CALCIUM AND PHOSPHORUS REQUIREfENT OF GROWING YANKASA LAMBS IN THE SAVANNA REGION OF NIGERIA.

BY

FRANK CHUKWUDOZIE OKOYE
B.Sc. Hons, (An.Sc.), U.N.N.
1972.

A
THESIS

Submitted to Ahmadu Bello University, Zaria in partial fulfilment for the degree
MASTER OP SCIENCE (IN AGRICULTURE)
Department of Animal Science.

November, 1980

THESIS APPROVAL

This thesis by Frank Chukwudozie Okoye, meets the regulations governing the degree, Master of Science of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

Internal examiners

.....
N.N. UMUNNA

.....
DR. C.N. CHINEME

External examiner

.....
PROFESSOR A.A. ADEGBOLA
Department of Animal Science
University of Ife
Ile-Ife.

2nd March, 1981
.....
Date

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation and thanks to Drs. N.N. Umunna and C.N. Chineme for their assistance and advice in initiating and completing this study, as well as in the preparation of this manuscript. He is grateful to the University Board of Research of Ahmadu Bello University, Zaria for its financial support covering a great portion of this project. The author is also indebted to Dr. O.C. Onazi, Director, Division of Agricultural Colleges, A.B.U., Zaria for granting him the permission to undertake the study. Thanks are due to Mr. L. Lawal of the Soil Science Section of the I.A.R. for his invaluable assistance in the analysis of the samples. He is also very grateful to the staff of the statistical Section of the I.A.R. for their assistance in the statistical analysis of the data.

Special thanks are due to my wife, Ngozi Okoye and parents, Mr. Raphael Okoye and Mrs. Caroline Okoye for their moral and material support during my study.

ABSTRACT

Two experiments were conducted to determine the calcium and phosphorus requirement of growing Yankasa lambs in the Savannah region of Nigeria, The first experiment which was designed to study the calcium requirement of growing lambs in the region involved two studies with varying dietary calcium levels:- 0.28%, 0.42%, 0.56%, 0.70%, 0.86%, 0.99% and 1.15%. Rations were formulated to be adequate and similar in protein, energy and vitamin D. The criteria of adequacy employed included growth performance, mineral retention, serum calcium and phosphorus levels and bone development. The results indicated that the provi#ion of dietary calcium at the rate of 305 nig/kg body weight per day was adequate for growth.

The second experiment was conducted to determine the optimum levels of calcium and phosphorus for growing lambs in this region. Three levels of dietary calcium and three levels of dietary phosphorus were used in a 3 X 3 factorial arrangement. The nine rations were formulated to be isocaloric and isonitrogenous and vitamin D was provided at the rate of 5.6 I.U per kg body weight per day. The same criteria of adequacy were used as in first experiment. The optimum level of dietary calcium for growing lambs was found to be 295 mg/kg body weight per day while the optimum level of dietary phosphorus was found to be

276 mg/kg body weight per day.

Endogenous values for calcium and phosphorus obtained by regressing the faecal and urinary outputs of the elements on the intake were found to be 5.5mg/kg body weight per day for calcium in experiment 1, 9.1mg per kg body weight per day for calcium in experiment 2 and 32.3 mg/kg bodyweight per day for phosphorus in experiment 2. The merit of expressing mineral requirement on net basis is discussed and recommended.

TABLE OF CONTENTS

	Page
Acknowledgement	i
Abstract	ii
Table of contents	iv
List of tables	v
List of figures	ix
List of plates	x
Introduction	1
Literature review	5
Experimental procedure	43
Results	60
Discussion	85
Literature cited	97
Appendix tables	114

LIST OF TABLES

Table		Page
1.	Composition (%) of some mineral supplements with respect to calcium and phosphorus	30
2.	Composition (%) of supplements fed in experiment 1	46
3.	Composition (%) of the rations fed in experiment 2	54
4.	Average response of lambs fed different dietary calcium levels in experiment 1	61
5.	Balance trial - experiment 1 - calcium balance	62
6.	Balance trial - experiment 1 - phosphorus balance.	63
7.	Biochemical data of blood serum and physico-chemical data of bones.	66
8.	Average response of lambs fed different levels of calcium and phosphorus in experiment 2.	68
9.	Balance trial for calcium in experiment 2.	69
10.	Balance trial for phosphorus in experiment 2.	70
11.	Biochemical data of blood serum and physico-chemical data of bones in experiment 2.	74
12.	Regression equations relating to calcium intake (X), phosphorus intake (X) and faecal excretion of calcium and phosphorus (Y) and urinary excretion of calcium and phosphorus (Y).	75

Table		Page
13.	Comparison of clacium and phosphorus requirements as recommended in this study with some recommendations of temperate workers.	76
14.	Simple effects of calcium and phosphorus on dry matter digestibility.	77
15.	Comparison of the endogenous calcium and phosphorus losses obtained in the present studeis with some temperate values.	78
16.	Analysis of variance talbe for rate of gain in experiment 1.	114
17.	Analysis of variance table for feed intake in experiment 1.	114
18.	Analysis of variance for feed efficiency in experiment 1.	114
19.	Analysis of variance for serum calcium levels in experiment 1.	114
20.	Analysis of variance for serum phosphorus levels experiment 1.	115
21.	Analysis of variance for faecal output of calcium in experiment 1.	115
22.	Analysis of variance for faecal output of phosphorus in experiment 1.	115
23.	Analysis of variance for calcium retention in experiment 1.	115
24.	Analysis of variance for phosphorus retention in experiment 1.	115
25.	Analysis of variance for specific gravity of humerus in experiment 1.	116

		Page
26.	Analysis of variance table for % Ash in Dry Fat Free Bone in experiment 1.	116
27.	Analysis of variance table for % calcium in dry fat free bone in experiment 1.	116
28.	Analysis of variance table for % phosphorus in dry fat free bone in experiment 1.	116
29.	Analysis of variance table for dry matter digestibility (%) in experiment 1.	117
30.	Analysis of variance table for urinary output of calcium in experiment 1.	117
31.	Analysis of variance talbe for calcium availability in experiment 1.	117
32.	Analysis of variance table for phosphorus availability in experiment 1.	117
33.	Analysis of variance talbe for rate of gain in experiment 2.	118
34.	Analysis of variance talbe for dry matter feed intake in experiment 2.	118
35.	Analysis of variance for feed efficiency in experiment 2.	118
36.	Analysis of variance table for serum calcium in experiment 2.	119
37.	Analysis of variance table for serum phosphorus levels.	119
38.	Analysis of variance for % Ash in dry fat free bone in experiment 2.	120
39.	Analysis of variance table for dry matter digestibility in experiment 2.	120
40.	Analysis of variance table for % calcium in dry fat free bone.	120

Page

41. Analysis of variance for phosphorus in dry fat free bone. 121

42. Analysis of variance table for faecal output of calcium in experiment 2. 121

43. Analysis of variance for urinary output of calcium in experiment 2. 121

44. Analysis of variance table for calcium retention (g) in experiment 2. 122

45. Analysis of variance table for faecal output of phosphorus in experiment 2. 122

46. Urinary output of Phosphorus in experiment 2. 122

47. Phosphorus retention of experiment 2. 123

48. Analysis of variance for availability of dietary calcium in experiment 2. 123

LIST OF FIGURES

Figures		Page
1.	Interactions of calcium and phosphorus on Average Daily gain in experiment 2.	79
2.	Interactions of calcium and phosphorus on feed intake in experiment in experiment 2.	80
3.	Interactions of calcium and phosphorus on feed efficiency in experiment 2.	81
4.	Interactions of calcium and phosphorus on dry matter digestibility in experiment 2.	82

LIST OF PLATES

Plate		Page
1.	X-ray of the humeri in experiment 1A	83
2.	X-ray of the humeri in experiment 1B	83
3.	X-ray of the humeri in experiment 2	84

INTRODUCTION

Calcium and phosphorus are two of the most important mineral nutrients required by all farm animals. Aside from their more direct physiological functions, their role in the metabolism of rumen microorganisms have been recognised. The studies of Burroughs et al. (1950, 1951), Anderson et al.(1956) and Varner and Woods (1972) have shown that calcium and phosphorus are involved in different phases of bacterial metabolism in the rumen, ultimately enhancing the digestibility of crude fibre and organic matter. Inadequate supply of these elements in the diet of the animal will therefore adversely affect the utilization of other nutrients in the diet ultimately affecting the performance of the animals.

For a long time, stockowners and pastoralists in Nigeria have left their sheep to fend for themselves by grazing on natural grasslands and fodders. The low nutritive value of these native grasses and fodders have been widely recognized (Oyenuga, 1958; Landsbury, 1960; Kapu, 1976). The result is that the animals are malnourished since feeding is often at or near subsistence level. Consequently, the development of these animals is slow and their general performance poor. Nutritionists working in research stations, government farms or the Universities where some form of supplementary feeding is practised have on

their part used the calcium and phosphorus requirement of temperate sheep in formulating their rations. This clearly is an abnormal practice in view of the numerous variables which affect the calcium and phosphorus needs of animals. Some of these variables include breed, species, function, climate, soil and chemical form in which the mineral is presented. On the other hand, information on the mineral composition of West African feedstuffs and forages is scanty. As Adegbola (1971) pointed out, the few analysis made indicate that calcium and phosphorus are deficient in some West African soils (Landsbury, 1960, Oyenuga, 1958) and this deficiency will invariably be reflected in the status of the feedstuffs with respect to these minerals. Phosphorus deficiency has been widely reported in tropical forages (Landsbury, 1960, Kapu 1976) and even in some improved legume species e.g. Stylosanthes humilis (cv. verano) (Humphreys, 1978). Williamson and Payne (1959) reported that in several tropical regions, pastures are so deficient in calcium that pathological bone conditions are induced in ruminants. A lot of other studies have shown low concentrations of calcium and phosphorus in pasture plants, especially those growing in the tropical and subtropical regions (Neal and Shealy, 1933). Writing on the nutritonal

values of tropical grasses and fodders, French (1957) noted the wide variation in calcium concentration, but concluded that the calcium content is never as dangerously low as that of phosphorus.

As a result of climatic influence, tropical forages are relatively low in crude fibre and crude protein. Adegbola (1971) pointed out that since the absorption of calcium and phosphorus from feed can be reduced by high fibre content, the condition of animals with respect to these nutrients may be further aggravated by the poor quality of the feed. Also in pasture plants, a strong positive correlation has been shown to exist between phosphorus content and protein content (Stillings et al., 1964) which tends to worsen the situation by reducing the phosphorus and calcium absorbed by the animals. The consequence of the deficient calcium and phosphorus content of herbages will be the inadequate supply of these nutritents to the animal. The contribution of these low levels of calcium and phosphorus to the general low productivity of the Nigerian sheep cannot be readily assessed but are obviously important since data has shown that reproductive performance in affected (Molokwu et al., 1979). Natural grazings, especially during the dry season are therefore inadequate in meeting the calcium and phosphorus needs of the ruminants grown in some parts of Nigeria.

It is therefore mandatory that supplementary feeding of calcium, phosphorus and some other nutrients is necessary for efficient production and increased productivity of the Nigerian sheep. The present studies were therefore conducted to determine the calcium and phosphorus requirement of growing Yankasa lambs in the Savannah region of Nigeria.

LITERATURE REVIEW

FACTORS INFLUENCING THE CALCIUM AND PHOSPHORUS REQUIREMENT OF SHEEP

1. Chemical Form of the Mineral:

Mineral supplements vary in the availability of any specific element they contain. Lorg et al. (1956) reported that while the phosphorus of soft phosphate is readily available to growing lambs, the phosphorus of colloidal clay is not as readily available. This variation in availability can significantly influence the net requirements of the particular animal.

2. The Species or Breed of the Animal:

Differences exist in the species and breed requirements of minerals. Majundar (1962) reported that the goat requires more calcium for maintenance than the sheep. MaCkenzie (1967) also stated that the mineral requirement of the goat is outstanding and that minerals that may be adequate for other stock is likely to be deficient for the goat. Similarly, sheep have a higher phosphorus requirement per unit of feed consumed than cattle (Undewood, 1966).

3. Functional Needs:

In view of the difference in the metabolic size of animals of the same species and age, slight differences are expected to

occur in their requirements of calcium and phosphorus for maintenance, Also production functions such as growth and milk production will vary among animals of the same species and age. The variation in production functions will be reflected in differences in their calcium and phosphorus needs.

4. Adaptation:

Sheep is capable of adapting to variations in dietary supply of calcium and phosphorus (Underwood, 1966). Apart from withdrawals from the skeleton, sheep can increase the efficiency of absorption from the intestinal tract or reduce the rate of excretion under conditions of inadequate supply (Young et al. 1966).

5. Climate:

Abdel Aal, (1968) working with Freisian cattle showed that phosphorus retention was lower in summer (35°C) than in winter (18°C). He attributed this to slight increase in urinary and faecal excretion of phosphorus in summer resulting from heat stress. Ragsdale et al. (1950); cited by Bailes and Forbes (1974) showed that feed intake of cattle decreased at high temperatures and increased in cold conditions.

Driver et al. (1974) reported an increase in serum prolactin in growing sheep when day-length was increased and this was associated with increased feed intake. These changes

in feed intake will obviously affect the calcium and phosphorus intake of the sheep.

6. Mineral Balance:

The requirement of farm animals for calcium and phosphorus are influenced by the proportion of the two i.e. the ratio in which they occur, the quantities of each present and the presence of vitamin D (Underwood, 1966; Irving, 1970).

Other mineral interactions exist as between calcium and zinc, phosphorus and magnesium (Suttle, 1968). Mineral inbalances can lead to mineral deficiencies or toxicities in the animal (Suttle, 1968).

7. Criteria of Adequacy Employed:

The requirement of farm animals for calcium and phosphorus will vary depending on the criteria of adequacy employed. For example, the calcium and phosphorus required for growth of an animal may be inadequate for maximum bone growth and maintenance of serum calcium and phosphorus levels (Mitchell, 1947).

8. Age and Rate of Growth:

Calcium and phosphorus requirements are higher in the early, rapid growth stage of an animal than in the later growth stages. This is because bone calcification which requires calcium and phosphorus takes place at a faster rate in growing animals than in mature animals. There is also the added

fact that metabolic rate in which phosphorus is particularly involved is faster in young animals than in older animals.

ABSORPTION OF CALCIUM AND PHOSPHORUS AND FACTORS AFFECTING IT

Although calcium is absorbed from all sites of the intestinal tract, studies of the rate of disappearance from the lumen showed the principal site of absorption to be the duodenum (Nicholaysen, 1951; Coates and Holdsworth, 1961). Schacter and Rosen (1959) and Schacter et al. (1960a) showed that the major mechanism of calcium transport across the intestinal mucosa into the blood was by active transport against concentration gradient. In 1961, Schacter et al., found that small doses vitamin D_2 or D_3 given to vitamin -D- depleted rats restored the absorptive mechanism along the whole length of the small intestine, but especially in the duodenum. They also found that Oxidative metabolism affected the active transport mechanism rather than simple diffusion. Wasserman and Kallfelz (1962) showed that vitamin D_3 affected active transport of calcium by influencing permeability changes in the mucosal cell. Wasserman and Taylor (1966) reported the discovery of a calcium binding protein (CABP) in the intestinal mucose of rachitic chicks given vitamin D_3 72 hours

before sacrifice, Kallfelz et al. (1967) using rachitic rats, detected a calcium binding protein (CABP) 72 hours after giving vitamin D_2 or D_3, the mucosa of vitamin -D deficient rats having much less. Subsequent work (Norman et al., 1970; Melanon and DeLuca, 1970; Tanaka and DeLuca, 1971; Avioli, 1972; Irving 1973 and Wasserman and Taylor, 1973) showed that the active metabolite of vitamin D_3, 1, 25-dihydroxycholecalciferol acts at the **transcriptional** level on the mucosal cell, thereby stimulating the production of a calcium-binding protein (CABP) which transport calcium across the cell, and may have actions on other target tissues.

The absorption of calcium and phosphorus is influenced by several physiological and nutritional factors. These include overall nutritional state, age and reproduction status of the animal (gestation, lactation), the absolute level of calcium and phosphorus intake, vitamin D intake, the ratio of calcium to phosphorus in the diet and certain diseases states for example steatorrhea, vitamin-D resistant rickets, malignancy of the parathyroids and the presence of dietary agents that can form insoluble complexes with calcium (Moore and Tyler, 1955).

The major dietary factors affecting calcium absoprtion are:

1. Fats

Fats have a depressing effect on calcium utilization by ruminants (Tillman and Brethcur, 1958a), presumably due to the formation of insoluble caclium soaps (Roberts and McKirdy, 1965). Under practical conditions, the adverse influence of fat on calcium absorption is only apparent when high levels of fat a(above 10% of diet) are ingested (Kaneko et al., 1970).

2. Bile

Bile acids have been implicated in calcium absorption. Lengemann and Dobbins (1958) reported that an increased bile flow enhanced calcium absorption. Webbling and Holdsworth (1965, 1966) reported that bile acids increased the solubility of calcium in lipid solvents thereby increasing calcium absorption.

3. Phytic Acid

The anticalcifying effect of cereals was first noted by McCance and Widdowson (1942a), and was ultimately traced to the presence of phytin or inositol hexaphosphoric acid. This substance constitutes 50-58% of the phosphate of cereal

(Irving, 1973) and is hydrolysed only to the extent of 37-61% in the alimentary tract of monogastrics. As phytin also forms insoluble calcium phytate with calcium, a proportion of the ingested calcium is rendered unavailable. Ruminants have been reported to use phytin satisfactorily (Martur, 1953, Tillman and Brethour,1958b) due to the production of phytase enzyme by the rumen microbes (Raun et al., 1956).

4. Protein

According to McCance et al. (1942), addition of protein to a basal ration increased calcium absoprtion and retention in animals. He postulated that the effect of protein intake upon calcium absoprtion was presumably due to soluble calcium compounds formed with the amino acids produced by the digestion of the protein . Better retention was presumed to be due to the creation of a favourable nitrogen balance which assists in the laying down of matrix necessary for deposition. Stillings et al. (1964) showed that calcium retention was greater in animals consuming high nitrogen forages as compared to those consuming low nitrogen forages, even though calcium intake was less. Wasserman et al. (1956, 1957a) reported that the amino acids, lysine and arginine promoted calcium absorption and retention.

5. Lectose

Fournier (1954) and Wasserman et al. (1956, 1957a) showed that lactose enhanced calcium absportion and that it had a stronger effect on calcium absorption than lysine but that the effect was additive if given with lysine.

6. Citrates

Addition of citrate to a rachitic diet has been observed to render it non-rachitic (Schacter et al., 1960a) and to aid calcification (Harrison and Harrison, 1960). It was suggested that citrates lower the p^H of the intestinal tract, form calcium citrate which is relatively soluble and aid deposition subsequent to absorption by raising the p^H of tissue fluids (Coates and Holdsworth, 1961).

7. Oxalates

Walthall and McKenzie (1976) reported that horses grazing some pasture species in South-Western Australia developed typical signs of Osteodystrophia fibrosa. Cenchrus ciliaris (buffel grass), Panicum maximum var. trichoglume (green panic), Brachiaria mutica (para grass) and Setaria anceps were the major grass species grazed. They found that while the calcium and phosphorus levels of the grasses were normal, all of them contained high levels of oxalates which were suspected of causing the disease. Ruminants grazing the same pastures as

the affected horses were not observed to show signs of disease attributable to oxalate ingestion. However, negative calcium balances have been reported in cattle fed plants containing more than 2% soluble oxalate on dry matter basis (Talapatra et al., 1948).

8. Calcium: Phosphorus Ratio

Dowe et al. (1957) reported that a great excess of either calcium or phosphorus interferes with the absorption of the other. He explained that this is due to the fact that at the p^H of the intestine, tricalcium phosphate is not readily soluble. With a large excess of either element, the other one tends to become tied up as the insoluble tricalcium phosphate. Studies with mature sheep have indicated that neither calcium nor phosphorus absorption is affected by increasing the ratio from 1 to 10 (Luecker and Lofgreen 1961; Young et al. 1966). The adverse effects of wide Ca:P ratios are aggravated when vitamin D is also deficient (Duckworth et al., 1943; Andrews and Cunningham, 1945; Dowe et al., 1957). Adverse Ca:P ratios also have effect on the growth and feed efficiency of many species. For non-ruminants, Chapman et al. (1962) showed that changes in the ratio of Ca:P greater than 2:1 may adversely affect phosphorus utilization. Wise et al. (1963) found that the Ca:P ratio of the diet of young ruminants had to be increased

to 8:1 before an adverse effect on performance was apparent. The work of Wise et al. (1963) further showed that ratios lower than 1:1 had more adverse effect on the animal than ratios higher than 8:1. Feeds rich in phosphorus and poor in calcium have been known to cause bone disease known as fibrous osteodystrophy in animals although the disease is not as important in sheep and goats as it is in pigs and horses. The isotopic data of Young et al. (1966) showed that wide ratios of Ca:P had little effect on phosphorus utilization but that an inadequate supply of phosphorus reduced calcium deposition in and removal from bone and decreased calcium absorption. They also reported that urinary calcium was higher in animals given inadequate phosphorus in the diet. Krook et al. (1971) studied the effects of life-long excessive dietary calcium in bulls (3.5 times optimal in young bulls, 4.8 times in middle aged bulls) by blood chemistry and morphologic observations. From their results they condluded that the following sequence of events occur:-

Excessive dietary calcium will lead to hypercalcitonism resulting from C-cell hyperplasia or neoplasia. There is consequently arrested bone resoprtion with hyphosphataemia and osteopetrosis. As calcitonin has nullified the action of

parathormone on bone, there is hypocalcaemia and consequent hyperparathyroidism.

9. Gastric HCL

Better absorption of calcium in the duodenum is due to the low p^H that prevails there (Webbling and Holdsworth, 1965). These acidic conditions are provided by the secretion of HCL by the gastric glands in the abomasum.

10. Magnesium

Magnesium has been shown to cause increased loss of calcium in adult animals and hinders its deposition in young animals. There seems little doubt that high levels of magnesium act antagonistically to calcium utilization. MacIntyre et al. (1961) demonstrated that increased intake of calcium produced higher faecal loss of magnesium. Alcock and MacIntyre (1960) showed that deficiency of calcium or magnesium produced increased absorption of the other.

11. Sodium and Potassium

Sodium and potassium ions can inhibit calcium transport at high calcium concentrations (more than 36 millimoles) under certain conditions (Harrison and Harrison, 1963). The depressing effect of sodium ions on the calcium pump may be due to competition of Na^+ and Ca^{++} for a common carrier (Harrison and Harrison, 1963b).

12. Age

Hansard et al. (1954) reported that net absorption of calcium in cattle decreased with age. They observed that absorption decreased from 99% in the young calf to 23% in cattle 12 years old, and absorption dropped from 95% at one month of age to 41% at 6 months of age. Bronner (1964) however stated that the actual amount of calcium absorbed remains about the same as the animal grows older, but with an increasing intake of feed (and Ca), the percentage of absorbed calcium declines.

13. Vitamin D

In spite of earlier controversy, it is now generally accepted that the intestinal calcium absorption coefficient is principally controlled by the circulating level of parathyroid hormone (Parsons and Potts, 1972). Although many details of the control mechanism remain to be worked out, the evidence now seems overwhelming that the sensitive regulation of calcium absorption in normal health depends on the parathyroid hormone modulating the hydroxylation of vitamin D (Parsons and Potts, 1972). It is now generally accepted that 1,25-Dihyroxcholecaciferol is the active form of vitamin D and plays the biological role of a hormone

(Norman and Henry, 1974). Increases in the circulating level of parathyroid hormone do increase the level of 1,25-Dihydroxycholecalciferol (Melanon and DeLuca, 1970) which interacts with a pre-existing carrier protein (Wasserman's calcium binding protein, CABP), which is then converted to another protein with apparently lower molecular weight (Parsons, 1976). The new protein has calcium binding activity and plays a central role in the subsequent energy requiring calcium uptake at the mucosal membrane, mediated by ATP-ase (Parsons, 1976).

Phosphorus is absorbed from the distal duodenum (Smith et al., 1955). Its absorption is enhanced in acid media and in the presence of low concentrations of berrylium, calcium, strontium and magnesium (Smith et al., 1955). The intestinal absorption of phosphate is passive in contrast to that of calcium (Moore and Tyler, 1955). This anion is transported across the intestinal mucosa secondarily to the active transport of calcium (Moore and Tyler, 1955). The efficiency of absorption depends upon several dietary factors including the form in which it is ingested, the p^H of the intestinal fluids, the Ca:P ratio and the amount of vitamin D present (Hansard and Barth, 1962). Hansard and Barth (1962) also showed that the true digestibilityof phosphorus was not

affected by source or levels of calcium, although data indicated that calcium absoprtion augmented metabolic excretion of phosphate. Compere et al. (1965) have reported similar data, indicating that the Ca:P ratio did not affect urinary excretion of phosphate nor its true digestibility, but increased faecal excretion. Manston (1967) found that absorption of phosphorus and calcium were optimum when cows received a Ca:P ratio of 2:1. Westerlund (1957) reported that reduction of phosphorus in the feed led to an increased faecal excretion of calcium. Different supplemental levels of magnesium had no effect on serum phosphorus (Dutton and Fontenot, 1967).

Thompson, et al. (1959) showed that added zinc sulphate interfered with phosphate absorption from the gastrointestinal tract of lambs. They concluded that since zinc did not change metabolic faecal phosphorus, that there was a reduction in phosphate absorption. Increased water intake may be expected to increase urinary phosphate excretion (Suttle and Field, 1966) and high nitrogen forages have been indicated as causing an improved retention of phosphorus and higher serum levels (Stillings et al., 1964) as compared to low nitrogen forages. A reduction in the amount of dietary protein may result in increased urinary phosphorus and reduced phosphorus retention

in calves (Mudgall and Kay, 1967). Ewer (1951a) reported that a single massive dose of vitamin D would temporarily improve the phosphorus retention of sheep maintained on a low-phosphorus diet.

HOMEOSTATIC CONTROL OF BLOOD CALCIUM AND PHOSPHORUS

McLean and Hastings (1935) described the level of calcium in body fluids as one of the critical "physiological constants" and indeed calcium is one of the most precisely regulated constituents of plasma. The normal concentration of calcium in normal adult sheep averages 10mg/100ml while the range is usually stated to be 9-12mg/100ml (Chohl, 1939; Robertson, 1941). In a recent study, using apparently normal West African dwarf sheep, Oduye and Adelevoh (1976) found that the average serum calcium level was 9.59mg% while the range was 7.1 - 13.3mg%. The principal factors involved in calcium homeostasis are the bone, the parathyroid hormone (PTH) and calcitonin (Copp et al., 1969). Aubert and Bronner (1965) noted that the regulation of plasma calcium appeared to depend primarily on "bone catabolism" which is also the process primarily affected by PTH and calcitonin. PTH is involved in raising the level of plasma calcium under conditions of hypocalcaemia while calcitonin is involved in lowering it (Copp et al., 1969). According to

Blum et al. (1974), PTH acts to restore normocalcaemia by three separate mechanisms mediated through

(a) the kidney (b) the intestine and (c) the skeleton.

(a) The action of the PTH on the kidney results in distal reabsorption of calcium and the rejection of phosphate at the proximal tubule resulting in a substantial phosphaturia (Agus, 1971; Parsons, 1976).

(b) PTH regulates the absorption of calcium in normal health by modulating the hydroxylation of vitamin D (Parsons and Potts, 1972). According to Arnaud and Tenenhouse (1970) PTH controls the conversion of 25-hydroxycholecalciferol (25-HCC) to 1,25-dihydroxycholecalciferol by the kidney. They stated that under conditions of low plasma calcium, the PTH stimulates the kidney to release an enzyme hydroxylase which releases 1,25-dihydroxcholecalciferol from 25-hydroxycholecalciferol. The 1,25-DH CC then reacts with a pre-existing protein. The protein is then converted to another protein which has calcium binding activity and which takes a central role in the subsequent energy requiring calcium uptake at the mucosal membrane. The studies of Copp et al. (1962)

demonstrated the existence of a plasma calcium lowering

demonstrated the existence of a plasma calcium lowering
hormone called calcitonin. Their study showed that as the plasma calcium level rises above normal, the level of calcintonin rises. The major site of action of calcitonin is bone where it inhibits bone resorption thereby eliciting a rapid hypocalcaemic-hypophosphataemic response in post natal animals (Aliapoulois et al., 1966). Calcitonin operates by inhibiting PTH mediated osteocytic osteolysis (Simmons, 1976). If the blood calcium is abnormally low, calcitonin has no effect (Bell and Stern, 1970). The action of calcitonin is greatly reduced in older animals (Talmage, 1973).

The primary action of PTH on bone is to resorb calcium from bone (Raisz, 1970; Rasmussen, 1971) in order to prevent the serum calcium level from falling under conditions of low dietary calcium (Nordin et al., 1972). The mechanisms that underline the more obvious actions of PTH on target organs are complex. They include not only the stimulation of osteoclastic activity in bone but also the conversion of osteoblasts to osteoclasts (Parfitt, 1976; Parsons, 1976). The rapid increase in ionized plasma calcium which follows PTH administration is accompanied and paralleled by an increase in resorptive activity of osteocytes and this accounts for the increase in rapidly

exchangeable bone calcium which is a documented consequence of hyperparathyroidism (Blum et al., 1974). The mechanism of osteocytic osteolysis seems to involve activation of membrance bound adenylate cyclase (Nordin et al.1972). Parsons (1976) also reported that PTH stimulated the formation of 3^1 5^1 - Adenosine monophosphate in bone cells and that this is also involved in the osteocytic response. The work of Raisz et al., 1972) showed that vitamin D is involved synergistically in the PTH - mediated skeletal osteolysis.

The maintenance of plasma phosphate level is less closely controlled tham that of calcium. The normal range of plasma inorganic phosphate is 4.5 - 6.5mg/100ml (Smith et al., 1960) and in the West African sheep, Oduye and Adadevoh (1976) found the values to range between 3.9 - 12.8mg% with a mean of 5.68mg%.

Bijvoet and Van der Sluys Veer (1968) consider that plasma phosphate homeostasis is regulated through the kidney. Irving (1964) indicated that for monogastrics, the major mechanism of controlling blood phosphate is through control of excretion by PTH. Mayer and Abdel Bari (1966) reported that bovine parathyroid extract, when administered to dry cows, resulted in a marked increase in urinary excretion of phosphorus. Parathyroidectomy resulted in abrupt hypophosphaturia (Towns et al., 1978). According to Towns et al., (1978), salivary

secretion usually contributes more phosphorus to the gastrointestinal tract than the diet (Tomas and Somers, 1974). Towns et al., (1978) showed that renal excretion of phosphorus plays a minor role in phosphorus homeostasis except when salivary secretion of phosphorus is reduced. Tomas (1974a) demonstrated a reciprocal relationship between renal and salivary secretion of phosphorus. Albright and Reifenstein (1948) established an inverse relationship between plasma calcium and phosphorus which is more apparent at high concentrations (Neuman and Neuman, 1958; Stanbury and Lumb, 1966).

EFFECTS OF CALCIUM AND/OR PHOSPHORUS DEFICIENCY ON GROWING LAMBS

According to Underwood (1966), calcium deficiency when uncomplicated by lack of vitamin D is rare in grazing sheep except in acid, sandy or peaty soils in humid areas where quick-growing grasses abound and leguminous species are lacking. A survey carried out by Ema (1978) on cattle and sheep slaughtered in Zaria showed that their bones were submaximally calcified and many live animals suffered from spontaneous fractures of the leg. He surmised that calcium and phosphorus deficiency was involved in the sub-maximal calcification and spontaneous fractures as well as contributing to the slow growth and general poor performance of Nigerian sheep.

Franklin et al. (1948) fed a basal ration of cereal grains and chaff to weaned lambs and after prolonged periods of feeding caused 38% fall in the level of plasma calcium. McRoberts et al. (1965) found that a diet low in calcium caused a moderately large depression in serum calcium when fed to growing lambs. They observed that the lambs exhibited a rapid decline in serum calcium from the normal 9 to 12mg per 100ml to below 8mg and subsequently 4 to 5mg/100ml. The work of McRoberts et al. (1965) showed that the low calcium intake also resulted in reduced bone ash but did not produce clinical defects of the skeleton. Clinical manifestations of calcium and phosphorus deficiency on the skeleton are only evident when the deficiency is prolonged (Benzie et al., 1957; McRoberts et al., 1965). The skeleton serves as a reservoir of these two elements and under conditions of insufficient dietary intake, the elements are withdrawn from the bones to meet the physiological demands. Underwood (1966) stated that where the animals are exposed for long periods to unsupplemented phosphorus-deficient grazing or calcium deficient feed, the mobilization of skeletal calcium and phosphorus become excessive and structural deformities of the bones result. In the young growing animal, rickets - bone

disorder in which calcium salts fail to be deposited in the newly formed bone matrix result (Theiler and Green, 1932; Franklin et al., 1948; Colovos et al., 1951; Benzie et al., 1959 and McRoberts et al., 1965). In adult animals, the condition is marked by excessive mobilization of calcium and phophorus from the skeleton, resulting in osteomlacia, (Franklin et al., 1948). In both rickets and osteomalacia, there is a reduction in the total mineral content of the bones with little alteration in the proportions of calcium and phosphorus in the remaining ash (Stewart, 1935).

Underwood (1966) stated that the earliest and most sensitive index of phosphorus deficiency andthe most satisfactory single diagnostic criterion in all livestock is a decline in the level of serum inorganic phosphate. In most normal farm animals, the inorganic phosphorus content of serum lies between 4.5 - 6.5mg/100ml (Smith et al., 1960). Oduye and Adavevoh showed that in the West African dwarf sheep, the level of inorganic phosphorus in the serum was between 3.9 - 12.8mg/100ml. Undewood (1966) suggested that values consistently below 4.5mg/100ml in sheep, goat and cattle are highly suggestive of phosphorus deficiency. Wise et al., (1958) reported that increased alkaline phosphatase activity accompanied decreased serum inorganic phosphate levels

in 3 to 6-month old calves fed different levels of dietary phosphorus. This rise in serum alkaline phosphatase activity is used as an additional criterion for phosphorus deficiency (Neuman and Neuman 1958). However, Duckworth et al. (1943) and Ewer (1951a) rejected the alkaline phosphatase activity values for diagnosis of phosphorus deficiency in sheep as being of little value.

Poor growth, loss of appetite and thrift (Becker et al., 1933), subnormal growth and abnormal appetite (Theiler and Green, 1932) and the craving for and consumption of abnormal materials such as soil, wood, flesh and bones are all symptoms of phosphorus deficiency (Theiler and Green, 1932, Benzie et al., (1959). In young growing animals, teeth and bones will be less dense and less completed mineralized (Benzie et al., 1959). Gains will be reduced and fertility is apt to be reduced in females (Morrow, 1969). Underwood (1966) surmised that while reduction in feed efficiency resulted from disturbance in energy metabolism consequent upon the subnormal phosphorus content of the body, poor growth is caused mainly by depression in the appetite of the animals.

SOURCES AND AVAILABILITY OF CALCIUM AND PHOSPHORUS AND FACTORS AFFECTING THEIR AVAILABILITIES

Farm animals derive their calcium and phosphorus from two main sources - the feed that they consume and the inorganic compoents of geological or industrial origin which are used as supplements to these feeds. The feed of farm animals as sources of calcium and phosphorus is influenced by many factors. These include the genus, species, or strain of plant, the nature of the soil upon which the plant grows, the climatic conditions under which the plant grows and the stage of maturity of the plant (Underwood, 1965). The most consistent and the best known differences in the mineral content of plants are those which exist between legumes and grasses. Under similar environmental conditions and at all growth stages, legumes are commonly three to five times richer in calcium than grasses (Underwood, 1966). Within the grass and legume families, significant interspecies differences in calcium and phosphorus content also occur. The mineral composition of all plants reflects in varying degrees the nature of the soil upon which they grow. Deficiencies of calcium and phosphorus in soils will be reflected in the plants through limiting their growth, reducing the content of the deficient elements in their

tissues or by both (Lansbury, 1965). Soil mineral deficiences may be intrinsic or due to unavailability of the mineral in the soil to the plant.

Climate influences the content in plants of various nutrients including calcium and phosphorus. The onset of the dry season, for example, leads to the increased lignification of most herbage and the stoppage of the production of new, green and leafy shoot. This onset of maturity is followed by the increase in the concentration of calcium in the plant vegetative parts and a decline in the phosphorus content of the same parts (Underwood, 1966). It is also possible that as the plants mature there may be corresponding changes in the availability to animals of calcium and phosphorus. The above factors therefore will greatly influence the adequacy or otherwise of a natural feed to meet the calcium and phosphorus needs of an animal.

Wherever possible, the calcium and phosphorus requirement of ruminants should be met by the proper selection or combination of available feeds alone. Frequently, however, combinations of natural, available feeds are inadequate for the purpose, especially with modern, high producing animals. At other times, the calcium and phosphorus may be in forms

in natural feeds which are not readily available to the animal. In these circumstances, mineral supplements become essential and some times obligatory. According to Underwood (1966), the choice of a mineral supplement is determined by its cost per unit of the element or elements required, the chemical and physical form in which the element is combined, the fineness of division and its freedom from harmful impurities. To this list, of course must be added the availability of the element. A large number of inorganic salts are now available as calcium and phosphorus supplements for livestock feeding. As the list of calcium and phosphorus supplements is expanding, the present effort will be limited to the most widely used sources. The main calcium supplements for livestock feeding are limestone, calcium carbonate, oyster shell and egg shells. Mixed calcium and phosphorus supplements are bone meals of various brands, dicalcium phosphate, tricalcium phosphate, rock phosphate and monocalcium phosphate. Sole phosphorus supplements are phosphoric acid, monosodium phosphate, disodium phosphate, urea phosphate, mono-ammonium phosphate and magnesium phosphate. The approximate composition of the various calcium and phosphorus supplements are shown in Table 1 .

TABLE 1: The Approximate Composition of the Various Calcium and Phosphorus Supplements

Supplements	% Ca	% P
Steamed bone meal	31.3	14.4
Roasted bone meal	35.5	17.9
Dicalcium phosphate	23.5	18.7
Tricalcium phosphate	38.7	20.0
Superphosphate	23.24	10.0
Rock phosphate	37.38	16.2
Deflourinated rock phosphate	33.8	18.0
Urea phosphate	-	18.5
Monoammonium phosphate	-	23.5
Magnesium phosphate	-	18.5
Limestone	38.5	-
Calcium carbonate	40.0	-
Oyster shell	38.05	0.07
Monosodium phosphate	0.53	30.5

Adapted from: Mineral Nutrition of Livestock by Underwood, E.J. (1966), FAO Rome.

The usefulness of feeds or mineral supplements as sources of calcium and phosphorus to animals depends not only on their content of the minerals but also on the availability of the minerals to the animals concerned. Various procedures have been used for the determination of the availability or calcium and phosphorus for various species. The methods include whole body analysis (Drake et al., 1949; Sur and Subrahmanyan, 1952) and balance trials Mitchell and Curzon, 1939 and Forbes et al., 1929). Bone breaking strength, body retention, milk production, growth data and blood values have been used as supporting criteria for determining the calcium and phosphorus status of an animal in relation to dietary treatment (Moxon et al., 1947). Advances in radioisotope procedures have permitted the quantitative differentiation between exogenous and endogenous calcium and phosphorus of the faeces. This has made feasible the subsequent and independent measurement of the true absorption of dietary calcium and phosphorus (Hansard et al., 1954).

Relatively fewer studies have been done to determine the availability of various calcium sources for animals than for phosphorus. The main study on the availability of various

calcium sources was carried out by Hansard et al. (1954). The study showed that calcium from inorganic sources was utilized more efficiently by cattle than calcium from some hays. Availability values for calcium phosphate, bone meal and dicalcium phosphate were similar and rated highest followed by ground limestone, deflouinated calcium phosphate and calcium carbonate which were all of intermediate availability between bone meal and the hay sources. They demonstrated a clear relationship between the age of the animal and the availability of dietary calcium. The age of the animal was found to have more influence on availability than the calcium source - younger animals having consistently higher availabilities than older animals. From further studies on calcium availability for sheep by Lueker and Lofgreen (1961); Tillman and Brethour (1958c) and Thompson et al. (1959), the ARC (1965) suggested that for sheep less than 6 months of age, the availability of dietary calcium should be taken to be 55% and in mature animals to be 45%. Deflourinated rock phophate was shown to be fully equivalent to dicalcium phosphate (Ammerman et al., 1957) for cattle, but not for sheep (Wise, et al., 1961. Curacao Island phosphate has been reported to be fully equivalent to dicalcium phosphate for both cattle and sheep (Ammerman, 1957) and for cattle (Wise et al., 1961). Phosphoric acid has been shown to be as fully

equivalent for cattle as dicalcium phosphate (Tillman and Brethour, 1958a) and as steamed bone flour (Richardson et al., 1961) Monosodium phosphate and sodium acid pyrophosphate have been shown to be equally effective phosphorus sources for cattle and much superior to sodium meta-phosphate (Tillman and Brethour 1958a). Ammerman et al., (1957) reported that calcium meta-phosphate was inferior and calcium pyro-phosphate as much poorer source of phosphorus than dicalcium phosphate for sheep. Diammonium phosphate was shown by Oltjen et al. (1963) to be as useful a source of phosphorus as monosodium phosphate for lambs but not as palatable. Urea phosphate has been shown to be an effective phosphorus source for cattle and sheep (Perez et al., 1967).
Bone meal was shown to be as good a source of phosphorus as dicalcium phosphate for sheep by Lofgreen (1960) and Ammerman et al. (1957). Lofgreen (1960) also indicated that calcium phytate was somewhat inferior to dicalcium phosphate for sheep but Tillman and Brethour (1958c) considered it to be fully equivalent to monocalcium phosphate. Soft phosphate and colloidal clay has been consistently shown to be much inferior sources of phosphorus compared with dicalcium phosphate (Long et al., 1956; Ammerman et al., 1957; Lofgreen, 1960; Wise et al., 1961). From this heterogenous collection, the

ARC (1965) suggested the following rates of availabilities, assuming a decline with age as in cattle:-

Lambs to 1 year of age 85 - 90%

Sheep 1-2 years 80%

Adult sheep over 2 years 60%.

PREVIOUS STUDIES ON THE CALCIUM AND PHOSPHORUS REQUIREMENT OF GROWING LAMBS

There is virtually no information on the calcium and phosphorus requirement of growing indigenous lambs in Nigeria. Figures which have been used were based on temperate sheep and cattle. Nutritionists and stockmen working in the tropics have continued to use these temperate standards for tropical stock. While there may be apparent harm in using these figures, it did not mean that the figures are adequate for tropical stock which are exposed to lower quality feed than their temperate counterparts and may therefore require more of such feed to meet their needs. The environmental stress conditions imposed on the tropical sheep may also superimpose additional requirements on the mineral needs of such animals. Besides the differential requirements of the temperate and tropical animals for minerals resulting from breed, species, feed sources and climatic variations, an additional variation is introduced by animal function or type. The temperate breeds of sheep

are mainly wool producing and fast growing types while the Nigerian breeds are hair-producing and slow growing types. Clearly their requirements will be different. As most of the studies on the calcium and phosphorus requirement of lambs have been done in the temperate regions of the world, the present review is used as reference point in estimating the calcium and phosphorus needs of growing Nigerian sheep.

Fraser (1934) reported that growing lambs ranging from 24 - 48kg live weight and gaining at 110g per day required a daily calcium intake of 5.8g for normal growth and development. They indicated that daily intakes of 1.5g or less were associated with calcium deficiency symptoms. Sherman (1935) recommended that the dietary calcium requirement of a growing lamb was about 1% of its protein requirement for maintenance. When converted to dietary concentration, this ranged from 0.15%-0.20%. Subsequent work (Mitchell, 1947; Hodge, 1973) has shown that this range is associated with inadequate bone mineralization. Jones and Stengel (1938) also working with growing lambs of about the same weight range as used by Fraser (1934), showed that while 2g dietary calcium per day was inadequate, 6g was fully adequate. The findings of Fraser (1934) and Jones and Stengel (1938) were based mainly on growth performance and

the manifestation of deficiency symptoms. Mitechell and McClure (1937) estimated the calcium requirement of growing lambs based on endogenous losses, body storages and availability of dietary calcium to be 1.0g per day i.e. a dietary concentration of 0.17%. For sheep weighing between 20 and 40kg liveweight, the value recommended was 1.5g per day or 0.25% of diet. At a later date, Mitchell (1947) updated his earlier recommendation and estimated that the calcium requirement of lamb of 10kg liveweight was about 0.24% based on dietary concentration. He considered that this concentration was inadequate for the very young animal but assumed that the deficiency could only be expressed as submaximal calcification of the bones which would be corrected by later excesses as maturity approached. Benzie et al. (1960) reported that although young whethers grew satisifactorily on a diet that provided 0.40g calcium daily, bone development was inadequate. Mitchell (1964) used the factorial method to arrive at the net calcium requirement of growing Shropshire lambs. He estimated that the net calcium requirement for maintenance was 1% of the net protein requirement. His estimates of body storages were based on the daily increments in calcium to the bodies of growing Shropshire lambs computed

from the weight changes in carcass composition. Assuming an availability figure of 50%, he recommended that the calcium needs of growing lambs ranged from 0.21% for a 9kg ewe lambs to 0.1l% for a 59kg ewe. For growing rams within the same weight range, he recommended the values of 0.2l% to 0.13%. The ARC (1965) based their recommendations of the calcium requirement of growing lambs on rate of gain, endogenous loss of calcium, body storages and the availability of dietary calcium. For lambs growing at the rate of 50g per day, it recommended 110mg/kg/day; for lambs gaining at 100g per day it recommended 130mg/kg/day; for lambs gaining at 200g per day, it recommended 170mg/day. The Agricultural Development and Advisory Services (A.D.A.S., 1971) up-dated the ARC (1965) recommendations, and estimated that for lambs weighing between 13-28kg gaining at 113-227g per day, the calcium requirement was between 1.9 to 5.3g per day or 0.25% to 0.51% of dietary concentration. McDonald et al. (1973), based on factorial estimates, recommended that the minimum calcium requirement of growing lambs of about 20-60kg liveweight was between 3.20 and 7.28g/day. Hodge (1973) working withthe pre-ruminant lamb between 5.70 days of age reported that dietary calcium levels between 0.20% to 0.30% were associated with depressed growth rates, depressed serum calcium levels and death of the

animal. They recommended that until more evidence was available on the effects of various dietary concentrates of calcium between 0.3% to 0.8%, the higher level should be taken as the minimum concentration which could safely be given to young growing lambs up to 18kg liveweight. Their recommendation of 250mg/kg liveweight per day implied that an 18kg lamb would require 4.5g of calcium per day in the diet. The NRC (1957) recommended that growing lambs weighing between 30-40kg would require a daily calcium intake of 5.9-6.3g based on 100% dry matter.

As with calcium, there is little information on the phosphorus requirement of Nigerian sheep. Temperate standards or projections from there have been widely used in formulating rations for Nigerian sheep. The fact that this situation is not normal has been recognised and emphasized.

The early students of Martin and Peorce (1934) showed that growing Merino lambs made poor growth and showed signs of phosphorus deficiency when fed a diet supplying only 0.6gP daily. They found that raising the dietary concentration of phosphorus to 0.27% or 1.6g per day was adequate for the lambs without their showing symptoms of aphosphorosis. Stewart (1935) found that dietary phosphorus levels of 0.16% to 0.25%

or 1 to 1.5g per day given to lambs 8 to 10 months of age was associated with the development of phosphorus deficiency symptoms. According to Beeson et al. (1937) growing lambs weighing between 30-45kg and gaining at 120g per day required daily phosphorus intakes of 2.8g for normal growth. They found that daily intakes of 1.8g and less were inadequate. Morris and Ray (1939) working with 14 month old sheep gaining at 80g per day reported that while a daily intake of 4.6gP supported good growth, 0.5g per day resulted in reduced growth and development of symptoms of phosphorus deficiency. Based on growth, efficiency of feed utilization and serum inorganic phosphorus levels, Beeson and Hickman (1944) recommended that daily phosphorus intakes of 3.4 was optimal in supporting the above parameters and they recommended it as the minimum phosphorus requirement for growing lambs. Reinarch and Louw (1958) reported that while 1.5gP per day was adequate for the normal growth of young lambs weighing 22-32kg and gaining at 40g, 0.5g per day was associated with signs of phosphorus deficiency. According to Weir et al. (1958) dietary phosphorus levels below 3.5g per day was found to be inadequate for lambs weighing between 30-45kg and gaining

at 180g per day. Mitchell (1964) recommended that the net phosphorus requirement of growing ewes weighing between 9-15kg was 0.14%-0.13% while growing rams within the same weight range was put at 0.16% to 0.13%. He arrived at this factorial estimate of the net requiement by assuming that the net phosphorus requirement of growing lambs for maintenance was 2% of their net protein requirement for maintenance. He estimated the requirement for growth from the daily increments in phosphorus to the carcass of growing Shropshire lambs computed from the weight changes in body composition. He assumed an availability figure of 50%. Preston and Pfander (1964) studied the phosphorus requirement of growing lambs from data based on growth, digestibility, plasma phosphorus levels and bone development. He developed an equation for arriving at the phosphorus requirement of growing lambs, viz:-

$P = 0.019W (1+0.0171G)$ where

P = daily phosphorus requirement in g

W = body weight of animal in kg

G = daily gain in g.

The ARC (1965) recommended that the phosphorus requirement of lambs about 80mg/kg body weight for lambs growing at 100g per day and 100mg/kg body weight for lambs growing at

200g per day. The ARC (1965) arrived at the values for different rates of gain based on endogenous losses, body storages and availability of dietary phosphorus. The ARC (1965) admitted that its recommendations were subject to large errors because the data were computed for a wide range of conditions and from various sources. The Agricultural Development and Advisory Services (A.D.A.S., 1971) recommended that lambs weighing between 13-28kg and gaining at 113-340g/day, their daily phosphorus requirement ranged from 1.1g to 2.9g. The A.D.A.S. (1971) suggested that in view of the paucity of information on the phosphorus requirement of growing lambs, their own recommendations which were derived from that of the ARC (1965) were tentative. According to McDonald et al. (1973), the minimum phosphorus requirement of growing lambs weighing between 20-60kg and gaining at the rate of 100g per day ranged from 1.6g-5.24g per day. Their recommendations were based on factorial estimates for maintenance and growth. The NRC (1975) estimated that the phosphorus requirement of replacement lambs and yearlings ranged from 3.3g to 3.5g per day. Its estimates were based on 100% dry matter but was silent on the criteria of adequacy used.

The present review has highlighted the wide variation that exist in the calcium and phosphorus requirements for temperate sheep. As Hodge (1973) ponted out, the discrepancies in the various estimates may be due to different estimates of endogenous calcium, body storages and availability of dietary calcium that were adopted. However, while most of the early estimates were based on incomplete criteria of adequacy, other more recent estimates were based on limited data or heterogenous data collected over wide areas and yet some assumptions used in arriving at the recommendations were not based on experimental findings. The present study is aimed at overcoming most of these deficiencies in arriging at the calcium and phosphorus requirement of growing lambs in the Savanna region of Nigeria.

EXPERIMENTAL PROCEDURE

MATERIALS AND METHODS

Experiment 1A

1. Experimental animals

Thirty-two Yankasa lambs of mixed sexes were used in this study to determine the calcium requirement of growing lambs. The lambs, aged between 6-8 months were bought locally from markets around Zaria, quarantined and conditioned for about a month during which time they were dewormed twice with Thibenzole (Merck, Sharp and Dohme). The animals were subsequently randomly assigned to four diet groups and balanced for sex and weight. The diet consisted of four different levels of calcium, viz: 0.28%, 0.42%, 0.56%, and 0.70% respectively. Phosphorus was kept constant at the level in the basal ration (0.31%).

At the end of the growth study, a balance trial was conducted. Twelve young ram lambs aged between 6-9 months were purchased from local markets around Zaria, quarantined and dewormed as in growth study and randomly assigned to the same diets used in the growth study. The animals were fed the experimental diet for a preliminary period of 21 days. On the 17th day, each animal was fitted with a faecal collection harness and placed on a metabolism cage for an adjustment period of four days. The three-week

preliminary period was immediately followed by a 7-day total faecal and urine collection period. Urine was collected in plastic buckets containing 100ml of 50% HCL. This balance trial was replicated three times.

Experiment 1B

In the second experiment, twenty Yankasa lambs of mixed sexes were used. The lambs aged between 6-8 months were obtained from the University Farm where they were managed semi-intensively. The animals were dewormed as in the first study and randomly assigned to four different levels of dietary calcium rations:- 0.70%, 0.86%, 0.99% and 1.15% respectively. Phosphorus was kept constant at the level in the basal ration (0.31%) as in the first study. At the end of the second study, a balance trial was conducted. Twelve ram lambs aged between 6-8 months and weighing between 10-16 kg were used. They were purchased from markets around Zaria, quarantined for about a month during which time they were dewormed with Thibenzole. At the end of the quarantine period, the animals were randomized and allocated to the four dietary calcium levels used in the second growth study. The feeding, management, faecal and urine collection was as described in the first study. The balance trial was also replicated three times.

TABLE 2

COMPOSITION (%) OF SUPPLEMENTS FED IN EXPERIMENT 1

ITEM	RATION NO. 1	2	3	4	5	6	7
Calcium in diet (%)	0.28	0.42	0.56	0.70	0.86	0.99	1.15
Phosphorus in diet (%)	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Salt	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Vitamin-tracemineral premix[a]	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125
Maize	72.54	71.73	70.99	70.23	68.97	70.84	70.36
Groundnut cake	26.71	26.97	27.13	27.30	27.48	25.50	25.33
Calcium carbonate	-	0.55	1.13	1.72	2.30	2.90	3.55
ANALYZED CHEMICAL COMPOSITION OF THE RATIONS							
Crude Protein (%)	21.4	21.3	20.5	20.5	19.70	20.1	20.5
Calcium)(%)	0.34	0.41	0.56	0.67	0.83	0.94	1.07
Phosphorus (%)	0.38	0.35	0.33	0.39	0.31	0.30	0.29
Ca : Pratio	1:1;	1:1:	1.7:1;	2.3:1:	2.7:1;	3:1;	3.7:1
Energy Content of ration DE (Mcal/kg. DM)	3.20	3.20	3.20	3.20	3.20	3.20	3.20

a: Composition of premix per 1000g:- Vitamin A, 7,500,000 I.U.; Vitamin D_3, 1,500,000 I.U.; Vitamin B_1, 1000mg; Vitamin B_{12}, 5mg; D-Calcium pantothenate 5000mg; Vitamin E, 2500mg; Vitamin K, 1500mg; Niacin, 12,500mg; Choline chloride, 60,000mg; Ethoxyquin, 5000mg; Mangenese oxide, 16,130mg; potassium iodide, 353mg cobalt sulphate, 286mg; Zinc oxide, 12500mg; Copper oxide, 1283mg; Ferrocarbonate, 20323mg, Milocarn ad. 1000g.

2. Housing

All lambs were individually penned and fed in containers on laterite floored and roofed barn.

3. Diet

The composition of the test rations are shown in Table 2. Forty per cent of the ration was provided by native hay (Andropogon and Hyperrhenia spp. predominating, 5% C.P.), while the remaining 60% was made up of supplements (Table 2). The rations were formulated to be isocaloric and isonitrogenous. Phosphorus was kept constant at the level in the basal ration (0.31%). Vitamin D was provided to supply at least 5.6 I.U. per kg live weight per day (NRC, 1975). The calcium content of the basal ration (0.28%) was varied by the addition of calcium carbonate so as to achieve the dietary levels of the mineral for the eight experimental treatment groups. The supplements containing the various calcium levels were mixed weekly and stored in labelled jute bags. The composition of the rations used in the balance trials were the same as in the feeding studies (Table 2).

4. Feeding

The hay and supplements were weighed out separately and fed together at 0800 hours daily. Feed refusals were weighed back at intervals of 2 days and the actual amount consumed was determined by difference. Feed was offered to

the lambs ad libitum and was adjusted every other day in an attempt to maintain the adopted ratio of hay to concentrate. In the balance trials, all the animals were given equal and fixed amounts of the ration through the preliminary and collection periods. The actual amount of ration consumed was determined by difference as in the growth study.

5. Weighing of Animals

In both studies, the lambs were weighed at the beginning of the experiment and thereafter at two-weekly intervals. All weights were taken after fasting the animals for about 14 hours.

Clinical observations

The lambs were observed weekly for clinical signs. Examination included the inspection of animals in standing position and in motion. Signs of respiratory distress, gastrointestinal symptoms, stiff-joints and lameness were looked for.

Sampling and preparation of samples

1. Blood

Blood samples were taken from the jugular vein of each lamb a day before the treatments were imposed and thereafter at two-weekly intervals. The samples were allowed to clot, centrifuged and the serum decanted and used

in the determination of calcium, magnesium and phosphorus.

2. Faeces and urine

The daily faecal output from each animal in the balance trial was collected, weighed and stored in labelled polythene bags at -15°C. At the end of each collection period, the total faecal collection from each animal was bulked, thoroughly mixed and then subsampled for analysis. Duplicate samples of the faeces from each animal were weighed, dried in a forced-draught oven at 100°C and ground to pass through a 0.51 mm sieve. Daily urine output from each animal was bulked, thoroughly mixed and subsampled for analysis.

3. Feed samples and refusales

Hay and samples of supplement from each treatment group as well as the feed refusals were subjected to the same preparatory treatment as the faeces.

4. Bones

The left humerus of each slaughtered lamb was removed. cleaned of soft tissues and dried in an oven at 100°C for 24 hours. Fat was extracted (A.O.A.C., 1970) from each bone in a Soxhlet apparatus using Petroleum Spirit BP. 60°-80°C and dried in a muffle furnace overnight. The ash

was ground in a mortar and duplicate samples from each bone were digested with a mixture (5:1) of nitric acid and per chloric acid, until the solution became colourless. Duplicate samples of hay, supplements, faeces and urine were similarly digested.

Biochemical analysis

1. Nitrogen determination

The total nitrogen in the hay sample and supplement for each treatment group was determined by standard procedures and the crude protein content of each ration calculated.

2. Calcium magnesium phosphorus

The calcium and magensium content of the blood, bones, faeces, urine, feed samples and refusals were determined using the atomic absorption spectrophometer (Willis, 1960, 1961) with strontium chloride as the diluent. Phosphorus in bone, faeces, urine, feed samples and refusals and inorganic phosphorus in serum were determined by the molybdovanadate method of Fiske and Subbarow (1925) after trichloroacetic acid precipitation of blood proteins.

Physico-chemical examination of bones

1. Gravimetry data

The right humerus removed at slaughter was cleaned of soft tissues, weighed in air and in water at $4^{\circ}C$ for

determination of specific gravity and volume.

2. Macroradiography

The bones used for specific gravity determination were radiographed at the Radiology Unit of the A.B.U. Teaching Hospital, Zaria. The cortical indices of the bones at the narrowest part of the diaphysis (sum of the width of the two cortices divided by the total diameter, Chineme et al., 1976) were determined from the radiographs.

Statistical analysis

The data obtained from the growth studies and balance trials were combined and subjected to the analysis of variance and treatment means were compared using Duncan's New Multiple Range Test as outlined by Steel and Torrie (1960).

EXPERIMENT II

1. Experimental animals

Fifty-four Yankasa lambs of mixed sexes were used in this study to determine the optimum levels of calcium and phosphorus required by growing lambs. The lambs weighed between 12-22kg and aged 8-10 months at the commencement of the study. The lambs belonged to the University Farm and were normally managed semi-intensively. The animals were confined for about 21 days in preparation for the experiment during which time they were dewormed twice with Thibenzole (Merck, Sharp and Dohme). The lambs were then weighed and randomly allocated on the basis of sex and weight to nine dietary groups in a 3 x 3 factorial arrangement. The three dietary calcium levels used were 0.28%, 0.56% and 0.77% while the dietary phosphorus levels were 0.31%, 0.40% and 0.60%, thus providing dietary calcium to phosphorus ratios of 0.93:1; 0.70:1; 0.5:1; 1.8:1; 1.4:1; 0.93:1; 2.5:1; 1.9:1 and 1.3:1 for the nine treatment combinations. In the balance trial, nine Yankasa ram lambs weighing between 12-16 kg and aged about 6-8 months were used. The lambs which were bought from markets around Zaria were quarantined for one month during which time they were dewormed twice with Thibenzole. The lambs were subsequently

randomized on the basis of weight to the nine treatment combinations used in the growth study. The lambs were fed the experimental diet for a preliminary period of 21 days. On the 17th day, each animal was fitted with a faecal collection harness and placed on a metabolism cage for an adjustment period of four days. The three-week preliminary period was immediately followed by a 7-day collection period. Urine was collected in plastic buckets containing 100ml of 5O% HCL. This balance trial was replicated twice.

2. Housing

For the growth study, each lamb was kept in an individual pen with laterite floors in roofed barns. In the balance trial, the lambs were similarly housed prior to their placement on metabolism cages.

3. Diet

The composition of the nine rations is shown in Table 3. Forty per cent of the diet was provided by native hay (Andropogon and Hyperrhenia spp., predominating, 5% CP), while the remaining 60% was made up of supplement Table 3. The rations were formulated to be isocaloric and isonitrogenous. Vitamin D was added to supply at 5.6 I.U. per kg live weight per day (NRC, 1975). The calcium content of the basal ration (0.28%) was varied by the use of charred bone meal and

TABLE 3

COMPOSITION (%) OF THE RATIONS FED IN EXPERIMENT 2

INGREDIENT	TREATMENT NO. 1	2	3	4	5	6	7	8	9
Calcium in diet (%)	0.28	0.28	0.28	0.56	0.56	0.56	0.77	0.77	0.77
Phosphorus in diet (%)	0.31	0.42	0.62	0.31	0.42	0.62	0.31	0.42	0.62
Maize	42.7	42.4	41.73	42.0	42.0	41.5	41.5	41.5	41.1
Groundnut cake	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
Salt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin-tracemineral premix[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Monosodium phosphate	-	0.35	1.02	-	-	0.57	-	-	0.13
Chawed bonemeal	-	-	-	-	0.73	0.74	-	0.73	1.47
Calcium carbonate	-	-	-	0.69	-	-	1.18	0.49	-
Native hay	40	40	40	40	40	40	40	40	40
ANALYZED CHEMICAL COMPOSITION OF THE RATIONS									
Crude protein (%)	14.9	14.8	14.7	15.1	15.5	14.6	14.9	15.3	14.7
Calcium (%)	0.27	0.30	0.30	0.52	0.57	0.61	0.76	0.73	0.73
Phosphorus (%)	0.28	0.43	0.66	0.28	0.42	0.66	0.30	0.38	0.58
Ca : P ratio	1:1;	0.7:1;	1:2;	1.9:1;	1.4:1;	0.9:1;	2.5:1;	1.9:1;	1.3:1
Energy content of ration DE (Mcal/kg. DM)	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20

a: Composition of premix per 1000gi - Vitamin A, 7,500,000 I.U.; Vitamin D_3, 1,500,000 I.U.; Vitamin B_1, 1000mg; Vitamin B_{12}, 5mg; D-calcium pantothenate, 5000mg; Vitamin E, 2500mg; Vitamin K, 1500mg; Niacin, 12500mg; choline chloride, 60,000mg; Ethoxyquin, 5000mg; Manganese oxide, 16,130mg; potassium iodide, 353mg; cobalt sulphate, 286mg; Zinc oxide, 12500mg; copper oxide, 1283mg; Ferrocarbonate, 20323mg; Milocorn ad. 1000mg.

calcium carbonate so as to achieve the three levels of dietary calcium in the nine rations. The phosphorus content of the basal ration (0.31%) was varied by the addition of monosodium phosphate and charred bone meal so as to achieve the three levels of dietary phosphorus in the nine rations. The supplements were mixed weekly and stored in labelled jute bags. The composition of the rations used in the balance trial was the same as in the feeding trial (Table 3).

4. Feeding

The native hay and supplements were weighed out separately and fed together once daily at 0800 hours. Unconsumed portions of the feed were weighed back at intervals of 2 days and the actual amount consumed was determined by difference. Feed was offered ad libitum to the lambs and was adjusted every other day in an attempt to maintain the adopted ratio of concentrate to roughage. In the balance trial, all the lambs received equal and fixed amounts of the ration throughout the 21-day pre-feeding period and 7-day collection period. The hay and supplements were fed as in experiment 1 and feed consumed was determined by difference.

5. Weighing of animals

The lambs were weighed at the beginning of the experiment and thereafter at two-weekly intervals after

fasting for about 14 hours.

B. Clinical observations

The lambs were observed weekly for clinical signs. Examination included the inspection of animals in standing position and in motion. Signs of respiratory distress, gastrointestinal symptoms, stiff gaits, arched back and lameness were looked for.

C. Sampling and preparation of samples

1. Blood

Blood samples were taken from the jugular vein of each lamb a day prior to the beginning of the experiment and thereafter at two weekly intervals. Samples were allowed to clot, centrifuged and the serum decanted and used for the determination of calcium, magnessium and phosphorus.

2. Faeces

The daily faecal output from each animal in the balance trial was collected, weighed and stored in labelled polythene bags at -15°C. At the end of the collection period, the total faecal collection from each animal was bulked, thoroughly mixed and then subsampled for analysis. Duplicate samples of the faeces from each animal were weighed, dried in a forced-draught oven at 100°C (AOAC, 1970) and ground to pass through a 0.51mm sieve.

3. Urine

The daily urine output from each animal in the balance trial was measured and a 10% aliquot sample was taken and stored at -15°C in plastic bottles.

4. Feed samples and refusals

Duplicate samples of the supplement for each treatment group, hay and feed refusals were dried and ground to pass through a 0.51mm sieve.

5. Bones

The left humerus of each lamb was removed after slaughter, cleaned of soft tissues and dried in an oven at 100°C (AOAC, 1970) for 24 hours. Fat was extracted from each bone in a Soxhlet apparatus using petroleum spirit (B.P. 60°-80°C) as the solvent. The dried fat free bones were ashed at 600°C (AOAC, 1970) in a muffle furnace overnight. The ash content of each bone was then calculated. The bone ash was ground in a mortar and duplicate samples from each bone were digested with a mixture (5:1) of perchloric acid and nitric acid, until the solution became colourless.

D. Biochemical analysis

1. Nitrogen determination

The total nitrogen in the hay sample and supplement

for each treatment group was determined by standard procedures and the crude protein content of each ration calculated.

2. Calcium, magnesium and phosphorus

The calcium and magnesium content of the blood, bones, faeces, urine, feed sample and refusals were determined using the atomic absorption spectrophotometer (Willis, 1960, 1961) with strontium chloride as the diluent. Phosphorus in bone, faeces, urine, feed samples and refusals and inorganic phosphorus in serum were determined by the molybdovanadate method of Fiske and Subbarow (1925) after trichloroacetic acid precipitation of blood proteins.

E. Physico-chemical examination of bones

1. Gravimetry data

The right humerus removed from each lamb at slaughter was weighed in air and then in water at $4^{o}C$ for the determination of specific gravity and volume.

2. Macroradiography

One sample of the right humerus from each treatment group was selected and all were radiographed at the Radiology Unit of the A.B.U. Teaching Hospital, Zaria. The cortical index of the bones from each group was determined from the radiographs as in the first experiment.

F. Statistical analysis

The data obtained from the growth study and balance trials were subjected to the analysis of variance and treatment means were compared using Duncan's New Multiple Range Test as outlined by Steel and Torrie (1960).

RESULTS

EXPERIMENT I

Growth performance

The results of the growth studies on (experiments 1A and 1B) are presented in Table 4. Significant difference existed among treatments for rate of gain ($P < .01$), feed intake ($P < 0.05$) and feed efficiency ($P < 0.01$). Mean weight gain increased and feed efficiency improved with increasing dietary levels of calcium. However, there were no significant differences among groups 4, 5, 6 and 7 in growth rate. Apparent dry matter digestibility (Table 5) increased significantly ($P < 0.001$) with increases in dietary calcium levels. Animals on the two highest dietary calcium levels (group 6 and 7) had the highest apparent dry matter digestibilities which were significantly different ($P < 0.05$) from those of all other treatments.

Calcium and phosphorus balance

The data for calcium and phosphorus balance are presented in Tables 5 and 6. Significant differences existed for the faecal excretion of calcium ($P < 0.001$) urinary excretion of calcium ($P < 0.001$) and calcium retention ($P < 0.001$). The mean values for calcium retained showed that 3.4g Ca/day was the highest retained and this was significantly different ($P < 0.01$) from the calcium retained by all other groups. Animals on

TABLE 4

GROWTH PERFORMANCE OF LAMBS FED DIFFERENT CALCIUM LEVELS IN EXPERIMENT 1

	TREATMENT NO.								
	1	2	3	4	5	6	7	Gr. Mean	S.E.[1]
Analyzed Ca content of diet, %	0.34	0.39	0.56	0.67	0.83	0.94	1.07		
Analyzed P content of diet, %	0.38	0.35	0.33	0.39	0.31	0.30	0.29		
Av. Initial weight, kg.	14.3	14.4	15.1	18.3	17.4	17.1	17.0		
Av. Final weight, kg.	17.7	18.7	20.1	24.3	23.5	24.2	24.3	21.8	
Av. daily gain, g.	35.5^{b}	51.0^{b}	58.8^{b}	70.6^{a}	71.8^{a}	83.9^{a}	85.9^{a}	65.9	±7.5
Daily DM feed intake, g.	539.3^{b}	604.3^{a}	635.8^{a}	685.9^{a}	669.0^{a}	682.4^{a}	707.4^{a}	646.2	±33.5
Feed efficiency g/g	13.7	11.8^{a}	10.8^{b}	9.7^{b}	9.3^{b}	8.2^{b}	8.2^{b}	10.2	± 0.59

[1] Standard Error of treatment means

[a,b] Means on the same line with different superscripts differ significantly ($P < 0.05$).

TABLE 5

BALANCE TRIAL - EXPERIMENT 1 - CALCIUM BALANCE

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	Grand mean	S.E.[1]
DM. digestibility (%)	63.1^{e}	65.2^{d}	68.8^{c}	70.5^{c}	73.4^{b}	76.6^{a}	77.2^{a}	70.2	± 0.56
Faecal intake, g/day	1.82	2.64	3.57	4.6	5.6	6.4	7.5		
Urinary calcium, g/day	0.03^{a}	0.04^{a}	0.05^{a}	0.06^{a}	0.08^{a}	0.09^{a}	0.11^{a}	0.07	± 0.068
True retention, g/day	0.91^{g}	1.30^{f}	1.59^{e}	2.07^{d}	2.72^{c}	3.04^{b}	3.4^{a}	2.15	± 0.06
Availability (%)	50	49	45	45	49	48	45	48	± 3.06

[1] Standard Error of treatment means

a,b,c, ---g; Means on the same line with different superscripts differ significantly ($P < 0.05$)

TABLE 6

BALANCE TRIAL - EXPERIMENT 1 - PHOSPHORUS BALANCE

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	Grand mean	S.E.[1]
Phosphorus intake, g/day	2.04	2.12	2.08	1.98	2.06	2.08	2.06	1.25	
Faecal phosphorus, g/day	1.33[a]	1.28[a]	1.26[a]	1.26[a]	1.23[a]	1.20[a]	1.20[a]	1.25	±0.12
Uminary phosphorus, g/day	0.009	0.009	0.009	0.007	0.007	0.006	0.006	0.008	±0.0013
True retention, g/day	1.4	1.5	1.5	1.4	1.5	1.5	1.5	1.47	
Availability (%)	69.0[b]	70.8[b]	72.1[b]	70.7[b]	72.8[a]	72.1[a]	72.8[a]	71.47	±0.42
Endogenous loss of phosphorus, g/day		0.657							

[1] Standard Error of treatment means

[a,b] Means on the same line with different superscripts differ significantly ($P < 0.05$)

treatment 6 retained 3.04g Ca/day which was also significantly different ($P < 0.01$) from the calcium retained by all other dietary groups. Availability of dietary calcium did not differ significantly among treatments. Faecal phosphorus excretion (Table 6), urinary phosphorus excretion and phosphorus retention did not differ significantly among treatments. However, availability of dietary phosphorus differed significantly ($P < 0.01$) among treatments.

Clinical observations

Two animals died during the experiment, one from group 3 (0.56%Ca) and the other from group 4 (0.70% Ca). Their deaths were apparently unrelated to the experimental treatments. Aside from these, the other animals appeared clinically healthy. There were no cases of feed rejection, stiff gait, arched back or lameness.

Biochemical determination

The data for serum calcium and phosphorus levels are presented in Table 7. Serum calcium levels were normal in all groups throughout the experiment and significant differences did not exist among treatments. The mean for all treatments was 11.83 ± 0.36mg %. The serum inorganic phosphorus was not

determined in the first study due to persistent power cuts. It was, however, normal for all groups in the second study and significant differences did not exist among groups. The mean serum inorganic phosphorus values for all groups was 5.30 ± 0.60mg %.

Physico-chemical determination of bone

The values for the physico-chemical determinations are presented in Table 7. Bone density as determined by specific gravity showed that animals on the two highest calcium levels 0.99%/day and 1.15%/day had much denser bones than all other groups. The specific gravity of the bones from the two groups were significantly ($P < 0.05$) different from the others. There were no significant differences among groups in percentage ash content of dry fat free bone, percentage content of calcium and phosphorus in the dry fat free bone. However, groups 5, 6 and 7 animals had the highest percentage calcium content in dry fat free bone.

Radiographic examination

Radiographs of the humeri of lambs in treatments 1 to 7 are presented in Plates 1 and 2. The mean cortical indices are presented in Table 7. Significant differences ($P < 0.05$) existed among groups for cortical index. Animals on groups 4, 6 and 7 had the highest cortical indices which were significantly ($P < 0.05$) different from that of all others.

TABLE 7

BIOCHEMICAL AND PHYSICO-CHEMICAL DATA OF BLOOD AND BONES IN EXPERIMENT 1

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	Grand mean	S.E.[1]
Serum calcium levels, mg. %	11.92	12.07	11.76	12.11	11.69	11.95	11.34	11.83	±0.36
Serum phosphorus levels, mg %	-	-	-	5.46	5.44	5.12	5.17	5.30	±0.60
Specific gravity of humerus	1.17^{d}	1.19^{d}	1.21^{d}	1.32^{b}	1.28^{c}	1.36^{a}	1.36^{a}	1.27	±0.011
Ash in humerus (%)	51.2	50.2	53.1	51.6	50.3	48.4	48.8	50.5	±1.47
Calcium in dry fat bone (%)	21.1^{a}	20.7^{b}	22.0^{a}	23.5^{a}	24.1^{a}	24.0^{a}	24.2^{a}	22.8	±0.92
Phosphorus in dry fat free bone (%)	8.8^{a}	8.7^{b}	9.4^{a}	9.8^{a}	9.1^{a}	9.1^{a}	9.1^{a}	9.1	±0.30
Cortical index	0.23^{c}	0.23^{c}	0.29^{b}	0.33^{a}	0.27^{b}	0.31^{a}	0.35^{a}	0.29	±0.018

[1] Standard Error of treatment means

a,b,c,d Means on the same line with different superscripts differ significantly ($P < 0.05$).

EXPERIMENT 2

Growth performance

The results of the growth study are shown in Table 8. Significant differences existed among groups in the growth rate ($P < 0.01$) and feed efficiency ($P < 0.01$) but not in the feed intake. Although animals on the highest levels of calcium and phosphorus (0.77% Ca and 0.62% P) in their diet gained at a faster rate than all other groups, there were no statistical differences among animals on treatments 5, 6, 7, 8 and 9. The feed efficiencies of animals on treatments 6 and 9 were similar and differed significantly ($P < 0.05$) from that of all other groups. Apparent dry matter digestibility (Table 9) was significantly different ($P < 0.001$) among treatments (Table 9). The animals on the high calcium, high phosphorus treatment group (0.77% Ca, 0.62% P) had the highest apparent dry matter digestiblity which differed significantly ($P < 0.01$) from those of groups 1, 2, 3, 4, 5 and 7 but were similar to those of groups 6 and 8.

Calcium and phosphorus balance

The calcium and phosphorus blance data are presented in Tables 9 and 10. Significant differences existed among treatment groups in faecal excretion of calcium ($P < 0.001$), urinary excretion of calcium ($P < 0.05$), calcium retention

TABLE 8

GROWTH PERFORMANCE OF LAMBS FED DIFFERENT LEVELS OF CALCIUM AND PHOSPHORUS IN EXPERIMENT 2.

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	8	9	Grand mean	S.E.[1]
Av. initial weight, kg.	18.2	17.5	18.2	18.4	17.7	18.2	18.3	18.0	18.2		
Av. final weight, kg.	22.35	20.75	21.81	22.53	22.5	23.53	22.65	22.8	24.4	22.6	±6.84
Av. daily gain g.	48.96	38.24^{b}	42.47^{b}	48.58^{b}	56.47^{a}	62.70^{a}	51.18^{a}	56.47^{a}	72.99^{a}	52.9	±6.84
Daily dry matter feed intake e.g.	898.6	793.6	791.2	917.0	829.0	785.8	866.5	891.8	894.5	852	±51.8
Feed efficiency	18.4^{a}	20.8^{a}	18.6^{a}	18.9^{a}	14.7^{a}	12.5^{b}	16.9^{a}	15.8^{a}	12.3^{b}	16.5	±1.98

[1]Standard Error of treatment means

^{a,b} Means on the same line with different superscripts differ significantly (P 0.05).

TABLE 9

BALANCE TRIAL FOR CALCIUM IN EXPERIMENT 2

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	8	9	Grand Mean	S.E.[1]
Apparent DM digested (%)	64.8^{c}	66.4^{c}	69.8^{b}	71.6^{b}	72.5^{b}	74.9^{a}	72.2^{b}	75.5^{a}	77.7^{a}	71.7	±0.59
Calcium intake, g/day	2.38	2.41	2.41	4.75	4.75	4.80	6.57	6.54	6.56		
Faecal calcium, g/day	1.24^{c}	1.30^{b}	1.27^{c}	2.24^{b}	2.09^{b}	1.98^{b}	3.16^{a}	3.06^{a}	2.92^{a}	2.14	±0.09
Urine calcium, g/day	0.04^{b}	0.05^{a}	0.04^{b}	0.06^{a}	0.05^{a}	0.04^{b}	0.09^{a}	0.09^{a}	0.07^{a}	0.05	±0.12
True retention, g/day	1.25^{b}	1.21^{b}	1.25^{b}	2.60^{a}	2.76^{a}	2.93^{a}	3.47^{a}	3.54^{a}	3.72^{a}	2.53	±0.28
Availability (%)	53^{b}	50^{b}	52^{b}	55^{a}	58^{a}	61^{a}	53^{b}	54^{b}	57^{a}	55	±1.86
Endogenous loss mg/kg body weight per day		9.1									

[1]Standard Error of treatment means

a,b,c Means on the same line with different superscripts differ significantly ($P < 0.05$).

TABLE 10

BALANCE TRIAL FOR PHOSPHORUS IN EXPERIMENT 2

ITEM	TREATMENT NO. 1	2	3	4	5	6	7	8	9	Grand mean	S.E.[1]
Phosphorus intake g/day	2.5	3.4	5.2	2.6	3.5	5.2	2.6	3.4	5.2	2.	
Faecal phosphorus g/day	1.9^{b}	2.4^{a}	2.9^{a}	1.7^{b}	2.3^{a}	2.9^{a}	1.6^{b}	2.2^{a}	2.5^{a}	2.30	±0.18
Urine phosphorus g/day	0.007	0.008	0.03	0.008	0.009	0.03	01009	0.01	0.01	0.013	±0.007
True retention g/day	1.30^{b}	1.65^{b}	2.93^{a}	1.55^{b}	1.85^{b}	3.1^{a}	1.65^{b}	1.85^{b}	3.4^{a}	2.1	±0.12
Availability (%)	52^{a}	49^{b}	56^{a}	60^{a}	53^{a}	60^{a}	63^{a}	54^{a}	64^{a}	57	±2.31
Endogenous loss, (mg/kg body weight per day)		32.3									

[1]Standard Error of treatment means

^{a,b}Means on the same line with different superscripts differ significantly ($P<0.05$).

Biochemical determinations

The data for the serum calcium and phosphorus levels are presented in Table 11. Plasma calcium and phosphorus levels were normal in all groups throughout the trial. Although serum calcium levels tended to be elevated at the high calcium levels, the differences among treatments were not statistically significant. The mean serum calcium levels for all groups was 12.02 $\pm$ 0.41mg %. On the other hand, significant differences ($P < 0.05$) existed among groups for serum inorganic phosphorus, although phosphorus levels for all groups was normal and averaged 5.19 $\pm$ 0.55mg %.

Physico-chemical data

The data are summerized in Table 11. The measurements made on the bones were quite sensitive to dietary levels of calcium and phosphorus. Significant differences existed among treatment groups for specific gravity ($P < 0.01$), percentage ash in dry fat free bone ($P < 0.01$), percentage phosphorus in dry fat free bone ($P < 0.01$) and percentage calcium in dry fat free bone ($P < 0.01$). The high calcium, high phosphorus diets (0.77% Ca, 0.62% P) gave consistently higher values than others in those parameters suggesting that the bones were more mineralized than the bones from other groups.

Radiographic examination

Radiographs of humeri of lambs from all treatment groups are shown in Plate 3. The cortical indices at the narrowest part of the diaphysis (sum of the width of the two cortices divided by the total diameter, Chineme et al., 1976) are presented in Table 11. Significant differences ($P < 0.01$) existed among treatment groups for cortical index. The high calcium, high phosphorus group had the highest cortical index but significant differences ($P > 0.05$) did not exist with the indices of groups 3, 4, 5, 6, 8 and 9.

TABLE 11

BIOCHEMICAL AND PHYSICO-CHEMICAL DATA OF BLOOD AND BONES IN EXPERIMENT 2

	TREATMENT No.									Grand Mean	S.E.[1]
	1	2	3	4	5	6	7	8	9		
Serum calcium levels, mg %	11.74	11.67	12.31	11.93	11.62	12.55	12.65	12.12	12.12	12.02	± 0.44
Serum phosphorus levels. mg %	4.85^{b}	5.05^{a}	6.07^{a}	5.00^{b}	4.94^{b}	5.71^{a}	4.81^{b}	4.95^{b}	5.35	5.19	± 0.33
Calcium in dry fat free bone, %	19.63^{6}	20.30^{b}	21.73^{b}	20.18^{b}	21.33^{a}	22.33^{a}	20.05^{a}	22.38^{a}	24.12^{a}	24.12	± 0.61
Phosphorus in dry fat free bone, %	8.41^{b}	8.55^{b}	9.92^{a}	9.20^{b}	8.83^{b}	9.35^{b}	9.23^{b}	10.76^{a}	11.49^{a}	9.53	± 0.37
Specific gavity of humerus	1.20^{b}	1.19^{b}	1.21^{a}	1.22^{a}	1.20^{b}	1.21^{a}	1.21^{a}	1.22^{a}	1.25^{a}	1.21	± 0.01
Ashi in dry fat free beon, %	49.7^{e}	49.8^{e}	52.30^{c}	50.5^{d}	51.3^{d}	52.6^{c}	51.5^{d}	53.0^{b}	54.9^{a}	51.7	± 0.59
Cortical index	0.29^{b}	0.23^{b}	0.31^{a}	0.33^{a}	0.36^{a}	0.31^{a}	0.27^{b}	0.33^{a}	0.38^{a}	0.31	± 0.012

[1]Standrad Erro of treatment means

a,b,c,d,e Means on the same line with different superscripts differ significantly ($P < 0.01$)

TABLE 12

REGRESSION EQUATIONS RELATING CALCIUM INTAKE (X), PHOSPHORUS INTAKE (X) AND FAECAL EXCRETIONS OF CALCIUM AND PHOSPHORUS (Y) AND URINARY EXCRETION OF CALCIUM AND PHOSPHORUS (Y)

EXPERIMENT 1 ITEM	REGRESSED EQUATION	EXCRETION VALUE AT ZERO INTAKE	TOTAL ENDOGENOUS EXCRETION	r VALUE	r^2 VALUE
Faecal calcium excretion	Y = 0.094 + 0.53X	94mg	104mg	0.995	0.990
Urinary excretion	Y = 0.01 +0.014 X	10mg		0.994	0.988
Experiment 2 faecal calcium excretion	Y = 0.17 +0.42 X	170mg	185mg	0.988	0.976
Urinary calcium	Y = 0.015+0.009 X	15mg		0.730	0.533
Faecal phosphorus	Y = 0.65 +0.43 X	650	657mg	0.999	0.998
urinary phosphorus	Y = 0.007+0.005 X	7		0.943	0.889

TABLE 13

INTAKES OF DIETARY CALCIUM AND PHOSPHORUS AS SUGGESTED BY SOME TEMPERATE WORKERS COMPARED WITH OUR RECOMMENDED VALUES

Liveweight range (kg)	Rate of gain (g)	Calcium requirement Absolute dietary, g/day	Calcium requirement mg/kg body weight/day	Reference
20–30 ($\bar{x}$ =19.03)	78	5.8	305	Present study - expt. 1
20–30 ($\bar{x}$ =20.32)	60	6.0	295	Present study - expt. 2
25–40	170	6.0	200	Jones and Stengel (1938)
24–48	110	5.8	160	Fraser (1934)
40	80	4.6	115	Godden and Ray (1939)
10–18	-	4.5	250	Hodge (1973)
30–40	Growing lambs	6.3	183	NRC (1975)
		PHOSPHORUS		
20–30 ($\bar{x}$ =20.32)	60	5.6	276	Present study
40	80	4.6	115	Morris and Ray (1939)
30–40	Growing lambs	3.6	103	NRC (1975)

TABLE 14

SIMPLE EFFECTS OF CALCIUM AND PHOSPHORUS ON DRY MATTER DIGESTIBILITY (%) IN EPXERIMENT 2

		CALCIUM LEVELS			Phosphorus means
		Ca 1	Ca 2	Ca 3	
Phosphorus Levels	Ph1	64.8	71.6	72.2	69.5
	Ph2	66.4	72.5	75.5	71.5
	Ph3	69.8	74.9	77.7	74.1
Calcium means		67	73	75.1	

TABLE 15: Comparison of the endogenous calcium and phosphorus losses obtained in the present studies with some temperate values.

Endogenous calcium

Total endogenous calcium (mg/kg body weight/day)	Reference
5.5	Present study (expt. 1)
9.1	Present study (expt. 2)
8.0	Hodge (1973)
20.0	Braithwaite (1974)
60.0	Tillman and Brethour (1958)
16.0	Hansard et al. (1957)

Endogenous phosphorus

Total endogenous phosphorus (mg/kg body weight/day)	Reference
32.3	Present study (expt. 2)
42.0	Smith (1955)
41.5	A.R.C. (1965)
23	Field et al. (1974)
3g/day	Leibholz (1974)

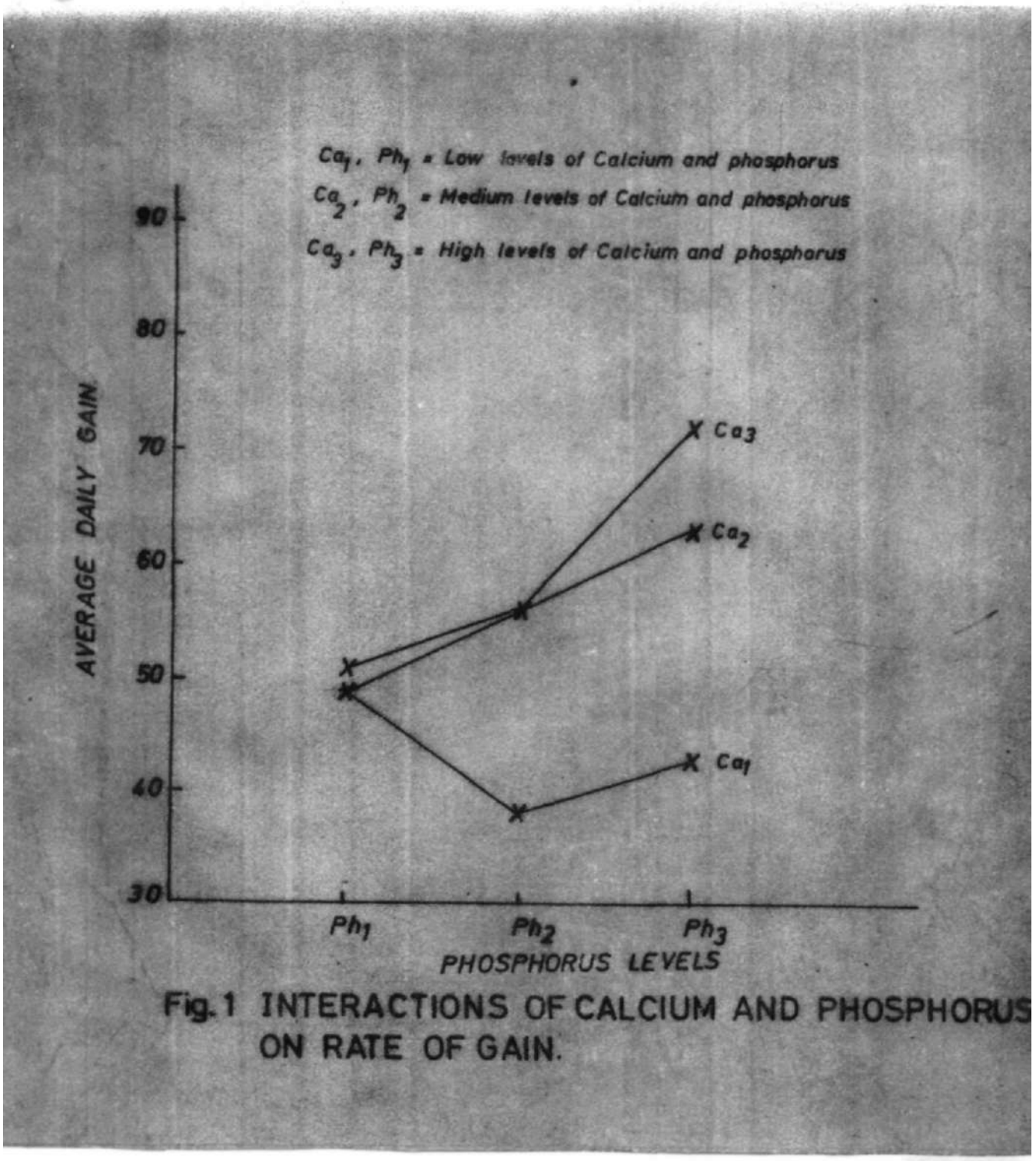


Fig. 1 INTERACTIONS OF CALCIUM AND PHOSPHORUS ON RATE OF GAIN.

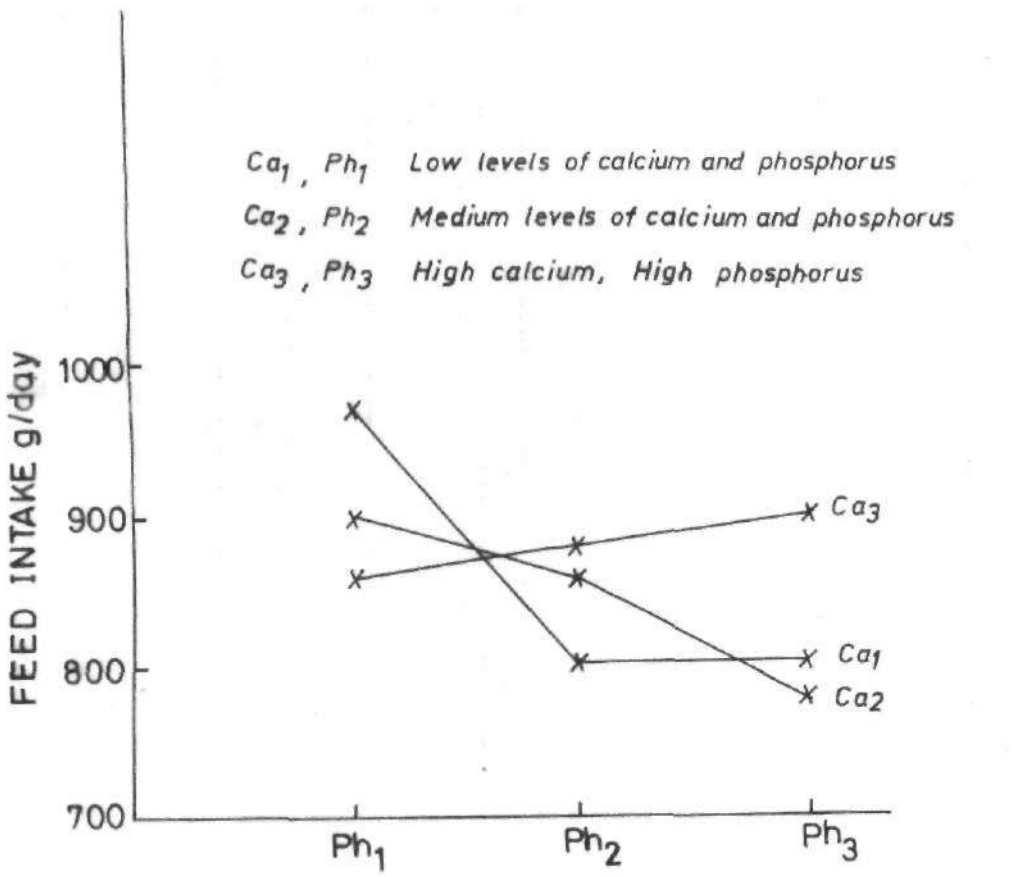


Fig.2 INTERACTIONS OF CALCIUM AND PHOSPHORUS ON FEED INTAKE.

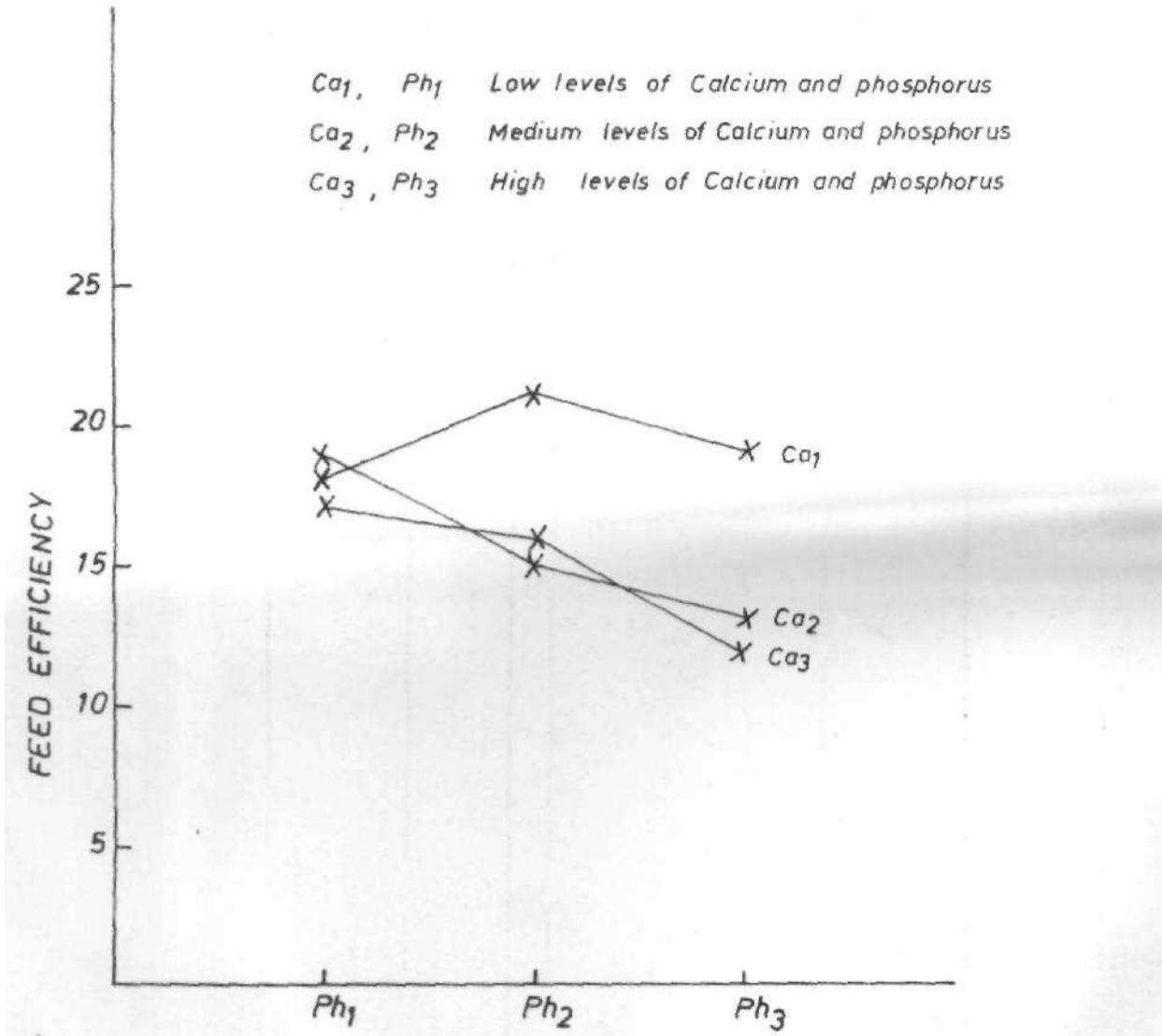


Fig.3 INTERACTIONS OF CALCIUM AND PHOSPHORUS ON FEED EFFICIENCY

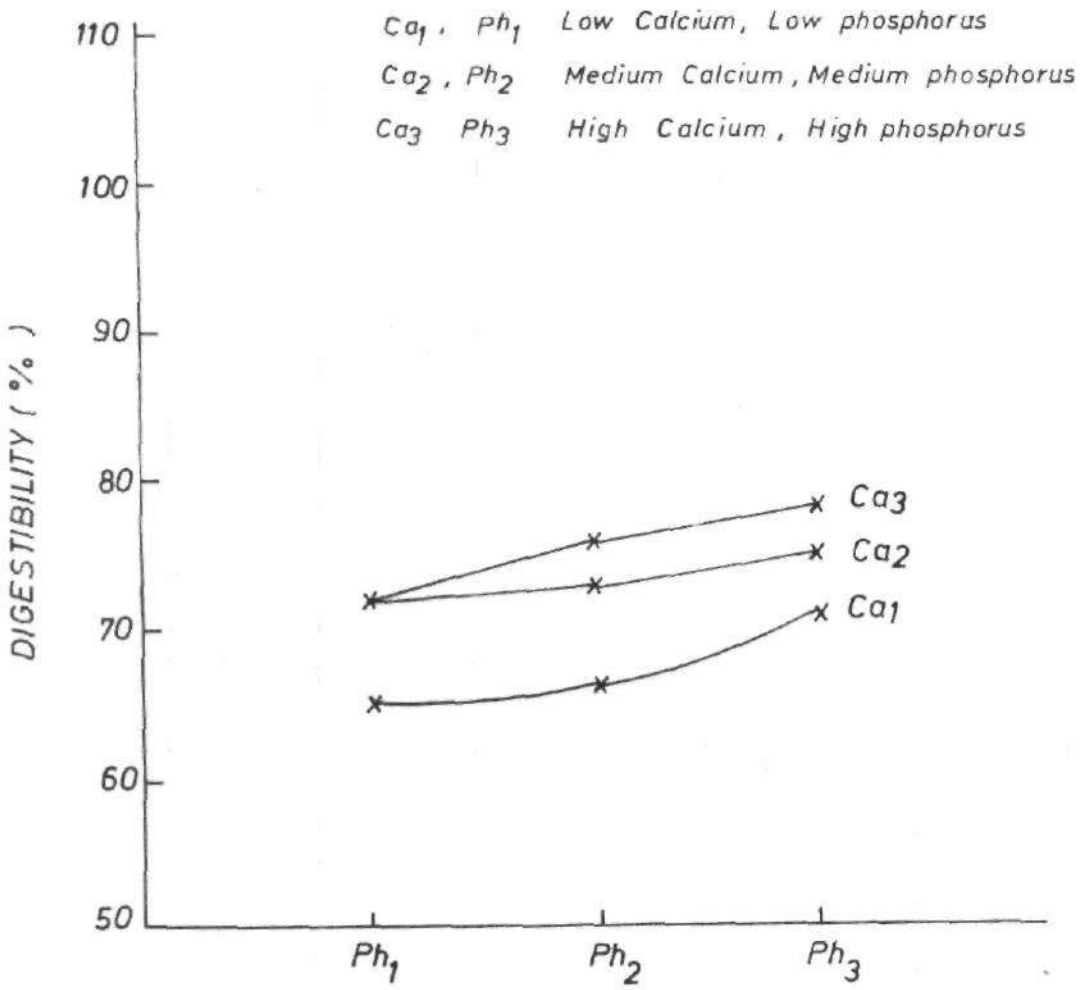


Fig. 4 INTERACTIONS OF CALCIUM AND PHOSPHORUS ON DRY MATTER DIGESTIBILITY

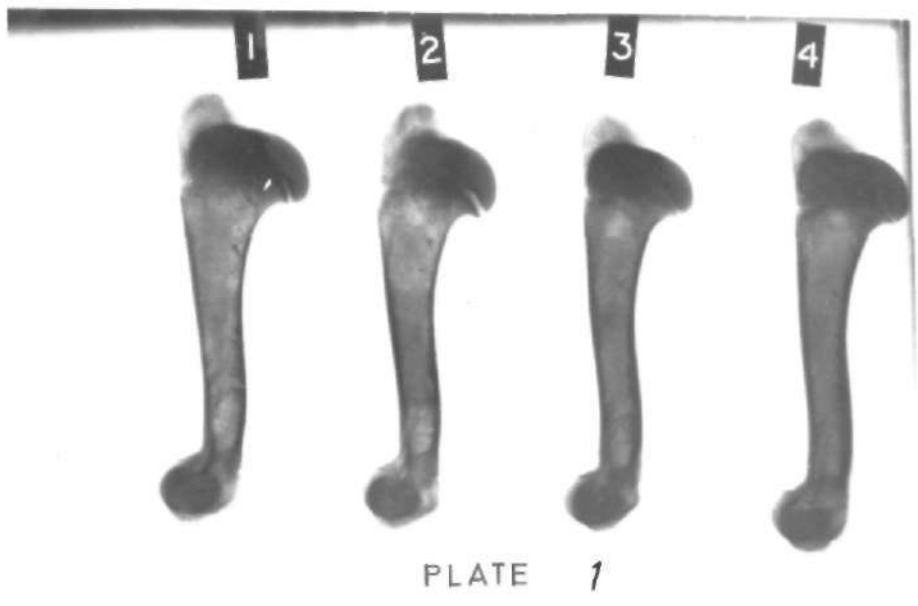


PLATE 1

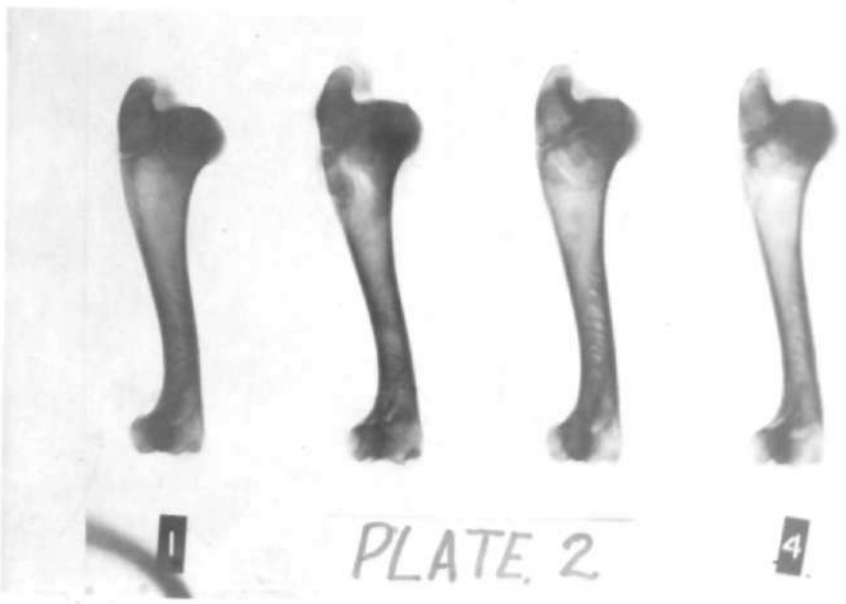


PLATE 2

PLATE 2

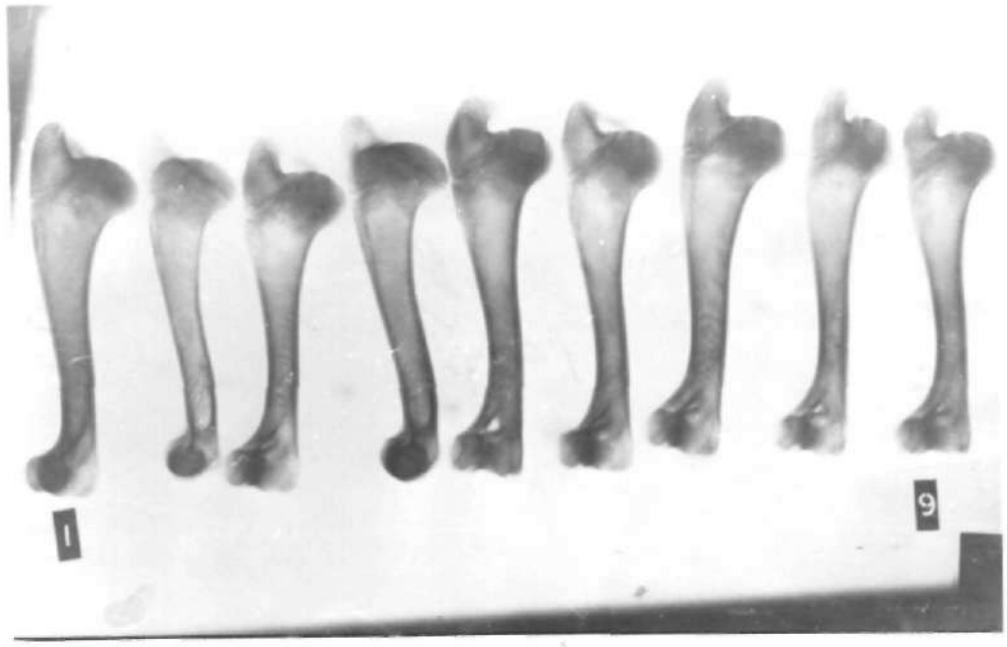


PLATE 3

DISCUSSION

Determination of the mineral requirement of farm animals by the factorial method is based on infomration of endogenous losses, body storages and availability. There is little or no information on endogenous values for calcium and phosphorus for tropical sheep. The values obtained by regressing the faecal and urinary outputs of the elements at zero intake were used as the endogenous losses and applied to the balance trials in arriving at the net calcium and phosphorus retentions. The equations presented in Table 12 show that the total endogenous calcium loss in experiment 1 was 104 mg per day or 5.5mg per kg body weight per day. The total endogenous calcium loss in experiment 2 was 185mg per day or 9.1mg per kg body weight per day, while the total endogenous phosphorus loss was 657mg per day or 32.3mg per kg body weight per day.

The reduced endogenous calcium loss in experiment 1 could be attributed to the fact that the animals were younger than those used in experiment 2. A comparison of the present values with that of some temperate workers is presented in Table 15. Although very wide range of values have been reported for temperate sheep, it is evident from the table that generally the lambs in this region have smaller endogenous losses of calcium

and phosphorus than their temperate counterparts. Lueker and Lofgreen (1961) suggested that metabolic faecal calcium does not vary with current intake while metabolic faecal phosphorus excretion varies with level of phosphorus intake. Although the physiological significance of endogenous faecal calcium and phosphorus has not been thoroughly resolved, it does not seem reasonable to assume that metabolic faecal calcium will be constant over varying calcium intakes. This is because bile secretions and the sloughed off portions of the intestinal mucosa which are the major sources of faecal endogenous calcium are subject to wide variations depending on dietary and physiological factors.

It is recommended that in the absence of more critical studies on the endogenous losses of these elements in gowing lambs in Nigeria, the value of 5.5mg/kg body weight per day should be used as the endogenous loss of calcium for lambs aged about eight months while for lambs between about eight months and one year of age, the value of 9.1mg/kg body weight per day should be used and applied to conventional balance trials in arriving at the net calcium requirement of growing lambs in this region. The value of 32.3mg/k_g body weight per day in recommended as the minimum endogenous loss of phosphorus for growing lambs in this region.

The results of the growth study and balance trial (Tables 4 adn 5) in experiment 1 showed that the overall performance of the lambs on treatments 4,5,6 and 7 were not statistically different. The relationship between the rate of gain and calcium retention was used in deriving the following equation:

$Y = 27.8 + 17.8\ X\ (r = 0.976)$

where X = calcium retention (g/day)

Y = average daily gain (g/day) for obtaining the net calcium requirement of growing lambs. The average rate of gain for animals on treatments 4, 5, 6 and 7 was 77.85 grams. Applying this to the above equation, the net calcium requirement of growing lambs is found to be 2.8 grams. The availability figure for the calcium source used was 48%. The lambs therefore required 5.8 grams calcium in their diet. On the basis of requirement per unit of body weight, this would be 305 mg/kg boyd weight per day.

The results of the growth study in experiment 2 (Table 8) indicated that the rate of gain of the lambs on treatments 5, 6, 7, 8 and 9 were not statistically different. The relationship between the simple effects of calcium retained and rate of gain was used in deriving the following equation:

$Y = 34.10 + 7.54\ X\ (r = 0.60)$

where X = calcium retention (g/day)

Y = average daily gain (g/day) for obtaining the net calcium

requirement of growing lambs. The average rate of gain for animals on treatment 5, 6, 7, 8 and 9 was approximately 60.0 grams. Applying this to the above equation gives the net calcium requirement of growing lambs in this experiment as 3.4 grams. The average availability of calcium in treatments 5, 6, 7, 8 and 9 was 57%. The lambs therefore required 6.0 grams of calcium in their diet. On the basis of requirement per unit of body weight, this would be 295 mg/per kg bodyweight per day (Table 13). The relationship between the simple effects of phosphorus retained and rate of gain in experiment 2 was used in deriving the following equation:

$Y = 39.2 + 6.5\ x\ (r = 0.84)$

where Y = average daily gain (g/day)

X = phosphorus retention (g/day) for obtaining the net phosphorus requirement of growing lambs. The mean availability of the phosphorus sources used in the experiment was 57%. The dietary requirement of the lambs for phosphorus was therefore 5.6 grams per day or 276mg per kg bodyweight per day.

A comparison of the present estimates with some recommendations made elsewhere in the temperate regions of the world are presented in Table 13. Although no clear pattern emerges, it is evident that on the basis of requirement per

kilogram body weight, the lambs in this region require more calcium and phosphorus in their diet than most of their temperate counterparts. Reasons for the higher requirement of the lambs in this region may include losses in sweat which would be significant at high temperatures and the lower quality feed intake which would imply a greater intake to meet metabolic needs.

The results of the metabolism trials in experiments 1 and 2 (Tables 5 and 9) showed that dry matter digestibility was markedly improved by calcium (experiment 1) and by calcium and phosphorus (experiment 2) supplementation. Table 14 shows the simple effects of calcium and phosphorus on dry matter digestibility. Calcium had a greater effect on dry matter digestibility than phosphorus. In a recent study, Varner and Woods (1972) reported that calcium carbonate and corn starch singularly or in combination significantly ($P < 0.05$) increased organic matter and cellulose digestion as compared to the basal ration. Their results confirmed the earlier findings of Burroughs et al. (1951), Hubbert et al. (1958) and Davidson and Woods (1961). Anderson (1965) also reported that cellulose digestion in the artificial rumen increased from 34% in the basal medium to 80% on the addition of 80mcg/ml of standard phosphate to the medium. Vande Wath (1942) had earlier observed

an increase in numbers of cellulolytic bacteria when phosphate was added to a phosphorus-deficient ration for sheep. It is evident therefore that the improved dry matter digestibilities observed with increasing calcium (experiment 1) or calcium and phosphorus (experiment 2) supplements were due to the mineral supplements. The improved growth performance observed at increased dietary calcium and phosphorus levels was a result of the better utilization of the nutrients achieved through the mineral supplements. The studies of Field et al. (1975) and Sykes and Dingwall (1976) had shown that energy digestibility (Field et al., 1975) or utilization (Ridall et al. 1934; Preston and Pfander, 1964) and nitrogen utilization (Sykes and Dingwall, 1976) were affected by calcium and phosphorus supplementation. In experiment 1, the dry matter digestibilities of rations in treatments 6 and 7 were similar and significantly ($P < 0.01$) different from that of rations in treatments 1-5. In experiment 2, the dry matter digestibility of the ration in treatment 9, was significantly ($P < 0.01$) different from all others and also supported maximum retention of calcium and phosphorus.

Neither plasma calcium nor phosphorus was depressed in both experiments. Oduye and Adadevoh(1976) gave the range of serum

calcium and phosphorus levels for apparently normal West African dwarf sheep as 7.1 - 13.3mg % and 3.9 - 12.8 mg % respectively. The range of values for serum calcium and phosphorus obtained in experiments 1 and 2 were within these ranges. Duckworth et al. (1943) and Benzie et al. (1959) indicated that the age at which the animal begins to eat an unbalanced diet capable of causing bone disease is of importance in determining the degree of clinical deficiency symptoms produced. Younger animals are more liable to exhibit such gross clinical symptoms as frank rickets and depressed serum calcium and phosphorus levels than older growing animals that are closer to the completion of skeletal development when they encounter a deficient diet. According to Hammond (1932) in lambs of five months of age, the leg bones have increased in length so that they are about four-fifths of adult bone. It is therefore evident that the risk of rachitic symptoms developing in lambs five months and above is less than in weaner lambs. The lambs used in the present studies were aged between 6-10 months. Clearly, the influence of bone osteolysis in buffering the blood calcium and phosphorus levels particularly at lower intakes may have been significant. Field et al. (1975) reported that rations as low

in calcium and phosphorus as 0.07% calcium and 0.13% phosphorus did not depress plasma calcium and only slightly decreased plasma phosphorus in these lambs. The minimum calcium and phosphorus retention (0.91g Ca and 1.4g P per day in experiment 1 and 1.25g Ca and 1.3g P per day in experiment 2) were clearly above those values. The normal values for serum inorganic phosphorus obtained in these studies may further be explained in terms of salivary phosphorus. The recent work of Tomas (1974) has shown that as suggested by Compere (1967), endogenous excretion via the saliva into the alimentary tract is an important part of the normal mechanism of phosphorus homeostasis in sheep. In view of the large amount of phosphorus which is secreted in saliva (Young et al., 1966, Tomas, 1974), one must envisage as was suggested by Bruce et al. (1966) that phosphorus is recirculated between the intestine and rumen mainly via the saliva to which system dietary phosphorus is being added. The NRC (1975) suggested that the salivary phosphorus buffers rumen phosphorus variations due to diet, particularly at low phosphorus intakes. It is evident therefore that the usefulness of serum values of calcium and phosphorus as indicators of nutritional status of the animal with respect to

these minerals is primarily influenced by the age of the animal and the period of imposed deficiency. Reduced serum calcium and phosphorus levels will be exhibited faster in younger animals than in older animals and after a prolonged period of deficiency rather than over a short period of time.

In experiment 1, the specific gravity of humeri of the animals on treatments 6 and 7 (0.99% Ca and 1.15% Ca) were the highest and were significantly (P 0.05) different from the specific gravities of other groups. Also judging from the cortical index and percentage calcium in dry fat free bone (Table 7), it is apparent that the bones of animals on 0.86%, 0.99% and 1.15% dietary calcium levels were more mineralized than the others. Percentage ash and phsophorus in dry fat free bone were reduced in the humeri of animals on 0.99% and 1.15% Ca. Underwood (1966) reporting the data of Stewart (1934) indicated that while the total ash in the humerus and femur of a normal sheep was 62.3%, the ash in a phosphorus deficient sheep was 54.9%. Similarly, he indicated that the percentage calcium and phosphorus in normal sheep humerus were 24.8% and 10.7% respectively while in a phosphorus sheep the values were 22.3% and 9.4% for calcium and phosphorus respectively. Clearly, the bone values reported in this experiment (Table 7)

were below that reported by Underwood (1966).

Ewer (1951a) and Benzie et al. (1959) showed that simple deficiencies of calcium, phosphorus or vitamin D with sufficient energy and protein for growth led to reduced bone accretion. Other studies involving simple deficiencies of calcium (Franklin, 1934) or phosphorus (Martin and Peirce, 1934) resulted in reduced bone accretion. Unfortunately, no values have been reported for Nigerian sheep in respect of the above bone parameters. The values for Nigerian sheep may be different from that reported by Underwood (1966) as a result of breed differences or the inadequacy of the dietary phosphorus level used in experiment 1 may be responsible for the reduced bone ash and per cent phosphorus levels observed. Both factors may also be operating concommittantly. However, on the basis of specific gravity, cortical index and calcium in dry fat free bone, animals on dietary levels 0.70%, 0.86%, 0.99% and 1.15% had the highest and similar values. In experiment 2 (Table 11) the animals on treatment 9 had the highest values for specific gravity, calcium and phosphorus in bone, percentage ash in bone and cortical index. The dietary levels of calcium and phosphorus used therefore supported optimal mineralization of the bones in

this experiment. The adequacy of the phosphorus level used is indicated by the fact that the percentage phosphorus in dry fat free bone obtained in this experiment (11.5%) is above the value (10.7%) reported by Underwood (1966) for normal sheep.

The mineral requirement of farm livestock have been generally expressed in terms of dietary concentration. The merits of this approach have been both the ease of formulation of the ration as well as the greater uniformity achieved in mineral concentration in the diet. Although many reasons can be adduced against this approach, the most potent is the availability factor. As pointed out by Hansard et al. (1954) the availability of calcium and phosphorus from different sources may vary widely. This variation in availability will signficantly influence the dietary requirement of the animal for the mineral. Besides, variations in dry matter intakes will affect the dietary concentration of the mineral which will also influence the net requirement of the animal for the mineral. It is therefore recommended that the calcium and phosphorus requirements of farm animals be expressed in terms of net requirement rather than dietary concentration. Alternatigely the availability figure for each mineral element in a supplement should be included to enable the dietary levels to be obtained.

SUMMARY

The results of these studies indicate that the dietary calcium requirement of growing lambs in this region range from 295 to 305 mg per kg body weight per day, while the phosphorus requirement is about 276 mg per kg body weight per day. The minimum endogenous loss of calcium in experiment 1 was 5.5 mg per kg body weight per day. The minimum endogenous loss of calcium in experiment 2 was 9.1 mg per kg body weight per day, while the endogenous loss of phosphorus was 32.3 mg per kg body weight per day. It is recommended that in the absence of more critical studies on the endogenous losses of these elements in growing lambs in Nigeria, these values should be used and applied to conventional balance studies in arriving at the net calcium and phosphorus requirement of sheep. On the basis of requirement per kilogram body weight, it is evident that growing lambs in this region require more calcium and phosphorus in their diet than their temperate counterparts.

LITERATURE CITED

Abdel Aal, A.E. (1968). M.Sc. Thesis, Cairo University. Cited in Some aspects of mineral nutrition problems in Egypt, In Mineral Studies with Isotopes in Domestic Animals. IAEA/FAO. Vienna.

Adegbola, A.A. (1971). Livestock production problems associated with mi mineral deficiencies or excesses in West Africa with special emphasis on Nigeria. In Mineral Studies with Isotopes in Domestic Animals. IAEA/FAO. Vienna.

Agricultural Development and Advisory Services (1971). Nutrient Allowances and Composition of Feedstuffs for Ruminants. Advisory paper No. 11. Ministry of Agric., Fisheries and Food. H.M.S.O. London.

Agricultural Research Council (1965). The Nutrient Requirement of Farm Livestock No. 2 Ruminants. Tech. Rev. Agric. Res. Counc. H.M.S.O. London.

A.O.A.C. (1970). Official Methods of Analysis of the Association of the Official Analytical Chemists. 11th ed. Washington D.C.

Agus, Z.S. (1971). Cited in the Biochemistry and Physiology of Bone IV (ed. G.H. Bourne). Academic Press. N.Y.

Albright, F.A. and E.C. Reifenstein (1948). The Parathyroid Glands and Metabolic Bone Disease. Selected studies. Williams and Wilkins. Baltimore. Maryland.

Alcock, N. and I. MacIntyre (1960). Interrelation of calcium and magnesium absorption. Biochem. J. 76: 17-20.

Aliapoulios, M.A., P. Gold-harber and P.L. Munson (1966). Thyrocalcitonin and PTH in tissue culture. Science N.Y. 151: 330-1

Ammerman, C.B., R.M. Forbes, U.S. Garrigus, A.L. Neuman and H.W. Norton (1957). Ruminants utilization of inorganic phosphate. J. Animal Sci. 16: 796.

Anderson, R.E. Cheng and W. Burroughs (1956). A laboratory technique for measuring phosphorus availability of feed supplements to ruminants. J. Animal Sci. 15: 489.

Anderson, A.W. (1933). Problems of animal nutrition and husbandry in Northern Nigeria. Imp. Burr. Anim. Nutr. Tech. Comm. No. 4. Row. Res. Inst. Aberdeen.

Andrews, E.D. and I.J. Cunningham (1945). N.Z. J. Sci. Tech. 27A:223

Arnaud, C.D. and Tenenhouse (1970). Parathyroid hormone. Ann. Rev. Physiol. 29: 349-72

Aubert, J.P. and F. Bronner (1965). A symbolic model for the regulation by bone metabolism of the blood calcium level in rats. Biophys. Journ. 5: 349

Avioli, L.V. (1972). Intestinal absorption of calcium. Arch. Int. Med. 129: 345-355.

Bailes, C.A. and J.M. Forbes (1974). Control of feed intake and regulation of energy balance in ruminants. Physiol. Revs. 54: 160-214.

Becker, R.B., W.M. Neal and A.L. Shealy (1933). Cited in Clinical Biochemistry of Domestic Animals 1 (eds. J.J. Kancko and C.E. Cornelius). Acd. Press, N.Y.

Beeson, W.M., D.W. Bolin and C.W. Hickman (1937). Rec. Amer. Soc. Anim. Production p. 345.

Beeson, W.M. and C.W. Hickman (1944). The phosphorus requirements of fattening lambs. J. Animal Sci. 3: 63-70.

Bell, N.H. and P.H. Stern (1970). Amer. J. Physiol. 218:64.

Benzie, D.A.W. Boyne, A.C. Dalgorno, J. Duckworth and B. Hill ((1959). Studies of the skeletaon of the sheep. III. The relationship between phosphorus intake and resorption and repair of the skeleton in preganancy and lactation J. agric. sci. camb. 52:1

Benzie, D., A.W. Boyne, A.D. Dalgarno, J. Duckworth, R. Hill and D.M. Walker (1957). Studies of the skeleton of the sheep II. The relationship between calcium intake and resorption and repair of the skeleton in pregnancy and lactation. J. agric. Sci. Camb. 48: 175.

Benzie, D., A.W. Boyne, A.C. Dalgarno, J. Duckworth and R. Hill (1960). Studies of the skeleton of the sheep IV. The effects of interactions of dietary supplements of calcium, phosphorus, Cod-liver oil and energy on the skeleton of growing whethers. J. agric. Sci. Camb. 54:202-221

Bijvoet, O.L.M. and J. Van der Sluys Veer (1968). The homeostasis of Plasma Calcium and Phosphate. Folia Med. Neth. 11: 161-78.

Blum, J.W., G.P. Mayer and J.T. Potts (1974). Cited in the Biochemistry and Physiology of Bone IV (ed. G.H. Bourne). Acad. Press N.Y. pp

Braithwaite, C.D. (1974). The effects of changes of dietary calcium concentration on calcium metabolism in sheep. Br. J. Nutr. 31: 319.

Bronnner, F. (1964). Dynamics and function of calcium. In Mineral Metabolism (eds. F. Bronner and C.L. (omar). Vol. 2A 342-427 Acad. Press. N.Y.

Bruce, J., E.D. Goodall, R.N.B. Kay, A.T. Philipson and E. Vowels (1966). The flow of organic and inorganic materials through the alimentary tract of the sheep. Proc. Roy. Soc. B. 166:46-62.

Burroughs, W., N.A. Frank, P. Gerlangh and R.M. Benthke (1950). Preliminary observations upon factors influencing cellulse digestion by rumen microrganisms. J. Nutr. 40: 9

Burroughs, W., A. Lantona, P. De Paul and R.M. Benthke (1951). Cited in Re actions in the Rumen (eds. A.J.G. Barnett and R.L. Reid). Arnold Publishers. pp. 170 - 203.

Bryant, M.P. and D. Robinson (1959). Factors necessary for the growth of Bacterioides succinogenes in the volatile acid fraction of the rumen. J. Dairy Sci. 38: 340.

Chapman, A.L., A.G.C. Kastelics, P.G. Homeyer, C.Y. Roberts, D.V. Catron and V.C. Speer (1962). Calcium and phosphorus requirement of growing finishing swine. J. Animal Sci. 21:112.

Chineme, C.N., L. Krook and W.G. Pond (1976). Bone pathology in hypervitaminosis D. An experimental study in young pigs. Cornell Vet. 66 (3) : 387-412

Clark, R.C., O.E. Budzt-Olsen, R.B. Cross, P. Finnamore and P.A. Bauerl (1973). The importance of the salivary glands in the maintenance of phosphorus homeostasis in the sheep. Austr. J. Agric. Res. 24: 913-19

Coates, M.E. and E.S. Holdsworth (1961). Vitamin D3 and the absorption of calcium in the chick. Br. J. Nutr. 15 : 131

Colovos, N.F., H.A. Keener, A.E. Teeri and H.A. Davies (1951). Cited in Clinical Biochemistry of Domestic Animals Vol. 2 (eds. J.J. Kaneko and C.E. Cornelius).

Compere, R. (1967). Cited in the Phosphorus requirement of preganant sheep. J. agric. sci. Camb. 86:584 - 594

Compere, R. S. Vanuytrecht and J. Fabry (1965). Cited in Digestive Physiology and Nutrition of Ruminants Vol. 2 (ed. D.C. Church). Publ. D.C. Church.

Copp, D.H., E.S. Cameron, B.A. Cheney, A.G.F. Davidson and K.G. Henze (1962). Evidence for calcitonin - a new hormone from the parathyroid that lowers blood calcium. Endocr. 70:638-49

Copp, D.H., C.E. Brooks, B.S. Low, F. Newsome and V. Walker (1969). (41) Endocrine control of calcium homeostasis. J. Endocr. 43:137-61

Davidson, K.L. and W. Woods (1961). Calcium and corn oil interrelationships as influencing ration utilization by lambs. J. Animal Sci. 20:532

Dowe, T.W. J. Matsushima and V.H. Arlhaud (1957). The effects of adequate and excessive calcium when fed with adequate phosphorus in growing rations for beef steers. J. Animal Sci. 16:817.

Drake, T.G., S.H. Jackson, F.F. Tisdal and W.M. Johnson (1949). The biological availability of calcium in bone. J. Nutr. 37:369.

Driver, P.M., A. Elshabat, T.G. Boaz, J.M. Forbes and C.G. Scannes (1974). Increase in serum prolactin in sheep associated with long day-length and feeding ad libitum. J. Endocr. 63:46

Duckworth, J.W. Golden and W. Thompson (1943). The relation between rates of growth and rickets in sheep on diets deficient in vitamin D. J. Agric. Sci. Camb 33: 190.

Duncan, D.B. (1945). Multiple Range and Multiple F Tests. Biometrics 11:1

Dutton, J.E. and J.P. Fontenot (1967). Effect of dietary organic phosphorus on magnesium metabolism in sheep. J. Animal Sci. 26: 1409.

Ema, A.N. (1978). Some blood profiles of sheep fed raw cottonseed with special reference to bone metabolism. Paper presented at the 5th Annual Conference of Animal Production Association of Nigeria, March 1978.

Ewer, T.K. (1951a). Rickets in sheep 1. The experimental production of rickets in young sheep. Br. J. Nutr. 5: 287-300

Field, A.C., N.F. Suttle and R.G. Gunn (1974). Effect of age and state of incissor dentition on faecal and urinary output of nitrogen and minerals of sheep grazing hill pastures. J. agric. Sci. Camb. 83: 151-60

Field, A.C., N.F. Suttle and D.I. Nisbet (1975), Effect of diets low in calcium and phosphorus on the development of growing lambs. J. agric. Sci. Camb. 85:435-442.

Fiske, C.H. and Y. Subbarow (1925). The colorimetric determination of phosphorus. J. Biol. Chem. 66:365.

Forbes, E.B., R.B. French and W. Letonoff (1929). The mineral metabolism of beef steer. J. Nutr. 1:201.

Fournier, P. (1954). Cited in Calsium and Phosphorus Metabolism (ed. J.T. Iruing). Acad. Press N.Y.

Franklin, M.C (1934). An investigation of the nutritional and biochemical effects of a low calcium diet on sheep. Univ. Camb. Inst. An. Path. 4:111-78.

Franklin, M.C., R.L. Reid and I.L. Johnston (1948). Dietary and other factors affecting serum calcium levels in sheep. Australian C.S.I.R.O. Bull. 240.

Fraser, A. (1934). A study of the blood of cattle and sheep in health and disease. Rep. Inst. An. Path. Camb. 1:114.

French, M.H. (1957). Nutritional value of tropical grasses and fodders. Herbage Abstr. 27:1-9.

Godden, W. and S.C. Ray. (1938). Cited in the Nutrient Requirements of Farm Livestock. No.2. Ruminants. ARC (London).

Hammond, J. (1932). Growth and Development of Mutton Qualities in the sheep. p.148. Edinburg. Oliver and Boyd.

Hansard, S.L. and J. Barth. (1962). Effects of dietary phytin and of calcium levels upon absoprtion and excretion of minerals by lambs. J. Animal Sci. 21:384.

Hansard, S.L., H.M. Crowdoer and W.A. Lyke (1957). The biological availability of calcium in feeds for cattle. J. Animal Sci. 16:437.

63

Hansard, S.L., C.L. Comar and M.P. Plumee (1954). The effects of age upon calcium utilization and maintenance requirements in the bovine. J. Animal Sci. 13: 25

Harrison, H.E. and H.C. Harrison (1960). Transfer of 45 Ca across the intestinal wall in vitro in relation to action of vitamin D and cortisol. Amer. J. Physiol. 199: 265.

Harrison, H.E. and H.C. Harrison (1963b). Na, K and intestinal transport of glucose, L-tyrosine, phosphate and calcium. Amer. J. Physiol. 205: 107.

Hodge, R.W. (1973). Calcium requirements of the young lamb II. Estimates of calcium requirements by the factorial method. Austr. J. Agric. Res. 24: 237

Hubbert, F., E. Cheng and W. Burroughs (1958). Cited in Reactions in the Rumen (eds. A.J.G. Barnett and R.L. Reid). Edward Arnold Publ. Ltd. London.

Humphreys, L.R. (1978). Tropical Pastures and Fodder Crops. Interm. Trop. Agric. Services. Longman Group Ltd. London.

Irving, J.T. and J.D. Heelay (1970). Calif. Tissue Res. 6:254

Irving, J.T. (1973). In Calcium and Phosphorus Metabolism). Acad. Press N.Y.

Jones, J.M. and W.L. Stengel (1938). Cited in The Nutrient Requirements of Farm Livestock No. 2 Ruminants. ARC (London).

Kallfelz, F.A., A.W. Taylor and R.H. Wasserman. (1967). Vitamin D induced calcium bineling factor in rat intestinal mucosa. Proc. Soc. Exp. Biol. Med. 125:54

73

Kaneko, J.J. and C.E. Cornelius (1970). In Clinical Biochemistry of Domestic Animals Vol. 1 pp. 313-347.

Kapu, M.M. (1976). The natural forages of Northern Nigeria. 1. Nitrogen and mineral composition of grasses and browse from the Northern Guinea Savanna and standing hays from the different savanna zones. Nig. J. Animal. Prod. 2 (2): 235.

Krook, L.L. Lutwak, K. McEntee, P. Henrikson, K Brown and S. Roberts (1971). Nutritional hypercalcitonism in bulls. Cornell Vet. 61 (4): 625-639.

Lansbury, J.T. (1960). A review of some limiting factors in the nutrition of cattle on the Accra Plains, Ghana. Trop. Agric. 35:185-92

Lansbury, J.T., R. Rose-Innes and G.L. Mabey (1965). Studies on Ghana grasslands: Yield and composition on the Accra Plains. Trop. Agric. 42 (1) : 1 - 18.

Leibholz, J. (1974). The flow of calcium and phosphorus in the digestive tract of the sheep. Austr. J. Agric. Res. (1974): 147 - 154.

Lengemann, F.W. and J.W. Dobbins (1958). The role of bile acids in calcium absorption. J. Nutr. 66:45.

Lofgreen, G.P. (1960). The availability of the phosphorus in dicalcium phosphate, bonemeal, soft phosphate and calcium phytake for mature whethers. J. Nutr. 70: 58-62.

Long, T.A., A.D. Tillman, A.B. Nelson, B. Davies and W.D. Gallup (1956). Dicalcium phosphate and soft phosphate with colloidal clay as sources of phosphorus for beef heifers. J. Animal Sci. 15:112.

Lueker, J.H. and G.P. Lofgreen (1961). Effects of intake and calcium to phosphorus ratio on absorption of these elements by sheep. J. Nutr. 74: 233-38.

Mackenzie, D. (1967). Goat Husbandry. Faber and Faber (London).

MacIntyre, I. S. Hanna, C.C. Booth and A.E. Read (1961). Intracellular magnesium deficiency in a case of idiopathic steatorrhea. Clin. Sci. 20: 297.

Majundar, B.N. (1962). In Handbook of Animal Husbandry. (eds. S.K. Sen and P. Nath). New Delhi. Indian Counc. Agric. Res. p. 75.

Manston, R. (1967). The influence of dietary calcium and phosphorus concentration on their absorption in the cow. J. agric. Sci. Camb. 68: 263

Martin, C.J. and A.W. Peirce (1934). Studies on the phosphorus requirement of sheep 1. The effect on young Merino sheep of a diet deficient in phosphorus but containing digestible protein and vitamins. Bull. Counc. Sci. Ind. Res. 77: 5-44.

Mathur, N.L. (1953). Assimilation of phytin phosphorus by dairy cows. Indian J. Vet. Sci. 4: 243.

Mayer, J.S. and W. Abdel-Bari (1966). Thyrocalcitonin-like activity in medullary carcinoma of the thyroid gland. New Englamd J. Med. 278:523

McCance, R.A. and E.M. Widdowson (1942a). Mineral metabolism of heathy adults on white and brown dietaries. J. Physiol. (London). 101:44.

McCance, R.A., E.M. Widdowson and M. Lehman (1942). The effect of protein intake on the absorption of calcium and magnesium. Biochem. J. 36:686.

McDonalds, P., R.A. Edwards and J.F.D. Greenhalgh (1973). Animal Nutrition (2nd ed.). p. 449 Longman Group (London).

McLean, F.C. and A.B. Hastings (1935). The state of calcium in the fluids of the body. 1. The conditions affecting the ionization of calcium. J. Biol. Chem. 108: 285.

McRoberts, M.R., R. Hill and C. Dalgarno (1965). The effects of diets deficient in phosphorus, phosphorus and vitamin D, or clacium, on the skeleton and teeth of the growing sheep 1. The mineral status of the skeleton and the clinical appearance of the teeth. J. agric. Sci. Camb. 65:1-10.

Melanon, M.J. and H.F. DeLuca (1970). Cited in the Biochem. and Physiol of Bone II. pp. 282-329. (ed. G.H. Bourne). Acad. Press N.Y.

Mitchell, H.H. and F.J. Mcclure (1937). Mineral nutrition of farm animals. N.R.C. Bull. 99.

Mitchell, H.H. and E.G. Curzon (1939). The dietary requirements of calcium and its significance. Herman Press, N.Y.

Mitchell, H.H. (1947). The mineral requirements of farm animals. J. Animal Sci. 6:356-377.

Mitchell, H.H. (1964). In Comparative Nutrition of Man and Domestic Animals. Vol. II. Acd. Press.

Molokwu, E.C.I., N.N. Umunna and S.M. Dennis (1979). Effect of phosphorus and vitamin A on reproduction in the brown goats of Nigerian Savanna zone.
Nig. J. Agric. Sci.1 (2) : 107-112.

Moore, J.H. and C. Tyler (1965). Studies on the intestinal absorption and excretion of calcium and phosphorus in the pig.
Br. J. Nutr. 9 : 63-93.

102

Morrow, D.A. (1969). Phosphorus deficiency and infertility in dairy heifers. J. Amer. Vet. Med. Assoc. 154: 762.

Morris, S. and S.C. Ray (1939). Cited in The Nutrient Requirements of Farm Livestock No. 2 Ruminants. ARC (London)

Moxon, A.L., T.N. Danielson and L.E. Johnson (1947). Blood calcium and phosphorus level in range cattle. J. Animal Sci. 6:489.

Mudgall, V.D. and S.N. Kay (1967). Cited in Digestive Physiology and Nutrition of Ruminants 2. (ed. D.C. Church). D.C. Church publishers.

National Research Council (1975). Nutrient Requirements of Domestic Animals. No. 5. Nutrient Requirement of sheep (5th rev. edn.). Publ. Natn. Res. Counc. Washington D.C.

Neal, W.M. and A.L. Shealy (1933). Stiffs or sweeny (phosphorus deficiency) in cattle. Florida Agric. Expt. Sta. Bull. 264

Neuman, W.F. and M.W. Neuman (1958). The Chemical Dynamics of Bone Mineral. Univ. of Chicago Press, Chicage.

Nicholaysen, R. (1951). Physiology of calcium metabolism Physiol. Revs. 33: 434.

Nordin, B.E.C., M. Peacock and R. Willinson (1972). In Calcium, P.T.H. and Calcitonin (eds. R.V. Talmage and P.L. Munson). pp. 263-7.

Norman, A.W., A.K. Mitchell, T.H. Adams and A. Spielvegal (1970). In Calcium and Phosphorus Metabolism. (ed. J.T. Irving) Acad. press. N.Y.

Norman, A.W. and H. Henry (1974). 1, 25-dihydroxychole-calciferol (1, 25 DHCC): A hormonally active form of vitamin D. Rec. Progr. Horm. Res. 30: 431-80.

113

Oduye, O.O. and B.K. Adadevoh (1976). Biochemical values in apparently normal Nigerian sheep. Journ. Nig. Vet. Med. Assn. 5 (1): 43-50

Oltjen, R.R., G.R. Waller, A.B. Nelson and A.D. Tillman (1963). Ruminant Studies with diammenium phosphate and Urea. J. Animal Sci. 22: 36.

Oyenuga, V.A. (1958). Problems of Livestock nutrition in Nigeria. Nutr. Abstr. Revs. 28: 985-1000.

Parsons, J.A. and J.T. Potts. (1972). In Biochemistry and Physiology of Bone IV (ed. G.H. Bourne) Acad. Press.

Parsons, J.A. (1976). Parathyroid physiology and the skeleton. In: Biochemistry and Physiology of Bone IV (ed. G.H. Bourne) Acad. Press.

Perez, C.B., R.G. Warner and J.K. Loosli (1967). Evaluation of Urea-Phosphate as a source of nitrogen and phosphorus for ruminants. J. Animal Sci. 26: 810

Potts, J.T. Jr., R.M. Buckle, L.M. Sherwood, C.E. Ramberg, G.P. Majer, D.S. Kronfield and G. Aubarch (1968). Cited in Parathyroid Hormone and Calcitonin (eds. R.V. Talmage and L.F. Belanger). pp. 407-416. Acad. Press, N.Y.

Preston, R.L. and W.H. Pfander (1964). Phosphorus metabolism in lambs fed varying phosphorus intakes. J. Nutr. 83: 369-378.

Ragsdale, A.C., H.J. Thompson, D.M. Worstell and S. Brody (1950). Missour Agric. Expt. Station Res. Bull. N. 460.

Raisz, L.G. (1970). Cited in the Biochemistry and physiology of Bone IV. (ed. G.H. Bourne). Acad. Press, N.Y.

Rasmussen, H. and J. Bordier (1974). The Physiological and cellular basis of metabolic bone disease. Williams and Wilkins, Baltimore, Maryland.

Raun, A.E. Cheng and W. Burroughs phytate phosphorus hydrolysis and availability to rumen microorganisms. J. Agric. Food Chem. 4:869.

Reinarch, N. and G. Louw (1958). The utilization of phosphorus from different sources by rat. J. Vet. Sci. 27: 617.

Richardson, D., F.H. Baker, E.P. Smith and R.F. Cox (1961). Phosphoric acid as a phosphorus source for beef cattle. J. Animal Sci. 20:522.

Ridall, W.H., J.S. Hughes and J.B. Fitch (1934). The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Tech. Bull. No. 36. Kansas Agric. Expt. Station.

Robertson, J.D. (1941). The molecular structure and contact relationships of cell membranes. Lancet 2:129.

Roberts, W.K. and J.A. Mckirdy (1964). Weight gains, carcass fat characteristics and ration digestibility in steers as affected by dietary rapeseed oil, sunflower seed oil and animal fallow. J. Animal Sci. 23:682.

Schacter, D. and S.M. Rosen (1959). Active transport of 45-Ca by the small intestine and its dependence on vitamin D. Amer. J. Physiol. 196:357-62

Schacter, D., E.B. Dowells and H. Shenker (1960a). Cited in Calcium and Phosphorus Metabolism (ed. J.T. Irring). Acad. Press, N.Y.

Schacter, D., D.V. Kimberg and H. Shenker (1961). Active transport of calcium by the intestine: Action and bio-assny of vitamin D. Amer. J. Physiol. 200:1263.

Shaw, T. and G. Colville (1950), Report of The Nigerian Livestock Mission pp. 69-76. H.M.S.O. London

Sherman, M.C. (1935). Cited in The comparative Nutrition of Man and Domestic Animals (ed. H.H. Mitchell) Vol. 1 Acad. Press N.Y.

135

Shohl, A.T. (1939). Mineral Metabolism. Reinhold Publ. N.Y. 384 pp.

Simmons, D.J. (1976). Comparative Physiology of Bone: In the Biochemistry and Physiology of Bone IV. (ed. G.H. Bourne). Acad. Press pp 479-488.

Smith, A.H., M. Kleiber, A.L. Black and C.F. Baxter (1955). Transfer of phosphate in the digestive tract of sheep. J. Nutr. 57: 507-27.

Smith W.G., R.H. Davies and P. Fourman (1960). Calcium deprivation in hypoparathyroidism Lancet 2: 51--513.

Stanbury, S.W. and G.A. Lumb (1966). Parathyroid function in chronic renal failure. Q. J. Med. 35: 1-24

Steel, R.G.D. and J.H. Torrie (1960). Principles and Proceedures of Statistics. McGraw-Hill Book Co. New York.

Stewart, J. (1935). The effects of phosphorus deficient diets on the metabolism, blood and bones of sheep with special reference to conditions existing in Great Britain. Univ. Camb. Inst. Physiol. 4: 179-205.

Stillings, B.R., J.W. Bratzler, L.F. Marriot and R.C. Miller (1964). Utilization of magnesium and other minerals by ruminants consuming low and high nitrogen forages and vitamin D. J. Animal Sci. 23: 1148.

Sur, B. and V. Subrahmanyan (1952). Availability of calcium in lucerne and its value in nutrition. Indian J. Med. Res. 40: 481

Suttle, N.F. and A.C. Field (1966). Studies on magnesium in ruminant nutrition. Effect of intake of water on the metabolism of magnesium, calcium, sodium, potassium and phosphorus in sheep. Br. J. Nutr. 20:609

Suttle, N.F. (1968). Some consequences of mineral imbalance. Proc. 2nd Nutr. Conf. for Feed Manufacturers. Univ. Notingh. Sch. Agric. (eds. H. Swan and D. Lewis).

146

Sykes, A.R. and R.A. Dingwall (1976). The phosphorus requirement of pregnant sheep. J. agric. Sci. Camb. 86: 584-594.

Talapatra, S.K., S.C. Ray and K.C. Sen (1948). Calcium assimilation in ruminants on oxalate - rich diet. J. agric. Sci. Camb. 38:163.

Talmage, R.V. and P.L. Wunson (1975). Calcium, PTH and Calcitonin. In Biochemistry and Physiology of Bone IV (ed. G.H. Bourne). Acad. Press.

Tanaka, Y. and H.F. DeLuca (1971). Cited in the Biochemistry and Physiology of Bone II. (ed. G.H. Bourne). Acad. Press N.Y. pp 296-325.

Theiler, A. and H.H. Green (1932). Aphosphorosis in ruminants. Nutr. Abstr. Revs. 1: 359

Thompson, A., S.L. Hansard and M.C. Bell (1959). The influence of aluminium and zinc upon the absorption and retention of calcium and phosphorus in lambs. J. Animal Sci. 18:187

Tillman, A.D. and J.R. Brethour (1958a). Dicalcium phosphate and phosphoric acid as phosphorus sources for beef cattle. J. Animal Sci. 17:100

Tillman, A.D. and J.R. Brethour (1958b). Utilization of phytin phosphorus by sheep. J. Animal Sci. 17: 104-112.

Tillman, A.D. and J.R. Brethour (1958c). The effect of corn oil upon the metabolism of calcium and phosphorus by sheep. J. Animal Sci. 17: 782-6

Tomas, F.M. and M. Somers (1974). Phosphorus homeostasis in sheep 1. Effect of ligation of parotid salivary ducts. Austr. J. Agric. Res. 25 : 475-83

Tomas, F.M. (1974a). Phosphorus homeostasis in sheep III. Relationship between the amount of salivary phosphorus secreted and the quantities of phosphorus excreted via the urine and faeces. Austr. J. Agric. Res. 25: 495 - 500.

Towns, K.M., R.C. Boston and D.D. Leaver (1978). The effect of intravenous administration of phosphorus on calcium metabolism in sheep. Austr. J. Agric. Res. 29: 587

Underwood, E.J. (1966). The Mineral Nutrition of Livestock. F.A.O. and Comm. Agric. Burr. Publ. Central Press. Aberdeen.

Van der Wath (1942). Thesis, University of Pretoria. cited in Reactions in the Rumen (eds. A.J.G. Barnett and R.L. Reid). Edwards Arnold Publ. London.

Varner, L.W. and W. Woods (1972). Effect of calcium and starch addition upon ration digestibility by steers. J. Animal Sci. 35: 410-414

Walthall, J.C. and R. McKenzie (1976). Osteodystrophia fibrosa in horses at pasture in Queensland. Field and Laboratory observations. Austr. Vet. Journal 52:11-16

Wasserman, RH., C.L. Comar and M.M. Nold (1956). The influence of amino acids and other organic compounds on the gastrointestinal absorption of calcium - 45 and strontium - 89 in the rat. J. Nutr. 59: 371

Wasserman, R.H., C.L. Comar, J.C. Schooley and F.W. Lengemann (1957). Interrelated effects of L - lysine and other dietary factors in the gastrointestinal absorption of calcium - 45 in the rat and chick. J. Nutr. 62: 367.

Wasserman, R.H. and F.A. Kallfelz (1962). Vitamin D_3 and the unidirectional calcium fluxes across the rachitic chick duodenum. Am. J. Physiol. 203: 221

Wasserman, R.H. and A.N. Taylor (1966). Vitamin D_3 induced calcium binding protein in chick intestinal mucosa. Science 152:791.

Wasserman, R.H. and A.N. Taylor (1973). Intestinal absorption of phosphate in the chick effect of vitamin D_3 and other parameters. J. Nutr. 103: 586-99.

Webbling, D. and E.S. Holdsworth (1965). The effect of bile acids and detergents on calcium absorption in the chick Biochem. J. 97:408.

168