b]	37.08 [a]
Mg retention, gm.	1.01	2.95	2.04
Mg retention, % of intake	19.99	20.61	15.09

a,b,c means on the same line with different superscript letters are significantly ($P < .05$) different.

d The values for the supplements were calculated by difference using the method of Crampton and Lloyd (1959).

e Expressed as the percentage of dietary magnesium excreted in the urine as outlined by Rook *et al.*, (1964).

The daily magnesium intake was 4.85 gm. for the control ration (ration A). The daily intakes were 14.38 and 13.47 gm. for the rations supplemented with dolomitic limestone (ration B) and magnesium oxide (ration C), respectively. Thus, supplemental magnesium, above that supplied by the basal ration, amounted to 9.5 gm. for ration B and 8.6 gm. for ration C.

The apparent magnesium absorption was 2.57 gm. for the basal ration. When the basal ration was supplemented with dolomitic limestone to supply 9.5 gm. of magnesium, absorption of magnesium increased to 3.92 gm. ($P < .05$). Supplementing the ration with magnesium oxide resulted in a markedly higher ($P < .05$) magnesium absorption (6.97 gm.), compared to dolomitic limestone. When absorption of magnesium was expressed as a percentage of the amount fed values were 52.9, 27.3 and 51.5% for rations A, B, and C, respectively. The mean foriration B was significantly ($P < .01$) different from the means for rations A and C.

Urinary excretion of magnesium was highest for ration C, which had the highest level of absorption. The high urinary excretion was probably a reflection of the large amount of magnesium absorbed in excess of requirement (Rook et al., 1958).

Two methods were used to estimate the availability of the magnesium from dolomitic limestone and magnesium oxide. One method consisted of calculating availability, by difference, using apparent absorption values by the method of Crampton and Lloyd (1959). The other method consisted of calculating the percentage of dietary magnesium excreted in the urine (Rook et al., 1964). The availability of supplemental magnesium was 14.3 and 51.1%, respectively, for dolomitic limestone and magnesium oxide ($P < .01$) when calculated by the method of Crampton and Lloyd (1959). Magnesium availability values were 32.9, 6.7

and 37.1% for rations A, B, and C, respectively, when calculated by the method of Rook et al., (1964). The values for rations A and C were not significantly different from each other, but were significantly (P<.05) greater than the mean for ration B.

The steers fed rations A, B and C retained 20, 21 and 15% of the magnesium fed respectively (Table 4). The values were not significantly different.

Blood serum magnesium values are given in Table 5. There was a trend for blood serum magnesium to increase from the beginning to the end of the trials for the steers fed the ration supplemented with magnesium oxide. There was a trend for a decrease in the case of the control ration. There was a large decrease (0.48 mg./100 ml.) in serum magnesium for the steers fed the dolomitic limestone supplemented ration. The differences in the changes in serum values are significant (P<.05). However, the multiple range test did not show significant differences between the three treatments.

TABLE 5. AVERAGE BLOOD SERUM MAGNESIUM VALUES FOR ALL TRIALS.

Time [a]	Blood serum Mg levels by rations [b]		
	A	B	C
Initial	2.320	2.351	2.322
Final	2.154	1.868	2.418
Change	- 0.166	- 0.483	+ 0.096

a Initial refers to beginning of trial and final refers to end of trial. Change refers to the change from the beginning of the trial to the end.

b Expressed as mg./100 ml.

Calcium absorption and retention values (Table 6) were similar for the control ration and the magnesium oxide supplemented ration. The values for the dolomitic limestone supplemented ration (ration B) were considerably lower. The depression resulted from a higher fecal calcium excretion for ration B, although urinary excretion for this ration was lower than for the control ration. Blood serum calcium values, also given in Table 6, were all high. However, the changes in serum calcium generally agreed with the retention data. Differences in blood serum calcium values due to experimental treatment were not significant.

TABLE 6. CALCIUM BALANCE AND BLOOD SERUM DATA

Item	Ration A	Ration B	Ration C
Calcium intake, gm.	19.70	19.27	19.68
Calcium excretion, gm.			
Fecal	11.60	14.20	12.06
Urinary	3.60	2.66	2.21
Total	15.20	16.86	14.27
Calcium absorption, gm.	8.10 [b]	5.07 [c]	7.62 [b,c]
Calcium retention, gm.	4.50 [b,c]	2.41 [c]	5.41 [b]
Blood serum calcium,[a] mg/100ml.			
Initial	18.91	21.41	19.24
Final	21.64	21.60	21.42
Change	+ 2.73	+ 0.19	+ 2.18

a Initial refers to beginning of trial and final refers to end of trial. Change refers to the change from beginning to end of trial.

b,c Means with different superscript letters are significantly ($P < .05$) different.

Phosphorus absorption and retention values were not significantly different (Table 7). Urinary excretion was higher for ration B, resulting in a trend toward a lower phosphorus retention for this ration than for ratiohs A and C. Blood serum inorganic phosphorus (Table 7) was lower for thės ration supplemented with dolomitic limestone (ration B), but differences were not significant.

TABLE 7. PHOSPHORUS BALANCE AND BLOOD SERUM INORGANIC PHOSPHORUS DATA

Item	Ration A	Ration B	Ration C
Phosphorus intake, gm.	12.51	12.51	12.48
Phosphorus excretion, gm.			
Fecal	5.83	5.52	6.27
Urinary	2.60	3.49	1.28
Total	8.43	9.01	7.55
Phosphorus absorption, gm.	6.68	6.99	6.21
Phosphorus retention, gm.	4.08	3.50	4.93
Blood serum inor. P, mg/100 ml.[a]			
Initial	9.12	9.90	9.20
Final	9.27	8.82	9.33
Change	+ 0.15	- 1.08	+ 0.13

a Initial refers to beginning of trial and final refers to end of trial. Change refers to the change from beginning to end of trial.

The apparent digestion coefficients for dry matter, crude fiber, nitrogen-free extract and energy were significantly lower for the ration supplemented with dolomitic limestone than for the other two rations (Table 8). Digestibility values were similar for the control and magnesium oxide supplemented rations. It appears that differences in carbohydrate (crude fiber and NFE) digestibility were responsible for the large differences in dry matter and energy digestibility. Individual data appear in the appendix.

TABLE 8. EFFECT OF MAGNESIUM SUPPLEMENTATION ON APPARENT DIGESTIBILITY.

Ration	Apparent coefficients of digestibility (%)					
	Dry matter	Crude prot.	Ether extract	Crude fiber	NFE	Energy
A (Control)	69.0[a]	74.0	72.4	65.6[a]	69.8[a]	67.9[a]
B (Dolomitic limestone)	59.9[b]	72.1	72.0	51.4[b]	60.0[b]	59.5[b]
C (Magnesium oxide)	70.1[a]	74.0	73.2	67.2[a]	70.7[a]	69.33[a]

a,b Means within the same column with different superscript letters are significantly ($P < .01$) different.

Discussion

The steers performed well during the course of the experiment and exhibited no outward adverse effects attributable to the rations. Data on weight gains is presented in the appendix in Table 5.

The low level of absorption of magnesium from the dolomitic limestone used in this experiment suggests that this material is of limited value as a source of supplemental magnesium for the prevention of hypomagnesemia. There is little information in the literature on the use of dolomitic limestone and magnesium carbonate as sources of supplemental magnesium. Barrentine and Morrison (1953) reported the control of grass tetany in ewes by feeding magnesium carbonate. Fontenot et al., (1965) reported the apparent effectiveness of dolomitic limestone when used as a source of supplemental magnesium in field studies with beef cows. Both of the above observations were made under field conditions. The data obtained in the present experiment suggest that excessively large quantities of dolomitic limestone would have to be consumed by lactating animals to supply appreciable amounts of absorbed magnesium. Low availability of magnesium plus the adverse effect on digestibility suggest that dolomitic limestone may be of rather limited value as a preventive for hypomagnesemia.

On the other hand, supplemental magnesium supplied as magnesium oxide was absorbed to a much greater extent. The data reported here indicate that relatively small amounts of magnesium oxide should be effective in the prevention of hypomagnesemia.

Storry and Rook (1963) reported that magnesium oxide was comparable in availability to magnesium acetate, magnesium nitrate, and magnesium lactate. Magnesium citrate was superior to magnesium oxide in availability according to these workers, while magnesium sulfate, magnesium silicate and magnesium chloride gave lower values. Magnesium carbonate was not investigated by these workers.

The values obtained for the absorption of magnesium from the basal and magnesium oxide supplemented rations were higher than the values of Rook et al. (1963), who reported the excretion of 66 to 77% of the dietary magnesium in feces of cows fed a variety of stall rations. In the present experiment, fecal excretion accounted for less than 50% of the intake of magnesium from rations A and C. However, fecal excretion was 73% of intake for ration B (dolomitic limestone).

Urinary excretion was probably a reflection of the amount of absorbed magnesium. As suggested by Rook et al. (1958), this is the major route for the disposal of magnesium absorbed in excess of body requirements. Thus, the high urinary excretion for the magnesium oxide supplemented rations is undoubtedly a reflection of the large amount absorbed above body needs rather than an indication of poor utilization. The results of this experiment when magnesium oxide was used are in agreement with the findings of Rook et al. (1964) who reported that measurable urinary excretion occurred in lactating dairy cows receiving 15 and 33 gm. of dietary magnesium per day.

There was no marked elevation of blood serum magnesium levels during the course of the trials. Blood samples were taken 14 hours after feeding the supplemented rations. This time interval could have contributed to the failure to detect large increases in the blood serum magnesium levels of the supplemented steers. Ritchie and Hemingway (1963a, 1963b) found that drenching sheep with 6.6 gm. of magnesium oxide did not result in the elevation of serum magnesium levels when measured 24 hours later.

The basal ration, although lower in magnesium content than rations normally fed beef cattle, apparently contained sufficient magnesium to meet the needs of the steers used in this experiment. Urinary excretion of 1.6 gm. per day by steers fed ration A (basal) would indicate that for these cattle a daily intake of 4.8 gm. of magnesium was at least sufficient. Rook et al. (1964) found that 9 to 13 gm. per day from partially purified basal rations met the needs of dairy cows as shown by maintenance of blood serum levels and continued urinary excretion. The requirement for magnesium of the steers used in this experiment would be expected to be considerably lower than those of a lactating dairy cow. Blaxter and McGill (1956) reported a calculated requirement of 3.39 gm. per day for a 273 kg. dairy heifer. Ray (1942) reported a requirement of 30.8 mg. per kg. of body weight or

8.31 gm. for a 273 kg. steer. In the present experiment, the level fed in the control ration was intermediate between these values.

The data on magnesium retention (Table 4) showed that the most magnesium was retained when ration B (dolomitic limestone) was the supplement. In this instance 2.95 gm. was retained compared with 1.00 gm. for the basal rations and 2.04 gm. for the ration supplemented with magnesium oxide. These differences were not significant. The adequacy of all rations in meeting the magnesium requirement of these animals is indicated by the urinary excretion of 1.56 gm. per day by steers on the basal ration. Therefore, it would appear that relatively less importance should be attached to the fact that magnesium supplied as dolomitic limestne was retained to a greater extent than was magnesium supplied as magnesium oxide. Of greater importance is the evidence that magnesium supplied as magnesium oxide was absorbed to a considerably higher degree than that supplied as dolomitic limestone.

Data obtained on calcium absorption and retention indicated that substantially less calcium was absorbed from the dolomitic limestone supplemented ration than from the basal and magnesium oxide supplemented rations. This suggests that the factor (s) causing low availability of magnesium from dolomitic limestone may have also affected the calcium availability from this source. Retention of calcium was also lower for ration B for reasons that are not apparent. However, this finding does agree with the data on blood serum calcium which showed that there was considerable increase in blood serum calcium levels for rations A and C (basal and magnesium oxide supplemented) while only a slight increase occurred when dolomitic limestone was fed.

Phosphorus absorption and retention values were similar for all rations, indicating that there was no substantial treatment effect on phosphorus availability. There was a drop in blood serum inorganic phosphorus levels during the trials when dolomitic limestone was fed and little change for the other two rations. However, the differences in change in serum values were not significant.

The reduced retention of calcium,trend toward a lower phosphorus retention, and the tendencies for differences in blood serum calcium and inorganic phosphorus resulting from supplementation with dolomitic limestone may be manifestations of the factor (s) which also decreased availability of magnesium and blood serum magnesium.

The factors in dolomitic limestone which caused the depression of carbohydrate digestion are not apparent. Probably, unknown factor (s) exerted an adverse effect on organisms in the rumen. This aspect needs further study.

SUMMARY

An experiment was conducted to study the utilization of supplemental magnesium by beef steers when supplied as dolomitic limestone and magnesium oxide. The basal ration supplied 4.85 gm. of magnesium per day. In supplemented rations, total magnesium intakes were 14.38 and 13.47 gm. for the rations supplemented with dolomitic limestone and magnesium oxide, respectively. Highly significant differences ($P < .01$) were obtained in the percentage of dietary magnesium absorbed. These values were 53, 27 and 52% for the basal, dolomitic limestone and magnesium oxide treatments, respectively. The availability of magnesium was much higher ($P < .01$) for magnesium oxide than for dolomitic limestone.

There was a significant difference ($P < .05$) in the change in blood serum magnesium values attributable to the experimental treatments; steers fed dolomitic limestone tended to show lowered serum magnesium levels. Calcium absorption and retention values were lower when dolomitic limestone was fed and blood serum calcium values, correspondingly tended to be lower for this ration. No significant differences between rations were observed for phosphorus absorption and retention or for blood serum inorganic phosphorus.

Feeding dolomitic limestone depressed the digestibility of the carbohydrate fractions of the ration.

The results of the experiment seem to indicate that magnes-

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ium oxide is a very satisfactory source of supplemental magnesium for the prevention of hypomagnesemia. Dolomitic limestone was found to be of considerably lower value as a source of supplemental magnesium due to its low level of absorption and adverse effect on digestibility of carbohydrates.

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APPENDIX

TABLE 1. DAILY MAGNESIUM BALANCE

Trial no.	Steer no.	Intake gm.	Fecal gm.	Absorbed gm.	Absorbed %	Urine gm.	Retention gm.	Retention % of intake
				Ration A				
1	3	4.81	2.00	2.81	58.48	1.87	0.94	19.60
1	6	4.81	2.40	2.41	50.01	1.45	0.96	19.94
2	2	5.38	2.46	2.92	54.31	0.81	2.11	39.19
2	8	5.38	2.43	2.95	54.78	1.63	1.32	24.58
3	5	4.36	2.51	1.85	42.37	1.63	0.22	4.94
3	9	4.36	1.85	2.51	57.52	2.00	0.51	11.69
	Av.	4.85	2.28	2.57	52.91	1.56	1.01	19.99
				Ration B				
1	8	14.18	10.18	4.00	28.19	1.52	2.48	17.46
1	9	14.18	8.58	5.60	39.51	0.61	4.99	35.22
2	5	14.67	11.73	2.94	20.01	1.57	1.37	9.34
2	6	14.67	11.07	3.60	24.56	0.23	3.37	22.99
3	2	14.28	10.55	3.73	26.08	0.42	3.31	23.14
3	3	14.28	10.62	3.66	25.62	1.45	2.21	15.48
	Av.	14.38	10.46	3.92	27.33	0.97	2.95	20.61
				Ration C				
1	2	13.56	5.92	7.64	56.33	5.29	2.35	17.30
1	5	13.69	6.24	7.45	54.41	5.18	2.27	16.61
2	3	13.79	5.73	8.06	58.43	4.34	3.72	27.00
2	9	13.79	5.48	8.31	60.28	7.00	1.31	9.56
3	6	12.98	8.60	4.38	33.78	1.95	2.43	18.72
3	8	12.98	7.01	5.97	45.97	5.79	0.18	1.37
	Av.	13.47	6.50	6.97	51.53	4.92	2.05	15.09

TABLE 2. CALCULATION OF MAGNESIUM AVAILABILITY BY DIFFERENCE[a]

Trial no.	Latin Square no.	Ration	Steer no.	T	T-A	$\frac{(T-A)\ 100}{s}$	S[b]
1	1	B	8	28.19	-30.29	-45.81	12.67
		C	5	54.41	- 4.07	- 6.27	52.21
	2	B	9	39.51	-10.50	-15.88	34.13
		C	2	56.33	6.32	9.97	59.80
2	1	B	5	20.01	-34.77	-53.83	0.95
		C	3	58.43	3.65	5.99	60.77
	2	B	6	24.56	-29.75	-47.00	7.31
		C	9	60.28	5.97	9.79	64.10
3	1	B	3	25.67	-16.75	-24.10	18.27
		C	8	45.97	3.60	5.42	47.79
	2	B	2	26.08	-31.44	-45.24	12.88
		C	6	33.78	-23.74	-35.73	21.79

a Method outlined by Crampton and Lloyd (1959)
Basic equation: $S = \frac{100\ (T-A)}{s} + A$

(S = availability of supplemental magnesium (%); T = availability of magnesium in supplemented ration (%); A = availability of magnesium supplied by basal ration (%); s = percent of total magnesium in ration supplied by supplement.)

b Availability or apparent absorption of magnesium from supplemental sources.

TABLE 3. EFFECT OF RATION ON MAGNESIUM "AVAILABILITY" [a]

Trial no.	Steer no.	Magnesium intake	Urinary Mg excretion	Magnesium "availability"
		gm.	gm.	%
		Ration A		
1	3	4.81	1.87	38.87
1	6	4.81	1.45	30.07
2	2	5.38	0.81	15.12
2	8	5.38	1.63	30.19
3	5	4.36	1.63	37.43
3	9	4.36	2.00	45.83
	Av.	4.85	1.57	32.92
		Ration B		
1	8	14.18	1.52	10.74
1	9	14.18	0.61	4.28
2	5	14.67	1.56	10.66
2	6	14.67	0.23	1.58
3	2	14.28	0.42	2.95
3	3	14.28	1.45	10.14
	Av.	14.38	0.97	6.73
		Ration C		
1	2	13.56	5.29	39.02
1	5	13.69	5.18	37.80
2	3	13.79	4.34	31.43
2	9	13.79	7.00	50.72
3	6	12.98	1.95	15.01
3	8	12.98	6.30	48.53
	Av.	13.47	4.92	37.08

a "Availability" expressed as grams urinary magnesium per gram magnesium intake times 100. (Rook et al., 1964)

TABLE 4. CHANGE IN BLOOD SERUM MAGNESIUM LEVELS.

Trial no.	Steer no.	Blood serum magnesium (mg./100 ml.) Initial[a]	Final[b]	Change[c]
			Ration A	
1	3	2.26	1.78	-0.48
1	6	2.65	2.07	-0.58
2	2	2.38	2.40	+0.02
2	8	2.05	1.90	-0.15
3	5	2.22	2.30	+0.08
3	9	2.35	2.48	+0.13
	Av.	2.32	2.16	-0.16
			Ration B	
1	8	2.25	1.57	-0.68
1	9	2.50	1.06	-1.44
2	5	2.00	2.08	+0.08
2	6	2.80	2.35	-0.45
3	2	2.38	2.30	-0.08
3	3	2.18	1.85	-0.33
	Av.	2.35	1.87	-0.48
			Ration C	
1	2	2.76	1.97	-0.79
1	5	2.64	2.44	-0.20
2	3	2.17	2.58	+0.41
2	9	2.27	2.53	+0.26
3	6	2.35	2.65	+0.30
3	8	1.74	2.35	+0.61
	Av.	2.32	2.42	+0.10

a Beginning of trial.
b End of trial.
c Difference from beginning to end of trial.

TABLE 5. STEER BODYWEIGHT DATA.

Trial no.	Steer no.	Bodyweight data (kg.)		
		Initial[a]	Final[b]	Gain[c]
		Ration A		
1	3	272.7	281.8	9.1
1	6	286.4	295.5	9.1
2	2	263.6	281.8	18.2
2	8	243.2	254.5	11.3
3	5	304.5	311.4	6.9
3	9	302.3	309.1	6.8
	Av.	278.8	289.0	10.2
		Ration B		
1	8	231.8	238.6	6.8
1	9	268.2	279.6	11.3
2	5	293.2	302.3	9.1
2	6	302.3	300.0	-2.3
3	2	279.5	293.2	13.7
3	3	300.0	309.1	9.1
	Av.	279.2	287.1	7.9
		Ration C		
1	2	268.2	268.2	0.0
1	5	275.0	290.9	15.9
2	3	277.3	302.3	25.0
2	9	293.2	302.3	9.1
3	6	315.9	315.9	0.0
3	8	256.8	272.7	15.9
	Av.	281.1	292.1	11.0

a Beginning of trial.
b End of trial.
c Gain from beginning to end of trial.

TABLE 6. TREATMENT AND ERROR MEAN SQUARES (FROM ANALYSIS OF VARIANCE).

Source Degrees of freedom	Treatment 2	Error 8
Mean squares for items		
Mg absorption, gm.	30.4353***	0.3295
Mg absorption, %.	1242.2888***	11.5095
Urinary Mg excretion, gm.	27.296 **	1.091
"Availability" of Mg, %.[a]	1625.1814***	92.2126
Mg retention, gm.	5.6957	1.2820
Mg retention, % of dietary	48.5710	85.5432
Mg retention, % of absorbed	3066.5197**	345.9655
Change in serum Mg, mg./100 ml.	0.5044*	0.0722
Change in serum Ca, mg./100 ml.	9.8684	6.6887
Change in inorganic P, serum mg./100 ml.	2.9814	1.1815
Ca balance, gm.	14.1701*	2.5735
P balance, gm.	3.14	2.15
Ca absorption, gm.	15.9406	3.4866
Digestion coefficients		
Dry matter, %.	186.9860***	0.8837
Crude protein, %.	7.0931	3.6840
Ether extract, %.	1.1675	30.8218
Crude fiber, %.	457.1720***	19.0716
NFE, %.	210.8214***	4.0049
Organic matter, %.	194.2168***	26.1274
Energy, %.	168.24 **	1.43

* $P < .05$
** $P < .01$
*** $P < .001$

a Expressed as the percentage of dietary magnesium excreted in the urine as outlined by Rook *et al.*, (1964).

Availability and Utilization of Magnesium
From Dolomitic Limestone and Magnesium
Oxide in Steers

by

Hubert John Gerken, Jr.

(ABSTRACT)

Six beef steers were used in a series of three metabolism trials to determine the availability and utilization of supplemental magnesium from dolomitic limestone and magnesium oxide when fed at levels supplying approximately 9 gm. per day. The experimental design consisted of two randomly selected 3 x 3 Latin squares. The basal rations supplied 4.85 gm. of magnesium per day. Intake of magnesium was 14.38 gm. per day for the ration supplemented with dolomitic limestone and 13,47 gm. for the ration supplemented with magnesium oxide. Highly significant differences ($P < .01$) were obtained in the percentage of dietary magnesium absorbed. These values were 53, 27 and 52% for the basal, dolomitic limestone and magnesium oxide treatments, respectively. The availability of magnesium was much higher ($P < .01$) for magnesium oxide than for dolomitic limestone.

There was a significant difference ($P < .05$) in the change in blood serum magnesium values attributable to the experimental treatments; steers fed dolomitic limestone tended to show lowered serum magnesium levels. Calcium absorption and retention values were lower when dolomitic limestone was fed and blood

serum calcium values, correspondingly, tended to be lower for this ration. No significant differences between rations were observed for phosphorus absorption and retention or for blood serum inorganic phosphorus.

Feeding dolomitic limestone depressed the digestibility of the carbohydrate fractions of the ration.

The results of the experiment seem to indicate that magnesium oxide is a very satisfactory source of supplemental magnesium for the prevention of hypomagnesemia. Dolomitic limestone was found to be of considerably lower value as a source of supplemental magnesium due to its low level of absorption and adverse effect on digestibility of carbohydrates.