THE EFFECT OF STAGE OF MATURITY ON THE BIOLOGICAL AVAILABILITY OF MAGNESIUM FROM WHEAT AND ORCHARDGRASS FED TO SHEEP

by

Cynthia Lee Stager

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APPROVED:

Chairman: Dr. J. P. Fontenot

Dr. H. J. Gerken, Jr.

Dr. K. E. Webb, Jr.

Mr. W. H. McClure

Dr. M. B. Wise

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Blacksburg, Virginia

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TABLE OF CONTENTS

Page

LIST OF TABLES

TABLES IN TEXT

TABLES IN APPENDIX

INTRODUCTION

Hypomagnesemic tetany, also referred to as grass tetany, grass staggers, wheat pasture poisoning and lactation tetany, is a disease of ruminants which can represent a substantial financial loss to the livestock producer. It occurs most frequently in aged beef cows nursing young calves early in the spring. The disease may occur in ewes shortly after parturition,particularly in ewes suckling twin lambs. The disorder often occurs shortly after the animals have been placed on lush, fast growing native or cereal pastures. The symptoms of grass tetany are undue excitement and incoordination, twitching and tetanic contractions of the muscles, pounding heart, convulsions and death.

Generally, a physiological deficiency of magnesium has been associated with grass tetany. This deficiency of magnesium may be due to a simple magnesium deficiency or from factors which interfere with magnesium utilization. The body has limited ability to store magnesium. Magnesium ingested above the requirement is excreted in the urine. Hence, low serum magnesium values rapidly reflect decreased magnesium intake or absorption and are characteristic of grass tetany.

It appears that in grass tetany the biological availability or utilization of magnesium may be suboptimal in forages in early stages of maturity. Data on magnesium availability in such forages are quite limited. The research reported here was designed to determine the availability of magnesium from two forages. The effect of stage of maturity of the forages was also investigated.

REVIEW OF LITERATURE

Distribution, Function and Requirements of Magnesium

Distribution of Magnesium in the Animal Body. Magnesium comprises .05%of the animal body (Rook and Storry, 1962). The magnesium of extracellular fluids represents approximately 1% of the total magnesium, whereas almost 60% is distributed in the skeleton and 40% in soft tissues.

The magnesium content of the extracellular fluid is considered to be evenly distributed, although McCance and Watchorn (1931) have reported that concentration of magnesium in cerebrospinal fluid was slightly higher than in plasma. In ruminants, serum and plasma levels of magnesium generally range from 1.8 to 3.2 mg per 100 ml, although apparently normal values as low as 1.66 mg per 100 ml in cattle (Sjollema, 1932) and as high as 6.9 mg per 100 ml in goats (Watchorn, 1933) have been reported. In whole blood Field et al. (1958) reported values of 2.14 to 2.8 mg per 100 ml, indicating that the magnesium of serum and blood cells are similar. However, McAleese et al. (1961), using radioisotopic techniques, reported very little magnesium was taken up by the red blood cells. The magnesium in the blood which is considered to be of physiological importance is the ultrafilterable magnesium found as free ions (Rook and Storry, 1962).

Benjamin et al. (1933) found that magnesium in blood was present in three forms: as a filterable, absorbable form; a nonfilterable form probably bound to protein; and as the absorbable free ion. Watchorn and McCance (1932) found that the ultrafilterable portion of magnesium in serum comprised 75% of the total serum magnesium.

The magnesium in soft tissues ranges from .03 to .13% of the dry matter (Wilkins, 1934). The highest magnesium concentration of tissue was found in the heart, liver, spleen, lung, kidney, and skeletal muscle (McAleese et al., 1961; Field, 1961; Lengemann, 1959). In soft tissues Scott (1940) found that the magnesium content was higher within the cell than in the surrounding interstial fluid.

Neumann and Weikel (1954) found that the magnesium of bone was present not only on the surface but also in the crystalline center. McLean (1958) hypothesized that the magnesium present in bone was actually an impurity resulting from the formation of mineral deposits from the magnesium present in the body fluids. Field (1960) reported a range of 90 to 100 g of magnesium in the skeleton of cattle and a range of 8 to 10 g in sheep. He found that the areas of highest magnesium content in the bone were the lipid metabolizable regions. The magnesium content was highest in the femur and ribs.

The magnesium of bone can be mobilized to some extent by the animal. The proportion of magnesium that is soluble increases with increasing hydration of bone and decreases with increasing recrystalization of bone(Neumann and Weikel, 1954). In ruminants, Taylor (1959) reported that 70% of the bone magnesium was soluble in dilute acid. The stability of the magnesium in bone increased with age in rats and cattle (Breibart, 1960; Field, 1960). Rook and Storry (1962) concluded that the reduction of magnesium lability of bone results partially from increasing recrystalization of bone with age, but was mainly the result of a decreasing blood supply to bone with age.

Functions of Magnesium in the Body. The function of magnesium in hard tissue is unknown (Pike and Brown, 1975). A reduction of magnesium in extracellular fluid would result in an increase of the irritability of the muscular system (Rook and Storry, 1962). The magnesium in soft tissues, however, plays an important role in many biochemical reactions (Wacker, 1965). Enzymes, including phosphatases and those involved with adenine triphosphate, which split and transfer phosphate groups, are activated by magnesium. Magnesium acts as a cofactor in decarboxlyation. In is also involved in the stability of ribosomes and muscular activity (Lehninger, 1970).

Magnesium Requirements. Blaxter and Rook (1954) calculated the magnesium requirement of calves to be .96 to 1.08 g per day by taking into consideration the magnesium excretion on a magnesium free diet and assuming additional losses in the utilization of dietary magnesium. For dairy cattle in midlactation, Rook et al. (1964) determined a dietary magnesium requirement of 9 to 13 grams. O'Kelley and Fontenot (1969) used dietary magnesium levels of 9.5 to 42.2 g per day to determine the level of magnesium necessary to maintain serum magnesium levels of 2 mg per 100 ml in lactating beef cattle. Using regression equations, they predicted that magnesium intake should be 20.9, 22.1 and 18 g per day for cows during early, mid and late lactation, respectively. In a similar experiment, O'Kelley and Fontenot (1973) determined the magnesium requirement for beef cattle during gestation to be 8.5, 7 and 9 g per day at 155, 200 and 255 days of gestation, respectively. In lambs, Henry and Smith (1976) determined the requirement of magnesium to be 660 ppm.

Magnesium Absorption, Secretion and Excretion

Magnesium Absorption. In young calves fitted with cannulas, magnesium absorption from the large intestine has been found to account for 25 to 40% of the dietary magnesium (Smith, 1959a, 1959b and 1962). Absorption of magnesium from the small intestine was shown to be approximately 25% of the intake (Smith, 1962). Perry *et al*. (1967) reported that the small intestine was the major site of absorption in calves. In the same experiments, these researchers observed that magnesium absorption decreased with maturity in the large intestine, but did not vary with age in the small intestine. Robson and Kay (1972) also noted a decrease in magnesium absorption with age with young calves. Forty-four percent of the dietary magnesium was absorbed in calves in the large intestine but was reduced to 12% when the calves were only a few months old.

By studying the magnesium content of blood samples taken from the veins draining the gastrointestinal tract of sheep, Stewart and Moodie (1956) concluded that the principle site of magnesium absorption in sheep was the small intestine. Field (1961) observed that the greatest extent of magnesium absorption occurred in the middle third of the small intestine. He used a radioisotope technique in which he determined the radioactivity of the digesta from various sections of the gastrointestinal tract. Determinations were made 10 hr after the administration of ^{28}magnesium, either orally or intraveneously. Care and van't Klooster (1965), however, found that the ileum had the greatest ability to absorb magnesium. This was concluded from experiments involving Thiry Vella loops of the small intestine. Their work is in agreement with that of Phillipson and Storry (1965) who also isolated loops of the intestine of sheep. These workers concluded that the middle gut and ileum were major sites of magnesium absorption although absorption could occur in the anterior regions of the gastrointestinal tract.

Work has been done on absorption in other regions of the gastrointestinal tract of ruminants. Storry (1961), using the digesta from both cannulated animals and animals sacrificed for this experiment, determined the amounts of ultrafilterable magnesium in the gut. Since ultrafilterable magnesium was higher at low pH's, Storry concluded that due to the pH of the various regions of the intestinal tract, magnesium could be absorbed as the free ion only in the abomasum. The work of Pfeffer (1970) with sheep indicates that the cecum and colon are sites of magnesium absorption.

Allsop and Rook (1972) found that in sheep cannulated in the duodenum and ileum and with polyethelyne glycol used as a marker, considerable amounts of magnesium were absorbed after the ileum.

Although Phillipson and Storry (1965) reported that the rumen-reticulum was impermeable to magnesium, more recent work indicates that the forestomachs play a more important role than previously thought.

In dairy cows fitted with both ruminal cannulas and simple or reentrant cannulas in the intestine, Kemp et al. (1973) determined that approximately 20% of the dietary magnesium is absorbed before reaching the duodenum. The amount of magnesium absorption in this region tends to increase with increasing magnesium intake.

Ben-Ghedalia et al. (1975) found that in sheep, magnesium was absorbed mainly in the stomachs and the colon. They hypothesized that the region of the forestomach responsible for this was the omasum.

In a study to determine the effects of feeding regimen and protein supplementation on magnesium absorption, Grace and MacRae (1972) determined that 94 and 50% of the total magnesium absorption occurred in the stomach, depending on whether the sheep were fed continuously or once a day. In agreement with that work, Tomas and Potter (1976a) found that between 70 and 91% of the absorption of magnesium occurred in the rumen of sheep. In ewes, Tomas and Potter (1976b) found that when magnesium was absorbed in the rumen, magnesium absorption in the colon was decreased but was increased in the small intestine. They found that a small but significant amount of magnesium was absorbed in the small intestine in all circumstances studied. They also noted that the capacity for magnesium absorption in the colon increased when infused post ruminally.

It appears that the principle site of magnesium absorption occurs in the forestomachs (Kemp et al., 1973; Ben-Ghedalia et al., 1975; Grace and MacRae, 1974; Tomas and Potter 1976a and 1976b). A significant amount of magnesium is absorbed in the colon (Pfeffer, 1970; Allsop and Rook, 1972; Ben-Ghedalia et al., 1975; Tomas and Potter, 1976b).

Magnesium Secretion. Magnesium secretion occurs mainly in the upper small intestine with particularly large amounts being secreted in the bile (Field, 1959; Chutkow, 1964; Phillipson and Storry, 1965; Perry et al., 1967; Allsop and Rook, 1972; Ben-Ghedalia et al., 1975; Grace and MacRae, 1974). The secretion of magnesium in the small intestine has been reported to increase with age in ruminants (Smith, 1959a and 1959b). Smith also reported that endogenous magnesium was about .5 mg per kilogram bodyweight per day in calves 2 to 5 weeks of age but increased to 2.2 mg per kilogram bodyweight per day at 26 to 32 weeks of age. Rook and Storry (1962) estimated values of 3.5 mg per kilogram bodyweight in calves and 1.5 mg per kilogram bodyweight in mature cows.

Magnesium Excretion. Magnesium is secreted in cow's milk at the rate of approximately 12 mg per 100 ml (Rook and Storry, 1962). The magnesium excreted in urine is apparently controlled by magnesium concentration in the serum and by magnesium intake (Rook et al., 1958; Kemp et al., 1961, Ammerman et al., 1972). According to Storry and Rook (1963), urinary magnesium excretion should approach zero when serum magnesium approaches 2.15 mg per 100 ml in dairy cows.

Factors Affecting Magnesium Absorption

Magnesium absorption may be adversely affected by several factors (Rook and Storry, 1962). Some of these factors that have been investigated are dietary nitrogen and potassium (Fontenot et al., 1960), dietary calcium and phosphorous (Wise et al., 1963), feeding regimen (Grace and MacRae, 1972) and organic acids (House and van Campen, 1971).

Nitrogen. Head and Rook (1955) found that serum magnesium and urinary magnesium were reduced when ammonium acetate or ammonium carbonate was administered into the rumen. Moore et al. (1972) found that neither form nor level of nitrogen affected magnesium absorption in sheep. Grace and MacRae (1972) used treated and nontreated casein to determine whether protein available in or beyond the rumen had an effect on apparent magnesium absorption. They concluded that protein regardless of site of protein availability did not affect magnesium absorption.

Potassium. The association of high potassium levels with decreased magnesium absorption is quite well established (House and van Campen, 1971; Newton et al., 1972). Bohman et al. (1969) showed that a reduction of plasma magnesium levels occurred in heifers administered high levels of potassium chloride. Similar reductions were noted in ewes by Suttle and Field (1967) when 4.44% potassium was added to the diet. House and van Campen (1971) demonstrated that high potassium levels decreased magnesium absorption in sheep. These authors used an isotope-dilution technique with radiomagnesium. High dietary potassium resulted in increased total fecal magnesium but endogenous fecal magnesium and urinary magnesium were reduced.

Moore (1971) noted decreased urinary excretion of magnesium in cattle fed high potassium levels, indicating decreased apparent absorption. He also found that magnesium absorption was less in lambs on high potassium levels. Newton et al. (1972) reduced apparent magnesium absorption in sheep from 49% in a diet containing .6% potassium to 26% in a diet containing 4.9% potassium. Frye (1975), upon feeding various levels of potassium and magnesium, concluded that the response of apparent magnesium absorption to potassium level of the diet was quantitative. Lambs were used in a 2 x 4 factorial design with potassium levels of .7 and 4.7% and magnesium levels of .08, .17, .33 and .61%, dry basis. Apparent magnesium absorption, expressed as grams per day, increased linearly with increasing magnesium intake for both levels of potassium. High potassium caused a decrease in magnesium absorption, particularly at the lower levels of magnesium intake.

Nitrogen and Potassium. Fontenot et al. (1960), in two trials, found that a diet containing 4.7% potassium and 34.4% crude protein decreased apparent magnesium absorption from 43% in the basal diet to 28%. The basal diet contained 1.4% potassium and 12.8% crude protein. Moore et al. (1972) determined the effect of high potassium and high nitrogen on magnesium utilization in ruminants. In a 2 x 2 factorial design, ruminants were fed rations containing a high or low level of crude protein and a high or low level of potassium. High potassium alone decreased apparent magnesium absorption and serum magnesium. High nitrogen in combination with high potassium did not further alter absorption of magnesium.

Calcium and Phosphorous. Wise et al. (1963) reported that low calcium to phosphorous ratios decreased magnesium absorption. Smith and McAllan (1966, 1967) found that the presence of phosphates in the digesta of calves caused an increase in the amount of bound magnesium in the small intestine. Dutton and Fontenot (1967) found that form of phosphorous in the diet of sheep (inorganic or organic) did not affect magnesium absorption whether magnesium was fed at a high or low level. Gunn (1969) found that neither oral doses of 12 g of calcium carbonaten or 13 g of monosodium phosphate caused a decrease in serum magnesium levels in ewes. Pless (1973) found that high levels of phosphorous (1.3% of the ration) and high levels of calcium (1.4% of the ration) caused a decrease in apparent magnesium absorption. Chicco et al. (1973) reported a similar reduction in apparent magnesium absorption from diets containing .43% and .36% calcium and phosphorous compared to .14 and .12% calcium and phosphorous, respectively.

Other Factors. Burt and Thomas (1961) found that a reduction in serum magnesium levels occurred when 50 g of sodium acetate was fed to sheep. Wright and Wolff (1969) could not produce any effect on magnesium absorption when trans aconitic acid was fed to sheep. House and van Campen (1971) failed to affect magnesium absorption when citric acid was added to the diet of sheep.

Smith (1961) found that wood shavings contributed to the decrease in magnesium absorption in young calves. By muzzling calves to inhibit the consumption of shavings, he found that magnesium utilization was higher for these calves than for those that had access to the shavings.

In isonitrogenous and isocaloric diets, Kemp et al. (1966) found that diets with 800 g of added fat reduced the apparent magnesium absorption from 25% to approximately 10% in dairy cows.

Care et al. (1967) found that the addition of sodium chloride had no affect on magnesium absorption. In performing parathyroidectomies and thyroidectomies in sheep they also found that these hormones did not affect magnesium metabolism. Grace and MacRae (1972) determined that feeding regimen had no effect on magnesium absorption. There were no differences in quantities of magnesium absorbed in the sheep whether they had been fed once daily or continuously.

According to Fordyce et al. (1974) level of nutrition does not affect magnesium absorption in cows. With lactating beef cows they found that the magnesium lost in the urine and milk was increased with plane of nutrition.

Hypomagnesemic Tetany

Occurrence. Sjollema (1932) associated the incidence of tetany with pastures that had 1) high nitrogen content with crude protein of approximately 30%; 2) high nitrate levels of around 2%; 3) high potassium levels and 4) low sodium levels with the ratio of potassium to sodium sometimes being as low as 50 to 1.

Sims and Crookshank (1956), in a survey in Texas, found that 80% of the grass tetany cases occurred between 60 and 150 days after the cows had been turned out on wheat pasture. Seventy-nine percent of the cows had calves at their sides which were under 60 days old.

Butler (1963), in a survey of 64 farms of south Scotland, found that 8.7% of the cows surveyed had hypomagnesemia but only 1.1% showed signs of tetany. On farms with the highest incidences of tetany, he found that there was a higher potassium to calcium and magnesium ratio than on the farms where tetany incidences were low. Fontenot et al. (1965) noted that unusual stress tended to precipitate grass tetany.

Symptoms. Crookshank and Sims (1955) and Sims and Crookshank (1956) described hypomagnesemic tetany in detail. From the first symptoms to death, the usual time lapse was 6 to 10 hours. The symptoms that are first noticeable are undue excitement, incoordination, loss of appetite, viciousness, staggering and falling. The animals exhibit muscle twitching, an anxious expression, grinding of the teeth and salivation. The third eyelid protrudes or flickers, breathing is labored, and the heart is pounding and can be heard several feet away. A comatose state occurs and if the animal is not treated before the coma, death will result. Sjollema (1932) found, upon autopsy, that dark flesh and emphysematous lungs were characteristic of animals with grass tetany.

Parr and Allcroft (1953) reported low serum magnesium levels in calves with experimentally produced grass tetany. Values were found to be as low as .6 mg of magnesium per 100 ml of serum. These authors also associated tetany with low serum calcium levels. Butler (1963) reported serum magnesium values below 1.2 mg per 100 milliliters. Henry and Smith (1976) reported values as low as .5 mg per 100 milliliters.

Cause. According to Blaxter and Rook (1954) in hypomagnesemic tetany cases, the magnesium depletion occurs mainly in the extracellular fluid. Bartlett et al. (1957) found an association between low serum magnesium values and high concentration of nonprotein nitrogen, urea nitrogen and ammonia nitrogen in the blood during early grazing seasons. They hypothesized that the high ammonia levels in the gut might interfere with magnesium metabolism.

Bartlett et al. (1954, 1957) found that fertilization of fields with nitrogen or potassium decreased serum magnesium levels in grazing milk cows to 1 mg per 100 ml and increased the incidence and severity of tetany. This work is supported by that of Kemp (1960) in which he found that heavy application of potassium and/or nitrogen on forages decreased serum magnesium in grazing milk cows. However, Smyth et al. (1958) found no greater incidence of tetany in cattle grazing Italian rye grass with either potassium or nitrogen fertilization, but did note an increase in the incidence of tetany when the forage was fertilized with both potassium and nitrogen.

Burau and Stout (1965) and Stout et al. (1966) suggested that high levels of organic acids may contribute to the grass tetany syndrome. This was concluded when they found that forages that were tetany prone may contain as much as 2.5% trans aconitic acid. Bohman et al. (1969), from an oral administration of citric acid or trans aconitic acid alone or with potassium chloride to Hereford heifers, found that neither acid produced tetany when administered alone, but produced tetany when given in combination with potassium chloride.

Treatment. Treatment of grass tetany is limited and must be done before the animal reaches the comatose state (Crookshank and Sims, 1955). Generally, the treatment is an intravenous solution of magnesium and calcium with varying amounts of dextrose and phosphates (Miller, 1965).

Prevention. Fontenot _et al_. (1965) suggested the use of a mineral supplement containing dolomitic limestone, magnesium oxide or epsom salts as a preventative measure against grass tetany. Gerken _et al_. (1967) found that the use of dolomitic limestone was not advisable due to poor digestibility of the magnesium in the limestone and the decreased digestibility of energy resulting from the use of this substance. Frye _et al_. (1977) found that with various mixtures of magnesium oxide with trace mineralized salt, cottonseed meal, molasses and steamed bonemeal, cattle would consume 11 to 30 g of magnesium per head per day.

Line _et al_. (1958) found that serum magnesium levels could be maintained above 2 mg per 100 ml with calcined magnesite as a drench or in combination with feed supplements such as oats and barley and linseed.

McConaghy _et al_.(1963) suggested the use of calcined magnesite as a dust to the herbage to supplement magnesium intake from herbage. These authors used blood level of magnesium as an indicator of the adequacy of the treatment. Fertilization with calcined magnesite did not prove as beneficial as dusting the forage with the compound.

Ritchie _et al_. (1962) found that two magnesium alloy bullets each weighing 40 g and containing 10.8 g of magnesium would sufficiently maintain serum magnesium levels for 46 days in nonpregnant, nonlactating ewes fed diets supplying 200 mg of magnesium per day. The use of magnesium alloy bullets was tested by House and Mayland (1976). They found that although the bullets released magnesium, as determined by *post mortem* examination of the digestive tract, the rate of release was not uniform, as demonstrated by serum magnesium levels.

Availability of Magnesium from Feedstuffs

Forages. Field *et al*. (1958) determined the availability of magnesium from pasture herbages that were tetany and non-tetany prone. The herbage from fields where tetany had occurred consisted of perennial and Italian ryegrass, cocksfoot and white clover. Control fields contained the above forages with broad red clover and uncultivated grass and weeds. There was no difference in magnesium availability between forages but magnesium availability did differ among sheep. Availability, expressed as the percent of dietary magnesium not excreted in the feces, was 13 and 26% for the two sheep involved.

In grazing sheep, Field (1967) found the true availability of a mixture of perennial S23 ryegrass and wild white clover to be 12 to 26% when using fecal excretion as the determining factor. This was calculated as the regression coefficient of urinary magnesium on dietary intake of magnesium. Magnesium intake was measured indirectly and urinary magnesium was determined using an indicator.

When calculated as the percent of dietary magnesium not excreted in the feces, Kemp *et al*. (1961) found that in lactating cows, the average availability of magnesium in freshly cut grass was 17% and was not significantly different from a winter ration of hay, silage, fodder beets and concentrates. They found magnesium in herbage cut at an early stage of maturity was only 10% available, whereas, in later stages of maturity availability was 16 to 20%.

Defining availability as urinary magnesium expressed as the percent of magnesium intake, Rook and Campling (1962) determined magnesium availability from forages for nonpregnant, nonlactating cows ranged from 7 to 25%. The highest availabilities were found from coarse grasses. Availabilities of less than 10% were found in early cuttings of H-1 ryegrass. Later cuttings of ryegrass had magnesium availibilities of between 12 and 20% for nonpregnant, nonlactating dairy cows.

Rook and Balch (1958, 1962) found availability of magnesium to be 18 to 21% in cocksfoot sward, whereas the availability in a sward containing a mixture of cocksfoot and ryegrass was 17 to 18%. The use of nitrogenous fertilizers apparently decreased magnesium availability. They did not find a difference in availability when the cocksfoot ryegrass sward was cut at different stages of maturity.

Stillings et al. (1964) reported magnesium availabilities of 11 to 24% in orchardgrass for sheep. When orchardgrass was fertilized with 136 kg of either ammonium nitrate or urea, the availability was 11 to 16% as compared to 18 to 24% in the control herbage with no fertilizer.

Rosero et al. (1975) found that in sheep the magnesium absorption for orchardgrass or fescue-ryegrass hybrid dehydrated forages was not significantly different. Fertilization decreased apparent magnesium absorption in both forages. In early maturities, magnesium retention was decreased.

Mixed Feeds. Rook et al. (1958) determined the availability of magnesium was 8 to 38% in various rations. The inclusion of decorticated ground nutmeal decreased the availability to 8% in lactating cows. In a ration consisting of hay, concentrates and dairy cubes, they found the availability to be 38%. In agreement with this work is that of Rook and Balch (1962) in which availability of magnesium in diets containing decorticated ground nutmeal was only 8%. Rook et al. (1958) and Rook and Balch (1962) calculated magnesium availability as the percent of dietary magnesium excreted in the urine and milk.

Rook and Campling (1962) determined the effect of concentrates on the availability of magnesium from cocksfoot hay in two nonpregnant, nonlactating cows. A protein supplement of linseed and decorticated ground nut cake decreased the magnesium availability of the ration whereas the addition of flaked maize increased availability. Magnesium availability was calculated as the percent of dietary magnesium not excreted in the urine.

Rook et al. (1964) determined magnesium availability of 24% in a ration of wheat straw and flaked maize supplemented with bloodmeal, minerals and vitamins. Urinary magnesium as percent of dietary magnesium was used to express availability. Similar values were obtained for milk cows when expressed as the percent of dietary magnesium not excreted in the feces (Kemp et al., 1966). The ration used in the study consisted of a mixture of hay and concentrates.

In sheep fed a diet of shelled corn, corn cobs, and corn gluten meal, Gerken and Fontenot (1967) determined the apparent absorption of magnesium to be 53%. When availability was calculated as a percent of dietary magnesium excreted in the urine, the value was 33%.

Newton et al. (1973) found the magnesium availability to be 49% for a ration of shelled corn, corn cobs, soybean meal and cerelose with mineral and vitamin supplements when fed to lambs. Availability was calculated as apparent magnesium absorption, expressed as a percent of intake.

Mineral Supplements. Huffman et al. (1941) studied the effects of magnesium salts on the magnesium content of the blood. By determining the amount necessary to maintain normal plasma magnesium levels in calves they found that magnesium oxide, magnesium carbonate, magnesium chloride and magnesium phosphate were of similar value to the animal. Magnesium salts of citrate, sulfate and silicate and metallic magnesium were very inefficient in maintaining plasma magnesium levels.

Storry and Rook (1963) evaluated the availability of magnesium from several supplements. Availability from magnesium oxide was 32% for nonpregnant, nonlactating dairy cows when availability was calculated as the urinary magnesium expressed as a percent of the magnesium in the supplement. When using the magnesium oxide as a standard, these authors found that magnesium chloride was similar in availability of magnesium to magnesium oxide. As reported by Huffman et al. (1941), they found that magnesium salts of trisilicate and phosphate, when compared to magnesium oxide, were poorly available. Although Huffman et al. (1941) reported that magnesium citrate was a poor source of magnesium, Storry and Rook (1963) found it to be more available than magnesium oxide. Magnesium acetate, nitrate and lactate were found to be similar in availability of magnesium to magnesium oxide.

Rook et al. (1964) calculated the availability of magnesium from magnesium oxide to be from 54 to 77% in dairy cattle. Availability was calculated as the increase in magnesium content of milk and urine due to the addition of the supplement to the basal ration, expressed as a percent of the magnesium in the supplement. A value of 51% magnesium availability in magnesium oxide has been reported in steers (Gerken and Fontenot, 1967). Availability, when expressed as percent apparent absorption of magnesium, has been reported as 52% in magnesium oxide for wethers (Ammerman, 1972). Chicco et al. (1972), by varying levels of magnesium oxide in the basal ration, determined the true availability of magnesium from magnesium oxide to be 75% for sheep when determined by the use of regression equations.

In support of the work of Huffman (1941), both Moore et al. (1971) and Ammerman et al. (1972) found the magnesium in magnesium carbonate to be of similar value to that in magnesium oxide. Moore et al. (1971) found the magnesium availability from this source to be 46% in steers and Ammerman et al. (1972) reported a value of 56% in sheep.

In disagreement with Huffman et al. (1941) and Storry and Rook (1963), Ammerman et al. (1972) found magnesium from magnesium sulfate was highly available in sheep. They found the magnesium availability from the sulfate salt was similar to the availability from magnesium oxide. The apparent absorption of magnesium sulfate was 56% as compared to 52% in magnesium oxide.

Fishwick and Hemingway (1973) agree with Huffman et al. (1941) in that they also found that magnesium phosphate was of similar value to magnesium oxide in growing sheep when using blood magnesium as the parameter of comparison.

The availability of magnesium from dolomitic limestone is poor. Gerken and Fontenot (1967) determined that in steers, the availability of magnesium from dolomitic limestone was 14%. This value was calculated by difference. Another natural ore, magnesite, has been found to be poorly available in magnesium. Ammerman et al. (1972) reported that from magnesite, there was only 9% apparent absorption of magnesium whereas the true absorption was 14%.

OBJECTIVES

The main objective of this investigation was to determine the biological availability of magnesium in wheat and orchardgrass at different stages of maturity when fed to sheep. The availabilities of calcium, phosphorous, and potassium were also studied.

EXPERIMENTAL PROCEDURE

Harvest of Forages

Wheat (*Triticum aestivum*) and orchardgrass (*Dactylis glomerata L.*) were cut at three different stages of maturity from pure stands of the forages at the Shenandoah Valley Research Station, Steeles Tavern, Virginia. Three plots of wheat and one of orchardgrass were chosen for harvest. Each plot was divided into three strips which were randomly assigned to be harvested at three stages of maturity. All stages were cut during the first growth of the plant.

As shown in table 1 wheat was cut at the vegetative, boot and milk stages on May 8, May 14, and June 6, 1975, for maturities 1, 2 and 3, respectively. The three maturities of orchardgrass were early joint, early bloom and milk, and were cut on May 9, May 16, and June 9, 1975, for maturities 1, 2 and 3, respectively. Vegetative stage for wheat refers to the period of growth during which only leaves were present. During the boot stage, the inflorescense was enclosed in the leaf sheath. Milk stage was used to define the period during which the seeds are immature and the endosperm is milky. Early joint defines the stage during which the stem first begins to elongate with only a portion of the leaves being exposed. During the early bloom stage, the plants were first beginning to flower. The heights for the three maturities of wheat and orchardgrass are shown in table 1. Heights were similar for corresponding maturities of wheat and orchardgrass and ranged from 23 to 114 cm. The mature height of orchardgrass was in the range indicated by Heath *et al*. (1973).

Table 1. DESCRIPTION OF WHEAT AND ORCHARDGRASS HARVESTED AT DIFFERENT MATURITIES

Kind of forage	Forage maturity	Stage of growth	Height of plant	Dry matter content
			cm	%
Wheat	1	Vegetative	25	20.3
Wheat	2	Boot	51	19.3
Wheat	3	Milk	102	31.0
Orchardgrass	1	Early joint	23	19.9
Orchardgrass	2	Early bloom	56	17.2
Orchardgrass	3	Milk	114	33.2

Forages were cut in single swaths with a sickle mower, equipped with crimp rollers and windrower. The rollers were set loosely to ensure that the stems would not be crushed. The forage from each swath was sampled and loaded on a truck by hand. During hand loading, weeds were separated and discarded. After the entire maturity had been harvested, it was transported to Blacksburg and dried in forced air ovens at 70 C. Following drying, the forages were stored in burlap bags until ground and mixed. Each maturity of the forages was ground in a hammermill through a 2.5 cm screen and stored in large burlap bags until used. Total amounts of the fresh forages harvested were approximately 1100 kg for all maturities of wheat and maturities 1 and 2 of orchardgrass. Approximately 900 kg were harvested for orchardgrass maturity 3.

A handful sample of forage (approximately 25 g) was taken at about 2.5 m intervals throughout the swath, mixed and separated into two samples, each of which was sealed in double plastic bags, and placed in an ice chest, transported to Blacksburg and frozen. This sample was analyzed for nitrogen components. Total nitrogen was determined on subsamples of each forage by the A.O.A.C. procedure (1970). True protein was determined by precipitating the protein with 10% tungstic acid solution and analyzing for nitrogen by the A.O.A.C. procedure. Nonprotein nitrogen was determined as the difference of total nitrogen and true protein nitrogen. The other sample was used for proximate analysis.

Metabolism Trials

Two metabolism trials were conducted with 18 wether lambs averaging 35.4 kg bodyweight. The experimental design was a 2 x 3 factorial with the two types of forage harvested at three stages of maturity. Animals were placed in blocks of six animals by weight. For the first trial the lambs within each block were allotted to treatments. For the second trial the lambs were allotted at random with the restriction that no animal received the same treatment in both trials.

The lambs were maintained in false bottomed metabolism stalls similar to those described by Briggs and Gallup (1949). Animals were fed 350 g of forage plus 5 g of iodized salt twice daily at 12-hr intervals. Wethers had access to water at all times except during the 2 hr feeding periods.

Each trial, consisting of a 10-day preliminary period followed by a 10-day collection period, was commenced after adjustment to stalls and a transition period to the experimental ration at the rate of 20 percentage units per feeding from a preliminary ration of 700 g of chopped hay per day. The preliminary period of each trial began when all animals consumed all of the experimental ration offered during a 24 hr period.

Feed was sampled at each feeding and all refusals were saved from four feedings prior to the beginning of the collection period until four feedings prior to the end of the collection period. During the collection period, all feces were collected once daily, dried for 24 hr at a maximum of 60 C in a forced air oven and composited in containers with loosely fitted lids. Following the collection period the feces were allowed to air equilibrate for 5 days. Feces were then weighed, mixed and a subsample was ground for analysis.

Total urine was collected in glass jars located directly under large plastic funnels covered with a metal grill. To maintain the acidity of the urine it was collected in a mixture of 15 ml of 1:1 (w/w) concentrated sulfuric acid and water. It was diluted to a constant volume, checked for acidity and a 1% sample was taken. Samples for each animal were composited and refrigerated for each collection period in 1 liter containers and tight-fitting caps.

Immediately before the transition period of trial 1 and at the end of each trial, ruminal fluid samples were taken by stomach tube 2 hr after the morning feeding and 5 ml and 50 ml of blood were taken by jugular puncture 6 and 10 hr postfeeding, respectively. Ruminal fluid samples were immediately strained through four layers of cheese cloth, and pH was determined. Duplicate 5 ml samples were placed in 5 ml of 0.1 N HCl for the determination of ruminal ammonia following the procedure of Conway (1958). Duplicate 5 ml samples were placed in 1 ml of 25% metaphosphoric acid for the determination of volatile fatty acids by gas chromatography by the method of Erwin et al. (1961).

Blood samples taken 10 hr after feeding were placed in a water bath at 37 C for 30 minutes to allow coagulation, centrifuged for 30 min and the serum was withdrawn for the analysis of serum magnesium, calcium, inorganic phosphorous and potassium. All samples were frozen until analyzed. Blood taken 6 hr after feeding was placed in heparinized tubes and analyzed for blood urea following the procedure of Coulombe and Favreau (1963).

Samples of feeds, feces and refusals were wet-ashed by the procedure of Sandell (1950) for the analysis of magnesium, calcium, phosphorous and potassium. Magnesium, calcium and potassium in feed, feces, refusals, serum and urine were analyzed with a Perkin-Elmer 403 Atomic Spectrophotometer. Serum inorganic phosphorous and phosphorous in urine, feed, feces and refusals were determined by the method of Fiske and Subbarow (1925). The method of Whitehouse et al. (1945) was used to determine crude fiber. The other proximate components were determined by the method of A.O.A.C. (1970).

The data were stastically analyzed by analysis of variance. Orthogonal comparisons by the method of Snedecor (1956), were made to test for significance between forages and among maturities of each forage.

RESULTS AND DISCUSSION

Composition of Forages

The dry matter values for all maturities of wheat and orchardgrass are given in table 1. Corresponding maturities of each forage were similar in dry matter content and ranged from 17.2 to 33.2%. In both forages dry matter was highest for the third maturity. In both wheat and orchardgrass, the second maturity was harvested in rain. The lower dry matters of these two cuttings is probably the result of precipitation.

Differences in total nitrogen, as shown in table 2, were not consistent. In maturity 1 of both forages total nitrogen was above 3% of the dry matter, with the value for orchardgrass being slightly higher than for wheat. The values for the other two maturities tended to be higher for wheat. Total nitrogen in the wheat followed a quadratic pattern ($P < .01$). It decreased about 0.5 percentage unit from maturity 1 to maturity 2 and slightly more than 1 percentage unit from the second to the third maturity. The response in orchardgrass was linear ($P < .01$) with decreases slightly greater than 1 percentage unit between successive stages of maturity.

Also shown in table 2 are true protein and nonprotein nitrogen expressed as percent of the total nitrogen. True protein nitrogen was higher in orchardgrass than wheat ($P < .01$). Correspondingly, the reverse was true for nonprotein nitrogen. Wheat averaged 28.9% nonprotein nitrogen and orchardgrass averaged 19.9%.

Table 2. NITROGEN CONTENT OF WHEAT AND ORCHARDGRASS HARVESTED AT DIFFERENT MATURITIES

Kind of forage	Forage maturity	Total nitrogen[c]	Percent of total nitrogen[d]	
			True protein[d]	Non-protein[d]
		%		
Wheat	1[a]	3.03[e]	70.0	30.0
Wheat	2[a]	2.54[e]	72.4	27.6
Wheat	3[a]	1.41[e]	70.9	29.1
Average wheat		2.32	71.1	28.9
Orchardgrass	1[b]	3.34[f]	78.4	21.6
Orchardgrass	2[b]	2.32[f]	82.3	17.7
Orchardgrass	3[b]	1.18[f]	79.7	20.3
Average orchardgrass		2.28	80.1	19.9

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Dry basis.

[d]Wheat significantly different from orchardgrass ($P < .01$).

[e]Significant quadratic effect within forage ($P < .01$).

[f]Significant linear effect within forage ($P < .01$).

The mineral composition of the forages is shown in table 3. The percent of magnesium in the dry matter was less in wheat, at an average of .14% for all maturities, than in orchardgrass at .21% ($P < .01$). Magnesium content was similar among maturities in wheat, but decreased linearly with maturity in orchardgrass ($P < .01$). Stillings et al. (1964) reported values ranging from .15 to .28% magnesium for orchardgrass. The values reported here ranged from .18 to .24%. Kemp (1960) found that permanent grassland contained an average of .17% magnesium. This value was obtained from 30 samples taken from the same plot over a 5-mo period.

The average calcium, phosphorous and potassium contents of wheat and orchardgrass were similar. The average values were .29, .33 and 2.36% of the dry matter, respectively, for wheat and .27, .35 and 2.28%, for orchardgrass. For wheat maturity 2, the phosphorous and potassium content was .39 and 2.78%, respectively. These values are similar to the phosphorous and potassium values of .41 and 2.55% reported by Kemp (1960). However, these authors reported a value of .54% for calcium which is higher than .34% determined for maturity 2 of wheat in this study. This may be due to a difference in species as Kemp (1960) did not indicate the species of forage used in his study. In all maturities of orchardgrass reported here calcium content was lower (.23 to .32%), phosphorous was similar (.27 to .42%) and potassium was lower (1.77 to 2.66%) than the values reported by Stillings et al. (1964). They reported calcium values ranging from .42 to .57% of the dry matter, phosphorous values ranging from .29 to .49% and potassium values ranging from 3.30 to 5.00%.

Table 3. MINERAL COMPOSITION OF WHEAT AND ORCHARDGRASS HARVESTED AT DIFFERENT MATURITIES (DRY BASIS)

Kind of forage	Forage maturity	Magnesium[c]	Calcium	Phosphorous	Potassium
		%	%	%	%
Wheat	1[a]	.13	.31[e]	.38[e]	2.78[e]
Wheat	2[a]	.15	.34[e]	.39[e]	2.80[e]
Wheat	3[a]	.14	.22[e]	.23[e]	1.49[e]
Average wheat		.14	.29	.33	2.36
Orchardgrass	1[b]	.24[d]	.32[e]	.42[f]	2.66[f]
Orchardgrass	2[b]	.20[d]	.26[e]	.37[f]	2.40[f]
Orchardgrass	3[b]	.18[d]	.23[e]	.27[f]	1.77[f]
Average orchardgrass		.21	.27	.35	2.28

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly lower than orchardgrass ($P < .01$).

[d]Significant linear effect within forage ($P < .01$).

[e]Significant quadratic effect within forage ($P < .01$).

[f]Significant quadratic effect within forage ($P < .05$).

Stage of maturity had a quadratic effect ($P < .01$) on the calcium content in both wheat and orchardgrass. In wheat, calcium was highest in the second maturity at .34%. The first maturity was slightly less (.31%). Calcium content dropped considerably in the third maturity (.22%). In orchardgrass, calcium content decreased with maturity. The decrease was larger from maturities 1 to 2 than from maturities 2 to 3.

Phosphorous decreased quadratically with maturity in both wheat ($P < .01$) and orchardgrass ($P < .05$). For wheat, maturity 1 and maturity 2 were similar at about .4%. Phosphorous content dropped considerably from the second to the third maturity (.39 and .23%, respectively). In orchardgrass, phosphorous content decreased with maturity with a larger decrease occurring between the second and third maturities.

Potassium decreased quadratically with maturity in wheat ($P < .01$) and orchardgrass ($P < .05$). In wheat, potassium for the first two maturities was similar at about 2.8%, but was much lower for the third maturity. The potassium content in maturity 3 was 1.49%. In orchardgrass, potassium content decreased with maturity. The decrease from maturity 1 to 2 was approximately .3 percentage unit and from maturity 2 to 3, was approximately .6 percentage unit.

Metabolism Trials

Magnesium. Magnesium balance data are shown in table 4. Magnesium intake was significantly less for those fed wheat than for those fed orchardgrass ($P < .01$). Fecal excretion values were higher for the

Table 4. UTILIZATION OF MAGNESIUM BY LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

	Forage by maturity							
	Wheat[a]				Orchardgrass[b]			
Item	1	2	3	Avg.	1	2	3	Avg.
Magnesium intake, g/day[c]	.86[d]	.95[d]	.93[d]	.91	1.50[f]	1.31[f]	1.18[f]	1.33
Fecal magnesium, g/day[c]	.67[e]	.73[e]	.57[e]	.66	.96	.87	.86	.90
Urinary magnesium, g/day[c]	.27	.33	.31	.30	.40	.39	.30	.36
Apparent absorption, Mg								
Grams per day[c]	.19[g]	.21[g]	.36[g]	.25	.54[f]	.44[f]	.33[f]	.44
Percent of intake	22.12[f]	22.43[f]	38.58[f]	27.71	36.04	33.66	27.60	32.43
Magnesium retention, g/day[c]	-.08	-.12	.05	-.05	.14	.06	.03	.08

[a]Maturities were 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Significant quadratic effect within forage ($P < .01$).

[e]Significant quadratic effect within forage ($P < .05$).

[f]Significant linear effect within forage ($P < .01$).

[g]Significant linear effect within forage ($P < .05$).

lambs fed orchardgrass than for those fed wheat, apparently reflecting differences in intake. In the case of orchardgrass, fecal excretion was generally related to intake. However, for wheat, excretion was lowest for the last maturity, although the intake was similar to maturity 2 and was considerably higher than for maturity 1. The quadratic effect was significant ($P < .01$). In evaluating the fate of dietary mineral elements, Lomba et al. (1968) reported a correlation coefficient of .74 between fecal magnesium and magnesium intake. Fecal magnesium in this study ranged from .67 to .96 g per day. Field (1962) found values from .8 to 1.05 g per day in sheep fed grass nuts supplying 1.02 to 1.7 g of dietary magnesium per day. The grass nuts used in that study were similar in chemical composition to the third maturities of wheat and orchardgrass used in the present study, but were lower in nitrogen free extract and higher in calcium.

Apparent magnesium absorption, expressed in grams per day was less ($P < .01$) from wheat than orchardgrass. In wheat the values increased linearly ($P < .05$) with maturity. However, grams of apparent magnesium absorption per day decreased linearly with maturity in orchardgrass ($P < .01$). For wheat, the difference was small between the first two maturities but was large between the last two. Differences were similar between successive maturities in orchardgrass.

Availability of magnesium, calculated as apparent absorption as a percent of magnesium intake, was not significantly different between forages, although the values tended to be higher for orchardgrass. Averages over maturities were 27.7% for wheat and 32.4% for orchardgrass. Increasing maturity in wheat resulted in a linear ($P < .01$)

increase in magnesium availability. The difference between maturities 1 and 2 was quite small, compared to the difference between maturities 2 and 3. Values for maturities 1 and 2 were approximately 22%, and for the third maturity the value approached 39%. Increasing maturity in orchardgrass did not significantly affect magnesium availability but values tended to decrease with maturity. For maturity 1, magnesium availability was 36% and decreased to 27.6% for maturity 3. Animals within treatments showed a large degree of variation. Field et al. (1958) found magnesium utilization varied from 13 to 26% in two sheep fed the same ration, which consisted of herbage. However, they found no difference in availability from herbage obtained from tetany and non-tetany prone fields. Stillings et al. (1958) reported the magnesium availability in orchardgrass to be 11 to 24% for sheep, depending on the degree of nitrogen fertilization. Field (1967) found the availability ranged from 16 to 26% in a mixture of perennial ryegrass and wild white clover for grazing sheep.

Urinary excretion of magnesium was also higher in orchardgrass than in wheat ($P < .01$), probably reflecting greater amounts of magnesium absorbed. According to Rook and Storry (1962), magnesium of the diet above the requirement is excreted in the urine. Chicco et al. (1972) reported a correlation of .67 between absorbed magnesium and urinary magnesium. Within wheat, stage of maturity had no effect on urinary excretion of magnesium, but within the orchardgrass, there was a significant quadratic effect ($P < .01$) which resulted in a sharp decrease in urinary magnesium for sheep fed the third maturity, compared to those fed maturity 1 or 2.

Serum magnesium, as shown in table 5, did not differ with type of forage or with stage of maturity in the forage. Values ranged from 1.85 to 1.96 mg per 100 ml and tended to be lower for the lambs fed the third maturity of both wheat and orchardgrass. In sheep fed herbage, Field et al. (1958) found blood serum values to range from 2 to 4 mg per 100 ml. These authors found no relationship between magnesium intake (1.1 to 2.7 g per day) and blood serum levels. Rook and Balch (1962) reported values in dairy cows that ranged from .6 to 2.5 mg per 100 ml in diets composed of herbage alone. Field (1962) found that sheep fed diets of grass nuts with .13% magnesium, dry basis, maintained an average serum magnesium level of 2.57 mg per 100 ml.

Potassium. Potassium balance data are shown in table 6. Potassium intake ranged from 9.66 to 17.92 g per day and was higher ($P < .01$) for lambs fed wheat than for those fed orchardgrass. In both forages, intake responded quadratically to maturity with the third maturity supplying less than maturities 1 and 2. Fecal potassium was lower for lambs fed wheat than for those fed orchardgrass ($P < .01$), although dietary intake was higher for the lambs fed wheat. There was a linear ($P < .01$) decrease with maturity in the case of orchardgrass.

Apparent absorption of potassium ranged from 85 to 93%. These values are only slightly higher than values for orchardgrass reported by Stillings et al. (1964) who found that apparent absorption of potassium ranged from 76 to 88%. Apparent absorption, expressed in grams per day or as a percent of intake, was higher for the wheat than the orchardgrass ($P < .01$). There was a quadratic response ($P < .01$) for

Table 5. BLOOD SERUM MINERAL LEVELS OF LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

Kind of forage	Forage maturity	Blood serum levels, mg/100ml			
		Magnesium	Calcium	Inorganic phosphorous	Potassium
Wheat	1[a]	1.93	10.76	6.96	25.94
Wheat	2[a]	1.95	10.74	6.59	26.50
Wheat	3[a]	1.85	10.29	5.72	24.03
Average wheat		1.91	10.60	6.42	25.49
Orchardgrass	1[b]	1.99	10.84	6.46	24.98
Orchardgrass	2[b]	1.94	10.97	6.47	25.71
Orchardgrass	3[b]	1.91	10.73	5.55	23.65
Average orchardgrass		1.95	10.85	6.16	24.78

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

Table 6. UTILIZATION OF POTASSIUM BY LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

	Forage by maturity							
	Wheat[a]				Orchardgrass[b]			
Item	1	2	3	Avg.	1	2	3	Avg.
Potassium intake, g/day	17.92[e]	17.75[e]	9.96[e]	15.21	17.17[e]	15.58[e]	11.54[e]	14.76
Fecal potassium, g/day[c]	1.35	1.16	1.43	1.31	2.26[d]	1.74[d]	1.58[d]	1.86
Urinary potassium, g/day[c]	15.66[e]	15.31[e]	8.25[e]	13.07	14.52[e]	13.55[e]	9.86[e]	12.64
Apparent absorption, K								
Grams per day[c]	16.57[e]	16.58[e]	8.23[e]	13.79	14.92[d]	13.83[d]	9.96[d]	12.90
Percent of intake[c]	92.46[e]	93.43[e]	85.13[e]	90.34	86.87[f]	88.82[f]	86.30[f]	87.33
Potassium retention, g/day[c]	.91[e]	1.27[e]	-.02[e]	.72	.40	.28	.11	.26

[a] Maturities were: 1-vegetative, 2-boot and 3-milk.

[b] Maturities were: 1-early joint, 2-early bloom and 3-milk

[c] Wheat significantly different from orchardgrass ($P < .01$).

[d] Significant linear effect within forage ($P < .01$).

[e] Significant quadratic effect within forage ($P < .01$).

[f] Significant quadratic effect within forage ($P < .05$).

lambs fed wheat, with absorption from the first two maturities being similar, and higher than for maturity 3. In orchardgrass, increasing maturity resulted in a linear decrease ($P < .01$) in apparent absorption of potassium with maturity, when expressed as grams per day. If expressed as percent of intake, the response was quadratic ($P <$ 05), with the highest value for lambs fed maturity 2.

Potassium retention was positive for all treatments except for wheat maturity 3. Average potassium retention of lambs fed wheat was higher ($P < .01$) than for those fed orchardgrass. Retention values for lambs fed orchardgrass tended to decrease with maturity. Values for wheat showed a quadratic effect ($P < .01$), with maturity 3 being much lower than maturities 1 and 2.

Serum potassium response to type of forage was negligible. There was a trend toward a slight drop in serum potassium levels in sheep fed the third maturities of each forage.

Calcium. Calcium balance data are shown in table 7. Calcium intake was significantly greater for lambs fed wheat than for those fed orchardgrass ($P < .01$). In the case of wheat, stage of maturity exhibited a quadratic effect, with the third maturity being almost .5 g less than maturity 2. Calcium intake also decreased quadratically with maturity ($P < .05$) for orchardgrass.

There were no significant differences in fecal calcium between lambs fed the two forages. Values ranged from 1.63 to 2.00 g per day. Fecal calcium was higher for the lambs fed maturity 2 wheat than for those fed the other two maturities; the quadratic effect was significant ($P < .01$). Fecal calcium showed a linear pattern ($P < .01$) with

Table 7. UTILIZATION OF CALCIUM BY LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

Item	Forage by maturity							
	Wheat[a]				Orchardgrass[b]			
	1	2	3	Avg	1	2	3	Avg
Calcium intake, g/day[c]	2.03[d]	2.13[d]	1.41[d]	1.86	2.07[e]	1.72[e]	1.49[e]	1.76
Fecal calcium, g/day	1.65[d]	1.97[d]	1.63[d]	1.75	2.00[f]	1.86[f]	1.69[f]	1.85
Urinary calcium, g/day	.13[f]	.21[f]	.24[f]	.19	.18	.16	.21	.18
Apparent absorption, Ca								
Grams per day	.38[f]	.16[f]	-.23[f]	.10	.07[f]	-.14[f]	-.21[f]	-.09
Percent of intake[c]	18.37[f]	7.55[f]	-15.85[f]	3.36	3.71[f]	-7.72[f]	-14.01[f]	-6.01
Calcium retention, g/day	.23[f]	-.05[f]	-.46[f]	-.09	-.21[g]	-.27[g]	-.42[g]	-.30

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Significant quadratic effect within forage ($P < .01$).

[e]Significant quadratic effect within forage ($P < .05$).

[f]Significant linear effect within forage ($P < .01$).

[g]Significant linear effect within forage ($P < .05$).

maturity for the lambs fed orchardgrass; fecal calcium for the second and third maturities was greater than the calcium intake. Similar findings were reported by Stillings et al. (1964) and Field et al. (1958). Stillings et al. (1964) reported fecal calcium to be 81 to 102% of the calcium intake when the lambs consumed 3.2 to 4.3 g of calcium per day from orchardgrass. Field et al. (1958) upon feeding sheep herbage from tetany and nontetany prone fields, found fecal calcium ranged from 85 to 105% of the intake. Calcium intake ranged from 4.5 to 8.1 per day.

Apparent absorption of calcium from both wheat and orchardgrass decreased linearly with maturity, when expressed as either grams per day or percent of intake. When expressed as a percent of intake, calcium absorption was greater ($P < .01$) from wheat than orchardgrass, but the difference was not significant when expressed in grams per day.

Calcium balance was negative for all treatments except wheat maturity 1. Retention decreased linearly with increasing maturity. The calcium retention in lambs fed wheat decreased from .23 to -.46 g per day ($P < .01$). For animals fed orchardgrass, calcium retention decreased from -.21 to -.42 g per day ($P < .05$).

Serum calcium was not significantly affected by maturity or by type of forage. All values were between 10 and 11 mg per 100 ml of serum, which is in the normal range.

Phosphorous. As shown in table 8, phosphorous intake was higher ($P < .01$) in lambs fed orchardgrass than in those fed wheat (2.29 vs 2.14 g per day). For both forages, maturity exhibited a quadratic effect ($P < .01$). For wheat, values were similar for maturities 1 and

Table 8. UTILIZATION OF PHOSPHOROUS BY LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

Item	Forage by maturity							
	Wheat[a]				Orchardgrass[b]			
	1	2	3	Avg	1	2	3	Avg
Phosphorous intake, g/day[c]	2.45[f]	2.45[f]	1.52[f]	2.14	2.71[f]	2.41[f]	1.76[f]	2.29
Fecal phosphorous, g/day[c]	2.30[d]	2.56[d]	1.78[d]	2.21	2.66[f]	2.69[f]	1.94[f]	2.43
Urinary phosphorous, g/day[h]	0	0	0	0	0	0	0	0
Apparent absorption, P								
Grams per day	.14[d]	-.10[d]	-.26[d]	-.07	-.06[g]	-.28[g]	-.18[g]	-.17
Percent of intake	5.89[d]	-4.20[d]	-17.22[d]	-5.18	-2.06[e]	-11.44[e]	-10.41[e]	-7.97
Phosphorous retention, g/day	.14[d]	-.10[d]	-.26[d]	-.07	-.05[g]	-.28[g]	-.18[g]	-.17

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Significant linear effect within forage ($P < .01$).

[e]Significant linear effect within forage ($P < .05$).

[f]Significant quadratic effect within forage ($P < .01$).

[g]Significant quadratic effect within forage ($P < .05$).

[h]Phosphorous concentration < .8 mg/day.

2 and dropped by almost 1 g per day in maturity 3. For orchardgrass values dropped with each maturity with the greater decrease occurring between maturities 2 and 3. Fecal phosphorous was greater than phosphorous intake for all treatments except for lambs fed wheat maturity 1. Stillings et al. (1964) found fecal phosphorous to be 101 to 114% of the phosphorous intake in lambs fed dried orchardgrass fertilized with different nitrogen levels. Rook and Balch (1962), however, reported that apparent phosphorous absorption was positive for dairy cows when fed cocksfoot (orchardgrass) or cocksfoot-ryegrass sward. In this study, fecal excretion for lambs fed wheat were higher ($P < .01$) than for those fed orchardgrass. In lambs fed wheat there was a linear decrease of fecal phosphorous with maturity ($P < .01$). In lambs fed orchardgrass a quadratic effect was noted. Values for maturities 1 and 2 were similar and that for maturity 3 was much lower ($P < .01$).

Apparent absorption of phosphorous was similar between forages. For wheat apparent absorption, expressed in grams per day or as a percent of intake, decreased linearly with maturity ($P < .01$). For orchardgrass maturity exhibited a quadratic effect on apparent phosphorous absorption, in grams per day, with maturity 2 being lower than either maturities 1 or 3 ($P < .05$). However, when expressed as percent of intake, values decreased linearly ($P < .05$).

Phosphorous in urine was below detectable limits. The concentration was below .8 mg per 100 ml. In ruminants, there is usually only small quantities of phosphorous excreted in urine (Ammerman et al., 1957).

Serum inorganic phosphorous ranged from 5.55 to 6.96 mg per 100 ml. Although differences were not significant, values tended to be lowest for the third maturity.

Nitrogen Balance. Nitrogen balance data are shown in table 9. Nitrogen intake was higher for animals fed wheat than for those fed orchardgrass ($P < .01$). For both forages there was a quadratic effect of maturity ($P < .01$). In lambs fed wheat, nitrogen intake decreased only slightly from maturities 1 to 2, but decreased sharply in maturity 3. There was a gradual decrease with maturity for lambs fed orchardgrass. Fecal nitrogen was higher for lambs fed orchardgrass ($P < .01$). In lambs fed wheat fecal nitrogen responded quadratically, with similar values for those fed maturities 1 and 3 (3.7 g per day) and higher values for those fed maturity 2 (3.9 g per day, $P < .01$). For orchardgrass there was a significant linear decrease from 4.3 to 3.5 g per day in maturities 1 and 3, respectively.

Urinary nitrogen was not consistently different between forages. Within each forage, the values were related to nitrogen intake. A quadratic pattern ($P < .01$) was noted for different maturities of orchardgrass.

Nitrogen retention, expressed as a percent of intake and percent of absorbed, was higher for wheat than orchardgrass ($P < .05$; $P < .01$, respectively). Within each forage, nitrogen retention decreased linearly with maturity whether expressed as grams per day, percent of intake or percent of absorbed. For both forages, nitrogen balance was negative for the third maturities.

Table 9. UTILIZATION OF NITROGEN BY LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY

	Forages by maturity							
	Wheat[a]				Orchardgrass[b]			
Item	1	2	3	Avg	1	2	3	Avg
Nitrogen intake, g/day[c]	19.8[e]	18.0[e]	10.4[e]	16.07	22.0[e]	15.9[e]	8.4[e]	15.43
Fecal nitrogen, g/day[c]	3.7[e]	3.9[e]	3.7[e]	3.8	4.3[f]	4.0[f]	3.5[f]	3.9
Urinary nitrogen, g/day	13.9[e]	13.1[e]	7.1[e]	11.4	15.9[f]	11.7[f]	6.1[f]	11.2
Nitrogen retention								
Grams per day	2.2[f]	1.0[f]	-.3[f]	.97	1.9[f]	.1[f]	-1.2[f]	.27
Percent of intake[d]	11.1[f]	5.4[f]	-3.2[f]	4.43	8.4[f]	.9[f]	-14.4[f]	-1.7
Percent of absorbed	13.6[f]	6.9[f]	-5.2[f]	5.1	10.4[f]	1.1[f]	-25.1[f]	-4.53

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Wheat significantly different from orchardgrass ($P < .05$).

[e]Significant quadratic effect within forage ($P < .01$).

[f]Significant linear effect within forage ($P < .01$).

Ruminal Parameters and Blood Urea. Ruminal pH did not differ significantly with treatment but tended to increase with maturity. Ammonia nitrogen was significantly higher in lambs fed wheat than in those fed orchardgrass and for both forages it decreased with maturity ($P < .05$; $P < .01$, respectively). Blood urea also decreased with maturity of the forages but did not differ between lambs fed the two forages ($P < .01$). Both values are probably reflections of intake. Moore et al. (1973) reported higher values of ruminal ammonia and blood urea for high-nitrogen diets.

Ruminal Fluid Volatile Fatty Acids. Data on ruminal fluid volatile fatty acids are shown in table 11. Total amounts of volatile fatty acids were significantly higher in lambs fed wheat than those fed orchardgrass. For wheat there was a quadratic effect ($P < .01$) of maturity with values being similar for lambs fed maturities 1 and 2 but considerably lower for those fed maturity 3 (92 vs. μmole per ml).

Acetic acid was significantly higher in lambs fed wheat than in those fed orchardgrass, when expressed in μmoles per ml, but was lower for lambs fed wheat when expressed as moles per 100 moles. Acetic acid decreased linearly with maturity for lambs fed wheat, expressed as moles per ml ($P < .01$) or as moles per 100 moles ($P < .05$).

Propionic acid was higher ($P < .01$) in lambs fed wheat than those fed orchardgrass when expressed as μmoles per milliliter. When expressed in moles per 100 moles the differences were not significant. There was a linear increase with maturity in propionic levels in lambs fed wheat when expressed in moles per 100 moles. However, when expressed

Table 10. EFFECT OF STAGE OF MATURITY AND KIND OF FORAGE ON RUMINAL pH AND AMMONIA NITROGEN AND BLOOD UREA

Kind of forage	Forage maturity	Ruminal Fluid pH	Ruminal Fluid Ammonia nitrogen[c]	Blood urea
			mg/100ml	mg/100ml
Wheat	1[a]	6.6	34.9[d]	20.3[d]
Wheat	2[a]	6.6	36.7[d]	19.2[d]
Wheat	3[a]	6.8	20.0[d]	13.8[d]
Average wheat		6.7	30.5	17.8
Orchardgrass	1[b]	6.7	39.0[d]	20.1[d]
Orchardgrass	2[b]	6.8	27.7[d]	15.8[d]
Orchardgrass	3[b]	6.9	17.4[d]	14.3[d]
Average orchardgrass		6.8	28.0	16.7

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .05$).

[d]Significant linear effect within forage ($P < .01$).

Table 11. EFFECT OF STAGE OF MATURITY AND KIND OF FORAGE ON ON RUMINAL FLUID VOLATILE FATTY ACIDS

Item	Wheat[a] 1	Wheat[a] 2	Wheat[a] 3	Wheat[a] Avg	Orchardgrass[b] 1	Orchardgrass[b] 2	Orchardgrass[b] 3	Orchardgrass[b] Avg
Volatile fatty acids, μ moles/ml								
Acetic[d]	62.90[e]	57.94[e]	42.44[e]	54.43	45.78	51.81	42.04	46.54
Propionic[c]	19.24	21.01	16.53	18.93	14.40	14.61	14.70	14.57
Butyric[c]	7.21[g]	8.11[g]	5.94[g]	7.09	4.92	4.69	3.70	4.44
Valeric	.89[g]	1.39[g]	.41[g]	.90	1.01	.80	.58	.80
Isobutyric	1.11[g]	1.56[g]	.54[g]	1.07	1.17[f]	1.10[f]	.87[f]	1.05
Isovaleric	.90[g]	1.41[g]	.41[g]	.91	1.15[f]	.95[f]	.54[f]	.88
Total	92.24[e]	91.31[e]	66.26[e]	83.27	68.43	73.96	62.41	68.27
Volatile fatty acids, moles/100 moles								
Acetic[c]	67.86[f]	63.43[f]	64.15[f]	65.15	66.96	70.27	67.56	68.26
Propionic[c]	21.12[f]	23.23[f]	24.97[f]	23.11	21.09	19.67	23.54	21.43
Buteric[c]	7.81[h]	8.81[h]	8.99[h]	8.54	7.15[f]	6.31[f]	5.90[f]	6.45
Valeric	.98[h]	1.48[h]	.60[h]	1.02	1.46[f]	1.06[f]	.85[f]	1.12
Isobutyric	1.24[h]	1.68[h]	.79[h]	1.24	1.70[f]	1.45[f]	1.34[f]	1.50
Isovaleric	1.00[h]	1.38[h]	.60[h]	.99	1.66[f]	1.24[f]	.81[f]	1.24

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Wheat significantly different from orchardgrass ($P < .05$).

[e]Significant linear effect within forage ($P < .01$).

[f]Significant linear effect within forage ($P < .05$).

[g]Significant quadratic effect within forage ($P < .01$).

[h]Significant quadratic effect within forage ($P < .05$).

as μ moles per ml there was no significant difference. Lambs fed the third maturity tended to have lower propionic levels than those fed maturities 1 and 2. In lambs fed wheat, ruminal fluid butyric acid levels were higher ($P < .01$) than for those fed orchardgrass.

Kind of forage fed had no consistent effect on the quantity or fraction of valeric acid in ruminal fluid. For lambs fed the first and third maturities, valeric acid tended to be higher for lambs fed orchardgrass but for lambs fed maturity 2, valeric acid tended to be higher for those fed wheat. For lambs fed wheat, stage of maturity caused a quadratic response when expressed as μ moles per ml ($P < .01$) or as moles per 100 moles ($P < .05$). Values were highest for the second maturity. There was a gradual decrease with stage of maturity of orchardgrass, but the effect was significant only when expressed as mole per 100 moles.

Kind of forage or stage of maturity did not affect ruminal fluid isobutyrate concentration or proportion.

Isovaleric acid levels of the lambs were not consistently affected by type of forage fed. In sheep fed wheat, there was a quadratic response to stage of maturity when expressed in μ moles per ml ($P < .01$) or as moles per 100 moles ($P < .05$). Values for lambs fed maturity 2 were higher than for those fed maturities 1 and 3, with a larger difference in lambs fed the last two than in those fed the first two maturities. In lambs fed orchardgrass, isovaleric values decreased linearly ($P < .05$) with increasing stage of maturity.

Apparent Digestion Coefficients. As shown in table 12, digestion coefficients of dry matter, crude protein, crude fiber, ether extract and nitrogen-free extract for lambs fed wheat were higher ($P < .01$) than for those fed orchardgrass. Stage of maturity caused a quadratic effect ($P < .01$) on apparent dry matter digestibility in both forages, with the first two maturities being similar and the third maturity being considerably lower. Stage of maturity caused a quadratic effect ($P < .01$) on the crude protein digestibility in lambs fed either forage. Crude protein digestibility decreased with maturity with a larger difference between maturities 2 and 3 than between maturities 1 and 2 for both forages.

For crude fiber, digestion coefficients of the lambs fed wheat were affected quadratically by maturity ($P < .01$). There was a slightly lower digestibility for lambs fed maturity 2 than for those fed maturity 1. For lambs fed maturity 3, apparent digestibility of crude fiber was considerably lower than for the first two maturities. In lambs fed orchardgrass, there was a significant quadratic effect ($P < .01$) with similar values for maturities 1 and 2 and considerably lower values for maturity 3.

The apparent digestibility of ether extract for lambs fed either forage decreased linearly ($P < .01$) with maturity. Stage of maturity caused a linear decrease ($P < .01$) in the apparent digestibility of nitrogen-free extract in both forages.

Discussion

Wheat, a tetany prone grass, contained less magnesium than

Table 12. EFFECT OF STAGE OF MATURITY AND KIND OF FORAGE ON APPARENT DIGESTIBILITY COEFFICIENTS

Item	Forages by maturity							
	Wheat[a]				Orchardgrass[b]			
	1	2	3	Avg	1	2	3	Avg
	%	%	%	%	%	%	%	%
Dry matter, %[c]	78.78[d]	75.20[d]	60.77[d]	71.58	73.88[d]	72.21[d]	49.85[d]	65.31
Crude protein, %[c]	81.43[d]	78.29[d]	64.67[d]	74.80	80.58[d]	74.73[d]	58.27[d]	71.19
Crude fiber, %[c]	81.19[d]	77.90[d]	54.49[d]	71.19	77.02[d]	78.79[d]	48.26[d]	68.02
Ether extract, %[c]	62.88[e]	58.87[e]	53.71[e]	58.49	57.49[e]	54.85[e]	44.95[e]	52.43
Nitrogen-free extract, %[c]	81.06[e]	75.28[e]	65.61[e]	73.98	73.73[e]	70.91[e]	50.52[e]	65.05

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

[c]Wheat significantly different from orchardgrass ($P < .01$).

[d]Significant quadratic effect within forage ($P < .01$).

[e]Significant linear effect within forage ($P < .01$).

orchardgrass, a nontetany prone grass. The wheat maturity 1, corresponding to a lush stage of growth, contained .13% magnesium. Based on a daily dry matter intake of 10.5 kg per day (N.R.C., 1976) for a beef cow in early lactation, the wheat used in this study would supply only 14 g of dietary magnesium per day. O'Kelley and Fontenot (1969) determined the dietary requirement of magnesium from diets in which the main portion of the magnesium was supplied by magnesium oxide to be approximately 20 g per day for a lactating beef cow. Assuming a biological availability of 50% for magnesium from magnesium oxide (Gerken and Fontenot, 1967; Ammerman et al., 1972), the requirement would be 10 g of available magnesium per day. From wheat maturity 1 (22% available magnesium), the cow would obtain slightly more than 3 g of available magnesium per day which is considerably less than the calculated requirement.

In the case of the orchardgrass used in this study, the magnesium level was .24% for the first maturity (corresponding to a lush stage of growth). Based on the dry matter intake of the 10.5 kg per day, the magnesium intake would be around 25 g per day. If calculated in terms of available magnesium required per day, orchardgrass maturity 1 would supply 9 g of available magnesium per day which is only slightly less than the 10 g of available magnesium requirement.

High potassium levels have been associated with the increased incidence of grass tetany in beef cows grazing lush pastures (Sjollema, 1932) and high dietary potassium has been shown to decrease magnesium absorption in ruminants (Newton et al., 1972). In the present study, in the case of wheat, potassium intake appeared to be associated with apparent magnesium absorption. In lambs fed maturities 1 and 2 with 22% absorption of magnesium, potassium intake approached 18 g per day, and in maturity 3 with a 39% absorption of magnesium, potassium intake was only 10 g per day. However, orchardgrass maturity 1 supplied 17 g of potassium per day to the lambs, but the availability of magnesium for this maturity of orchardgrass was considerably higher than that of maturities 1 and 2 of wheat (36 vs 22%). It is also noted that for lambs fed the third maturity of orchardgrass the magnesium availability was only 28%, whereas potassium intake was lower than for orchardgrass maturity 1 (17.2 vs 11.5 g per day).

There is a possibility that potassium could lower magnesium utilization by directly interfering with its absorption. In this study, the apparent absorption of potassium was higher from wheat than orchardgrass, especially in the first two maturities which were lowest in magnesium availability. The lowest availability of magnesium in wheat is associated with the highest apparent absorption of potassium. However, this does not explain the changes in magnesium availability with maturity in orchardgrass. In the third maturity of orchardgrass the apparent absorption of potassium was low and the biological availability of magnesium was low.

High levels of nonprotein nitrogen in the forage has been associated with the incidence of tetany (Sjollema, 1932). In this study the values for nonprotein nitrogen were higher in wheat than orchardgrass and could partially explain the lower availability of magnesium in wheat. However, there appears to be no association of the change of nonprotein nitrogen with maturity with the change in magnesium availability in wheat or orchardgrass. Head and Rook (1955) hypothesized that high rumen ammonia levels, associated with grazing high nitrogen forages, might interfere with magnesium absorption. In this study, although rumen ammonia levels were higher in lambs fed wheat than in those fed orchardgrass, the biological availability of magnesium does not appear to be entirely related to the rumen ammonia levels. For example, the highest ruminal ammonia levels were found in orchardgrass maturity 1 which was comparatively high in magnesium availability. Earlier work in this laboratory indicated that level of nonprotein nitrogen in the diet did not affect magnesium absorption (Moore et al. 1972).

The lignin content of the forages might explain the low magnesium availability in orchardgrass maturity 3. However, lignin values followed the same pattern in both forages. For the first two maturities in both forages, lignin content was 3 to 4% whereas the third maturities approached 8% in wheat and 9% in orchardgrass.

Factors which were not studied but may have had an effect on magnesium absorption are long chain fatty acids (Kemp et al., 1966), trans-aconitic acid and citric acid (Stout et al., 1966; Bohman et al., 1969) and chlorophyll (Todd, 1961).

SUMMARY

Wheat, a tetany prone forage, and orchardgrass, a non-tetany prone forage, were cut at three stages of maturity to determine the magnesium availability in these forages for lambs. The forages were dried in forced air ovens and ground through a 2.5 cm screen. The nitrogen contents of the forages were not significantly different between forages but decreased quadratically with maturity in wheat ($P < .01$) and linearly in orchardgrass ($P < .01$). Nonprotein nitrogen was significantly higher in wheat than in orchardgrass. The magnesium content of the wheat was lower ($P < .01$) than orchardgrass (.14 vs .21%). Magnesium content in wheat was similar at all maturities but decreased with maturity in orchardgrass. Potassium, calcium and phosphorous levels in the forages were similar between wheat and orchardgrass but decreased with advancing maturity in both forages.

In two metabolism trials with 18 wether lambs, the biological availability of magnesium was determined for the two forages cut at three stages of maturity. The biological availability of magnesium for lambs fed wheat was slightly lower than for those fed orchardgrass. It increased linearly with increasing maturity in wheat ($P < .01$) and tended to decrease with maturity in orchardgrass. In the first two maturities of wheat, the biological availability of magnesium was approximately 22% and for the third maturity it approached 39%. In orchardgrass, it was 36, 34 and 28% for maturities 1, 2 and 3, respectively.

The intake and percent apparent absorption of potassium, calcium and phosphorous decreased with maturity in both forages. In general, apparent absorption values of these minerals were higher for lambs fed wheat than for those fed orchardgrass, although differences were not always significant. Serum mineral levels were not significantly affected by type of forage or stage of maturity.

Ruminal fluid pH was not significantly affected by kind of forage or stage of maturity. Ruminal fluid ammonia nitrogen levels were higher ($P < .05$) for lambs fed wheat than orchardgrass and decreased linearly ($P < .01$) with increasing maturity in both forages. Blood urea decreased ($P < .01$) with maturity in both forages. In general, ruminal fluid volatile fatty acids were higher in lambs fed wheat than in those fed orchardgrass, although all the acids did not follow this pattern.

Apparent digestion coefficients were higher for lambs fed wheat than for those fed orchardgrass ($P < .01$). In both forages these parameters decreased with maturity.

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APPENDIX

Table 1. BLOOD SERUM MINERAL LEVELS OF LAMBS FED WHEAT AND ORCHARDGRASS HARVESTED AT THREE STAGES OF MATURITY. INITIAL.

Kind of forage	Forage maturity	Blood serum levels, mg/100 ml			
		Magnesium	Calcium	Inorganic phosphorous	Potassium
Wheat	1[a]	1.66	10.85	6.95	23.62
Wheat	2[a]	1.73	11.04	6.82	22.98
Wheat	3[a]	1.68	11.03	6.81	22.78
Average wheat		1.69	10.97	6.86	23.13
Orchardgrass	1[b]	1.80	10.79	6.67	22.68
Orchardgrass	2[b]	1.67	10.83	7.02	22.32
Orchardgrass	3[b]	1.84	10.83	6.61	23.64
Average orchardgrass		1.77	10.82	6.77	22.88

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

Table 2. EFFECT OF STAGE OF MATURITY AND KIND OF FORAGE ON RUMINAL pH AND AMMONIA NITROGEN AND BLOOD UREA. INITIAL

Kind of forage	Forage maturity	Ruminal fluid		Blood urea
		pH	Ammonia nitrogen	
			mg/100 ml	mg/100 ml
Wheat	1[a]	6.86	13.33	13.42
Wheat	2[a]	6.81	13.39	11.44
Wheat	3[a]	6.84	13.39	11.75
Average wheat		6.84	13.37	12.21
Orchardgrass	1[b]	6.88	12.50	10.71
Orchardgrass	2[b]	6.85	13.15	11.40
Orchardgrass	3[b]	6.85	12.68	11.92
Average orchardgrass		6.86	12.78	11.51

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

Table 3. EFFECT OF STAGE OF MATURITY AND KIND OF FORAGE ON RUMINAL FLUID VOLATILE FATTY ACIDS. INITIAL

Item	Forages by maturity							
	Wheat[a]				Orchardgrass[b]			
	1	2	3	Avg	1	2	3	Avg
Volatile fatty acids, μmoles/ml								
Acetic	42.09	44.33	47.95	44.79	45.53	43.48	40.51	43.17
Propionic	14.07	16.23	16.33	15.54	16.31	15.38	14.89	15.53
Butyric	4.24	4.07	4.50	4.27	4.55	4.09	4.27	4.30
Valeric	.53	.46	.54	.51	.53	.53	.46	.51
Isobutyric	.69	.50	.58	.59	.59	.67	.53	.60
Isovaleric	.49	.43	.47	.46	.47	.47	.45	.46
Total	62.10	66.02	70.37	66.16	67.96	64.57	61.10	64.54
Volatile fatty acids, moles/100 moles								
Acetic	67.60	67.17	68.44	67.74	67.35	67.17	66.51	67.01
Propionic	22.80	24.48	22.94	23.41	23.69	23.91	24.12	23.91
Butyric	6.89	6.19	5.50	6.19	6.65	6.40	6.99	6.68
Valeric	.84	.74	.74	.77	.78	.80	.77	.78
Isobutyric	1.08	.76	.82	.89	.84	1.02	.85	.90

[a]Maturities were: 1-vegetative, 2-boot and 3-milk.

[b]Maturities were: 1-early joint, 2-early bloom and 3-milk.

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THE EFFECT OF STAGE OF MATURITY ON THE BIOLOGICAL AVAILABILITY OF MAGNESIUM FROM WHEAT AND ORCHARDGRASS FED TO SHEEP

by

Cynthia Lee Stager

(ABSTRACT)

Wheat, a tetany prone forage, and orchardgrass, a non-tetany prone forage, were cut at three stages of maturity to determine the magnesium availability in these forages for lambs. The forages were dried in forced air ovens and ground through a 2.5 cm screen. The nitrogen contents of the forages were not significantly different between forages but decreased quadratically with maturity in wheat ($P < .01$) and linearly in orchardgrass ($P < .01$). Nonprotein nitrogen was significantly higher in wheat than in orchardgrass. The magnesium content of the wheat was lower ($P < .01$) than orchardgrass (.14 vs .21%). Magnesium content in wheat was similar at all maturities but decreased with maturity in orchardgrass. Potassium, calcium and phosphorous levels in the forages were similar between wheat and orchardgrass but decreased with advancing maturity in both forages.

In two metabolism trials with 18 wether lambs, the biological availability of magnesium was determined for the two forages cut at three stages of maturity. The biological availability of magnesium for lambs fed wheat was slightly lower than for those fed orchardgrass. It increased linearly with increasing maturity in wheat ($P < .01$)

and tended to decrease with maturity in orchardgrass. In the first two maturities of wheat, the biological availability of magnesium was approximately 22% and for the third maturity it approached 39%. In orchardgrass, it was 36, 34 and 28% for maturities 1, 2 and 3, respectively.

The intake and percent apparent absorption of potassium, calcium and phosphorous decreased with maturity in both forages. In general, apparent absorption values of these minerals were higher for lambs fed wheat than for those fed orchardgrass, although differences were not always significant. Serum mineral levels were not significantly affected by type of forage or stage of maturity.

Ruminal fluid pH was not significantly affected by kind of forage or stage of maturity. Ruminal fluid ammonia nitrogen levels were higher ($P < .05$) for lambs fed wheat than orchardgrass and decreased linearly ($P < .01$) with increasing maturity in both forages. Blood urea decreased ($P < .01$) with maturity in both forages. In general, ruminal fluid volatile fatty acids were higher in lambs fed wheat than in those fed orchardgrass, although all the acids did not follow this pattern.

Apparent digestion coefficients were higher for lambs fed wheat than for those fed orchardgrass ($P < .01$). In both forages these parameters decreased with maturity.