EVALUATION OF MINERAL STATUS OF SMALL RUMINANTS IN MARSABIT SOUTH DISTRICT OF NORTHERN KENYA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTERS DEGREE IN ANIMAL NUTRITION AND FEED SCIENCE

FACULTY OF VETERINARY MEDICINE

UNIVERSITY OF NAIROBI

MOSES IMA LENGARITE

JUNE, 2012

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Signature ______________ Date 25/07/012

Moses Ima Lengarite

This thesis has been submitted for examination with our approval as University supervisors.

Signature: ______________ Date 26/7/2012

Professor Paul N.Mbugua

Department of Animal production

Signature: ______________ Date 27/7/12

Professor Charles K. Gachuiri

Department of Animal production

Signature: ______________ Date 27/7/12

Dr. Lucy W. Kabuage

Department of Animal production

DEDICATION

I dedicate this thesis to my all daughters, sons and wife Alice Muslimo. Glory be to God the provider of knowledge and wisdom.

ACKNOWLEDGEMENTS

Many people and Institutions contributed directly and indirectly in the preparation of this thesis. First I would like to thank Kenya Agricultural Research Institute (KARI)-Marsabit team for their commitment and participation in the field data collection even when Christmas and the New Year eve festival seasons were going on. Among them was Mr. Hussein Walaga for his resourceful assistance in the field, the most important being in the botanical identification of the forage plants collected in the study sites. Also the drivers, Mr. James Lekeren and Abdi Adan, for driving and taking care of the animal tissue samples preserved in the mobile fridge.

Immense thanks also go to the Centre Director, KARI-Marsabit for availing all the resources required to conduct the field work. I appreciate the input of the herders experienced in the local flora and for participation in the feeding observation and collection of the forage plants. I acknowledge the local community elders for their welcome spirit and accepting us to conduct the study in the locality. Great thanks are extended to Mrs. Jane Muthoni and Anne Kimende of the Department of Animal Production, University of Nairobi, for the tireless efforts and extended periods spent together in the preparation and digestion of samples in the laboratory.

Also many thanks are extended to KARI-National soil survey for their timely effort to analyze the forage and animal tissue samples. Among them was Allan Chek for many consultations in expressing the analytical mineral reading, and in sending results on time. I would not forget to thank the head of pathology section, KARI-Trypanosomiasis Research Institute (TRC) for allowing me to use their laboratory and equipments to homogenize the liver samples. I especially acknowledge the assistance of Mr. Makau of KARI-TRC in homogenizing the liver samples.

I most importantly appreciate the contribution and effort of my supervisors Prof. Paul Mbugua, Prof. Charles Gachuiri and Dr. Lucy Kabuage for bearing the many consultations during the study, their useful comments and the correction of the thesis. I acknowledge research funding by KARI through the Kenya Arid and Semi-arid Lands (KASAL) project. I thank the KASAL coordination team led by Dr. David Miano and Dr. Mario Younan for preparing all the necessary facilitation on time and for their willingness to discuss arising issues during the course of the study. Finally I would like to thank Director KARI through the Assistant Director Human Resource development for granting me the KASAL scholarship and the study leave which finally lead to the production of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
asl	above the sea level
ALLPRO	Arid lands Livestock Program
AOAC	Association of Official Analytical chemists
ANOVA	Analysis of Variance
ASAL	Arid and Semi-arid Lands
conc.	concentration
DFF	Dry fat free
DM	Dry Matter
G	grams
GDP	Gross domestic product
gkg^{-1}	grams per kilogram
km	kilometers
KASAL	Kenya Arid and Semi-arid land
LSD	Least significant difference
$mgkg^{-1}$	milligrams per kilogram
mo	month
MoLD	Ministry of Livestock Development
mg/g	milligrams per gram
n	sample size
P-value	Probability value
Ppm	parts per million
SD	Standard deviation
Spp.	Species
StastiXl Excel	Statistical Excel
TLU	Tropical livestock unit
vs.	versus

ABSTRACT

A study was carried out in Merille location of Marsabit South district, Kenya to investigate mineral status of sheep and goats under the pastoral production system. The objectives of the study were (i) to assess indigenous knowledge (IK) on mineral nutrition in small ruminants (ii) to identify the most preferred forage species consumed by small ruminants during wet and dry seasons (iii) to determine the mineral profiles of most preferred forage species and to assess the content of macro and micro minerals in bone and liver tissues. In the first part of the study, a cross-sectional survey was undertaken using a structured questionnaire to gather herder's knowledge on mineral nutrition. In the second part, the most preferred forage species were identified by direct observation of 120 young sheep and goats between 0830-1130 hours for six consecutive days. During each of the seasons, ten forage samples constituting the most preferred forages were randomly collected along the grazing path and analyzed to determine concentrations of Ca, P, Mg , K , Na, Fe, Zn, and Mn. A composite of ten most preferred forages was then formulated based on bite counts and analysed for the same minerals. Mineral intake was then computed based on dry matter intake, body weight of the animals and mineral content of the composite. In the third part of the study, twenty-two sheep and twenty-two male goats (14-16 months old) were randomly purchased from three herds/flocks in Merille, slaughtered and whole liver and 12th rib removed. The liver sample was used to analyze for Cu, Fe, Zn and Mn while the 12^{th} rib was analyzed for Ca, P, Mg and Zn. The results showed that herders use specific indicators to detect mineral status of animals and ninety four percent correct salt deficiencies by grazing herds in salty plants, saline water and salt licks. Eighty five percent observed mineral deficiencies during the dry season pastures, while 46% observed mineral deficiencies in the wet season. Ten most preferred forages represented 88.5% and 85% of dry season forage bites in sheep and goats respectively while in the wet season, preferred forages constituted 76.4 % of sheep and 75.9% of goat's bites. Preferred forages/types showed species and seasonal variation in mineral profiles. Browses had higher levels of Ca, Mg, K, Na and Fe while grasses/herbs were rich in Zn and Mn. The contents of P and K were higher in wet than dry season. In both seasons, sheep and goats had adequate intake of Ca, Mg and low intake of P and K during the dry season. In the case of micro-minerals all animals had adequate intake of Fe, sheep showed low Zn (14.98 $mgkg^{-1}$ DM) intake in the wet season and goats had low Mn (18.05 $mgkg^{-1}$ DM) intake during the dry season. Liver and bone tissues of sheep and goats indicated adequate body status of Ca, Mg, Cu, Zn, Fe and Mn in the wet season. In the dry season, sheep showed low hepatic Zn (83.34 mg/kg DM) and Mn (7.54 mg/kg DM) and goats in Cu (236.29 mg/kg DM) and Mn (6.85 mg/kg DM) while both species showed low rib Zn and marginal P bone reserves. Based on the information on herders knowledge, mineral intake and liver and bone tissues mineral content it can be concluded that small ruminants suffered from P, K, Zn and Mn and goats in Cu deficiencies during the dry season. The small ruminants would benefit from P, K, Zn and Mn and goats in Cu supplementation during the dry season.

Keywords: Forages, goats, indigenous knowledge, liver, macro and micro-minerals, rib, sheep

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

This is organized into eight chapters. The introduction presented here covers the eight chapters. The livestock sub-sector is a key component of agricultural system in Kenya and generates 42–45% of the agricultural GDP and 10% of the national GDP (Mwinyikione, 2010). The Kenyan Ministry of livestock Development (MoLD, 2007) estimated the national livestock population to be 13million cattle, 10 million and 9 million sheep and goats, respectively. About 900,000 camels are found in some parts of the arid and semi arid lands of Kenya. Over 60% of these animals are kept in the arid and semi-arid lands (ASAL) by pastoral and agro-pastoral farmers. The small ruminants (sheep and goats) are major component of livestock production, contributing 30% of red meat, and 4% of total milk production (Cheruyot, 2004).

The ASALs are conventionally divided into Southern and Northern Rangelands. The latter has approximately 4 million sheep and goats and accounts for 22% of small ruminants kept in the ASAL (Kariuki and Letitiya., 1998). The study area was in Marsabit South district, which is one of the ASAL districts in Kenya. Data from the MoLD (2008) show that 240,000 sheep and 650,000 goats are raised in this district.

Livestock is a very important resource particularly in the ASAL, where the producers rely on the small ruminants for food, income and food security. In the pastoral system, many livestock producers rely on small ruminants as the major source of daily food in the form of meat and milk nutrition. As means to generate household cash, a high proportion of pastoral households

frequently sell sheep and goats. In periods of food insecurity. pastoral farmers fall back on camels, sheep and goats to provide emergency food to households (Kariuki and Letitiya., 1998)
In comparison to other ruminant livestock, livestock producers in the ASAL have shifted to sheep and goat production due to their rapid rate of reproduction, ability to exploit a wide range of feed resources in different ecological environments, rapid post-drought recovery, lower watering frequency, and adaptation to cope with climatic changes.

Albeit the shift to small ruminant production and the role these animals play in sustaining pastoral and agro-pastoral livelihoods, their performance, has been reported to be below optimum level particularly in the ASAL (ALLPRO, 2007). In spite of interventions on animal health care over the years, the productivity of small ruminants in ASAL has been on the decline (Ndungu *et al.*, 2003). In the northern rangelands, small ruminant producers acknowledge the decline in small ruminant productivity, against the rising market demand for quality sheep and goats.

Inadequate nutrition is a major factor contributing to the low productivity of small ruminant under arid and semi-arid conditions. The major source of nutrients for these animals is rangeland forages and their nutritional status directly influences herd productivity and product quality of marketed animals. Seasonal changes in moisture availability influence the quantity and quality of these forages and the available nutrients (Harry, 1999) and thus herd performance.

To optimize livestock performance, including small ruminants, their diets should contain sufficient protein, energy, vitamins and minerals. Of the nutrient inadequacies, mineral deficiencies, imbalances and overload in native pastures affect the productivity of grazing animals in the tropics (McDowell *et al*., 1984). Minerals are vital in life, influencing growth, health status, immune system function and synthesis of animal products.

Past studies on camel and cattle mineral nutrition indicate that mineral imbalances and deficiencies exit in many areas of ASAL (Mwakatundu, 1977; Howard *et al.*, 1962; Kuria, 2004). Further work on mineral nutrition and effect on productivity should include other livestock species, such as sheep and goats, which are numerically the most important livestock in the ASAL. In the arid areas of Kenya, sheep and goats depend on natural forages, salt licks and occasionally commercial supplements for their mineral requirements. In free grazing animals, minerals derived from natural feedstuffs are often inadequate and require supplementation to satisfy animal requirements (Sowande *et al*., 2008). The balanced mineral supplements promoted to improve livestock production in the arid and semi-arid lands (ASALs) of Kenya, may not correct the mineral deficits of small ruminants kept in specific regions due to lack of adequate knowledge. Therefore, prior to formulation of mineral supplements, a thorough knowledge on mineral status of diets and body tissues of animals would be necessary. Among all the nutrients, mineral supplementation gives better response per unit cost compared to energy or protein supplementation and is the cheapest nutritional intervention. In Marsabit South district, pastoralists have reported behavioral characteristics associated with mineral deficiencies such as chewing of bones, geophagy and craving for saline waters in their flocks/herds (personal observation).

It was towards this realization that a study was initiated to assess the mineral status of grazing sheep and goats receiving no mineral supplements. The study aims to generate mineral nutrition information by analysis of diet and body tissues of animals which can be used to address any mineral deficiency and imbalances affecting small ruminants in Marsabit South district.

1.1 Justification

The rapid growth of demand for livestock products in developing countries, including Kenya, will be met through a corresponding increase in animal production. In Kenya, the increased demand can be met by improving the productivity of animals in the arid and semi-arid lands, where the majority of meat animals are kept. Since the majority of livestock producers in the ASAL concentrate on small ruminant production, it is imperative to alleviate the constraints that limit their performance. The productivity of small ruminants has been hampered by inadequate availability of quality feed or inadequate intake of specific nutrients as well as inadequate health inputs. One key option is to alleviate the nutritional constraint affecting the small ruminants, without neglecting the mineral component of the diet. Studies conducted in Sub Saharan Africa on mineral nutrition have shown that mineral deficiencies exist and have adverse effect on animal production (Schillhorn van Veen and Loeffler, 1990). There is very little available information on the relationship of mineral nutrition and productivity of the small stock in the pastoral production systems.

Mineral deficiencies lower animal performance, and the nutritional value of animal food products, the latter can adversely affect human nutrition and health status. Animal products (meat and milk) derived from small ruminants, not only provide humans with protein and energy, but also with a wide range of readily available minerals. Meat and milk are rich sources of readily available macro minerals (such as calcium, phosphorus, magnesium) and micro minerals (zinc, copper, iron, cobalt, selenium).

In the northern rangelands, small ruminant producers have reported high incidence of mortality. associated with under nutrition and diseases, and slow growth rate of young stock. Since minerals are necessary for growth, and immune system function, inadequacies can affect growth and response of young stock to disease challenges. It is imperative to ascertain the adequacy of the minerals in the diet of sheep and goats, as it can be related to young stock performance and herd growth.

In the study area, pastoralists associate reduced helminths infection of small ruminants to consumption of salty forages and saline water sources. Small ruminants originating from lowlands are highly preferred by consumers for their tasty meat, associated to consumption of salty forages and saline water sources. In the lowland areas, sheep and goats consuming salty forages and saline water have a glossier coat, good health and higher reproductive performance.

Evaluation of mineral status of animals is a useful diagnosis tool that provides guidance in addressing mineral nutrition problem and formulation of mineral supplements. This study attempts to assess mineral status of small ruminants in Marsabit South district (study area) and the information generated would be used to address the adequacy of mineral nutrition in sheep and goats in the area.

1.2 The specific objectives of the study were:

1. To assess pastoral indigenous knowledge on mineral nutrition and it's implication on small ruminant production.
2. To identify the most preferred forage species by small ruminants in wet and dry seasons
3. To determine the mineral profiles of most preferred forage species by small ruminants
4. To assess the mineral status of small ruminants in ASAL of northern Kenya

1.3 Hypotheses

The study tested the following hypotheses:

1. Small ruminants in the study area do not suffer from mineral deficiencies.
2. The season does cause mineral deficiencies in forage and the small ruminants.
3. Mineral status in forage is not influenced by the plant species.

CHAPTER TWO

LITERATURE REVIEW

The literature review presented here covers all aspects of the thesis presented in the eight chapters.

2.1 Minerals in Animal nutrition

Mineral nutrients are simple-structured, inorganic substances that constitute a small proportion of an animal's diet. They are vital for many metabolic processes that ensure the animals are healthy and productive (Soetan *et al*, 2010). Minerals play their role through activation of enzymes; functions as cofactors, as components of molecular structures, and body's acid-base and electrolyte balance. As part of the diet, minerals are so potent, that inadequacy hinders utilization of other nutrients and animal productivity (Szefer and Nriagu, 2007). At least 22 minerals are essential in livestock metabolism, but numerically less than fifteen are considered in dietary supplements (Tisch, 2006). The essential macro-elements are: calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), sodium (Na), chlorine (Cl) and sulphur (S), while the essential trace elements include iron (Fe), iodine (I), zinc (Zn), copper (Cu), manganese (Mn), cobalt (Co), and selenium (Se) as classified by Underwood and Suttle, (1999). The nutritional quality, absorption and bioavailability of minerals, mainly depends on the chemical form, digestibility of the mineral, and interaction between minerals and other dietary components (Underwood and Suttle, 1999; Soetan *et al*., 2010).

Animals obtain minerals through dietary sources, that comprise of natural and commercial feeds, drinking-water and mineral supplements. Mineral deficiencies and excesses adversely affect animal performance. However, sub-optimal mineral deficiency and imbalances are more serious in reducing performance than manifested mineral deficiency that can be detected and rectified (Shamat *et al.*, 2009).

2.2 Mineral sources for grazing ruminants

2.2.1 Grazing forages

Grazing livestock in the tropics most often do not receive mineral supplementation, except for common salt and must depend almost solely upon forages for their mineral requirements (McDowell *et al*, 1984). The concentration of minerals in the forages are influenced by several factors such as soil type, soil pH, moisture content, plant species, plant maturity, season, vegetative part, pasture management, and locality (Khan, *et al.*, 2006; McDowell *et al.*,1993).

The parent rocks in which the soils are derived influence the soil mineral content. Young and alkaline geological formations are more abundant in most trace elements than older, more acidic, coarse and sandy formations (McDowell, 1996). Soil characteristics such as pH, salinity and alkalinity influence mineral solubility and availability in plants. In high soil pH (>7) the forage concentration of Mn, Zn, P and Fe decreases and in contrast, the concentration of Ca and Mo increases (Mayland and Wilkinson, 1996). The soils in Merille Location, the study area, are calcareous, acidic with a pH of 6.0, low in phosphorus levels (4.5ppm), but rich in calcium (Lelon, *et al.*, 2010; Ongweny, *et. al.*, 1983). This pH level favours uptake and availability of Mg, K, S, and Cu in forage plants.

Mineral concentration in forages varies among different forage type and plant species. Except for sodium, manganese and zinc, legumes have higher content of minerals than grasses (Mayland

and Wilkinson, 1996). Green plants are excellent sources of Mg, attributed to the presence of magnesium in the chlorophyll moiety (Wilkinson. *et. al.*, 1990). In the arid and semi-arid lands, evergreen browse plants are thus expected to be rich sources of magnesium (Mg). Grasses generally have high concentration of manganese than legumes (Underwood, 1977). Many tropical legumes have low content of sodium, with most of them having less than 4g Na /kg of dry matter (Minson, 1990). Jumba *et al.* (1996), in a study of mineral concentrations in Rhodes, Setaria and Napier grasses in western Kenya concluded that the mineral contents of Ca, S, Cu and Zn significantly varied between the grasses.

Studies on camel mineral nutrition in Sudan showed that browses had significantly higher mineral content than crop residues and grasses (Shamal *et al*, 2009). In 1995, Schwartz and Shultka reported that browse trees and bushes in Isiolo District were important sources of minerals for browsing species, containing about 18.3% DM of total mineral content. A study by Kuria and associates (2006) in Marsabit showed that about 22-50% of forages in the camel diets were marginal in K, P, Cu and Zn. In Marsabit South district, most herbs, shrubs and tree forages were found to be low in P and Na, but high in Ca, Mg and K (Kayongo-Male, 1983).

Salt-tolerant forage species, which via the means of deep roots, salt glands and dilution process tolerate sodium in saline soils, can be rich sources of Na (Underwood and Suttle, 1999). Halophyte plants are characterized by high accumulation of minerals in the above ground tissues, which limit their use in animal feeding, particularly as sole source of forage (Al-Dakheel et al., 2008). Salty species such as *Atriplex vesicaria*, with high ash content mostly as salt, can depress digestibility and lead to energy losses in animals (Arieli *et al.*, 1989). In Marsabit South district, salty plant such as *Salsola dendroides* was shown to have exceptionally high levels of Na. Cu and Zn content (Kuria, 2004).

As plants mature, mineral content decline due to translocation of nutrients to the root system, with the concentration of most trace elements declining with plant maturity (Reid and Horvath, 1980).

Studies involving range Spanish goats and camels in Sudan, showed that forage K and P declined with plant maturity, shedding of leaves and seed (Rami´rez, *et al.*, 2005; Shamat *et al.*, 2009). Consequently, most naturally occurring mineral deficiencies in livestock are associated with specific seasons (Aregheore *et al.*, 2007). In South Marsabit (study area), dry season forages were deficient in most minerals, while P, Mg and Na were generally low in cattle diets throughout the year (Kayongo-Male, 1983). Similar findings were reported by Holler, *et al*, (1989) who showed that mineral supply to camels in the dry season was marginal to deficient. Pastures in the rangelands are reportedly deficient in several minerals particularly Na, P and Cu (Underwood and Suttle, 1999).

In farm animals, mineral disorders have been associated to specific regions. In Africa, Cu deficiency ranked second to P and prevalence was high in the parts of Rift valley in East Africa (Howard, 1963). Mwakatundu (1977) confirmed that P and Cu deficiencies were widespread in Kenya as shown by low levels in soil, pasture and bovine plasma. In Western Kenya, forages were reported to be deficient in P, Na, and Zinc (Musalia, *et al.*, 1989). Also, reported in Kenya was selenium deficiency, indicated by a Se related disease condition (Schillhorn van Veen and Loeffler, 1990).

2.2.2 Minerals in drinking-water

In the ASAL of northern Kenya. sheep and goats are watered at a frequency of every three to four days (personal observation). The common watering sources in the study area are boreholes, shallow wells, pans and natural surface water. Most minerals, which are essential as dietary nutrients for livestock are found in water (Buttery *et al.*, 2005). The principle anions dissolved in drinking water include chlorides, sulphates, nitrates while the cations are Na, Ca and Mg (Harris and Van Horn, 2003).

Data from the Integrated Project on Arid Lands based in Marsabit district showed that most ground water sources are alkaline with a pH of 7 or more (Ongweny *et. al.*, 1983). The Na, K, Mg, Ca and F concentrations in various water sources in Marsabit South district (study area) ranged from 600-900, 16-80, 96-146, 19-127, 1.55-2mg/l respectively (Schwartz *et al.,* 1991). High levels of specific essential ions and potentially toxic minerals such as As, F, Pb, and Hg in the water can cause health problems and possibly animal death (Zinash *et al.*, 2003).
Drinking water is not normally considered a major source of minerals to livestock (Underwood and Suttle, 1999). However, some deep aquifers and salty water sources contain exceptionally high levels of sulphur and sodium that can be a valuable supplementary source in areas where the diet is low in such minerals (Smart *et al*, 1986; Smith and Middleton, 1978a).

2.2.3 Mineral supplements

Livestock keepers in the study area, seldom supplement the stock with any form of mineral salts (personal observation). However, the animals can access natural salt licks, salty bushes and saline water sources in the normal grazing routines. Ingestion of soil and natural salt licks can supplement the intake of some minerals (Mayland and Wilkinson, 1996). Mineral supplementation provides a safety margin against potential deficiency (Beede, 1991). Mineral supplements can be administered to animals via drinking water, mineral licks, salt mixtures, oral drenches, rumen boluses and regular injections (Underwood, 1981; McDowell *et al.,* 1993). The commercial mineral supplements are made from such compounds as salts, oxides, carbonates and phosphates depending on availability, solubility, price and freedom from toxicity (Underwood and Suttle, 1999). For mineral supplements to be beneficial they should be formulated to correct mineral deficiencies of animals in specific regions (Khan *et al.*, 2008).

In Marsabit district, supplementation of lactating camels with Cu, Co and P was found to be beneficial by increasing milk yield from 3.4 litres day-1 to 5.4 litres day-1 (Onjoro et al., 2006).

2.3 Indicators of mineral status in animals

Appropriate biochemical analyses of tissues and fluids of animals are valuable aids in the early detection and differential diagnosis of mineral abnormalities in livestock (Mills, 1987). Status of a nutrient is the balance between the supply and the demand. When the demand outstrips supply, then the animal is deficient in the mineral.

2.3.1 Use of liver tissue

The liver plays a key role in the storage, turnover, and homeostasis of many trace minerals. It serves as the primary storage organ for many essential elements and is therefore the most preferred post-mortem tissue for trace mineral analysis (Blezinger, 2006). Liver is the organ that may reflect the status of several trace minerals in animals (McDowell, 1992). Concentration of trace minerals in the liver is affected by such factors as: interaction with other minerals; animal physiological demand; and rate of mineral absorption and use. The liver concentrates high levels of Fe, Zn and Cu (Szefer and Nriagu, 2007).

Mineral analysis of the liver can be done by necropsy or biopsy sampling techniques, the later assuming liver mineral concentration is homogenous. However, samples collected from cattle liver have shown that variation in mineral concentration exist to some small degree between the lobes (Ludwick *et. al.*, 2008).

2.3.2 Use of bone tissue

One of the major roles of bones is the repository and homeostasis of minerals which is vital for animal life. Of the body tissues, bones have proved useful in diagnosing depletion of Ca, P, and Mg, which constitute the bone inorganic component (Underwood and Suttle, 1999). The content of these minerals in the bones depends on the type of bone assayed and age of the animal (Miller, 2007). Bone mineral assessment can be achieved by biopsy and post-mortem sampling whereby the values obtained are expressed as concentration per gram of ash (Underwood and Suttle, 1999) since bone ash is considered more reliable than fresh or dried bone weight for expressing mineral values (Miller, 2007).

Several studies preferred the short bones like the ribs which are easier to biopsy, collect and store. Growing animals have high requirement for minerals and therefore have elevated levels of minerals that make up the bone tissue. Young growing cattle of between 6-18months had levels of 12.37 mg/g bone ash of Mg (Miller, 2007).

Deficiencies of minerals related to growth, such as Ca, P, Mn, Zn and Cu, can reduce animal growth, lead to bone abnormalities, fractures and poor mineralization of bones (Johnson *et. al.*, 2007).

The bone, analyzed as fat-free and dry weight, to remove the age variability of fat and moisture content, are better indicators of the body status of Ca, P and Mg than those expressed on dry and fresh weight basis (Hall, 2005). However, when tissues are ashed at high temperatures, some ash elements such as phosphorus, sulphur, chloride, potassium and some micro-elements may be lost (Georgievskii *et al.,* 1982). Studies carried out in cattle and goats have shown that rib bone Ca, P and Mg were indicative of the animal body status (De Waal and Koekemoer, 1997; Goedegebuure and Obwolo, 1996). In Bolivia, evaluation of mineral status of sheep has shown that rib ash Ca, P, Mg and Zn was 29.5%, 16.8%, 0.65% and 0.03% respectively (Espinosa *et al*., 1982).

2.3.3 Use of enzyme assay

It has been estimated that about 25-30% of all known enzymes involve metal ions as component (cofactor) of their structures (Nielsen, 1993). The enzymes that require minerals for their activity are in two groups–metal activated enzymes and metalloenzymes. The former use divalent cations which are not tightly bound to the ligand while the latter use transitional metals that are tightly bound to the ligand.

Metalloenzyme require trace elements such as Fe, Zn, Cu, Mn, Mo, Co and Se for their function (Soetan et al., 2010). Such minerals have fixed number of specific metal ion(s) firmly attached to specific protein moiety (Underwood and Suttle, 1999). Removal of the metal ion from the protein moiety leads to the loss of the enzyme activity (Nielsen, 1993). The enzyme assay determines the activity of a specific enzyme in substrate solution and high presence is indicated by high levels of substrate used and product formed. Absence of adequate level and activity of metalloenzyme can be linked to deficiency in the element associated to their structures.

There is a wide range of metalloenzymes and enzyme assays performed to test specific activity of an enzyme. For instance. glutathione assay is conducted to assess the activity of glutathione peroxidases (GPXs) on the substrate reduced glutathione (Congleton and Welker, 1997). Selenium is the cofactor of the metalloenzymes GPXs, and the concentration and activity of GPX in tissues cell extracts reflect dietary supply of selenium (Ullrey, 1987). Some mineral elements such as Ca, Mg, K, Fe, Zn and Mn play vital role in enzymes activation or stabilization. Enzymes such as adenosine triphophatase (ATPase), Succinic dehydrogenase and lipase are activated by Ca. Magnesium are essential activator for enzymes myokinase, diphophopyridinenucleotide kinase, and creatine kinase (Soetan et al., 2010). The deficiency of the mineral results in reduced activity of the enzyme.

In India, supplementation of lambs with 0.15 mg Se/ kg DM organic and inorganic sources was found to significantly enhance the RBC glutathione peroxidise (GSH-Px) activity and indicates the Se and antioxidant status of the animals (Kumar at al., 2009). In China, goats supplemented with 2 mg Se /kg DM showed the highest GSH-Px activity in seminal plasma than non supplemented group (Shi et al., 2010).

References

ALLPRO., 2007. Sheep and goats manual for the Arid and Semi Arid lands of Kenya, ministry of livestock development, ADB, ALLPRO manual, Hill plaza, Nairobi.

Aregheore, E.M., Hunter, D., Perera, D. Mautoatasi, M.T., 2007. The soil-plant-animal phenomena: Serum mineral status of Fuji fantastic sheep grazing Bantiki grass and Pangola grass in Samoa. *Journal of Animal and Veterinary advances* 6 (3).

AL-Dakheel, A., AL-Hadrami. G., AL-Shoraby, S., Shabbir, G. 2008. The potential of salt-tolerant plants and marginal resources in developing and integrated forage-livestockproduction system. 2nd International salinity Forum. Adelaide, Australia.

Arieli, A., Naim, E., Benjamin, R.W., Pasternak, D., 1989. The effects of feeding saltbush and sodium chloride on energy metabolism in sheep. *Animal production* 49, 451-457.

Blezinger,S.B., 2006. Assess mineral status of herd to prevent problems. Cattle today online, http://www.cattletoday.com/archives/2006/march/CT452.html.

Buttery, P.J., Max, R., Kimambo, A., Ku-Vera, J., Akbar, A., 2005. Animal response to nutrient supply. In (E.Owen, A. Kitalyi, N. Jayasuriya and T. Smith, eds.): *Livestock and wealth creation.* Nottingham University Press, Nottingham, UK.

Beede, D.K., 1991. Mineral and water nutrition. Vet. Clin north AM Food Anim Prac, July7 (2):373-390.Congleton, J., Welker, T. 1997. Improved nutrition to increase the viability and hatchery smolts.Fishery research, University of Idoha, USA.

Cheruiyot, J.P., 2004. Livestock production in Kenya. In: Proceedings of the 5th EAGODEN Conference 7-9th June 2004, held at Kenya Methodist University (Kemu), Meru, Kenya

Cogleton,J., Welker,T., 1997. Improved nutrition to increase the viability of hatchery smolts. Annual report to Idoha department of fish and game. University of Idoha, USA.

De Waal, H.O., Koekemoer, G.J., 1997. Blood, rib bone and rumen fluid as indicators of phosphorus status of grazing beef cows supplemented with different levels of phosphorus at Armoedsvlakte. S.Afr.Tydskr.Veek, pp: 76-84.

Espinosa, J.E., McDowell, L.R., Rodriguez, J., Loosli, J. K., Conrad, J.H., Martin, F.G., 1982. Mineral status of Llamas and sheep in the Bolivian Altipiano. *Journal of nutrition*, pp.2286-2291.

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

Georgievskii, V.I., and Annenkov, B.N., Samokhin, V.T., 1982. Mineral nutrition of Animals. P.69.

Harry, I., 1999. Effect of seasonality on productivity of pastoral goat herds in northern Kenya PhD dissertation, Berlin University., Germany.

Hall, J.O., 2005. Appropriate methods of diagnosing mineral deficiencies. Mid-South ruminant nutrition conference, pp: 21-26.

Harris, B., VanHorn, H.H.2003. Water and its importance to animals. University of Florida, IFAS extension, CR1017, pp.1-8.

Holler, H., Breves, G, Lechner-Doll, 1989.Mineral profiles and turnover in the forestomachs of camels in Kenya grazing under various seasonal conditions.

Howard, D.A., 1963. Notes on animal diseases. XXIII. Mineral deficiency diseases. East Africa *Agricultural and forestry journal* 28: 191-194.

Howard, D.A., Burdin, M.L., Lampkin, G.H., 1962. Variation in mineral and crude protein content of pastures at Muguga in the Kenya Highlands. Journal of Agricultural Science, 59: 251-256.

Johnson,H.E, Bleich,V.C, Krausman,P.R, 2007.Mineral deficiencies in the Tule Elk, Owen valley, California. *Journal of wildlife diseases*, 43(1), pp. 61-74.

Jumba, I.O., Suttle, N.F., Hunter, E.A., Wandiga, S.O., 1996. Effects of botanical composition, soil origin and composition on mineral concentrations in dry season pastures in western Kenya. In; Appleton, J.D., Fuge, R., McCall, G.J.H (eds) Environmental Geochemistry and health. Geological society special Publication No. 113, London, pp.39-45.

Kariuki, D.P., Letitiya, W. 1998. Livestock production and health challenges in pastoral areas. Samburu District, Kenya, pp: 16-17.

Kayongo-Male, 1983. Feeding habits forage quality and food intake of Zebu cattle grazing natural rangeland in the IPAL study area, in IPAL technical report E-8, small stock and cattle productivity, nutrition and diseases of northern Kenya, UNESCO, Nairobi, 1986.

Khan, Z.I., Ashraf, M., Valeen, E.E. 2006. Forage mineral status evaluation: The influence of pastures. Pak.J., 38(4) pp. 1043-1054.

Khan, Z.I., Danish, M., Ahmed, K. 2008. Macro mineral profile in forage, blood plasma and urine of grazing buffaloes with respect to seasonal variation. Buffallo bulletinVol.27, pp.173-176.

Kuria, S.G, Wahome R.G, Wanyoike M.M., Gachuiri C.K., 2006. The effect of mineral supplementation on plasma minerals concentration of Camels, *International journal of Agricultural and biology.*

Kuria, S.G., 2004. Mineral nutrition on settlement (Manyatta) based milk camel herds among the Rendille community of Northern, PhD thesis, University of Nairobi, Kenya, pp. 93-99.

Kumara, N., Garga, A.K., Dassa, R.S., Chaturvedi, V.K. Mudgal, V. , Varshney, V.P., 2009. Selenium supplementation influences growth performance, antioxidant status and immune response in lambs. *Animal Feed Science and Technology* 153, 77–87

Lelon, J. K., Muga M. O, Odee D. W., Wekesa, C., Ndakwe, B., 2010. Effect of chemical properties of soils on gum elementary compositions from *Acacia Senegal* variety *kerensis* in Samburu and Marsabit districts. *African Journal of Plant Science* Vol. 4 (2), pp. 021-025.

Ludwick.T.P. Poppenga, R.H. Green,P.G, Puschner, B., Melton,L.A, Hoar,B.R. Nyberg,N.L, Mass, J.2008.The correlation of Potasium content and moisture in bovine liver samples analyzed for trace mineral concentration. *Journal of veterinary diagnostic investigation,* vol.20 Issue 3,314-320.

Mills, C.F., 1987. Biochemical and physiological indicators of mineral status in animals: copper, cobalt, and zinc. Journal of Animal science 65, 1702-1711.

Miller, G., 2007. Magnesium bioavailability update. Premier chemicals. http//www.premierchemicals.com.

Mayland, H.F., Wilkinson, S.R.1996. Mineral Nutrition. Cool-season forage grasses. Agronomy monograph no.34. pp.165-191.

McDowell, L.R., Conrad, J.H., Glen Hembry, F., 1993. Minerals for Grazing Ruminants in tropical Regions, 2nd edn. University of Florida, Gainesville.

McDowell, L.R., 1992. Mineral in Animals and Human nutrition. Academic press, New York, USA.

McDowell, L.R., 1996. Feeding minerals to cattle on pasture. Animal feed science technology 60, pp. 247-271.

McDowell, L.R., Conrad, J.H., Ellis, G.I., 1984. Mineral deficiencies and imbalances and their diagnosis. Proc. Symp. On Herbivore nutrition in subtropics and tropics, Pretoria pp. 67-88.

Minson, D.J.1990. Forages in ruminant nutrition. Academic press, San Diego California, pp.208-229.

Musalia, L.M., Semenye P.P., Fitzhugh H.A. 1989. Mineral status of dual-purpose goats and forage in Western Kenya. *Small Ruminant Research* 2(1):1–9.

MoLD., 2007. Ministry of livestock National report, Hill Plaza, Nairobi. Kenya.

MoLD., 2008. Ministry of livestock and Fisheries Development. Laisamis district Annual report.

Mwinyikione, W.. 2010. The ministry of livestock development, leather and leather products, Division report, Kenya, Nairobi.

Mwakatundu, A.G.K., 1977. A study of the nutritive value of East African pastures for ruminant livestock with special reference to mineral nutrition in grazing dairy cattle. PhD thesis, University of Nairobi, Kenya.

Nielsen, F.H.,1993. Ultra trace elements of possible importance for human health: An update, pp.355-376, Wiley-Liss, Inc.

Ndungu J, Mbuvi D, Lengarite M., 2003. On farm evaluation and improvement in young stock husbandry practices in Rendille and Gabbra areas of Marsabit district, EU/KARI report.

Ongweny,G,S., Baur, P.J., Bergeson, R.H., Ndombi, J.M., 1983.Preliminary account of erosion, sediment transport and surface water resources of Marsabit district. IPAL technical report. pp.20-26.

Onjoro, P.A., Njoka-Njeru, E.N., Ottaro, J.M., Simon, A., Schwartz, H.J., 2006. Effects of mineral supplementation on milk yield of free-ranging camels (*Camelus dromedarius*) in northern Kenya. *Asian-australasian journal of animal science*, vol.19, no.11 pp: 1597-1602.

Ram´ırez-Ordu˜na, R., Ram´ırez, R.G., Gonz´alez-Rodr´ıguez, H., Haenlein, G.F.W., 2005. Mineral content of browse species from Baja California Sur, Mexico. Small Rumin. Res. 57,1–10.

Reid, R.L. and Horvath, D.J., 1980. Soil chemistry and mineral problems in farm livestock. A review. Anim.Feed Sci. Technol., 5: 95-167.

Shamat, A.M., Babiker, I.A.. Mukhtar, A.M.S, Ahmed, F.A. 2009. Seasonal and Regional variations in mineral content of some important plant species selected by Camels (*Camelus dromedaries*) in arid and semi-arid lands of Sudan. *Journal of Applied Sciences Research* 5 (10), pp.1676-1684.

Schwartz, H .J., Shultka, W., 1995. A compendium of important forage plants in the semi-arid and arid rangelands of Kenya. Range management hand book of Kenya, Vol. III, 9, GTZ, Nairobi, Kenya

Schwartz, H.J., Shaabani, S., Walther, D., (eds), 1991. Range management Handbook of Kenya, Vol.II, 1, MoLD, Nairobi, Kenya, pp. 68-71.

Schillhorn van Veen T.W. and Loeffler I.K. 1990. Mineral deficiency in ruminants in sub Saharan Africa: A review. Tropical Animal Health and Production 22(3):197–205.

Shi Lei, Chunxiang Zhang, Wenbin Yue,, Liguang Shia,, Xiaomin Zhua,, Fulin Lei. 2010. Short term effect of dietary selenium-enriched yeast on semen parameters, antioxidant status and Se concentration in goat seminal plasma. *Animal Feed Science and Technology*, 157, 104–108.

Soetan, K.O., Olaiya, C.O., Oyewole., 2010. The importance of mineral elements for human, domestic animals and plants. A review. *African journal of food science*, vol.5 (5) , pp. 200-222.

Smart, M.E., Cohen, R., Christensen,D.A., Williams, C.M., 1986.The effects of sulphate removal from drinking water on plasma and liver copper and zinc concentrations of beef cows and their calves. *Canadian journal of Animal science* 66, 669-680.

Smith. G.S.. Middleton. K.R.. 1978a. A classification of pasture and fodder species according to their ability to translocate sodium from their roots to aerial parts. *New Zealand journal of experimental agriculture* 6, 183-188.

Sowande, O.S., Odufowora.E.B., Adelakun, A.O., Egbeyale, L.T., 2008. Blood minerals in wad sheep and goats grazing natural pastures during wet and dry seasons. Arch.Zootec.57 (218):275-278.

Szefer, P., and J. O., Nriagu ,2007 .Mineral components in foods, chemical and fuctional properties of food components series, CRC press, Tylor and Francis group, FL, USA. pp: 163-195.

Tisch, D.A., 2006. Minerals. In: Animal feeds, feeding and nutrition, and ration evaluation. accessed at http//www.high.beam.com/doc/1G1-184231974.html.

Underwood E.J., Suttle N.F, 1999. The mineral nutrition of livestock 3rd edition, CABI publishing.

Underwood, E.J. 1977. Trace elements in human and animal nutrition, 4th edn, Academic press, New York, pp.545.

Underwood, E.J., 1981.The mineral nutrition of livestock. CAB books, London, pp.93-96.

Ullrey, D.J., 1987. Biochemical and physiological indicators of selenium status in animals. *Journal of Animal science* 65, 1712-1726.

Wilkinson, S.R., Welch, R.M., Mayland, H.F., Grunes, D.L., 1990. Magnesium in plants: uptake, distribution, function, and utilization by man and animals. In metal ions in biological systems, Marcel Dekker, New York. Vol. 26, pp. 3-56.

Zinash, S., Tegegne, A., Tsadik, G.T., 2003. Water resources for livestock in Ethiopia: Implication for research and development.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

The study was conducted in Merille location (1°39'-55'N, 37°64'-85'E) of Marsabit South District in northern Kenya (Figure 3.1). The area is inhabited by Rendille and Arial pastoral communities and is a major market outlet for livestock in the district. It has an arid climate with an annual mean rainfall of 275mm (Xiaogang, 2005) and temperatures ranging between 28-42°C. The annual precipitation is distributed between two seasons, long rains from March to May and the short rains occurring from November to December.

The landscape of the area is characterized by basement hill outcrops, prominent seasonal river originating from Mathew ranges, and the sedimentary plain sloping towards the east. The seasonal riverine valley forms an integral grazing ecosystem for small ruminants throughout the year. The soil texture derived from basement system of rocks range from deep sandy, sandy loam to stony sandy loam (Touber, 1991).

The major vegetation types found in the area are riverine woodland, dwarf shrubs and shrub grass land. The dominant vegetation along the riverine includes *Acacia tortilis, Cordia* sinensis, *Salvadora persica* and under storey of annual grasses and herbs. In the sedimentary plains and hills, the woodland vegetation consists of *Acacia* and *Commiphora* communities and dwarf shrubs of *Indigofera spinosa, sericocomopsis hildebrandtii* and *barleria acanthoides.*

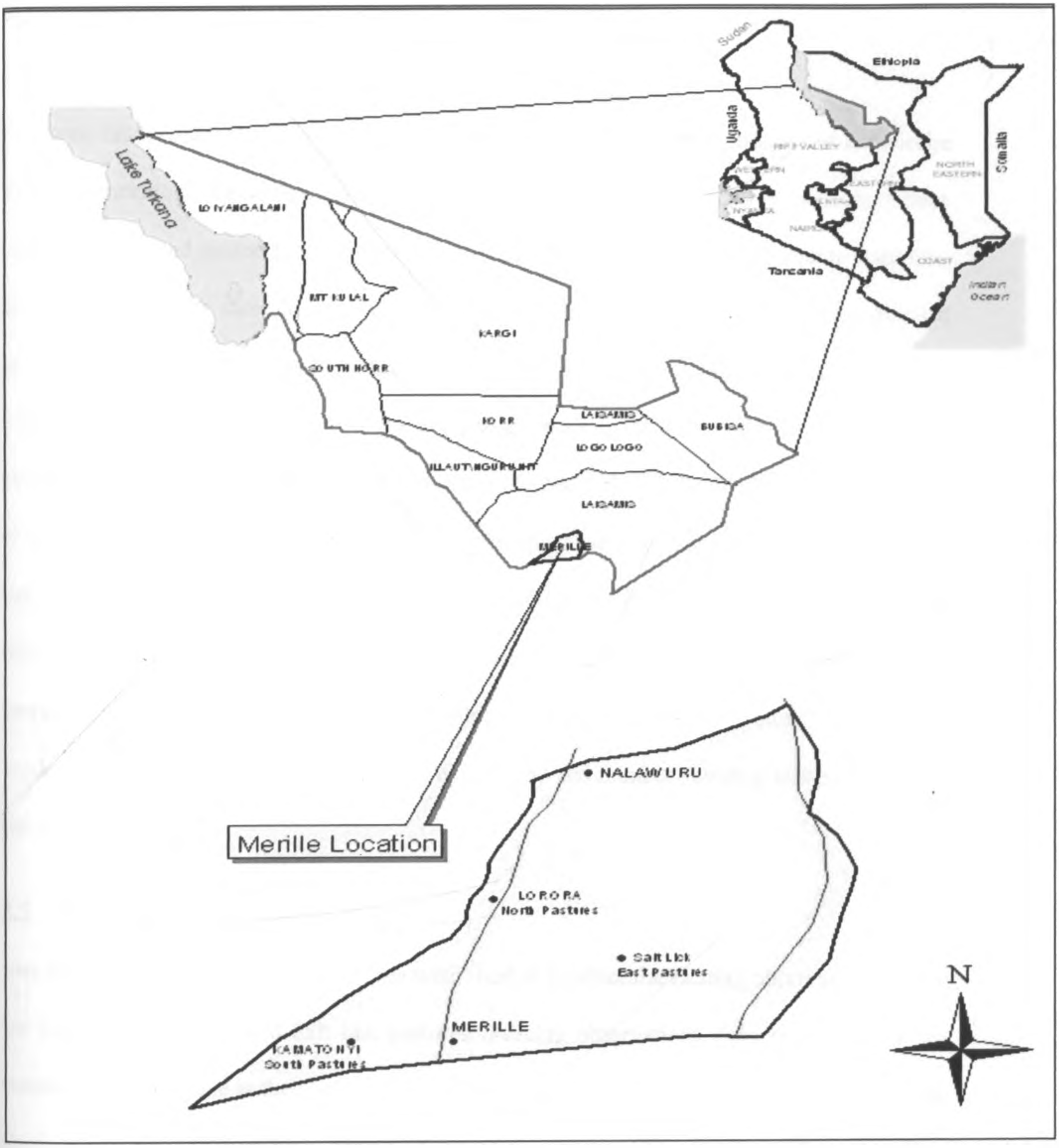

Figure 3.1: Map of Merille Location and study sites, Kenya

(Source; GoK, Marsabit District Annual report, 2008)

3.2 Methods of data collection

3.2.1 Household survey

Systematic random sampling survey technique was used to gather data on indigenous knowledge on mineral nutrition. The survey involved administering questionnaires to 60 households in three purposively selected pastoral settlements in the study area. The pastoral settlements (sampling units) had roughly the same households, about (30-40). In each settlement a list was compiled and 20 households were randomly selected to participate in the survey. The proportion of the 20 households selected in each of the settlement represented about (50-60%) of the households. The three pastoral settlements, namely Kamotonyi, Lorora and Salt lick (located on the south, west and eastern part of the location, respectively) represented the main semi-sedentary settlements, spatially spread and use different grazing areas of Merille location. Information on traditional indicators of mineral status of animals, local sources of mineral supplements, and perceived mineral deficiencies and adequacies were collected. To estimate herd productivity, data on annual number of young stock (360-720 day old) owned and number showing low performances were collected.

3.2.2 Grazing area and feeding observation

Three herders most preferred grazing sites were used to conduct the feeding observations. These were Kamotonyi, Lorora and Salt lick pastures. Feeding observations were conducted in two consecutive seasons, one at the peak of wet season (November to December) and the other at the end of the dry season (February to March). Feeding observations were conducted between 0830-1130 hours for six consecutive days. Each sheep/goat was observed for 10 minutes and complete bites of forage species and the parts consumed were recorded. The names of the species were identified and for each site and the number of bites of each species was summed up for the study area. The forages were ranked according to the number of bites which reflects the feeding preference. Based on the number of bites ten most preferred forages were identified in each season for each livestock species.

3.2.3 Forage sampling

The herder's most preferred grazing areas and sub-sites were randomly selected for the study. The most preferred forage species selected by sheep and goats in the dry and wet seasons, were identified by directly observing 120 mixed herds of young growing animals (1-2 year old). During each season, sixty sheep and 60 goats were randomly selected from twelve herds grazing different pastures and directly observed for 10 minutes, between 0830-1130 hours for six consecutive days. Forage bites, species selected and forage parts consumed were noted and recorded. The number of feeding bites were summed up and ranked to determine the most preferred forage. For dry and wet seasons, ten most preferred forages were sampled from different grazing areas. The forage samples corresponding to parts consumed (leaves, tender twigs, flowers, seeds and pods) were randomly collected along the grazing path, at the peak of the wet season (December, 2009) and late in the dry season (March, 2010). For each selected forage species, 10-15 plants were used to source 200g which were bulked to 600g representative samples. The samples were air dried to constant weight at 70°C and milled to pass 1mm sieve and packed in sealed zip lock nylon bags.

3.2.4 Formulation of forage composite

During both the wet and dry the seasons, the ten most preferred forages by sheep and goats were used to simulate the animals diet. These constituted 88.5% and 85% during dry season and 76.4% and 75.9% during wet season of the number of bites for sheep and goats respectively. For each respective season and animal species, forages were mixed based on bite % to constitute the simulated diet. The composite, which reflected the diets of sheep and goats were digested for mineral determination.

3.2.5 Estimation of mineral intake

The mineral content of composite diet was used to compute mineral intake as:

Mineral intake = DM Intake (4 % Bwt, assumed to be on low quality diet) x macro ($gkg^{-1}DM$) and micro ($mgkg^{-1}DM$) mineral content in composite. The body weight of growing sheep (17 kg) and goats (16 kg) weighed in the field and estimated DM intake in sheep was (0.68 kg) and goats (0.64 kg).

3.2.6 Flock/herd and animal sampling

Three semi-sedentary flocks/herds grazing different pastures in Merille location (namely Kamotonyi, Lorora and Salt lick) were selected for sampling of tissues in the dry and wet seasons. In each of the grazing sites, farmers willing to sell their 1-2 yr old entire males Somali Black Head sheep and Small East African goats were identified. Twenty of each were then randomly selected from a list of all the available animals and purchased for slaughter. From each carcass, the liver and the left and right 12th rib were obtained for mineral determination.

3.2.7 Collection of liver and rib bones samples

After slaughter, the right and left 12th whole ribs and the whole liver were removed from each carcass. The fresh liver and rib samples were packaged in tightly sealed nylon bags and immediately frozen at -20^{0}C awaiting analysis. Sampling precautions taken included slaughtering animals on same day, peeling off the gall bladder from whole liver, and minimizing blood contamination in tissues.

3.3 Laboratory analysis

3.3.1 Forage species and composite

Air-dried samples were milled to pass 1mm sieve, using laboratory mill (HR& ORRS Ltd, Chelmsford, England. For each forage species and composite, a sample of 0.3 g in duplicate, were digested according to AOAC (1998) in tubes with sulfuric acid (H_2SO_4), salicylic acid and selenium as stabilizer. At relatively low temperatures (100^0C) the organic matter in the samples were oxidized by Hydrogen peroxide (H_2O_2). After decomposition using H_2O_2, the digestion was completed by use of concentrated H_2SO_4 at elevated temperatures (330^0C) under the influence of selenium as catalyst. The concentration of Ca, Mg, Fe, Zn, and Mn were analyzed by use of an atomic absorption spectrophotometer (Perkin Elmer A Analyst 100, USA) while K and Na were determined by use of flame photometer. The forage P concentration was analyzed calorimetrically using spectrophotometer.

3.3.2 Liver and bone tissues

Sterile surgical gloves and blades were used to skin the capsule from whole liver tissues. In each of the four quarters of the liver, i.e. the right, left, caudate and quadrate lobes, samples of about 20 g were collected in different sub sites of each lobe and pooled. During sampling, precautions were taken to avoid the fibrous tissues, fat and blood vessels. Pooled liver samples were placed in centrifuge tubes and homogenized by use of an utra-Turrax homogenizer (IKA model T25). Homogenized samples were used for wet digestion (AOAC, 1998) and subsequent mineral analysis. The samples weighing 4 g were digested overnight in 20 ml mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HCLO_4$) in the ratio of (3:1).The digested sample mixture was placed on hotplate until it turned clear. The solution was cooled, filtered, diluted to a final volume of 50ml with deionized water and analyzed for copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) using an atomic absorption spectrophotometer (Perkin Elmer A Analyst 100, USA).

Stainless surgical blades and sterile gloves were used to remove flesh and cartilage from whole 12th right and left ribs. Whole ribs were cut into smaller pieces, pooled to one sample and oven dried to constant weight at 105 ^{0}C. The bones were defatted by washing with petroleum ether, re-dried in the oven, and ashed at 550 ^{0}C for 12 hrs. The ashed bones were crushed to a fine powder by a pestle and mortar. Samples of ash weighing 100 milligrams were digested in 1ml concentrated hydrochloric acid, diluted to a final volume of 100 ml with deionized water and analysed for calcium (Ca), phosphorus (P), magnesium (Mg), and zinc (Zn). The bone Ca and Mg, Zn and were analyzed by use of the AAS (Perkin Elmer A Analyst 100, USA). Phosphorus was determined calorimetrically by mixing 2 mls of extracted ash solution with 15 mls of mixed solution (vanadate-molybdate reagent) and diluted to a final volume of 50 ml. Standards ranging from 0-10ppm were prepared with dipotassium phosphate (K_2HPO_4), and sample absorbance and standards were read at 450nm using Beckman visible double beam spectrophotometer.

3.4 Data analysis

The survey data on herd productivity was subjected to one way analysis of variance and means between sites were compared by student Newman Keuls test using statistiXL version 1.7.

MS Excel (2007) was used to generate descriptive statistics and derive percentages of most preferred forage species in sheep and goats diets. The bite count of most preferred forages in different seasons were analyzed by one way ANOVA using GenStat. The mineral profiles of most preferred forages were subjected to two way analysis of variance with forage type and season as the main factors while the forage composite data was analyzed by one way ANOVA using GenStat 12th edition.

Liver and bone mineral data were subjected to two-way ANOVA with season and herd as main factors and differences in mineral concentration between seasons and herds were separated by LSD $_{(0.05)}$ (GenStat 12th edition).

References

AOAC., 1998. Official methods of Analysis of the Association of Official Analytical Chemistry.16th Edition, Vol.I. p.32.

GoK., 2008. Marsabit District Annual report.

GenStat software 12th edition (2010). www.vsni.co.uk/

MS Excel., 2007. StatistiXL version 1.7, Add-in Microsoft office Excel data analysis software package.

Touber, L., 1991. Landforms and Soils. In: Range management handbook of Kenya, Vol II, 1, Nairobi, Kenya, pp.5-24.

Xiaogang Sun., 2005. Dynamics of continuity and change in pastoral subsistence among the Rendille in northern Kenya: With special reference to livestock management and responses to social-economic change. African study Monographs, suppl.31:1-94.

CHAPTER FOUR

INDIGENOUS KNOWLEDGE ON MINERAL NUTRITION IN SMALL RUMINANTS IN THE PASTORAL AREAS OF NORTHERN KENYA

Abstract

A cross-sectional survey was undertaken in Merille location, Marsabit South district of northern Kenya to assess indigenous knowledge on mineral nutrition of sheep and goats. The questionnaire was administered to herders randomly selected from three purposively selected pastoral settlements. Information was collected on indicators of mineral adequacy and deficiencies, mineral nutrition practices and health and production characteristics of sheep and goats. The results showed that herders could identify mineral deficiencies (81.3%) and adequacies (87.0%) in their herds using indigenous knowledge. The indicators of mineral adequacy were healthy appearance, shiny skin and fatness, while those of mineral deficiencies were poor health conditions, rough coat, pica and slow growth in sheep and goats. Eighty five percent of respondents observed mineral deficiencies to dry season pastures, while 46% observed mineral deficiencies in the wet season. Ninety four percent of respondent used local supplementary remedies such as grazing animals on salty plants, facilitating access by stock to saline water and natural salt licks. Halophyte plants, such as *Lycium europaeum, Salsola dendriodes, and Salvadora persica* species, which are mostly found in the riverine, emerged as the most prominent salt supplements for herds. Traditional indicators of low productivity, which included general poor health, pica, and diarrhea among others were significantly different ($P<0.05$) between sites. The indigenous knowledge on mineral nutrition demonstrated by the herders need to be recognized and form part of mineral nutrition interventions in the area. The riverine ecosystem rich in mineral resources of salt lick, halophyte plants and salty waters, and perceived to be declining, need to be protected and sustainably utilized.

Key words: Indigenous knowledge, mineral nutrition, sheep, goats

4.1 Introduction

Local knowledge is an important asset for smallholder farmers who operate differently in diverse crop and livestock production system in the tropics (Komwihangilo *et al*, 2007). Pastoral producers in the arid and semi-arid lands of northern Kenya, rely mostly on the indigenous knowledge system in the management of their flocks/herds of sheep and goats. The traditional lifestyle involves seasonal migration of herds in search of pasture and water (Langill and Ndathi, 2002). Migratory pastoralism remains the most important land use system allowing full exploitation of resources that are unequally distributed in space and time (Ellis *et al.*, 1988) as well as managing risks. Seasonal movement of herds is a common feature in pastoral system and affects livestock production and rangeland utilization (Schwartz *et al.*, 1991).

The pastoral herding system has implication on feed, mineral and water availability for the animals (Kaufmann, 1998). It enables the animals to access wide rangeland areas and exposes them to different soils, forages and water sources. Consequently, the animals are able to obtain mixed diets that provide a wide range of nutrients (Schillhorn van Veen and Loeffler, 1990).
This system of production is, however, gradually changing, from migratory to sedentary pastoralism in vicinities proximal to trading settlements (Harry, 1999). The shift to sedentary herding system, which is characterized by limited mobility, influences small ruminant productivity.
Studies conducted in the rangelands of northern Kenya, indicate that sheep and goats are the most dominant livestock species kept by sedentary pastoralists. DeVries and Pelant (1987) noted that sedentary households keeping a significant proportion of sheep and goats are likely to adapt more readily to a sedentary lifestyle. Traditionally, grazing distance in sheep and goats are adjusted to allow the frequent watering regime. This limits small ruminant mobility, thus they have access to poor quality pastures near permanent water sources. The reduced degree of mobility is likely to expose small ruminants to nutrient deficiencies, including minerals, which can adversely affect herd productivity.

Pastoral sheep and goat producers recognize the value of mineral nutrition as exemplified by their efforts to move animals to areas with natural salt licks, salty plants and saline water sources (Kariuki and Letitiya, 1998). Consumption of salty plants and saline water sources are used as traditional remedies to deworm sheep and goats (Lengarite and Mbuvi, 2004). Soil licks in specific localities of the lowlands are also collected for supplementing sheep and goats in high altitude areas. Mobile herds have been observed by pastoralists to have high craving for soil licks and saline waters than sedentary herds. In the low lands of northern Kenya, indigenous mineral supplementation strategies are commonly used to correct mineral deficiencies in camel herds (Kuria *et al.*, 2004). The information gathered on indigenous knowledge on mineral nutrition will contribute to mineral nutrition interventions for semi-sedentary small ruminant herds, in Marsabit South district.

One of the objectives of this study was to assess indigenous knowledge on mineral nutrition in small ruminants. Therefore, the specific objectives were:

(i) To assess herder's indigenous knowledge on mineral nutrition in sheep and goat production and health.

(ii) To establish the traditional indicators on perceived mineral inadequacies and adequacies

(iii) To identify traditional mineral sources and supplementary strategies

Materials and methods

The materials and methods used in the study of indigenous knowledge are presented in Chapter Three sections 3.2.1 and 3.4.

4.2 Results and Discussion

4.2.1 Traditional indicators of perceived mineral deficiencies and adequacies

Perceived mineral adequacies and deficiencies were observed by 87% and 81.3% of respondents, respectively (Table 4.1). A high proportion of respondents (85%) associated mineral deficiencies to dry season pastures, while only about 45.7% observed mineral deficiencies in the wet season. The traditional indicators of mineral adequacy in sheep and goats were given as healthy appearance, shiny skin, fatness, fast growth and high milk yield. However, the indicator on milk yield was valued in goats and fast growth rate only in sheep. The key indicators of mineral adequacy were healthy appearances (82.8%, 84.5%) and a shiny skin (55.2%, 35%) for sheep and goats respectively (Table 4.2). Fatness was a lesser indicator of mineral adequacy and was indicated by 24.1% and 13.8% of respondents for sheep and goats respectively.

During the dry season, a decline in the quantity and quality of available pasture was assumed to result in low mineral consumption and thereby perceived deficiency. Herders perceive that animals exposed to good pastures were less vulnerable to disease attack. The improved health status and skin appearances observed mostly in the wet season, were attributed to adequate diet and salt consumption. In northern Kenya, pastoral communities such as the Samburu place great value on natural salt claiming that it improves health, prevent illness and has curative properties for worms (Kariuki and Letitiya, 1998).

Table 4.1: Respondents who reported on perceived mineral adequacies, deficiencies in wet and dry seasons (%) at Merille location in Marsabit South District

	Settlement area			
IK[1] observation	Kamotonyi[2]	Lorora[2]	Salt lick[2]	Mean
Who observed mineral deficiencies	90.0	94.0	60.0	81.3
Who observed mineral adequacy	80.0	95.0	85.0	87.0
Pastures with mineral deficiencies				
Dry season	85.0	90.0	80.0	85.0
Wet season	50.0	42.0	45.0	45.7

1 = Indigenous knowledge, 2 = number of respondents per settlement area was 20 (i.e. n = 20

Conversely the indicators of mineral deficiencies in sheep and goats were poor health, rough skin coat, pica and slow growth in young stock (Figure 4.1). Poor health was a strong indicator of mineral deficiency status of herds. About 74.3% and 86.4% of respondents attributed poor health to mineral inadequacies in sheep and goats, respectively. Pica was ranked second by 35.6% and 30.4% of respondents in sheep and goats respectively. Rough hair coat as an indicator was third reported by 28% and 33.1% of respondents in sheep and goats respectively. Perceived slow growth was less attributed to mineral deficiencies in sheep and goats (Figure 4.1).

Table 4.2: Percentage of respondents on various traditional indicators of mineral adequacies in sheep and goats at Merille location in Marsabit South District

	% of respondents who own	
Indicators (observations)	Sheep[1]	Goats[1]
Healthy appearance	82.8	84.5
Shiny skin	55.2	35
Fatness	24.1	13.8
Fast growth	6.9	*
High milk yield	*	14.9

*Not valued as indicator by herders, 1 = number of respondents who own sheep and goats was 60 (i.e. n = 60)

It can be concluded that healthy appearance and shiny skin were the key traditional indicators of mineral adequacy as captured by the percentage of respondents (Table 4.2).

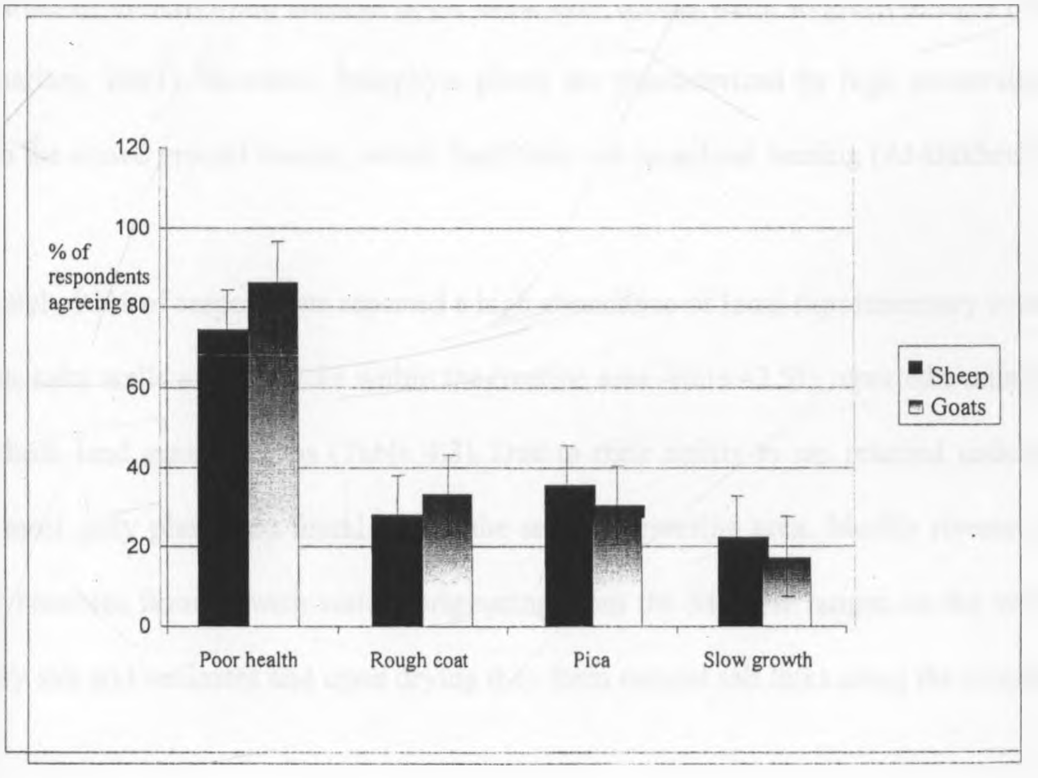

Figure 4.1: Respondents on the major indicators of mineral deficiencies in sheep and goats (%)

Disease incidences such as contagious caprine pleuropneumonia (CCPP) and parasite infestation such ectoparasites and helminths were among the major health problems affecting pastoral herds in Kenya (Kosgey et. al., 2008) The deficiency of minerals in the diet may accentuate parasitic infestation leading to severe clinical signs of diseases (Szefer and Nriagu, 2007).

4.2.2 Sources of minerals and practices of mineral supplementation

Two percent of the respondents in the study area supplemented sheep and goats with commercial minerals formulations. However, 94% of respondents used local supplement remedies such as grazing on salty plants, facilitating access by the stock to saline water and salt lick. Salty plants emerged as the main mineral source for sheep and goats in the study area, mostly the *Lycium europaeum, Salsola dendriodes, and Salvadora persica* species. Salty forage plants are good natural sources of minerals and animals at the same time access water in green forages (Dinucci and Zeremariam, 2003). However, halophyte plants are characterized by high accumulation of minerals in the above ground tissues, which limit their use in animal feeding (Al-Dakheel *et. al.*, 2008).

Approximately 93% of respondents reported a high abundance of local supplementary sources of salty plants, salty wells and salt licks within the riverine area while 42.5% reported availability in the bush shrub land grazing areas (Table 4.3). Due to their ability to tap retained underground moisture, most salty plants are found within the seasonal riverine area. Merille riverine valley seasonally becomes flooded with waters originating from the Mathew ranges on the west. The waters carry salt and sediment and upon drying they form natural salt licks along the riverbed.

Table 4.3: Respondents use of various sources as mineral supplements, area of abundance and indicators of rich mineral sources in Merille location, Marsabit South District (%)

	Grazing site			
IK[1] indicators	Kamotonyi[2]	Lorora[2]	Salt lick[2]	Mean
Mineral supplementary sources				
Commercial mineral	5	0	0	2
Salty plants	97	98	95	96
Saline water	86	94	95	92
Natural salt licks	86	98	86	90
Area of abundance (local sources)				
Riverine	95	89.5	95	93.2
Bush shrub land	25	52.6	50	42.5
Perceived rich mineral sources				
Drinking water	63.2	57.9	15	45.4
Soil type	63.2	84.2	50	65.8
Natural salt licks	31.6	47.4	10.0	29.7
Vegetation type	73.7	21.1	25.0	39.9

1 = Indigenous knowledge; 2 = Number of respondents per grazing site = 20

Ten salty plants were identified by herders, who however noted that the abundance of these plants was declining (Table 4.4). Important salty plants (Figure 4.2) browsed by sheep and goats were *Salvadora persica* (SP) *Dactyloctenium aegyptium* (DA), *Indigofera hochstetteri* (IH), *Salsola dendroides* (SD) *Bauhimia taitenis* (BT) and *Lycium* europaeum (LE*).* The Rendille herders in the Marsabit district have been reported to move camels to access salt rich plants such as *Salsola dendroides* (Kauffmann, 1998). Analysis of salty plants by Kuria (2004) in south west Marsabit showed that *Lycium europaeum, Salsola dendriodes, Salvadora persica, Indigofera hochstetteri and Dactyloctenium spp.* had sodium levels of 24, 54, 15, 1 and 28 $gkg^{-1}DM$, respectively. Except for *Indigofera hochstetteri*, which was low in Na, these plants accumulate sodium and levels surpass sheep and goats (Na) requirement of 1g Na/Kg DM.

Table 4.4: Respondents' observation of the number of most preferred grazing forages, salty waters and salty plants for small ruminants in Merille location between 1989 and 2010

	Numbers observed			
IK criterion	1989/90[1]	1999/2000[2]	2009/2010[3]	% decline (20yrs)
Preferred forages	17	17	14	7.6
Salty plants	10	6	6	40
Salty waters	5	3	3	40
Natural salt licks	4	3	3	25

1, 2, correspond to Lmeoli and Lmetili traditional age groups and 3 the current study period

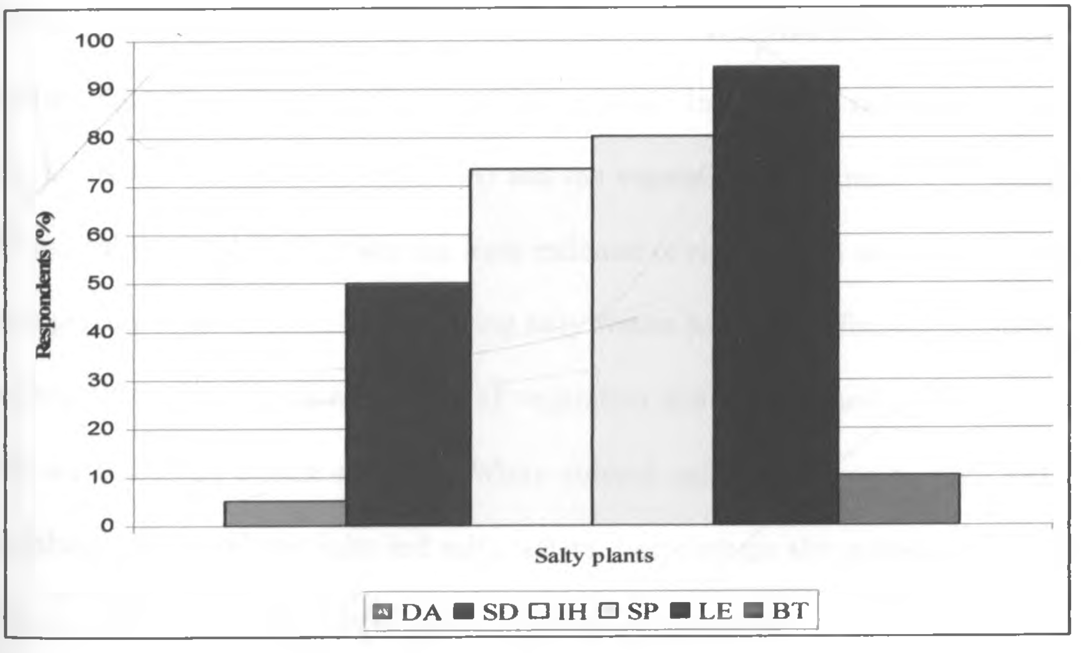

Figure 4.2: Respondents indicating consumption of salty plants by sheep and goats (%) Legend (*D. aegyptica* (DA), *S. dendroides* (SD), *I. hochstetteri* (IH), *S.persica* (SP), *L.europaeum* (LE), B.taitenis (BT).

Watering herds/flocks in the salty wells was one way of providing minerals to sheep and goats during the dry season. Direct ingestion of soil from natural salt licks may supplement the intake of some minerals (Mayland and Wilkinson, 1996). However, in the study area, natural salt lick was not an important local mineral supplement compared to salty plants and water sources. A study conducted in Peru confirmed that natural licks had higher concentration of minerals than non-salt lick soils (Montenegro, 2004). It appears that salty plants and water sources satisfied the salt supplementation needs of herds in the area. Where naturally occurring salt content is high, the salt component of the mineral supplements need to be substituted with other palatable stimulators such as molasses (McDowell, 1996).

Herders in the study area have wealth of knowledge on mineral nutrition as indicated by their ability to identify rich sources of minerals. Indicators of a rich mineral source varied among respondents, with soil type (66%) identified as major indicator of rich mineral resources of an area. Drinking water was second (45%) and the vegetation type found in an area. third (40%). The natural salt lick (29.7%) was the least indicator of rich mineral sources. The semi-sedentary herds grazing on salty plants and drinking salty waters had less preference for salt licks. Herders perceive that soils influence the type of vegetation and water found in an area. Traditionally, soils are classified by use of color. White colored soils are linked to high salt content and availability of natural salt licks and salty waters. Respondents also perceive that various type of drinking water vary in taste, level of sediments and salt content.

In the study area, herders recognized the mineral value of forage plants, drinking water and natural salt lick. However, over the last 20 years, the number of accessible salty water sources and salty plants have both declined by 40 % (Table 4.4). The most preferred forage plants and natural salt licks have also declined by about 17.6% and 25% respectively. Natural salt licks found along watering points provide animals with minerals (Njoro, 2003). The general decline in the availability of key mineral sources could be ascribed to overgrazing in the semi-sedentary settlements, and reduced accessibility of natural salt licks and salty waters found in specific localities.

4.2.3 Traditional indicators of reduced productivity in the study area

In the study area, growing sheep and goats are an important class of small ruminants that dominate in herd market offtake and form the foundation of future sheep and goat herd. The proportions of growing animals in a herd were generally indicators of herd productivity. Young animals were perceived to succumb to diseases with under-nutrition and mineral inadequacies leading to loss of weight. The traditional indicators of reduced productivity in young sheep and goats were poor health, slow growth, weight loss, pica, skin diseases and diarrhea. These indicators were significantly different ($P<0.05$) between study sites. Based on these indicators, observations revealed more sheep and goats with low productivity in Lorora than in other areas (Tables 4.5 and 4.6).

By IK diagnosis 42.6% of growing sheep were said to be in poor health, 41% with diarrhea, 24% suffered from skin diseases, 25.4% showed pica, 26% loss of weight and 9.1% showed stuntedness (Table 4.5). In the young goats, IK revealed that 33.8% were showing poor health, 20% stunted growth, 17% loss of weight, 20.2% pica condition, 12.3% skin diseases and 23% had diarrhea incidences (Table 4.6).

The survey showed that a high proportion of sheep (42%) and goats (34%) suffered from poor health. Retarded health and diarrhea were the main factors responsible for low production of sheep and goats. Poor health was the key limiting factor to productivity of sheep and goats in the tropics (Kosgey *et al*, 2008).

Table 4.5: The proportion (%) of sheep in flock identified using IK having poor health and production in Merille location, Marsabit South District

	Grazing area			
IK criteria	Kamotonyi	Lorora	Salt lick	Mean
Impaired health	39.8 ± 7.3^{a}	65.1 ± 7.1^{b}	20.0 ± 6.0^{ab}	41.6
Stunted growth	15.4 ± 5.7^{ab}	7.0 ± 5.5^{b}	5.0 ± 5.2^{b}	9.1
Loss of weight	26.1 ± 7.9^{a}	39.7 ± 7.4^{a}	11.1 ± 3.3^{ab}	25.6
Pica	21.6 ± 6.0^{a}	38.1 ± 7.0^{b}	16.4 ± 4.6^{a}	25.4
Skin diseases	17.9 ± 6.1^{a}	40.2 ± 8.0^{b}	15.1 ± 5.2^{a}	24.4
Diarrhea	32.5 ± 7.2^{a}	58.7 ± 7.6^{b}	30.6 ± 7.8^{a}	40.6

^{ab}*Means in a row with different superscripts are different (p<0.05)*

Incidences of loss of weight and pica, affected growing sheep and goats respectively. The incidence of pica can be associated to mineral, protein and energy deficiencies (Underwood and Suttle, 1999).

Table 4.6: The proportion (%) of goats in herd identified using IK having poor health and production in Merille location, Marsabit South District

	Grazing area			
IK criteria	Kamotonyi	Lorora	Salt lick	Mean
Impaired health	37.2 ± 7.5^{a}	49.8 ± 6.5^{a}	14.5 ± 4.1^{b}	33.8
Stunted growth	20.0 ± 7.7^{a}	36.3 ± 5.3^{a}	4.0 ± 2.3^{ab}	20.1
Loss of weight	18.5 ± 6.0^{a}	24.1 ± 5.2^{a}	7.4 ± 2.8^{ab}	16.7
Pica	14.6 ± 3.7^{a}	28.6 ± 4.9^{b}	17.5 ± 5.6^{a}	20.2
Skin diseases	8.8 ± 2.9^{a}	22.4 ± 6.0^{b}	5.6 ± 2.3^{a}	12.3
Diarrhea	22.8 ± 5.5^{a}	28.4 ± 4.6^{b}	17.8 ± 5.0^{a}	23.0

^{ab}*Means in a row with different superscripts are different (p<0.05)*

4.3 Conclusion

Small ruminant owners, through indigenous knowledge, recognized the value of minerals and could detect mineral deficiencies and adequacies in their herds/flocks. Through this knowledge, mineral deficiencies and adequacies were reported to occur mostly in dry and wet season respectively. Mineral deficiencies mainly affecting herds/flocks in the dry season need to be addressed by further assessment of mineral status of forages consumed by sheep and goats, analysis of mineral content of body tissues of animals and formulation of appropriate mineral supplements.

References

AL-Dakheel, A.. AL-Hadrami. G., AL-Shoraby, S., Shabbir, G. 2008. The potential of salt-tolerant plants and marginal resources in developing and integrated forage- livestock production system. 2nd International salinity Forum. Adelaide, Australia.

Dinucci, A ., Zeremariam, F. 2003. Understanding the indigenous knowledge and information systems of pastoralists in Eritrea. FAO, UN, Rome, Italy.pp.1-14.

Ellis, J.E., Swift, D.M.1988. Stability of African pastoral systems: Alternative paradigms and implications to development. Journal of range management, Vol.41:450-459.

Harry, I., 1999. Effect of seasonality on productivity of pastoral goat herds in northern Kenya. PhD dissertation, Berlin University., Germany.

Kaufmann, B. 1998. Analysis of pastoral camel husbandry in Northern Kenya, Hoheinheim Agricultural series, Stuttgart, Germany.

Kariuki, D.P., Letitiya, W. 1998. Livestock production and health challenges in pastoral areas. Samburu District, Kenya, pp: 12-16.

Komwihangilo, D.M., Lekule, F.P., Kajembe, G.C., Petersen, P.H. 2007. Role of local knowledge in mixed livestock production systems: Methodology and implications for research and development in Sub-Saharan Africa. Outlook on Agriculture, Vol 36, No.3, pp: 187-192(6).

Kosgey, I.S, Rowlands, G.J, Arendonk, J.A.M., Baker, R.L. 2008. Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. Small ruminant research 77, pp.11-24.

Kuria, S.G., 2004. Mineral nutrition on settlement (*Manyatta)* based milk camel herds Among the Rendille community of Northern Kenya. PhD thesis, University of Nairobi, Kenya, pp.96-97.

Kuria, S.G., Wanyoike, M.M., Gachuiri, C.K., Wahome, R.G.2004. Indigenous camel mineral supplementation knowledge and practices on manyatta based camel herds by the Rendille pastoralists of Marsabit district, Kenya. Livestock research for rural development 16(7).

Langill,S., Ndathi,A.J.N. 2002. Drought coping strategies among the Rendille of Marsabit. In: Animal production society of Kenya proceedings on challenges of drought to livestock production in Kenya, Njoro, Kenya, pp.67-71.

Lengarite, M.I., Mbuvi, D. 2004. Up scaling of improved package on young stock management technologies on regular deworming, supplementary feeding and mobile house in Kargi area, EU/KARI report, pp.2-7.

McDowell, L.R. 1996. Feeding minerals to cattle on pastures, Animal science technology,60, pp.247-271.

Mayland, H.F., Wilkinson, S.R., 1996. Mineral nutrition. American society of Agronomy, crop science society of America, Madison, USA, Agronomy monograph no.3.

Montenegro, O.L.2004. Natural licks as keystone resources for wildlife and people in Amozonia. PhD dissertation, University of Florida, USA, pp.41-53.

Njoro, J.N. 2003.Community initiative in livestock improvement: The case of Kathakani, Kenya. ITDG-EA, Nairobi, Kenya. In: Community-Based management of Animal genetic resources, FAO, Rome, pp.77-84.

Schillhorn van Veen T.W. and Loeffler I.K. 1990. Mineral deficiency in ruminants in sub Saharan Africa: A review. Tropical Animal Health and Production 22(3):197–205.

Shwartz, H.J., Shabaani, S., Walther, D., 1991. Marsabit District Range management Handbook of Kenya. Vol.II.1. Ministry of Livestock Development, Republic of Kenya, Nairobi, Kenya, pp.130-162.

Szefer, P., and J. O., Nriagu ,2007 .Mineral components in foods, chemical and fuctional properties of food components series.,.CRC press,Tylor and Francis group,FL, USA. pp: 127-132.

Underwood E.J., Suttle N.F, 1999. The mineral nutrition of livestock 3rd edition, CABI publishing p.120.

CHAPTER FIVE

SEASONAL FORAGE PREFERENCE BY SHEEP AND GOATS IN THE RANGELANDS OF NORTHERN KENYA

Abstract

To document the feeding habits and identify the most preferred forages selected by sheep and goats a study was conducted in Merille location in northern Kenya. Sixty of each growing sheep and goats were used for feeding observation during two consecutive seasons. The most preferred grazing pastures by the herders in the location were used for the feeding observations. Both sheep and goats diets had a wider selection of forages and bite count in the wet season than dry season. In the dry season, browses formed the primary component of the diet of sheep (72.7%) and goats (87%). Browse bite of sheep (57.9%) and goats (75%) was higher in the dry season than wet season. Dietary overlap of species consumed by both sheep and goats was higher for browses 82.3 and 55.6% in dry and wet seasons, respectively. Ten most preferred forages represented 88.5% and 85% of dry season forage bites in sheep and goats respectively. In the wet season, the ten most preferred forages constituted 76.4 % of sheep and 75.9% of goat's bites. In conclusion, the ten most preferred forages selected by sheep and goats contributed a major proportion of the diet of grazing small ruminants particularly during the dry season and are representative for feed analysis. Among the preferred forages, dwarf shrubs such as *Indigofera spinosa* can provide small ruminants with browse feed though out the year. In the dry season, interventions are warranted to compensate for low bite count observed in sheep and goats.

Key words; Bites, browses, goats, grasses, herbs, sheep

5.1 Introduction

The arid and semi-arid lands, under pastoral and agro-pastoral production system, are the major sheep and goat production areas in Kenya. About 75and 84% of the national flock/herd of sheep and goats, respectively are found in these lands (Kariuki and Letitiya, 1998). Though natural forages are the main feed resources for these stock, their availability and diversity is strongly influenced by season and vegetation type (Sanon *et al.,* 2007). In the extensive system of sheep and goat production, inadequate nutrition is the major constraint limiting small ruminant productivity particularly in the dry season (Njwe, 1992). In open grazing system practised in the arid lands of northern Kenya, sheep and goats co-graze, and share the available dietary forage resources. Mixed pasture provides the best forage classes for mixed-browsing animals (Lusigi *et al.*,1984). Goodwin *et al.*, (2002) indicated that goats grazing mixed pastures produced greater average daily gain than those on grass-only pastures. This is because botanical composition of the pasture affects ingestive behaviour of goats and sheep (Animut and Goetsch, 2008).

Studies conducted in northern Kenya on small ruminants showed that goats were highly selective feeders. In the wet and dry season, goats consistently selected diets higher in crude protein and low in crude fiber content than sheep and cattle (Abusuwar and Ahmed (2010). In African savannas goats depend largely on utilization of browse species for their nutrition (Dziba *et al.*, 2000), whilst sheep prefer to select from the herbaceous and graminoids species, with graminoids constituting the largest proportion of their diet (Liu *et al.*, 2007). Preference of forage by sheep and goats is influenced by season (Omphile *et al.*, 2004). Diet selection is also influenced by body size, rumen anatomy, energy requirements and social structure of the herds/flocks of these animals (Hofmann, 1989).

One of the objectives of this study was to identify the forage species consumed by sheep and goats in dry and wet seasons. Therefore, the specific objectives were:

(i) To identify the most preferred forage species/types consumed by sheep and goats as prerequisite for sampling to determine their mineral content.

(ii) To assess the feeding habits of small ruminants in dry and wet seasons.

Materials and methods

The materials and methods used for this part of the study are shown in Chapter Three sections 3.2.2 and 3.4.

5.2 Results and discussion

5.2.1 Forage types

The number and type of forages consumed by both sheep and goats are shown in Table 5.1. During the dry season, sheep and goats consumed 22 species, out of which 73, 18 and 9% were browses, grasses and herbs, respectively for sheep. The corresponding values for goats were 87, 13 and 0%. In the wet season, the number of grasses and herbs in sheep diet increased, but the proportion of browses declined from 73 to 53.1%. In the same season, the goats consumed less of the browses and increased consumption of grasses and herbs. The results suggest that sheep and goats have higher mixed diet in the wet season than dry season.

Browses contribute a high proportion of forage plants in the diet of sheep (73%) and goats (87%), particularly in the dry season. This observation is consistent with the report by Abusurwar *et al.*, (2010) who indicated that use of browse by livestock generally increases as the dry grazing season progresses. Indeed, browse forage species have been observed to be a key component of goat's diet in the dry seasons when other forages are limiting (Yahaya *et al*, 2000). In contrast, browse forages in sheep diets were not affected by season. Sheep selected a similar range of about 16 browse plants in the dry season and 17 browse species in the wet seasons.

Table 5.1: Number/type of forages consumed by sheep and goats during wet and dry seasons in Merille location, Marsabit South District

	Dry season Number			Wet season Number		
	Sheep	By goats	By both *S&G	By sheep	By goats	By both S &G
Browses						
No. of spp	16	20	14	17	30	15
%	72.7	87	82.3	53.1	68.2	55.6
Grasses						
No. of spp	4	3	3	9	8	8
%	18.2	13	17.7	28.1	18.2	29.6
Herbs						
No. of spp	2	0	0	6	6	4
%	9.1	0	0	18.8	13.6	14.8
Total spp.	22	23	17	32	44	27

**S &G (Number consumed by both sheep and goats)*

Herbaceous plants and grasses were important to both sheep and goats in the wet season as they were more available. Precipitation positively influences forbs consumption (Ramirez, 1999). In the wet season sheep selected a range of 9 grass species versus 8 species in goats. There was drastic decline in the grass and herbaceous forage species in the dry season (Table 5.1). The herb layer was less important component of sheep and goats diets in the dry season.

There was high dietary overlap of forages consumed by both, 55.6% in the wet season and 82.3% in the dry season in the browse layer. Sheep and goats also had high dietary overlap in the herb (14.8%) and grass stratum (29.6%) in the wet season. Overlap was higher in dry season on browses and herbaceous layer in the wet season (Table 5.1). The results suggest that dietary overlap was influenced season, forage category and plant species diversity. The intensity of competition could be high in herb and browse layers in the wet and dry seasons, respectively. High dietary overlap, which was observed in the dry season particularly on browses, could lead to overuse of overlapping forages. The results shows that forage categories selected by sheep and goats had less variation in the dry season than wet season. This shows that sheep and goats diet, albeit the competition between the two was very similar in the dry season compared to wet season.

5.2.2 Seasonal forage selection

Selection of different forage categories by both sheep and goats during the wet and dry seasons are shown in Table 5.2. Consumption of browses by sheep (57.9%) and goats (75%) increased during the dry compared to the wet season (30.6 and 52.4% for sheep and goats respectively). This is an indication that they rely on browses of trees, bushes and dwarf shrubs as main source of feed in the dry season. However, goats had higher preference on browse (52.4%) than sheep (30.6%) in the wet season. In the wet season, goats spent almost equal time selecting grasses and herbs (47.6%) and browse (52.4%), while sheep consistently selected grasses and herbs (69.4%). During both seasons, sheep selected more herbaceous biomass than goats (Table 5.2). This suggests that sheep preferred a mixed diet of grasses and herbs.

The results show that sheep and goats bite magnitude vary with forage class and seasons. In the dry season, sheep shifted their diet selection from grazing (69.4%) to browsing (57.9 %). Goats which were intermediate grazers (47.6%) and browsers (52.4%) in the wet season switched to browsing (75%) in the dry season. Sanon (2007) observed that sheep and goats shift to browsing in the dry season when herbaceous biomass was less available. Across the seasons, dwarf shrubs consistently contributed higher bite magnitude than browse of trees and shrubs to sheep and goats implying that dwarf shrubs could provide sheep and goats with browse throughout the year.

Table 5. 2: Percentage feeding bites of different forage categories by sheep and goats in the dry and wet seasons for a total period of 300 min, in Merille location, Marsabit South District

	Dry season		Wet season	
	Sheep	Goats	Sheep	Goats
Browses	**57.9**	**75.0**	**30.6**	**52.4**
Trees and bushes	21.0	34.1	0.4	10.8
Shrubs	4.8	15.3	2.2	15.8
Dwarf shrubs	32.1	25.6	28.0	25.8
Grasses and herbs	**42.1**	**25.0**	**69.4**	**47.6**
Grasses and sedges	36.5	25.0	64.1	43.2
Herbs	5.6	0.0	5.3	4.4

Forage selection and number of bites has important implication in the animal nutrient intake and hence their fitness (Shipley *et at*., 1999). The number of bites for both sheep and goats were higher ($p<0.001$) in the wet season than in the dry season (Table 5.3). The number of bites could be attributed to availability of forage biomass and plant diversity. Inadequate forage availability, increased walking activity and forage selectivity could be responsible for the decline in the number of bites in sheep and goats in the dry season.

Table 5.3: Mean number of feeding bites of sheep and goats in dry and wet season for a period of 10 minutes in Merille location, Marsabit South District

	Sheep	Goats	N
Dry season	19.5 ± 1.7^{a}	14.9 ± 1.0^{a}	60
Wet season	33.2 ± 2.4^{b}	31.9 ± 2.5^{b}	60

^{ab}*Means with a different letter along a column are significantly different ($p<0.001$)*

5.2.3 Forage preference by sheep and goats

Tables 5.4 and 5.5 show the ten forages with the highest number of bites in both wet and dry seasons. During the dry season, sheep fed on 22 and goats on 23 different types of forages while in the wet season, the number increased to 32 for sheep and 44 forages for goats. In the dry season, ten most preferred forages represented 89.8% and 84.4% of total forage bites in sheep and goats, respectively. Whilst in the wet season the most preferred forages constituted 91.3% and 75.8% of the total feeding bites in sheep and goats respectively. In dry season the browses constituted 47.8% and grasses and herbs 42% of the bites by sheep. In the wet season, consumption of browse by sheep declined to 27.7%, while grasses and herbs increased to 63.6% (Table 5.4). The shift to grass consumption in the wet season was attributed to increased availability of grass and preference of these species by sheep in the wet season. The change to browsing by sheep was due to higher availability of browse during the dry season. Goats browsing behaviour also followed similar pattern to sheep, browse bite increasing from 35.8% in the wet season to 60.4% in the dry season. However, there was reduction in grass bite from 40% in the wet season to 26% in the dry season by goats (Table 5.5). The increased browse bite and reduction in grass consumption by goats could be ascribed to higher availability of browse and low number of grass species in the dry season. Forage species with high selectivity by both species and during both seasons were *Indigofera spinosa* and *Tetrapogon cenchriformis*. Other browse spp such as *Indigofera hochstetteri* and *Crotalaria fasicularis* species were utilized in the wet season but not in the dry season as they were not available.

During the wet season, sheep and goats selected almost the same species of grass/sedge. The grasses included *Bracharia leersiodes, Tetrapogon cenchriformis Cenchrus pennisetiformis* while *Mariscus macropus,* sedge, was only available in the wet season was highly selected by sheep. Of the grass species, *Tetrapogon cenchriformis* was most selected by sheep (18.6%) and *Bracharia leersiodes* by goats (25.4%) in the wet season. During the dry season, *Aristida adscensionis* was the most cropped by both sheep and goats.

Table 5.4: List of some of the forages observed to be consumed by sheep, their bite numbers in 300 minutes in the wet and dry season in Merille location, Marsabit South District

Dry season	Bite counts	Bite (%)	Wet season	Bite counts	Bite (%)
Browses					
Sericocomopsis hildebrandtii [3]	9	1.8	*Indigofera cliffordiana* [3]	24	2.5
Duosperma eremophilum [3]	33	6.6	*Crotalaria fasicularis* [3]	30	3.1
Commiphora africana [1]	40	8.0	*Indigofera hochstetteri* [3]	40	4.1
Cordia sinensis [1]	42	8.4	*Indigofera spinosa* [3]	177	18.1
Indigofera spinosa [3]	112	22.4			
Sub-total		47.2			27.8
Grasses and herbs					
Commicarpus stellatus [5]	10	2.0	*Mariscus macropus* [6]	16	1.6
Blepharis linariifolia [5]	15	3.0	*Commicarpus stellatus* [5]	23	2.4
Bracharia leersiodes [4]	18	3.6	*Cenchrus pennisetiformis* [4]	37	3.8
Tetrapogon cenchriformis [4]	38	7.6	*Aristida adscensionis* [4]	84	8.6
Aristida adscensionis [4]	126	25.1	*Bracharia leersiodes* [4]	133	13.6
			Tetrapogon cenchriformis [4]	182	18.6
Sub-total		41.3			48.6
Total feeding bites	443	88.5		746	76.4

1Tree/bush; 2shrub; 3dwarf shrub; 4grass; 5herb; 6sedge

Table 5.5: List of some of the forages observed to be consumed by goats, their bite numbers in 300 minutes in the wet and dry seasons in Merille location, Marsabit South District

Dry season	Bite counts	Bite (%)	Wet season	Bite counts	Bite (%)
Browses					
Maerua crassifolia[1]	10	3.1	*Commiphora africana*[1]	10	1.1
Barleria acanthoides[3]	11	3.4	*Lippia carviodora*[2]	35	3.7
Combretum aculeatum[2]	12	3.8	*Bauhimia taitenis*[2]	40	4.2
Acacia tortilis[1]	16	5.0	*Grewia tenax*[2]	49	5.2
Bauhimia taitenis[2]	19	5.9	*Indigofera hochstetteri*[3]	63	6.6
Commiphora africana[1]	25	7.8	*Indigofera spinosa*[3]	144	15.1
Cordia sinensis[1]	39	12.2			
Indigofera spinosa [3]	65	20.3			
Sub-total		61.5			35.9
Grasses and herbs					
Tetrapogon cenchriformis[4]	14	4.4	*Cenchrus pennisetiformis*[4]	20	2.1
Aristida adscensionis[4]	61	19.1	*Mariscus macropus*[6]	41	4.3
			Tetrapogon cenchriformis[4]	78	8.2
			Bracharia leersiodes[4]	242	25.4
Sub-total		23.5			40.0
Total feeding bites	272	85.0		722	75.9

[1]Tree/bush; [2]shrub; [3]dwarf shrub; [4]grass; [5]herb; [6]sedge

However, grass species such *Cenchrus pennisetiformis* were available during the wet season only. Goats showed less preference for herbs compared to sheep, while M. *Macropus* sedge was the most preferred by sheep and goats in the wet season. In the dry season the herb layer consumed by sheep constituted mainly the dead biomass. The wet season supported more grass and herb layer favouring selection by grazing sheep. Small ruminants in the dry season heavily depended on browses that mainly consisted of *C.africana, C. sinensis* and *I. Spinosa*. The tree/bush browse was of green and fallen leave biomass and the dwarf shrubs bite composed of tender twigs and green leaf foliage. The forage components consumed included green/dry leaves, tender twigs, flowers, fruits, leaf litter and barks. *Indigofera spinosa*, which was highly preferred, had tender twigs, flowers, pods and leaves in wet season but showed defoliation, the loss of leaves in the dry season. Generally, leguminous thorny plants have high protein content (Celaya *et al*, 2007). Animals may select *Indigofera spinosa,* a leguminous plant as a source of protein. In the wet season animals consumed green grass with flower and seed head, and dry grass in the dry season. Dietary selection can thus occur at both the plant level and at a within-plant level (Palo *et al*., 1992).

The diet of sheep and goats in the dry season comprised of similar forage plants, but differed in the wet season. In the wet season, sheep balanced their diets by maximizing selection from available leguminous forages and grass species. Penning *et al.,* (1997) observed that sheep had high preference for leguminous forages compared to goats; they spent 70% of the time grazing white clover than 50% of the time observed for goats.

5.3 Conclusion

The feeding habits of sheep and goats demonstrate seasonal variation in diet selection. Sheep shift from grazing in the wet season to browsing in the dry season, whilst goats switch from browsing in the dry season to balance grazing and browsing in the wet season. The small ruminants rely more on grasses and browse in wet and dry seasons respectively. The wide diversity of forage plants in the wet season has potential to offer adequate feed to sheep and goats. However, limited species diversity especially in the dry season reduces diet selectivity and bite count of sheep and goats.

The ten most preferred forages selected by sheep and goats in dry season; includes *Sericocomopsis hildebrandtii, Duosperma eremophilum, Commiphora africana, Cordia sinensis, Indigofera spinosa, Commicarpus stellatus, Blepharis linariifolia, Bracharia leersiodes, Tetrapogon cenchriformis, Aristida adscensionis* and *Maerua crassifolia, Barleria acanthoides, Combretum aculeatum, Acacia tortilis, Bauhimia taitenis, Commiphora africana, Cordia sinensis, Indigofera spinosa, Tetrapogon cenchriformis, Aristida adscensionis,* respecctively. In the wet season, ten most preferred forages consumed by sheep and goats includes; *Indigofera cliffordiana, Crotalaria fasicularis, Indigofera hochstetteri, Indigofera spinosa, Mariscus macropus, Commicarpus stellatus, Cenchrus pennisetiformis, Aristida adscensionis, Bracharia leersiodes,Tetrapogon cenchriformis* and *Commiphora africana, Lippia carviodora, Bauhimia taitenis, Grewia tenax, Indigofera hochstetteri, Indigofera spinosa, Cenchrus pennisetiformis, Mariscus macropus, Tetrapogon cenchriformis, Bracharia leersiodes,* respectively.

In conclusion, the ten most preferred forages selected by sheep and goats constitute the major diet composition of small ruminants particularly in the dry season and can be used for nutritional quality analysis. Among the preferred forages, dwarf shrubs such as *Indigofera spi*nosa can provide small ruminants with browse feed though out the year.

References

Abusuwar, A.O., Ahmed ,E.O.2010. Seasonal variability in nutritive value of ruminant diets under open grazing system in the semi-arid rangeland of Sudan (South Darfur state), Agriculture and biology journal of north America, pp.243-249

Animut, G., Goetsch, A.L. 2008.Co-grazing of sheep and goats: Benefits and constraints. Small ruminant Research. 77.127-145.

Celaya , R., Olivan, M., Ferreira,L.M.M., Martinez,A., Garcia, U., Osoro, K., 2007.Comparison of grazing behaviour, dietary overlap and performance in non lactating domestic ruminants grazing on marginal heathland, Livest.Sci.,106,271-281.

Dziba, L.E., Scogings,P.F., Gordon, I.J., Raats,J.G. 2003. Effects of season and breed browse species intake rates and diet selection by goats in the False Thornveld of Eastern Cape, South Africa, Small ruminant research. 47, 17-30.

Goodwin,D.J., Muir,J.P., Wittie, R.D. 2002.Goat performance, selectivity and forage quality dynamics in three cultivated warm season pastures in northern-central Texas. In sheep and goats, wool and mohair CPR, pp. 90-98.

Hoffman, R.R. 1989. Evolutionary steps of ecophysical adaptations and diversification of ruminants: a comparative view of their digestive system. Oecologica 78: 443-457.

Kariuki. D.P., Letitiya. W. 1998. Livestock production and health challenges in pastoral areas. Samburu District. Nairobi, Kenya. pp: 12-16.

Liu, Z., Wang, X., Teng, L., Cao, L. 2007. Food habits of blue sheep, *Psedois nayaur* in the Helan Mountains, China. Folia Zool.-56(1) .pp.13-22.

Lusigi,W.J., Nkurunziza,E.R., Masheti,S., 1984. Forage preference of livestock in the arid lands of Northern Kenya. J.Range manage. 37, pp.542-548

Njwe, R.M. 1992. Strategies for matching feed resources to small ruminant needs. Are view. In small ruminant research and development in Africa, proceedings of the first biennial conference, Nairobi, Kenya, pp.329-344

Palo, R.T., Bergstron, R., Danell, K., 1992. Digestibility, distribution of phenols, and fiber at different twig diameters of birch in winter. Implications of browsers.Oikos65,450-454.

Penning ,P.D., New man, J.A., Persons, A.J., Harvey, A., Orr , R.J., 1997. Diet preferences of adult sheep and goats grazing ryegrass and white clover, Small Ruminant, Res.24,175-18.

Ramirez, R.G. 1999. Feed resources and feeding techniques of small ruminants under extensive management conditions. Small Ruminant Research. 34,215-230.

Shipley, L.A., Illius, A.W., Danell, K., Hobbs, N.T., Spalinger, D.E., 1999. Predicting bite size selection of mammalian herbivores a test of a general model of dietoptimazation.Oikos 84 55-68.

Sanon, H. O., .2007. The importance of Sahelian browse species as feed for goats. Doctoral thesis, Swedish university of Agricultural sciences, Uppsala, Sweden.

Sanon. H.O., Kabore'-Zoungrana. C., Ledin, I. 2007. Behavour of goats, sheep and cattle and their selection of browse species on natural pastures in a Sahelian area. Small ruminant research 67, pp.64-74.

Yahaya, M.S., Takahashi, J., Matsuoka, S., Kibon, A., Dibal, D.B.2000. Evaluation of arid region browse species from north eastern Nigeria using pen fed goats. Small ruminant research .38, 83-86.

CHAPTER SIX

MINERAL PROFILES OF MOST PREFERRED FORAGES GRAZED BY SHEEP AND GOATS IN MARSABIT SOUTH DISTRICT, KENYA

Abstract

A study was conducted to assess the mineral content of the most preferred forage species by sheep and goats in Merille location, Marsabit South district of northern Kenya. Twenty two most preferred forages by sheep and goats in both the dry and wet seasons were analysed for the macro minerals (Ca, P, Mg, K and Na) and trace elements (Fe, Zn and Mn). For each season and animal species, ten most preferred forage samples were collected in different grazing areas. The effect of season and forage type on mineral content and ability of forages provide adequate minerals to the animals was determined. Using the known number of bites for each forage, a composite diet was formulated and mixed and the mineral profile determined and used to estimate the mineral intake of animals. Season had significant effect on P and K content of forages selected by sheep, but no effect Ca, Mg and Na content. However, the Ca and Mg content differed among forages selected by sheep while P, K and Na content was not different. Of the forages selected by goats, season also had significant effect on P and K content, while forage type influenced the level of K, but no effect on Ca, P, Mg and Na contents. The Ca, P, Mg, and K content in browses and grasses/herbs consumed by sheep and goats were higher in wet than dry season. However, the Na content was higher in dry than wet season. The preferred forages were high in Ca and Fe content. Browses had high levels of Ca, Mg, K and Na, while grasses/herbs were higher in Zn and Mn levels. Season and forage type had no effect on Fe, Zn and Mn content of forages selected by sheep and goats. Generally, Zn content tended to be higher in the wet and Mn in dry season, while the Fe content of forage was high in both seasons. Forages consumed by goats tended to have higher K and Na content, while those consumed by sheep tended to have higher levels of Ca, Mg, Fe, Zn and Mn. In both seasons, all the plants consumed by sheep and goats provided adequate intake of Ca, Mg and Fe levels. The animals also consumed sufficient intake of K and Mn in the wet season and Na and Zn in the dry season. Both sheep and goats consumed low Na and marginal K in the dry season. Sheep had adequate intake of P in the wet season, but both species had low intake during the dry season. Sheep suffer from Zn deficiency in the wet season and goats in Mn during the dry season. In conclusion, sheep and goats would benefit from P, K in the dry season and Na in wet season. In the case of micro-elements sheep would need to be supplemented with Zn in the wet season and goats with Mn in dry season.

Keywords: Preferred forages, minerals, intake, sheep and goats

6.1 Introduction

Sheep and goats significantly contribute to the animal protein consumed in Kenya. It is estimated that these livestock produce nearly 98 million litres of milk and 120,000 tonnes of red meat, which is about 30% of the total red meat produced in Kenya (Cheruyot, 2004). Sixty percent of sheep and goats slaughtered in Kenya originate from the arid and semi-arid areas of the country (EPZ, 2005).

Marsabit south district, the region in which this study was carried out, is one of the major suppliers of sheep and goats for slaughter at the terminal markets. Albeit the large contribution of small ruminants to the consumption protein pool, a study by the Livestock Development Group, ranked access to forage as the primary problem affecting livestock in Kenya (Owen *et. al.*, 2005).

The feeding system of small ruminants in the arid and semi-arid areas is based on natural forages of browses, herbs and annual grasses (Personal observation). The productivity of these pastures is subjected to high variability between and within years, related to rainfall and seasons (Sanon, 2007). In the arid areas, options of increasing livestock feed supply is limited (Coppock, 1994) and increased knowledge on the quantity and quality of available feeds is prerequisite to correct the nutrient deficits.

Minerals are an important component of animal foods and are required by organisms to utilize other nutrients in the diet (Szefer and Nriagu, 2007). Minerals are important to sustain life and animal productivity as the levels of macro and trace mineral in the diet influences the biological productivity of ruminants (Kincaid, 1999). In free grazing animals, minerals derived from natural feedstuffs are often inadequate and require supplementation to satisfy animal requirements (Sowande *et al.*, 2008).

Forage quality and quantity varies appreciably with climate and often leads to nutritional inadequacy (Ramirez, 1999). The amount of nutrients, including minerals, in the forages greatly vary depending on soil, plant species and management factors (Haenlein, 1991). Of the nutritional inadequacies, mineral deficiencies have adverse effect on both animal production and health (Schillhorn van Veen and Loeffler, 1990). However, in the arid and semi-arid lands of Kenya, where the bulk of small ruminants are found, there is limited information on the mineral content of the forages consumed by grazing sheep and goats.

In free grazing systems, analysis of forage for mineral composition should be coupled with estimating their contribution to the mineral intake of animals. In free-grazing animals, obtaining herbage samples representative of that selected by goats or sheep is normally intricate (Aregheore *et al.*, 2006). The composition of most preferred forages in diet of sheep and goats influence nutrient intake and thus animal productivity.

One of the objectives of this study was to determine the mineral profiles of most preferred forages consumed by sheep and goats.

Therefore, the specific objectives were:

(i) To determine the levels of Ca, P, Mg, K, Na Fe, Zn, and Mn in forages preferred by sheep and goats.

(ii) To assess the effect of season on minerals levels in the preferred forages.

(iii) To determine whether the forages consumed by sheep and goats provide adequate minerals.

(iv) To assess whether there are any differences in access to minerals between sheep and goats.

(v) To estimate the mineral intake of sheep and goats.

Materials and methods

The materials and methods used in the study of mineral profiles are presented in Chapter Three sections 3.2.3, 3.2.4, 3.2.6 and 3.4.

6.2 Results and discussion

6.2.1 Main forages preferred by sheep and goats

The ten most preferred forages by sheep were browses and grasses/herbs (Table 6.1a). In the dry season the sheep fed on five species of browses and five species of grasses/herbs. However, in the wet season the number of species of browse decreased to four while the species of grasses and herbs increased to six.

Table 6.1b shows the ten most preferred forages by goats in the study area. During the dry season, goats preferred browse plants with eight species being among the most preferred. However, only two grass/ herb species formed an important component of the diet of goats in this season. In the wet season, the number of preferred browses decreased to six but the number of grass/herb species increased to four. Out of the 11 species of browse plants that were consumed by goats in the dry and wet seasons only 4 of them formed part of their diets in the two seasons. These were *B.taitenis*, *C. africana*, *C.sinensis and I. Spinosa.* For both sheep and goats, consumption of different forages is influenced by palatability, availability and the energy cost of accessing the plants.

Table 6.1a: Most preferred forages by sheep at Merille location in Marsabit South District in the year 2009/10

Forage	Dry season	Wet season
Browses	*Duosperma eremophilum*	*Crotalaria fasicularis*
	Commiphora africana	*Indigofera hochstetteri*
	Cordia sinensis	*Indigofera spinosa*
	Indigofera spinosa	*Indigofera cliffordiana*
	Sericocomopsis hildebrandtii	
Grasses /herbs	*Aristida adscensionis*	*Commicarpus stellatus*
	Commicarpus stellatus	*Bracharia leersiodes*
	Blepharis linariifolia	*Tetrapogon cenchriformis*
	Bracharia leersiodes	*Aristida adscensionis*
	Tetrapogon cenchriformis	*Cenchrus pennisetiformis*
		Mariscus macropus

Table 6.1b: Most preferred forages by goats at Merille location in Marsabit South District in the year 2009/10

Forage type	Dry season	Wet season
Browse	*Acacia tortilis*	*Bauhimia taitenis*
	Barleria acanthoides	*Commiphora africana*
	Bauhimia taitenis	*Grewia tenax*
	Combretum aculeatum	*Indigofera hochstetteri*
	Commiphora africana	*Indigofera spinosa*
	Cordia sinensis	*Lippia carviodora*
	Indigofera spinosa	
	Maerua crassifolia	
Grasses and herbs	*Aristida adscensionis*	*Bracharia leersiodes*
	Tetrapogon cenchriformis	*Cenchrus pennisetiformis*
		Mariscus macropus
		Tetrapogon cenchriformis

6.2.2 Mineral profile of forages consumed by sheep

Macro-elements

Forage type (browse vs. grasses/herbs) had significant effect ($P<0.05$) on Ca, Mg levels, while season had no effect ($P>0.05$) on Ca and Mg content of forages (Table 6.2a). However, season had significant effect ($P<0.05$) on P and K content of forages, but forage type had no influence ($P>0.05$) on P and K. The sodium contents of forages was not affected ($P>0.05$) by season and forage type (Table 6.2a).

The profiles of Ca, P, Mg, K and Na of individual forages consumed by sheep in the two seasons are shown in Table 6.2b. The mineral content of the browses consumed in the dry season were variable. Thus the average Ca, P. Mg, K and Na content were 38.0, 1.18, 5.7, 1.86 and 0.76 gkg-1 DM, respectively (Table 6.2b). The wide variation in concentration of these minerals between species of browses was expected since different plants have different capacities to sequester minerals. C.sinesis had 105 and 2.1 gkg-1 DM of Ca and Na while S. hildebrandtii was relatively low in these minerals.

Other than for sodium, the browses consumed by sheep in the wet season had relatively higher levels of the macro minerals analyzed except for sodium. The mean concentrations for Ca, P, Mg, K and Na were 55.9, 2.45, 7.9, 2.35 and 0.5 gkg^{-1} DM, respectively. *C. sinensis* which was not part of the forages consumed in the wet season can explain the relatively low level of Na reported.

The average content of Ca, P, Mg, K and Na in grasses and herbs consumed in the dry season was 14.3, 1.1, 2.9, 1.4 and 0.5 gkg^{-1} DM, respectively. The corresponding values for the grasses/herbs consumed in the wet season were 19.7, 2.4, 4.9. 2.3 and 0.5 gkg^{-1} DM. The average mineral content was higher in the wet than the dry season (Table 6.2b).

The mean browse and grass/herb Ca contents of (38 vs.14.3) and (56 vs. 19.6) gkg^{-1}DM in dry and wet season respectively, were higher in browses than grasses and herbs (Table 6.2a). It appears that browse plants, most which are deep rooted, are able to extract and accumulate higher calcium than grasses/herbs. The calcium level was markedly higher in *cordial sinensis,* which grows along the seasonal river. The calcium levels in the forages were comparable to levels reported by Aganga *et al*. (2008) in browse plants of Botswana, (Niekerk *et al*., 2004) in South Africa, and Kuria (2004) in browse plants of west Marsabit District. Irrespective of season, the Ca content was above the critical level in forages (Givens *et al*., 2000) (Table 6.2b). However, excess Ca can interfere with P utilization leading to aphosphorosis (Kallah *et al.*, 2000) and Mn absorption (McDowell, 2003).

Table 6.2a: Mean macro-elements levels (DM basis) in forage types consumed by sheep in dry and wet seasons at Merille location in Marsabit South District

	Dry season		Wet season	
Element	Browses	Grasses & herbs	Browses	Grasses & herbs
Ca, gkg^{-1}	38.04^a	14.3^b	55.9^a	19.7^b
P, gkg^{-1}	1.18^b	1.1^b	2.5^a	2.4^a
Mg, gkg^{-1}	5.7^a	2.9^b	7.9^a	4.9^b
K, gkg^{-1}	1.9^b	1.38^b	2.4^a	2.8^a
Na, gkg^{-1}	0.76^a	0.4^a	0.5^a	0.5^a

^{ab}*Means of same element* along *a row for different seasons and forage types with different letters differ (p<0.05).*

Table 6.2b: Macro-elements levels (gkg^{-1}DM) in forages consumed by sheep in dry and wet seasons at Merille location in Marsabit South District

	Dry season					Wet season				
Forages	Ca	P	Mg	K	Na	Ca	P	Mg	K	Na
Browses										
S. hildebrandtii[3]	10.5	1.1	8.7	2.5	0.5	–	–	–	–	–
D. eremophilum[3]	32.1	1.8	9.8	2.1	0.4	–	–	–	–	–
C. africana[1]	12.6	0.9	3.6	1.43	0.5	–	–	–	–	–
C. sinensis[1]	105	1.3	4.7	1.0	2.1	–	–	–	–	–
I. spinosa[3]	30.0	0.8	1.7	2.3	0.3	59.5	2.4	6.0	2.0	0.4
I. cliffordiana[3]	–	–	–	–	–	45.9	2.1	8.0	2.5	0.5
C. fasicularis[3]	–	–	–	–	–	41.8	2.4	10.5	2.5	0.7
I. hochstetteri[3]	–	–	–	–	–	76.2	2.9	6.9	2.4	0.4
Mean	**38.04**	**1.18**	**5.7**	**1.9**	**0.76**	**55.9**	**2.5**	**7.9**	**2.4**	**0.5**
SD	38.7	0.4	3.4	0.6	0.8	15.5	0.3	1.9	0.2	0.1
Grasses and herbs										
C. stellatus[5]	26.0	1.6	5.3	0.8	0.3	49.5	2.8	8.7	2.5	0.5
B. linariifolia[5]	12.7	1.4	1.2	2.6	0.5	–	–	–	–	–
B. leersiodes[4]	17.2	1.3	5.5	2.2	0.7	15.3	3.1	6.9	2.6	0.5
T. cenchriformis[4]	9.3	0.6	1.3	0.7	0.4	11.6	2.2	3.0	2.9	0.5
A. adscensionis[4]	6.4	0.7	1.3	0.6	0.3	6.2	2.1	1.4	1.3	0.4
M. macropus[6]	–	–	–	–	–	19.5	1.3	2.5	2.3	0.7
C. pennisetiformis[4]	–	–	–	–	–	15.8	2.9	6.6	2.1	0.5
Mean	**14.3**	**1.1**	**2.9**	**1.38**	**0.4**	**19.7**	**2.4**	**4.9**	**2.8**	**0.5**
SD	7.7	0.4	2.3	0.9	0.2	5.0	0.7	2.5	0.6	0.1

[1]*Tree/bushes;* [3]*dwarf shrub;* [4]*grass;* [5]*herb,* [6]*sedge;* SD (Standard deviation)

The P content of browse declined by (52%) from 2.5 g P kg^{-1}DM in the wet season to 1.2 g P kg^{-1}DM in the dry season (Table 6.2a). In grasses and herbs the P content also declined by 54% from 2.4 in the wet season to 1.1 g P kg^{-1}DM in the dry season. The mean browse, grasses and herbs P contents of 2.5 vs. 2.4 g P kg^{-1}DM in the wet season were comparable to the level of 2.9 g Pkg^{-1}DM of most tropical forages (Minson,1990) , but lower than value of 6.9 g P kg^{-1} DM in grazing forages of Tanzania (Rubanza *et al.*, 2005). Except for *M.macropus*, most of the preferred species in the wet season had high P content. However, in the dry season browses, grasses and herbs with mean levels of 1.2 vs. 1.1 g P kg^{-1}DM were poor in P compared to wet season. The low P was also reported by Kuria *et al.* (2006) in 50% of the forages preferred by camels in Marsabit south district. The P content of plants is influenced markedly by the availability of P in soil and plant maturity, as grasses mature, P is transferred to the grain (Soetan *et al.*, 2010). Individual forages consumed by sheep in the dry season were therefore low in phosphorus.

The concentrations of Mg in browses were 5.7 and 7.9 and gkg^{-1}DM in dry and wet season respectively. Grasses and herbs had lower Mg than browses (Table 6.2a). The mean Mg content of 2.9 in dry season was similar to 2.8 gkg^{-1} DM of tropical grasses (Minson, 1990).

The mean K content in browses and grasses/herbs of (1.9 vs. 1.38) gkg^{-1}DM in the dry season and (2.4 vs. 2.8) gkg^{-1}DM in wet season were similar. However, during the dry season the K content of browses and grass/herbs declined by 21 and 51% respectively. The decline in K content was higher in grasses/herbs than browses. The concentration of K in plants varies with age, as plants mature the concentration of K rapidly declines (Mayland *et al*, 1987). Thus forage plants generally contain higher level of K in wet than dry season since they are younger. Seasonal fluctuation in K content might be related to water availability, since K absorption by the root is linked to soil moisture (McDowell, 2003).

The mean Na content of 0.76 and 0.5 gKg^{-1}DM in browses and 0.4 and 0.5 gKg^{-1}DM in grasses/herbs were low (Table 6.2b). Of the browse plants, *C.sinensis* had the highest level of 2.1 gKg^{-1}DM, while *A.adscensionis* had the lowest content of 0.3 gKg^{-1}DM. Similar values of Na were reported by Ramírez *et al.* (2006) in browse plants of north eastern Mexico and forage plants of South Africa by Lukhele and Ryssen (2003). In saline soils, many plants have mechanisms to avoid excess intake of Na and thus plant Na have no correlation with soil Na (Underwood and Suttle, 1999).

Micro-elements

Season and forage type had no significant effect ($P>0.05$) on Fe, Zn and Mn content of forages (Table 6.3a). Table 6.3b shows the Fe, Zn, and Mn concentrations in browse and grass/herb plant species during the dry and wet seasons. In the dry season, the average Fe, Zn and Mn content in the browse plant species was 1089.5, 49.1 and 76 $mgkg^{-1}$ DM respectively. During the wet season, the level of Fe, Zn and Mn in browses was 660.6, 81.7 and 53.1 $mgkg^{-1}$ DM. During the dry season the level of Fe, Zn and Mn in the grasses/herbs was 330, 66 and 83 $mgkg^{-1}$ DM respectively. The corresponding micro-mineral content in the wet season was 585.3, 69.2 and 58.5 $mgkg^{-1}$ DM.

Table 6.3a: Mean micro-elements levels (DM basis) in forage types consumed by sheep in dry and wet seasons at Merille location in Marsabit South District

	Dry season		Wet season	
Element	Browses	Grasses & herbs	Browses	Grasses & herbs
Fe, $mgkg^{-1}$	1089.5^a	330.0^a	660.6^a	585.3^a
Zn,$mgkg^{-1}$	49.1^a	66.0^a	81.7^a	69.2^a
Mn, $mgkg^{-1}$	76.06^a	83.0^a	53.1^a	58.5^a

^{ab}*Means of same element* along *a row for different seasons and forage types with different letters differ ($p<0.05$).*

Table 6.3b: Trace mineral levels (mgkg^{-1}DM) in forages consumed by sheep in dry and wet season at Merille location in Marsabit South District

	Dry season			Wet season		
Forages	Fe	Zn	Mn	Fe	Zn	Mn
Browses						
S. hildebrandtii[3]	2175.5	16.7	249.0	_	_	_
D. eremophilum[3]	215.5	18.1	27.4	_	_	_
C. africana[1]	2746.5	16.2	88.6	_	_	_
C. sinensis[1]	150.5	134.0	12.6	_	_	_
I. spinosa[3]	159.5	60.5	2.7	342.5	94.0	75.5
I. cliffordiana[3]	_	_	_	245.0	193.0	25.0
C. fasicularis[3]	_	_	_	526.5	16.5	61.4
I. hochstetteri[3]	_	_	_	1528.5	23.3	50.4
Mean	**1089.5**	**49.1**	**76.06**	**660.6**	**81.7**	**53.1**
SD	1268.4	51.1	102.3	590.2	82.1	21.4
Grasses and herbs						
C. stellatus[5]	523.0	58.4	41.2	2650.5	29.1	94.5
B. linariifolia[5]	598.6	20.4	212.5	_	_	_
B. leersiodes[4]	252.0	15.3	56.3	224.0	30.7	70.0
T. cenchriformis[4]	131.5	71.4	44.9	131.5	71.1	44.9
A. adscensionis[4]	145.0	164.5	60.2	130.5	57.5	35.4
M. macropus[6]	_	_	_	31.9	132.5	30.8
C. pennisetiformis[4]	_	_	_	342.5	94.0	75.5
Mean	**330.0**	**66.0**	**83.0**	**585.3**	**69.2**	**58.5**
SD	217.4	60.1	72.8	1017.2	39.6	25.3

[1]*Tree/bushes;* [3]*dwarf shrub;* [4]*grass;* [5]*herb;* [6]*sedge; SD* (Standard deviation)

Individual browses, grasses and herbs had high content of iron. Some browse plants, such as *S. hildebrandtii* and C. *africana,* which are preferred in the dry season had exceptionally high levels of 2175.5 and 2746.5 mg Fe kg^{-1} DM respectively compared to others. While others such as *I. hochstetter*, which was consumed in the wet season had a high content of 1528.5 mg Fe kg^{-1} DM. Dust contamination in the dry season and floods during the wet season could be responsible for high Fe content of these forage species. The mean browse iron contents of 1089.5 mg kg^{-1}DM and 660.6 mg Fe kg^{-1}DM in dry and wet season respectively were comparable to values reported by Kuria (2004) and Rubanza *et al.* (2005). The Fe contents in browses were also comparable to the levels of 700mg Fe kg^{-1}DM of tropical grasses and legumes (McDowell, 1992) but lower than those reported by Shamat *et al.* (2009). Although not significant (P>0.05) grasses and herbs had lower Fe content than browses.

The level of Zn among the individual browses, grasses and herbs was variable. In the wet season, *C.fasicularis* had low content of 16.5 mg Zn kg^{-1}DM and *I.cliffordiana* had the highest content of 193 mg Zn kg^{-1}DM. In the dry season, *A .adscensionis* and *C.sinensis* had the highest levels of Zn (Table 6.3b). The higher level of Zn in *A.adscensionis* could be ascribed to intact seed head as Zn is associated with cell walls. The concentration of Zn in *C. sinensis* (134 $mgkg^{-1}$DM) obtained in this study was higher than 19 $mgkg^{-1}$DM reported by Kuria (2004) in the Marsabit district.

The forage showed species variation in Mn content. Leguminous browse plants such as *I.cliffordiana* and *I. spinosa* with levels of 25 $mgkg^{-1}$DM and 2.7 $mgkg^{-1}$DM in the wet and dry season respectively were poor in Mn. However, others such as B. *linariifolia* and S. *hildebrandtii* consumed in the dry season had high levels of 212.5 and 249 mg Mn kg^{-1}DM respectively.

The mean Mn content in browses and grasses/ herbs (Table 6.3b) were lower than 102.2 $mgkg^{-1}$DM reported by Rubanza *et al.* (2005) in grazing land forages in Meatu district of Tanzania. However, the mean values were higher than that of 1.25-17.2 $mgkg^{-1}$ DM analyzed by Aganga *et al.* (2008) in browse plants of Botswana, but were comparable to the level of 93.17 $mgkg^{-1}$DM obtained by Kakengi *et al.* (2007) in browse trees and grasses of Tanzania. It appears that, although not significant (P>0.05), that Mn in forages was higher during the dry season than wet season. However, the high dietary Ca exhibited by forages consumed by sheep in dry and wet seasons may reduce Mn bioavailability (Hidiroglow, 1979).

6.2.3 Mineral profiles of forages consumed by goats

Macro-elements

Analysis of variance results showed that season and forage type had no significant effect ($P>0.05$) on forage Ca, Mg and Na contents. However season and forage type had significant effect ($P<0.05$) on K content of forages (Table 6.6). On forage P contents, forage type had no effect ($P>0.05$), while season had significant effect ($P<0.05$). The macro-mineral concentration of individual forages and the mean content in browses, grasses and herbs consumed by goats in the dry and wet seasons are shown in Table 6.4a and 6.4b.

Individual forage species showed variation in macro-mineral content. In the dry season, the mean content of Ca, P, Mg, K and Na in browse plants was 22.6, 1.6, 5.5, 11.2, and 2.4 gkg^{-1} DM respectively. During the wet season, the macro-mineral content in browses was Ca (45.1), P (2.5), Mg (4.5), K (21.2) and Na (0.9) $g\ kg^{-1}$ DM. The Ca, P, Mg, K and Na mineral profile in grasses/herbs was 7.5, 1.1, 1.0, 6.8 and 0.6 gkg^{-1} DM respectively in the dry season. The corresponding level of macro-minerals of grasses/herbs in the wet season was 15.2, 3.0, 4.5, 29.8 and 0.7 gkg^{-1} DM.

Table 6.4a: Mean macro-elements levels (DM basis) in forage types consumed by goats in dry and wet seasons at Merille location in Marsabit South District

	Dry season		Wet season	
Element	Browses	Grasses & herbs	Browses	Grasses & herbs
Ca, gkg^{-1}	22.6^{a}	7.5^{a}	45.1^{a}	15.2^{a}
P, gkg^{-1}	1.6^{b}	1.1^{b}	2.5^{a}	3.0^{a}
Mg, gkg^{-1}	5.5^{a}	1.0^{a}	4.5^{a}	4.5^{a}
K, gkg^{-1}	11.2^{a}	6.8^{ab}	21.2^{b}	29.8^{b}
Na, gkg^{-1}	2.4^{a}	0.6^{a}	0.9^{a}	0.7^{a}

^{ab}*Means* along *a row for different seasons and forage types with different letters differ (p<0.05).*

Table 6.4b: Macro-elements levels (gkg^{-1}DM) in forages consumed by goats in dry and wet seasons in Marsabit South District at Merille location

	Dry season					Wet season				
Forages	Ca	P	Mg	K	Na	Ca	P	Mg	K	Na
Browses										
M.crassifolia[1]	17.0	1.3	19.2	23.3	0.6	–	–	–	–	–
B.acanthoides[1]	12.9	1.4	3.6	14.0	0.7	–	–	–	–	–
C.aculeatum[1]	29.9	1.5	3.8	6.2	0.6	–	–	–	–	–
A.tortilis[1]	14.0	2.3	2.8	14.0	1.1	–	–	–	–	–
B.taitenis[1]	18.2	1.6	3.1	11.5	0.6	14.0	2.2	2.7	15.5	0.5
C.africana[1]	15.7	1.4	4.1	3.3	1.1	30.2	2.0	3.0	14.5	0.7
C.sinensis[1]	54.1	1.9	5.1	12.5	14.3	–	–	–	–	–
I. spinosa[3]	19.0	1.4	2.0	4.9	0.5	19.2	2.8	5.1	17.3	0.7
L.carviodora[2]	–	–	–	–	–	26.7	2.7	3.9	21.4	0.5
G.tenax[2]	–	–	–	–	–	80.1	2.0	6.7	27.9	1.9
I. hochstetteri[3]	–	–	–	–	–	100.4	3.0	5.5	30.5	1.2
Mean	**22.6**	**1.6**	**5.5**	**11.2**	**2.4**	**45.1**	**2.5**	**4.5**	**21.2**	**0.9**
SD	13.8	0.3	5.6	6.4	4.8	36.0	0.4	1.6	6.7	0.5
Grasses and herbs										
T.cenchriformis[2]	8.6	1.1	1.0	7.3	0.7	15.5	2.3	2.6	30.4	0.6
A.adscensionis[2]	6.3	1.1	1.0	6.3	0.5	–	–	–	–	–
C.pennisetiformis[4]	–	–	–	–	–	10.9	3.2	6.1	32.3	0.5
M.macropus[5]	–	–	–	–	–	20.9	3.2	2.7	24.5	0.7
B.leersiodes[4]	–	–	–	–	–	13.6	3.1	6.5	32.0	1.0
Mean	**7.5**	**1.1**	**1.0**	**6.8**	**0.6**	**15.2**	**3.0**	**4.5**	**29.8**	**0.7**
SD	1.6	0.0	0.0	0.7	0.1	4.2	0.4	2.1	3.6	0.2

[1]*Tree/bushes;* [2]*shrubs;* [3] *dwarf shrub;*[4]*grass;*[6] *sedge*; *SD (Standard deviation)*

The browses had variable level of Ca as compared to grasses and herbs. Individual browse plant species, particularly in the wet season, showed high variation in Ca content. The calcium level ranged from 14.0 in *B.taitenis* to 100.4 g kg^{-1} DM in *I.hochstetteri* (Table 6.4b). The Ca content in browses and grasses/herbs were comparable to the range of 10-55 g Ca kg^{-1}DM reported by Ramirez *et al.* (2006) in northern Mexico.

The calcium content in forages tended to be higher. though non-significantly, in the wet season compared to dry season and in browses compared with grasses/herbs (Table 6.4a).

Forages exhibited species variation in P content. During the dry season, *A. tortilis,* a deep rooted tree had high level of 2.3 g P kg^{-1}DM, while grasses had low content of 1.1 g P kg^{-1}DM. Browses and grasses/herbs showed similar levels of P content (Table 6.4a). However, browses and grasses/herbs had higher levels of P in wet than dry season. The browse content of 2.5 g P kg^{-1}DM in the wet season declined by 40% to 1.6 g P kg^{-1}DM in the dry season. The P concentration in grasses and herbs sharply declined by 70% from 3.0 g P kg^{-1}DM in the wet season to 1 g P kg^{-1}DM in the dry season. The P content in shrubs declined with increasing maturity and shedding of seed (Ramírez *et. al.*, 2006). Grasses in the wet season tended to have higher level of P than browse plants ($P>0.05$). The higher P in grasses was similar to those reported by García-Cíudad *et al.* (1997) in some semi arid grasses in Spain. The P contents of browse and grasses/herbs in wet season were within the level of 2.7 g Pkg^{-1} DM of tropical pastures (Minson, 1990).

Of the browses, *M.crassifolia,* an evergreen tree preferred in the dry season had the highest content of 19.2gkg^{-1}DM of magnesium. The Mg content of *M.crassifolia* was slightly lower than the value of 24-32g kg^{-1}DM reported by Kuria (2004) in a similar environment. Grasses had the lowest level of Mg (1.0 g kg^{-1}DM) in the dry season. Green plants are an excellent dietary source of Mg, which is attributed to the presence of Mg in the chlorophyll moiety (Wilkinson *et al.*, 1990). The browse Mg contents of 5.5 and 4.5 g kg^{-1} DM in dry and wet seasons were similar to those reported by Shamat *et al.*(2009) in forages of Sudan. However, the content of Mg in browses and grasses in the wet season were higher than the value of 2.7 g kg^{-1} DM observed by

Rubanza *et al.* (2005). Although not significant (P>0.05) Mg contents in grasses and herbs tended to be higher, though non-significantly, in wet than dry season (Table 6.4a). With the exception of grasses/ herbs in the dry season, browses in both seasons and grasses in the wet seasons had Mg levels of 2 gkg^{-1}DM similar to those reported for tropical forages (Minson, 1990).

Browse, grasses and herbs showed variation in K content with the highest levels of 23.3 and 32.3 g Mg kg^{-1}DM in *M.crassifolia* and *C.pennisetiformis* (Table 6.4b). The former forage plant which is deep rooted tree and evergreen has high capacity to extract and accumulate K in the leaves. The lowest level of 3.3 g Mg kg^{-1}DM was found in dried leaves of *C. africana* consumed during the dry season.

The mean potassium content in browses, which was 21.2 g kg^{-1}DM in the wet season declined by 47% to 11.2 g kg^{-1}DM in the dry season (Table 6.4a). In grasses/herbs, potassium sharply declined by 77% from 29.8 in the wet season to 6.8 g kg^{-1}DM in the dry season. The fall of potassium during the dry season was in agreement with the observation that K concentrations can decrease markedly as the season progresses (Reid *et al.*, 1984). Potassium is reported to be extremely mobile in plants and is translocated from the oldest to the fastest growing tissues (Gomide *et al.*, 1969). The mean concentration of K in forages was higher than the range of 1.4-3.8g K kg^{-1}DM reported in South Africa (Lukhele and Ryssen, 2003). However, the contents of K in forages were slightly lower than values reported by Kuria (2004). Irrespective of season the mean K content in browses and grasses/ herbs were above the critical levels observed in tropical forages (Givens *et al.*, 2000).

During the dry season Na content ranged from 0.5 in *I.spinosa* to 14.3 g kg^{-1}DM in *C. sinensis*. In the wet season, Na content ranged from 1.9 in *G.tenax* to 0.5 g kg^{-1}DM in some browses and grass species (Table 6.4b). The low levels of Na are supported by a report by Minson (1990) that tropical forages have low levels of less than 1.5 g Na kg^{-1}DM. Extensive areas of sodium deprivation in livestock occur in many continents including tropical Africa (McDowell., 1992). Plant species vary in Na contents (natrophobic vs. natrophilic), and among the forage plants, *C.sinensis* and *G.tenax* were rich sources of Na. *C.sinensis*, which is a tree forage plant, grows along the seasonal riverine with salt lick deposits, however, this plant was not considered as a salty plant by herders.

Micro-elements

Analysis of variance showed that season and forage type had no significant effect (P>0.05) on Fe, Zn and Mn content of forages (Table 6.5a). The trace mineral concentrations of individual forages and the mean contents of browses, grasses and herbs consumed in dry and wet seasons are shown in Table 6.9. In the dry season, the mean content of Fe, Zn and Mn in browses was 267, 15.4 and 45.3 mg kg-1 DM and 100, 25.4 and 34.8 mg kg-1 DM in the wet season respectively. Whereas, during the wet season, grasses/herbs, had Fe, Zn and Mn content of 96, 40 and 38.8 mg kg-1 DM respectively, while the values in the wet season were 67, 48 and 49.6 mg kg-1 DM.

In the dry season, individual browse, and grasses/ herbs had Fe content that ranged between 85.8-1278.5 and 65-128 mg kg^{-1}DM respectively and 59.4-135 and 37.1-87.2 mg kg^{-1}DM respectively in the wet season (Table 6.5b). High iron content of 135 and 1278.5 mgkg^{-1}DM were observed in *I. hochstetteri* and *C.aculeatum* in wet and dry season respectively. The high Fe content found in *C.aculeatum* was comparable to levels of 1-2 g Fe kg^{-1}DM reported in camel forages by Kuria (2004). Iron content found in grasses, herbs and browses during the wet season were comparable to values of 107-109.88 $mgkg^{-1}$DM reported by Shamat *et al.* (2009) in Sudan. The concentrations of iron in browses, grasses and herbs, which tended to be higher during the dry season (P>0.05), can be attributed to dust contamination of plants. Most of the forage plants consumed in both seasons had high level of iron.

Table 6.5a: Mean micro-elements levels (DM basis) in forage types consumed by goats in dry and wet seasons at Merille location in Marsabit South District

	Dry season		Wet season	
Element	Browses	Grasses & herbs	Browses	Grasses & herbs
Fe, $mgkg^{-1}$	267^a	96^a	100^a	67^a
Zn,$mgkg^{-1}$	15.4^a	40^a	25.4^a	48.0^a
Mn, $mgkg^{-1}$	45.3^a	38.8^a	34.8^a	49.6^a

[ab]*Means of same element* along *a row for different seasons and forage types with different letters differ (p<0.05).*

Table 6.5b: Trace mineral levels (mgkg^{-1}DM) in forages consumed by goats in dry and wet season at Merille location in Marsabit South District

Forages	Dry season			Wet season		
	Fe	Zn	Mn	Fe	Zn	Mn
Browses						
M.crassifolia[1]	109.5	6.3	26.3	_	_	_
B.acanthoides[1]	140.5	4.4	44.5	_	_	_
C.aculeatum[1]	1278.5	4.9	75.8	_	_	_
A.tortilis[1]	157.0	11.9	136.0	_	_	_
B.taitenis[1]	130.5	3.5	20.0	79.7	9.9	16.3
C.africana[1]	85.8	24.9	23.2	124.5	1.8	52.1
C.sinensis[1]	133.0	63.7	22.3	_	_	_
I. spinosa[3]	104.0	3.3	14.1	116.0	122.5	59.9
L.carviodora[2]	_	_	_	59.4	5.3	20.9
G.tenax[2]	_	_	_	83.4	5.0	9.4
I. hochstetteri[3]	_	_	_	135.0	7.8	50.3
Mean	**267**	**15.4**	**45.3**	**100**	**25.4**	**34.8**
SD	409.2	20.8	41.7	29.7	47.7	21.7
Grasses and herbs						
T.cenchriformis[2]	128.0	1.8	43.9	87.2	22.0	43.9
A.adscensionis[2]	65.0	78.8	33.6	_	_	_
C.pennisetiformis[4]	_	_	_	37.1	122.0	49.5
M.macropus[5]	_	_	_	85.1	8.3	46.8
B.leersiodes[4]	_	_	_	57.0	40.2	58.1
Mean	**96**	**40**	**38.8**	**67**	**48.0**	**49.6**
SD	44.5	54.4	7.3	24.0	51.0	6.1

[1]Tree/bushes; [2]shrubs; [3] dwarf shrub; [4]grass;[6] sedge ; SD: standard deviation.

Individual plant species consumed by the animals during different seasons showed variable Zn content. In dry and wet seasons, zinc contents in individual browse plants ranged between 1.8-122.5 and 3.3-63.7 mg kg^{-1}DM, while grasses/ herbs ranged between 8.3-122 and 1.8-78.8 mg kg^{-1}DM respectively. The highest Zn levels of 122.5 and 122 mg kg^{-1}DM were observed in wet season in *I.spinosa* and *C. pennisetiformis* respectively. During the dry season, *C. sinensis* and *A. Adcensionis* had high levels of Zn, while *I. spinosa*, *B.taitenis* and *T.cenchriformis* showed low levels of zinc (Table 6.5b). The mean Zn contents in grasses and herbs were similar to the value of 36 mgkg^{-1}DM reported by Minson (1990) in forage grasses.

However, the low mean content of Zn in browses was comparable to the value of 20.96 mg kg^{-1}DM reported in the browse and grasses of Tanzania by Kakengi *et al.* (2007). Although not significant (P>0.05), zinc content tended to be higher in grasses than browses and during the wet season (Table 6.5a).

In dry and wet seasons, Mn content in individual browse plants ranged between 14.1-136 and 9.4-59.9 mg kg^{-1}DM, while grasses and herbs ranged between 33.6-43.6 and 43.9-58.1 mg kg^{-1}DM respectively. *I. spinosa* which is a leguminous dwarf shrub had the highest level of 59.9 in wet season, but showed low level of 14.1mg kg^{-1}DM in dry season. This dwarf shrub in wet season had palatable green leaves, flowers and pods but in the dry season it was heavily defoliated. In the dry season, *A. tortilis,* with green leaves and flowers had the highest level of 136 mg Mn kg^{-1}DM. It appears that green leaves and flowers of *Acacia tortilis* are high in Mn. Irrespective of season, the different grass species seemed consistently good sources of Mn. The mean concentrations of Mn in forages were comparable to the levels of 43.5-44.5 mg Mn kg^{-1}DM reported by Shamat *et al.* (2009) in Sudan.

6.2.4 Estimated mineral intake of growing sheep and goats

Macro-elements

Analysis of variance showed that Ca and Mg concentrations in forage composite of sheep and goats was not effected (p>0.05) by season. The contents of P and K were higher (p<0.05) in wet than dry season (Table 6.6). The forage composite of sheep had higher level (p<0.05) of Na in dry (1.97±0.52 g kg^{-1} DM) than wet season (0.57±0.03 g kg^{-1} DM), while Na in goat composite was similar ($p>0.05$) in both seasons. Irrespective of season, sheep and goats intake of Ca was above the recommended body requirement of 2.0 and 3.5 g kg^{-1} DM respectively (Grace, 1994; NRC, 1981; NRC, 1985). Thus sheep and goats consume adequate levels of Ca.

In both seasons, goats P intake was below the recommended requirement 2.45 g kg^{-1} DM (NRC, 1981). However, growing sheep in the dry season consumed less than recommended while in wet season they consumed levels above the recommended requirement of 1.6 g kg^{-1} DM (NRC, 1985). In dry and wet season, sheep and goats consumed adequate levels of Mg to satisfy their body requirements. However, for K, sheep and goats with daily requirement of 5 g kg^{-1} DM (NRC, 1981) consumed high levels during the wet season, but had marginal deficiency in the dry season (Table 6.6).

In the dry season, sheep and goats with a Na requirement of 0.8 and 0.8-2.5 g kg^{-1} DM respectively, consumed sufficient levels of Na to certify their body requirement. However, in the wet season Na intake in sheep and goats were below the recommended requirement.

Micro-elements

Analysis of variance showed that Fe concentrations in forage composite of sheep and goats were not affected ($p>0.05$) by season. The forage composites of sheep and goats, had higher contents of Zn in dry ($p<0.05$) than wet season (6.6). The Mn contents in forage composite of sheep were not affected by season (37.06±3.5 vs. 46.78±0.6 mg kg^{-1} DM). In contrast, Mn concentration in forage composite of goats was significantly higher in wet (42.67±5.8mg kg^{-1} DM) than dry season (28.21±7.8 mg kg^{-1} DM). In both seasons, sheep and goats consumed levels of iron above the requirements of 50 and 100 mg kg^{-1} DM in sheep and goats respectively (NRC, 1985; Kessler, 1991; Haenlein, 1980). Thus growing sheep and goats consumed excess levels of iron.

In the wet season sheep consumed low levels of Zn, but during the dry season the intake of Zn in growing sheep was above the maximum requirement of 33 mg kg^{-1} DM (NRC, 1985). However, goats in both seasons consumed adequate levels above the requirement of >10 mg kg^{-1} DM (Kessler, 1991; Haenlein, 1980). Therefore growing sheep and goats consumed adequate levels of Zn in the dry season, but sheep seems to suffer from Zn deficiency in the wet season.

Both sheep and goats, with a requirement of 20 mg Mn kg^{-1} DM (NRC, 1985; Kessler, 1991; Haenlein, 1980), consumed adequate levels in the wet season. However, during the dry season, Mn intake in goats was below the minimum requirement.

Table 6.6: Mineral content of composite diet (DM basis±SE) and estimation of mineral intake in sheep and goats (1-2 years old) at Merille location in Marsabit South District

	Mineral profile of composite				[1]Estimated mineral intake/day based on study findings				Mineral requirements[2]	
	Sheep		Goats		Sheep		Goats		Sheep	Goats
Element	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet		
Ca, gkg^{-1}	16.7± 3.1[a]	16.9± 2.3[a]	15.3±3.5[a]	22.8±0.3[a]	11.37	11.47	9.77	14.61	2.0	3.5
P, gkg^{-1}	0.87±0.03[a]	2.57±0.03[b]	0.80±0.1[a]	2.23± 0.2[b]	0.56	1.75	0.52	1.43	1.6	2.45
Mg, gkg^{-1}	3.2 ±0.2[a]	2.23±0.5[a]	3.33±0.4[a]	2.77±0.2[a]	2.18	1.52	2.13	1.77	1.2	0.8-2.5
K, gkg^{-1}	6.73±0.5[a]	23.77 ±0.5[b]	6.4±0.9[a]	26.7±0.01[b]	4.58	16.16	4.10	17.09	5	5
Na, gkg^{-1}	1.97±0.5[a]	0.57±0.03[b]	1.37±0.3[a]	0.77±0.03[a]	1.34	0.39	0.88	0.49	0.9	0.8-1
Fe, $mgkg^{-1}$	789.94±122[a]	1000.96± 201[a]	904.68±243[a]	711.7±193[a]	537.16	680.65	579.0	455.49	30-50	30-100
Zn,$mgkg^{-1}$	106.67±7.3[a]	22.03±10.1[b]	99.26±1.7[a]	18.62± 5.4[b]	72.54	14.98	63.53	11.92	20-33	>10-50
Mn, $mgkg^{-1}$	37.06 ±3.5[a]	46.78±0.6[a]	28.21±7.8[a]	42.67±5.8[b]	25.2	31.81	18.05	27.31	20-40	20-40

[ab]*Means within a row of same animal lacking common letters differ* ($p<0.05$); *2=Requirements for growing sheep and goats were compared with 1 = Estimated mineral intake of animals (Grace, 1994; Kessler, 1991; Haenlein, 1980; NRC, 1981, NRC, 1985)*

6.2.5 General discussion

Sheep and goats consumed different forage species in different seasons. Browses were important sources of minerals in the dry season, while a mixture of browses and grasses/herbs provided minerals to animals in the wet season. Precipitation appear to influence browse (shrub) consumption negatively and grasses/forbs ingestion positively (Ramirez, 1999). The seasonal shift in the preferred forages consumed by sheep and goats could be ascribed to changes in the vegetation composition, plant species availability and palatability.

In both seasons, *I. spinosa* and *T.cenchriformis* were the most selected browse and graminoid respectively by sheep. Goats consistently consumed *I.spinosa, B.taitenis, C.african and T. cenchriformis* browse and grass species respectively. *I. spinosa,* a dwarf shrub most preferred by sheep and goats in both seasons, was accessible, with pods, flowers and green leaves in the wet season and edible twigs in the dry season. *T.cenchriformis* a perennial grass, was available in both dry and wet seasons.

The different forage species consumed by sheep and goats exhibited seasonal variation in mineral profiles. The macro-mineral content of Ca, P, Mg, and K in browses and grasses/herbs consumed by sheep and goats tended to be higher in wet than dry season. However, the Na content appeared to be higher in dry than wet season.

The high Na content of forage types was attributed to selection of plants high in sodium during the dry season. Of the macro-mineral elements, P and K levels declined faster and this was observed more in grasses/herbs than browses.

The concentration of Ca, Mg, P and K was expected to decline as plants mature. The observation was in agreement with the reports by (Kiatoko *et al,* 1982; Underwood and Suttle, 1999). The range grasses/herbs which grow and mature faster than browses resulted in rapid decline in P and K content in dry season. The Fe, Zn and Mn content in the preferred forages varied for sheep and goats. The Zn content tended to be higher in the wet and Mn in dry season. Plant maturity has been reported to affect Zn concentration of forages (Underwood, 1981). However, in the case of Mn, differences due to stage of maturity and plants were small (Minson, 1990). The Fe content of forage types was inconsistent with high values in dry and wet season were due to soil contamination of plants via dust and flooding. The grazing pastures, near the highway, are prone to dust contamination, while the pastures along the riverine seasonally get flooded.

The forages consumed by goats tended to have higher K and Na content than those eaten by sheep. However, forages consumed by sheep seemed to have higher levels of Ca, Mg, Fe, Zn and Mn. The grazing behaviour of sheep feeding on dwarf shrubs and grasses/herbs could explain the high Fe content in sheep forages. The differences in grazing area, forages selected and plant parts consumed could be associated to high K and Na content in forages consumed by goats. The leguminous dwarf shrubs and some browse plants consumed by sheep were high in Ca, Mg and Zn. This was in agreement with the report by Turner *et al.* (1978) that legumes are richer in Ca and Mg than grasses. The high Zn content in legumes compared to grasses was also reported by García-Ciudad (1997) in Spain. The high Mn consumed by sheep was associated to the high manganese content in grasses/herbs. This was consistent with the report by Underwood (1977) that grasses commonly contain higher concentration of Mn than legumes.

Irrespective of season, the mineral profile of forages preferred by sheep and goats had sufficient levels of Ca, Mg and Fe. In the case of K, sheep and goat forages showed adequate levels in the wet season and marginal deficiency in the dry season. Sheep and goat forages also showed P deficiency during the dry season. However, in the wet season sheep forages had adequate P content, while goat forages were deficient. The preferred forages consumed by sheep and goats showed adequate levels of Mn and Zn in the wet and dry season respectively. In the dry season, goat forages had low levels of Mn, while in the wet season sheep forages showed low levels of Zn. The differences in the mineral content accessed by sheep and goats could be due to variation in the foraging behaviour of animals, forages selected and grazing area.

6.3 Conclusion

All the preferred forages were high in Ca and Fe content. Of the forage types, browses showed high levels of Ca, Mg, K and Na, while grasses/herbs were rich in Zn and Mn levels.

The forages and types consumed by the small ruminants tended to have higher Ca, P, Mg, K and Zn in the wet than dry season. The P and K levels declined during the dry season. In contrast, the levels of Na and Mn in the forages tended to be high in the dry season.

In both seasons, all the plants consumed by sheep and goats provide adequate intake of Ca, Mg and Fe levels. The small ruminants also had sufficient intake of K and Mn in the wet season and Zn in the dry season. Both animal species appear to suffer from Na and marginal K deficiency in the dry season. In the case of P, sheep had adequate intake in the wet season, but both species had low intake during the dry season. Sheep seems to suffer from Zn deficiency in the wet season and goats in Mn during the dry season.

In comparison, sheep tended to consumed more Ca, Fe, Zn and Mn, while goats had high intake of potassium and sodium. In conclusion, sheep and goats would benefit from P, K in the dry season and Na in wet season. In the case of micro-elements sheep would need to be supplemented with Zn in the wet season and goats with Mn in dry season.

References

Aganga, A.A., Mesho, E.O., 2008. Mineral contents of browse plants in Kweneg District in Botswana. Agricultural Journal 3(2) 93-98.

Aregheore, E.M., Ofori,A.L., and Rere,T. 2006. Studies on grazing behaviour of goats in the Cook Islands: The Animal-plant complex in forage preference/palatability phenomena. International Journal of Agriculture & Biology, 2,147-153.

Cheruiyot J.P., 2004.The status of livestock industry in Kenya with specific emphasis on small ruminants. In Proceedings of the 5th EAGODEN conference held on 7-9th June 2004 at Kenya methodist university, Meru, Kenya, pp.3-5.

Coppock, D.L. 1994. The Borana plateau of southern Ethiopia: synthesis of pastoral research development and change, 1980-91. International Livestock Center for Africa (ILCA), ILCA Systems Study No.5, Addis Ababa, Ethiopia.

EPZ-Export Processing Zones Authority, 2005. Meat production in Kenya. Also accessed at http:/www.epzkenya.com/Userfiles/File/Meatindustry.pdf in September 2005.

García-Cíudad, A., Ruano-Ramos, A., Vázquez de Aldana, B.R., García-Criado., 1997. Interannual variations of nutrient concentrations in botanical fractions from extensively managed grasslands. Animal feed science Technology, 66, pp.257-269.

Givens, D.I., Owen, E., Axford, R.F.E., Omed, H.M (eds.)., 2000. Forage evaluation in ruminant nutrition, CABI publication, p. 38.

Grace, N.D., 1994. Managing trace element deficiencies. Ag Research, N.Z.Pastoral Agric. Res, Inst, Palmerston North, NZ.

Gomide, J.A., Noller, C.H., Mott, G.O., Conrad, J.H., Hill, D.L., 1969. Mineral composition of six tropical grasses as influenced by plant age and nitrogen fertilization, Agronomy journal, 61: 120-123.

Hidiroglow, M., 1979. Manganese in Ruminant nutrition. Can.J.Anim.Sci.59, pp. 217 236.

Haenlein, G.F.W., 1980. Mineral nutrition of goats. J. Dairy Sci 63: 1729-1748.

Haenlein,G.F.W., 1991.Advances in the nutrition of macro and microelements in goats. In: Proceedings of the Seventh Annual Conference on Goats Production, Monterrey, NL. Mexico, pp. 290-320.

Kakengi, V.A.M., Ndabikunze, S.M., Sarwatt, S.V., Fujihara, T., 2007. Trace mineral contents of grass and browse in Tanzania and implication to ruminant feeding and reproduction. Journal of Food, Agriculture & environment, vol.5, pp. 210-215.

Kallah,M.S., Bale, J.O., Abdullahi, U.S., 2000. Nutrient composition of native forbs of semi-arid and dry sub-humid savannas of Nigeria. Animal feed science and technology, 84, 137-145.

Kessler, J., 1991. Mineral nutrition of goats. In: Morand-Fehr, P. (Ed) Goat nutrition, Vol.46 EAAP Publication, pp.104-119.

Kincaid, R.L., 1999. Assessment of trace mineral status of ruminants: A review. Proceedings of the American society of Animal science.

Kiatoko, M., McDowell, L.R., Bertrand, J.E., Chapman, H.C., Pete, F.M., Martin, F.G., Conrad, J.H., 1982. Evaluating the nutritional status of beef cattle herds from four soil order regions of Florida. I. Macroelements, protein, carotene, vitamins A and E, haemoglobin and haematocrits. Journal of Animal Science 55, pp.28-47.

Kuria, S.G., Wahome, R.G., Wanyoike, M.M., Gachuiri, C.K., 2006. Effect of mineral supplement on plasma concentration of Camels (*Camelus dromedarius*) in Kenya, International Journal of Agriculture and biology, 168-171.

Kuria, S.G., 2004. Mineral nutrition on settlement (Manyatta) based milk camel herds among the Rendille community of Northern, PhD thesis, University of Nairobi, Kenya, pp. 93-99.

Lukhele, M.S., Ryssen, J.B.J., 2003. The chemical composition and potential nutritive value of foliage of four subtropical tree species in southern Africa for Ruminants. South African Journal of Animal Science, 33(2), pp.132-141.

McDowell, L.R., 1992. Minerals in animals and human nutrition. Academic Press Inc., San Diego, USA.

McDowell, L.R., 2003. Minerals in Animals and Human nutrition. 2nd Edition, Elsevier. The Netherlands.

Minson, D., J. 1990. *Forage in ruminant nutrition.* Academic press Inc., London, UK.

Mayland, H.F., Kramer. T.R., Johnson. W.T., 1987. Trace elements in nutrition and immunological response of grazing livestock. In: *Grazing livestock Nutrition Conference Proceedings.* University of Wyoming, Jackson, Wyoming.

Niekerk, W.A. Sparks, C.F. Rethman N.F.G. Coertze R.J.2004. Mineral composition of certain *Atriplex* species and *Cassia sturtii.* South African Journal of Animal Science, 34.

NRC, 1981. Nutrient Requirements of Goats: Agora, Dairy and Meat Goats in Temperate and Tropical Countries, National Academy Press. Washington, D.C.

NRC, 1985. Nutritional requirement of sheep. 6th ed. Natl. Acad. Press. Washington, D.C.

Owen, E., Kitalyi, A., Jayasuriya, N., Smith, T., 2005. Livestock and wealth creation. Improving the husbandry of animals kept by resource-poor people in developing countries. Nottingham, England, p.74.

Ramirez, R.G., 1999.Fee resources and feeding techniques of small ruminants under extensive management conditions. Small ruminant Res. 34, pp. 215-230.

Ramírez, R.G., Gonzålez-Rodri´guez, H., Ramírez-Orduña, R., Cerrillo-Soto, M.A., Juárez- Reyes, A.S., 2006. Seasonal trends of macro and micro minerals in 10 Browse species that grow in northeastern Mexico. Animal feed science and technology, Elsievier 128, pp.155-164.

Rubanza, C.D.K., Shem, M.N., Bakengesa, S.S., Ichinohe, T., Fujihara, T., 2005. The content of macro and micro minerals of deferred forages in silvo-pastoral fodder banks (Ngitiri) of Meatu district of central north-western Tanzania. Livestock Res. for rural development 17(12).

Reid, R.L., Baker, B.S., Vona, L.C.. 1984. Effects of magnesium sulphate supplementation and fertilization on quality and mineral utilization of Timothy hays by sheep. Journal of Animal science 59,1403-1410.

Sanon, H.O., Kabore´-Zoungrana, C., Ledin, I. 2007. Behavour of goats, sheep and cattle and their selection of browse species on natural pastures in a Sahelian area. Small ruminant research 67, pp.64-74.

Shamat, A.M., Bakiker,I.A., Mukhtar,A.M.S., Ahmed,F.A.,2009. Seasonal and regional Variation in Mineral content of some Important Plants species selected by Camels (*Camelus dromedaries*) in Arid and Semi-arid Lands (ASAL) of Sudan. Journal of Applied Sciences Res,5(10): 1676-1684.

Schillhorn van Veen T.W., Loeffler I.K. 1990. Mineral deficiency in ruminants in sub Saharan Africa: A review. Tropical Animal Health and Production 22(3):197–205.

Sowande, O.S., Odufowora,E.B., Adelakun, A.O., Egbeyale, L.T., 2008. Blood minerals in wad sheep and goats grazing natural pastures during wet and dry seasons. Arch.Zootec.57(218):275-278.

Soetan, K.O., Olaiya, C.O., Oyewole., O.E., 2010. The importance of mineral elements for humans, domestic animals and plants: A review. African journal of Food science Vol. 4(5) pp. 200-222.

Szefer, P., and J. O., Nriagu ,2007 .Mineral components in foods, chemical and functional properties of food components series., CRC press, Tylor and Francis group,FL, USA, pp.163-195.

Turner, M.A., Neall. V.E.. Wilson. G.F.. 1978. Survey of Magnesium content of soils, and pastures and incidences of grass tetany in three selected areas of Taranaki. *New Zealand Journal of Agricultural Research* 21, pp.583-592.

Underwood E.J., Suttle N.F, 1999. The mineral nutrition of livestock 3rd edition, CABI publishing, p.68.

Underwood, E.J., 1977. Trace elements in Humans and Animal nutrition, 4th edn. Academic Press, New York.

Underwood, E.J., 1981. The mineral nutrition of livestock. Commonwealth Agricultural Bureaux, Slough, England, p.10.

Wilkinson, S.R., Welch,R.M., Mayland, H.F., Grunes, D.L., 1990. Magnesium in plants: Uptake, distribution, function and utilization by man and animals. In: Metal ions In biological systems, Vol.26, compendium on magnesium and its role in biology, nutrition and physiology, Mercel Dekker, New York, USA, pp.3-56.

CHAPTER SEVEN

MINERAL STATUS OF SHEEP AND GOATS GRAZING IN THE ARID RANGELANDS OF NORTHERN KENYA

Abstract

A study was conducted in dry and wet season to determine macro and micro mineral status of growing sheep and goats in arid rangelands of northern Kenya. Forty four, 22 each of sheep and goats (1-2 year old), randomly purchased from three herds/flocks in study area, were sacrificed for whole liver and 12th right and left ribs. Homogenized liver samples pooled from all the lobes and defatted bone ash from whole left and right 12th ribs were used for determination of Ca, P, Mg, Cu, Fe, Zn and Mn status. Liver mineral analysis, showed that in sheep Cu (303 vs.184 mg/kg DM), Zn (94.1 vs. 83 mg/kg DM) and Mn (13.2 vs.7.5 mg/kg DM) were higher ($P<0.05$) in wet than dry season. In goats, season had no effect on Cu (274.28 vs. 236 mg/kg DM) and Fe (183 vs. 171 mg/kg DM), but had significant influence on Zn ($P<0.05$) (102 vs. 126 mg/kg DM) and Mn (13.6 vs. 6.8 mg/kg DM). Sheep grazing in different pastures showed variation ($P<0.05$) in hepatic Zn, Cu and Mn contents, while goat varied ($P<0.05$) in hepatic Cu, Fe and Mn concentrations. Rib analysis indicated that season had significant effect ($P<0.05$) on sheep and goats DFF% ash. The rib Ca (359 vs. 362 mg/g), P (157 vs. 147 mg/g) and Mg (9.56 vs. 8.54 mg/g) contents of sheep was not influenced by season and grazing area ($P<0.05$), whereas goats rib Ca (360 vs. 326 mg/g), P (147 vs. 165 mg/g) content was affected by season and grazing area ($P<0.05$), but Mg showed no seasonal variation. In the wet season, liver and bone tissue of sheep and goats indicated adequate body status of Ca, Mg, Cu, Zn, Fe and Mn. However, in the dry season, sheep showed deficient levels of Zn, goats in Cu, while both species suffered from low liver Mn and rib Zn reserves. With the exception of P which was marginal in all seasons, mineral deficiencies affected animals mostly in the dry season. The liver and rib bone of sheep and goats has demonstrated seasonal fluctuation in tissue mineral reserve. It can be concluded that, sheep and goats would benefit from P, Cu, Zn and Mn supplementation, particularly in the dry season.

Key words: Minerals, bone, liver, sheep, goats

7.1 Introduction

In the low-rainfall areas of Africa and Asia, small ruminant production represents the principal economic output, contributing a large share of the income of farmers (Ben Salem and Smith, 2008). Sheep and goats are integral component of food production and livelihood systems of many pastoral and agro-pastoral farmers, most of who are found in Northern Kenya. The pastoralists keep these livestock to broaden their animal asset base and also to tap the product synergy derived from the two species.

The main breeds raised by the pastoralists in Northern Kenya are the Small East African goat, the Galla goat and Black Head Somali sheep (personal observation), and they are well adapted to the arid conditions found in this area. To meet the demand for meat and the emerging markets, producers are seeking for ways that will lead to improved productivity of their livestock. Nutritional supplementation has been aimed at rectifying energy and protein deficiency in local feeds. The low performance of sheep and goats could be linked to disorders in other nutrients such as minerals. Throughout the tropics, mineral deficiencies and imbalances exert a significant effect on health and productivity of livestock (Aregheore *et al.*, 2007). Minerals have been recognized as potent nutrients and deficiency can impair utilization of other nutrients (Szefer and Nriagu, 2007) and thereby leading to poor animal performance.

Minerals play an important role in growth, health and reproduction functions of livestock (Gonul *et al.*, 2009). Consequently, mineral deficiencies and imbalances can affect the productivity of ruminants (Kincaid, 1999). 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, 1977).

In the 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 level of minerals in forages and mineral mixes (Corah, 1996). The balanced mineral supplements promoted to improve livestock production in the arid and semi-arid lands (ASALs) of Kenya, may not correct the mineral deficits of small ruminants kept in specific regions. Prior to formulation of mineral supplements, thorough knowledge on mineral status of diets and body tissues of animals would be necessary. Of the body tissues, the liver and bone are the most commonly used in the assessment of micro and macro element levels in animals respectively (Underwood and Suttle, 1999). The liver is the primary storage for many of the essential minerals, which can augment diagnosis of mineral deficiency and adequacy in animals (Hall, 2005). The hepatic tissue often represents the status of several trace elements in animals (McDowell, 1992). The bone has proved a good indicator for the level of Ca, P and Mg concentrations in animals (Beighle *et al.*, 1993). There is limited information on the mineral nutrition of sheep and goats in the pastoral production systems of Kenya.

One of the objectives of the study was to assess the mineral status of sheep and goats. The specific objectives were:

(i) To determine the content of micro-minerals (Cu, Fe, Zn and Mn) in the liver of sheep and goats as indicator of their body status.

(ii) To determine the content of Ca, P and Mg and Zn in the 12th rib of sheep and goats as indicator of their body status.

Materials and methods

The materials and methods used in the study of the mineral status of sheep and goats are presented in Chapter Three sections 3.2.6, 3.2.7, 3.3.2 and 3.4.

7.2 Results and discussion

7.2.1 Trace mineral concentration in sheep liver

Other than zinc, the mineral concentrations in the liver were higher ($P < 0.05$) in the wet season than in the dry season. Also, with the exception of iron, the concentration of Cu, Zn and Mn varied ($P<0.05$) with the grazing area. The hepatic concentration of Cu, Fe, Zn and Mn in sheep liver is shown in Table 7.1a and 7.1b.

The mean hepatic copper content was 184 mg/kg DM of tissue during the dry season (Table 7.1a). This increased to 303 mg/kg DM in the wet season, a 65% increase. The effect of season on hepatic copper concentration affected by the grazing site. Thus, in Kamotonyi and Lorora, the copper levels were three and a half times higher in the wet season than in the dry season. However, in Salt lick grazing site, copper levels were lower in the wet season than in the dry season. The mineral concentration in the liver reflects the dietary status of animals (Webb *et al.*, 2001). Thus, differences between seasons and grazing sites could be attributed to variation in dietary Cu contents.

Table 7.1a: Mean sheep liver mineral concentrations ($mgkg^{-1}DM$) in dry and wet seasons in Merille location, Marsabit South District

	Season	
Element	Dry	Wet
Cu	184.07^{a}	303.12^{b}
Fe	187.04^{a}	213.11^{b}
Zn	83.34^{a}	94.11^{a}
Mn	7.54^{a}	13.24^{b}

^{ab}Means along a row with different letters differ ($p<0.05$)

Table 7.1b: Sheep liver mineral concentrations (mgkg^{-1}DM) in dry and wet seasons in three grazing sites of Merille location, Marsabit South District

	Grazing area					
	Kamotonyi		Lorara		Salt Lick	
Mineral element	Dry	Wet	Dry	Wet	Dry	Wet
Cu	93.73^{a}	326.88^{b}	85.65^{a}	306.08^{b}	325.65^{b}	276.40^{b}
Fe	193.32^{a}	205.49^{b}	182.08^{a}	231.10^{b}	186.05^{a}	202.74^{b}
Zn	36.13^{a}	93.36^{a}	100.32^{b}	84.18^{a}	106.01^{b}	104.79^{a}
Mn	7.99^{a}	15.61^{b}	6.94^{a}	13.23^{b}	7.65^{a}	10.87^{b}

^{ab}Means along a row with different letters differ ($p<0.05$)

The concentration of liver Cu was within the range reported by Radositis et al. (1994) and similar to that analyzed by Ziehank et al. (2008) for sheep. In the dry season, copper levels in liver obtained in this study were similar to those reported by Bakhiet et al. (2007). The higher hepatic Cu in wet season could be ascribed to consumption of green plants higher in Cu by sheep. The increase in forage Cu during the wet season was associated to new plant tissues that are capable of extract soil copper, but as plants mature Cu was translocated to the root system (Sousa, 1978). In the dry season, sheep from Kamotonyi and Lorora grazing sites had liver Cu levels below normal of 182 mg/kg DM reported by Radositis *et al,* (1994) and can be considered to be Cu deficient.

The mean iron concentration in sheep liver were 187 and 213 mg/kg DM, in the dry and wet season, respectively. There was a consistently higher liver iron level during the wet season than in the dry season for the three grazing sites. This implies sheep consumed and deposited more Fe in the wet than dry season. The concentration of iron in the sheep liver was above the marginal band of 69.9-100.1 mg/kg DM considered as deprivation in sheep (Underwood and Suttle, 1999). The increase in liver Fe during the wet season was due to increased extraction of soil Fe by plants and thus elevated concentration of iron in forages (Shamat *et al.*, 2009).

The mean liver concentration Zn was not affected by season (83.3 and 94.1 mg/kg DM in dry and wet season respectively). The effect of season on zinc levels in sheep from the three grazing sites was not consistent. Higher zinc levels were observed in the dry season than in the wet season in Larora and salt lick sites, while the reverse was observed in Kamotonyi grazing area. In wet season, sheep liver Zn was closer to values reported by Gartenberg *et al.* (1990). The levels of liver Zn were lower than the range of 116.7-130.5 mg/kg DM reported by Ziehank *et al.* (2008). The variation in grazing site on liver Zn could be due to differences in individual animal Zn metabolism and pasture Zn contents. The mean liver Zn content during the dry (83.3) indicates that the sheep were deficient in this mineral during that season. However, in wet season, the level of Zn was above 90 mg/kg DM considered normal in sheep (Underwood and Suttle, 1999).

The mean manganese concentration in sheep liver was 7.54 and 13 .24 mg/kg in the dry and wet season, respectively. In the wet season, the liver manganese concentration was 75% higher than in the wet season. The interaction of grazing site and season had no influence ($P>0.05$) on sheep hepatic manganese. The wet season manganese level was above the value of 8-9 mg/kg DM considered marginal in sheep (Underwood and Suttle, 1999). However, in the dry season the mineral level fell to 7.54 mg/kg DM which is considered marginal in sheep. In the different grazing areas and seasons, animals had varied in liver Mn (Table 7.1b), which could be attributed to differences in pasture manganese. All sheep flocks in the dry season were deficient in manganese, but had adequate Mn in wet season.

7.2.2 Trace mineral concentration in goat liver

Season had no effect on Cu and Fe but affected Zn and Mn concentration ($P < 0.05$) in goat liver. Grazing area had significant influence on liver copper and manganese levels, but no effect ($P > 0.05$) on iron and zinc concentration. The concentration of Cu, Fe, Zn and Mn in goat liver is shown in Table 7.2a and 7.2b.

Table 7.2a: Mean goat liver mineral concentrations ($mgkg^{-1}DM$) in dry and wet seasons in Merille location, Marsabit South District

	Season	
Element	Dry	Wet
Cu	236.29^{a}	274.28^{b}
Fe	171.69^{a}	183.64^{a}
Zn	126.83^{a}	102.37^{b}
Mn	6.85^{a}	13.65^{b}

^{ab}Means along a row with different letters differ ($p<0.05$)

Table 7.2b: Goat liver mineral concentrations (mgkg^{-1}DM) in dry and wet seasons in three grazing sites of Merille location, Marsabit South District

	Grazing area					
	Kamotonyi		Lorara		Salt Lick	
Element	Dry	Wet	Dry	Wet	Dry	Wet
Cu	287.65^a	267.72^a	255.93^a	159.25^b	278.01^a	281.89^a
Fe	159.86^a	183.12^a	135.88^a	196.65^a	207.40^b	171.17^a
Zn	128.14^a	105.49^a	103.64^a	101.60^a	143.23^a	100.02^a
Mn	6.24^a	10.06^a	6.13^a	20.93^b	7.85^a	9.96^a

^{ab}*Means along a row with different letters differ (p<0.05)*

The mean copper concentration was 236.3 and 274.3 mg /kg DM in the dry and wet season, respectively. In the wet season, goats grazing in Lorora area showed significantly lower (P<0.05) Cu levels of 159.3 mg/ kg DM compared to 281.9 and 267.7 mg/kg DM in Salt lick and Kamotonyi herds, respectively. Liver copper level in the two seasons was lower than 315±15 mg/kg DM reported by Solaiman *et al.* (2001). Bakhiet et *al.* (2007) reported lower levels in wet weight of 65.5 ppm in Sudan goat. The constancy of Cu levels during both seasons in goats could be attributed to their feeding behaviour (of grazing and browsing) and utilization of diverse plant species high in Cu content. However, goat's liver Cu was within the normal range in wet season, but was below the reference range in the dry season. Liver Cu levels observed in goats were below the concentrations of >405mg/kg DM considered to cause Cu poisoning (Underwood and Suttle, 1999).

Hepatic iron concentration in goats was not affected by season (P > 0.05), 171.7 mg/kg DM and 183.6 mg/kg DM for dry and wet season respectively. However, there was a significant (P<0.01) interaction between season and grazing site. In the dry season, goats grazing in Salt lick area. deposited relatively higher ($P<0.05$) Fe levels of 207.4 mg/kg DM compared to135.88 mg/kg DM and 159.86 mg/kg DM in Lorora and Kamotonyi grazing areas, respectively (Table 7.2b).

The mean liver Fe content was lower than that reported by Bakhiet et *al*. (2007 in Sudan goats. Iron deficiencies, except in young ruminants, rarely occurs in ruminants because of the ubiquitous nature of the mineral (Mollenberg, 1975).

In the dry season, liver zinc concentration was 126.8 mg/kg DM, higher ($P < 0.05$) than 102.3 mg/kg DM for the wet season (Table 7.2a). However, the grazing site had no influence ($P>0.05$) on liver Zn concentration. The concentration of liver Zn was relatively closer to the level reported for kids and calves (Underwood and Suttle, 1999). The liver zinc was lower than 177±99 mg/kg DM reported by Haenlein (1980) in goats. Zinc, as with other trace elements, is actively involved in enzyme functions, most notably metalloenzymes (Corah, 1996). The seasonal differences in goat liver Zn could be ascribed to dietary variations in Zn pasture contents. The intensity of Zn deposition in the liver depends on its concentration in the diet (Georgievskii *et al*., 1981). Thus, during the dry season increased Zn accumulation in the liver of goats could be associated to intake of forage plants which were higher in Zn. However, mean seasonal liver Zn content in goats for both seasons were within the normal range considered adequate in goats.

Liver Zn although affected by factors such as stress, disease, age of the animal and levels of other storage pools can be used to verify Zn status of the body (Hall, 2005).

The mean liver Mn concentration was significantly ($P<0.001$) lower in the dry season (6.85) than in the wet season (13.65) (Table 7.2a). There was a significant ($P<0.05$) interaction between grazing site and season. In the wet season, the liver Mn was higher than 10mg/kg DM considered normal for goats (Anke *et al.*, 1988), while in the dry season, it was lower than the expected normal level (Underwood and Suttle, 1999). Wet season liver Mn was comparable to 13.2 mg/kg DM reported by Haenlein (1980) in male goats. In the wet season, goats grazing in Lorora area showed higher Mn level of 20.93 mg/kg DM compared to 9.96 and 10.06 mg/kg DM in Lorora and Kamotonyi areas respectively (Table 7.2b). Of the body tissues the liver is considered the most indicative of body Mn status (Kincaid, 1999).

Tissue Mn is highly responsive to dietary Mn (Underwood and Suttle, 1999). The observed decrease in goat's liver Mn could be due to low diet intake, and antagonism with other elements. Low P diet has been reported to affect the concentration of Mn in the liver (Neathery *et al.*, 1990). In young growing goats, symptoms of Mn deficiency includes slow growth, staring coat, offspring weak at birth, and impaired health (Naylor and Ralston, 1992).

7.2.3 Mineral content in 12th rib of sheep carcass

Grazing area and season had significant effect ($P<0.05$) on ash dry fat free ash in sheep. The bone ash DFF% was higher in dry than wet season. The mean ash content of the 12th rib was 62.4% in the dry season, higher ($P < 0.05$) than 60.8 % obtained in the wet season (Table 7.3a). The mean dry and wet season ash content of 62.41 and 60.79%, respectively were comparable to those reported by Williams *et al.* (1990) for the 12th rib of 7-30 months old beef cattle. The mean ash % was slightly lower than values of 68 and 69% reported by Felix *et al.* (2008) in lambs. In the wet season, sheep grazing in Lorora site had significantly ($P < 0.05$) lower ash content of 57.9% than those grazing in Salt lick area with 64.4% ash. Kamotonyi sheep had lower ash content in the rib than Lorora and Salt lick herd in dry season (Table 7.3b).

Season and grazing site had no effect ($P>0.05$) on rib bone Ca content. The mean dry season Ca of 359 was similar to that of Beighle *et al.* (1993), who reported 346.3 mg/g calcium in the 12th left rib of cattle. The seasonal rib bone Ca was slightly higher than the value of 333.23±163.02 mg/g reported by Gonul *et al.* (2009) in dry bones of cattle and Espinoza *et al.* (1982) in sheep. The rib bone Ca concentration was lower than those reported by Felix *et al.* (2008) in lambs. The bone Ca concentration of sheep in the current study indicates adequate body status. This would be expected since calcium deficiency is rare in grazing animals.

Table 7.3a: Mean mineral content in the 12th rib of sheep carcass in dry and wet seasons at Merille location in Marsabit South District

	Season	
	Dry	Wet
Ash, %	62.41[a]	60.79[b]
Ca, mg/g	359.3[a]	362[a]
P, mg/g	157[a]	147[a]
Mg, mg/g	9.56[a]	8.54[a]
Zn, mg/g	0.015[a]	0.219[b]

[ab]Means along a row with different letters differ (p<0.05)

Table 7.3b: Mineral content in the 12th rib of sheep carcass in dry and wet seasons in three grazing sites of Merille location, Marsabit South District

	Grazing area					
	Kamotonyi		Lorara		Salt Lick	
Mineral	Dry	Wet	Dry	Wet	Dry	Wet
Ash, %	61.29[a]	60.38[b]	62.59[a]	57.93[b]	63.12[a]	64.35[a]
Ca, mg/g	358[a]	381.1[a]	351.2[a]	344.1[a]	368.3[a]	361.3[a]
P, mg/g	155.7[a]	129.1[a]	179.5[a]	146.4[a]	135.9[a]	165.5[a]
Mg, mg/g	8.56[a]	8.16[a]	11.19[a]	8.74[a]	8.93[a]	8.72[a]
Zn, mg/g	0.015[a]	0.293[b]	0.013[a]	0.170[b]	0.017[a]	0.195[b]

[ab]Means along a row with different letters differ (p<0.05)

The season and grazing site had no effect (P>0.05) on rib bone phosphorus. The P seasonal values were 147.0 and 157.0 mg/g in wet and dry season, respectively. The mean P concentration was however lower than that of 183.4 mg/g reported by Beighle *et al.* (1993) in bovine 12th rib but was relatively closer to value by Williams *et al.* (1990) in the rib bone of heifers. Rib bone P concentration reflects the animal mineral reserve

(De Waal and Koekemoer, 1997). In both seasons the low P in sheep, which was below the expected value of 180 mg/g ash, was indicative of marginal deficiency. Phosphorus deprivation is predominantly a chronic condition of grazing cattle and also small ruminants, arising from a combination of soils, climate and forage P content (Underwood and Suttle, 1999).

Season and grazing site had no effect ($P>0.05$) on bone Mg content. The mean bone Mg content was 9.05 mg/g ash. This level of bone Mg was comparable to 9.51mg/g ash reported by Beighle *et al.* (1993), but higher than value of 2.38±0.32 mg/g reported by Gonul *et al.* (2009) and Espinoza *et al.* (1982) in sheep. In ruminant livestock (6-12 months old) the Mg content in the rib bone was <12 mg/g ash. Therefore sheep in the study area, with mean levels of 9.56 and 8.54 mg/g ash in dry and wet season respectively were adequate in Mg.

The Zn content in the 12th rib was 0.15 mg/g ash in the dry season which significantly ($P < 0.001$) increased to 0.219 mg/g in the wet season (Table 7.3a). The Zn content in sheep rib declined by 93.2% during the dry season. In wet season, Zn content was relatively closer to that reported by Espinosa *et al.* (1982) in sheep (0.02% ash). It could imply that growing sheep adequately consumed and deposited more Zn in wet than dry season.

7.2.4 Mineral content in 12th rib of goat carcass

Season had significant effect (P<0.05) on rib ash content. The ash content was 62.3% in the dry season, which was lower than 60.6% obtained in the wet season. However, the grazing site did not affect (P > 0.05) the ash content in the rib. The ash level reported in this study was close to 63% reported by Cooper *et al.* (1998) and Underwood and Suttle (1999) in cattle calves. The ash, Ca, P, Mg and Zn in goat 12th rib are shown in Table 7.4a and 7.4b.

Season, herd, interaction between herd and season had significant effect (P<0.05) on rib bone calcium. Dry season Ca level of 360.5 mg/g was significantly higher (P<0.05) than the wet season value of 326.7 mg/g ash (Table 7.4a). In the wet season, herds varied in bone Ca content, with lower bone contents of 280.0 mg/g exhibited by Kamotonyi and higher calcium levels of 351.6 mg/g observed in Lorora herd (Table 7.4b). The mean rib Ca was relatively close to those reported by Gonul *et al.* (2009) in cattle and Beighle *et al.* (1993) in bovine rib bones. However, the mean goat rib bone Ca was slightly higher than those reported by Espinoza *et al.* (1982) in sheep. The concentration of Ca observed in the ribs of goats in this study indicate adequate body reserve of Ca.

Table 7.4a: Mean mineral content in the 12th rib of goat carcass in dry and wet seasons in Merille location, Marsabit South District

	Season	
	Dry	Wet
Ash, %	62.32[a]	60.62[b]
Ca, mg/g	360.5[a]	326.0[b]
P, mg/g	142.7[a]	165.9[a]
Mg, mg/g	8.81[a]	9.05[a]
Zn, mg/g	0.026[a]	0.208[b]

[ab]Means along a row with different letters differ (p<0.05)

Table 7.4b: Mineral content in the 12th rib of goat carcass in dry and wet seasons in three grazing sites of Merille location, Marsabit South District

	Grazing area					
	Kamotonyi		Lorara		Salt Lick	
Mineral	Dry	Wet	Dry	Wet	Dry	Wet
Ash, %	63.46[a]	60.32[b]	62.06[a]	60.23[b]	61.67[a]	61.31[a]
Ca, mg/g	357.7[a]	280[a]	364.2[a]	351.6[b]	359.6[a]	348.4[b]
P, mg/g	111.1[a]	172[b]	175[b]	178[b]	141.7[a]	147.7[a]
Mg, mg/g	9.23[a]	8.83[a]	8.78[a]	9.44[a]	8.42[a]	8.89[a]
Zn, mg/g	0.018[a]	0.198[b]	0.040[a]	0.215[b]	0.015[a]	0.212[b]

[ab]Means along a row with different letters differ (p<0.05)

In the dry season, the mean P content in the 12th rib was 142.7 mg/g DM which was lower (P < 0.05) than 165.9 mg/g DM obtained in the wet season. In the dry season, goats grazing in Larora had higher P than those grazing in Salt lick or Kamotonyi areas. This trend was seen also seen in the wet season. The bone P in the wet season was closer to the mean value of 185.74 mg P/g ash reported in young bovines by Beighle *et al.* (1993).

Little and Shaw (1979), in a study of rib bone P in grazing cattle, concluded that P levels of about 120 mg/ml in the 12th rib indicate P deficiency while levels over 150 mg/ml indicate adequacy. Since ash/unit volume is roughly similar to ash/unit dry fat-free weight, the low P in herds grazing Kamotonyi area in the dry season indicate P deficiency. Sheep appear to be efficient in P metabolism in dry season, whereas goats on contrary are better in bone P deposition in wet season. During periods of deficiency P is resorbed from the bones and may offset any dietary deficiency (Ternouth, 1990). Long term P deficiency results in poor reproductive performance, impaired immune response, bone abnormalities and pica (Kincaid, 1999).

The Mg content in rib bone of goats was not influenced ($P<0.05$) by season and grazing area. The mean Mg content was 9.05 mg/g in the wet season and 8.81 mg/g in the dry season and was within the range 7-12 mg/g ash reported in rib bone of ruminant livestock (Underwood and Suttle, 1999). The rib bone Mg contents were slightly higher than those reported by Espinoza *et al.* (1982) in Llamas and Felix *et al.* (2008) in lambs. However, the mean rib Mg was in agreement with that reported by Beighle *et al.* (1994) in 12th rib of bovine. Espinoza *et al.* (1982) reported mean magnesium value of 0.68% ash in sheep rib bone. Thus, rib Mg content of goats indicates adequate body status.

Rib Zn content was significantly influenced ($P<0.001$) by season, while the grazing site had no effect ($P>0.05$). The rib Zn content drastically declined (by 87.5%) in wet season from 0.208 mg/g to 0.026 mg/g in the dry season. In the case of deficiency, Zn in the bone and muscle tissues is redistributed to other body pools to perform vital body processes such as enzyme function (Underwood and Suttle, 1999). Wet season Zn content was comparable to 0.02% of ash reported by Espinoza *et al.* (1982) in Llamas, but higher than those reported by Heinlein (1980) and Underwood and Suttle (1999) in goat rib. In this study, goats had adequate bone Zn in wet season, but are at risk in rib Zn during the dry season.

7.3 Conclusion

The mineral concentration in liver and rib bone of sheep and goats in the study area has demonstrated seasonal fluctuation in tissue mineral reserve. The variation in tissue mineral content could be ascribed to the mineral concentration of forages consumed by animals in dry and wet seasons. In the wet season, liver and bone tissue of sheep and goats indicated adequate body status of Ca, Mg, Cu, Zn, Fe and Mn. However, in the dry season, sheep showed deficient levels of Zn, goats in Cu, while both species suffered from low liver Mn and rib Zn reserves. With the exception of P which was marginal in all seasons, mineral deficiencies affect animals mostly in the dry season. It can be concluded that, sheep and goats would benefit from P, Cu, Zn and Mn supplementation, particularly in the dry season.

References

Anke.M.,Groppel.B.,Krause,U.,Angelow,L.,Regius,A.,Masaoka,T.,Kosla.T.,Langer,M.,988. Diagnostic possibilities of the status of Zinc, manganese, copper, iodine, selenium, molybdenum, cadmium, nickel, lithium and arsenic. Proc. Macro and trace Elements Seminar, University Leipzig-Jena, Germany, Dec.20-21,368.

AOAC, 1998. Official methods of Analysis of the Association of Official Analytical Chemistry.16th Edition, Vol.I. p.32.

Aregheore, E.M., Hunter, D., Perera, D., Mautoatasi, M.T., 2007. The soil-plant-animal phenomena: Serum mineral status of Fuji fantastic sheep grazing Batiki grass(*Ischaemum aristatum* Var. *indicum*) and Pangola grass (*Digitaria decumbens*) in Samoa. Journal of Animal and veterinary Advances, 6(3): 349-357.

Bakhiet, A.O., Mohammed, A.A., Siham, E.S.M., Samia El Badwi, M.A., 2007. Some Trace-elements profile in the liver of camels, cattle, sheep and goats. International Journal of tropical medicine, 2(1): 1-2.

Beighle,D.E., Boyazoglu, P.A., Hemken, R.W., 1993. Use of bovine rib bone in serial sampling for mineral analysis. J Dairy Sci 76: 1047-1052.

Ben Salem, H., Smith, T., 2008. Feeding strategies to increase small ruminant production In dry environments. Small ruminant Research, 77. pp. 174-194.

Cooper, S.R., Topliff, D.R., Freeman, D.W., Collier,M.A., Balch, O.K., 1998. Evaluation of bone mineral contents in Equine cadavers and pregnant Mares. Animal science research report, pp.125-131.

Corah, L., 1996.Trace mineral requirements of grazing cattle. Animal feed Science Technology, 59.pp.61-70.

De Waal, H.O., Koekemoer, G.J., 1997. Blood, rib bone and rumen fluid as indicators of phosphorus status of grazing beef cows supplemented with different levels of phosphorus at Armoedsvlakte. S. Afr.Tydskr.Veek, 27(3/4), 76-84.

Espinosa, J.E., McDowell, L.R., Rodriguez, J., Loosli, J. K., Conrad, J.H., Martin, F.G., 1982. Mineral status of Llamas and sheep in the Bolivian Altipiano. Journal of nutrition, pp.2286-2291.

Felix,T.L.,McDowell,L.R.,O'Connor,G.A.,N.S., Wilkinson, N.S., Kivipelto,J., Brennan,M., madison,R.K.,Warren,L.K., Brendemuhl, J.H., 2008. Effects of dietary aluminium source and concentration on mineral status of feeder lambs. Small ruminant Res.80.pp.1-7.

Gartenberg, P.K., McDowell, L.R., Rodriguez, D., Wilkinson, N.,Conrad, J.H.,Martin,G.,1990. Evaluation of the trace mineral status of ruminants in northeast Mexico. Livestock Research for Rural Development, Vol.2.No.1.

Georgievskii, V.I., Annenkov, B.N., Samokhin, V.T., 1981. Mineral nutrition of Livestock. Butterworth and Co publishers, UK, pp.192-196.

Gonul, R., Kayar, A., Bilal, T., Erman, (Eds). O.R.M., Parkan, D.V.M., Dodurka, H.T., Gulyasar, T., Barutcu, B., 2009. Comparison of mineral levels in bone and blood serum of cattle in Northwestern Turkey. Journal of Animal and veterinary advances, 8(7): 1263-1267.

Haenlein, G.F.W., 1980. Mineral nutrition of goats. J Dairy Sci 63: 1729-1748.

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

Kincaid, R.I., 1999.Assessment of Trace mineral status of Ruminants: A review. Proceedings of the American Society of Animal Science.pp.1-10.

Lelon, J. K., Muga, M. O., Odee D. W., Wekesa, C., and Ndakwe, B., 2010. Effect of chemical properties of soils on gum elementary compositions from *Acacia Senegal* variety *kerensis* in Samburu and Marsabit districts. African Journal of Plant Science Vol. 4 (2), pp. 021-025.

Little, D. A., Shaw, N. H., 1979. Superphosphate and stocking rate effects on native pasture overs own with Stylosanthes humilis in central Queensland. 5. Bone phosphorus levels in grazing cattle. Australian Journal of Experimental Agriculture and Animal Husbandry 19(1): pp.645-651

McDowell, L.R., 1992. Minerals in Animal and human nutrition. Academic press, New York.

Mollerberg, L.,1975.A hematologic and blood chemical study of Swedish purchased calves.Acta Vet.Scand.16.pp.1-8.

Naylor, J. M., Ralston, S. L.,(eds).,1992.Recent advances in mineral nutrition of goats. In: Large animal nutrition. Mosby book Publ. St.Lous,pp.339-355.

Neathery,M.W., Crowe, N.A., Miller,W.J., Crowe, C.T., Varnadoe, J.L., Blackmon, D.M., 1990. Influence of dietary Aluminium and phosphorus on zinc metabolism in dairy calves. J. Anim. Sci. (68), 4326-4333.

Radositis, O.M., Blood, D.C., Gay, C.C., 1994. Veterinary medicine.VII edition, Bailliere Tindall London, pp.1379-1394; 1495-1499.

Shamat,A.M., Bakiker,I.A., Mukhtar,A.M.S., Ahmed,F.A.,2009. Seasonal and regional Variation in Mineral content of some Important Plants species selected by Camels (*Camelus dromedaries*) in Arid and Semi-arid Lands (ASAL) of Sudan. Journal of Applied Sciences Res,5(10): 1676-1684.

Solaiman. S.G., Maloney. M.A., Qureshi, M.A., Davis. G., D'Andrea. G., 2001. Effects of high copper supplements on performance, health, plasma copper and enzymes in goats..www.ncbi.nlm.nih.gov/pubmed/11445421.

Sousa, J.C. de., 1978. Interrelationships among mineral levels in soils, forage and animal tissues on ranches in Northgen Mato Grosso, Brazil. PhD dissertation, University of Florida, Gainesville, Florida.

Szefer, P., Nriagu, J.O., (Eds), 2007. Mineral components in Foods. CRC press, Taylo and Francis Group, USA, p.123.

Ternouth,J.H.,1990. Phosphorus and beef production in northern Australia: Phosphorus in cattle- A review. Tropical grasslands.Vol.24, 159-169.

Underwood, E.J., 1977. Trace elements in humans and animal nutrition, 3rd and 4th ed, Academic Press, New York.

Underwood, E.J., Suttle, N.F., 1999. The mineral nutrition of livestock, 3rd Edition, CAB international, willingford, UK.

Webb,E.C., Van Ryssen, J.B.J., Erasmus, M.E.A., McCrindle, C.M.E., 2001. Copper manganese, cobalt and selenium in liver samples from African buffalo (*Syncerus caffer*) in the Kruger National Park. Journal.Monit., 3, pp. 583-585.

Williams,S.N., Lawrence, L.A., McDowell, L.R., Warnick, A.C., Wilkinson, N.S., 1990. Dietary Phosphorus Concentrations Related to Breaking Load and Chemical Bone Properties in Heifers. Journal of Dairy Science, 73, pp. 1100-1106.

Ziehank, E.H., Ganter, M., Pauka, I.H., Binder,A., 2008. Trace mineral status and liver and blood parameters in sheep without mineral supply compared to local roe deer (*Capreolus capreolus*) populations. Small ruminant Res.75, pp.185-191.

CHAPTER EIGHT

8.0 GENERAL DISCUSSION AND CONCLUSION

Herders have accumulated local knowledge on mineral nutrition of their sheep and goat flocks/herds. Using indigenous knowledge livestock keepers have identified salty plants, natural salt licks and most preferred forage plants that supply minerals to grazing sheep and goats. Mineral deficiencies have been observed to affect herds/flocks mostly in the dry season. Analysis of the most preferred forages and animal tissues have shown that mineral deficiencies mainly occur in the dry season. Thus herder's local knowledge concurs with findings on mineral inadequacies reflected in the dry season in consumed forages and animal tissues analysis. Deficiencies in Na, P, Zn and Mn can be linked to the perceived poor health, slow growth and pica expressed by the small ruminant owners.

The most preferred forages are important sources of Ca, P, Mg, K, Na, Fe, Zn and Mn for grazing sheep and goats. Of the forage types, browses showed high levels of Ca, Mg, K and Na, while grasses/herbs were rich in Zn and Mn levels. With the exception of Na, consumed forages in wet season contained macro-minerals levels above the critical range found in tropical forages. The composite diet of sheep and goats is better indicator of mineral intake of sheep and goats than values obtained in forage types. The simulated diet takes account of differences in bite number of the forages consumed and thus mineral intake of sheep and goats.

Forage, liver and rib bone mineral content in sheep and goats demonstrate seasonal fluctuation in mineral levels. Evaluation of minerals in animal diet, liver and bone tissues during different periods can be useful in the diagnosis of mineral status of animals. Analysis of body tissues are better indicators of mineral status of sheep and goats. In spite of excess Fe in sheep and goat diet the levels in liver tissue were within the normal range. This was expected since mineral status in the body is one of the factors influencing mineral absorption. In goats, low Mn intake (18.05 mg kg^{-1}DM) during the dry season and adequate intake (27.3 mg kg^{-1}DM) in the wet season was reflected in hepatic Mn levels. The findings are in agreement with the report by Underwood and Suttle (1999) that tissue Mn is highly responsive to dietary contrast. In contrast, the low Zn intake in sheep of 14.98 mg kg^{-1}DM in the wet season was not reflected in liver Zn content. This was an indication of sheep accessing Zn from other sources such as water and other forages that were not part of most preferred forages analyzed in the wet season.

Irrespective of season, sheep and goats showed adequate diet intake and rib bone reserves of Ca and Mg. The low intake of P was reflected in the rib bone of sheep and goats. The study was in agreement with the finding by Read and Engels (1985) that the P content of bone samples proved a reliable and sensitive indicator of the P status of grazing cattle. Long term P deficiency results in poor reproductive performance, impaired immune response, bone abnormalities and pica (Kincaid, 1999). In spite of species differences storage of some bone and liver minerals are closely related in sheep and goats.

8.1 RECOMMENDATIONS

From this study the following are the recommendations:

- Herders should be educated on the value of other mineral elements as their knowledge was only limited to common salt found in salty plants, saline water and natural salt licks.
- The riverine ecosystem, which have natural resources of salt in the form of salt lick, halophyte plants and salty waters need to be protected and sustainably utilized.
- A feeding trial should be conducted during the dry season to validate the findings by feeding sheep and goats with mineral supplements fortified with P, K, Zn, Mn, Cu and molasses as palatable stimulator.
- Evaluations of other trace elements such as selenium, cobalt, molybdenum and chromium need to be considered in future research.

References

Kincaid, R.I., 1999.Assessment of Trace mineral status of Ruminants: A review. Proceedings of the American Society of Animal Science.pp.1-10.

Read, M.V.P., Engels, E.A.N., 1985. Phosphorus and grazing ruminants.3. Rib bone samples as an indicator of P status of cattle. Agricultural research institute, Glen, 9360, South Africa.

Underwood, E.J., and Suttle, N.F., 1999. The mineral nutrition of livestock, 3rd Edition, CAB international, willingford, UK.

APPENDICES

Appendix 1: Bite number of different forage species by sheep and goats in wet season in Merille location, Marsabit South District

Samburu name	Species	Plant family	No.of total bites	
			Sheep	Goats
Trees& bushes				
Ltepes	*Acacia tortilis*	Leguminosae(Mimosoideae)	0	2
Silaleiy	*Boswellia hildebrandtii*	Burseraceae	0	32
Rasia	*Cadaba ruspolii*	Capparaceae	0	1
Lcheni ngiro	*Commiphora africana*	Burseraceae	2	10
Laichimi	*Commiphora sp*	Burseraceae	1	26
Silapani	*Cordia sinensis*	Boraginaceae	1	2
Lororoiy	*Fiacourtia indica*	Flacourtiaceae	0	14
Lkinoi	*Lannea alata*	Anacardiaceae	0	14
Koitakino	*Maerua triphylla*	Capparaceae	0	1
Sokoteiy	*Salvadora persica*	Salvadoraceae	0	1
Shrubs				
Logirisoiy	*Bauhimia taitenis*	Leguminosae(caesalpinioideae)	2	40
Lekurunyoiy	*Cassia mimoisoides*	Leguminosae(Mimosoideae)	0	8
Lebokish	*Combretum hereroensis*	Combretaceae	1	1
Lemawoiy	*Combretum molle*	Combretaceae	0	1
Lkogomi	*Grewia tenax*	Tiliaceae	2	49
Lpupoiy	*Grewia villosa*	Tiliaceae	0	1
Lamanira	*Justicia exigua*	Verbenaceae	0	1
Lomunyayi	*Lippia carviodora*	Verbenaceae	1	35
Lpalalit	*Talinum portulacifolium*	Portulacaceae	4	0
Letomia	*Tephrosia volgelii*	Leguminosae(papilionoideae)	9	4
Lekuruki	*Tarenna graveolens*	Rubiaceae	2	11
Dwarf shrubs				
Sucha	*Barleria acanthoides*	Acathaceae	2	0

Kakanteiy	*Crotalaria fasicularis*	Leguminosae(papilionoideae)	30	12
Ldurkunyanto	*Duosperma eremophilum*	Acathaceae	0	13
Lodoporo	*Gutenbergia sp*	Compositae	0	1
Ananis	*Indigofera cliffordiana*	Leguminosae(papilionoideae)	24	14
Charda	*Indigofera hochstetteri*	Leguminosae(papilionoideae)	40	63
Lkitagesi	*Indigofera spinosa*	Leguminosae(papilionoideae)	177	144
Lturkan	*Sericocomopsis hildebrandtii*	Amaranthaceae	0	1
Grasses&sedges				
Ntalagwani	*Aristida adscensionis*	Gramineae	84	20
Lanana	*Bracharia leersiodes*	Gramineae	133	242
Lorokwe	*Cenchrus ciliaris*	Gramineae	5	3
Nankuka	*Cenchrus pennisetiformis*	Gramineae	37	20
Naiteteyiay	*Commelina benghalensis*	Commelinaceae	3	0
Lapuran	*Dactyloctenium aegyptica*	Gramineae	1	1
Loririmouwo	*Erogrostis minor*	Gramineae	2	0
Lonoro	*Leptothrium senegalenses*	Gramineae	13	4
Lyaput	*Mariscus macropus*	Cyperaceae	164	41
Lesao	*Sehima ischaemoides*	Gramineae	0	3
Lorepirepi	*Setaria verticillata*	Gramineae	0	1
Lterian	*Tetrapogon cenchriformis*	Gramineae	182	78
Herbs				
Nyorte	*Commicarpus stellatus*	Ncytaginaceae	23	17
Lgalayoiy	*Cucumis hirsutus*	Cucurbitaceae	4	6
Ndeti	*Forsskalea viridis*	Urticaceae	1	0
Lekulupani	*Heliotropium albohispidum*	Boraginaseae	7	13
Lmasigirai	*Heliotropium steudneri*	Boraginaseae	7	**2**
Sakurdumi	*Kedrostis gijef*	Cucurbitaceae	0	3
Lomuruaki	*Tribulis terrestris*	Zygophyllaceae	10	1
Ilmarepare	*Zehneria anomala*	Cucurbitaceae	0	1

Appendix 2: Bite number of different forage species by sheep and goats in dry season in Merille location, Marsabit South District

Samburu name	Species	Plant family	No.of total bites	
			Sheep	Goats
Trees&bushes				
Ltepes	*Acacia tortilis*	Leguminosae(Mimosoideae)	3	16
Silaleiy	*Boswellia hildebrandtii*	Burseraceae	3	5
Lcheni ngiro	*Commiphora africana*	Burseraceae	40	25
Laichimi	*Commiphora sp*	Burseraceae	3	7
Samanderi	*Commiphora sp*	Burseraceae	0	2
Lguita	*Cordia sinensis*	Boraginaceae	42	39
Ldumeiy	*Maerua crassifolia*	Capparaceae	8	10
Lderendeiy	*Zisiphus mauritania*	Rhamnaceae	0	3
Lgiriay	*Lawsonia inermis*	Lythraceae	6	2
Shrubs				
Logirisoiy	*Bauhinia taitenis*	Leguminosae(caesalpinioideae)	0	19
Lebokish	*Combretum hereroensis*	Combretaceae	3	2
Lemawoiy	*Combretum aculeatum*	Combretaceae	7	12
Lkogomi	*Grewia tenax*	Tiliaceae	1	3
Lamanira	*Justicia exigua*	Verbenaceae	8	0
Lomunyayi	*Lippia carviodora*	Verbenaceae	5	4
Lekuruki	*Tarenna graveolens*	Rubiaceae	0	3
Letomia	*Tephrosia volgelii*	Leguminosae(papilionoideae)	0	6
Dwarf shrubs				
Sucha	*Barleria acanthoides*	Acathaceae	7	11
Ldurkunyanto	*Duosperma eremophilum*	Acathaceae	33	0
Lkitagesi	*Indigofera spinosa*	Leguminosae(papilionoideae)	112	65
Lturkan	*Sericocomopsis hildebrandtii*	Amaranthaceae	9	6

Grasses&sedges				
Ntalangwani	*Aristida adscensionis*	Gramineae	126	50
Lanana	*Bracharia leersiodes*	Gramineae	18	5
Nankuka	*Cenchrus pennisetiformis*	Gramineae	1	0
Lterian	*Tetrapogon cenchriformis*	Gramineae	38	14
Herbs				
Lmarag	*Blepharis linariifolia*	Compositae	15	0
Nyorte	*Commicarpus stellatus*	Ncytaginaceae	10	0
Loiyeti	*Cissus sp*	Vitaceae	3	0

Appendix 3: Inventory of salty plants, season of availability and locality found as reported by herders in Merille location, Marsabit South District

Samburu name	Species	Plant family	Available	
			season	pastures
Logirisoiy	*Bauhinia taitenis*	Leguminosae	Wet & dry	Riverine
Larasoro	*Cadaba granulosa*	Capparaceae	Wet & dry	Riverine
Lapuran	*Dactyloctenium aegyptica*	Gramineae	wet	Bush shrub land
Laburan	*Dactyloctenium portulacifolium*	Gramineae	wet	Bush shrub land
Charda	*Indigofera hochstetteri*	Leguminosae	Wet	Bush shrub land
Lokii	*Lycium europaeum*	Solanaceae	wet	Riverine
Nchunge	*Oxygonum sinuatum*	Polygonaceae	Wet	Riverine
Adum	*Salsola dendroides*	Chenopodiaceae	Wet & dry	Riverine
Sokoteiy	*Salvadora persica*	Salvadoraceae	Wet & dry	Riverine
Lamuruaki	*Tribulis terrestris*	Zygophyllaceae	wet	Bush shrub land

Appendix 4: Sheep and Goats mineral nutrition and productivity questionnaire

Small Ruminant Meat Value Chain

Date of interview................................ flock/herd name..............................grazing area.........................
Name of interviewee........................... Sex..................
Age...
Name of interviewer........................... GPS points...

A. Small ruminant flock and marketing information (pre- drought)

	No of animals in flock	No of animals marketed	Marketing age (yrs)*	Sex of marketed animal	Prices Kshs.
sheep					
goats					
Total					

[1-2 yrs, 2-3 yrs]**, [3-4yrs, >4yrs]*** ** young animals, ***Adults

2. What are the market requirement for sheep and goats?
Local market...
External market..
3. Are you able to attain these requirements? Yes/No
4. If No, what are the nutritional problems in your sheep and goats?...
5. If Yes, How?...
6. Which products and resources do you most frequently get from your herd of small ruminants, cattle and camels?

meat		milk		hide		skin		Cash income	
monthly	seasonally	monthly	seasonally	monthly	seasonally	monthly	seasonally	monthly	seasonally

B: Grazing information

Which are the major grazing areas used by your flocks in this locality?

Grazing areas(name)	Distance from manyatta	Dominant vegetation type	Soil type	Condition of SR*	
				Sheep	goats

*Poor (P), fair (F), good (G)

C: Mineral nutrition Information

1. Do you understand the value of mineral nutrition for your flock of sheep and goats? Yes/No.
2. If yes, what is the condition of animals with adequate mineral nutrition?

Sheep………………………………… ………………………when is this observed?...................

Goats………………………………… …………………… when is this observed?......................

3. What about the conditions of animals showing mineral nutrition deficiency?

Sheep…………………………………..................... class effected……….when is this noticed?..

Goats………………………………… ……………………class effected…………….when is this observed.............................

3b. Which of the following performances attributed to low productivity have you observed in **growing** sheep and goats? (Season-tick where appropriate), (quantify the symptoms with the no of the total growing animals in the flock)

Symptoms observed	**Sheep**	**season**	**goats**	**season**
Poor health conditions (no of the total)				
Slow growth rate(birth-weaning-maturity) - age in months to maturity				
Diarrhea incidences(no of the total)				
Loss of weight(no of the total)				
Pica (chew non food materials)				
Skin diseases(alopecia, dermatosis)				
Stiffness of joints/ paralysis				
Craving for saline well waters				
Weak offspring at birth/dwarfed kids/lambs				
Reduced disease resilience				
Skeletal deformation				

Start of wet (SW), peak wet (PW), end of wet (EW), start of dry (SD), mid dry (MD), end of dry(ED) seasons

4. Do your flock of sheep and goats require mineral salt by showing deficiency symptoms? Yes/No

5. If yes, how do you provide them with mineral salts? (Tick 1or all)

Supplement with commercial salts……………local salts……………

Move them to access salty plants…………water sources……………

Move them to mineral licks……………………………………………

6. If No, why?…………………………………………………………

7. Which are the salty plants for sheep and goats?

Vernacular name	Plant class/type	Rank according to availability and preference	Where are they found?	Period of availability

8. What is the trend of availability (number) of plants, salty water sources and natural salt licks?

	Period		
Natural mineral sources (#)	*1987/88	**1997/98	**2007/8
Salty plants			
Natural salt licks			
Saline water sources			
Most preferred plants			
Grazing area(distance)			

*Iinitiation of Lmeoli age group ** Elnino period *** One year ago

9. Which are the most preferred forages in the diets of sheep and goats in your grazing area?

9.1 Goat forages (wet)

Plant Name		Parts eaten	*Plant class	Preference Rank
vernacular	Botanical			

*class= grasses (annual, perennial) & Browse= trees, bushes, dwarf shrubs, herbs, forbs

9.2 Sheep forages (wet)

Plant Name		Parts eaten	Plant class	Preference Rank
vernacular	Botanical			

9.1 Goat forages (dry)

Plant Name		Parts eaten	*Plant class	Preference Rank
vernacular	Botanical			

*class= grasses (annual, perennial) & Browse= trees, bushes, dwarf shrubs, herbs, forbs

9.2 Sheep forages (dry)

Plant Name		Parts eaten	Plant class	Preference Rank
vernacular	Botanical			

10. What is the way forward for sufficient mineral nutrition of small ruminants in the locality?..
....
....