AN EVALUATION OF SELECTED BRACHIARIA CULTIVARS ON THE WEIGHT CHANGE OF GALLA GOATS IN THE COASTAL LOWLANDS OF KENYA

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DECLARATION

I understand that plagiarism is an offence and therefore declare that this thesis is my original work and has not been presented to any other institution for any other award.

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God bless you all.

DEDICATION

I dedicate this work to the following:

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ACRONYMS AND ABBREVIATIONS

ACZ	Agro-climatic zones
ADF	Acid detergent fiber
ADL	Acid detergent lignin
ADWG	Average daily weight gain
ANOVA	Analysis of Variance
AOAC	Association of official analytical chemists
ASALs	Arid and semi-arid lands
BecA	Biosciences for Eastern and Central Africa
CP	Crude protein
Cv	Cultivar
CRD	Completely randomized design
DM	Dry matter
DDM	Digestible dry matter
DoMD	Dry organic matter digestibility
DMD	Dry matter digestibility
EE	Ether extracts
GDP	Gross domestic product
FAO	Food agricultural organization
ILRI	International Livestock Research Institute
IVDMD	*In-vitro* dry matter digestibility
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agriculture and Research Institute
LR	Long rains
LWG	Live weight gain
NDF	Neutral detergent fiber
OMD	Organic matter digestibility
Sida	Swedish International Development Co-operation Agency
SR	Short rains

DEFINITIONS OF TERMS

Arid and semi-arid lands: Are areas that receive rainfall of 150 mm-550mm (arid) and (550mm-800mm) per year. Temperatures are also high throughout the year resulting to high rates of evapo-transpiration. There are occurrence of droughts and severe feed and food shortages during the dry periods of the year.

Agro-pastoral production system: Is a system characterized by a high degree of reliance on pastoral activities for household revenue, but rain fed cultivation by, or on behalf of, the household also contributes up to 50 per cent of the total share.

***In Vitro* Dry matter Digestibility (IVDMD):** *In vitro* generally refers to a technique of performing a given biological procedure in a controlled environment-outside of a living organism. IVDMD is determined by incubating ground samples of feed with rumen fluid in a test tube for 24-48 hours and thereafter an addition of acid and pepsin incubation for 24 hours.

ABSTRACT

Inadequate and erratic rainfall in the arid and semi-arid lands (ASALs) of Kenya that are accompanied by long dry spells lead to drought. This leads to low feed availability. Inadequate quality and quantity of feeds is the major constraint to livestock production in the ASALs of Kenya. It is the major input factor to livestock production and accounts for 60-70% of the production cost. There is therefore a need to introduce climate smart forage species in order to expand the forage resource base to realize the full potential of ASALs as well as curb this challenge. This study was carried out to determine the chemical composition and *in vitro* dry matter digestibility of three cultivars of *Brachiaria* and their effects on live weight changes on Galla goats.

It was conducted at the Sheep and Goat Multiplication Centre, Matuga, Kwale. Three cultivars of Brachiaria namely; *Brachiaria brizantha* cvs. Piata and MG4, *Brachiaria hybrid* Mulato II were given as basal feeds and used to assess the performance of the goats in reference to weight gain, feed intake and nutritive quality. Rhodes grass (*Chloris gayana*) was used as control. Sixteen Galla goat bucklings ranging from 10-24 kg live weight were randomly allocated to the four dietary treatments with four animals per treatment. All the goats were supplemented with 100g/day of maize germ. Mineral licks and water were provided *ad libitum*.

Piata and MG4 had higher ($P<0.05$) crude protein (12.6 and 12.1% respectively) than Mulato II (3.0%) and Rhodes grass (6.7%). The cvs. Piata and MG4 were also more digestible than Mulato II and Rhodes grass. There was no difference ($P>0.05$) in grass dry matter intake among the goats and it ranged between 513-661 g/goat/day. Average daily live weight gain was higher ($P<0.05$) for goats fed on Piata (45.2 g/day) and MG4 (41.3 g/day) than those fed on Mulato II (2.0 g/day) and Rhodes grass (9.6 g/day). Likewise goats fed on Piata (3.8 kg) and MG4 (3.5 kg) had a higher ($P<0.05$) total weight gain compared with bucklings fed on Mulato II (0.2 kg) and Rhodes grass (0.8 kg).

From the results and findings in this study, it is recommended that cvs. Piata and MG4 to be integrated in cut and carry feeding systems for better growth and live weight gain in Galla goats and generally for all ruminants. Further research should also be conducted to assess other cultivars of *Brachiaria* apart from the ones assessed on other animal performance variables such as milk yield and reproductive performance.

CHAPTER ONE

1. 0 INTRODUCTION

1.1 Background to the study

Arid and semi-arid lands (ASALs) cover 80% of Kenya's landmass (Mganga *et al.*, 2010). These areas are characterized by low rainfall, high temperatures, poor quality feed resources, and high incidences of livestock diseases (Kahi *et al.*, 2006). The ASALs support 60% of the livestock population and the largest proportion of wildlife (Ngugi and Nyariki, 2003). According to Mbogoh and Shaabani (1999), agro-pastoralism and pastoralism are the main economic activities in ASALs from which majority of the people attain their livelihoods. This is mostly based on cattle (the small East African zebu – SEAZ and Boran), goats, sheep and camels, and thus constitutes a major source of Kenya's meat (Herlocker, 1999). The coastal lowlands of Kenya lie in the south-eastern part of the country and cover an area of about 80,000 km^2 (Njarui and Mureithi, 2004) and are considered as ASALs.

According to Njarui *et al.* (2011), the productivity of livestock in Kenya is strongly linked to feed availability. Feed is the major input factor in livestock production systems and account for between 60–70% of the production cost. Productivity of ruminants is considered low due to inadequate and poor quality feeds. There is a feed resource deficit for about 4-6 months in a year across many regions in Kenya particularly during the dry season when there is limited pasture growth.

Livestock is considered one of the key assets for rural households in most parts of the world and it is a primary livelihood resource for most rural communities. According to FAO (2012), about 752 million of the world's poor keep livestock mainly to; generate cash income, produce food for subsistence use, manage risks and to build up assets for security purposes. Another limitation of livestock production is that there is lack of suitable fodder crops that can produce green forage throughout the year (Leeuw *et al.*, 1992). This situation becomes even worse in the areas that are constrained by low rainfall.

Most small ruminants in the ASALs suffer from nutritional stress (Bruinsma, 2003). This is because most of the grasses have low crude protein (CP) falling below 7% minimum level that is required for optimum microbial growth (Wambui *et al*., 2006). When this occurs, it calls for0 supplementation, which is not always possible for resource poor farmers (Gitunu *et al*., 2003). There is a need, therefore, for pasture species that can improve the quality of the natural pastures and significantly increase dry matter production to enhance livestock productivity. One of these pastures has been found to be *Brachiaria* (Machogu, 2013).

Brachiaria grasses have been reported to have good adaptability, tolerant and resistant to abiotic factors. Furthermore, the grasses have high forage quality and high dry matter production making them capable of meeting the nutritional requirements of animals especially during the dry seasons (Lascano and Euclides, 1996; Brighenti *et al*., 2008).

Goats are found in many parts of Kenya and are an important source of income to many small-holder farmers. They are preferred to cattle as they can be converted to cash easily. They also provide a higher offtake compared to cattle because of their shorter generation interval and higher prolificacy (Ahuya and Okeyo, 2006). Galla goats also known as Somali or Boran goats are indigenous to the arid and semi-arid regions of northern Kenya and are kept mainly for meat (Ahuya and Akeyo, 2006).

The full potential of the ASALs for livestock production can be exploited by expanding the forage resource base. This can be achieved by introducing climate smart forage species to boost nutrient quality and quantity hence supplying the nutritive requirements of livestock. Studies on climate smart *Brachiaria* grass species developed elsewhere have shown that they could be the key to improvement of livestock production and also serve to boost composition and nutritive values of local *Brachiaria* cultivars.

However, there are hardly any studies on goat feeding on *Brachiaria* grasses in Kenya. The study was therefore done to determine its suitability on goat performance. The objective was to evaluate the growth of Galla goats fed selected *Brachiaria* grass cultivars.

1.2 Statement of the problem

A major problem facing livestock farmers worldwide is how to economically maximize animal production with limited land availability (Osakwe *et al*., 2006). The situation is even worsened by desertification, leaching and urbanization. Tropical pastures have long been recognized as capable of producing large quantities of forage dry matter; however, individual animal performance is normally less per animal than for similar animals grazing temperate zone forages (Minson and Wilson 1981; Moore and Mott, 1973). According to Ellis *et al*. (1976), grazing behaviour of animals is based on availability and preference for plant species and/or portions of plants.

The livestock sector in Kenya is faced by several constraints such as lack of feed especially during the dry seasons, pests and diseases, limited land availability, insecurity among others (ASDS, 2010). Feed inadequacy in terms of quality and quantity, however, is the major constraint to livestock production in the ASALs (Mnene *et al*., 2006). The production of the natural pastures in the ASALs is limited by low annual rainfall which ranges between 500 and 800 mm, characterized by prolonged dry season usually from June to September and frequent droughts; hence, severe feed shortages result.

1.3 Justification

Livestock, especially the ruminant species are a major component of Kenya's economy and are distributed across all the production systems. The livestock sub-sector in Kenya contributes about 40% of the agricultural Gross Domestic Product (GDP) and 10% of total GDP (KARI, 2009). The sub-sector employs 90% of the population living in the ASALs and contributes 95% of their income. Njarui (2016) reports that, among the pastoral communities living in the ASALs, ownership of livestock is recognized as indicator of wealth and prosperity. According to the 2009 census, KNBS (2010) estimates the total population of ruminants to be 67 million, whereby 3.4 million are dairy cattle, 14.1 million Zebu cattle, 27.7 million goats, 2.9 million camels, 17.1 million sheep and 1.9 million donkeys.

Pasture is the most important source of feed for ruminants in the tropical countries where numerous forage species exist naturally Herrera (2004). The author further notes that, the forages can be cultivated, and that they are not used as human food, hence a cheap, economical feed for the ruminants. Napier grass which is the most commonly grown fodder grass by most farmers in Kenya has been recently attacked by pests and diseases rendering it vulnerable (Orodho, 2006). *Brachiaria* forages have been found to be very palatable and have a good leaf to stem ratio. They are also productive and can support high stocking rates under continuous or rotational grazing (Cook *et al*., 2005).

1.4 Objectives

1.4.1 General Objective

The overall objective of this study was to evaluate the performance of goats fed on *Brachiaria* grass cultivars in the coastal lowlands of Kenya.

1.4.2 Specific Objectives

1. To determine the chemical composition and *in vitro* dry matter digestibility of selected *Brachiaria* grass cultivars.
2. To determine dry matter intake of goats fed on selected *Brachiaria* grass cultivars.
3. To determine the effect of *Brachiaria* grass cultivars on the growth of Galla goats.

1.5 Hypotheses

1. There is no difference (H_0) in the chemical composition and *in vitro* dry matter digestibility of the selected cultivars of *Brachiaria* grass.
2. There is no difference (H_0) in dry matter intake of goats fed on *Brachiaria* grass cultivars.
3. There is no difference (H_0) in the weight change/ growth rate of goats fed on the three *Brachiaria* grass cultivars.

1.6 Scope of the Study

This study was carried out in Matuga, Kwale County and focussed on analysing the weight change/growth rate of Galla goats fed on selected *Brachiaria* cultivars (Piata, MG4 and Mulato II) for a period of 84 days (20^{th} April-13^{th} July, 2016). Data analysis was guided by use of SAS (2010). The operations, activities and data collection were strictly confined within the boundaries set by the objectives of this study.

CHAPTER TWO

2. 0 LITERATURE REVIEW

2.1 Introduction

Small ruminants play an important role in the farming systems of most countries of the world, through; production or provision of milk, meat, draught power, manure as well as hides and skins. The ability of ruminant livestock to provide food, income as well as employment are important to most communities in the ASALs (Thorpe *et al*., 1992). Natural pasture constitute the major ruminant feed resources, providing more than 90% of animal feed requirement.

This section therefore discusses the role of small ruminants in both agro-pastoral and pastoral systems. It considers the available goat genetic resources and their distribution, their nutritional requirements, diet selection and plant preference. The importance of supplementation of goats under grazing, nutritional quality and animal production on pasture is also considered.

Literature on goat production in Kenya however, is scanty while the literature available for goat production and nutrition is old.

2.2 The role of small ruminants in traditional farming systems

2.2.1 Agro-pastoral production system

Crop-livestock mixed farming systems comprise sedentary smallholder farmers carrying out mixed crop and livestock farming concurrently as the main activity (Kosgey *et al*., 2006). In the tropics, the crop-livestock mixed farmers are found mainly in the medium- to high- potential areas (Rege, 1994) and own small sizes of land. Animals are confined to small areas for grazing or left to wander freely around villages scavenging for feed (Gatenby, 1986). In some cases, stall feeding, where grass is cut and carried to the animals is practised.

Small holder farming is livelihood oriented, unlike with commercial farming, the former tend to keep animals for family needs, rather than purely as an economic enterprise. Animals have intangible roles to the farmer (e.g., savings, insurance, cultural, prestige, and ceremonial) and farmers expect their animals to fulfil these traditional functions (Wilson, 1985; Ayalew *et al*., 2003). Survival of animals in the face of multiple stresses (heat, parasites and disease, and poor nutrition) is one of the most important traits, while increasing growth rate is of less value (Upton, 1985; Solkner *et al*., 1998).

2.2.2. Pastoral production systems

In Kenya, pastoral farming systems are found in medium to low potential areas where crop production is difficult due to low rainfall and high evapotranspiration. In these systems, livestock forms an integral part of the socio-cultural life of the people. Pastoral farmers rely on livestock as their main source of livelihood, and usually own relatively large numbers of animals under extensive or communal grazing management (Kosgey *et al*., 2006). Most of the livelihood is directly from livestock use and sales or exchange (Adu and Lakpini, 1988). Pastoral communities often herd cattle, camels, donkeys, sheep, and goats together. Only a few raise sheep and/or goats exclusively (Adu and Lakpini, 1988; Peters, 1988).

Nomadic life, overgrazing, and low productivity are common features of pastoral systems, especially in the arid areas. Risk avoidance is an integral part of production in these marginal areas (Janke, 1982; Solkner *et al.*, 1998). The farmers adopt a two-pronged approach. First, in addition to stock diversification, pastoral communities use mobility to counter problems of uncertainty in the timing and distribution of rainfall, and hence availability of forages, water shortage, and incidence of diseases (Adu and Lakpini, 1988). Secondly, farmers use adapted breeds that survive and thrive in the environment (Mason and Buvanendran, 1982). Therefore, survival (e.g., pre-weaning, post-weaning, and adult animal) traits and reproductive traits (e.g., litter size and lambing frequency) are important under this system.

2.3 Available goat genetic resources and their distribution

Goats are wide spread and found in all regions of the world. The world goat population is estimated to be 975.8 million (FAOSTAT, 2015). The reason for their dispersal across the world is due to goat's great adaptability to varying environments. Most of goats are found in Asia and Africa. Goats are appealing because of their high turnover in reproduction and small size, they are cheap to purchase, reliable producers in bad times, lower nutritional requirements and perhaps most important goats do not compete with humans for food (Escareno *et al*., 2013).

Goats in Kenya are an integral component of the livestock enterprise (GOK, 2002). They are spread in all the agro-ecological zones of Kenya and are mostly reared to provide meat, milk, skins and manure (Nyendwa, 2002). The major breeds of goats reared include Anglo-Nubian, Alpine, Toggenburg, East African, Saanen, Granadina and the Galla goats (Kipserem *et al*., 2012).

The increase in number of goats per year has been between 1 to 4 % and the total number of goats in the world has increased by 166 % from 1990 (589.2 million) to 2013. The goat population in Kenya is predominantly Galla and the East African Goats. Both Galla and East African goats are concentrated in Arid and Semi-arid areas. The East African is a meat goat while the Gallas which are common in North Eastern and Eastern provinces are dual purpose. The Gallas are found mainly in the lower areas and are mainly intrusions from the neighbouring Isiolo districts while the East African is found mainly in the higher areas but also in the lower parts. There is a small population of improved goats (less than 1% of the national population) mainly crossbreds of exotic temperate dairy breeds with Galla and East African (Ahuya and Okeyo, 2006).

Table 2.1 below shows the number and distribution of goats in Kenya in every province. Most of the goats are found in the Rift Valley, North Eastern and Eastern province.

Table 2.1: Goat distribution in Kenya per province

Province	**Number of goats**
Nairobi	46,837
Central	531,209
Coast	1,570,728
Eastern	4,729,057
N. Eastern	7,886,586
Nyanza	961,269
Rift Valley	11,750,521
Western	263,946
Total	27,740,153

Source: KNBS, 2010.

2.4 Nutritional requirements of goats

2.4.1 Energy requirement

Efficiency in utilization of nutrients largely depends on adequate supply of energy. Deficiency in energy delays puberty, retards kid growth, reduces fertility, and depresses milk production (Singh and Sengar, 1970; Sachdeva *et al*., 1973). Energy limitations could result from; low quality of feed or inadequate feed intake. Low energy intake that results from either feed restriction or low diet component prevents goats from meeting their nutritional requirements as well as from attaining their full genetic potential (NRC, 1981).

Energy in feed is assessed in mega joules of metabolizable energy per kilogram of dry matter (MJ ME/kg DM). Digestibility is positively related to protein content. Good quality roughages provide about two Mcal metabolizable energy (ME) per kg dry matter (DM). Roughage-concentrate mixed rations are sometimes necessary to increase the energy content of the diet to 2.5 or 3.0 Mcal ME/kg DM when feeding early weaned kids or high-producing dairy goats. According to NRC (1981) the efficiency with which energy is utilized for weight gain, lactation, and pregnancy usually increases with increasing levels of ME concentration in the diet.

2.4.2 Protein requirement

Proteins are the pre dominant elements of the body of an animal and are needed continuously in the feed for synthetic processes as well as cell repair. The conversion of feed protein into body protein is an important process of metabolism and nutrition. Proteins are made up of amino acids which are the building blocks of all body cells. Secretions such as hormones, mucin, enzyme and milk have extra amino acid requirements. Proteins are, therefore, vital for growth, maintenance, reproduction as well as milk production (Harmeyer and Martens, 1980).

Deficiencies of protein in the diet deplete stores in the liver, muscles and blood, and make animals vulnerable to a variety of serious and even mortal ailments. Below a minimum level of 6% crude protein (CP) in the diet, feed intake will be reduced, which leads to a combined deficiency of both energy and protein (NRC, 1981). This deficiency in CP further reduces rumen function and lowers the efficiency of feed utilization. Long-term protein deficiencies retard foetal development, lead to low birth weights, affect kid growth, and depress milk production (Singh and Sengar, 1970).

2.4.3. Water requirement

Water is important for maintenance and satisfactory levels of production. Water requirement by goats depends on temperatures, age and the amount of fat in the body. Water requirements would be expected to exceed 75% of the non-bony tissues and 60% of the body weight (NRC, 1981).

Water requirements may be met by free water consumption, but other important sources include metabolic water resulting from oxidation of energy sources and water contained in the feed ingested. Water in animals is lost through perspiration, evaporation, urine and lactation. A safe general recommendation is to provide goats with all the clean water that they will drink (*ad libitum* intake) (NRC, 1981).

Goatcher and Church (1970) reported that, extremes in water temperature (too hot or too cold) will increase the energy requirements. Taste factors will also affect normal water intake. In the humid tropics Devendra (1967) found that penned indigenous meat goats had a mean daily free water intake of 680 g, of which 80% was consumed during the day. Goats are often more delicate and reluctant than other species to drink from foul-tasting water sources. Poor quality water leads to undesirable mineral intake or infection. Goats are more adaptable to high temperature stress than other species of domestic livestock such as wooled sheep and cattle and require less water evaporation to control their body temperature. They also have the ability to conserve water by reducing losses in urine and faeces. (NRC, 1981).

Factors affecting the free water intake of goats are; water content of forage consumed, lactation level, amount of exercise, environmental temperature, and mineral and salt content of the diet. Therefore, the daily range of free water intake may be from zero to several litres. When water is lacking and there is feeding on dry forages, the efficiency of reproduction will suffer (Brown and Lynch, 1972; Lynch *et al*., 1972). Below optimum water intake will result initially in reduced feed intake, then reduced performance and gradual starvation. Serious problems result when goats are unable to maintain water balance or control their body temperatures.

2.4.4 Minerals and Vitamins

According to NRC (1981), requirements for minerals have not yet been established definitively for goats at either maintenance or production levels. The literature on mineral nutrition in goats was recently reviewed by Haenlein (1980). In addition to the elements in organic matter (carbon, oxygen, hydrogen and nitrogen), seven major and nine minor minerals are believed to be dietary prerequisites for livestock. The major minerals that must be fed in relatively large amounts are potassium, calcium, phosphorus, sulphur, sodium, chlorine, and, magnesium.

Minor or trace minerals, required in small amounts, include manganese, cobalt, iron, iodine, copper, fluorine, molybdenum, zinc, and selenium. Others which are possibly essential at extremely low levels are tin, chromium, nickel, arsenic, vanadium, and silicon. Most of these essential or possibly essential elements occur naturally in feedstuffs at levels that do not constitute problems in nutrition. However, there are situations that do exist when one or more minerals, especially the major ones, are sufficiently low to reduce the productivity of animals. Trace minerals for example, can be present in amounts that are toxic to animals. Proper balance of minerals as well their bioavailability from supplements are often more important than actual levels (Miller, 1981). Functions and practical implications of various important minerals are discussed in the section below.

Calcium is a crucial nutrient in ration formulation for all species of livestock. Although most of the calcium found in the body is in the skeleton, the element has numerous critical functions in the soft tissues as well. Calcium deficiency in young animals leads to retarded growth and development, and can make them susceptible to rickets. It is important to supply adequate levels of calcium for lactating goats to prevent milk fever (parturient paresis). In browsing or grain-fed goats, the inclusion of a calcium supplement (limestone, dicalcium phosphate, etc.) to the feed or to a salt or trace mineral–salt mixture will calcium requirements. Legumes (e.g., clover, alfalfa, kudzu) are also good sources of calcium. (NRC, 1981)

Phosphorus is required for both bone and tissue development. Deficiency in Phosphorus results in unthrifty appearance, depraved appetite, and slowed growth. Goats can maintain milk production on phosphorus-deficient diets for several weeks by using phosphorus from their body reserves, but when phosphorus deficiency is prolonged, production in milk will go down by 60%. The calcium: phosphorus ratio should be maintained between 1:1 and 2:1, preferably 1.2–1.5:1 in goats because of their susceptibility to urinary calculi. Phosphorus deficiency in grazing goats is more likely than deficiency in calcium. In cases of struvite calculi, the ratio should be maintained at 2:1. (NRC, 1981)

Magnesium is required for proper functioning of the nervous system and many enzyme systems. It is also closely associated with the metabolism of Phosphorous and Calcium. Deficiency in magnesium is associated with grass tetany also known as hypomagnesemic tetany, but normally this condition is less frequent in grazing goats than it is in cattle. Goats do have an adaptability to counter balance for low magnesium by reducing the amount of magnesium they excrete. Both milk production and urinary excretion are reduced in a magnesium deficiency. (NRC, 1981)

Sodium chloride (NaCl) is a necessary dietary component but is often neglected. Goats may consume more salt than what is needed when it is offered without restraint; this does not present any nutritional problem but may lower feed and water intakes in some arid areas where the salt content of the drinking water is quite high. Salt formulations are used as transporters for trace minerals, because goats have a clear urge for sodium intake. (NRC, 1981)

Potassium deficiencies in grazing goats are quite rare, however Potassium has an important role in metabolism. Slight potassium intake is seen only in heavily lactating does fed diets composed primarily of cereal grains. Excessive potassium intake especially during late gestation may be associated with hypocalcemia particularly in dairy goats. If hypocalcemia is a herd problem, therefore attention should be shifted to reducing or monitoring potassium-rich feedstuffs (eg, alfalfa) (NRC, 1981).

Iron deficiency is rarely seen in mature grazing goats. Such deficiency might be seen in young kids because of their low stores during birth, and also the low iron content of the dam's milk. This mostly affects kids fed in complete confinement and animals that are heavily parasitized. Iron deficiency however, can be prevented by access to pasture or a good quality trace mineral salt that has iron. In critical cases, and for kids reared in confinement, iron dextran injections at 2 - 3-wk intervals (150 mg, IM) for the first few months may be curative. In the cases of mixed iron/selenium deficiencies, care should be undertaken when injecting iron dextrans until the selenium deficiency is also corrected (NRC, 1981).

Iodine deficiency in the soil and crops, is seen in some areas of the world. Iodine therefore, should be supplied in stabilized salt. Conditional iodine deficiency may develop with normal to marginal iodine intake in goats consuming plants that are goitrogenous. Marked deficiency of iodine results in poor growth, an enlarged thyroid, poor reproductive ability and small, weak kids at birth (NRC, 1981).

Table 2.2: Daily nutrient requirements of goats per animal

Body Wt. (kg)	Dry Matter (kg/head)	% Body Weight	Total Protein (kg)	Ca (kg)	P (kg)	Vitamin A (IU)
10	0.29	2.80	0.02	0.0009	0.0009	400
20	0.49	2.40	0.04	0.0009	0.0009	700
30	0.66	2.20	0.05	0.0018	0.0014	900
41	0.82	2.03	0.06	0.0018	0.0014	1200
51	0.97	1.90	0.08	0.0032	0.0023	1400
61	1.11	1.82	0.09	0.0032	0.0023	1600
71	1.25	1.80	0.10	0.0041	0.0027	1800
81	1.38	1.70	0.10	0.0041	0.0027	2000
92	1.51	1.64	0.12	0.0041	0.0027	2200
102	1.62	1.60	0.13	0.0050	0.0036	2400

Source: Adopted from National Research Council, 1981

2.5 Forage Utilization of Goats

Compared with other domestic animals, goats have unique preferences for shrubs and tree leaves, whether evergreen or deciduous. They select from a wider array of plants particularly woody plants (NRC, 1981). Goats show a special preference for the inflorescences of grasses. Goats consume approximately the same weight of forage DM as do sheep of similar size (Geoffroy, 1974; NRC, 1981). The exact amount that they will voluntarily consume is influenced by several factors. Malechek and Leinweber (1972) suggest that goats will eat more forage if they have access to the more preferred species.

Devendra (1975) found that voluntary intake by goats declined as the forage matured. This effect is overcome partially by chopping and pelleting the forage (Fehr, 1971; Fonolla *et al*., 1972; Devendra, 1977). Environmental factors such as humidity and temperature also often affect the level of voluntary intake (Chenost, 1972). Browse (leaves and twigs of trees and shrubs) and forbs generally contain higher levels of crude protein and phosphorus during the growing season than do grasses (Rector and Huston, 1976). Browse species are limited in value because of one or more inhibitors/impediments that may bind or otherwise prevent utilization of nutrients contained in the plants. These inhibitors include excessive lignification of woody twigs, and tree leaves that physically bind or encapsulate the nutrients (Short and Reagor, 1970; Singh *et al*., 1972).

2.6 Diet selection and plant preference by goats

2.6.1 Browsing: Grazing Ratio

Goats are classified as intermediate selector feeds (Van Soest, 1981). Although goats have definite plant preferences, they show high variability in their feeding practices in different ecological zones as well as seasonal variation within the same region (McCammon-Feldman *et al*., 1981). On average, goats select about 60%, 30%, 10% of shrubs, grass, and forbs throughout the year.

Diurnal (morning vs. afternoon) variation is a major factor affecting the feeding behaviour of goats and has a major influence on both grazing and browsing activities (Grova and Bjelland, 1997). In most cases, morning feeding periods are governed by browsing while grazing is the dominated activity during the afternoon. With plenty forage, the time spent browsing during the mornings is more than four times of that of grazing and decrease to equal time spent on grazing and browsing when forage is perhaps limited. During the afternoon this changes with a decrease in the availability of forage. (Raats *et al*., 1996).

Table 2.3: Average time spent browsing, grazing and on non-feed activities by goats (%)

Behavioural Activities	**Period 1 (0-22 goat b-days/ha)**	**Period 2 (23-53 goat b-days/ha)**	**Period 3 (148-205 goat b-days/ha**
Browsing	42.4	37.2	31.0
Grazing	17.4	29.0	46.0
Non-feed activities	40.3	33.8	23.0
Browse: Graze ratio	2.44	1.28	0.67
Lying down	20.3	10.7	1.8
Standing	26.2	35.6	36.8
Walking	53.6	53.7	61.5

Source: Grova and Bjelland (1997)

Church (1979) has shown that there are differences between breeds in taste sensation. According to Warren *et al*. (1984), plant species selection differ depending on the breed of goat: Spanish goats for example, select a higher quantity of browse than Angora goats; Indigenous goats (South Africa) on the other hand were found to select more grass and less forbs and browse when compared with Boer goats; Aucamp (1979) also reported a consistently higher browse content when fistula samples were collected from Boer goats to that of Angora goats over a period of twelve months. Even within a species, each animal shows preference for certain parts of plants, plant species, plants in certain growth stages and individual plants (Heady, 1975). Studies at Fort Hare (Grova and Bjelland, 1997) could not show any differences that were significant in feeding behaviour between Indigenous Ciskeian and Boer goats.

2.6.2 Plant species selection

Selection of diets by goats is primarily determined by; the relative abundance of plant species as well the variety of plant species (Merrill and Taylor, 1981). Most studies on browsing habits of goats have shown a significant correlation between chemical composition of the diet and season of use as well as the species selection. (Taylor and Kothmann, 1990). Preference for any one, or combination of grass, forbs and shrubs is normally influenced by the availability of these plants which in turn is affected by rainfall and season. Substances like tannins, lignin, alkaloids, terpenes and many others have been shown to depress intake of plants or plant components.

Nutrients such as nitrogen, fibre and fat also relate to digestibility, but likely in an indirect or correlative sense. Goats prefer plants high in nitrogen content but low in tannins (Woodward, 1989). Further complicating factors may be the adaptation to certain odours, which has been demonstrated in sheep (Arnold *et al*., 1980) and conditioned flavour aversion (Provenza *et al.,* 1990).

2.7 Grazing with Supplementation.

2.7.1 Supplementation with concentrates

The major feed resources in East Africa cannot sustain effective animal production or maintenance when fed alone especially during the dry season because of their inherent nutrient deficiencies, poor quality pastures and cereal crop residues. Therefore, appropriate supplementary feedstuffs provision would be an important step to enhance the productivity of goats in smallholder and pastoral production systems of East Africa. It is possible to enhance productivity of small ruminants or at least avoid body weight loss during the critical feed shortage periods of the year by supplementing poor quality forage and crop residues with small quantities of high quality supplements; studies conducted so far on small ruminants have shown that.

Okello *et al*. (1996) for example, reported that goats fed on un-supplemented elephant grass lost body weight while supplementation with cottonseed cake, maize bran or banana peels increased body weight gain. Supplementary concentrates such as cereals and cereal by-products, and oil seed cakes provide readily fermentable nitrogen, carbohydrates and other essential nutrients. Besides supplying the deficient nutrients to affect the quantities of nutrients absorbed, it is also possible that some effects of supplementation are due to changes in the array of nutrients available to host tissues, which in turn influence efficiency of nutrient absorption.

Ebro *et al*. (1998), reported that supplementation of grazing goats with lablab hay and(or) concentrate led to a 23.6% increase in live weight gain compared with un-supplemented goats and that there were no remarkable differences between concentrate and lablab hay supplements in live weight gain in the middle Rift Valley area of Ethiopia. A study conducted on the effects of various supplements; maize bran, cotton seed cake, leucaena leaves and banana peels on weight gain and carcass characteristics of male Mubende goats fed elephant grass *ad libitum* in Uganda (Okello *et al*., 1996) revealed that the goats supplemented with cotton seed cake had the highest growth rate, which was credited to a higher energy and protein supply from the cottonseed cake. In addition, supplementation with maize bran and cotton seed cake improved body condition scores and carcass weight when compared with the other diets.

Tessema and Emojong (1984) reported that the body weight gains of sheep and goats grazing pasture in a dryland region of Kenya were increased when molasses, minerals and urea were added to supplemental maize stover. In another study done in Lesotho (Ng'ambi and Kekena-Monare, 1996) showed that spraying molasses on wheat straw increased by 37% the voluntary intake of straw without affecting digestibility. Based on the results, spraying palatable molasses on unpalatable or poorly palatable straws or forages was prescribed as a practical method of improving the feeding value of poor quality roughages.

Concentrates however, are expensive and not readily available in most developing countries. In some East African countries there is a shortage of cereal grains even for human consumption. Agro-industrial by-products (oil seed cakes and by-products from cereal processing plants) are in limited supply and the availability is restricted mainly to the region of the urban centres where most of the processing plants are located and may not be easily accessible to smallholder farmers, who are scattered in the countryside.

2.7.2 Supplementation with forage legumes.

Supplementation with forage legumes involves supplementation with shrubby and herbaceous or tree legumes. Forage legumes can increase the use of poor quality roughages in smallholder mixed farming systems. They are rich in protein (both bypass and fermentable protein depending on the level of tannins) as well as other nutrients such as vitamins and minerals.

Reynolds (1989) reported results from a study in which four levels (200, 400, 800 and 1200 g) of a 1:1 (w/w) mixture of *Leucaena leucocephala* and *Gliricidia sepium* were supplemented to pregnant and lactating Dwarf West African goats fed a basal diet of chopped *Panicum maximum* and 50 g of sun-dried cassava peels. The kids were also supplemented after weaning with a reduced level of the browse mixture proportional to their size. At 16-20 week of age they were given 16 g of cassava peels and 62.5, 125, 250 and 375 g of the browse mixture, whereas the amount of cassava peels increased to 20 g/day and the browse mixture increased to 75, 150, 300 and 450 g at 20-24 wk of age. Browse intake of dams and kids and survival and growth rate of the kids increased with increasing level of supplementation. Moreover, productivity (weight of kid weaned/doe/year) increased by 0.64 kg for each 100 g of browse consumed by the does (Reynolds, 1989).

2.7.3 Legume-Straw Supplementation.

Legume crop residues such as peas, peanuts, cowpeas etc. are high in protein (about 10% or more) and, therefore, can serve as supplements to low quality roughages such as cereal crop residues and poor quality pastures. Macala *et al*. (1996) did a study on the effect of supplementing three (0, 300 and 600 g/day) levels of peanut hay on the performance of lactating Tswana does grazing natural pastures during the dry season and on the growth rate of their kids. Supplementation of does with peanut hay resulted in higher daily gain and milk production compared with un-supplemented does. The amount of milk produced increased with increasing amounts of peanut hay supplemented. Moreover, kids that were supplemented with peanut hay had higher daily weight gain and final weight at weaning.

2.7.4 Other feedstuffs used as Supplements

Based upon the production system of a given area, there is a variety of agricultural and agro-industrial by-products that could be used as supplementary feedstuffs. Household wastes and brewery by-products constitute important sources of feeds that can be used as supplements. This is mostly important for landless farmers maintaining a small number of dual purpose or dairy goats or for farmers residing in the locality of commercial breweries. Vegetables and reject fruit could also serve as an important source of feed for goats in areas where horticultural crops are grown and marketed. Dropped coffee leaves could be a small or minor source of feed, whereas coffee pulp and hulls represent a relatively underutilized feed resource in coffee growing areas.

Other agricultural by-products such as cassava leaves, sweet potato vines, banana leaves and peels, enset (*Ensete ventricosum*) leaves and sugar cane leaves could also serve as important sources of supplementary feed especially in the dry season. Sweet potato is traditionally grown to provide tubers for human consumption and the vines can be utilized as useful supplementary feed for goats in areas where the crop is grown. Oteino *et al*. (1992) reports that sweet potato vines have a high nutritive value, with a digestibility of about 70% and a crude protein content of over 20%. Because of very high water content (86%), sweet potato vine is not appropriate lactating does but good for growing kids. Goats on sweet potato vines do not require additional free water. However, when the vine is offered to a lactating doe as a sole diet it can only support sub optimal levels of production because of DM intake limitations.

2.7.5 Molasses –Urea Supplementation

Dry mature pasture or cereal crop residues given alone are unbalanced in nutrients and do not create the environment for efficient rumen function and thus do not ensure an efficient utilization of absorbed nutrients. Feed intake and the nutrients absorbed from such diets are insufficient to even meet the maintenance requirements of the animals and thus animals are prone to lose weight if they do not receive additional nitrogen and mineral supplements. Thus, supplementation with fermentable nitrogen, energy and minerals enhances rumen microbial growth and voluntary feed intake of animals fed low quality roughages. Molasses-urea blocks added to such an unbalanced diet ensure animal's maintenance requirements because they enhance efficient ruminal fermentation. Anindo *et al.* (1998), showed that supplementation of molasses-urea blocks improved the daily feed intake, body weight gain and body condition score of grazing sheep in Ethiopian highlands. The addition of bypass protein (e.g., cottonseed meal) results in a synergistic effect that could considerably improve the average daily gain of ruminants, and they become much more efficient in using the available nutrients. Moreover, molasses could serve as a carrier for urea and mineral supplements.

2.7.6 Mineral Supplementation.

Mineral deficiencies could result in depression of animal performance. According to Kabaija and Little (1988) sub clinical mineral deficiencies are widespread and responsible for yet un-estimated, but probably great, economic losses in livestock production. However, mineral status of grazing animals in most African countries has received very little attention. In general, most forages and crop residues used as livestock feed in the Rift Valley areas of Ethiopia are deficient or marginal in sodium, phosphorus and copper (Kabaija and Little, 1988; Tolera and Said, 1994; Abebe *et al*., 2000). Thus supplementation regimes involving these elements are likely to produce beneficial results. A typical example would be supplementation with multi-nutrient blocks. In some parts of southern Ethiopia, local mineral soils such as *Bole* and *Megadua* may supply adequate or even excess amounts of most of the essential minerals except phosphorus (Tolera and Said, 1994).

2.7.7 Use of Poultry Litter as Supplementary Feed

Poultry litter is a significant by-product of poultry production, which is a mixture of poultry excreta, bedding material, feathers, spilled feed, etc. Poultry litter is high in crude protein, ranging from 15 to 35% of dry matter. Thus, poultry litter can serve as a source of nitrogen in ruminant diets and the potentially digestible nitrogenous compounds in the litter are very soluble and are rapidly degraded to ammonia in the rumen. Moreover, poultry litter is characterized by a high ash content and could be an excellent source of essential minerals such as calcium, phosphorus, potassium, magnesium, sulfur and copper, thereby lessening the need for mineral supplementation (Goetsch and Aiken, 2000). Thus, poultry litter could play a significant role replacing protein concentrates in goat feeding in areas where large- scale poultry production is practiced

2.8 Nutritional Quality and Animal Production on Pasture.

One of the most principal sources of nutrients for domesticated ruminants in many production systems during a large part of the year is grass (Taweel *et al*., 2005). Despite it being a major feed for ruminants in many parts of the world, Yan and Agnew (2004) noted that the nutritive value of grass silage is extremely variable. The nutritive quality of forage as defined by Reid, (1994) is the product of the voluntary intake, digestibility and efficiency of nutrients that are used by the animal. The digestibility of different grass species could be distinctly different, and is influenced by several factors such as; area of origin, including, light intensity, temperature, total rainfall, soil type, fertilization level, and by preservation method as well as the stage of maturity (Huhtanen *et al.,* 2006; Jančík *et al*., 2009). Digestibility is a useful measure of quality because it is directly and positively related to the energy content of pasture (Bell, 2006).

Components of the diets of grazing animals can have high dry matter digestibility. This is especially apparent in the extent and rate of ruminal degradation of neutral detergent fibre (NDF) (Hoffman *et al*., 1993). Van Soest (1994) reports that, lignin concentration affects mainly the availability of cell wall polysaccharides. Cellulose, which along with lignin forms acid detergent fibre (ADF), reduces the digestion rate and extent of digestion which are related to the lignin content. Hemicellulose (presenting NDF along with cellulose and lignin) is closely associated with lignin, and the digestibility of hemicellulose is directly related to that of cellulose and inversely related to lignification (Van Soest, 1994). Crude protein (CP) is one of the key nutrients in feeds and is a gross measure of the Nitrogen (N) contained in feedstuff. It has been concluded that minerals deficiency results in poor animal health, productivity and reproductive faults even if sufficient green fodder is present (Tiffany *et al*., 2000). Ganskopp and Bohnert (2003) observed that mineral composition of grasses changed seasonally, especially in dry climate. In productivity of grazing livestock, both the excess and deficiency of minerals are the major constraints. Calcium (Ca) and Phosphorus (P) are important major minerals. When P level in the forage is higher than Ca, producers should seek a high calcium mineral supplement. Otherwise a standard mineral supplement should take care of Ca and P needs.

Grasses provide energy and nutrients for animal growth and maintenance. Their leaves are more palatable than stems and re-growths more nutritious than old tissues (Briske, 1991). During the early stages of growth at the onset of the rains, the plants put out soft leaves which are very rich in protein and sugar. At this stage the contents within the cellulose cell wall are readily available to the animal (Barrett and Larkin, 1974). As the grass plant matures, the leaves reach their full size and contain less digestible protein and the carbohydrates which in turn are less available to the animal. Grasses are most negatively affected when grazed during their reproductive period and least affected during dormancy.

2.9 Brachiaria: History, Cultivars and Variations

The genus *Brachiaria* of tribe *Paniceae*, includes about 100 species, which occur in the tropical and subtropical regions of both eastern and western hemispheres. Seven of these species are of African origin: *B. arrecta*, *B. brizantha*, *B. decumbens*, *B. dictyoneura, B. humidicola, B. mutica, and B. ruziziensis*. They have been used as fodder plants in tropical America, and less so in Asia, the South Pacific, and Australia (Keller-Grein *et al*., 1996). In Brazil for example, *B. mutica* goes up to 500 years back. The grass was highly favoured by animal owners because they could persist under grazing and had a higher nutrient value when compared to indigenous grasses. Ndikumana and De Leeuw (1996) reported that cut and carry or extensive grazed pasture is often practised in small holder dairies in the highlands in East Africa.

The most common and extensively evaluated Brachiaria species are *B. brizantha*, *B. ruziziensis*, *B. decumbens* and *B.mutica* (Ndikumana and de Leeuw, 1996). These species have shown to produce high yields, show excellent response to fertilizer are persistent and remain green long into the dry season.

Brachiaria decumbens and *B. brizantha* are tetraploid (2n = 4x = 36) and apomictic, that is the embryo is produced without fusion of male and female gametes. Sexuality has been found at the diploid level in these species and in *B. ruziziensis*, and is generally associated with regular chromosome pairing and division. As a breeding tool, apomixis offers several advantages, because it associates fixation of hybrid vigour with seed propagation. Apomictic hybrids breed true and superior genotypes can be rapidly increased by seed (Valle do and Savidan, 1996). Brachiaria hybrid cv. Mulato II was developed from three crosses between *B. ruziziensis* (sexual tetraploid), *B. decumbens* and *B. brizantha* (apomitic tetraploid) (Miles *et al*., 2006)

The best known and most widely used *Brachiaria* cultivar is *B. decumbens* cv. Basilisk (signal grass). It derives from seed (CPI 1694) introduced into Australia from the Ugandan Department of Agriculture in 1930. It was approved for commercial release in Australia in 1966 and registered in 1973 (Oram, 1990). The cultivar is well adapted to infertile soils and forms and aggressive, high yielding sward that withstands heavy grazing and trampling (Keller-Grein *et al*., 1996; Sani, 2009). Low, (2015) reported that it is also adapted to a wide range of soil types and environments and grows to an at a wide range of altitudes (500-2300 m asl).

Njarui *et al*., (2016) reports that, although Africa is the centre of origin and diversity of *Brachiaria* grasses, their contribution especially to livestock production has been negligible in Kenya because there has been limited selection of suitable species for 6cultivation. The authors go on to say that it is therefore imperative to introduce suitable high quality species and develop management practices for high yield and quality.

2.10 Constraints to small ruminant production in Kenya

The following section is going to discuss some of the major constraints small ruminant production in Kenya.

Diseases: Tropical environments are characterized by high incidences of parasitic diseases. These diseases account for high mortality rates (25%) that result in reduced livestock productivity (Herlocker, 1999; Jalang'o 2001). This situation is even worsened where disease control measures are inadequate. The most prevalent diseases include foot and mouth disease (FMD), rinderpest, lumpy skin and bovine pleuropneumonia (Jalang'o, 2001)

Droughts: Many livestock deaths have been recorded in the past due to starvation as a result of drought. These deaths were as a result of lack of disaster preparedness especially in the pastoral communities. This has resulted in invasion by pastoralists of private land in the commercial ranches leading to conflicts resulting to loss of livestock and life as well as sour relationships between ranchers and pastoralists (Mwanje *et al*., 2001; Peeler and Omore, 1997).

Government land policy: The policies governing land ownership need to be revised. Fragmentation of land resulting to reduction of grazing land area in the ranges has led to a fall in beef production. Privatization and settlement of land by the pastoral communities has also resulted to land degradation (Herlocker, 1999; Prettejohn and Retief, 2001).

Government policy on research**:** Currently KALRO former KARI is mandated to carry out agricultural research in the country. Other research organizations have to collaborate with them, a restriction which, for organizational and bureaucratic reasons, may have led to the slow generation of agricultural research technologies. Other national agricultural research systems e.g. universities, with their well-trained scientists, rarely receive direct funding for research from the Kenya government or from organizations (e.g. the World Bank, European Union).

Insecurity**:** Cases of cattle rustling have been reported which have left several communities without any animals. These incidents cause pastoralists to move to safer places, which are unable to support stock (Kahi *et al*., 2006)

Feeding: Ruminant production in Kenya is pasture-based and hence dependent on land availability. Continuous subdivision of land and persistent droughts pose a particular challenge to ruminant production especially during the dry seasons. Subdivision has led to shrinkage in the grazing resource base and consequently affects the productivity of the animals (Kinyamario and Ekeya, 2001).

***Traditional pastoral production*:** Pastoralists keep livestock for other purposes besides beef production. As a result, productivity of the animals often does not count as much as the size of the herds. Animals are kept for social purposes, inducing a reluctance amongst owners to dispose of animals for, say, beef sales (Kahi *et al*., 2006)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Site

The feeding trial was conducted at the Sheep and Goat Multiplication Centre, Matuga (4^0 9’6’S, 39^0 32’40’E), in Kwale County, Kenya. The centre is located at an altitude of 60 m.a.s.l. The centre is in coastal lowland 3 (CL3) agro-ecological zones, also referred to as the Coconut-Cassava zone (Jaetzold *et al.*, 2006). The average annual rainfall is 1100mm while the relative humidity ranges from 70% - 80% and an average temperature from 22 – 30°C.

3.2 Feed Preparation.

Plate 3.1: *Brachiaria* hybrid cv. Mulato II under propagation

Brachiaria cultivars used for feeding were *Brachiaria brizantha* cv. Piata and MG4 and *B. hybrid* Mulato II. *Chloris gayana* (Rhodes grass) was used as the control. The cv. Piata, MG4 and Rhodes grass were grown at KALRO-Katumani in the semi-arid region of Eastern Kenya while Mulato II was grown at KALRO-Mtwapa in the coastal lowlands. The recommended agronomic practices were followed in order to provide good quality forage for feeding. The grasses were harvested at 5cm above ground and allowed to dry, baled into hay and transported to Matuga.

During feeding, all animals were supplemented with a 100g/day of maize germ that was purchased from a commercial maize miller to last for the whole experiment. The supplement was given before the basal diets were offered at 0700 hrs. Water and a mineral supplement were provided *ad libitum*. The hay made up of stem and leaves were chopped using a motorized chaff cutter to approximately 5 cm length and mixed thoroughly to prevent selection. The feeds were offered for a 14 days adaptation period and 12 weeks experimental period from 20th April to 13th July 2016. The grass basal diet was offered *ad libitum* by offering feed in the morning and adding during the day to ensure feed availability at all times. Any left overs were removed and weighed the following day before fresh feed was added.

Plate 3.2: Feed being chopped using a chaff cutter before forage was offered to goats.

3.3 Experiment 1: Chemical composition of different Brachiaria grasses

A small amount of herbage was taken from each bale used for feeding and a composite sample of about 2 kg per treatment constituted for laboratory analysis. The forage samples were oven-dried at 65°C for 72 hours and then ground to pass 1mm using a Wiley mill (AOAC, 1990) in preparation for proximate analysis and *in vitro* dry matter digestibility. The samples were then analysed in duplicates for chemical composition at the Animal and Nutrition Laboratory at KALRO- Muguga.

3.3.1 Forage analysis

a) Crude protein

The Nitrogen content of the feed is the basis for calculating the crude protein (CP). The method established by Kjeldahl converts the nitrogen present in the sample to Ammonia which is determined by titration (AOAC official method, 2000). The Kjeldahl process begins by first digesting the feed sample in a digestion flask by heating it in the presence of sulfuric acid (an oxidizing agent which digests the feed), anyhydrous sodium sulphate and a catalyst. Digestion converts any nitrogen in the sample into ammonia and other organic matter to carbon dioxide and water. Ammonia gas is not liberated in an acid solution because the ammonia is in the form of the ammonium ion (NH_4^+) which binds to the sulphate ion and thus remains in solution. The solution is then made alkaline by addition of sodium hydroxide, which converts the ammonium sulphate into ammonium gas. The ammonia gas that is formed is liberated from the solution and moves out of the digestion flask into the receiving flask – which contains an excess of boric acid. The low pH of the solution in the receiving flask converts the ammonia gas into the ammonium ion, and simultaneously converts the boric acid to the borate ion. The nitrogen content is then estimated by titration of the ammonium borate formed with standard sulphuric or hydrochloric acid, using a suitable indicator to determine the end-point of the reaction. Assuming that the average nitrogen content of proteins is 16%, multiplying the nitrogen content in % obtained via Kjeldahl analysis with 6.25 gives an approximate protein content of the sample.

CP= 6.25 x %N   where CP is crude protein and N is nitrogen

b) Crude fibre

Fibre analysis was done using the Ankom fibre method which is a modification of the Van Soest System (1967) of forage analysis. The carbohydrates in a feed sample are retrieved in two fractions; Crude fibre (CF) and Nitrogen free extractives (NFE) of the proximate analysis. The fraction, which is not soluble in a defined concentration of alkalis and acids, is defined as crude fiber (CF). This fraction contains cellulose, hemicellulose and lignin. Sugars, starch, pectins and hemicellulose etc. are defined as nitrogen-fee extractives (NFE). This fraction again is not determined chemically it is rather calculated by subtracting CP, ether extracts (EE) and CF from organic matter (Goering and Van Soest, 1970)

c) Ash

The samples were ignited in a furnace at 600°C for 2 hours to oxidize all organic matter. Ash was then determined by weighing the resulting inorganic residue (AOAC, 2000).

d) In vitro dry matter digestibility

The samples were incubated under anaerobic conditions with rumen microorganisms for 48 hours at 39°C. This was then followed up by a 24 hour acid-pepsin digestion phase at 39°C, also under anaerobic conditions. Following this 72 hour incubation, residual plant materials was later collected, filtrated and oven dried (105°C for 12 hours) and weighed. Thus;

%IVDMD = (1-wd-wb/ws)*100

Where; wd = weight of dry plant residue, wb = weight of dry residues from blank, and ws = dry weight of original plant sample. (Tilley and Terry, 1963; Harris, 1970).

e) Calcium

The samples were ignited at 550°C to burn all organic material. The remaining minerals are digested in 6 M HCl to release calcium, which is then determined using a spectrophotometric assay based on reaction of calcium with o-cresolpthaleincomplexone (CPC) in alkaline solution. Calcium was then calculated as follows;

% Calcium = (C x V x DF) / (W x 10)

Where,

C = concentration calcium in measure solution (mg/litre), V = volume of solution (in litres, i.e. 0.025 (L)), DF = dilution factor (normally, i.e. 1), W = weight of the sample (g), and 10 = factor to convert g/kg to %. (Okalebo *et al.*, 2002).

f) Phosphorous

Feed material was ashed following digestion in hydrochloric acid. Molybdovanadate reagent is added which results in a characteristic yellow colour after reacting with phosphorus, which was measured spectrophotometrically. Percentage of phosphorous is calculated;

% Phosphorus = (C x V x DF) / (W x 10)

Where,

C = concentration phosphorus in measured solution (mg/litre), V = volume of solution (in litres, i.e. 0.025 L), DF = dilution factor (normally, i.e. 1), W = weight of the sample (g), and 10 = factor to convert g/kg to %. (Okalebo *et al.*, 2002).

3.4 Experiment 2: Effect of feeding *Brachiaria* grass on feed intake and weight gain of goats

3.4.1 Experimental Treatments

Treatments for this experiment included; *Brachiaria brizantha* cv. Piata and MG4, *Brachiaria* hybrid Mulato II. *Chloris gayana* (Rhodes grass) was used as a control

3.4.2 Management of animals

Sixteen Galla "goat bucklings" aged between 6-12 months and weighing 10-24 kg were selected from centre herd. They were divided into four groups of four animals which were balanced for age and weight. The groups were randomly assigned to four dietary treatments; *Brachiaria brizantha* cvs Piata and MG4, *Brachiaria hybrid* cv. Mulato II and Rhodes grass (*Chloris gayana*). The goats were kept in well ventilated individual pens that were constructed using wood planks. Dry grass was used for bedding. Both the feeding and sleeping areas were disinfected before the goats were brought in. During the adjustment period, animals were dewormed against endo-parasites and sprayed weekly against ecto-parasites. The pens were cleaned every morning and beddings changed weekly.

Plate 3.3: Herd from which the goats were selected

Plate 3.4: Goats in their individual feeding pens

3.5 Data Collection and calculation

After an adaptation period of 14 days, feed intake was estimated from the difference between the feed offered and refused. Live-weight changes were calculated as the difference between the initial and final weight while the average daily weight gain was obtained by dividing the weight change by number of experimental days (84 days).

Daily feed intake of dry matter (DM), organic matter (OM), crude protein (CP), were calculated as the difference between feed offer and refusal corrected for the respective contents in the original sample (Balehegn *et al*., 2014).

Plate 3.5: Weighing of goats using electronic scale

3.6 Statistical Analysis

The nutritive quality composition (DM, CP, OM, Ash, NDF, ADF, ADL, Ca, P) and digestibility of feeds were analysed using the general linear model (GLM) procedures of the Statistical Analysis System (SAS, 2010).

Values for feed intake and live weight gain were subjected to analysis of variance (ANOVA) in a completely randomised design using GLM procedures of the Statistical Analysis System (SAS, 2010) based on the following model:

$Y_{ij} = \mu + T_i + e_{ij}$

Where Y_{ij} = the $_j$th observation of the $_i$th treatment

μ = overall mean

T_i = the effect of the feed of the $_i$th grass treatment (1-4)

e_{ij} = the residual error

The least significant difference (LSD) option of SAS (2010) was carried out for subsequent separation of means as described by Steel and Torrie (1981).

CHAPTER FOUR

4.0 RESULTS

Table 4.1: Chemical composition and *in vitro* digestibility of feeds used in the experiment in %

Feeds	**CP**	**NDF**	**ADF**	**ADL**	**Ash**	**DoMD**	**DMD**	**Ca**	**P**
MG4	12.10	57.05	36.85	4.34	10.68	48.74	55.47	0.27	0.22
Mulato II	3.00	70.72	46.93	6.26	5.04	38.22	41.36	0.27	0.19
Piata	12.59	56.98	35.43	3.65	10.77	49.02	54.96	0.27	0.20
Rhodes	6.74	68.75	44.28	5.50	7.72	39.83	44.62	0.39	0.08
Maize germ	13.94	27.50	7.73	0.41	3.56	84.67	87.36	0.03	0.73
LSD (P<0.05)	0.82	2.57	1.50	2.86	0.73	32.85	4.05	0.03	0.15
CV (%)	2.72	2.09	2.47	22.87	3.19	3.40	3.98	11.08	19.35

CP Crude protein *NDF* neutral detergent fiber *ADF* acid detergent fiber *ADL* acid detergent lignin *DoMD* Dry organic matter digestibility *DMD* dry matter digestibility *Ca* Calcium *P* phosphorous

4.1. Chemical composition and In vitro digestibility of feeds

***Ash, calcium and phosphorous*:** There was a significance difference ($P<0.05$) in the ash content among the grasses as shown in Table 4.1 above. The highest value of ash content for the *Brachiaria* cultivars was in Piata (10.77% of DM) followed by MG4 (10.68% of DM), and the lowest content in Mulato II (5.04% of DM). Rhodes grass had a value of (7.72% of DM). There was no significance difference ($P>0.05$) in the phosphorous and calcium content for all the grasses.

Crude Protein: Crude protein values for the forages as shown in Table 4.1 were significantly different ($P<0.05$). Piata had the highest CP (12.59%) followed by MG4 (12.10%), and Mulato II had the lowest CP content (3.01%) for the *Brachiaria* cultivars. Rhodes grass had a CP content of (6.74%) which was significantly higher than cultivar Mulato II but lower than cultivars Piata and MG4.

Neutral Detergent Fiber: Mean NDF content was significantly different ($P<0.05$) among the grasses as shown in Table 4.1. Cultivar Mulato II recorded the highest NDF (70.72%) followed by MG4 (57.06%) and Piata had the lowest value (56.99%) which was not significantly different from that of MG4. Rhodes grass had (68.35%) which was not significantly different from that of Mulato II but was higher than that of Piata and MG4.

Acid Detergent Fiber: ADF content was highest ($P<0.05$) in cultivar Mulato II (46.93%). Cultivars MG4 and Piata had similar ADF contents (36.85%) and (35.43%) respectively. Rhodes grass had an ADF value of (44.28%) which was significantly lower than that of cultivar Mulato II but also significantly higher than that for cultivars Piata and MG4.

Acid Detergent Lignin: ADL values for the forages as shown in Table 4.1 were significantly different ($P<0.05$). Mulato II had the highest ADL value (6.26%). MG4 had a significantly higher value of ADL (4.43%) than Piata (3.65%) which had the lowest for all the forages. Rhodes grass and MG4 had similar ADL contents (5.50%) but was lower compared to that of Mulato II.

In-vitro dry matter digestibility: High IVDMD were recorded for cultivars Piata and MG4, (54.96%) and (55.47%) respectively during the entire period. (P<0.05). Mulato II had the lowest IVDMD for the Brachiaria cultivars (41.36%). Rhodes grass had a significantly lower (44.62%) IVDMD compared to cultivars Piata and MG4 (44.62%) but was similar to that of cultivar Mulato II.

Dry organic matter digestibility (DoMD) also differed significantly for all the forages (P<0.05). High values of DoMD were recorded in cultivars Piata and MG4 (54.94%) and (54.57%) respectively. Mulato II had the lowest (40.25%) OMD for the Brachiaria cultivars. Rhodes grass had a significantly lower OMD compared to cultivars Piata and MG4 but was not different to that of Mulato II.

Table 4.2: Live weight gain of Galla goats fed Brachiaria cultivars and Rhodes grass.

Feeds	**IBW (kg)**	**FBW (kg)**	**ADWG (g/day)**	**AWC (kg)**
MG4	16.00	19.47	41.28	3.47
Mulato II	15.63	15.80	1.99	0.17
Piata	15.25	19.05	45.21	3.80
Rhodes	15.87	16.68	9.64	0.81
LSD (P<005)		NS	17.22	1.45
CV (%)		30.3	43.9	43.9

IBW Initial body weight *FBW* Final body weight *ADWG* Average daily weight gain *AWC* Average weight change *NS* Not significant

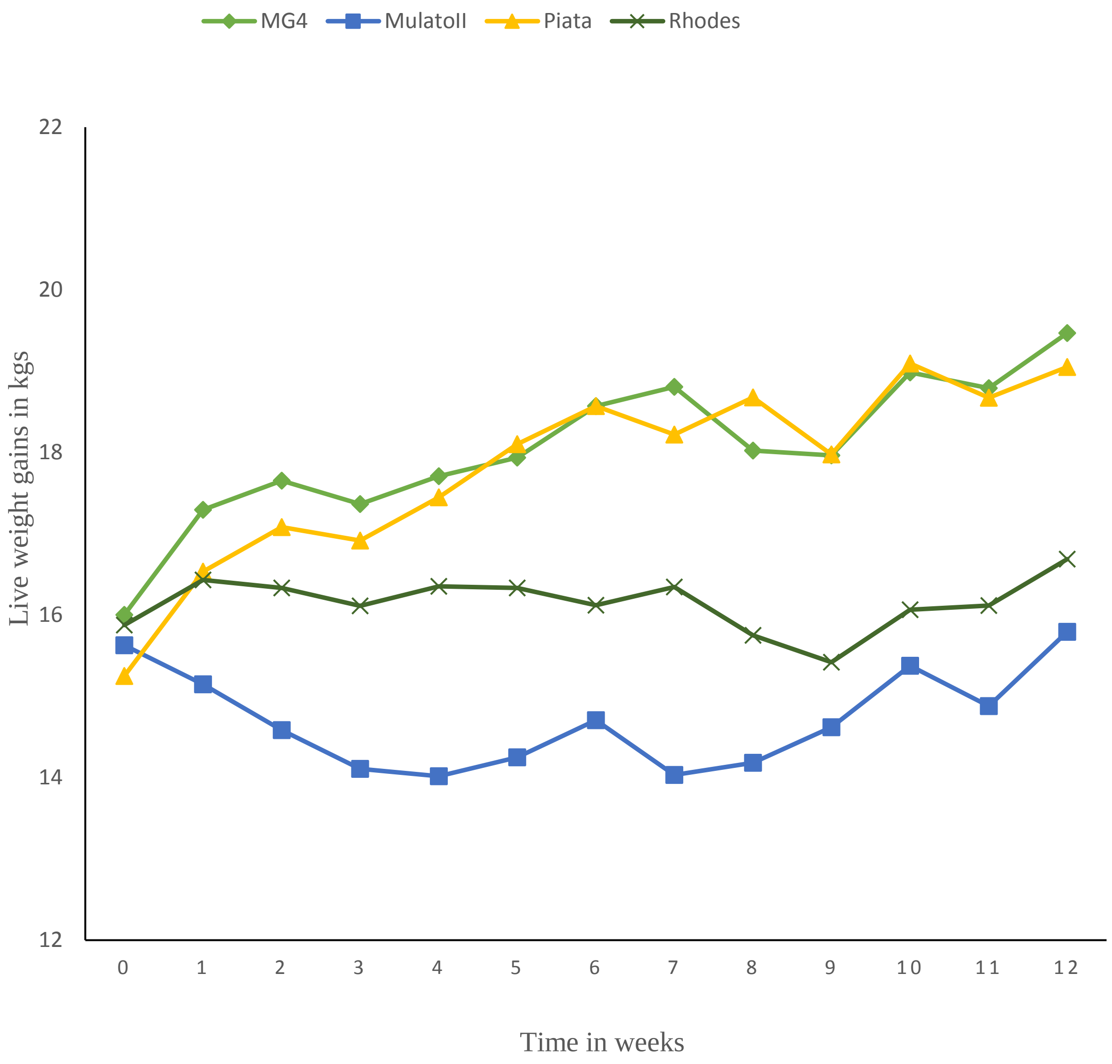

Figure 4.1: Average weekly weights of goats during the experimental period

4.2 Live weight gains (LWG)

Results from live weight gain (LWG) are shown in Table 4.2 and Figure 4.1. Bucklings fed Mulato II decreased in weight until week 10 where they finally increased their weight. Bucklings under Rhodes grass maintained their weight while those fed MG4 and Piata generally increased their weight during the entire period. Average daily weight gain (ADWG) differed significantly for the four treatments (P<0.05). Bucklings fed Piata had the highest ADWG (45.21 g/day). This was followed by those fed MG4 (41.28 g/day) and lastly, by Mulato II. Bucklings fed Rhodes grass had ADWG lower than goats fed Piata and MG4.

The total live weight gain was also high on bucklings under cultivar Piata and MG4 ($P<0.05$) and were (3.80 kg) and (3.47 kg) respectively. Bucklings under cultivar Mulato II generally had lower weight and had a mean weight of (0.17 kg) while those under Rhodes grass had a mean weight of (0.81 kg) after the 12 weeks.

4.3 Feed intake

The goats ate all of the (100g) maize germ supplements offered. The average feed intake on weekly basis for the entire feeding period are shown in Figure 4.2. Feed intake was low for all the feeds during the first four weeks. However, Mulato II had generally low intake throughout the period. There was no difference ($P>0.05$) in the basal feed intake in all the weeks among the goats. Generally the average feed intake increased over time and ranged from 513-661 g/goat/day.

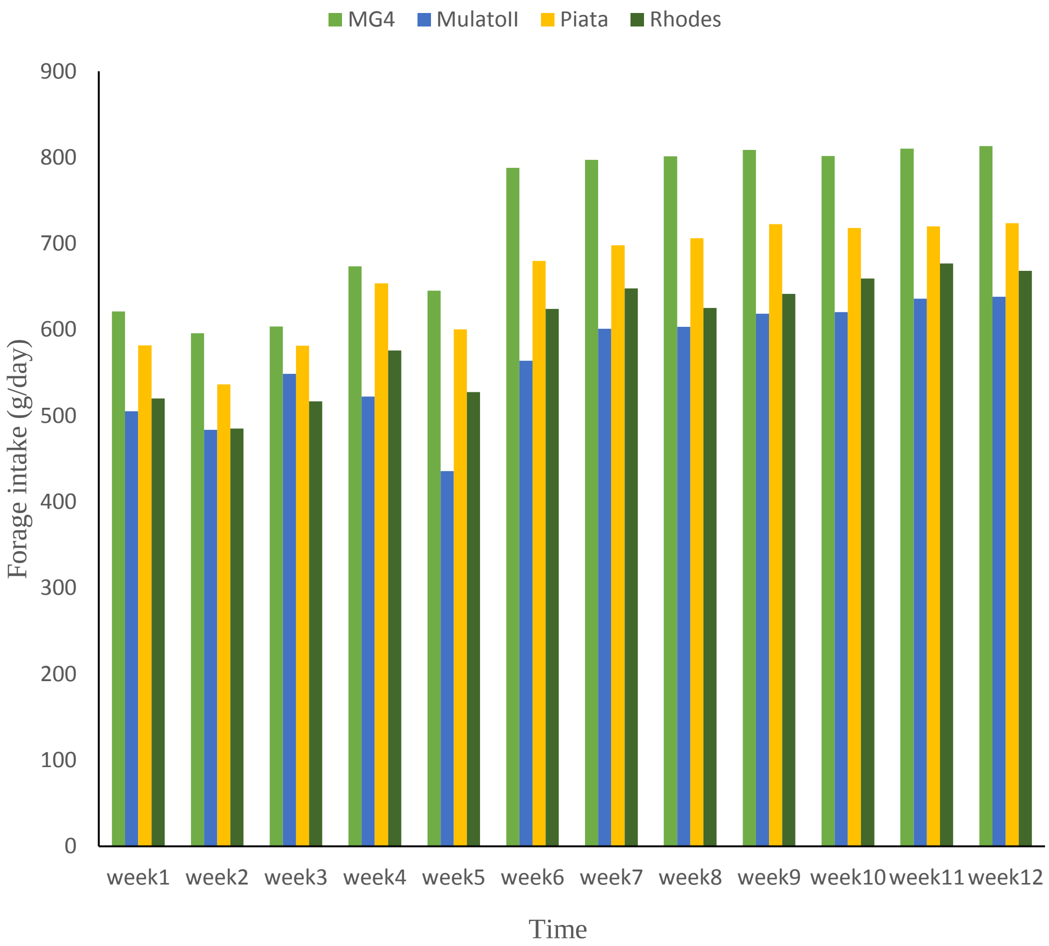

Figure 4.2: Average weekly feed intakes by goats for the four dietary treatments

CHAPTER FIVE

5.0 DISCUSSION

5.1. Chemical composition and *in vitro* digestibility

Crude Protein: Afzal and Ullah (2007) reported that crude protein (CP) and digestible dry matter are the most important components of a feed. In this study, Piata and MG4 were found to be better sources of protein than Mulato II and Rhodes grass. They contained the minimum CP of 7.5% suggested as necessary for optimum rumen function and production by Van Soest (1994). Crude protein requirement for small ruminant maintenance is 9.6, 11.2 and 11.7% for pregnant ewes, does and kid finishing respectively (NRC, 2007). The CP content of Mulato II content was low compared to that reported by Nguku (2015) of 7-12.8% in a semi-arid region of Kenya, 15% in central Kenya (Nyambati *et al*. 2016) and 12-17% by Vendramini *et al*. (2011) in Florida, USA.

The low CP of Mulato II was attributed to poor management of the grass at harvesting and baling. Further Mulato II was grown in the coastal lowlands and generally due to the high temperatures experienced in the region, the growth was fast and accumulated more fibre resulting to low CP and digestibility. On the contrary Piata, MG4 and Rhodes were grown in mid-altitude region where it is cooler resulting in slower growth and thus less accumulation of fibre.

Ash and minerals: Calcium (Ca) and phosphorous (P) are the most important minerals in the diet of animals because they are involved in the growth of bones (Miles and Manson, 2000). Calcium content was highest in Rhodes grass and was similar to that reported by Nguku (2015) of (0.37%). According to NRC (2007), Ca requirements for small ruminants range from 1.4-7.0 g/kg of DM. This is a very small quantity and all the forages met this minimum requirement. All the grasses attained the 0.9-3.0 g/kg of P requirement in small ruminants.

Piata and MG4 had the highest ash content and this showed that these cultivars were rich in mineral content as compared to the rest of the forages. The ash content of the *Brachiaria* cultivars were within the range of 3-12% reported by Linn and Martin (1999).

Fibers and Lignin: Fiber fractions are components that have low solubility in a specific solvent system and are relatively less digestible than starch (Tavirimirwa *et al.*, 2012). Neutral detergent fiber can be an important parameter in defining forage quality. More fibrous pasture is associated to longer ruminal retention and limits the intake rete. A high NDF of above 72% lead to low forage intake (Lima *et al*, 2002) and as NDF increase, dry matter intake generally will decrease (Schroeder, 2012).

ADF is the value that refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. The digestibility of foods is related to the fiber because the indigestible portion has a proportion of ADF, and the higher the ADF value, the lower the food digestibility (Costa *et al.*, 2005). According to Nussio *et al.* (1998), forage with ADF content of around 40%, or more, shows low intake and digestibility. Forage intakes and digestibility for both Mulato II and Rhodes grass were low and this agrees with Nussio *et al*. (1998).

ADL content for all the *Brachiaria* forages ranged from (3.65 to 6.26%) and was above the values reported by Nguku (2015) of 3.9-4.9%. Rhodes grass also recorded a high ADL content of 5.50% which is within the range reported by Nguku (2015) of 5.2-6.5%. Mean ADL values for all the grasses ranged between 3.65-6.26% and was slightly above the range reported by Sultan *et al*. (2007) that lignin contents of marginal land grasses when matured ranged between 3.4 to 5.7%.

In-vitro Dry Matter Digestibility (IVDMD): IVDMD of Mulato II and Rhodes was lower than that reported by De Gues (1977) that the digestibility of tropical grasses ranges between 50 and 65%, while that of temperate grasses is slightly higher and ranges between 65 and 80%. Coward-Lord *et al*. (1974) reported that the age of cutting forage crops has an influence on the digestibility, and is a function of the chemical constituents of forages. These results agree with what Njarui *et al*. (2003) who reported that the proportion of potentially digestible components decline as the fibrous content increases. The digestibility of Mulato II (41.36%) was lower than reported by Nguku (2015) of 51.4-57.5%. The IVDMD value of *C. gayana* give the range studied by Skerman and Riveros (1990) of 40 to 60% for sole Rhodes grass.

Organic matter digestibility: Organic matter digestibility for *C. gayana* was lower than that reported by Nguku of 47.4-50.3%. Other studies carried out in Kenya reported that intake of Rhodes grass decreased with maturity in grazing growing Friesian and Ayshire heifers (Mbwile *et al*., 1997).

5.2. Feed intake

There were no significance differences in the forage intake of the feed (P>0.05) by the Galla goats. The forage intake throughout ranged between 5.13-661 g/goat/day. This was however lower than what Sani (2009) of 796.4 g/day when he fed Yankassa sheep with Brachiaria ruziziensis without any supplementation

5.3 Live weight gains of Galla goats on *Brachiaria* forages

Weight gain was highest (P<0.05) in bucklings fed on Piata (3.80 kg), this could be attributed to high protein intake in Piata cultivar. The live weight gain obtained for Piata in this study was higher than 2.55 kg obtained by Sani (2009) on Yankassa sheep when cotton seed cake was fed in combination with *Brachiaria ruziziensis* and also higher than 2.63 kg obtained by Njarui *et al*. (2003) on Kenya dual-purpose goats when fed Napier grass and natural pastures supplemented with leucaena leaf meal. Another study done by Wambui *et al*. (2006) on German Alpine crosses of goats when supplemented with Tithonia, Calliandra and Sesbania had high ADWG of up to 82.7 g/day for Tithonia and Calliandra of 57.3 g/day. Goats under Sesbania for this experiment had a lower ADWG of 39.3 g/day. Piata and MG4 had higher ADWG when compared to Sesbania in this experiment. Bucklings under Mulato II had the lowest average gain (0.17 kg). This could be attributed to the low CP content in the diet and low CP intake.

According to Morais *et al*. (2014), when the quality of supplement and supplementation frequency remain the same, the difference in weight gain of an animal will be based on the quality of the roughage. As the four groups of Galla goats had received the same amount of the commercial concentrate, the major factor which influenced differences in their weights was the quality of roughages; where Piata and MG4 had higher CP content than Rhodes and Mulato II.

CHAPTER SIX

6.0. CONCLUSIONS AND RECOMMENDATIONS

The chemical composition and in vitro dry matter digestibility were highest in two cultivars (Piata and MG4). This showed that these grasses were superior in quality. The also contributed to the highest growth of the Galla goats and were superior to Rhodes grass (control). Thus these grasses could replace Rhodes grass in the coastal lowlands as livestock feeds. An average daily weight of 45.23g was obtained on Galla goats fed *B. brizantha* cv. Piata compared to 9.63g for those in the control group (fed Rhodes grass). This showed an increase in weight gain (daily weight gain) by 78.71% for animals on Piata over those fed Rhodes grass. This would bring about greater economic gain in terms of profit to Galla goat farmers due to increased daily and total live weight gain when animals are fed cv. Piata relative to lower daily gain and total live weight gain and economic gain when fed Rhodes grass.

Other studies in other areas of the country show that Mulato II has high crude protein content. The low quality of Mulato II is attributed to poor management of the grass during harvesting and baling. Another factor that could have led to the poor quality of the grass was the climatic variations in the areas that the grass was grown. While Piata, MG4 and Rhodes grass were grown in Machakos region which is a much cooler region when compared to Mtwapa where Mulato II was established. This could have led to fibrous accumulation during the early stages of its growth leading to the poor quality of the grass. Other studies done in the highlands of Kenya show that Mulato II actually has the highest crude protein content when compared with other grasses.

It is therefore recommended in future, that all the grasses should be established in the same area to avoid differences as a resulting in climatic variation. Other studies should also be done to investigate other cultivars of *Brachiaria* apart from the ones evaluated in this study such as Xaraes, Llanero, Mulato I, Marandu etc. Other grasses such as Napier grass should also be incorporated for further studies in the future.

It is also recommended that other aspects of animal performance such as milk yield, reproductive performance, rates of ruminal degradation among others could be further assessed. `

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APPENDICES

Appendix 1: Analysis of variance tables for feed composition

Analysis of variance for Ash

Source of variation	DF	SS	MS	VR	Pr>F
Rep stratum	1	0.01240	0.01240	0.18	
Rep. *Units* stratum Feed	4	84.78554	21.19638	306.98	<.001
Residual	4	0.27619	0.06905		
Total	9	85.07413			

R-Square	Coeff Var	Root MSE	Ash Mean
0.996581	3.194624	0.241226	7.551000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	84.78554	21.19638	306.98	<.001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	4	84.78554	21.19638	306.98	<.001

Analysis of Variance of Dry Matter (DM)

Source	DF	SS	MS	F	Pr>F
Model	4	9.20836000	2.30209000	7.15	0.0268
Error	5	1.61080000	0.32216000		
Corrected Total	9	10.81916000			

R-Square Coeff Var Root MSE DM Mean

0.851116 0.622714 0.567591 91.14800

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	9.20836000	2.30209000	7.15	0.0268

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	9.20836000	2.30209000	7.15	0.0268

Analysis of Variance for Crude protein (CP)

Source of variation	DF	SS	MS	VR	Pr>F
Rep stratum	1	0.00159	0.00159	0.02	
Rep.*Units*stratum Feed	4	171.43449	42.85862	492.44	<.001
Residual	4	0.34813	0.08703		
Total	9	171.78421			

R-Square Coeff Var Root MSE CP Mean

0.997978 2.723777 0.263553 9.676000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	171.43449	42.85862	492.44	<.001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	171.43449	42.85862	492.44	<.001

Analysis of Variance for NDF

Source	DF	SS	MS	F	Pr>F

Model	4	2385.915360	596.478840	433.61	<.0001
Error	5	6.878000	1.375600		
Corrected Total	9	2392.793360			

R-Square	Coeff Var	Root MSE	NDF Mean
0.997126	2.086865	1.172860	56.20200

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	2385.915360	596.478840	433.61	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	2385.915360	596.478840	433.61	<.0001

Analysis of Variance for OMD

Source	DF	SS	MS	F	Pr>F
Model	4	2854.441800	713.610450	198.39	<.0001
Error	5	17.985000	3.597000		
Corrected Total	9	2872.426800			

R-Square	Coeff Var	Root MSE	OMD Mean
0.993739	3.378297	1.896576	56.14000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	2854.441800	713.610450	198.39	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	2854.441800	713.610450	198.39	<.0001

Analysis of Variance for DoMD

Source	DF	SS	MS	F	Pr>F
Model	4	2848.924800	712.231200	226.47	<.0001
Error	5	15.724450	3.144890		
Corrected Total	9	2864.649250			

R-Square	Coeff Var	Root MSE	DoMD Mean
0.994511	3.404134	1.773384	52.09500

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	2848.924800	712.231200	226.47	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	2848.924800	712.231200	226.47	<.0001

Analysis of Variance of DMD

Source	DF	SS	MS	F	Pr>F
Model	4	2651.849760	662.962440	129.75	<.0001
Error	5	25.546850	5.109370		
Corrected Total	9	2677.396610			

R-Square	Coeff Var	Root MSE	DMD Mean
0.990458	3.982858	2.260392	56.75300

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	2651.849760	662.962440	129.75	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	2651.849760	662.962440	129.75	<.0001

Analysis of variance for ADL

Source	DF	SS	MS	F	Pr>F
Model	4	40.98676000	10.24669000	12.07	0.0088
Error	5	4.24440000	0.84888000		
Corrected Total	9	45.23116000			

R-Square	Coeff Var	Root MSE	ADL Mean
0.906162	22.87356	0.921347	4.028000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	40.98676000	10.24669000	12.07	0.0088

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	40.98676000	10.24669000	12.07	0.0088

Analysis of variance of ADF

Source	DF	SS	MS	F	Pr>F
Model	4	1945.491160	486.372790	681.07	<.0001
Error	5	3.570650	0.714130		
Corrected Total	9	1949.061810			

R-Square	Coeff Var	Root MSE	ADF Mean
0.906162	22.87356	0.921347	4.028000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	1945.491160	486.372790	681.07	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	1945.491160	486.372790	681.07	<.0001

Analysis of variance for Ca

Source	DF	SS	MS	F	Pr>F
Model	4	0.13396000	0.03349000	46.51	0.0004
Error	5	0.00360000	0.00072000		
Corrected Total	9	0.13756000			

R-Square	Coeff Var	Root MSE	Ca Mean
0.973830	11.08794	0.026833	0.242000

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	0.13396000	0.03349000	46.51	0.0004

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	0.13396000	0.03349000	46.51	0.0004

Analysis of variance for P

Source	DF	SS	MS	F	Pr>F
Model	4	0.52406000	0.13101500	43.96	0.0004
Error	5	0.01490000	0.00298000		
Corrected Total	9	0.53896000			

R-Square Coeff Var Root MSE P Mean

Source	DF	Type I SS	Mean Square	F value	Pr > F
Treatment	4	0.52406000	0.13101500	43.96	0.0004

Source	DF	Type III SS	Mean Square	F value	Pr > F
Treatment	4	0.52406000	0.13101500	43.96	0.0004

Appendix 2: Analysis of variance tables for Goat weights

Analysis of variance for goat weight

Source	DF	SS	MS	F	Pr>F
Model	18	5176.582445	287.587914	273.99	<.0001
Error	189	198.381777	1.049639		
Corrected Total	207	5374.964222			

R-Square	Coeff Var	Root MSE	Goat weight Mean
0.963092	6.142386	1.024519	16.67950

Source	DF	Type I SS	Mean Square	F value	Pr > F
Reps	3	4741.410813	1580.470271	1505.73	<.0001
Treatment	3	378.514149	126.171383	120.20	<.0001
Weeks	12	56.657483	4.721457	4.50	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Reps	3	4741.410813	1580.470271	1505.73	<.0001
Treatment	3	378.514149	126.171383	120.20	<.0001
Weeks	12	56.657483	4.721457	4.50	<.0001

Analysis of variance for weekly weight gain

Source	DF	SS	MS	F	Pr>F
Model	18	32.08570192	1.78253900	5.90	<.0001
Error	189	57.08903606	0.30205839		
Corrected Total	207	89.17473798			

R-Square	Coeff Var	Root MSE	Weekly weight gain
0.359807	346.7287	0.549598	0.158510

Source	DF	Type I SS	Mean Square	F value	Pr > F
Reps	3	0.34405913	0.11468638	0.38	0.7678
Treatment	3	3.12123606	1.04041202	3.44	0.0178
Weeks	12	28.62040673	2.38503389	7.90	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Reps	3	0.34405913	0.11468638	0.38	0.7678
Treatment	3	3.12123606	1.04041202	3.44	0.0178
Weeks	12	28.62040673	2.38503389	7.90	<.0001

Analysis of variance for daily weight gain

Source	DF	SS	MS	F	Pr>F
Model	18	654400.981	36355.610	5.90	<.0001
Error	189	1164488.692	6161.316		
Corrected Total	209	1818889.673			

R-Square	Coeff Var	Root MSE	Daily weight gain Mean
0.359780	346.6404	78.49405	22.64423

Source	DF	Type I SS	Mean Square	F value	Pr > F

Reps	3	7013.4423	2337.8141	0.38	0.7679
Treatment	3	63807.8654	21269.2885	3.45	0.0177
Weeks	12	583579.6731	48631.6394	7.89	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Reps	3	7013.4423	2337.8141	0.38	0.7679
Treatment	3	63807.8654	21269.2885	3.45	0.0177
Weeks	12	583579.6731	48631.6394	7.89	<.0001

Analysis of variance for Total weight gain

Source	DF	SS	MS	F	Pr>F
Model	18	441.5070697	24.5281705	25.12	<.0001
Error	189	184.5183350	0.9762875		
Corrected Total	207	626.0254047			

R-Square	Coeff Var	Root MSE	Total weight Mean
0.705254	99.27260	0.988073	0.995313

Source	DF	Type I SS	Mean Square	F value	Pr > F
Reps	3	10.6386129	3.5462043	3.63	0.0140
Treatment	3	375.0616975	125.0205658	128.06	<.0001
Weeks	12	55.8067594	4.6505633	4.76	<.0001

Source	DF	Type III SS	Mean Square	F value	Pr > F
Reps	3	10.6386129	3.5462043	3.63	0.0140

Treatment	3	375.0616975	125.0205658	128.06	<.0001
Weeks	12	55.8067594	4.6505633	4.76	<.0001