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**EFFECT OF PHOSPHORUS AND CALCIUM SUPPLEMENTATION
ON GROWTH PERFORMANCE OF COMMUNALLY GRAZED
GOATS IN A SEMI -ARID AREA**

BY

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Agriculture, Science and Technology, North West University**

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DECLARATION

I declare that, this dissertation has never been submitted by me or any other person in this or any other University for a degree, I confirm that this is my own work in design and execution and that all material contained herein has been duly acknowledged.

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ABSTRACT

The purpose of this study was to assess whether there exists a mineral deficiency especially phosphorus, calcium and magnesium in communally grazed “village” goats. Phosphorus deficiency has been reported to occur in both cattle and sheep in this region but not in goats. There is therefore a need to conduct this research to find the state of mineral concentrations of the above elements in the blood and faeces of goats as well as the pasture which they graze. This study was conducted at the Mafikeng University Campus, North West Province, South Africa. A total number of 24 female village goats, averaging one year of age and in different physiological states, were purchased from local farmers around Mafikeng. The goats were randomly grouped into two, the control and the supplemented groups. The supplemented group was fed dicalcium phosphate ad libitum in the evenings from June 2011 to May 2012. Faecal, blood and grass samples were collected monthly. Individual animals were also weighed on a monthly basis. Dicalcium phosphate supplement mildly influenced both faecal and serum P levels in treated goats compared to the untreated group. However, dicalcium phosphate supplemented goats, displayed more ($P < 0.05$) serum Ca and Mg concentrations indicating the significance of providing Ca and P supplements to grazing communal goats in this region. In terms of body mass gain, Ca and P supplemented goats also outperformed the unsupplemented goats throughout the trial period. There is a need therefore to supplement calcium and phosphorus to communally grazed goats so as to maintain normal body mass, serum calcium, magnesium and phosphorus levels.

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CHAPTER 1

1. INTRODUCTION

Before the 1990s, mineral supplements of goats were considered to be intermediate between those of cattle and sheep. Advances in mineral nutrition of goats in the last twenty years have occurred and show that some specific deficiencies exist for most of the macro-elements and trace elements (Meschy, 2000). In Southern Africa there is scarcity of mineral deficiency reports in goats except that of Goedegebuure and Obwolo (1996). In Eastern Africa, sodium, phosphorus, cobalt, zinc and manganese deficiencies have been reported in goats in several areas (Yami, 2005; Lengarite et al., 2012). Experiments conducted by Meschy (2000) in Spain showed that pregnant does had signs of phosphorus and calcium deficiencies due to multiple foetuses. The experiments indicated that goats were very sensitive to low levels of copper and selenium. Low levels of these elements lead to white muscle disease. Mineral deficiencies in goats have also been reported in Mexico where calcium and magnesium deficiencies reduced performance under natural range conditions (Mellado et al., 2004). In South Africa, there is scarcity of reports on mineral deficiency in goats. Mineral requirements for goats are extrapolated from those of sheep and farmers offer winter licks to sheep and goats in the same proportions (Groenewald and Boyazoglu, 1980). Read et al. (1986) found that sheep grazing natural pasture were phosphorus deficient and therefore recommended regular phosphorus supplements to improve productivity. Since the work of Read et al. (1986) was done in the same geographical area as Mafikeng, there is a need to assess whether goats also are prone to phosphorus deficiency although they are naturally browsers. Browse contains more mineral levels than grass (Groenewald and Boyazoglu 1980). Heinlein and Ramirez (2007) reported that communal goats fulfil multiple roles that include the provision of meat, milk, manure, skins and mohair. Phosphorus can be provided directly to grazing livestock in phosphatic salt licks and blocks and also in the water-supply (Miller et al. 1990). Yami (2005) found that phosphorus is a macro mineral required by all animals and is involved in many metabolic, neurological and cellular functions. In view of the lack of data on mineral deficiency in South Africa, there is a need to investigate this in the semi- arid areas of the North West Province. This study therefore investigated the levels of phosphorus and calcium in grass and the blood and faeces of goats. From the results of this

study it will be determined, whether phosphorus and calcium supplementation is necessary in communally-grazed goats in this area.

1.1 AIMS AND OBJECTIVES

1.1.1 Aims

The main aim of the research was to evaluate the levels of phosphorus and calcium in goat faeces and blood and in the pasture in the semi-arid area of the North West Province and to assess the effect of P and Ca supplementation on goat production in winter and summer seasons.

1.1.2 Objectives

The research objectives are:

- to assess pasture phosphorus, calcium and magnesium levels in dry and wet seasons.
- to assess whether phosphorus and calcium supplemented goats have higher serum and faecal phosphorus, calcium and magnesium levels in winter and summer as compared to the unsupplemented goats.
- to assess the effect of P and Ca supplements on body mass gain of communally grazed goats in summer and winter.

CHAPTER 2

2 LITERATURE REVIEW

In the low rainfall areas of Africa and Asia, small ruminant production is the principal economic activity, contributing a large share to the income of farmers (Ben Salem and Smith, 2008). Throughout the tropics, mineral deficiencies and imbalances exert a significant effect on the health and productivity of livestock (Aregheore et al., 2007). Minerals play an important role in growth, health and reproduction of livestock (Gonul et al., 2009). According to Kincaid (1999), mineral deficiencies and imbalances can affect the productivity of ruminants. In arid areas of Kenya, sheep and goats depend on natural forages, salt licks and occasionally commercial supplements for their mineral requirements. However, there is considerable variability in the levels of minerals in forages and mineral mixes (Corah, 1996). Minerals can be classified as macro and micro minerals. Calcium, phosphorus, magnesium, sodium, sulphur and chlorides are a few of the macro minerals needed in a goat's diet. Micro minerals usually supplemented in goat rations are iron, copper, cobalt, manganese, zinc, iodine, selenium, molybdenum and others. Feed tags report micro minerals as part per million (ppm) and macro minerals as percentages (Mamoon, 2008). The results of experiments performed by Meschy (2000) in Spain showed that pregnant does had signs of phosphorus and calcium deficiencies due to multiple foetuses. Certain grazing lands in many countries can be used properly for livestock production only when P supplementation is instituted (Goedegebuure and Obwolo 1996). Fertilizing grass-legume pastures with P may result in increased preference by cattle even though forage mineral analysis is comparable to similar unfertilized pasture (Jones, 1990). Phosphorus metabolism has been studied for many years, but the current focus on the environment has increased interest in mineral research (Valk et al., 2000). Moreover, excess P excreted in faeces represents an unnecessary cost to farmers. According to Bravo et al. (2003), knowledge about the mineral content of feedstuffs and P quality, as well as understanding of P kinetics, is beginning to affect P supplementation. Chapuis-Lardy et al. (2004) suggested that limestone used as a Ca supplement in the diet can affect faecal excretion of Ca and P because of Ca- P complex formation along the digestive tract reducing the bioavailability of both minerals. Hubber et al. (2009) reported that P homeostasis affected by high or low Ca and/ P supply in preruminant goats was characterised by balance studies in vivo. The main excretion pathway was the renal P excretion the extent of which was modulated by variations in dietary P and/

or Ca supply. Huber et al. (2009) further stated that faecal P excretion remained low irrespective of dietary regime. Calcium (Ca) can influence phosphorus (P) utilisation because of their close metabolic relationship (Tamim and Angel, 2003). According to Valk et al. (2002), dairy cows mobilize P from body reserves to compensate for excretion of P in milk and faeces. According to Wu et al. (2000), resorption and formation of bone can occur simultaneously, but net change in bone P storage in dairy cows may vary with stage of lactation and cows undergo a net loss of both Ca. and P from bone to help them to supply these elements during early lactation. Wu et al (2000) also mentioned that 0.37% dietary P did not affect bone P content or strength. Because the feed of goats is scarce, they have little choice of feed, resulting in poor body condition and low weight gains and higher predisposition of the animals to heavy helminth burdens (Calderia et al., 2007). According to Bravo et al. (2003), phytate P is hydrolysed by phytase produced by microbes in the rumen. Nevertheless, enzyme efficiency can be altered by different factors such as feed treatment, presence of Ca and Mg, rumen Ph and amount of phytate P in the diet.

Table 1. Acceptable Quantities of Macro and Micro Minerals in a Goat's Diet (Mamoon, 2008)

Macro minerals (%)		Macro minerals (ppm)	
Calcium (Ca)	0.3-0.8	Iron (Fe)	50-1000
Phosphorus (P)	0.25-0.4	Copper (Cu)	10-80
Sodium (Na)	0.2	Cobalt (Co)	0.1-10
Potassium (K)	0.8-2.0	Zinc (Zn)	40-500
Chloride (Cl)	0.2	Manganese (Mn)	0.1-3
Sulphur (S)	0.2-0.32	Selenium (Se)	0.1-3
Magnesium (Mg)	0.18-0.4	Molybdate (Mo)	0.1-3
		Iodine (I)	0.5-50

2.1 Essential role of minerals in livestock

Mammalian body systems require minerals for certain metabolic activities to take place. The essential ones include: P, Ca, Mg and Na (Table 1). Minerals also serve as intracellular buffer in the body fluids (Underwood, 1981). Insufficient supplies of phosphorus in the body, therefore, results in the rate and efficiency of growth tissues being depressed. Sometimes multiple mineral deficiencies occur, aggravating the complexity of the clinical symptoms as shown in a combined vitamin E and selenium deficiency (Blood et al. 1983). Lack of other minerals in pasture may also aggravate the effect of the others.

2.2 Sources of minerals for grazing stock

The soil is one of the sources of mineral elements and naturally most mineral deficiencies will occur in livestock grazing pastures poor in soil minerals (McDowell, 1985). Mineral deficiencies may also occur as a result of abnormal absorption caused by other factors even though a diet may contain adequate amounts of particular elements. Tissue and fluid indicators have been suggested to portray more accurately, the mineral status of livestock rather than the contribution from the total environment (soil and water) (McDowell, 1987). Minerals play a vital role in forage digestion, reproductive performance, and the development of bones, muscle, and teeth. According to Underwood and Suttle (2001), sub clinical traces mineral deficiencies occur more frequently than recognised by most livestock producers. Mahusson et al. (2004) reported that calcium, phosphorus and magnesium have a high diagnostic value in determining the nutritional status of animals due to their low variability in blood. Phosphorus is required for normal milk production, growth and efficient use of feed and by the rumen microorganisms in the digestion of cellulose and synthesis of microbial protein.

2.3 Phosphorus (P)

2.3.1 Functions of Phosphorus in the body

Phosphorus (P) has more known functions in the animal body than any other element. It is a part of bone structure, component of some proteins, lipids and nucleic acids. P takes part in the development and maintenance of skeletal tissue (Ternoth, 1990). The skeleton acts not only as a support, but also as a reservoir of Ca and P from which the rest of the body can draw. It undergoes a continuous process of absorption and release together with Ca particularly during animal pregnancy and lactation in ruminants and for hens, during the laying period (MacDowell, 1987). Minerals play an important role in the maintenance of osmotic pressure and acid base balance. Phosphorus plays a major role in the maintenance of osmotic pressure, buffer capacity and acid-base balance (Mamoon, 2008). In addition, P plays an important role in energy regulation. Phosphate molecules such as adenosine triphosphate (ATP) are universal accumulators and donors of energy. They are present in all body cells and ensure both the storage of energy and its utilisation. ATP is of prime importance in muscular activity during which chemical energy is converted into mechanical energy (Hale and Olson, 2005). P compounds are involved, directly or indirectly in major physiological functions such as protein synthesis, transport of fatty acids and amino acid exchange. Phosphorylation is responsible for intestinal absorption, glycolysis, direct

oxidation of carbohydrates and renal excretion. Phosphorus is also a component of a large number of co-enzymes (Hale and Olson, 2005). Ternouth (1990) further reported that rumino-reticulum P levels are normally at or above levels necessary for optimal microbial activity even when animals are on a P- deficient diet. According to Hale and Olson (2005), phosphorus is also involved in the chemical reactions of energy metabolism. They further reported that deficiency of phosphorus results in decreased animal performance, including reduced weight gain, poor reproductive efficiency and low milk production. Worldwide, phosphorus deficiency is reported to be the most prevalent mineral insufficiency in grazing livestock. Phosphorus is further involved in the control of appetite in a manner not yet fully understood and in the efficiency of feed utilization (Ternouth, 1990). Wang et al. (1985) reported that disturbances of glycolytic metabolism have been noted in erythrocytes from phosphorus-deficient cattle. In ruminants, the rumen and caecolonic micro flora also require high P diets (Petri et al., 1989, Ternouth 1990).

2.3.2 Phosphorus deficiencies

The phosphorus element deficiency has been reported to be the most widespread and economically important of all the mineral deficiencies affecting grazing livestock in the world (McDowell et al., 1984; McDonald et al.1988; Underwood, 1981). Severe a phosphorus deficiency in cattle, leading to the development of a stiffened gait, swollen joints and a general reluctance to move has been reported in Southern Africa (Beighle, 2000; Mokolopi and Beighle, 2006). Without an adequate supply of P, an animal will suffer from P deficiency, the consequences of which are varied. In all cases, however; it affects the animal's physical well being, as well as its economic performance. The initial effect is a fall in blood plasma phosphate levels followed by the response mechanism of Ca and P being withdrawn from the animal's bones. Apart from a generally lower resistance to infection, it also results in loss of appetite and a reduction in live weight gain due to impaired feed efficiency. Tallam et al. (2005) reported that dietary P did not affect the number of days to first postpartum ovulation or the diameter of ovulated dormant and ovulation follicles. Reports on the effect of dietary P on estrus and ovulation in cattle have been inconsistent. Tallam et al (2005) further stated that dietary P amount did not influence corpus luteum development or blood progesterone concentration.

Deficiency symptoms become more pronounced when conditions for animal husbandry are not ideal. These include reduced egg yield, as well as a reduction in shell thickness and

hatchability, often accompanied by 'cage layer fatigue syndrome' and osteomalacia in laying hens. Maintaining the correct Ca: P ratio is essential to ensure that the birds do not develop rickets which may lead to economic loss (Merck, 2010). In sows phosphorus deficiency may cause reduced fertility, posterior paralysis (Downer Syndrome) and osteomalacia, leading to a shorter animal life cycle and reduced productivity. In fattening pigs, reduced growth rates are some of the symptoms of P deficiency, feed efficiency is the most common sign observed. Development of rickets results in total loss of calcium and phosphorus while bone breakage during transport results in economic loss. In cattle, lower feed utilisation and intake, reduced fertility, irregular or suppressed ovulation, and lower conception rates are some of the symptom of P deficiency. Other symptoms include reduced milk yield, lameness, and stiffness of gait and in severe instances, enlarged and deformed joints and bones. In general like in cattle, the deficiency of phosphorus in ruminants is primarily reflected in retarded growth, poor reproductive performance, reduced milk yield, reduced wool growth and impaired skeletal health (Hemingway, 1967; Underwood, 1966; McDowell, 1985). In addition, in cattle, P deficiency is manifested as depraved appetite or pica and frequently chewing of bones, which may result in a higher incidence of botulism. Boyazoglu (1987), cited by Mazengera (1992) reported that these effects may be secondarily augmented during different physiological states of the animal, which require high nutritional demands especially during active growth, pregnancy and lactation. Several reports have revealed the beneficial effects of phosphorus supplementation on overall performance of livestock (Bischof, 1964; Beighle, 2000). In Southern Africa, most natural grazing lands in communal areas have poor quality pasture, which become very poor in mineral content especially in the dry seasons. This leads to low consumption of minerals by the animals resulting in mineral deficiencies (Bischof, 1964; Ndebele et al, 2005). Yami (2005) reported that young and growing animals were mostly affected. Deficiency symptoms are deformed bones, retarded growth and poor fertility and soil eating. Phosphorus (P) deficiency can result in reduced overall productivity in all types of cattle (Marcy, 2005). It has been reported that reduced reproductive performance however, may be a secondary effect due to reduced energy and protein intake (Marcy, 2005). However, Cohen (1975) and Ternouth (1990) indicated that there was not enough information to indicate whether P deficiency had a primary effect on reproduction and milk production or whether the effect was secondary, simply resulting from reduced feed consumption and consequently reduced energy and protein intake. The benefits of various P supplementation methods and feeding frequencies have been reported and it appears that free

choice feeding is probably the least reliable because animals may not consume enough P through this method. Both direct and indirect supplementation methods have been discussed more thoroughly by MacDowell (1987).

2.4 Calcium (Ca)

2.4.1 Functions of Calcium in the body

Calcium (Ca) is the most abundant mineral in the body and 99% is found in the skeleton (Underwood and Suttle, 2001). Calcium is required for healthy bones and teeth. Approximately 99% of the body's calcium is present in bones and teeth. Lloyd et al. (1978) reported that Ca and P are major mineral elements involved in the formation of body structures such as bones and teeth where they occur in crystalline form and as hydroxyapatite. Hale and Olson (2005) further stated that because of its importance in bone structure, deficiency of calcium in young animals leads to skeletal deformities. In older animals, fragile bones can result from extended periods of dietary calcium deficiency. Calcium is needed for many different functions in the body including blood clotting, formation and maintenance of bones and the development of teeth. Mammon (2008) reported that Ca gut absorption and or bone tissue metabolism seem important for the maintenance of appropriate calcium phosphate status (Michalek et al., 2008). It helps to lower cholesterol and helps prevent muscle cramps. Furthermore, it also helps with the synthesis of Deoxyribose Nucleic Acid and Ribonucleic Acid (Underwood, 1981). Its basic function is to provide a strong framework for supporting and protecting delicate organs (Underwood and Suttle, 2001).

2.4.2 Calcium (Ca) deficiency

Calcium deficiency has been reported to adversely affect young animals. It is characterised by deformed bones and retarded growth in young animals (Yami, 2005) and rickets and osteoporosis in older animals. Milk fever or lambing sickness is also a disease associated with a deficiency of calcium. Excess calcium reduces the absorption and utilisation of zinc. Ca deficiency in livestock may be primary or secondary, but in both cases, the end result is an osteodystrophy (Blood and Radostits, 1989). A primary calcium deficiency due to marginal Ca intake, aggravated by a high P intake is not uncommon (Blood and Radostitis, 1989). Ca deficiency may be expected if animals are fed mainly grain rations and receive small quantities of roughages or none at all (Blood and Radostitis, 1989). Such rations, if fed to hard worked or race horses, pigs, poultry and dogs, result in development of secondary calcium deficiency (Groenwald and Boyazoglu, 1980; Blood and Radostits, 1989). The

secondary Ca deficiency, which occurs in those animals, is often accompanied by a vitamin D deficiency because of the tendency to keep animals confined indoors. According to Blood and Radostits (1989), there are also well-recognised field reports of the occurrence of Ca deficiency in young sheep. However, excess magnesium decreases calcium absorption, replaces Ca in the bones, and increases calcium excretion. According to Nelson (1992), hypocalcaemia is a disease commonly seen in dairy cattle during or following calving. Sheep can experience hypocalcaemia during late pregnancy. This is associated with rapid calcium loss to the developing foetuses for bone mineralization. Nelson (1992) further stated that other species can experience hypocalcemia at or near the time of peak lactation (lactational eclampsia). Based on limited information available regarding goats, it seems dairy goats are potentially prone to all three manifestations of hypocalcaemia. Calcium can influence P utilization because of their close metabolic relationship (Tamim and Angel, 2003).

2.5 Magnesium (Mg)

2.5.1 Functions of Magnesium (Mg)

Magnesium is an essential cation, involved in many enzymatic reactions and also a cofactor to adenosine triphosphatases. It is critical in energy-requiring metabolic processes, in protein synthesis, membrane integrity, nervous tissue conduction, hormone secretion and in intermediary metabolism (Laires et al., 2004). Serum magnesium concentration is maintained within a narrow range by the small intestine and kidney which increase their fractional magnesium absorption under conditions of magnesium deprivation (Ghamdi et al., 1994). According to Herdt et al. (2000), grass tetany occurs when the level of magnesium in the blood falls below a critical threshold (below 1.2 mg per 100 ml).

2.5.2 Magnesium deficiency

Magnesium is inefficiently absorbed from the rumen. It plays a role in maintenance of blood Ca concentrations and hypomagnesaemia can induce hypocalcaemia. Besides mineral interactions, differences exist between grasses and legumes in Mg content. Grasses contain less Mg than legumes and when growing rapidly in cooler conditions (lush spring pasture), Mg availability is greatly reduced. Goats like other ruminants, have little ability to manage blood Mg concentrations if dietary levels or absorption are depressed. The combination of low intake coupled with greater losses during early lactation results in clinical hypomagnesia syndrome. According to Pugh (2002) hypomagnesaemia is a common problem in beef cattle

on spring pasture and is also sporadically seen in dairy cattle and small ruminants. Many clinical syndromes have been identified relative to disease circumstances, but all have hypomagnesaemia in common. Lactating cows on spring pasture are susceptible (grass tetany or lactation tetany) as well as growing kids on milk replacer (milk tetany). Goats deficient in magnesium have lowered urine and milk production and may become anorexic. Magnesium deficiency (grass tetany) usually occurs in lactating cows grazing grass-dominant pastures in late autumn and winter (Harris et al., 1983). The detrimental effect of low serum Mg levels on conception rates could be through an altered insulin secretion and sensitivity, which has been observed in Mg-deficient animals (Reis et al., 2000).

2.6 Indicators of mineral status in grazing livestock

Minerals have been recognised as potent nutrients and deficiency can impair utilisation of other nutrients (Szefer and Nriagu, 2007) and thereby animal performance. Minerals play an important role in growth, health and reproduction functions in livestock (Gonul et al., 2009). According to Kincaid (1999), mineral deficiencies and imbalances can affect the productivity of ruminants. However, sub-optimal mineral deficiency that affects growth and production is more serious than the manifested mineral deficiency showing clinical signs that can be corrected (Underwood and Suttle, 2001).

The liver and bone are the body parts most commonly used in the assessment of micro and macro element levels in animals respectively (Underwood and Suttle, 2001). Hall (2005) reported that the liver is the primary storage for many of the essential minerals, which can augment diagnosis of mineral deficiency and adequacy in animals. The hepatic tissue often represents the status of several trace elements in animals (McDowell, 1982). The bone has proven to be a good indicator of the level of Ca, P and Mg concentrations in animals (Beighle et al., 1993). In Kenya, Mtimuni et al. (1990) reported that information is required on interrelationships among minerals in soil, plant and animals. Since feeding is restricted, goats have little choice of feed, resulting in poor body condition and low weight gains and thereby a higher predisposition of animals to heavy helminth burdens (Calderia et al., 2007).

2.7 Mineral deficiency in dry and wet season

Communal rangelands provide the main source of energy and nutrients for free-ranging animals in subsistence agricultural systems and therefore, are important in sustaining

livestock in these systems (Scogings et al., 1999; Sanon et al., 2007). However, the reduced forage quantity and quality at the end of the dry season is widely recognised as the main constraint on animal production in communal rangelands (Scogings et al., 1999). In the wet season, forage is abundant and of high nutritional quality and in the dry season, forage is scarce and of low nutritional quality (Williams et al., 1996; Kanneganti et al., 1998, Devendra 1981, Nyamukanza et al., 2008). Corah (1996) found that in the arid area of Kenya, sheep and goats depend on natural forages, salt licks and occasionally commercial supplements for their mineral requirements. However, there is considerable variability in the level of minerals in forages and mineral mixes. According to Chew (2000), fluctuations in nutrient contents of the pasture results in the familiar pattern of growth rate of animals on native grasses, ie. rapid growth in rainy seasons followed by a loss of body weight in the dry seasons. According to Bakunzi et al. (2012), some farmers may supplement P impulsively in the winter season because that is when the pasture is so dry while others may also supplement in the summer seasons. Serum Ca concentration after parturition may reflect bone resorption (Tallam et al., 2005).

CHAPTER 3

3 MATERIALS AND METHODS

3.1 Study area

This research was conducted at the Molelwane Farm, in the Department of Animal Health, North West University, Mafikeng Campus, North West Province, RSA. Mafikeng is located at 25°52'S and 25°38'E, from June 2011 to May 2012.

3.2 Animal used

Twenty four female goats (village goats) between one to two years of age (as determined by dental eruption) were bought from local farmers around Mafikeng. The animals were randomly grouped into treated and control groups. The treated group was offered dicalcium phosphate ad libitum daily in the evenings until the end of the trial which lasted for twelve months. The control group was fed common salt ad libitum daily until the end of the trial. Both groups were weighed on the first day of the trial and every month thereafter up to the end of the trial period. Blood and faecal samples were also collected from the goats at the start of the trial and thereafter monthly up to the end of experimental period. The groups were housed separately at night in 30m x 30m shaded kraals where they received the salt supplements. All animals were released during the day and allowed to graze communally outside the university farm, together with cattle and sheep. The natural vegetation upon which the animals grazed comprises short grasses such as *Aristida* species, *Cenchrus* species, *Digitaria* species and *Arcacia* trees and bushes.

The meteorological data for Mafikeng for the trial period is shown in fig. 1

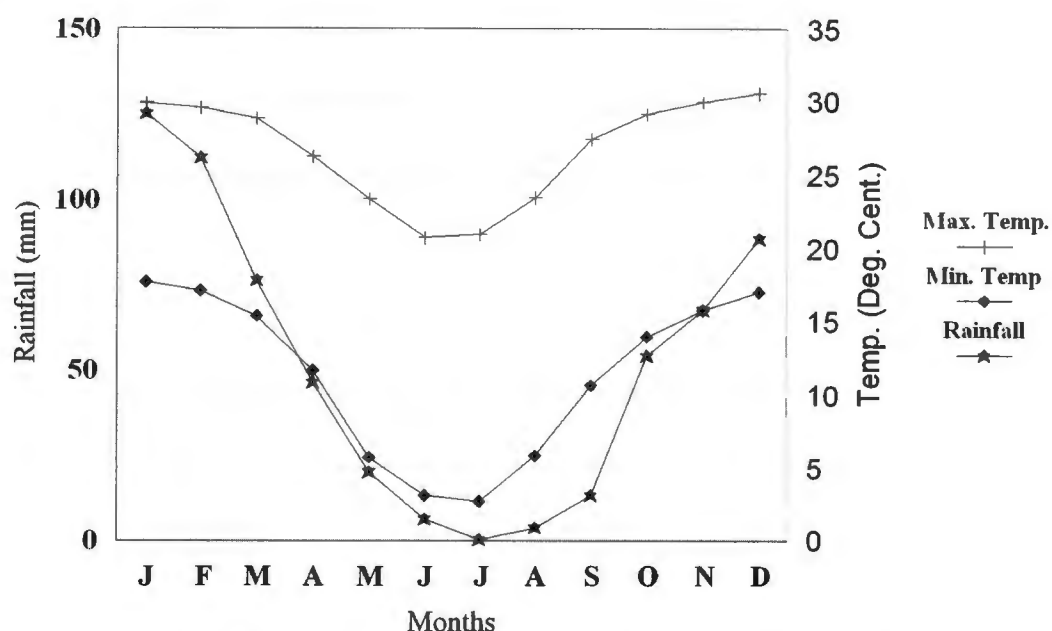


Figure 1. Average rainfall (mm) and temperature (°C) data for Mafikeng over the trial period (June 2011- May 2012)

3.3 PREPARATION OF LABORATORY EQUIPMENT

All necessary equipment (crucibles, volumetric flasks, McCartney bottles and glass beakers) used in the laboratory for digestion and analysis of faecal samples were soaked in 36% HCl and left overnight. They were then rinsed with distilled water 3 times the following day and dried in a hot oven for 16 hours at a temperature of 60°C. After drying, the crucibles were cooled in a desiccator for 16 hours. The dried crucibles were weighed to determine the empty weight.

3.4 SAMPLE COLLECTION

3.4.1 Faecal collection, digestion and analysis

3.4.2 Collection

A gloved hand was used to collect the faeces from the rectum after lubricating it with liquid paraffin. After drying the faecal samples in the sun, the samples were ground through a 2 mm screen after which 1g duplicate samples were weighed in the acid cleaned dried crucibles and their weights were recorded. The differences between the weights of the crucibles and the fresh sample were the fresh weights of the samples. The crucibles were then placed in an

oven at a temperature of 106°C for 16 hours (Mokolopi and Beighle 2006). The crucibles containing dried faeces were allowed to cool on a desiccator for 2 hours and were weighed to determine the dry weight of faeces. The crucibles were then placed in a muffle furnace for ashing at a temperature of 800° C for 16 hours and the samples allowed to cool. The crucibles were then weighed to determine the ash weight of the faeces. One ml of concentrated nitric acid was added to the crucibles and evaporated till dryness on a drying element (medium heated hot plate). The crucibles were then returned to muffle furnace for 2 hours at temperature of 600°C, removed and cooled. Ten ml of 5N HCl (hydrochloric acid) was added to each crucible and allowed to evaporate at a temperature of 60°C heat until 3 ml was left in the crucible. The solution was then transferred to a 100 ml volumetric flask, ensuring that all contents of each crucible were completely transferred and made up to mark with distilled water. Then, the flask content was mixed and left to stand overnight to allow undigested matter to settle at bottom of the flask. Thirty ml was removed from the flasks without disturbing the sediment at the bottom and stored in McCartney bottles for further analysis. The absorbance in cuvettes was then read at 646 nm for P, 282 nm for Mg and at 422 nm for Ca respectively in the Aquamate Spectrophotometer.

3.4.3 Faecal phosphorus (P) analysis

Five ml of digested sample was mixed with 5 ml of distilled water in 15 ml tubes. The sample solution was then mixed with 1.5 ml of ammonium molybdate, 1.5 ml of hydroquinone and 1.5 ml of sodium sulphite. The sample was thoroughly mixed and allowed to stand at room temperature for 40 minutes and then poured into cuvettes and analysed. The absorption was read at 646 nm for P in the Aquamate UV-Visible Spectrophotometer.

3.4.4 Determination of Faecal, Grass calcium (Ca) and magnesium

For the determination of faecal and grass, Ca and Mg, the supernatant fluid left after digesting the faecal and grass samples were diluted with 0.1 % (w/v) lanthanum chloride (LaCl₃) diluents in a 1:5 ratio. For the determination of Mg the dilution was made with deionised water. The dilution ratio was adjusted to ensure that concentrations fall within the absorbance range of the standards (Fernandez and Kahn, 1971). Analysis of Ca and Mg was done on the supernatant fluid of the sample solution. To determine Ca and Mg fractions in faeces and grass, two ml of digested sample was mixed with 8 ml of Lanthanum Chloride in 10 ml test tubes. A blank which was a reagent blank of 0.5 % LaCl₃ was poured in different

cuvettes and then read at a wavelength of 422 nm for Ca and 282 nm for Mg using the AAS 700 Flame spectrophotometer (AOAC, 1980).

3.5 BLOOD COLLECTION AND ANALYSIS

3.5.1 Blood collection

The goats were bled from their jugular veins and 10 ml of blood was collected immediately after restraining them to minimize the effect of excitement on blood mineral levels, especially P (McDowell et al., 1982). Blood samples were stored for 24 hours at 4°C to allow adequate separation of the serum from the clot. They were then centrifuged at 10,000 rpm and the serum was separated from the clot. Care was taken to avoid haemolysis of the samples in order to minimise inconsistent mineral levels, especially P (McDowell et al., 1982). The serum was then stored at -20°C until analysis.

3.5.2 Determination of blood P

3.5.2.1 Reagents

3.5.2.2 Ammonium Molybdate Solution

Solution A: Twenty five grams of ammonium molybdate was dissolved in 300 ml distilled water.

Solution B: Seventy five ml of concentrated sulphuric acid was slowly added to 125ml distilled water.

Ammonium molybdate solution was prepared by adding solution B to solution A in a 1 00ml volumetric flask and thoroughly mixing and filling to the volume with distilled water.

3.5.2.3 Sodium Sulphite solution

Ten grams of sodium sulphite was dissolved in 100 ml of distilled water and the solution prepared as a fresh solution daily.

3.5.2.4 Hydroquinone solution

One gram of hydroquinone solution was dissolved in 100 ml of distilled water and the solution prepared on a daily basis.

3.5.2.5 Trichloroacetic Acid solution (TCA)

Ten grams of TCA was mixed with 100 ml distilled water to make 10 % solution.

3.5.2.6 Blood P analysis

The serum was transferred into a clean test tube using a clean pipette, then 0.7ml of serum in duplicate was added to 6.65ml of stock trichloroacetic acid in clean test tubes covered and mixed individually on an electric stirrer and left to stand at room temperature for 5 minutes to precipitate the protein in the serum. Samples were then centrifuged at 2600 rpm for 10 minutes. 5ml of supernatant fluid from each sample was taken off with the pipette and transferred to clean tubes without disturbing the sediment. The sample solution was then mixed with 1.5ml of ammonium molybdate, 1.5ml of hydroquinone and 1.5ml of sodium sulphite. They were then thoroughly mixed and allowed to stand at room temperature for 40 minutes and then poured into cuvettes and analysed. The absorption was read at 646 nm for P in the Aquamate UV-Visible Spectrophotometer.

3.6 GRASS SAMPLING AND ANALYSIS

3.6.1 Grass sample

Sample was collected from the field where the animals grazed. A 50 m rope divided into five equal parts was used to measure randomly selected areas. Grass was collected from 50 cm around each knot. A pair of scissors was used to cut the grass. The sample was then air dried ground through a 2mm screen and digested in the same way as the faeces.

3.6.2 Grass sample analysis

Before the samples were analysed, the machine was warmed for 15 minutes and distilled water was passed through the tubes for cleansing purpose to prevent contamination from previous samples. The reagents were run through the tubes for 5 minutes. Standards and samples were transferred into cuvettes with their duplicates. The first five cuvettes were used for standards, 20 mg/100 ml was poured into the first two, cuvettes one being an initializer standard, then 15 mg/100 ml, 10 mg/100 ml and 5 mg/100 ml standards were then poured into the 3 remaining cuvettes. The blank was poured into the six cuvettes. Standards, blank and samples were then entered into the computer and samples analysed through the FASpac II Version R2M1 Auto- Analyzer: (Astoria Pacific International 1992-2005). The samples were analysed calorimetrically at 646 nano meter (nm) for P, Ca and Mg samples were read through an atomic absorption spectrometer (The Analyst 700 Model, 110 Bridgeport Avenue Shelton, CT 06484-4794, USA) and were analyzed as described by Trudeau and Freier 1967) at 422 and 282 nm respectively. Mineral concentrations of the unknown samples were obtained by relating to known references of standard solutions in mg/100 ml.

3.7 PREPARATION OF STANDARDS

3.7.1 Preparation of phosphorus standards

To prepare 5 mg /100 ml of P standards, 5 ml of 1000 ppm commercial stock standard was mixed with 95 ml of distilled water and 10 ml of the stock standard mixed clearly with 90 ml of distilled water to prepare a 10 mg/100 ml standards. To prepare 20 ml of the stock, standard was mixed with 80 ml of distilled water to make a 20 mg/100 ml standard.

3.7.2 Preparation of calcium standards

When preparing a 5 mg/100 ml of Ca. standard, 5 ml was drawn from 1000 ppm Ca. commercial stock standard solution added to 95 ml of 0.1 (W/V) lanthanum chlorides in a volumetric flask. For 10 mg/100 ml standard, 10 ml was drawn from a 1000 ppm Ca. commercial stock solution and added to 90 ml of 0.1% (w/v) lanthanum chloride and 20 mg% standard was prepared by adding 20 ml from 1000 ppm Ca. commercial stock solution to 80 ml of 0.1% (w/v) lanthanum chloride in a volumetric flask.

3.7.3 Preparation of magnesium standards

When preparing a 0.5 mg/100 ml of Mg standard, 0.5 ml% was drawn from a 1000 ppm Mg commercial stock standard solution and added to 95 ml distilled water in a volumetric flask. To prepare 1 mg/100 ml standard, 1 ml from 1000 ppm Mg commercial stock solution was added to 99 ml distilled water and a 2 mg/100 ml standard was prepared by adding 2 ml from 1000 ppm commercial stock solution to 98 ml distilled water. A 3 mg/100 ml standard was prepared by adding 3 ml from a 1000 ppm Mg commercial stock solution to 97 ml of distilled water in a volumetric flask.

3.8 STATISTICAL ANALYSIS

Analysis of co-variance was done to determine whether dicalcium phosphate supplement had an effect on the blood and faecal P, Ca and Mg levels and body mass of village goats grazed communally throughout the year. This was done to compare the effects of several rations on weight gain. Initial weight was correlated with weight gain, where the portion of the experimental error for gain can be the results of differences in initial weight. Least significant means were calculated for monthly differences of variables. Turkey-Kramer Adjustment for multiple comparisons was also employed. Probability was considered significant at $P < 0.05$ or less. Correlation was done by IBM SPSS statistics version 20 to compare if there was a relationship between mineral interactions and also between sample interactions.

CHAPTER 4

4 RESULTS AND DISCUSSIONS

4.1 Faecal phosphorus

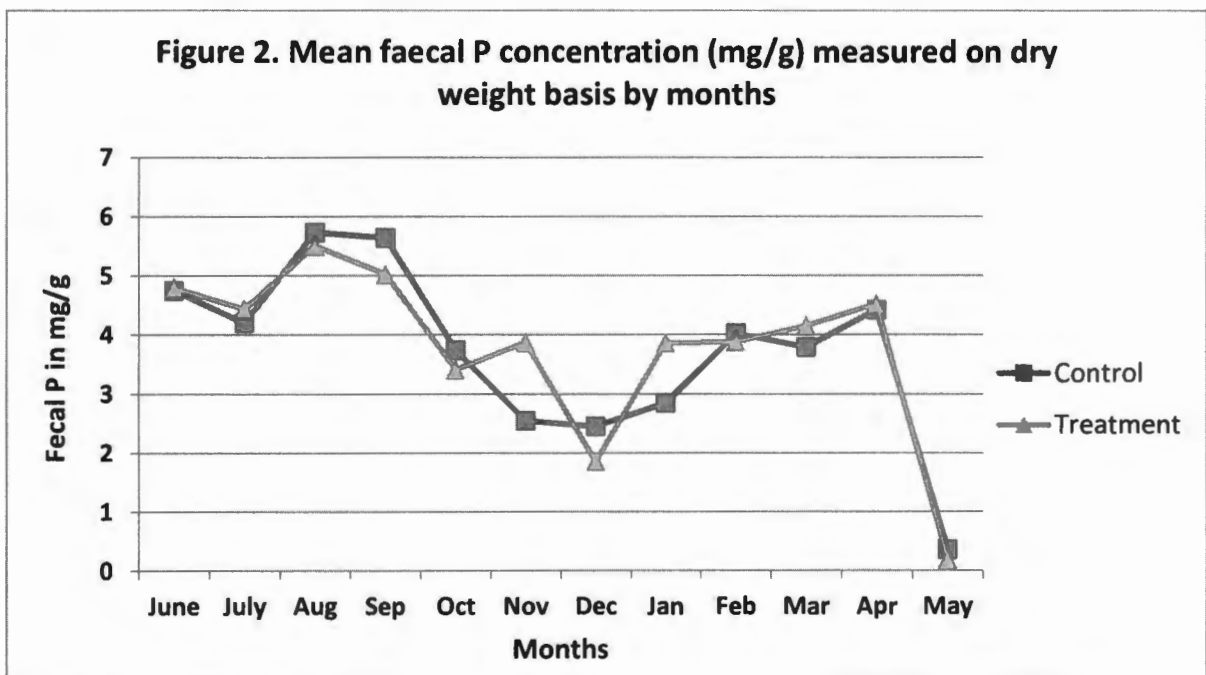
4.1.1 Faecal P on dry weight

Table 2 and Figure 2 below represent the faecal P concentrations on dry weight basis. Generally there was no significant difference between the treated and control groups in the twelve months of the trial period. However, overall the supplemented animals displayed more ($P < 0.05$) faecal P (Table 2). This shows that the supplemented goats were getting more phosphorus from dicalcium phosphate supplement compared to the controls which were not receiving mineral supplements. Faecal phosphorus concentration is associated with dietary phosphorus because nearly all dietary phosphorus is excreted in the faeces (Cohen, 1975). In this study more faecal phosphorus was excreted in supplemented group. The excretion of more phosphorus in faeces in supplemented animals has been reported previously (Read et al., 1986; Bakunzi, 2000) in sheep and cattle. Faecal phosphorus however, may not necessarily indicate the phosphorus status of grazing ruminant because responses may occur when faecal phosphorus is low or may cease when levels are considerably high (Winter, 1988). In both the treated and control groups, faecal phosphorus levels tended to follow a seasonal pattern (Figure 2) with decreasing levels in the dry season from May to October and increasing levels in the wet months of December to April (Figure 1). This tends to correlate with the grass phosphorus levels depicted in Figure 10, on dry weight basis, whereby dietary phosphorus is directly related to faecal phosphorus (Mokolopi and Beighle, 2006).

Table 2. Mean faecal phosphorus (P) levels (mg/g) measured on dry weight basis by months and their standard error of the means (S.M.E)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall Mean
CX	4.98 _a	4.49 _a	6.06 _a	5.94 _a	3.90 _a	2.76 _a	2.51 _a	3.12 _a	4.31 _a	4.06 _a	4.70 _a	3.94 _a	4.23 ^a ± 0.12
RX	4.90 _a	4.76 _b	5.83 _a	5.68 _a	3.98 _a	4.22 _b	1.96 _b	4.13 _a	4.18 _a	4.45 _a	4.79 _a	3.29 _b	4.34 ^b ± 0.60
	± 0.25	± 0.17	± 0.28	± 0.31	± 0.21	± 0.24	± 0.10	± 0.09	± 0.14	± 0.20	± 0.09	± 0.08	

^{a,b} different letters in columns signify that means differ significantly ($P < 0.05$); CX= Control group; RX = Treated group;



4.2 FAECAL CALCIUM

4.2.1 Faecal Ca on dry weight

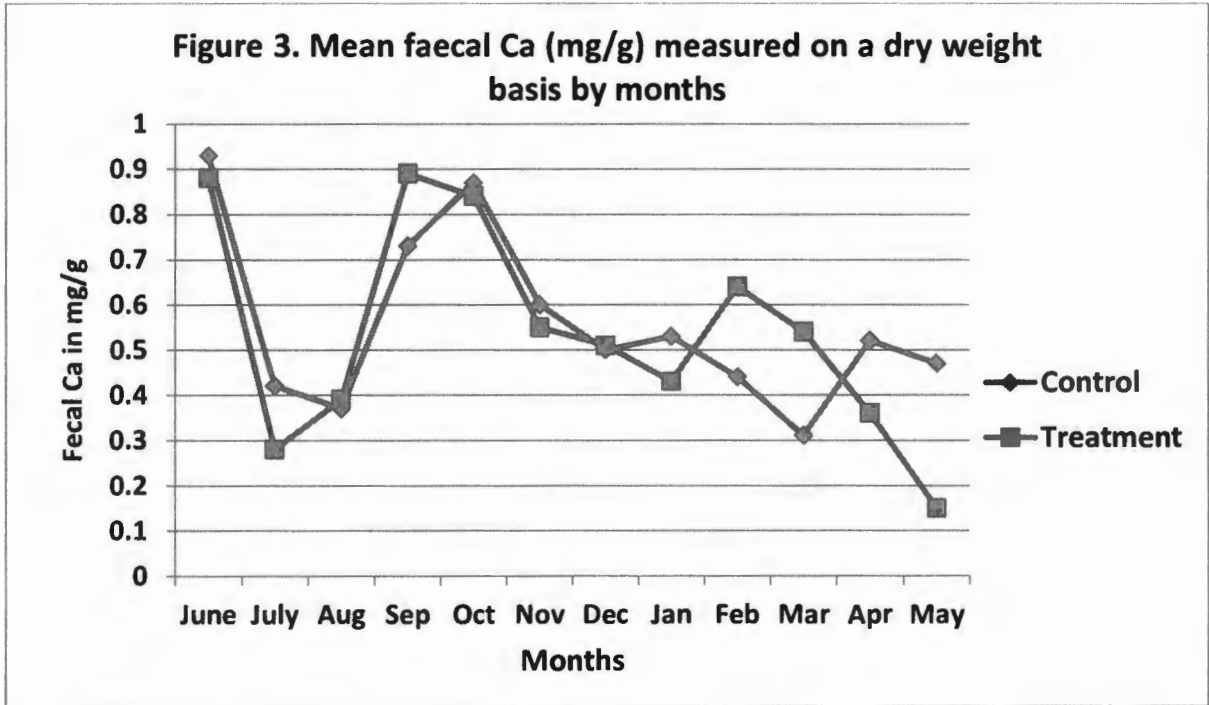
Results on calcium (Ca) concentration in faecal samples on a dry weight basis are shown in Table 3 and Figure 3. The goats receiving the mineral supplements overall had more ($P < 0.05$) faecal calcium levels on dry weight basis (Table 3) similar to what happened with faecal P above in Figure 2 above. This indicates that the supplemented animals were getting more calcium in the diets and then excreting it in the faeces. The faecal calcium levels in

both the treated and control animals did not follow a seasonal pattern unlike what happened in the case of faecal phosphorus. This is probably due to the fact that pasture calcium levels are usually adequate in both the dry and wet seasons (Groenwald and Boyazoglu 1980; Mazengera 1992). The grass Ca levels in this study were 0.60 and 0.42% on a dry weight basis in summer and winter respectively (Table 11). These were above the reported normal limits of 0.3 and 0.48% in winter and summer respectively for cattle (Groenwald and Boyazoglu, 1980) thus indicating that there is probably no Ca deficiency in pastures in this region.

Table 3. Mean faecal Ca (mg/g) measured on dry weight bases by months and their standard error of the means (S.E.M)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall Mean
CX	0.93 ^a ±	0.42 ^a ±	0.37 ^a ±	0.73 ^a ±	0.87 ^a ±	0.60 ^a ±	0.50 ^a ±	0.53 ^a ±	0.44 ^a ±	0.31 ^a ±	0.52 ^a ±	0.47 ^a ±	0.53 ^a ±
	0.35	0.03	0.02	0.09	0.07	0.02	0.05	0.07	0.07	0.04	0.06	0.06	0.01
RX	0.88 ^a ±	0.28 ^b ±	0.39 ^a ±	0.89 ^b ±	0.8 ^a ±	0.5 ^a ±	0.5 ^a ±	0.43 ^a ±	0.6 ^b ±	0.54 ^b ±	0.36 ^a ±	0.15 ^b ±	0.55 ^b ±
	0.35	0.04	0.03	0.07	0.05	0.05	0.05	0.09	0.06	0.04	0.06	0.03	0.15

^{a,b} different letters in columns signify that means differ significantly (P<0.05); CX= Control group; RX = Treated group;



4.3 FEAECAL MAGNESIUM

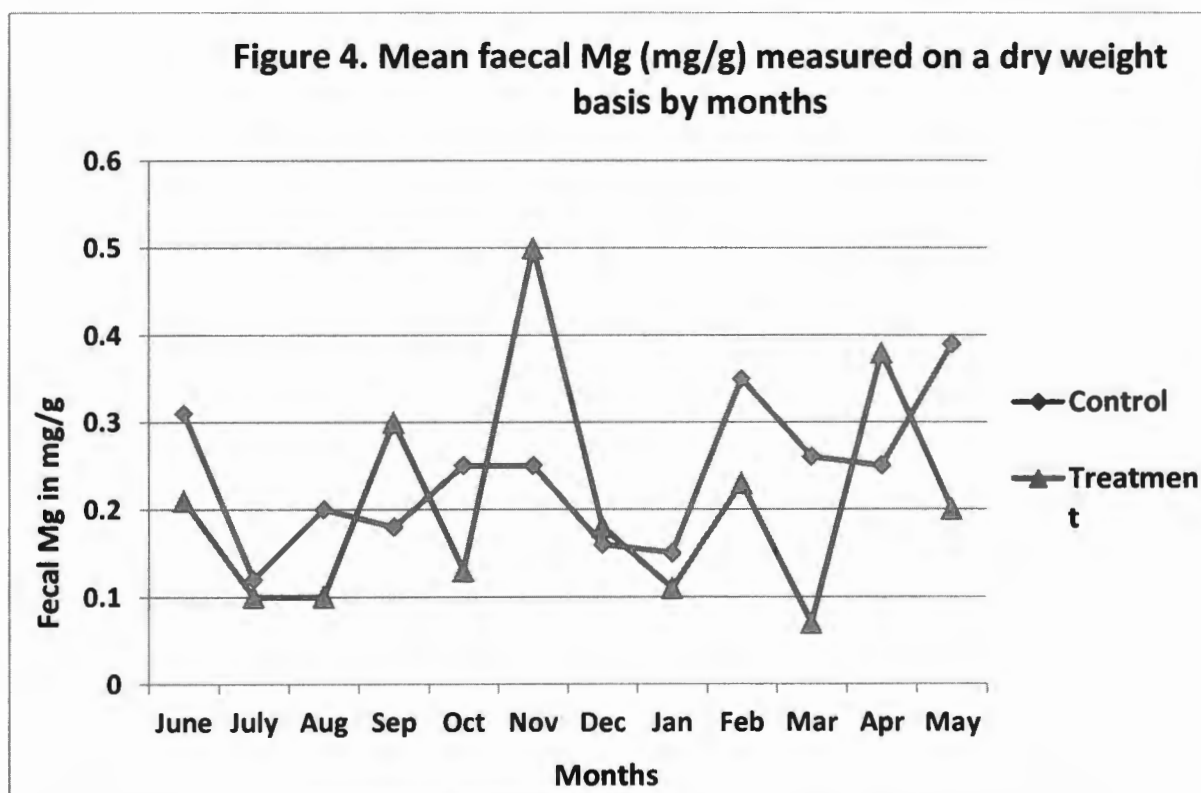
4.3.1 Faecal Mg on dry weight

Table 4 and Figure 4 below show faecal magnesium levels on a dry and weight basis. The supplemented animals generally had more ($P < 0.05$) Mg levels compared to the untreated goats (Table 4) as shown in not only in magnesium but also in the overall effect, P and Ca levels. This again reflects the direct relationship between dietary magnesium and excreted magnesium in the faeces. It has been reported that P increases an animal's appetite and feed utilisation (Ternouth and Budhi, 1996). It is possible therefore, that the supplemented animals probably consumed more forage biomass containing more magnesium and thus excreted more in the faeces as a result of increased appetite.

Table 4. Mean faecal Mg (mg/g) measured on dry weight basis by months and their standard error of the means (S.E.M)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall Mean
CX	0.31 ^a	0.12 ^a	0.20 ^a	0.18 ^a	0.25 ^a	0.2 ^a	0.16 ^a	0.15 ^a	0.35 ^a	0.26 ^a	0.25 ^a	0.39 ^a	1.20 ^a
	±	±	±	±	±	±	±	±	±	±	±	±	±
	0.11	0.01	0.02	0.02	0.02	0.01	0.007	0.003	0.03	0.03	0.05	0.03	0.15
RX	0.21 ^a	0.1 ^a	0.10 ^b	0.30 ^b	0.1 ^b	0.50 ^b	0.18 ^b	0.11 ^a	0.23 ^b	0.07 ^b	0.38 ^b	0.2 ^b	1.05 ^b
	±	±	±	±	±	±	±	±	±	±	±	±	±
	0.05	0.01	0.01	0.02	0.02	0.08	0.01	0.02	0.005	0.007	0.08	0.04	0.69

^{a,b} different letters in columns signify that means differ significantly ($P < 0.05$); CX = Control group; RX = Treated group;



4.4 BLOOD SERUM PHOSPHORUS, CALCIUM AND MAGNESIUM LEVELS

4.4.1 Blood serum inorganic phosphorus levels

The blood serum inorganic phosphorus levels are shown below in Table 5 and Figure 5 respectively. As indicated in Figure 5, serum inorganic phosphorus levels fluctuated from month to month between the control and treated goats with no significant difference ($P>0.05$) as was also observed for faecal Ca, P and Mg above. This observation was noted earlier by Read et al. (1986) in sheep, raised in the same geographical area. The concentrations ranged from 2.7 to 13.3 mg P/ 100 ml serum and from 4.5 to 19.8 mg P/ 100 ml serum in the treated and control goats respectively. Clinical signs of phosphorus deficiency include loss of condition which was reflected in this study in the untreated goats (Figure 13). However, loss of weight seen in individual goats was not related to low serum inorganic P concentrations. This suggests that either the critical level of serum inorganic phosphorus below which clinical signs occurs (Radostits et al., 1994), is substantially below the limit of 4.5 mg P/ 100 ml serum phosphorus or that the goats must have been below the critical level for a longer time. In both the treated and control goats, the blood serum inorganic phosphorus levels were above the critical range of 4.5 mg/100 ml serum (Underwood and Suttle, 2001) except in the month of March (2.7 mg P/ 100 ml serum) for the treated animals. The use of blood serum as an indicator of mineral status in grazing ruminants for phosphorus has not been found reliable (Mokolopi and Beighle 2006). A number of factors may affect blood serum inorganic P levels including exercise, excitement, time of the day, age, sex, site of sample collection and hydrolysis (McDowell et al., 1982; Forar et al., 1982). These factors were not easy to control during the blood collections from the animals. This could have resulted in higher serum inorganic phosphorus levels in this study. This confirms the observation that relying on blood serum inorganic phosphorus as an index of phosphorus status could give rise to erroneous conclusions (Mokolopi and Beighle 2006). Also the reason why there was high blood serum inorganic phosphorus in both treated and control animals (above 4.5mg P/ 100 ml serum) could probably be due to the fact that goats are natural browsers and there might have been adequate P from the green leafy parts of the plants (Groenewald and Boyazoglu 1980). There was a mild positive correlation ($r^2= 0.313$) between blood serum and grass P levels (Figure 6) in the supplemented goats. This implies that the supplemented goats were probably getting adequate amounts of P from the pasture and thus, adequate P was absorbed from the gut to the vascular system. The same trend was observed by Mokolopi and Beighle (2006) in communal grazing cattle.

Table 5. Mean blood serum P (mg P/ 100 ml serum) by months and their standard error of the mean (S.E.M) respectively

Months	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall Mean
CX	7.37 ^a ± 0.52	11.07 ^a ± 0.69	4.48 ^a ± 0.46	5.28 ^a ± 0.48	9.49 ^a ± 0.33	8.44 ^a ± 0.90	13.9 ^a ± 0.59	8.61 ^a ± 0.57	12.26 ^a ± 8.85	12.4 ^a ± 0.91	19.84 ^a ± 1.22	19.4 ^a ± 0.46	9.96 ^a ± 3.65
RX	7.46 ^a ± 0.70	6.91 ^b ± 0.24	7.86 ^b ± 0.56	5.3 ^a ± 0.39	9.01 ^a ± 0.26	9.34 ^a ± 0.75	15.3 ^a ± 1.03	10.03 ^a ± 1.28	10.9 ^b ± 1.31	2.69 ^b ± 10.9	13.3 ^b ± 0.45	13.39 ^b ± 0.22	9.60 ^a ± 6.57

^{a,b} different letters in columns signify that means differ significantly (P<0.05); CX= Control group; RX = Treated group;

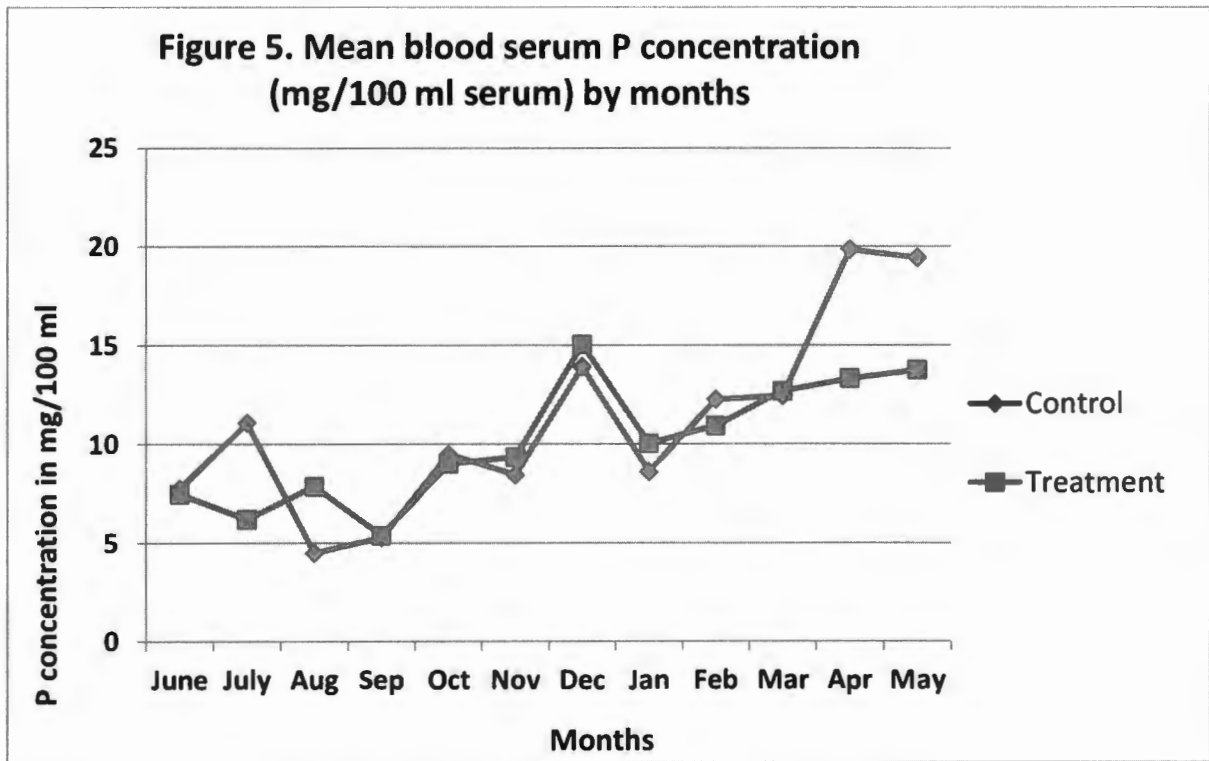
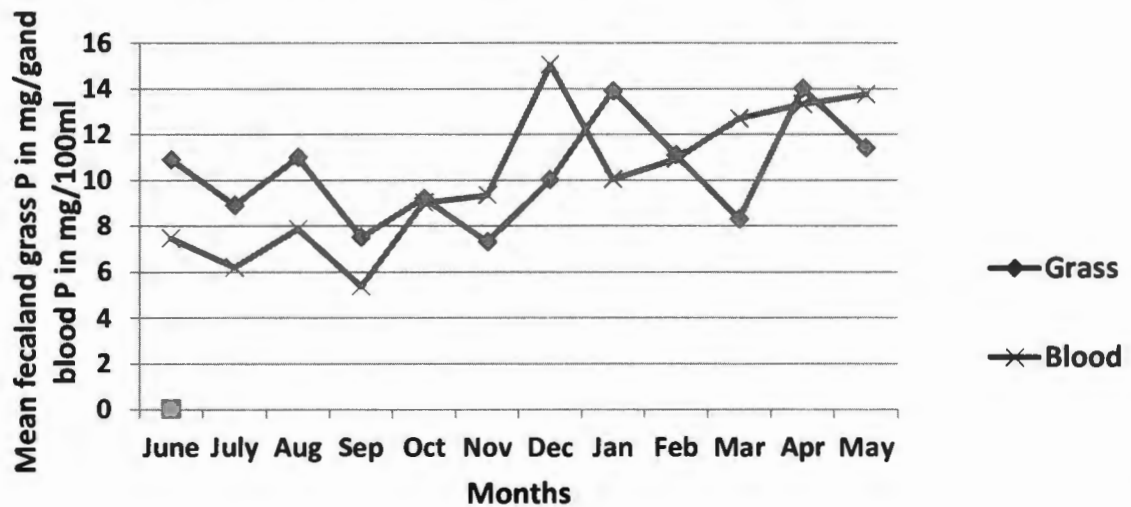


Table 6. Mean blood serum P and grass P in the treated goats

Month	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Grass	10.9	8.9	11	7.5	9.2	7.3	10	13.9	11.1	8.3	14	11.4
Blood	7.46	6.1	7.8	5.3	9.0	9.3	15.0	10.0	10.9	12.6	13.3	13.7
		9	6	7	1	4	4	3	3	9	2	5

Figure 6. Mean blood P (mg/100 ml serum) and grass P (mg/g dry weight) relationship



4.4.1.1 Blood serum calcium levels

Table 7 and figure 7 below present blood serum calcium levels in both the control and treated goats. The levels in control and treated goats ranged from 5.4 mg P/100 ml serum to 11.2mg P/100 ml serum and 6.0 mg P/100 ml serum to 14.3 mg P/100 ml serum respectively. These ranges seemed to be above the critical level of 6 mg P/100 ml serum suggested by Underwood and Suttle (2001). The reasons for high ranges above 6 mg P/100 ml serum could be the same reasons as those which affected the level of serum phosphorus in both the treated and control animal in Figure 5 and Table 5 above. The treated animals had significantly higher ($P < 0.05$) serum calcium levels compared to the control animals (Table 7). This indicates that the treated goats were getting extra dietary calcium from

supplemented dicalcium phosphate and thus higher blood calcium levels as reported previously (Read et al., 1986). The curves in both groups of animals followed a seasonal pattern with the lowest calcium levels in the dry months of April to August and highest levels in the wet months of October to March (Figure 1). This seasonal pattern correlates well with low calcium and high grass calcium in the same study (Figure 11) in the dry and wet months respectively, confirming the earlier findings that serum calcium levels are influenced by dietary calcium (Groenwald and Boyazoglu, 1980). This finding was also reported previously in the same geographical area in cattle by Mokolopi and Beighle (2006). Bakunzi et al. (2012) reported that cows not supplemented with calcium tended to have more serum calcium levels than the supplemented ones. This is in agreement with a previous report in cattle (Loxton et al., 1983) implying that blood is a poor indicator of calcium dietary intake (MacDowell et al., 1982). There was also a mild positive correlation ($r^2 = 0.329$) between blood Ca and grass Ca levels in supplemented goats (Table 8 and Figure 8). The blood and grass P positive relationship also indicates that the supplemented goats were getting additional Ca from the diet which influenced blood Ca positively.

Table 7. Mean blood serum Ca (mg Ca/100 ml serum) by months and their standard error of the mean (S.E.M)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall Mean
RX	6.01 ^a ± 1.20	6.25 ^a ± 2.01	7.66 ^a ± 2.58	11.56 ^a ± 3.85	14.32 ^a ± 4.24	13.02 ^a ± 2.45	14.22 ^a ± 3.85	13.45 ^a ± 3.65	12.84 ^a ± 3.54	14.00 ^a ± 3.91	12.67 ^a ± 3.81	10.94 ^a ± 2.60	11.90 ^a ± 3.25
CX	5.5 ^a ± 1.03	5.3 ^a ± 1.69	6.2 ^a ± 2.51	8.65 ^b ± 2.59	11.20 ^b ± 2.36	10.21 ^b ± 2.11	10.33 ^b ± 1.68	9.28 ^b ± .19	9.01 ^b ± 3.08	9.65 ^b ± 3.85	8.65 ^b ± 2.73	6.01 ^b ± 1.58	8.59 ^b ± 2.65

^{a,b} different letters in columns signify that means differ significantly ($P < 0.05$); CX = Control group; RX = Treated group;

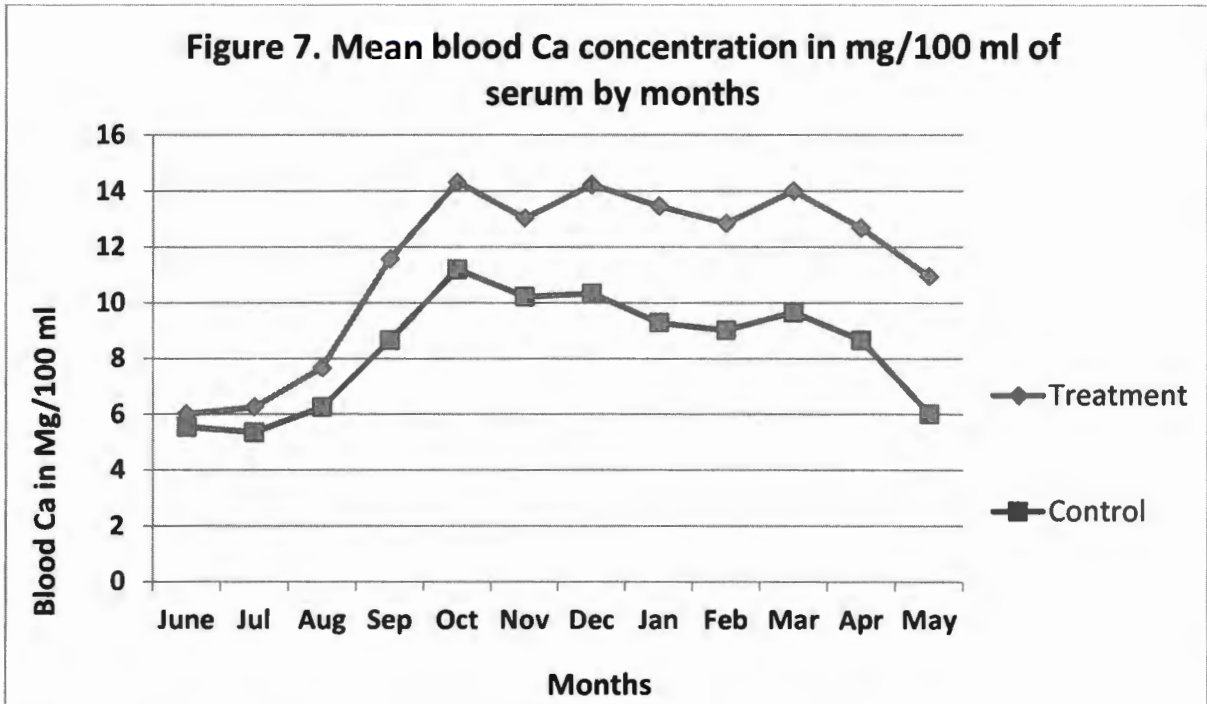
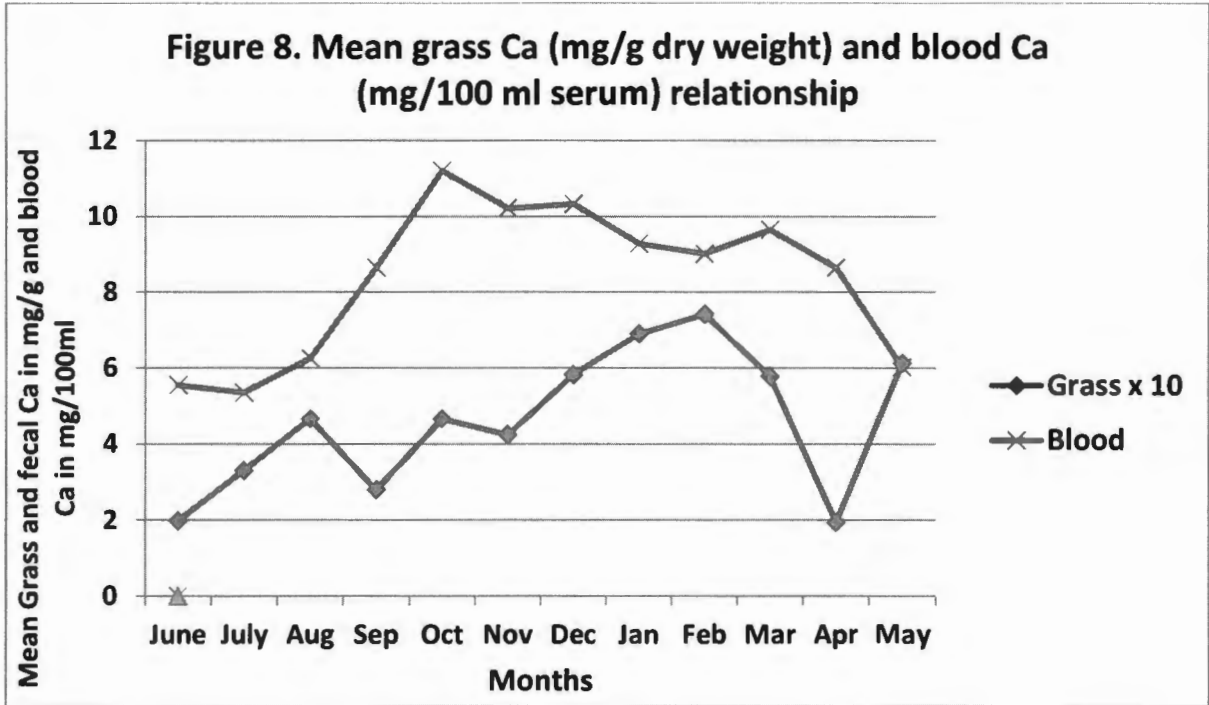


Table 8. Mean grass and blood Ca in the treated goats (dry weight)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Grassx10	1.97	3.3	4.66	4.24	4.66	4.24	5.82	6.9	7.41	5.77	1.93	6.12
Blood	5.55	5.35	6.25	8.65	11.2	10.21	10.33	9.28	9.01	9.65	8.65	6.01



4.4.2 Blood serum magnesium levels

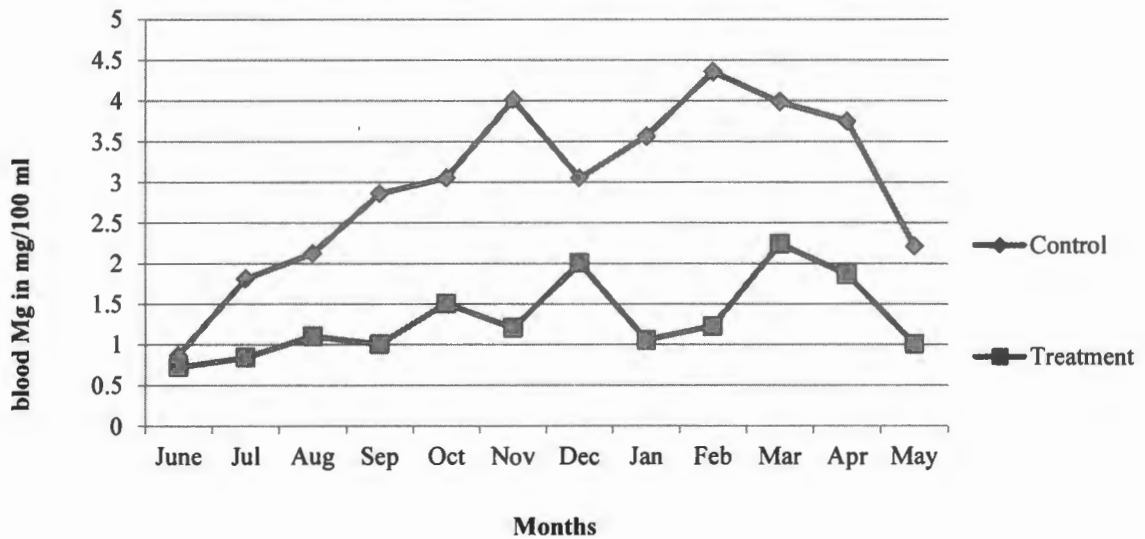
Table 9 and Figure 9 below present mean serum magnesium levels. The serum Mg levels ranged from 0.86mg Mg/100 ml serum to 4.35mg Mg/ 100ml serum and from 0.72mg Mg/ 100ml serum to 2.24mg Mg/100 ml serum in the treated and control animals respectively. In both cases, the curves followed a seasonal pattern with the lowest levels in the dry months of April to September and highest levels in the wet months of October to March as previously reported by Mokolopi and Beighle (2006) and Bakunzi et al, (2012). There was a significant difference ($P < 0.05$) between the two groups September to the end of the trial period (Table 9). The reason why the untreated goats had significantly less ($P < 0.05$) serum Mg levels is not clear since dicalcium phosphate has no Mg content. However, the high blood serum calcium levels in supplemented goats (Figure 7) could have probably stimulated more Mg absorption from the gut, since both elements naturally occur together in hydroxyapatite form in the bone (Reece, 2009). The serum magnesium levels reported in this study are generally within the normal reported serum magnesium levels range of 1 to 3 mg/100 ml serum (NRC 1985) and Underwood (1966) 1.8 to 3.2 mg%.

Table 9. Mean blood serum Mg (mg Mg/ 100ml serum) by months and their standard error of the mean (S.E.M)

Months	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall mean
RX	0.86 ^a ± 0.05	1.81 ^a ± 0.05	2.12 ^a ± 0.42	2.86 ^a ± 0.61	3.05 ^a ± 1.30	4.01 ^a ± 1.51	3.05 ^a ± 1.02	3.56 ^a ± 1.43	4.35 ^a ± 1.65	3.98 ^a ± 1.36	3.75 ^a ± 1.43	2.21 ^a ± 0.76	3.16 ^a ± 1.35
CX	0.72 ^a ± 0.04	0.84 ^a ± 0.09	1.10 ^a ± 0.10	1.00 ^b ± 0.10	1.50 ^b ± 0.85	1.20 ^b ± 0.74	2.00 ^b ± 0.15	1.05 ^b ± 0.21	1.22 ^b ± 0.30	2.24 ^b ± 0.65	1.86 ^b ± 0.45	1.00 ^b ± 0.34	1.36 ^b ± 0.23

^{a,b} different alphabets in columns signify that means differ significantly (P<0.05); RX= Treated group; CX = control group;

Figure 9. Mean blood Mg concentration in mg/100 ml of serum by months



4.5 GRASS PHOSPHORUS, CALCIUM AND MAGNESIUM LEVELS

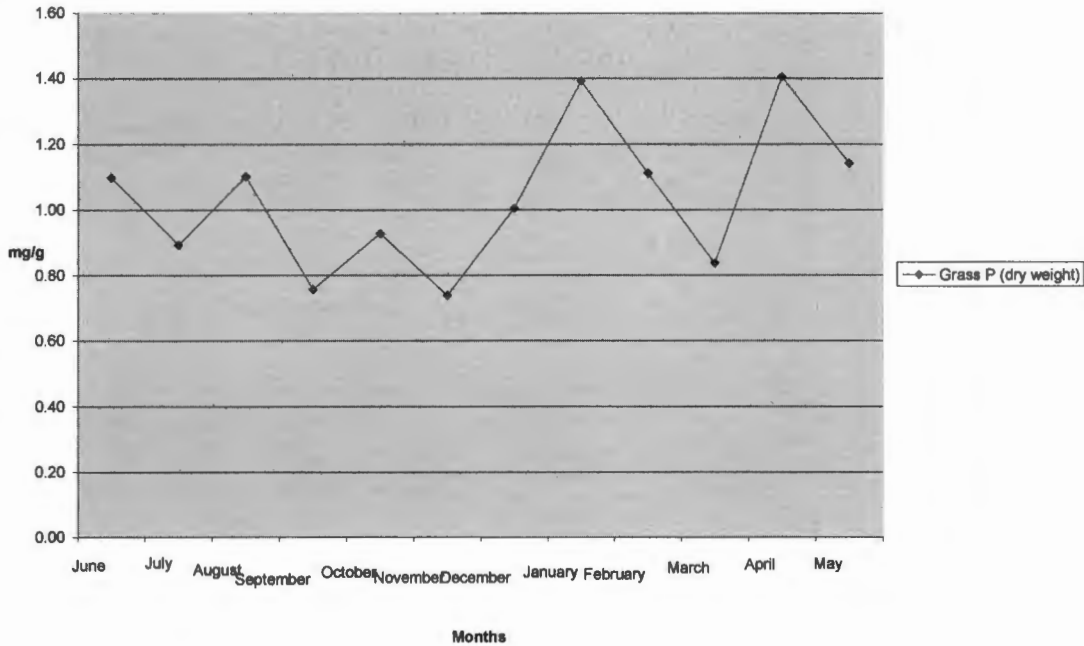
4.5.1 Mean Grass phosphorus levels

Table 10 and Figure 10 below show the mean grass phosphorus levels on a dry weight basis. The curve seemed to follow a seasonal pattern, with lowest values in the dry months of May to November and highest values in the wet months of December to April (Figure 1).

Table10. Mean grass Phosphorus, Calcium and Magnesium

Months	P dry	Ca dry	Mg dry
June	1.0976	0.1977	0.9277
July	0.8917	0.3336	1.0221
Aug	1.1014	0.4667	0.0886
Sep	0.7568	0.2778	0.1572
Oct	0.9275	0.4667	0.1104
Nov	0.7381	0.4248	0.1132
Dec	1.0044	0.5821	0.1077
Jan	1.3918	0.6900	0.1065
Feb	1.1113	0.7411	0.6239
Mar	0.8360	0.5773	0.3874
Apr	1.4048	0.1930	0.6407
May	1.1416	0.6124	0.0634

Figure 10. Grass P concentration (mg/g) measured on a dry weight basis by months

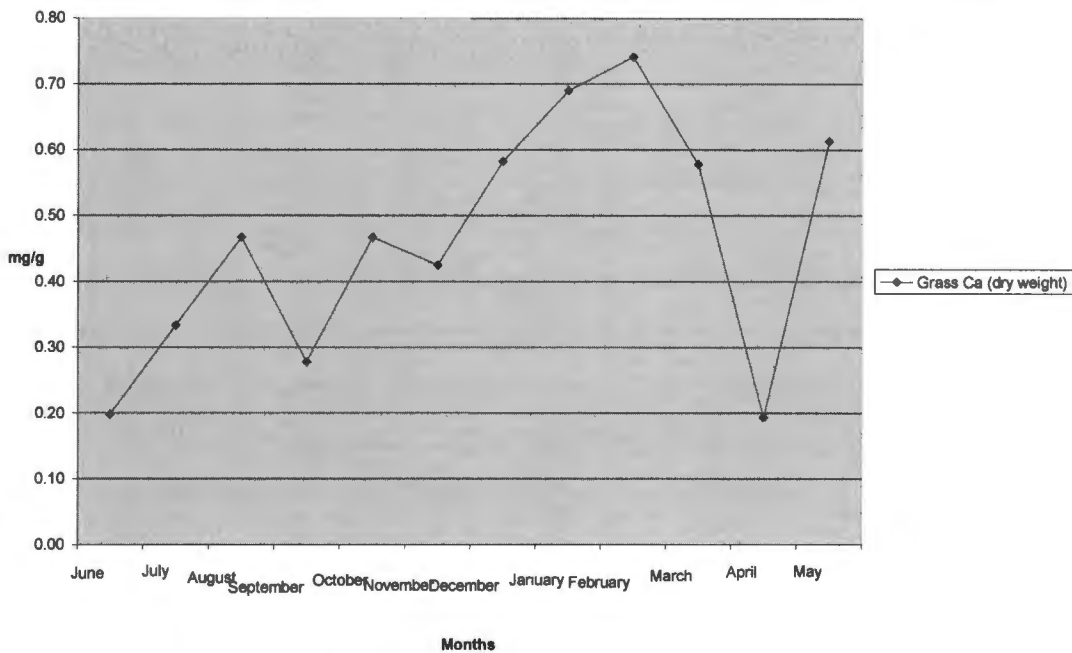


The mean grass phosphorus content was 1.0% during the trial period from June 2011 to May 2012 (Table10). The mean winter and summer phosphorus levels were 1.01 and 0.99% respectively (Table11). These values seem to be above the 0.25% recommended for mature grazing cattle (McDowell and Conard, 1977) and more than the 0.1% reported in the summer grasses in dry parts of South Africa as deficient (Groenewald and Boyazoglu, 1980). The reason for the high grass phosphorus content in this study could be probably due to the fact that there were more rains and thus, more phosphorus in the green pasture. However, the work done in the same geographical area showed variable phosphorus grass levels by different workers: 0.03% by Mazengera (1992) and 0.02% by Mokolopi and Beigle (2006). It is therefore essential to supplement phosphorus in this region to grazing goats as the supplemented animals in this study displayed higher ($P<0.05$) body mass gain compared to the untreated animals (Figure 7) although the grass P content apparently was above the recommended 0.25%.

4.5.2 Mean grass calcium levels

Table 10 above and Figure 11 below show the mean grass calcium levels during the period of study. The mean calcium value on a dry weight basis was 0.43% (Table 10) and the mean summer and winter values on dry weight basis were 0.60 to 0.42% respectively (Table 11). These values were above the reported normal limits of 0.3 to 0.4% in cattle (Groenewald and Boyazoglu 1980), indicating that calcium deficiency may not exist in the field grass samples. However, the study conducted by Mazengera (1992) reported low values of 0.17 and 0.18% in winter and summer respectively. In this study the curve tended to follow a seasonal pattern with lowest levels in the dry months of April to October and the highest levels in the wet months of November to March. This correlates well with low serum calcium in the dry months and high calcium levels in wet months (Figure 7 and 11) thus demonstrating a linear relationship between dietary and serum calcium levels.

Figure 11. Mean grass Ca concentration (mg/g) measured on a dry weight basis by months



4.5.3 Mean grass magnesium levels

Table 10 above and Figure 12 below represent the mean monthly grass magnesium levels in the trial period on dry weight basis. The mean monthly magnesium content of grass was 0.4% (Table 10) and ranged from 1.0 to 0.9% in winter and summer respectively on a fresh weight bases (Table 11) indicating almost no seasonal variations. These magnesium values were above the reported normal values of 0.1 to 0.2 % (Groenewald and Boyazoglu 1980)

showing that magnesium deficiency did not exist in grass samples where the animals grazed in this study. However a study conducted by Mazengera (1992) in the same geographical area reported a level of 0.07%. This difference could be attributed to seasonal changes from year to year.

Figure 12. Mean grass Mg concentration (mg/g) measured on a dry weight basis by months

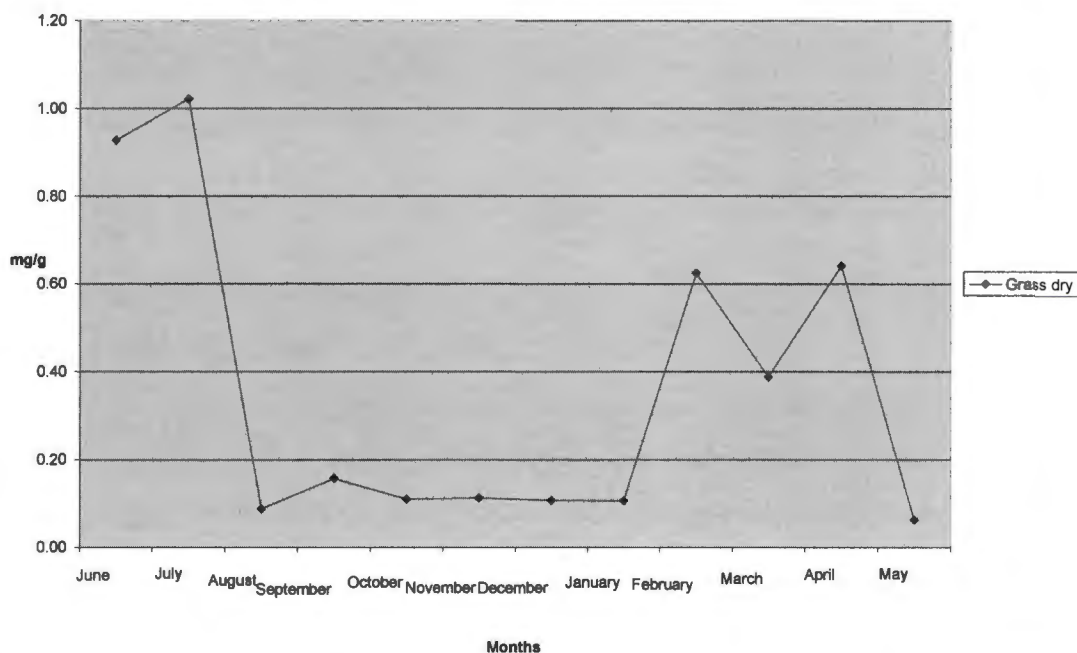


Table 11. Mean grass P, Ca and Mg summer and winter mineral concentration (mg/g)

Seasons	Grass P (Dry)
Winter (April-September)	1.07a
Summer (October-March)	1.00a
Seasons	Grass Ca (Dry)
Winter (April-September)	0.42a
Summer (October-March)	0.60b
Seasons	Grass Mg (Dry)
Winter (April-September)	0.53a
Summer (October-March)	0.24a

4.6 BODY MASS OF GOATS (kg)

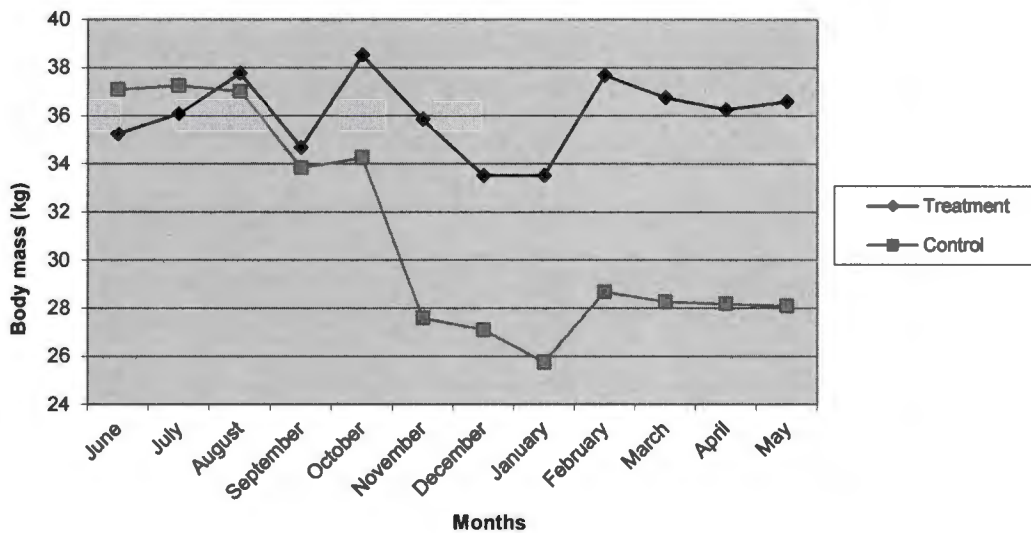
The mean monthly body mass of goats is shown below in Table 12 and Figure 13.

Table 12. Mean body mass in the treated and control groups (kg)

Months	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Overall
CX	35.25 ^a	36.08 ^a	37.75 ^a	34.67 ^a	38.5 ^a	35.83 ^a	33.5 ^a	33.5 ^a	37.67 ^a	36.75 ^a	36.25 ^a	36.08 ^a	36.09 ^a
RX	37.08 ^a	37.25 ^a	37.00 ^a	33.83 ^a	34.25 ^b	27.58 ^b	27.08 ^b	25.75 ^b	28.67 ^b	28.25 ^b	28.17 ^b	28.08 ^b	30.53 ^b

^{a,b} different alphabets in columns signify that means differ significantly ($P < 0.05$); RX= Treated group; CX = control group;

Figure 13. Mean body mass by months



From the start of the trial period the body mass gain fluctuated between the two groups of animals from June to September with no statistically significant difference ($P > 0.05$). From October onwards, up to the end of the trial period (May 2012), the supplemented group outperformed the unsupplemented group and displayed significantly more ($P < 0.05$) mass gain (Figure 26). The supplemented group had a weight change of 3.8% gain from the start of the study to the end. The control group lost 17% weight from the beginning to the end of the trial period (Table 12). At the end of the trial period in May 2012 the supplemented goats were 6 kg heavier (20%) than the control group. This clearly shows that the dicalcium phosphate supplementation highly improved the goats' performance in terms of body mass

gain and thus the use of body mass as an indicator of animal's mineral status identified a Ca and P deficiency in communal grazed goats in this study. The higher body mass of 20% in the treated goats reported in this study agrees fairly well with the 26% reported in P supplemented cattle (Bakunzi, 2000) and 15 % in P supplemented sheep (Loxton, et al, 1983). Phosphorus increases feed intake and utilisation in the animal (Ternorth and Budhi, 1996) while calcium maintains numerous body metabolic activities (Underwood and Suttle, 2001). These effects of both minerals therefore made the supplemented animals better able to maintain body mass compared to controls which depended entirely on natural pasture.

Chapter 5

5 CONCLUSIONS AND RECOMMENDATIONS

Dicalcium phosphate supplementation seemed to influence faecal P, Ca and Mg concentrations in the treated animals throughout the trial period. The same trend was displayed in the levels of blood serum inorganic P. The supplemented goats had more Ca and Mg serum levels, indicating the significance of Ca and P supplements to grazing goats in this region. In terms of body mass gain, the Ca and P supplemented goats outperformed the unsupplemented animals throughout the trial period. This points to the routine Ca and P supplements in communal grazing goats in this semi arid area of the North West Province of South Africa. More research is needed in goats in this region to ascertain whether the increase in body mass is solely due to Ca or P supplements or both. This can be achieved by using more reliable indicators like rib bone which shows little variation in mineral content as compared to faeces and blood.

REFERENCES

- Aregheore, E.M., D. Hunter, D. Perere and Mautoatasi 2007. The soil-plant-animal phenomena: serum mineral status of Fuji fantastic sheep grazing Batiki grass (*Ischaemum aristatum* Variable indium) and Pangola grass (*Digitaria decumbens*) in Samca. *Journal of Animal Veterinary Advances*. 6:349-357
- Association of Official Chemists (AOAC) 1980. *Official Methods of Analysis*. Minerals in feeds by Atomic Absorption Spectrophotometry- Official Final Action, Washing D.C.
- Bakunzi, F.R. 2000. The optimal period of phosphorus supplementation in range breeding cattle as reflected on body tissue and fluids, affecting reproduction and production. Thesis, Medical University of Southern Africa, Pretoria.
- Bakunzi, F.R., L. Motsei, M. Nyirenda, R. Ndou and B. Dzoma 2012. The effect of dicalcium phosphate supplement in summer and winter seasons as reflected on bone and blood phosphorus, calcium and magnesium levels in range breeding beef cattle. *Journal of Agriculture and Biodiversity Research*. 1: 60-64.
- Beighle, D.E., P.A. Boyazoglu, R.W. Hemken 1993. Use of bone in serial sampling for mineral analysis. *Journal of Dairy Science*. 76: 1047-1052.
- Beighle, D.E. 2000. Bone, blood and faecal response to an acidogenic lick for range cattle using different concentrations of ammonium chloride. *Journal of South African Veterinary Associations* 71(4): 215-218.
- Ben Salem, H. and T. Smith, 2008. Feeding strategies to increase small ruminant production in dry environments. *Small Ruminant Research*. 77: 174-194.
- Bishop, J.H.R. 1964. Feeding phosphates to cattle. *Science Bulletin, Department of Agricultural Technical Services, South Africa*.
- Blood, D.C., J.A. Henderson and H. Radostits 1983. *Veterinary medicine*. Bailliere, Tindall and Cassell, London
- Blood, D.C. and O.M. Radostits. 1989. *Veterinary medicine* 7th Edition. Bailliere: Tindall.

Bravo et al, D., F. Meschy, C. Bogaert and D. and Sauvant 2003. Effects of fungal phytase addition, formaldehyde treatment and dietary concentrate content on ruminant phosphorus availability. *Animal Feed Science and Technology*. 99:73-95.

Caldeira, R.M., A.T. Belo, C.C. Santo, M.I. Vazques and A.V. Portugal 2007. The effect of long-term feed restriction and over-nutrition on body condition score, blood metabolites and hormonal profiles in ewes. *Small Ruminant Research*. 68:242-255.

Chapuis-Lardy, L., J. Fiorini, J.D. Toth and Z. Dou 2004. Phosphorus concentrations in dairy feces: Variability and affecting factors. *Journal of Dairy Science*. 87:4334-4341.

Chew, B.P. 2000. Micronutrients play role in stress, production in dairy cattle. *Feedstuffs*. 72:11.

Cohen, R.D.H. 1975. Phosphorus for grazing beef cattle. A.M.R.C. Review for Australia meat. *Research of Community*. 23: 1-16.

Corah, L. 1996. Trace mineral requirements of grazing cattle. *Animal Feed Science and Technology*.

Devendra, C., 1981. Potential of sheep and goats in less developed countries. *Journal of Animal Science*. 51: 461-473

Fernandez, F.J. and H.L. Kahn 1971. Clinical methods for Atomic Absorption Spectroscopy *Clinical Chemistry Newlands*. 3:24.

Forar, F.L., R.L. Kincoide, R.L. Preston and K.K. Hillers 1982. Variation of inorganic phosphorus in blood plasma and milk of lactating cows. *Journal of Dairy Science*. 65:760.

Goedegebuure, S.A. and M.J. Obwolo 1996. Bone mineralization status of indigenous goats in Zimbabwe. *Small ruminant research* 23: 17-22.

Ghamdi, S.M., E.C. Cameron and R.A. 1994. Magnesium deficiency: pathophysiologic and clinical overview. *Animal Journal of Kidney Distributors*. 24(5): 737-752.

Gonul, R., A.Kayar, T. Billal, O.R.M. Erman, D.V.M. Parkan, H.T. Dödurka, T. Gulyasar and B. Barıtcu 2009. Comparison of mineral levels in bone and blood serum of cattle in Northwestern Turkey. *Journal of Animal Veterinary Advances* 8:1263-1267.

Groenwald, J.W. and P.R. Boyazoglu, 1980. *Animal Nutrition concepts and applications*. J.L. Van Schaik (Pty) Ltd. Pretoria. Republic of South Africa.

Haenlein, G.F.W. and R.G Ramirez 2007. Potential mineral deficiency on arid rangelands for small ruminants with special reference to Mexico. *Small Ruminants Research*. 68: 35-41.

Hale, C. and K.C. Olson 2005. Mineral supplements for beef cattle. *Department of Animal Sciences*. 7:7.

Hall, J.O. 2005. Appropriate Methods of Diagnosing Mineral Deficiencies. *Mid-South Ruminant Nutrition Conference*. 21-26.

Hemingway, R.G. 1967. Phosphorus and ruminant. *Outlook on Agriculture*. 5:172-180.

Harris, D.J., R.G. Lambell and C.J. Oliver 1983. Factors predisposing dairy and beef cows to grass tetany. *Australian Veterinary Journal*. 60: 230-4.

Herd, T.H., W. Rumbelha and W. Emmett Braselton 2000. The use of blood analyses to evaluate mineral status in livestock. *Veterinary Clinic. Food in Animal Practice*. 16:423-444.

Huber, K., U. Roesler, A. Holthausen, E. Pfeffer and G. Breves 2009. Influence of dietary Calcium and Phosphorus supply on epithelial phosphate transport in preruminant goats. *Department of physiology, School of Veterinary Medicine Hannover, Bischofsholer Damm 15: (102) 30173*.

Jones, R.J. 1990. Phosphorus and beef production in northern Australia. 1. Phosphorus and pasture productivity: a review of Tropical grasslands. 24: 131-139.

Kanneganti V.R., R.P. Walgenbach and L.J. Massingill 1998. Daily and seasonal forage availability under rotational grazing of a mixed species temperate pasture. *Journal of sustainable Agriculture*. 12: 49-66.

Kincaid, R.I. 1999. Assessment of trace mineral status of ruminants: A review. *Proceedings of the American Society of Animal Science*. 1-10.

Laires, M.J., C.P. Monteiro and M. Bitcho 2004. Role of cellular magnesium in health and human disease. *Front Bioscience*. 19:262-276.

Lengarite, M. I., P.N. Mbungua, C.K. Gachuri and L.W. Kabuage 2012. Mineral Status of Sheep and goats grazing in the arid rangelands of northern Kenya. *Pakistan Journal of nutrition* 11 (4): 383-390.

Lloyd, L.E., B.E. McDonald and E.W. Crampton . 1978. *Fundamentals of nutrition* 2nd Edition W.H. Freeman and company San Fransisco.

Loxton, D.I., G.M. Murphy and M.A. Toleman 1983. Effects of superphosphate application on the phosphorus status of breeding cattle based pastures in Northern Queensland. *Australian Journal of Experimental Agricultural Animal and Husbandry*. 23: 340-347.

Mahusoon, M.M., A.N.F. Perera, E.R.K. Perera and K.A. Perera 2004. Effects of molybdenum supplementation on circulating mineral levels, nematode infection and body weight gain in goats as related to season, *Peradeniya Tropical Agricultural Research*. 16:128-136.

Mammoon, R. 2008. *Goats and their Nutrition*. www.manitobagoats.ca.

Marcy, W.G.L. 2005. Phosphorus supplementation and requirements for beef cattle. AS-1286.

Mazengera, K.E. 1992. Factors affecting small holder diary production in the semi-arid areas of Bophuthatswana PhD. Thesis, Medical University of Southren Africa Pretoria.

McDonald, P.R., R.A. Edwards and J.F.D. Greenhalgh. 1988. *Animal nutrition* 4th Edition. Longman group. U.K. England.

McDowell, L.R. and J.H. Conrad 1977. Trace mineral nutrition in Latin America. *Word Animal Review* 24:24-33.

McDowell, L.R., B.Bauer, E. Galdo, M. Koger, J.K. Loosli and J.H. Conrad. 1982. Mineral supplementation of beef cattle in the Bolivian tropics of *Journal of Animal Science*. 55:964.

McDowell, L.R., J.H. Conrad and G.L. Ellis. 1984. In "Symposium on herbivore nutrition in sub-tropics problems and prospects". (F.C.M. Gilchrist and R. I. Mackie, Editions). 67-88 Pretoria, South Africa.

McDowell, L.R. 1985. *Nutrition of grazing ruminants in warm climates*. Academic Press In cooperation, Orlando, Florida 32887.

McDowell, L.R. 1987. Assessment of mineral status of grazing ruminants world review of Animal Production. 21(4): 19-32.

Mellado, M., R. Valdez, L.M. Lara and J.E. Garcia 2004. Risk factors involved in conception, abortion and kidding rates of goats under extensive conditions. Small ruminant research 55, 191-198.

Merck Veterinary manual 2010. Merck and company cooperation.

Meschy, F. 2000. Recent progress in the assessment of mineral requirements of goats. Livestock production science.64: 9-14.

Michalek, K., M. Ozgo and W.F. Skrzypczak 2008. Renal regulation of Calcium-phosphate transport in preruminant goats. Department of Animal Physiology and Cytobiology, West Pomeranian University of Technology, Doctor Judyma 6, 71-466.

Miller, C.P., W.H. Winter, D.B. Coattes and P.C. Kerridge 1990. Phosphorus and beef production in northern Australia. 10. Strategies for phosphorus use. Tropical grasslands 24,239-249.

Mokolopi, B.G. and D.E. Beighle, 2006. Evaluation of the mineral status of cattle on communal grazing in the North West Africa. Journal Science of Veterinary Association.77(4):79-183.

Mtimuni, J.P., M.W.Mfitilodze and L.R. McDowell 1990. Interrelationships of minerals in soil-plant-animal system at Kuti Branch, Malawi. Communal Soil Science and Plant Analysis. 21:415-427.

National Research Council 1985. Nutrient requirement of sheep. 6th reveal edition. National Academic Press Washington, DC.

Ndebele, N., J.P., Mtimuni, I.D.T., Mpofu, S. Makuza, and P.Mumba 2005. The status of selected minerals in soil, forage and beef cattle tissues in a semi-arid region of Zimbabwe. Tropical Animal Health and Production. 37(5), 381-3.

Nelson, D.R. and S.B. Guss 1992. Metabolic and Nutritional Diseases. Extension Goat Handbook, National Dairy Database (www.inform.umd.edu/EdRes/Topic/AgrEnv/ndd/goat).

Nyamukanza, C.C., P.F., Scogings and N.W. Kunene 2008. Forage cattle relationships in a communally managed semi-arid savanna in northern Zululand, South Africa. *Journal of Range and Forage Science*. 25: 131-140.

Pugh, D.G. 2002. *Sheep and Goat Medicine*. Philadelphia:W.B. Saunders.

Petri, A., H. Muscghen, G. Brevesh, O. Richter and E. Pfeffer 1989. Response of lactating goats to low phosphorus intake. 2. Nitrogen transfer from rumen ammonia to rumen microbes and proportion of milk protein derived from microbes and proportion of milk protein derived from microbial amino-acids. *Journal of Agricultural Science Cambridge*. 111:265-271.

Radositis, O.M., D.C. Blood and C.C.Gay 1994. *Veterinary medicine*. Volume II. Edition, Bailliere Tindall London. 1379-1394; 1495-1499.

Read, M.V.P., E.A.N. Engels and W.A. Smith. 1986. Phosphorus and the grazing ruminant. 3. Rib bone samples as an indicator of the phosphorus status of cattle. *Science African Journal in Animal Science*. 16: 13-17.

Reece, W.O. 2009. *Functional anatomy and physiology of domestic animals*. Wiley-Blackwell, Ames, USA.

Reis, M.A.B., F.G.R. Reyes, M.J.A. Saad and L.A. Velloso 2000. Magnesium deficiency modulates the insulin signalling pathway in liver but not muscle of rats. *Journal of Nutrition*. 130: 133-138.

Sanon, H.O., C. Kabore-Zoungrana and I. Ledin 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area. *Small Ruminant Research*.67:64-74.

Scogings, P.F.,T.D. de Bryn and S. Vetter 1999. Grazing into the future policy- making for communal rangelands in South Africa. *Development Southren Africa*. 16:403-414.

Szefer, P. and J.O. Nriagu 2007. *Mineral components in Foods*. CRC press, Tatlo and Francis Group, USA. 123.

Tallam, S.K., A.D. Ealy, K.A. Bryan and Z. Wu 2005. Ovarian activity and reproductive performance of cows fed different amounts of phosphorus. *Journal of Dairy Science*. 88 (10):3609-3618.

Tamim, N.M., and R. Angel 2003. Phytate phosphorus hydrolysis as influenced by dietary calcium and micro-mineral source in broiler diets. *Journal of Agricultural Food Chemistry* 51:4687-4693.

Ternouth, J.H. and S.P.S. Budhi 1996. Effects of dietary P deficiency in pregnant and lactating ewes. *Australian Journal of Experimental Agriculture*.

Ternouth, J.H. 1990. Phosphorus and beef production in northern Australia. 3. Phosphorus in cattle review *Tropical Grasslands*. 24: 159-169.

Trudeau D.L. and E.F. Freier 1967. Determination of Calcium in urine and serum by Atomic Absorption Spectrophotometer (AAS). *Clinic Chemistry*. 13 and 101.

Underwood, E.J. 1981. The mineral nutrition of livestock. Commonwealth Agricultural Bureau and Slaughter, England.

Underwood, E.J. 1966. The mineral nutrition of livestock. Commonwealth Agricultural Bureau. The Central Press (Aberdeen) Ltd., United Kingdom.

Underwood, E.J. and N.F. Suttle 2001. The mineral nutrition of livestock 3rd Edition.

Valk, H., J.A. Metcalf and P.J.A. Withers 2000. Prospects for minimizing phosphorus excretion in ruminants by dietary manipulation. *Journal of Animal Science*. 29:28-36.

Valk, H., L.B.J. Sebek and A.C. Beynen 2002. Influence of phosphorus intake on excretion and blood plasma and saliva concentrations of phosphorus in dairy cows. *Journal of Dairy Science*. 85:2642-2649.

Wang, X.L., C.H. Gallagher, T.J. McClure, V.E. Reeve and P.J. Canfield. (1985). Bovine post-parturient haemoglobinuria: effect of inorganic phosphate on red cell metabolism. *Research in Veterinary Science*. 39:333-339.

Williamson, S.N., L.A. Lawrence, L.R. McDowell, A.C. Warnick and N.S. Wilkerson 1996. Dietary phosphorus concentrations related to breaking load and chemical bone properties in heifers. *Journal of Dairy Science*. 73: 1100-1106.

Winter, W.H. 1988. Supplementation of steers grazing *Stylosanthes hamata* pastures at Katherine, Northern Territory. *Australian Journal of Experimental Agriculture*. 28:669-682.

Wu, Z., L.D. Satter and R. Sojo 2000. Milk production, reproduction performance and faecal excretion of phosphorus by dairy cows fed three amounts of phosphorus. *Journal of Dairy Science*. 83:1028-1041.

Yami, A. 2005. Nutrition and feeding of sheep and goats. Handbook for Ethiopia. Prairie View A&M University, Texas, USA.