To the Graduate Council:

I am submitting herewith a thesis written by David L. Hobbs entitled "Effect of Soil Ingestion on Certain Mineral Elements in the Bovine Gastrointestinal Tract." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Eric W. Swanson

Eric W. Swanson, Major Professor

We have read this thesis and recommend its acceptance:

M. C. Bell

J. K. Miller

Accepted for the Council:

Hilton A. Smith

Vice Chancellor for
Graduate Studies and Research

Ag-VetMed

Thesis
75
.H622
cop.2

EFFECT OF SOIL INGESTION ON CERTAIN MINERAL ELEMENTS IN THE BOVINE GASTROINTESTINAL TRACT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

David L. Hobbs

December 1975

1266355

ACKNOWLEDGMENTS

The author is deeply indebted with sincere appreciation and gratitude to several persons who helped to make this thesis a reality.

To Dr. Eric W. Swanson, major advisor, whose excellent guidance, advice and consideration allowed the completion of this thesis.

To Dr. James K. Miller, whose advice, time, research abilities and facilities help this thesis to be started and continued.

To Dr. Marvin C. Bell, who served on my graduate committee and whose advice was truly appreciated.

To David H. Gordon, Tony A. Fitz, and Jimmy T. Keeton whose friendship and companionship had an important part in the writing of this thesis.

To my parents, Mr. and Mrs. Glynn Hobbs, whose love, devotion, encouragement and financial support had a great influence in the writing and completion of this thesis.

To my fiancee, Janet, whose love, encouragement and confidence helped me to complete this thesis.

To, especially, my Heavenly Father, GOD, who gave me the physical and mental abilities to undertake and complete this thesis, and who has blessed me so much throughout life.

ABSTRACT

Soils of different types were fed to Hereford steers to determine effects of soil on total and soluble mineral concentrations in the gastrointestinal tract contents. All animals received 4.5 kg grass hay and 3.6 kg commercial dairy concentrate daily. Treatments consisted of controls (2 steers), sandy loam soil (2 steers), red clay subsoil (3 steers) or fine particle from sandy loam soil (2 steers). The amount of individual soil fed per day to each animal in soil fed groups was .9 kg and this was mixed with moistened concentrate. The steers were slaughtered after at least two weeks on the treatments and the digestive tracts were divided into the following sections: rumen-reticulum, omasum, abomasum, small intestine, cecum, and large intestine. The contents of each gastrointestinal section were weighed and sampled. Digesta as collected and ultracentrifuge supernatants of digesta were analyzed for calcium, magnesium, sodium, potassium and phosphorous. Dry matter, ash, and total and soluble mineral concentrations were determined.

The largest amount of dry matter was found in the rumen, while the abomasum had the smallest amount. However, feeding soil did not greatly increase total dry matter contents in sections posterior to the rumen. Average ash of the digestive tract contents was doubled by feeding soil. Total and soluble mineral contents measured were not increased by feeding soil, due to the low individual mineral concentrations found in the soil. Anterior to the cecum, mineral solubilities averaged Na > K > P > Mg > Ca in the concentrations. In most cases, minerals were most soluble in the

abomasal contents. The soil fed reduced the solubilities of magnesium and phosphorus, had no affect on sodium and potassium, but did increase the solubility of calcium.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
	Soil Ingestion Studies	2
	Excessive wear in sheep's teeth	2
	Relationships concerned with soil ingestion	3
	Effects of soil on animal health	6
	Element Absorption and Effects from Soil Ingestion	7
	Soil as a source of minerals for animals	7
	Elemental intake	10
	Studies showing soil as a source of microelements	12
	Effects of soil ingestion on rumen epithelium	13
	Mineral Studies on Ca, Mg, Na, K and P	13
	Flow of Ca, Mg, Na, K and P in the digestive tract	14
	Mineral interrelationships	16
III.	MATERIALS AND METHODS	18
	Experimental Description	18
IV.	RESULTS AND DISCUSSION	20
	Total Mineral in Ash	24
	Calcium	24
	Magnesium	24
	Sodium	29
	Potassium	32

CHAPTER PAGE

Phosphorous 32

Soluble Mineral Determination 37

Calcium 37

Magnesium 40

Sodium 43

Potassium 46

Phosphorous 49

Mineral Solubility in Digestive Tract Contents 52

V. SUMMARY AND CONCLUSION 56

LITERATURE CITED 58

VITA 62

LIST OF TABLES

TABLE PAGE

1. The Effects of Different Soil Types on Dry Matter and Ash in Digestive Tract Contents 21
2. Total and Water Soluble Mineral Content of Hay, Concentrate and Three Soils 22
3. The Average Percentage of Minerals in the Diets Consumed as Fed and on a Dry Matter Basis 23
4. Mineral Solubility in the Gastrointestinal Tract Compared to the Total Individual Mineral Concentration 53

LIST OF FIGURES

FIGURE PAGE

1. Concentration of Calcium in the Total Ash, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 25
2. Concentration of Magnesium in the Total Ash, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 27
3. Concentration of Sodium in the Total Ash, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 30
4. Concentration of Potassium in the Total Ash, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 33
5. Concentration of Phosphorous in the Total Ash, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 35

FIGURE PAGE

6. Concentration of Calcium in the Ultracentrifuge Supernatant, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 38

7. Concentration of Magnesium in the Ultracentrifuge Supernatant, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 41

8. Concentration of Sodium in the Ultracentrifuge Supernatant, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 44

9. Concentration of Potassium in the Ultracentrifuge Supernatant, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 47

10. Concentration of Phosphorous in the Ultracentrifuge Supernatant, Expressed as a Percentage of the Sample Dry Matter, from Different Sections of the Gastrointestinal Tract from Steers Fed No Soil or Different Types of Soil 50

CHAPTER I

INTRODUCTION

Grazing ruminants may consume large amounts of soil particularly during the winter months when growth of pasture is low (Healy, 1967; 1968). This ingested soil could be an important source of mineral elements but few studies have been conducted on the effect of soil ingestion on mineral availability and utilization.

Studies by Rogers and van't Klooster (1969) and Grace et al. (1974) have identified sections of the ruminant digestive tract in which absorption or secretion of several minerals occurs. Absorption and secretion of different minerals may occur all along the gastrointestinal tract, but for a particular mineral, either absorption or secretion may predominate in a given tract segment. Net absorption results when passage of a mineral into the blood exceeds the influx into the tract (Rogers and van't Klooster, 1969). When the influx exceeds the absorption the result is net secretion into the tract.

The purpose of this study was to determine effects of ingested soil on total and soluble mineral concentrations in gastrointestinal tract contents. Comparisons were made between steers fed different soils and controls and between the different parts of the gastrointestinal tract. Dried gastrointestinal tract contents of controls and soil fed animals were compared to determine the contribution of ingested soil to total concentration of each mineral, whereas ultracentrifuge supernatants were analyzed to detect changes in soluble mineral concentration.

CHAPTER II

REVIEW OF LITERATURE

A. SOIL INGESTION STUDIES

Grazing animals may consume surprisingly large amounts of soil with their feed. Most of the available data has been obtained with sheep (Healy, 1967) and cattle (Healy, 1968). Soil ingestion and its effects on the animal are considered in the following review.

Excessive Wear In Sheep's Teeth

Interest in soil ingestion by sheep in New Zealand resulted from the observation of excessive incisor tooth wear (Healy and Ludwig, 1965). Farms were classified on the basis of average sheep incisor length as "high wear" (0.3 cm or less), "medium wear" (0.8-1.0 cm) and "low wear" (1.3-1.5 cm). Fecal soil content was highest on the "high wear" farm, intermediate on the "medium wear" farm and lowest on the "low wear" farm. Soil separated from the feces was shown to be abrasive. These and other results (Ludwig et al., 1966) suggest that ingested soil was the main agent involved and that degree of wear was directly related to quantity of soil consumed.

Under New Zealand conditions, degree of incisor wear in 5-year old ewes was correlated with soil intake and was greatest from July to September, a period of low pasture growth (Healy, 1968). Peak levels of soil in feces could be reduced by half and tooth wear by two-thirds during this period by supplying supplementary feed. Soil ingestion

fell to negligible levels with growth of pasture in the spring. Two farms with a history of excessive tooth wear were studied for 11 months (Healy et al., 1967). When supplementary feed was supplied for 8-10 weeks during winter when pasture growth was low and animal appetite high, peak soil intake was reduced up to 75% and tooth wear by over 50%. Over the whole year incisor wear was reduced by about 50%. Thus, kind and quality of feed, method of feeding and access of animals to pasture all influence soil ingestion and hence tooth wear.

Relationships Concerned with Soil Ingestion

The influence of soil on grazing animals is usually considered to be a nutritional effect through pasture composition and forage dry matter production (Healy, 1968). Grazing animals ingest soil along with herbage and this ingested soil can be a source of elements, over and above that contributed by herbage (Healy, 1973). That soils differ in their ability to supply nutrient elements to animals through the pasture plants is recognized and the inadequacy of certain New Zealand soils to supply microelements such as Co, Se and Cu is well known (Healy, 1968). Soil type, stocking rate, earthworm population and management will all affect the amount of soil ingested (Healy, 1973). The physical structure of the soil itself will affect the amount of soil that is eaten. Soil appears to be ingested accidentally along with herbage and does not appear to be the result of depraved appetite (Healy, 1973). Soil ingestion by animals grazing pasture is greatest in the winter (Healy and Drew, 1970). Because pasture growth has been

shown to be less during the winter than any other time of the year, grazing animals increase their chances of ingesting soil. Soil, however, appears to be a normal component of herbage taken in by grazing animals, especially under management conditions aimed at maximum utilization of pasture (Healy et al., 1974).

Healy (1968) compared curves for soil intake and fecal soil content of cows. Increased soil ingestion was accompanied by a higher soil content of feces but the overall soil ingestion curve was a subdued version of the curve for soil content. Because forage soil content is expressed as a percentage of dry matter (DM) the amount of soil ingested, and hence fecal output is also dependent on quantity of DM intake, thus, although soil content on herbage can be low at periods of flush growth, the high DM inputs at that time may raise the quantity of the soil ingested. Likewise, when pasture growth is low, low DM inputs lessen the rise in soil ingestion that would be expected from the high fecal-soil contents found at such periods. While the soil intake by cattle may be large, up to 454 kg annually, it should be related to the amount of fresh herbage taken in by an animal during a year. If an animal ingests 22,700 kg of pasture (equivalent to 4540 kg DM, where DM is 20% of fresh weight), then ingestion of 363 kg of soil with it represents a soil contamination of a fresh weight basis of only 1.6%. In general, soil content of feces is a reasonable guideline to the pattern of soil ingestion (Healy, 1968). It must be realized that the percentage of soil in feces is only a guide to intake and that the actual weight of soil ingested depends on a number of variables, such

as soil type, quantity of pasture and stocking rate (Healy and Ludwig, 1965). Healy (1968) stated that the mean-soil ingestion by dairy cows on private farms ranged from about 182 to 318 kg each annually and intakes exceeding 454 kg have been observed. Paddock wintered animals ingested about 50% more soil than the platform wintered herds (Healy, 1968). This high soil intake in midwinter was probably related to very high stocking rates associated with nonlactating animals during this period.

Healy and Drew (1970) have shown that soil intakes of young sheep decreased markedly when they were moved to new breaks of swedes. In a trial on winter feeding, soil in feces of animals grazing on swedes reached a weekly mean of 61% of feces dry matter. As swedes were eaten closer to ground level more soil was ingested, but soil ingestion fell sharply when animals were moved to a new break. Soil ingested reached a weekly mean of one kilogram. Mean weights of soil, ingested for eleven weeks by animals on swedes, on swedes and hay and on unrestricted pasture were 6.5, 3.2, and 2.3 kilograms respectively. Their data suggest that soil intake was low while the high above ground portion of the crop was being eaten, but it increased progressively as the crop was eaten down to ground level. They also observed that individual animals within each group of studies showed variation in soil ingestion.

Healy (1968) investigated the effects of soil type on soil ingestion on a number of soils important in the sheep industry. Intensively farmed units were used and on all farms, sheep ingested

some soil in the winter months, but the amount of soil eaten and the period over which soil ingestion was appreciable, was related to soil type. Soils characterized by strong structure were associated with low levels of soil ingestion, while those of weak structures were associated with high levels of soil ingestion.

Effects of Soil on Animal Health

Apart from the element uptake, ingestion of soil in large quantities could affect animal health in other ways (Healy, 1967). Intake of soil of the order of up to 400 grams per day—perhaps over 150 kilograms per year—may have abrasive effects on the alimentary tract. Abrasion, if it occurs, could be harmful in its own right as an irritant, but may also pave the way for infection. As stocking rates rise, so does the possibility of stock diseases, and it is possible that ingested soil affects animal health in this way. Greater return of dung and urine associated with the increased soil uptake may increase the possibility of infection. Where infection increases, or there is a change in pattern with increased stock numbers, the possible influence of soil should be considered (Healy, 1967). Cunha (1957) recommended that soil fed to pigs should be taken from an area where no pigs have been kept for at least a year to guard against infestation with eggs of roundworms and other parasites. Thus soil may be a means of contamination as the animal grazes.

B. ELEMENT ABSORPTION AND EFFECTS FROM SOIL INGESTION

Soil contains varying amounts of different elements with the type of element being dependent upon several factors, one of these being soil type. The quantity of soil and kind of soil ingested must also be considered to play a part in element absorption.

Soil As A Source of Minerals For Animals

Ingested soil is a source of minerals to a grazing ruminant. Its importance depends upon the amount of soil ingested, the ratio of the concentration of the minerals in the soil to that in the herbage and the ability of the ruminant to use the form of mineral in the soil. The constituents of soil such as clay may interfere with the absorption of some minerals from the alimentary tract (Field and Purves, 1964). *In vitro* studies by Healy (1972) on the effects of soil on elements in ruminal, duodenal, and ileal liquors from sheep showed that in general for ruminal liquor Mg, Al, Fe, Mn, Se, and Zn increased and Ca and P decreased. For duodenal liquor, Ca, Mg, Al, Mn and Se increased and P, Cu and Fe decreased and for ileal liquor, Al, Cu, Fe, Mn and Se increased and Ca decreased. The type of soil, as well as the quantity, ingested by an animal may be important in animal nutrition. Soil may contribute to the pool of elements in solution, by raising the concentration, or it may compete for elements in solution and result in lower concentrations (Healy, 1972). Healy (1972) stated that different kinds of soil (because of composition and constitution) may also have a qualitative effect through its ability to alter composition of

digestive liquors. Thus similar amounts of different soils ingested by animals may produce different nutritional effects. Actual site or sites of absorption will also play a part in determining the effects of soil ingestion on blood and tissue composition.

Andrews et al. (1958) compared the effects on cobalt deficiency of long and short pastures, resulting from light and heavy grazing during the two seasons. Cobalt status was assessed by cobalt content of pasture and liver samples, weight changes of lambs and weight responses of lambs to cobalt dosing. Lambs in one lightly grazed paddock were marked by unthrifty but heavy grazing appeared to reduce the severity of cobalt deficiency and prevented it entirely in mildly cobalt deficient paddocks. It was considered that increased cobalt intake from soil contaminated pasture offers the most probable explanation of the protection afforded by heavy grazing. Short pastures also tended to prevent cobalt deficiency in lambs on other farms.

During both seasons it was shown, in all cases, that cobalt was higher in samples from heavily grazed pastures than from lightly grazed pastures. Light grazing favored cobalt deficiency disease; heavy grazing tended to prevent it. Prevention was partial or complete, depending upon the degree of deficiency to which lambs were exposed. Since soil invariably contains much more cobalt than does pasture, contamination would result in increased amounts of pasture associated cobalt. Rigg and Askew (1934) cured and prevented cobalt deficiency in sheep grazing pasture definitely associated with bush sickness by

drenching them with soil twice weekly. These results show the importance of soil in the maintenance of stock health.

Healy et al. (1972) found a high prevalence of enlarged thyroids in lambs from ewes on low stocked pastures. However, this condition was almost entirely absent in lambs from high stocked pastures. Feces from ewes on high stocked pastures which were closely grazed contained substantially more soil than feces from ewes on low stocked pastures which had ample feed in winter of 1971. The iodine in the feces followed a similar pattern to soil in feces. Iodine in herbage showed no difference between high and low stocked pastures. Thus ingested soil appeared to be a source of iodine and prevented the development of goiter in lambs from ewes on high stocked pastures.

Grace and Healy (1974) studied effects of soil ingestion (100 g per day) on fecal loss and apparent absorption and retention of Ca, Mg, Na, K, and P by sheep fed 600 and 900 g dried grass per day. When the amount of dried grass and thus intakes of Ca, Mg, Na, K and P were raised, fecal and urinary losses and apparent absorption and retention of the minerals were increased. The principal route of loss of Ca, Mg, and P from the sheep was feces but most of the Na and K was lost in the urine. The addition of soil to the dried grass only slightly increased the total intake of the macroelements.

Administration of 100 g of soil did not significantly influence fecal or urinary losses of Na and K when either 600 or 900 g dried grass was fed. Fecal P output was decreased and apparent absorption and retention of P were increased when soil was fed with the larger

amount of dried grass. The ingestion of soil markedly affected the metabolism of Mg and Ca in the sheep. At a dry matter intake of 600 g per day, daily administration of 100 g of soil reduced fecal Mg and Ca losses 50-70%, but did not affect losses of Mg and Ca in the urine. The increased apparent absorption and retention of Ca and Mg cannot be attributed directly to the Mg and Ca content of the soils, as the addition of the soils increased the daily intake of Mg by 0.145 g and of Ca by 0.245 g, while the apparent daily absorption was increased 0.447 g and 1.40 g for Mg and Ca respectively. Soil types varied in their ability to increase apparent availability of macroelements. Increased availability of macroelements such as Ca and Mg by ingested soil could be important to grazing animals, particularly when feed is restricted.

Elemental Intake

The fact that grazing animals can ingest some soil when pastures become muddied has been recognized for several years. Some elements may be presented in soil at much higher concentrations than those found in pasture, and since the ingested soil is subjected to digestive processes as it moves along the alimentary tract, it may make a direct contribution as a possible dietary source of elements to the mineral nutrition of the animal (Grace and Healy, 1974). Healy (1967) leached several types of soil with 0.1 N HCL to provide a crude estimate of the quantities of various elements that might be absorbed by the animal from ingested soil and compared these with quantities leached from pasture. He found that the various elements extracted from the soil varied from

fivefold to fiftyfold. To compare amounts of various elements that might be absorbed from ingested soil or from pasture, Healy (1967) assumed daily ingestion of 300 g soil and 500 g pasture dry matter by sheep. The highest figures for extraction of elements from soil and complete uptake of elements from pasture were assumed. From the 300 g of soil the highest figures extracted from soil (Ca—500 mg, Mg—40 mg, P—120 mg, Co—1 mg and Mn—60 mg per 100 g of soil) were used to calculate the contribution from ingested soil. On this basis, contributions of magnesium and phosphorous from soil were only a small part of that from pasture, but calcium approached 50%. The contribution of microelements from soil was more substantial and in most cases comparable to that of pasture or in the cases of cobalt and manganese substantially more. Because concentrations of certain elements are usually higher in soil than in pasture plants, it would be expected that soil contaminated pasture samples would show higher concentrations of these elements as shown by Healy et al. (1974). Research workers have usually considered high levels of elements such as Al, Fe, Si and Ti to be an indication of soil contamination. In the study mentioned above, the concentration of a number of elements was shown to be five times or more higher in grazed than in ungrazed herbage plants. Although only a fraction of the amount of a particular element in the soil, as it passes through the alimentary tract, may become available for absorption by an animal, heavy elements such as Cd, Ni, and V are usually present in animal tissues, especially in kidney and liver tissues. They can generally be detected in herbage, but usually at low levels. Ingested soil may be a

source of such elements, and this may help to explain their consistent concentration in animal tissues (Healy et al., 1974).

Studies Showing Soil As A Source of Microelements

Healy et al. (1970) investigated soil as a source of microelements by feeding sheep soil treated with ^{60}Co, ^{54}Mn, ^{75}Se, and ^{65}Zn. These isotopes were added in chemical forms considered to occur in the soil and were expected to occupy sites compatible with the chemistry of a particular element. Equilibrium appeared to be reached quickly suggesting that isotopic exchange occurred preferentially in the mobile fractions of the elements in the soil. These mobile fractions are the ones available to the animal as the soil passes through the alimentary system. Soil as it passes through the alimentary tract will be subjected to a variety of conditions such as changes in pH, the presence of complexing agents and anion and cation exchange effects. The gastrointestinal sites where the concentration of an element is increased may not be the site for absorption of the element. Under conditions of this study approximately 34% of the ^{75}Se, 14% of ^{65}Zn, 1% of the ^{60}Co, and 0.4% of ^{54}Mn were absorbed from ingested soil. These figures were considered minimal since some tissues of animals (hide, wool, brain) were not included in the total. Absorption of ^{65}Zn was within ranges reported for cattle by Miller and Cragle (1965). Thus results of this study support the hypothesis that ingested soil is a direct source of certain mineral elements to animals.

According to Cunha (1957) and Underwood (1966), young pigs that are kept away from earth usually develop anemia and may die by the

time they are four to six weeks of age. However, if the pigs have regular access to soil, they usually begin to eat a little of it a few days after birth. Thus they obtain the small amounts of iron and copper needed to prevent anemia.

Effects of Soil Ingestion on Rumen Epithelium

Healy and Wilson (1971) reported effects of feeding sheep 50 g of two different soil types on rumen epithelium color. At the end of the ten-week experiment the rumen epithelium of the control animals was cream or light gray in color and that of animals receiving soil was dark gray to black. This deposit on the epithelium appeared to be precipitated material instead of particulate matter of ingested soil. The dark gray to black substance was removed from tissue of the animal receiving Egmont soil by treating the epithelium with 6N HCI and was shown to contain P, Ca, Fe, Al, Mg, Mn and Ti. The animal on Papakauri soil only had a significant increase in Fe over the control animals. Significantly higher concentrations of Fe, Al, and Ti were present in this material from animals receiving soil than in that from the controls. Thus soil in the rumen may have increased the amount of deposit on the epithelium, and the concentration of certain elements in the deposit or both.

C. MINERAL STUDIES ON Ca, Mg, Na, K AND P

Several studies have been conducted on metabolism of the above minerals. However, few studies have been conducted on all of the

minerals together, as would be their state in soil. Thus a few studies on the flow of these minerals in the digestive tract and their inter-relationship with each other will be reviewed.

Flow of Ca, Mg, Na, K and P In The Digestive Tract

Flows of Ca, Mg, Na, K and P along the digestive tract and the sites of net absorption and secretion of these elements have been investigated in sheep by Grace et al. (1974) and in cattle by Rogers and van't Klooster (1969). Flow of individual minerals through the ruminant digestive tract is reviewed in the following pages.

Grace et al. (1974) measured absorption or secretion in sheep by comparing amounts of an element flowing into and from specific divisions of the digestive tract. Although results were influenced by type of feed (perennial ryegrass or white clover), and level of intake (450 to 1,000 g DM) there were net absorptions of Mg, Ca, and K from and net secretions of P and Na into compartments anterior to the duodenum. Phosphorous, K and to a lesser extent Na were absorbed from the small intestine while Mg and Ca were secreted into this region. Net absorption of Mg, Ca, P, K and Na from the large intestine occurred at the higher intakes.

Grace et al. (1974) showed that the flow of some of the macroelements along the digestive tract can be influenced by the diet and the intake of the element. The herbage fed appeared to have greater influence on the flow of P, K, and Na while levels of intake had a pronounced effect on the flows of Mg and K.

Rogers and van't Klooster (1969) found that extremely large amounts of Na (550 g) and P (58 g) entered the cows rumen in saliva. Net absorption of Na and K occurred in the reticulo-rumen. Mg absorption was highest in the stomach region and P was absorbed also. The abomasum is known to secrete large amounts of fluid containing Na. Secretion of Na occurred in the small intestine but this region was the major site of K, Ca, and P absorption. Secretion of Na was attributed to bile, pancreatic juice and succus entericus. Potassium absorption occurred in the cecum and large intestine, while the large intestine were important in Na absorption. Na was absorbed along the entire gastrointestinal tract. Little or no net absorption of Ca, Mg, or P occurred from large intestine.

Ben-ghedalia et al. (1975) reported net absorption of Mg and a large net secretion of P between the mouth and duodenum. The upper small intestine seemed to be the main site for Mg absorption. The most active site for P absorption was the upper small intestine. Very high concentrations of soluble Ca and Mg were obtained in the feces; however soluble P in feces was very low. The solubility of the three elements, expressed as a percentage of total, decreased as the digesta flowed down the small intestine. In the duodenum (0.05 m site), 84, 78, and 62% of the total Ca, Mg, and P were soluble, but in the digesta flowing through the terminal ileum (25 m site) the values were 3.2, 7.2 and 10% respectively. Up to the 7 m site there appeared to be a concurrent decrease in the solubility of the Ca and P. Between the 7 m site and the 15 m site there was a continuous fall in soluble Ca fraction, but

an increase in soluble P fraction. The solubility of minerals in the gut is one of the main factors affecting their absorption and a rise in pH as the digesta advances along the intestine is accompanied by a concomitant decrease in the solubility.

Mineral Interrelationships

Jacobson et al. (1972) discussed over 70 known mineral interrelationships in which an additional dietary quantity of one mineral element will influence absorption or utilization of another mineral element. The elements Ca, Mg, K and P are closely related to many metabolic events in the body (Jacobson et al., 1972). A deficiency of any of these elements leads to reduced voluntary feed consumption and reduced milk production. Many of the dietary interrelationships among these minerals occur at the absorption site and the following has been found concerning the interrelationship of these minerals. Jacobson et al. (1972) maintained that K has no specific effect on Mg requirement. Apparent absorption of Mg in rats was reduced by an increase in dietary Ca from .34 to .68 or of P from .39 to .79% and further reduced by increasing both. Also increasing dietary Ca decreased percent P absorption (Toothill, 1963). High P prevented Ca loss and high K tended to prevent Ca loss. Increased dietary P decreased absorption of Mg and when the diet is low in P, excess dietary Mg causes loss of Ca, but not when P is adequate. In ruminants a high percentage of the Ca and P excreted is via the gut. In a study by Fontenot et al. (1973), it was observed that a high

dietary level of potassium results in a large depression in apparent magnesium absorption in ruminants. This appears to be a reduction in magnesium absorption and not an increase in excretion in the digestive tract. This effect is usually accompanied by a reduction in urinary excretion of Mg that appears to result from the lower reabsorption of magnesium in the kidney. High levels of potassium appeared to decrease magnesium absorption about 40-50%.

Hogg (1970) found KCl top dressing increased Mg, Ca and Na losses from Horotiu sandy loam soil. Thus fertilization of soil may affect the uptake or ingestion of a mineral through its effects on soil mineral content. Kemp and Geurink (1970) investigated effects of dressing the pasture with Mg combined with light or heavy applications of K on Mg, K, Na, and Ca in soil, Mg in the herbage and serum Mg in cows. Light K dressing combined with Mg increased the magnesium in herbage from 0.15 to 0.25% of dry matter, but with more K, the effect was less. Mg dressing decreased Ca in herbage and when combined with heavy K the reduction was 35%. A large amount of K fertilizer reduced Na in herbage. Heavy dressing of sandy soil with Mg significantly increased serum Mg in cows, but on peat or clay soils, the method was not effective. Thus mineral interrelationships do vary among the individual minerals and the type of fertilizer applied to a soil may affect the uptake of a particular mineral by plants as well as when the soil is ingested by an animal.

CHAPTER III

MATERIALS AND METHODS

A. EXPERIMENTAL DESCRIPTION

Nine Hereford steers weighing between 445 and 492 kilograms were confined in stanchions and were fed 3.6 kg of dairy feed and 4.5 kg of hay each day. Treatments consisted of controls (2 steers), sandy loam soil (2 steers), fine soil particles (2 steers) and red clay subsoil (3 steers). Controls were only fed .9 kg/day of each individual soil in the treatments. Sacrifice of the animals occurred 14 or more days after the initial feeding of each diet.

Sacrifice of the animals was approximately 16 hours after their last meal. The entire gastrointestinal tract from each steer was removed and separated into the following segments: rumen-reticulum, omasum, abomasum, small intestine, cecum, and large intestine. Contents of each segment were weighed, mixed, and sampled separately. Rumen contents were mixed in a large Waring blender and all samples were placed in marked jars. Each soil, feed and digestive tract content sample and their water soluble supernatants were analyzed in duplicate for dry matter, ash, and the minerals: calcium, magnesium, sodium, potassium and phosphorous.

To obtain supernatants, weighed samples of each material were mixed with water, allowed to stand for 30 minutes and then centrifuged at 40,000 x gravity. These were then decanted and the residues were washed

once and centrifuged again, as stated above, and then decanted into the same test tube as the previous one. Each supernatant was filtered through Whatman No. 30 filter paper, washed with deionized water to a total of 75 ml, and refrigerated until analyzed.

For determining total minerals, duplicate samples of digestive tract contents were dried at 105°C and then ashed in a muffle furnace for four hours at 550°C. The samples were cooled in a dessicator, weighed, treated with 10 ml of 3N HCl and boiled gently for ten minutes. The solution was then filtered through No. 30 Whatman filter paper into a 100 ml volumetric flask and the paper was rinsed with deionized water until the 100 ml was obtained. The solutions were then placed in large marked test tubes, stoppered with cork stoppers wrapped in paraffin. Dry matter was determined in duplicate by weighing from one to twelve grams of each sample into marked aluminum pans. These were placed in a 105°C oven overnight. The pans were reweighed and dry matter calculated. The average dry matter of each sample was used to calculate mineral contents on a 100% dry matter basis.

Ash solutions and supernatants of each sample were analyzed for Ca, Mg, Na, K, and P. Calcium and magnesium were measured in a Unicam SP.90 atomic absorption spectrophotometer. Standard curves were constructed from dilutions containing 5, 10, 15, and 20 mg Ca or 2, 4, 6, 8, and 10 mg Mg per 100 ml. Sodium and potassium were measured by flame photometry. Standards contained 5, 10, 15, and 20 ppm Na or 2, 4, 6, and 8 ppm K. Phosphorous was measured by a colormetric method (Fiske and Subbarrow, 1925). The standard contained 5 mg/ml of phosphorous.

CHAPTER IV

RESULTS AND DISCUSSION

The total grams of dry matter (DM) and the percentage of ash from the different sections of the digestive tract are presented in Table 1. Feeding soil did not greatly increase total dry matter content in sections posterior to the rumen. Sandy loam increased both total dry matter and percentage of ash in rumen contents more than the other two soil types. The most DM was found in the rumen, while the abomasum had the smallest amount.

Feeding of soil increased the ash, as would be expected. Feeding soil doubled ash in contents of most of the digestive tract sections. Red clay and sandy loam increased ash in the anterior sections more than fine soil particles. Sandy loam increased ash content in posterior sections more than the other soil types. Based on increased ash content, less soil was retained in the omasum and small intestine than in other sections.

Average total and soluble mineral content of soil and feed are presented in Table 2. Mineral concentrations in total rations consumed by the steers are presented in Table 3. These were calculated from amounts and mineral composition in soil and the individual dietary components.

Table 1. The Effects of Different Soil Types on Dry Matter and Ash in Digestive Tract Contents

Gastrointestinal Tracts	Treatments							
	Controls		Red Clay		Sandy Loam		Fine Soil Particle	
	DM	Ash	DM	Ash	DM	Ash	DM	Ash
	(g)	%	(g)	%	(g)	%	(g)	%
Rumen	4811	15.73	5183	28.68	6065	30.92	5108	17.71
Omasum	1447	11.54	3088	21.03	1333	24.30	1455	18.53
Abomasum	174	17.95	214	47.42	281	42.49	113	25.24
Small Intestine	480	18.63	546	32.47	587	28.59	412	20.95
Cecum	176	16.92	360	35.15	277	40.39	301	33.87
Large Intestine	334	14.90	531	32.20	267	35.67	239	32.74

Table 2. Total and Water Soluble Mineral Content of Hay, Concentrate and Three Soils

Mineral	Hay		Concentrate		Red Clay		Sandy Loam		Fine Soil Particle	
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble
	(% of sample on a dry matter basis)									
Calcium	.767	.329	1.406	.096	.043	.0006	.1113	.0055	.063	.0110
Magnesium	.192	.062	.405	.111	.065	.0000	.0570	.0005	.027	.0010
Sodium	.046	.014	.305	.290	.071	.0011	.0190	.0012	.014	.0009
Potassium	2.188	1.037	1.083	.797	.268	.0004	.1000	.0015	.079	.0015
Phosphorous	.284	.133	.625	.155	.067	.0001	.0330	.0002	.025	.0003

Table 3. The Average Percentage of Minerals in the Diets Consumed as Fed and on a Dry Matter Basis

Minerals	Treatments							
	Controls		Red Clay		Sandy Loam		Fine Soil Particle	
	As Fed	DM	As Fed	DM	As Fed	DM	As Fed	DM
	%							
Calcium	.888	1.053	.803	.937	.810	.945	.806	.939
Magnesium	.242	.287	.224	.261	.223	.260	.220	.257
Sodium	.174	.206	.163	.191	.158	.185	.158	.184
Potassium	1.425	1.691	1.309	1.528	1.292	1.508	1.290	1.505
Phosphorous	.368	.437	.338	.394	.335	.390	.334	.389

A. TOTAL MINERAL IN ASH

Calcium

Higher concentration of calcium in the rumen of all animals than in the diets may be due to fermentation and absorption of organic matter causing a higher calcium concentration in the dry matter (Figure 1). Lower calcium concentrations in omasal contents may have resulted from absorption and expression of moisture from the digesta in the omasum. If the moisture contained more calcium than the remaining dry matter then a decrease in concentration of calcium would result. If calcium were absorbed from the omasum, this would also lower calcium concentration. Abomasal calcium concentrations were similar for all soil fed animals but the average for controls was higher due to one animal. The concentration of calcium in the small intestine of two soil fed groups decreased, indicating possible absorption of the mineral while the other animals did not change. Animals in all treatments had an increase in concentration of calcium in the cecum. Grace et al. (1974) found that secretions of calcium into the small intestine did occur and this would result in an increase in concentration in the cecum.

Magnesium

Magnesium concentrations were lower in the rumen than in the diets for all treatments (Figure 2). Concentrations of magnesium in omasal and abomasal contents changed little from concentrations in the rumen except for animals fed sandy loam or fine soil particles which decreased slightly between the omasum and abomasum. Rogers and van't Klooster

Figure 1. Concentration of calcium in the total ash, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (F = feed; R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

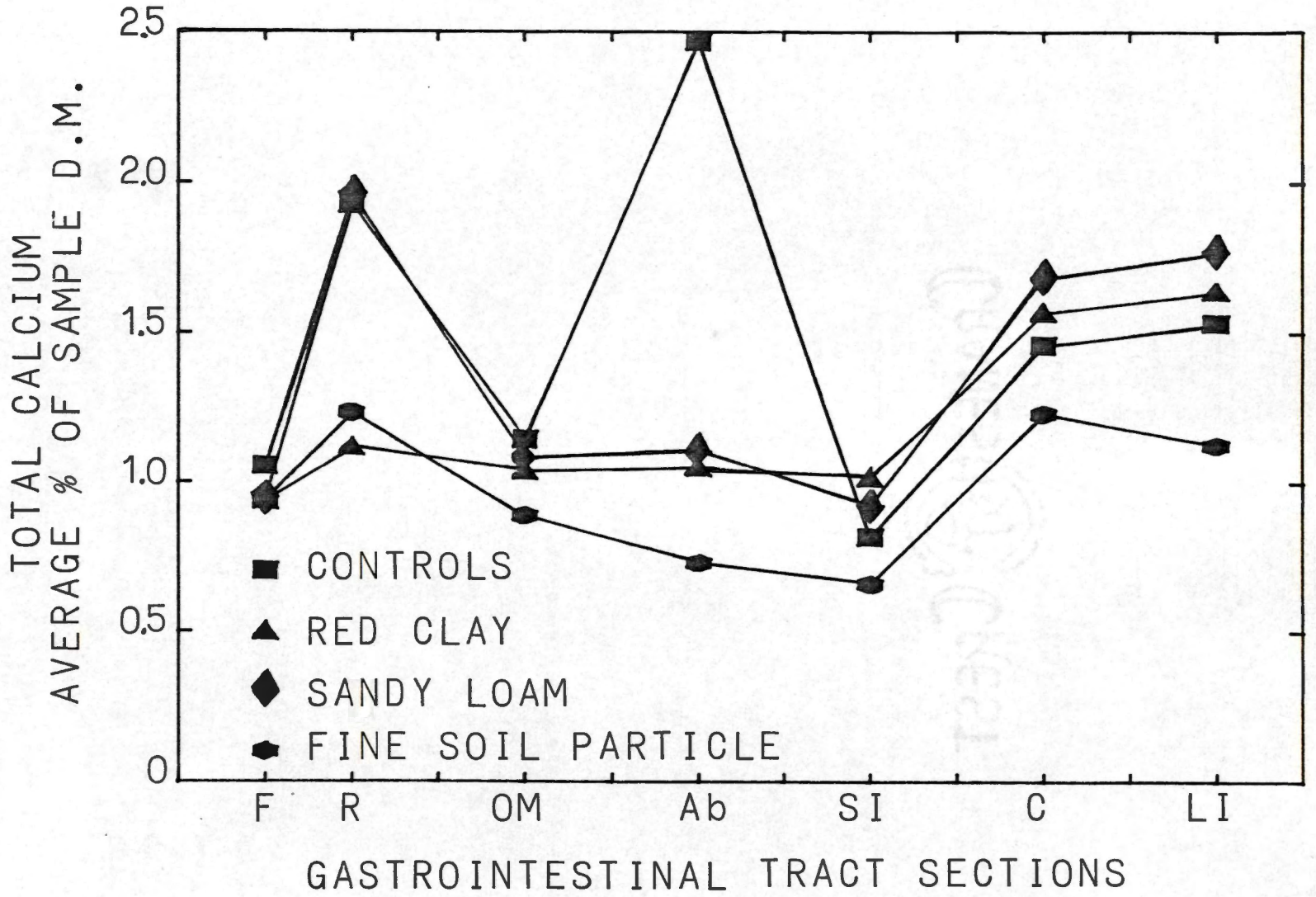

TOTAL CALCIUM
AVERAGE % OF SAMPLE D.M.
2.5
2.0
1.5
1.0
0.5
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
F
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 1

Figure 2. Concentration of magnesium in the total ash, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (F = feed; R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

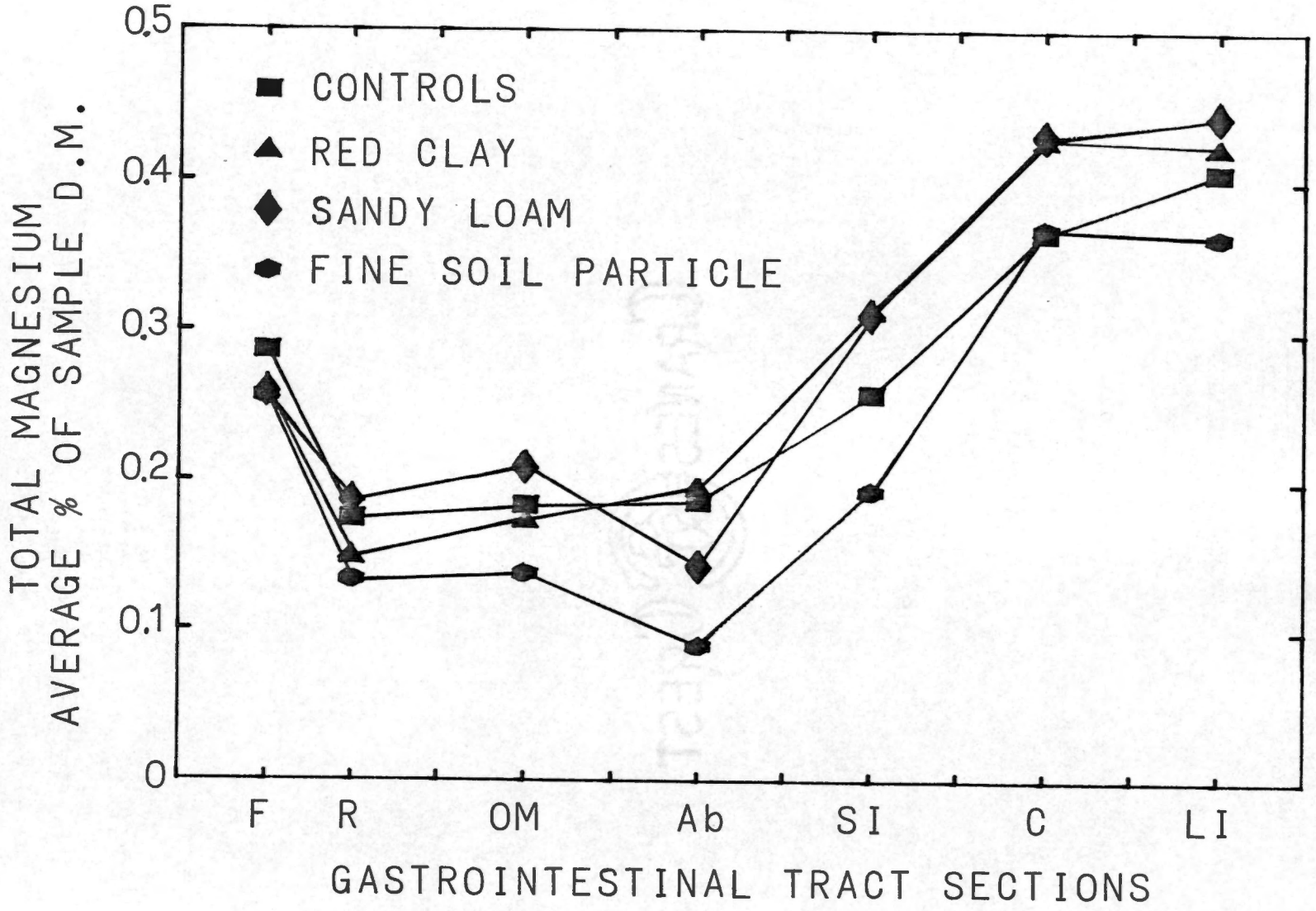

TOTAL MAGNESIUM
AVERAGE % OF SAMPLE D.M.
0.5
0.4
0.3
0.2
0.1
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
F
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 2

(1969) found that the stomachs as a unit were the site of major importance for magnesium absorption. The above results indicate that most of the magnesium absorption from the forestomachs occurs in the rumen. Magnesium concentrations increased in the small intestine and cecum for animals on all treatments. If the small intestine is not a site of magnesium absorption (Rogers and van't Klooster, 1969) these increased magnesium concentrations could have resulted from absorption of other constituents. Magnesium concentrations in the large intestine were similar to those in the cecum possibly due to lack of magnesium absorption from the large intestine (Rogers and van't Klooster, 1969).

Sodium

Sodium concentrations were higher in rumen contents than in the diets for animals on all treatments, suggesting addition of sodium to rumen contents (Figure 3). Addition of large amounts of sodium (550 g/day) in saliva (Rogers and van't Klooster, 1969) could account for this increase. Omasal sodium concentration decreased for animals on all treatments, probably as the result of absorption. Increased sodium concentrations in absomasal contents could have resulted from secretion of large amounts of fluid containing sodium into the abomasum (Rogers and van't Klooster, 1969). Sodium concentration increased further in the small intestine suggesting additional sodium secretion there. Sodium concentrations decreased in the cecum and large intestine of animals in all treatments, probably due to sodium absorption.

Figure 3. Concentration of sodium in the total ash, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (F = feed; R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

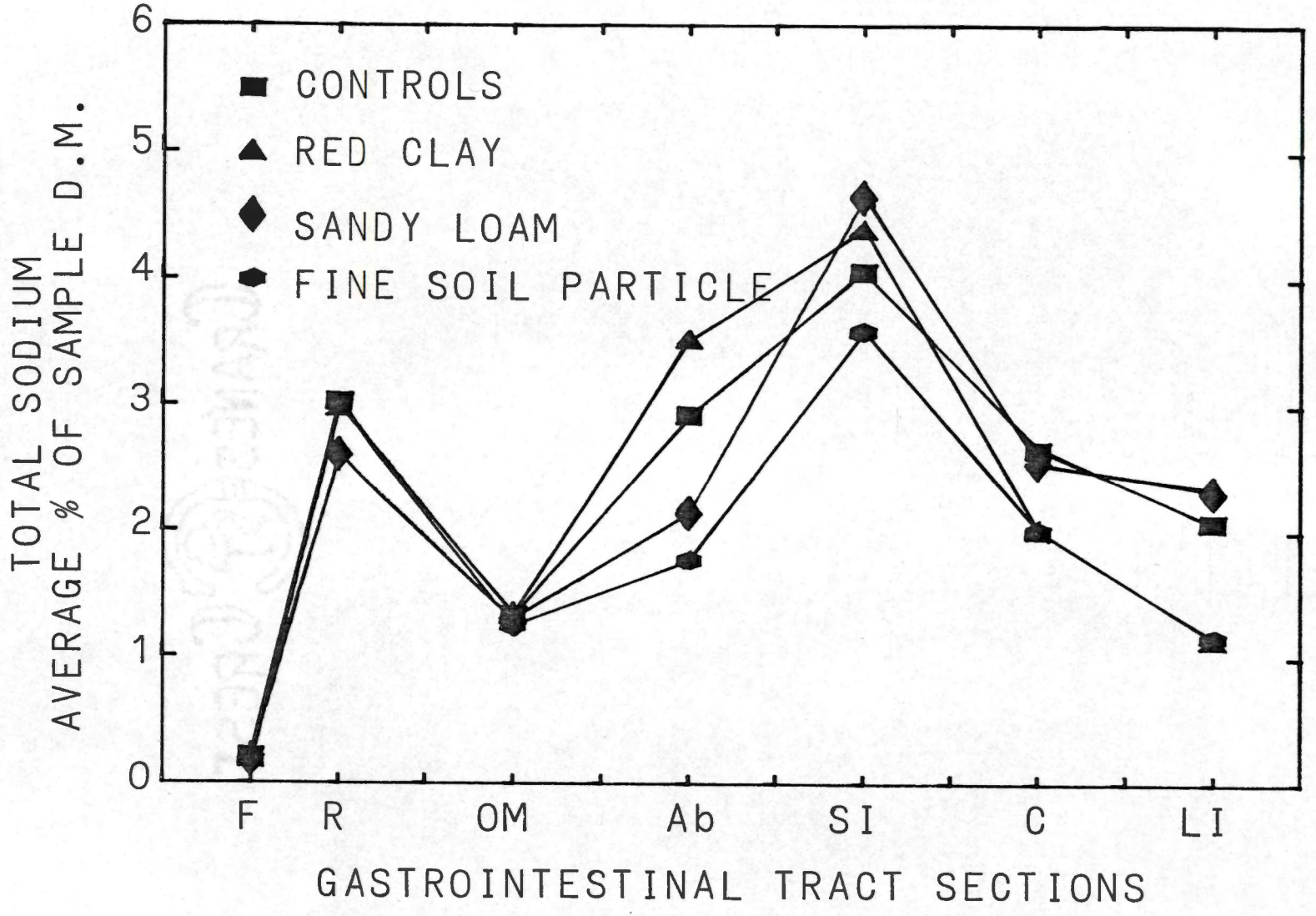

TOTAL SODIUM
AVERAGE % OF SAMPLE D.M.
6
5
4
3
2
1
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
F
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 3

Potassium

In agreement with results of Rogers and van't Klooster (1969), potassium appears to have been absorbed from the rumen of all animals as indicated by lower concentrations in rumen contents than in the diet (Figure 4). Further decreases in potassium concentration in omasal contents suggest additional absorption there. Potassium concentrations in abomasal contents increased in animals fed red clay or controls but remained near omasal concentrations for those fed sandy loam or fine soil particles. Between the abomasum and the small intestine, potassium concentrations of digesta increased for animals fed sandy loam or fine soil particles but remained unchanged for controls and those fed red clay. Grace et al. (1974) found significantly greater concentrations of potassium entering than leaving the small intestine, suggesting absorption. Absorption of potassium from the cecum and large intestines is suggested by progressively decreasing concentrations in these sections.

Phosphorous

Phosphorous concentrations were higher in the rumen (Figure 5) than in the diets, possibly due to addition of phosphorous in saliva (Rogers and van't Klooster, 1969). Omasal concentration of phosphorous increased in relation to the rumen for animals fed red clay or sandy loam, decreased for those fed fine soil particles and remained unchanged for the controls. Abomasal concentration of phosphorous increased in the controls and red clay fed animals, but decreased in

Figure 4. Concentration of potassium in the total ash, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (F = feed; R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

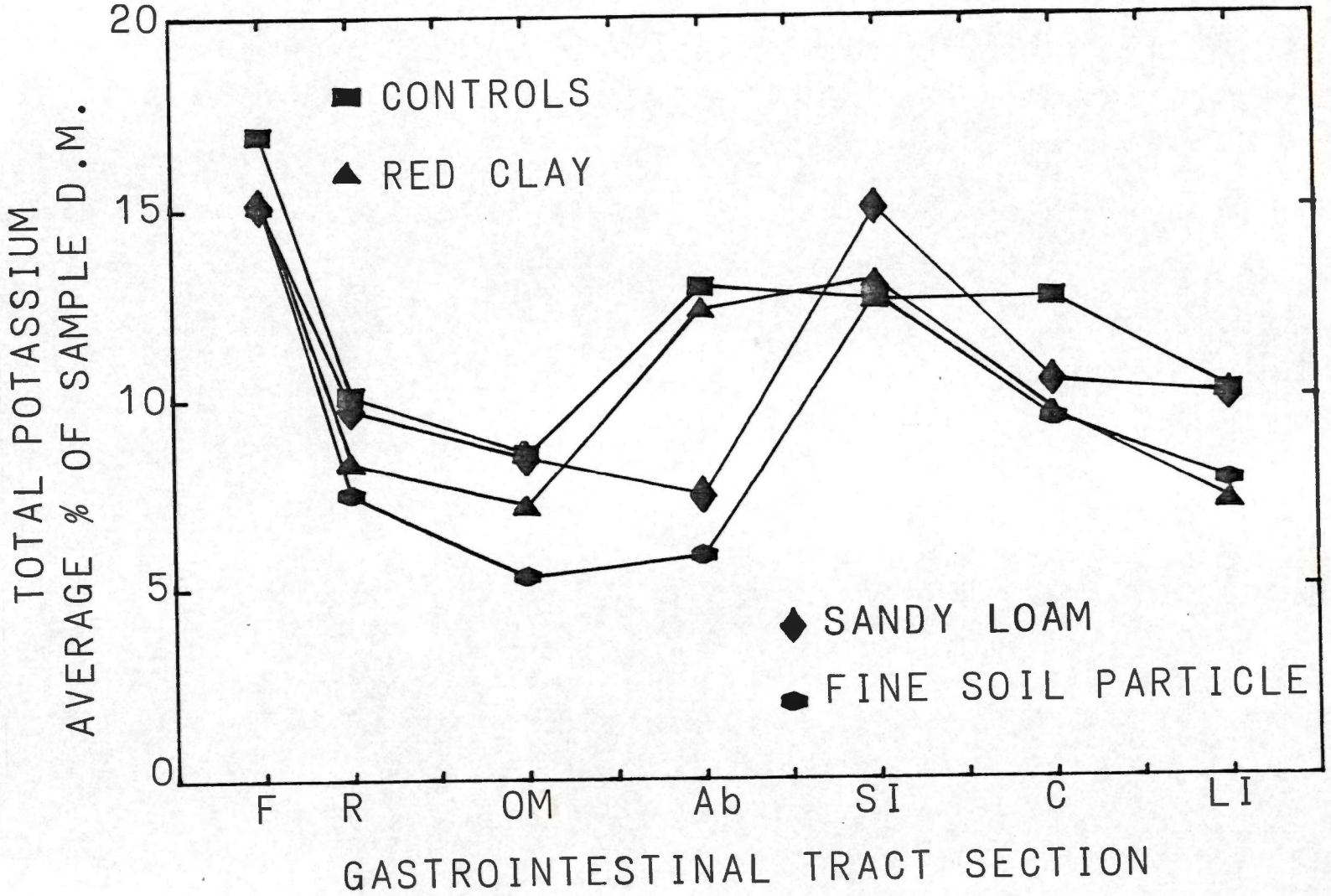

TOTAL POTASSIUM
AVERAGE % OF SAMPLE D.M.
20
15
10
5
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
F
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTION

Figure 4

Figure 5. Concentration of phosphorous in the total ash, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (F = feed; R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

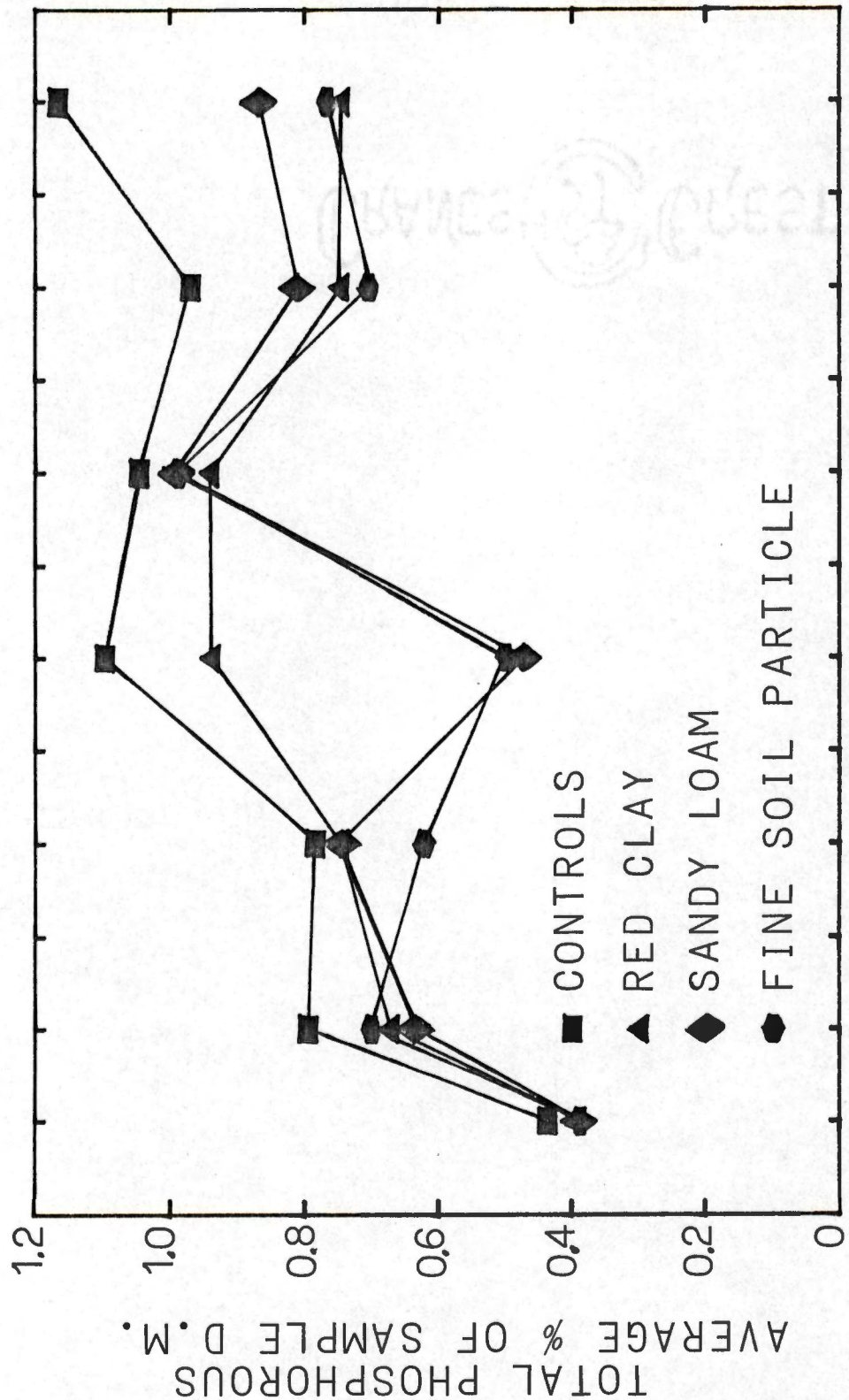

TOTAL PHOSPHOROUS
AVERAGE % OF SAMPLE D.M.
1.2
1.0
0.8
0.6
0.4
0.2
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
F R OM Ab SI C LI
GASTROINTESTINAL TRACT SECTIONS

Figure 5

the other animals on treatments. Secretion and absorption of phosphorous in this section may have resulted in the variable results. Increased phosphorous concentrations in the small intestine contents could result from greater absorption of nonphosphorous constituents or secretion of phosphorous into the small intestine. The former seems more logical than the latter since Rogers and van't Klooster (1969) found the jejunum and ileum to be the main site of phosphorous absorption. Concentrations of phosphorous in the cecum of all animals in the treatments decreased, possibly due to absorption, and concentrations of phosphorous in the large intestine was slightly increased in all animals except red clay fed animals which remained unchanged.

B. SOLUBLE MINERAL DETERMINATION

Calcium

It is shown in Figure 6 that all animals had similar concentrations of soluble calcium because the rumen may have helped proportion the concentration of soluble calcium. Omasal concentrations decreased for all soil fed groups and increased for the controls. Decrease of soluble calcium may be due to absorption, while the increase may be due to absorption of noncalcium constituents leaving a higher concentration of soluble calcium. Abomasal concentrations of soluble calcium increased for all animals on treatment, probably due to releasing of calcium from soil and feed in this section by the digestive processes and the low pH of this organ. Soluble calcium concentration decreased for all animals except sandy loam fed animals. The decrease was

Figure 6. Concentration of calcium in the ultracentrifuge supernatant, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

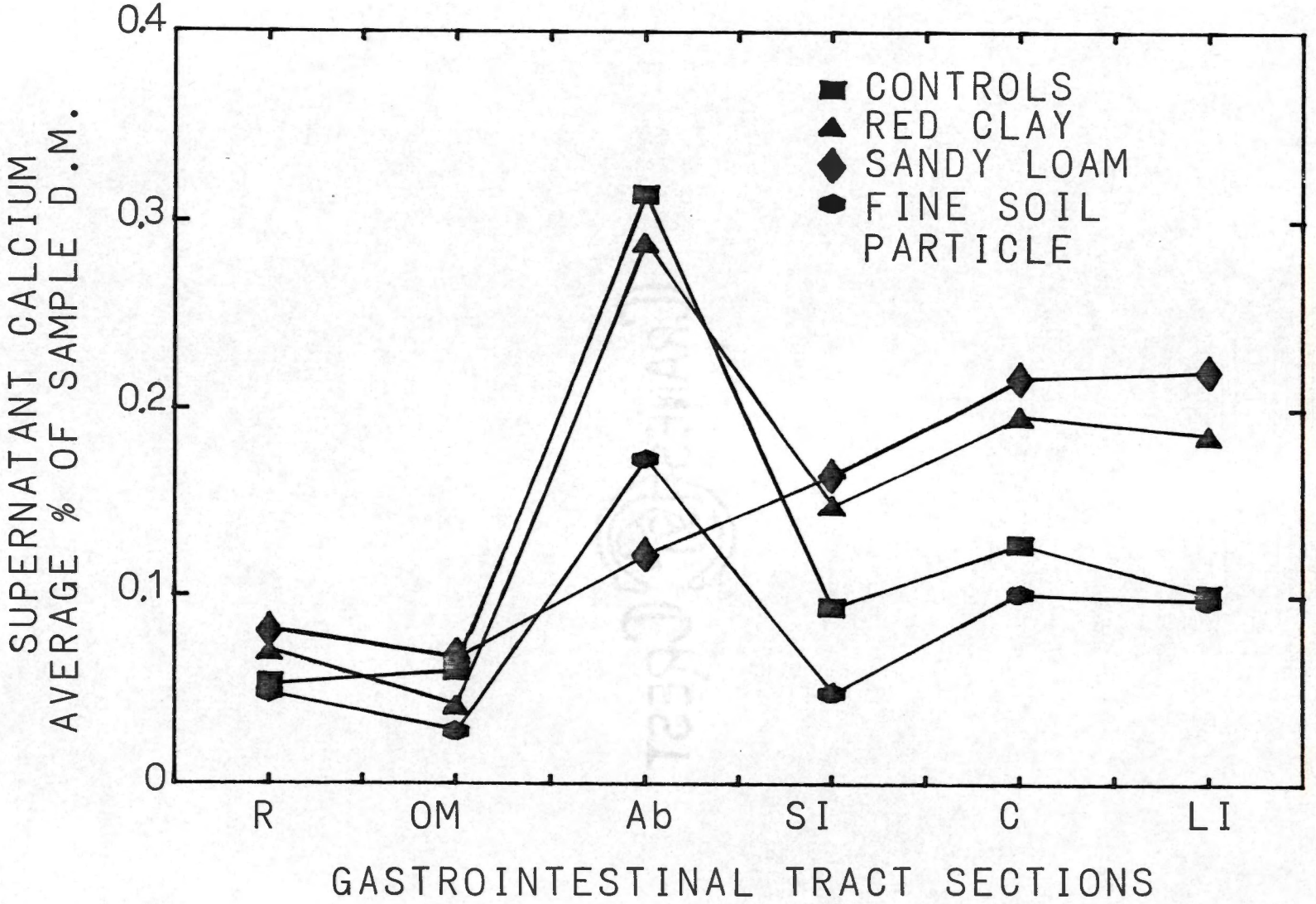

SUPERNATANT CALCIUM
AVERAGE % OF SAMPLE D.M.
0.4
0.3
0.2
0.1
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 6

probably due to absorption, while the increase may be because of a chelating factor between soil and mineral. All animals increased concentrations of soluble calcium in the cecum possibly because of secretion of calcium into this section as observed by Grace et al. (1974). Ben-ghedalia et al. (1975) found that the solubility of minerals in the gut is one of the main factors affecting their absorption, and a rise in pH as the digesta advances along the intestine is accompanied by a concomitant decrease in solubility. Since the pH does rise as digesta advances then a decrease in solubility plus secretion of calcium may have occurred. The large intestine was shown to have similar amounts of soluble calcium as found in the cecum in all animals.

Magnesium

Concentrations of soluble magnesium were similar for all animals (Figure 7). All soil fed animals had a decrease in soluble magnesium in the omasum probably due to absorption if as suggested by Rogers and van't Klooster (1969) the omasum is an organ of great importance in magnesium absorption. The increase in the omasum by the controls may be due to absorption of nonmineral constituents leaving higher concentrations of soluble magnesium. Increase in abomasal concentrations in animals on all treatments may be due to the releasing of magnesium by digestive processes. Soluble magnesium was increased in all animals probably due to secretion as was found by Rogers and van't Klooster (1969). The secretion of magnesium by the small intestine would result in an increase in the cecum as was found for

Figure 7. Concentration of magnesium in the ultracentrifuge supernatant, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

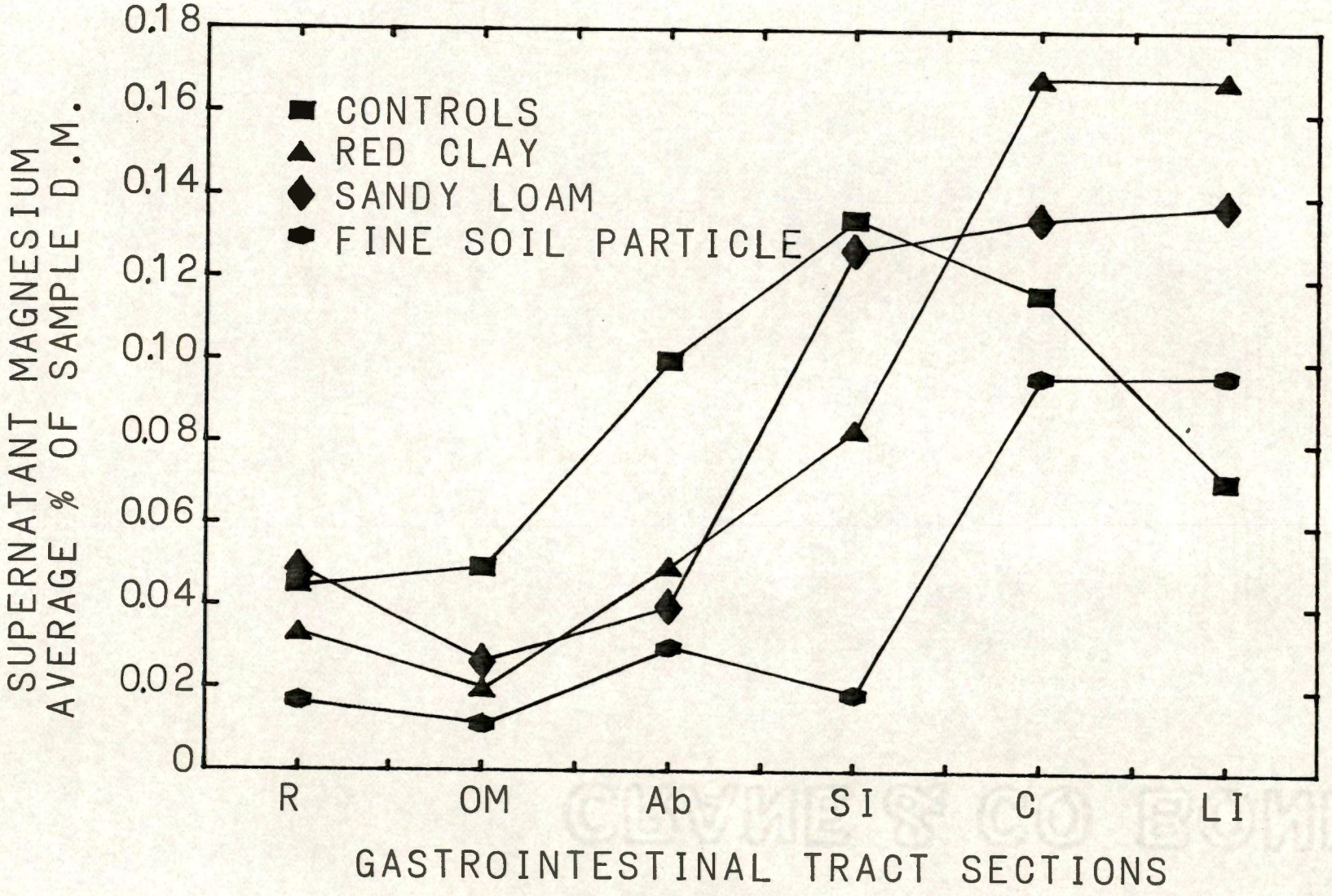

SUPERNATANT MAGNESIUM
AVERAGE % OF SAMPLE D.M.
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 7

all soil fed animals. The controls had a decrease in this section, which seems to indicate absorption. Ben-ghedalia et al. (1975) found that absorption did occur in the cecum. In the large intestine soluble magnesium remained unchanged compared to the concentrations in the cecum for all soil fed animals, but a decrease was found in the controls. The decrease of soluble magnesium in the controls agrees with Grace et al. (1974) and Ben-ghedalia et al. (1975) in which absorption of magnesium did occur in the large intestine or colon section.

Sodium

The large concentration of sodium in the rumen in all animals (Figure 8) has been previously discussed in the total sodium section. Decrease in omasal concentrations of sodium in animals on treatments would support Rogers and van't Klooster (1969), who found large amounts of sodium were absorbed from the omasum. The increase in abomasal concentration of calcium and magnesium in all animals has been discussed, and indications are that soluble sodium increases for the same reasons. The larger average increase in abomasal sodium of the red clay fed group was the result of one animal having a very high percentage of sodium. In the small intestine, the red clay fed group remained unchanged from the amount of soluble sodium found in the abomasum, but in all other animals an increase was found probably due to secretion. Rogers and van't Klooster (1969) stated that the addition of sodium to the duodenum was attributed to sodium in the

Figure 8. Concentration of sodium in the ultracentrifuge supernatant, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

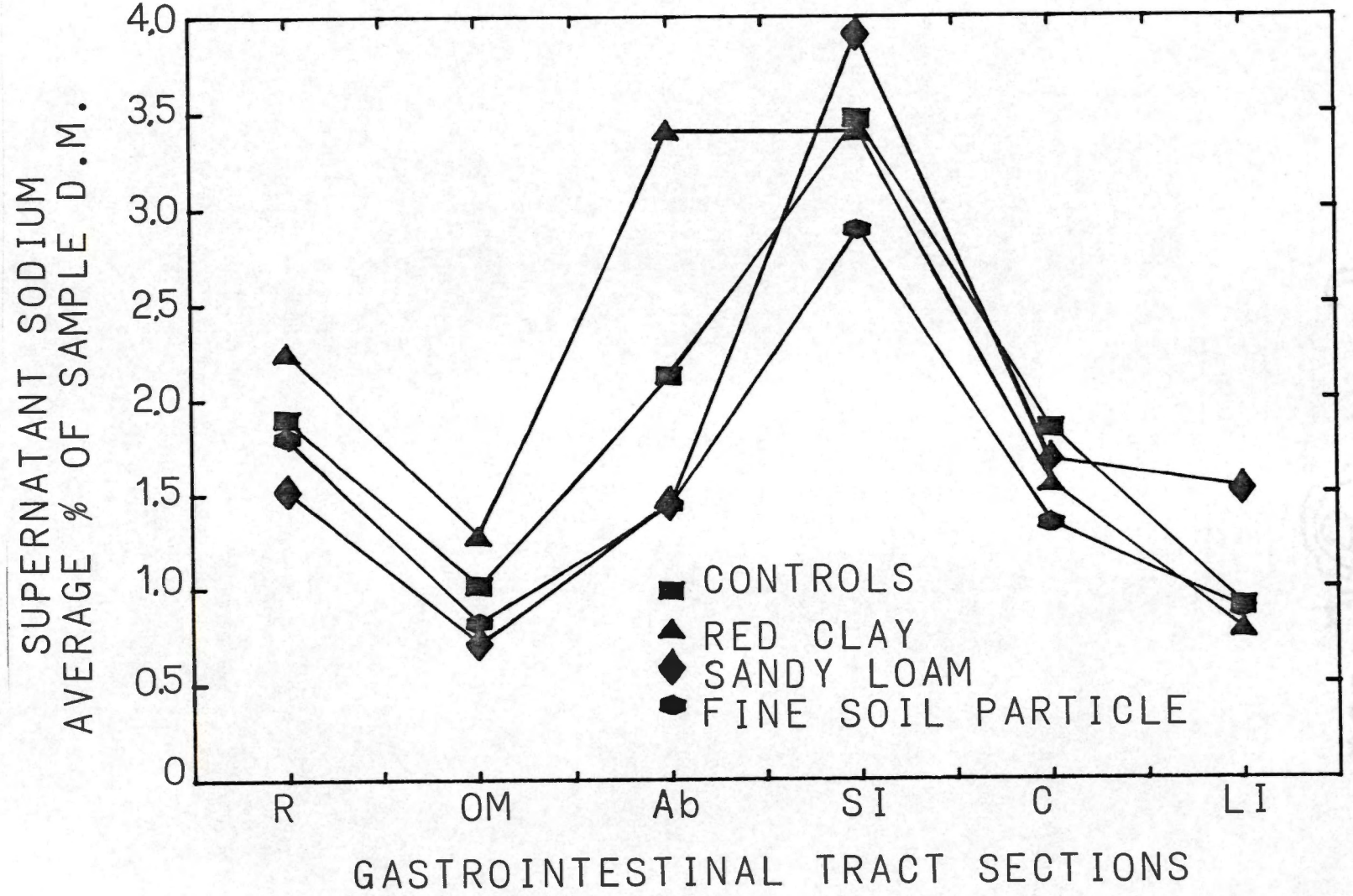

SUPERNATANT SODIUM
AVERAGE % OF SAMPLE D.M.
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 8

bile, pancreatic juice and succus entericus. The decrease in concentrations of soluble sodium in the cecum and large intestine of all animals coincides with results of Rogers and van't Klooster (1969), who found that a strong net absorption occurred in the lower small intestine, which would result in a lower concentration in the cecum. They and also Grace et al. (1974) found that net sodium absorption occurred in the large intestine.

Potassium

In the rumen (Figure 9), the concentrations of soluble potassium were similar for animals in all treatments, while the omasal concentration was decreased for all soil fed animals, but increased for the controls. The decrease and increase of soluble potassium in the omasum can be explained as for the other minerals and the increase in concentrations of soluble minerals in abomasa of all animals has also been discussed. All soil fed animals were found to have an increase in concentration of soluble potassium, while the controls decreased. In the cecum the concentration of soluble potassium decreased in all animals. The increase found in the small intestine was probably due to the releasing of potassium in the abomasum, which would cause a higher concentration in the small intestine. The decrease observed in the controls was probably due to absorption since Rogers and van't Klooster (1969) and Grace et al. (1974) found that the small intestine was the major site of net potassium absorption. Due to these findings, a decrease in soluble potassium would be expected in the cecum and this

Figure 9. Concentration of potassium in the ultracentrifuge supernatant, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

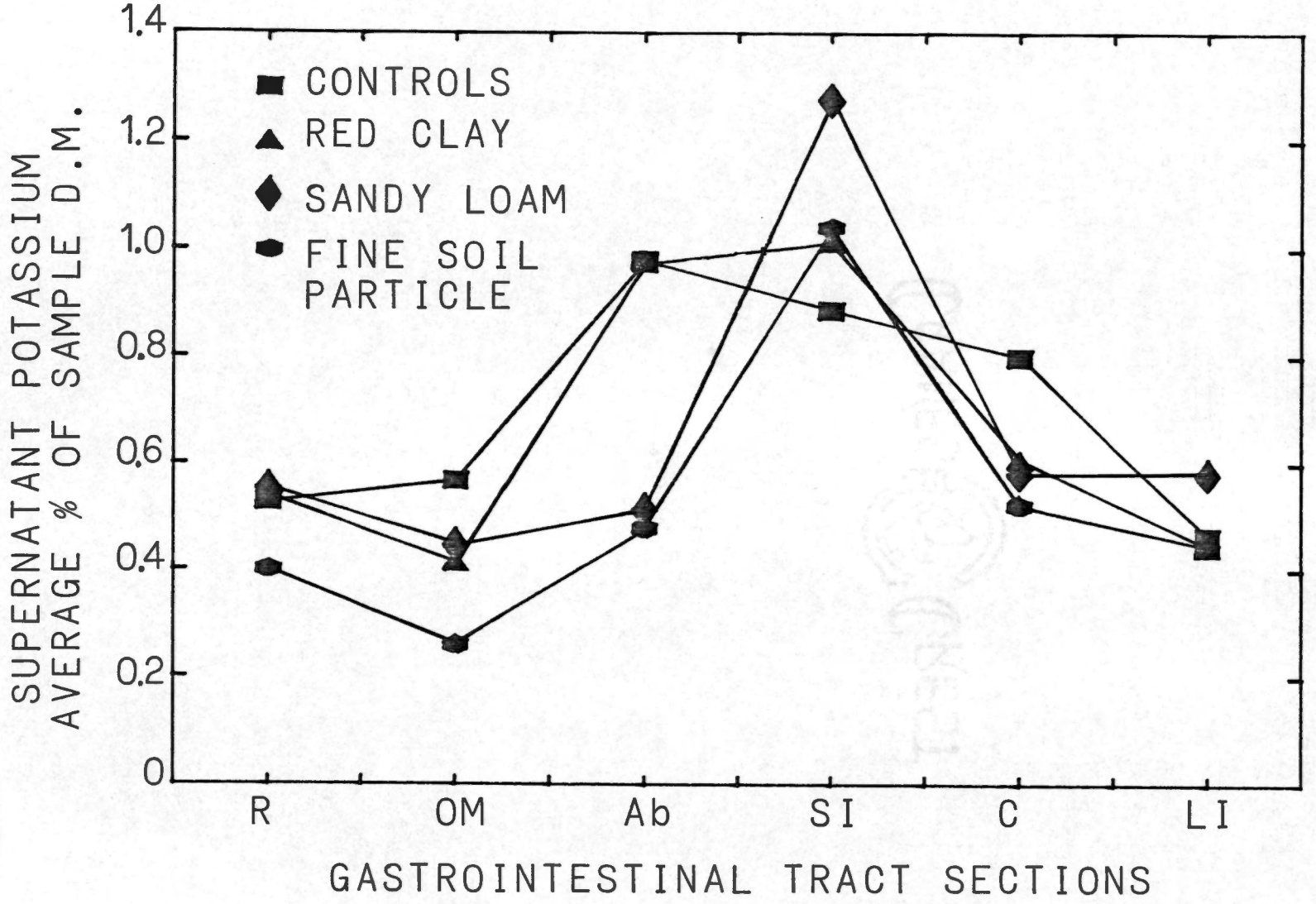

SUPERNATANT POTASSIUM
AVERAGE % OF SAMPLE D.M.
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
CONTROLS
RED CLAY
SANDY LOAM
FINE SOIL PARTICLE
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 9

did occur in all animals on treatment. Absorption may have occurred in the large intestine since a decrease in soluble potassium was found in all animals except sandy loam fed animals which remained unchanged.

Phosphorous

The controls had a higher concentration of soluble phosphorous than any of the soil fed animals (Figure 10). The difference in omasal concentrations of soluble phosphorous in all animals can be explained as with previous minerals. Abomasal concentrations of soluble phosphorous increased in animals on all treatments and the reason for these increases have been explained. Soluble phosphorous concentrations in small intestine contents decreased in controls and red clay fed animals but increased in the other groups. The increase in concentration in the small intestine of two groups of animals may be due to absorption of more nonphosphorous constituents than of phosphorous resulting in a higher concentration of phosphorous. The decrease in concentration of phosphorous in the small intestines of the controls and red clay fed animals may be due to absorption because Rogers and van't Klooster (1969), Grace et al. (1974), and Ben-ghedalia et al. (1975) found that net absorption of phosphorous occurred in the small intestine. Absorption in the small intestine could cause a lower concentration of soluble phosphorous in the cecum and this was observed in the animals on all treatments. Concentrations of soluble phosphorous in the large intestine were similar to that in the cecum for all animals, indicating little change in soluble phosphorous. This observation agrees with Rogers and van't Klooster (1969),

Figure 10. Concentration of phosphorous in the ultracentrifuge supernatant, expressed as a percentage of the sample dry matter, from different sections of the gastrointestinal tract from steers fed no soil or different types of soil. (R = rumen; Om = omasum; Ab = abomasum; SI = small intestine; C = cecum; LI = large intestine.)

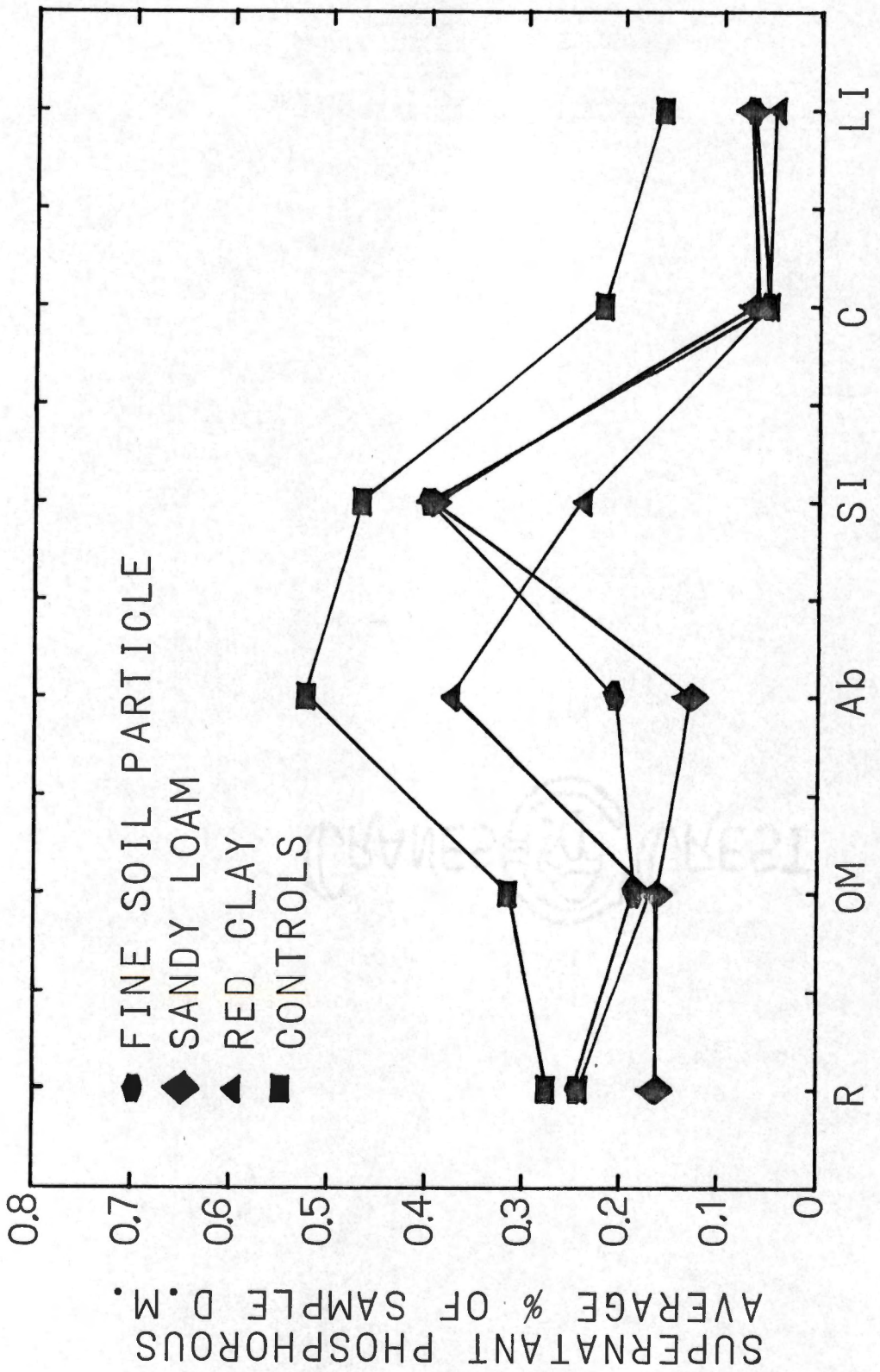

SUPERNATANT PHOSPHOROUS
AVERAGE % OF SAMPLE D.M.
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FINE SOIL PARTICLE
SANDY LOAM
RED CLAY
CONTROLS
R
OM
Ab
SI
C
LI
GASTROINTESTINAL TRACT SECTIONS

Figure 10

who found that little or no absorption of phosphorous occurred in the large intestine.

C. MINERAL SOLUBILITY IN DIGESTIVE TRACT CONTENTS

Solubility of minerals in the digestive tract contents as a percentage of the total concentrations is shown in Table 4. Indications are that anterior to the cecum mineral solubilities averaged Na > K > P > Mg > Ca in the concentrations. Calcium solubility was unaffected or increased in each section of the tract by all soils. Magnesium solubility was decreased in the omasum compared to the solubility in the rumen in all soil fed groups, but not in the controls. The cecum and large intestines were sections in which phosphorous was the least soluble, while the rumen and omasum were the sections in which calcium solubility was lowest. In most cases, minerals were most soluble in the abomasal contents. Apparent solubility would be influenced by absorption since soluble rather than insoluble fractions would be removed and in general, the percentage of soluble minerals decreased in each section posterior to the abomasum.

The presence of soil increased the percentage of dry matter and ash in diets of all soil fed animals. As would be expected, this had an effect upon the amounts of ash in the different gastrointestinal sections, resulting in different quantities present according to the types of soil fed.

From considering all figures and tables and comparing animals in all treatments, the following has been shown. Total concentration of

Table 4. Mineral Solubility in the Gastrointestinal Tract Compared to the Total Individual Mineral Concentration

Treatments and Minerals	Sections of the Gastrointestinal Tract					
	Rumen	Omasum	Abomasum	Small Intestine	Cecum	Large Intestine
	(% of total)					
Control						
Ca	2.80	5.23	12.74	11.52	8.77	6.62
Mg	25.94	26.87	53.75	52.12	31.80	17.47
Na	62.76	76.82	72.74	85.35	69.59	43.72
K	52.39	66.52	75.71	70.60	63.34	45.98
P	34.77	40.36	47.88	45.12	22.81	13.81
Red Clay						
Ca	6.29	3.98	27.51	14.66	12.53	11.35
Mg	22.33	11.49	25.36	26.44	39.39	39.69
Na	75.42	96.27	96.63	77.32	77.34	68.83
K	64.75	57.67	78.88	77.39	63.37	61.41
P	36.13	22.93	40.08	25.77	6.99	6.31
Sandy Loam						
Ca	4.15	6.15	11.09	17.84	12.85	12.45
Mg	26.20	12.73	27.97	40.70	31.28	31.10
Na	58.44	55.78	67.81	84.13	65.92	65.85
K	56.78	52.90	69.08	85.14	55.90	58.18
P	25.87	22.19	27.59	39.96	8.14	8.22
Fine Soil Particle						
Ca	3.91	3.14	23.78	8.09	8.24	8.65
Mg	12.74	8.41	33.67	9.84	26.15	26.65
Na	60.11	66.34	81.63	80.56	66.93	76.42
K	53.60	48.93	81.49	81.83	55.27	63.40
P	35.48	30.32	41.83	40.65	7.70	9.16

minerals over the concentrations found in the controls was not greatly affected by the presence of soil in the diets. The only minerals in which soil may have increased the concentration were sodium and potassium, especially as found in the small intestine. This increase of concentration may be due to a chelating effect between the soil and secreted minerals. Healy (1972) stated that soil types or different kinds of soil, because of composition and constitution, may have a qualitative effect through their ability to alter composition of digestive liquors. Similar amounts of different soils may produce differerent nutritional effects when ingested.

Animals fed fine soil particles were shown to have the lowest amounts of soluble minerals in most of the gastrointestinal sections. This type of soil was clay or clay-like in appearance, and its structure and fineness may have been a factor in the binding or releasing of minerals. Field and Purves (1964) stated that constituents of soil such as clay may interfere with the absorption of some minerals from the alimentary tract. Mineral solubility for all soil fed animals was not increased over the amounts soluble in the controls. Therefore it is unlikely that the presence of soil could result in a better absorption of soluble minerals by the soil fed animals over the amounts that were absorbed by the controls.

Solubilities of individual minerals were decreased or increased in different gastrointestinal tract sections. The decrease observed was probably influenced by absorption, while the increase may be due to secretion of a particular mineral into a section. Each individual

mineral was distinct in the amount of soluble mineral available. It was shown that the rank of solubilities averaged Na > K > P > Mg > Ca in the gastrointestinal sections anterior to the cecum. Apparent solubility would be affected by absorption since the soluble minerals would be removed by digestion more readily than the insoluble fractions.

CHAPTER V

SUMMARY AND CONCLUSION

Nine steers were used in an experiment to determine the effects of different soils on mineral solubility. Three treatments consisted of feeding different kinds of soil, while one was the control. The minerals determined were calcium, magnesium, sodium, potassium and phosphorous.

The amount of ash and dry matter in diets of all soil fed animals varied according to the type of soil fed. Feeding of soil doubled the percentage of ash in most sections of the gastrointestinal tract.

Total concentration of the minerals was not affected appreciably by the presence of soil, except for increase in total concentrations of sodium and potassium, mainly in the small intestine of the soil fed animals. This indicates that soils may have been a factor in the increased mineral concentration, but the method of producing this result is not clear.

Absorption of each soluble mineral was estimated for all animals on treatments from changes in concentrations through the alimentary canal. Soil fed animals seemed to absorb more of particular minerals than did the controls, but the amounts absorbed were not much greater than the amounts absorbed by the controls. Indicating that the soil did not help increase the absorption of soluble minerals and as a result the soil fed animals did not benefit from the soil ingested.

The amount of soluble mineral compared to the total concentration was different for each individual mineral. Na > K > P > Mg > Ca was found to be true in the gastrointestinal sections anterior to the cecum, while all minerals were more soluble in the abomasum than anywhere else. The presence of soil did affect the solubility of each mineral in the different gastrointestinal sections (Table 4, page 53).

One reason that greater mineral differences were not obtained from the soils is that the soluble amounts for all minerals from soil were extremely low, as shown in Table 2, page 22. The only significant amounts of soluble minerals were found in the hay and concentrate. This might have caused the similar results observed in all animals on all treatments since these were fed to all animals. Soils have varying amounts of different minerals and if a soil has a higher concentration of soluble mineral then the chances of greater absorption are improved.

The soils may have affected the concentration of some minerals in parts of the gastrointestinal tract by increasing the total concentration of certain minerals through binding. Type of soil used may have been a factor in determining the soluble amount of a mineral, due to the binding capabilities of that soil. This effect was hypothesized especially for the fine soil particles.

LITERATURE CITED

LITERATURE CITED

1. Andrews, E. D., B. J. Stephenson, J. P. Anderson, and W. C. Faithful. 1958. The Effect of Length of Pastures on Cobalt Deficiency Disease in Lambs. N.Z.J. Agric. Res. 1:125.

2. Ben-ghedalia, D., H. Tagari, S. Zamwell and A. Bondi. 1975. Solubility and Net Exchange of Calcium, Magnesium and Phosphorous in Digesta Flowing Along the Gut of Sheep. Brit. J. Nutr. 33:87.

3. Cunha, T. J. 1957. Swine Feeding and Nutrition. Volume 1, Interscience Publishers, Inc., New York.

4. Field, A. C. and D. Purves. 1964. The Intake of Soil by the Grazing Sheep. Proceedings of Nutrition Society, Volume 23.

5. Fiske, C. H. and Y. Subbarow. 1925. The Colormetric Determination of Phosphorous. J. Biol. Chem., 66:375-400.

6. Fontenot, J. P., M. B. Wise, and K. E. Webb, Jr. 1973. Interrelationship of Potassium, Nitrogen and Magnesium in Ruminants. Federation Proc. 32:1925.

7. Grace, N. D. and W. B. Healy. 1974. Effect of Ingestion of Soil on Fecal Losses and Retention of Mg, Ca, P, K and Na in Sheep Fed Two Levels of Dried Grass. N.Z.J. Agric. Res. 17, 73-78.

8. Grace, N. D., M. J. Ulyatt and J. C. Macrae. 1974. Quantitative Digestion of Fresh Herbage by Sheep. 3., The Movement of Mg, Ca, P, K and Na in the Digestive Tract. J. Agri. Sci. Camb., 82:321-330.

9. Healy, W. B. and T. G. Ludwig. 1965. Wear of Sheep's Teeth. I. The Role of Ingested Soil. N.Z.J. Agric. Res. 8, 737-752.

10. Healy, W. B. 1967. Ingestion of Soil by Sheep. Proc. N. Z. Soc. Anim. Prod. 27:109-120.

11. Healy, W. B., T. W. Cutress and C. Mickie. 1967. Wear of Sheep Teeth. IV. Reduction of Soil Ingestion and Tooth Wear by Supplementary Feeding. N.Z.J. Agric. Res. 10, 201-209.

12. Healy, W. B. 1968. Ingestion of Soil by Dairy Cows. N.Z.J. Agric. Res. 11:487.

13. Healy, W. B. 1968. The Influence of Soil Type on Ingestion of Soil by Grazing Animals. Transaction of the 9th International Congress of Soil Science 111:437-45.

14. Healy, W. B. and K. R. Drew. 1970. Ingestion of Soil by Hoggets Grazing Swedes. N.Z.J. Agric. Res. 13:940.

15. Healy, W. B., W. J. McCabe, and G. F. Wilson. 1970. Ingested Soil as a Source of Microelements for Grazing Animals. N.Z.J. Agric. Res. 13:503.

16. Healy, W. B. and G.F. Wilson. 1971. Deposits on Rumen Epithelium Associated with Ingestion of Soil. N.Z.J. Agric. Res. 14:122-131.

17. Healy, W. B. 1972. In Vitro Studies on the Effects of Soil on Elements in Ruminal, Duodenal, and Ileal Liquors from Sheep. N.Z.J. Agric. Res. 15:289.

18. Healy, W. B., J. R. Crouchley, R. L. Gilbert, P. C. Rankin and H. M. Watts. 1972. Ingested Soil and Iodine Deficiency in Lambs. N.Z.J. Agric. Res. 15:778.

19. Healy, W. B. 1973. Ingested Soil as a Source of Elements to Grazing Animals. Proceedings of the Second International Symposium on Trace Elements Metabolism in Animals. University Park Press, Baltimore.

20. Healy, W. B., P. C. Rankin and H. M. Watts. 1974. Effect of Soil Contamination on the Element Composition of Herbage. N.Z.J. Agric. Res. 17:59-61.

21. Hogg, D. E. 1970. Magnesium Losses From Horotiu Sandy Loam Following Application of Potassium Chloride. N.Z.J. Agric. Res. 3:377.

22. Jacobson, D. R., R. W. Hemken, F. S. Button and R. H. Hatton. 1972. Mineral Nutrition, Calcium, Phosphorous, Magnesium and Potassium Interrelationship. J. Dairy Sci. 55:935.

23. Kemp, A. and J. H. Geurink. 1970. Effect of Mg Fertilizer on Mg Contents of Soil, Herbage and Blood Serum of Cows. Versl. Landbouwk. Onderzolk No. 747, pp. 33. (Nutr. Abs. Revs. 41:1140, 1971.)

24. Ludwig, T. G., W. B. Healy, and T. W. Cutress. 1966. Wear of Sheep's Teeth. III. Seasonal Variation in Wear and Ingested Soil. N.Z.J. Agric. Res. 9:157-64.

25. Miller, J. K. and R. G. Cragle. 1965. Gastrointestinal Site of Absorption and Endogenous Secretion of Zinc in Dairy Cattle. J. Dairy Sci. 48:370-3.

26. Rigg, T. and H. O. Askew. 1934. Soil and Mineral Supplements in the Treatment of Bush Sickness. Empire J. Exp. Agric. 2:1.

27. Rogers, P. A. and A. Th. van't Klooster. 1969. Observation on the Digestion and Absorption of Food Along the Gastrointestinal Tract of Fistulated Cows. 3. The Fate of Na, K, Ca, Mg and P in the Digesta. Medelingen Landbouwhogeschool, Wageningen 69, No. 11, 26-39.

28. Toothill, J. 1963. The Effect of Certain Dietary Factors on the Apparent Absorption of Magnesium by the Rat. British J. Nutrition, 17:125.

29. Underwood, E. J. 1966. The Mineral Nutrition of Livestock. Central Press. Aberdeen.

VITA

David Lynn Hobbs was born in Wichita Falls, Texas, on July 27, 1952. His parents moved to McMinnville, Tennessee, where he attended elementary school and graduated from the Warren County Senior High School in 1970. In September of that same year, he entered Tennessee Technological University at Cookeville, Tennessee. In August of 1974, he received a Bachelor of Science degree in Agriculture. In September, he was enrolled in the Graduate School at The University of Tennessee, working toward a Master of Science degree in Animal Science. One of his lifelong ambitions is to become a Doctor of Veterinary Medicine.

On July 27, 1969, he became a member of the Church of Christ at West Riverside in McMinnville, Tennessee. With the Lord's help and will, he plans to marry and raise a good Christian family and become an elder in the church and serve the Lord, his Father, to the utmost of his ability.