PERFORMANCE OF RED MAASAI SHEEP FED ON BRACHIARIA AND RHODES GRASS HAY SUPPLEMENTED WITH CALLIANDRA LEAVES

RICHARD SUYIANKA KENANA

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Animal Nutrition of Egerton University

EGERTON UNIVERSITY

OCTOBER, 2022

DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been presented in this or any other University for the award of a degree

Date 03/10/2022

Richard S. Kenana

KM113/11820/16

Recommendation

This thesis has been submitted with our approval as University supervisors:

Date: 04/ 10/2022

Dr. Paul A. Onjoro, PhD

Department of Animal Sciences

Egerton University

Date: 04/10/2022

Prof. Mary K. Ambula, PhD

Department of Animal Sciences

Egerton University

COPYRIGHT

DEDICATION

This work is dedicated to my beloved wife Esther Wanja and our two daughters; Lily Soila and Joy Simalo.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Egerton University and the staff of Department of Animal Sciences for their support during my study. I also wish to thank my sponsors: Ruforum through the Master Card Foundation in partnership with Transforming African Agricultural Universities to meaningfully contribute to Africa's Growth and Development Program (TAGDev) and Kenya Climate Smart Agricultural Project (KCSAP) for funding my research project. Not forgetting my employer Kenya Agriculture and Livestock Research Organization (KALRO) for granting me the study leave which made it possible for me to concentrate on my studies. My appreciation goes to my supervisors Dr. Paul Onjoro and Prof Mary Ambula of the Department of Animal Science, Egerton University, for their support and guidance during the course of my study that culminated in the production of this thesis. I would like to thank the technologists in the Animal Nutrition laboratory of the Department of Animal Sciences for their assistance with chemical analyses. I also wish to thank my wife Esther Mwangi and my daughters Lily Soila and Joy Simalo for their prayers and emotional support. Finally, I would like to thank the Almighty God for His mercy and protection throughout the period of my studies.

ABSTRACT

Red Maasai sheep is a breed commonly found in the arid and semi-arid lands (ASALs) of Kenya and Tanzania. They often face severe nutritional deficits especially during the dry season which lead to low productivity, weight loss, health problems or even death. The objective of this study was to evaluate the effect of supplementing Brachiaria *(Brachiaria ruziziensis)* and Rhodes grass *(Chloris gayana)* hay with Calliandra leaves *(Calliandra calothyrsus)* on the performance of Red Maasai sheep. The specific objectives were to determine the chemical composition of the experimental diets, palatability, voluntary feed intake, digestibility and weight change. Twelve experimental diets were formulated consisting of three basal diets: Brachiaria grass hay, Rhodes grass hay and a 50:50 mixtures of Brachiaria and Rhodes grass hay, each supplemented with different levels of Calliandra leaves. Treatments (T) were based on the level of supplementation with Calliandra leaves where: (T1=0%), (T2=10%), (T3=20%) and (T4=30%) respectively. Chemical composition including polyphenols and *in-vitro* gas production characteristics were determined. Palatability study was conducted in a completely randomized design (CRD) using three (3) one-year-old male sheep with a mean weight of 22.0 ± 1.5 Kg in three replicates. Each sheep was offered 200 g daily with an allowance of 60 minutes feeding time. Daily feed offered and left over was weighed and recorded and intake determined by difference. In performance trials (feed intake, digestibility and weight gain), thirty-six (n=36) male, one-year-old sheep, with a mean weight of 22±2.5 Kg were used in a completely randomized design (CRD), with three replicates and 3 sheep per treatment. Daily feed offered, feed left-over and faeces were weighed and recorded. Weekly body weight measurements were recorded. Sheep were allowed a 14-day adaptation period prior to the feeding trial. The feeding trial lasted 12 weeks. Data were analysed by general linear model of the analysis of variance (ANOVA) using the statistical analysis system (SAS, 2002) version 9.0. Results showed that supplementation improved significantly ($p<0.05$) crude protein in the diets from 4.1% to 12.6%. Supplementation also increased significantly ($p<0.05$) palatability of the diets. Results indicated that supplementation positively influenced ($p<0.05$) feed intake, digestibility and weight gains. Brachiaria, Rhodes and 50:50 mix supplemented with 30% Calliandra leaves showed higher average daily gain (ADG) of 52.8 g/d, 42.0 g/d and 45.0 g/d respectively. This study concluded that Brachiaria grass hay supplemented with 30% Calliandra leaves has a great potential as a dry season forage for Red Maasai sheep.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrophotometer
Ad libitum	Unrestricted access to feed
ADF	Acid Detergent Fibre
ADWG	Average Daily Weight Gain
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BNI	Biological Nitrification Inhibition
BW	Body Weight
CP	Crude Protein
CRD	Completely Randomized Design
CT	Condensed Tannins
DM	Dry Matter
EE	Ether Extract
EAT	East African Time
GLM	General Linear Model
GP	Gas Production
ILRI	International Livestock Research Institute
IVDMD	*in-vitro* Dry Matter Digestibility
IVOMD	*in-vitro* organic matter Digestibility
In-vitro	A test done in artificial environment in glass in the laboratory
In-vivo	A test done within a living organism
KARI	Kenya Agricultural Research Institute
KALRO	Kenya Agricultural and Livestock Research Institute
LSD	List Significant Difference
LWG	Live Weight Gain
ME	Metabolizable Energy
N	Nitrogen
NDF	Neutral Detergent Fibre
RPI	Relative Palatability Index
SAS	Statistical Analysis System

CHAPTER ONE
INTRODUCTION

1.1 Background information

Kenya's development is significantly influenced by the production of livestock. It generates 10% of the overall Gross Domestic Product and 40% of the agricultural GDP (KARI, 2004). Over 83% of Kenya's land mass is comprised of arid and semi-arid lands (ASALs), which are home to more than 70% of the nation's cattle (GoK, 2015). The farming systems in the ASALs depend heavily on sheep production since they give the rural inhabitants food, manure, revenue, and jobs (Katiku *et al.,* 2013; Kosgey *et al.,* 2004; MacOpiyo *et al.,* 2013; Verbeek *et al.*, 2006). Red Maasai sheep is one of the most prominent native breeds commonly found across Kenya and Tanzania among the Maasai pastoralists (Ojango *et al.,* 2014; Solomon *et al.,* 1991). They are well adapted to ASAL areas and are known to be tolerant to internal and external parasites (Mugambi *et al.*, 1969; Ojango *et al.,* 2013). Natural grasses including shrubs and browses form the main feed resources for small ruminant animals in the ASALs (Gitunu *et al.,* 2003; Koech *et al.,* 2015). However, as climatic circumstances change throughout the year, their yields and nutritional status rapidly deteriorate. This leaves them unable to supply the nutritional needs of cattle during the dry season, which results in reduced output, weight loss, or mortality (Kahi *et al.,* 2006; Njarui *et al.,* 2010).

Tropical grasses of the genus Brachiaria are native to East and Central Africa. Brachiaria grasses have in recent years gained popularity in Africa, and a number of activities are currently being carried out to promote them in order to support livestock output, particularly during the dry season (Mass *et al.,* 2015; Mutai *et al.,* 2017). This is due to the fact that Brachiaria is a climate smart pasture with a wide range of advantageous properties, including: adaptation to marginal soils, water stress and shade tolerance, high biomass production potential, highly palatable and nutritious, ability to sequester carbon, increased nitrogen use efficiency through biological nitrification inhibition (BNI), ability to reduce greenhouse gas emissions and ground water pollution (Mutai *et al.,* 2017; Subbarao *et al.,* 2009). Research from South America, Asia, the South Pacific, and Australia has shown that Brachiaria is a great feed choice for animals (Boddey *et al.,* 2004; Miles *et al.,* 2004). However, very few animal performance studies employing Brachiaria have been documented in the East African region (Muinga *et al.,* 2016).

Rhodes grass *(Chloris gayana)* seeds are widely available and simple to plant and manage, they have been utilized extensively to improve pastures. Varieties in Kenya produce a substantial amount of biomass that is suitable for grazing and hay production. Despite the fact that their quality deteriorates quickly as they age, livestock will readily ingest them even when they are mature. In the past, initiatives have been made to promote Rhodes grass and other native grass species such as *Centchrus ciliaris, Eragrostis superba, Enteropogon macrostachyus,* and *Chloris roxburghiana*, in Kenya's southern and central-northern rangelands that are thought to be able to adapt to the ASALs' harsh climatic conditions (Gitunu *et al.,* 2003). However, as climatic circumstances in the region change, their yields and nutritional status tend to deteriorate.

Tropical grasses often have high levels of fibre and low levels of total nutrients that are digested, crude protein content, and digestibility (Loch *et al.,* 2004; Murphy, 2010). Tropical grasses belong to a group of plants with a growth pattern called the C4 photosynthetic pathway, which is more prevalent in hotter climates, and this is the main cause of their declining quality. The adaptation of C4 grasses to high-temperature and high-light intensity environments has resulted in increased structural carbohydrates that reduce soluble carbohydrates (starch) which negatively impact their nutritional quality for herbivores (Pedreira *et al.*, 2017; Temu *et al.,* 2014).

The seasonal variations in feed supplies, in both quality and quantity, make it difficult to feed livestock in the tropics (Lamidi *et al.,* 2014). One potential solution to the dry season's feed issue is to store grasses in the form of hay during the wet season to be fed during the dry. In general, hay made from grasses is considered to be of lower quality (Kawashima *et al.,* 2006; Kawashima *et al.,* 2007). For example, Congo signal grass *(Brachiaria ruziziensis)* in hay has an average crude protein content (CP) of 5% (Kawashima *et al.,* 2006; Kawashima *et al.,* 2007), which is below the 7% CP threshold necessary for optimal microbial growth in the rumen and necessitates supplementation (Ondiek *et al.,* 2016). Protein and energy are the two nutrients that have the biggest effects on sheep productivity.

Sheep require a minimum of 8 to 10 MJ/Kg DM, not to lose weight and a minimum protein level of about 80 gKg^{-1} DM for maintenance (Gatenby, 2002; Minson, 1990; NRC, 2007). However, lactating ewes and growing lambs need a protein level of about 110 gKg^{-1} DM (Gatenby, 2002; Minson, 1990; NRC, 2007). Compared to typical values observed in natural pastures and hay, these energy and protein levels are significantly higher. (Afzal *et al.,* 2007; CIAT, 2007). Leguminous fodder trees like the Calliandra are typically rich in protein and minerals, and because of their deep root systems, they can delve deeper into the soil and hence continue to thrive even in dry conditions. Not only are they accessible during the dry season, but they also offer a respectable CP content of between 10 and 30%.

(Olafadehan *et al.,* 2016). In order to improve the quality of the feed provided to animals during the dry season, leguminous fodder trees can be added to grass hay as a supplement rather than using commercial concentrates (Olafadehan *et al.,* 2016; Place *et al.,* 2009). Leguminous fodder trees, also known as multipurpose trees (MPTs), are high in soluble protein and have the potential to increase voluntary feed intake and digestibility when used to supplement forage (Widiawati, 2002).

The amount of nutrients contained in a feed and the efficacy of extracting nutrients during digestion determines its nutritive value. The voluntary feed intake and its digestibility are the major factors that determine how much nutrition can increase animal productivity (Norton *et al.,* 2000). Ruminant voluntary feed intake is also influenced by the rumen fill, which in turn affects the speed of digestion from the rumen to the lower digestive tract. It has been discovered that the poor quality of dry season grass lowers voluntary feed consumption. Preference and palatability have an impact on voluntary consumption. The acceptability of a particular feed can be assessed using these two characteristics. The term palatability refers to those characteristics of a feed that provoke a sensory response (Baumont, 1996; Yusmadi *et al.,* 2008). Preference on the other hand refers to the choice the animal makes when offered a variety of feeds (Baumont, 1996; Hussain *et al.,* 2009). Selection of feeds by animals depends on their palatability which are dependent on plant and animal factors. Plant factors that influence palatability include: species, chemical composition, physiological age, presence of ant nutritive factors (ANFs). Animal factors include: species or breeds, organoleptic senses, individual differences and familiarity to the feed (Baumont, 1996). There are other techniques for assessing palatability such as oesophageal fistula technique and stomach content and faecal analysis (Ngwa *et al.,* 2003). However, they are not convenient because they are laborious, costly, complicated and generally considered as invasive. Direct feeding on pasture or stall feeding seems to be more suitable for palatability studies (Ben Salem *et al.,* 1994; Kaitho *et al.,* 1997; Ngwa *et al.,* 2003).

Lower levels (2-4%) of tannins may be advantageous to ruminant animals as they reduce excessive degradation of high-quality protein in the rumen and suppress bloat (Naumann *et al.,* 2017; Patraa *et al.,* 2010; Waghorn, 2008). The objective of this study is to evaluate the effect of supplementing Brachiaria *(Brachiaria ruziziensis)* variety (Germain & Evrad) and Rhodes grass *(Chloris gayana)* “Boma” hay with Calliandra *(Calliandra calothyrsus)* on performance of Red Maasai Sheep.

1.2 Statement of the problem

One of the most significant tropical forages is the Brachiaria species. They have a great potential for improving productivity in animals. However, despite the immense desirable characteristics attributed to the species, their potential to address the challenge of livestock nutrition during the dry season remains unexploited in Kenya. In Kenya and the rest of East Africa, there are hardly any reports of animal performance studies using Brachiaria. Its performance on sheep has not been well understood. Its nutritional effect in combination with other forages such as Rhodes grass and Calliandra, has not been fully established. Therefore, there is lack of sufficient information that can be used to make recommendations to farmers on the best strategies for feeding Brachiaria hay supplemented with protein to sheep during the dry season.

1.3 Objectives

1.3.1 Broad objective

To contribute to increased sheep production by feeding Brachiaria and Rhodes grass hay supplemented with Calliandra leaves to growing Red Maasai sheep.

1.3.2 Specific objectives

i. To determine the chemical (nutrient) composition and *in-vitro* gas production of Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

ii. To determine the palatability of Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

iii. To determine the intake, digestibility and weight gain of Red Maasai sheep fed on Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

1.4 Hypotheses

i. There is no significant difference in the chemical and *in-vitro* gas production of basal Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

ii. There is no significant difference in the acceptability of basal Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

iii. There is no significant difference in the intake, digestibility and weight gain of sheep fed on basal diet of Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

1.5 Justification

At the national and household levels, sheep production plays an important economic role. However, the decline in supply of feed resources both in quality and quantity during the dry season results in low productivity, weight loss, poor health (diseases) or death. This translates to loss of revenue to sheep farmers and negatively affects the country's food and nutritional security. Brachiaria is an important tropical grass that is gaining a lot of popularity among farmers in Kenya (Maass *et al.,* 2015). This is because of its high biomass production potential, high palatability, nutritious and relative tolerance to drought. It can be grazed directly or can be conserved as hay and fed during the dry season. Moreover, Brachiaria is important because of its role in soil improvement and climate change mitigation (Jank *et al.,* 2014). Though Rhodes grass is a popular and widely grown grass in Kenya, its contribution to sheep nutrition in comparison with Brachiaria needs to be established. However, a sole diet of Brachiaria or Rhodes grass hay may not supply sufficient nutrients required for maintenance and growth of the sheep. Energy and protein are the most deficient nutrients during the dry season. There is therefore a need to supplement the grass hay with a suitable protein source. Calliandra is a leguminous fodder tree that is rich in protein and minerals. Research has shown that supplementation of low quality roughages with leguminous fodder trees increases dry matter (DM) intake and improves animal performance. The information from this study will be used to select the best feed combination for recommendation to the farmers with the aim of improving performance of their Red Maasai sheep.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic importance of sheep in Kenya

Kenya's sheep industry has an important economic role at the local, regional, and national levels. The 2009 census indicates that Kenya has approximately 17.3 million cattle (14 million indigenous and 3.3 million exotic), 27 million goats, 17 million sheep, 2.9 million camels, and 335,000 pigs. Sheep production is very vital to the farming systems in the ASALs since it helps to ensure the rural communities' access to food, nourishment, manure, revenue, and work, as well as important cultural functions (Katiku *et al.,* 2013; Kosgey *et al.,* 2008; Mac Opiyo *et al.,* 2013; Verbeek *et al.,* 2006). The majority of Kenya's red meat comes from them (Herlocker, 1999). About 65% of red meat is produced in dry and semi-arid regions. Sheep supply roughly 15%–20% of the red meat consumed in the country under the pastoral production. (KMT, 2014; MLFD, 2005). Along with the production of meat, the export of wool has increased dramatically from 1973 tonnes in 2007 to 2279 tonnes in 2014. (Mganga *et al.,* 2010). Many other regions of Kenya are home to a variety of sheep breeds that provide both milk and meat in quantities that are suitable for immediate consumption, which is a special advantage given the challenging storage conditions in the tropics in the absence of refrigeration or adequate transportation (Ademosun, 1994). They are preferable to cattle because they can be turned into money much more quickly. Due to their increased prolificacy and shorter generation interval than cattle, they also offer a higher off take (Ademosun, 1994).

2.1.1 Sheep production in Kenya

Sheep are raised under different production systems in Kenya. These systems fall into three categories namely; extensive, semi-intensive and intensive system.

2.1.2 Extensive systems

These systems are typically linked to pastoralism and nomadism, which are prevalent in arid and semi-arid regions (Payne, 1990; Wilson, 1991). The majority of the animals in these systems are sheep and goats. Normally, they are herded independently by mothers or children or along with cattle (Payne, 1990). Arid and semi-arid lands (ASALs) make up roughly 83% of Kenya, a country with 29 counties and a population of about 16 million (Odhiambo, 2013). Low, unpredictable rainfall and nearly recurrent droughts are features of these regions. With little to no supplemental feeding, the animals scavenge for food as they traverse the rangelands. They typically produce relatively little, as evidenced by their slow development rates, poor body conditions, delayed puberty, low conception rates, extended calving/lambing intervals, and other factors (Odhiambo, 2013).

2.1.3 Semi intensive systems

This system borders between areas of cultivation and pastoralism. In this system livestock production is integrated with crop agriculture. Livestock keeping is the major source of family's food and income supplemented to some extent by crops. These are rain-fed systems where livestock keepers take advantage of the shot wet seasons to grow crops and may move all, or part of their stock during the dry season (Wilson, 1995). These systems are characterized by small holdings with a mixture of semi-subsistence and cash economies. Cattle are kept for both milk and for draught purposes. Sheep and goats are kept but in modest herd sizes (Wilson, 1995). Due to short growing seasons, high input costs, and other factors, these systems' primary issue is the comparatively low production of crops and forage. The main problem in these systems is the relatively low productivity of crops and forage due to short growing periods, high pre-weaning mortality rates and occasional outbreak of diseases such as trypanosomiasis (Ademosun, 1994; Lebbie *et al.*, 1996; Payne, 1990; Wilson, 1991; Wilson 1995).

2.1.4 Intensive systems

In Kenya, intensive system is practised in the high potential locations with dense populations of people and small farms (Semenye *et al.*, 1989). The former provinces of Kenya, such as Central, Rift Valley, Nvanza, Eastern, and Western, are among these regions (MLFD, 2004). Some of these places, especially those over 5000 m in altitude, have favorable climatic and ecological circumstances that encourage the raising of wool sheep (Wymann *et al.*, 2014). Additionally, there are peri-urban landless farmers who raise cattle in their backyards to feed their families (Payne, 1990). These methods are primarily focused on milk production from cattle and goats (and, to the extent possible, sheep), which are frequently grown on lower-quality foods such crop wastes and grazing on cliff faces and by the sides of roads. Sheep and goats are seasonally tethered or confined year round in the highlands due to the heavy human population pressure, and are fed using a cut-and-carry system (Preston, 1990; Wilson, 1991). The frequency of supplementation depends on the availability of supplemental feed during the dry seasons. In a study conducted in Zambia, it was discovered that supplementing indigenous goats' diets with *Calliandra calothyrsus, Leucaena lencocephala*, *Sesbania sesban*, and *Gliriadia septum* greatly increased their growth rates (Phiri *et al.*, 1992).

2.2 Challenges in sheep production in Kenya

The main obstacle restricting small ruminant production in the tropics is the lack of an adequate year-round availability of good quality feeds. Animals are unable to reach their genetic potential, which is even worse during the dry season and extended drought (Ademosun. 1994). Due to recurring seasonal feed shortages, vulnerable ecosystems, and the possibility of environmental degradation, feed scarcity is particularly severe in arid and semi-arid regions (Devendra, 1986). According to Kosgey (2008), sheep are subjected to a variety of difficulties, including ongoing droughts, illnesses, parasites, conflicts, and inadequate nourishment. Small ruminants' resilience and consequent importance to resource-poor farmers and pastoralists are increased by their capacity to walk for long distances and adapt to harsh environments, as well as by some other distinctive characteristics like resistance to gastrointestinal nematodes (Baker *et al.,* 2003; Baker *et al.,* 2004; Owen *et al.,* 2005).

2.2.1 Impact of climate change on livestock nutrition and productivity

The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) predicts that by 2100, the average surface temperature on Earth would rise by 0.3°C to 4.8°C (1PCC, 2013). The quality of forages and feed crops could be significantly impacted, as well as animal productivity (Chapman *et al.,* 2012; IFAD, 2010; Polley *et al.,* 2011). The amount and quality of feed will be negatively impacted by the rise in atmospheric carbon dioxide (CO_2) levels and temperature. Due to an increase in CO_2 content, which will have a higher impact on C3 species, the growth of the herbage will outpace the yield of the grains (Chapman *et al.*, 2012). Due to variations in ideal growth rates, this will also modify the composition of pastures and the dynamics of species competition (IFAD, 2010; Thornton *et al.,* 2010). Additionally, if temperature, precipitation, and nitrogen deposition all rise at the same time, changes in species composition in pastures may lead to an increase in primary productivity (IPCC, 2007).

The quality of feed crops may also be affected by variations in nitrogen and water-soluble carbohydrates levels (Sanz-Saez *et al.,* 2012). Increased lignification, increased cell wall's constituents, and decreased cell contents in plants would cause a drop in digestibility and breakdown rates as well as a reduction in the availability of nutrients for animals (Polley *et al.,* 2011; Thornton *et al.,* 2010). Floods and other extreme weather events could alter the shape and structure of roots, alter the rate of leaf growth, and reduce overall production (Baruch *et al.,* 1995).

Although a rise in temperature may be beneficial in humid temperate areas, it will have a detrimental influence on pasture and animal productivity in arid and semi-arid regions (ASALs). The length of the growing season, which affects fodder quality and quantity since it dictates the length and times of forage availability, may be impacted by the rise in temperature (Polley *et al.,* 2011; Thornton *et al.,* 2010). A decline in forage quality may result in an increase in methane emissions per unit of gross energy consumed, according to Benchaar *et al.* (2001). The availability of fresh water for agriculture will be impacted by climate change due to an increase in evapotranspiration. Due to water scarcity and the depletion of water supplies, there is a tendency for competition to expand globally. By 2025, it is predicted that 64% of the world's population will be living in water-stressful situations (Rosegrant *et al.,* 2009). Development of crops and livestock systems that require less water should be the focus of research (Nardone *et al.,* 2000).

Animal health may be negatively impacted by climate change, particularly if temperatures continue to rise. High ambient temperatures raise the risk of illness and death. This is because a rise in temperature could hasten the growth of parasites and/or diseases (Nardone *et al.,* 2000). An increase in temperature will have an impact on the animals' thermal comfort zone, which is a range of ambient temperatures that are advantageous to physiological processes (FAO, 1986). If temperature rises above the upper critical temperature of the range, depending on the species and type, animals start to experience heat stress (FAO, 1986). Heat stress reduces forage intake and nutrient utilization, which results in decreased output, poor reproductive success, poor health, and high mortality (Nardone *et al.,* 2000; Thornton *et al.,* 2010).

As a result of climate change, biodiversity will decline in both plants and animals (UNEP, 2012). Climate change may result in the extinction of 15–37% of all species worldwide, according to Thomas *et al.* (2004). As a result of rising temperatures, climate change may cause a decrease in the amount of nutrients that can be digested, which could result in low livestock production (due to diminishing forage quality and quantity) or a drop in the amount of animal feed that animals consume (Hatfield *et al.,* 2008). Livestock are known for effectively converting naturally available resources, such cellulolytic plant biomass, into nourishing human food, like meat and milk, and as a result, they are a significant contributor to food security (FAO, 2011).

2.2.2 Breeds of sheep kept in Kenya

Sheep breeds can be broadly divided into four categories. These are: wool, mutton, dairy, and dual purpose (e.g. mutton and wool, or mutton and milk). However, the majority of the present commercial breed development has been focused on specialization to one core commodity, such as milk, mutton, wool, and hair. Based on how well they adapt to a particular habitat, sheep breeds are chosen. The majority of exotic breeds originate from temperate climates, where the weather is cool and there is a plenty of high-quality feed (Payne, 1990; Wilson, 1991).

2.2.3 Hair breeds

These breeds include: Black Head Persian; Dorper; Nyanza Fat-tail; Red Maasai and their crosses (Table 2.1). Most of the indigenous hair sheep are found in the arid and semiarid areas (Payne, 1990; Wilson, 1991).

2.2.4 Wool and dual-purpose breeds

These are mainly exotic breeds which include: Merino; Corriedale; Hampshire Down; Romney Marsh and their crosses including local breeds (Table 2.1). The wool sheep are suitable for the cool high rainfall areas (Payne, 1990; Wilson, 1991).

Table 2. 1 Sheep breeds suitable for different regions in Kenya

Region	Sheep
Low altitude	Dorper, Red Maasai and Black Head Persian
Medium altitude	Dorper, East African fat tailed type and East African fat rump type
High altitude	Hampshire Down, Corriedale, Merino, East African fat rump type

Source: Payne (1990)

2.2.5 Red Maasai sheep

Kenya and Tanzania are the original home to the Red Maasai sheep. They are a breed of fat-tailed sheep that are frequently kept by Maasai pastoralist groups (Solomon *et al.,* 1991). The breed is raised to provide meat, milk, dung, and skin. Additionally, it is used for cultural and ceremonial purposes, as well as savings, insurance against emergencies, and other uses (Verbeek *et al.,* 2006). Numerous studies have shown that the Maasai pastoralists favour it in particular because of its resistance to illnesses and drought. It is thought to have some tolerance to trypanosomiasis and be resistant to gastrointestinal worms (Baker *et al.,* 2003; Bishop *et al.,* 2012; McManus *et al.,* 2014). The Red Maasai sheep is more well-liked by people since it can wander for long distances and stores fat. It is name is associated with their common colour of red-brown, though they may also be pied or multi-coloured. It is a hair sheep hence not meant for wool production.

2.3 Role of grasses in livestock production

In the tropics, grasses naturally provide ruminants with a significant amount of nutrients (Taweel *et al.,* 2003). Forages supply the majority of ruminants' nutritional needs. Because ruminants can consume fibrous feed sources that are useless to humans, they are not only an inexpensive source of nutrition but also do not compete with human food (Herrera, 2004). Compared to bushes and trees, grasses are more accessible, pleasant, and digestible to most ruminants (Quraishi, 1999). According to Reid (1994), the nutritional quality of forage is the end result of voluntary intake, digestibility, and the animals' capacity to utilize nutrients effectively. According to Huhtanen *et al.* (2006) and Jank *et al.* (2009), the degree of digestibility in different grass species varies significantly and is primarily influenced by factors such as species, origin, temperature, light intensity, rainfall, soil type, soil fertility, maturity stage, and conservation techniques. The grasses' fibre content affects how quickly they degrade (Van Soest, 1991). Protein and energy rank as the two nutrients that ruminants need the most. The energy content of forages is determined by their fibre digestibility, and even forages with equal fibre digestibility can have significant differences (Van Soest, 1991).

Essential minerals and crude protein (CP) are frequently scarce in mature grasses. For optimal rumen microbial growth, ruminants require at least 7% CP. Ruminants need at least 7% CP, for rumen microbes to flourish optimally and for body maintenance (Van Soest, 1991). Lactating animal require at least 11% CP for maintenance and production (Van Soest, 1991). Ruminants receive minerals from grasses as well. Animals need minerals for development, upkeep, production, and reproduction. The availability of minerals for both plants and animals is influenced by a variety of environmental factors, including geographic characteristics, climate, the mineral composition of the soil, grazing pressure stress, seasonal fluctuations, and a plant's capacity to absorb minerals from the soil (Ganskopp *et al.,* 2003; Khan *et al.,* 2006). It has been observed that even where there is sufficient green fodder; minerals may be deficient resulting in poor animal performance (Tiffany *et al.,* 2000). The composition of minerals in grasses fluctuates seasonally, and is especially low during the dry season (Ganskopp, 2003). It is important to note that both the excess and deficiency of minerals are the major constraints in livestock nutrition. According to McDowell (1976), a milking cow needs 0.31% Ca and 0.21% P, whereas a dry cow needs 0.25% Ca and 0.16% P. It's crucial to keep the ratio of (Ca to P) at 1.5:1. The digestibility of forages determines their quality, which is positively correlated with their energy content (Bell, 2006). Mega joules of Metabolizable Energy per kilogram of Dry Matter (ME MJ/Kg DM) is the unit of energy measurement used in ruminant nutrition. Additionally, it has a positive relationship with protein content since high protein content is anticipated when digestibility is high (Bell, 2006).

2.4 Different species of Brachiaria

Africa is recognized as the origin of the genus Brachiaria and it species. There are about one hundred known species distributed in the tropics, most of which are found in Africa (Souza *et al.,* 2010). Brachiaria species have done exceptionally well in Brazil and it is estimated that about 85% of the cultivated land under grasses, comprise the same genus (Jank *et al.,* 2014; Vigna *et al.,* 2011). Improvement of Brachiaria in East and Central Africa began in the 1950's (Ndikumana *et al.,* 1996). East Africa plays a central role as the hub of diversity of the genus Brachiaria in Sub-Sahara Africa (Renvoize *et al.,* 1996). The five Brachiaria species that are most frequently encountered and thoroughly studied are *B. brizantha, B. ruziziensis, B. decumbens,* B. Hybrid cv Mulatto II, and *B. mutica. B. platynota* and *B. humidicola* have also received increased attention recently (Ndikumana *et al.,* 1996; Ngila *et al.,* 2016). Data available show that fodder from Brachiaria is very tasty to ruminant animals, resulting in high consumption (Ndikumana, 1985).

According to Urio *et al.* (1988), Brachiaria species often respond extremely well to fertilizer treatment, and the age of the sward appears to have an impact on both the response and yield. Further information provided by the same author demonstrates how few grass species can compete with Brachiaria species in terms of persistence, making the species particularly important on grazing lands. According to studies, Brachiaria species typically contain a lot of minerals. Studies on the mineral condition of several pasture species in Morogoro, Tanzania, found that *Brachiaria brizantha* had a higher mineral content than *Chloris gayana* and other pasture species examined (Urio *et al.,* 1988). In 2012, the Biosciences Eastern and Central Africa-International Livestock Research Institute (BecA-ILRI) Hub and the Kenya Agricultural and Livestock Research Organization (KALRO) launched a joint research project to assess the potential of Brachiaria species for increasing (milk and meat) production and seed production as well as for generating income from smallholder farmers (Mureithi *et al.,* 2016).

2.4.1 Yields and nutritional quality of different species of Brachiaria grass

When compared to other species of fodder grasses, Brachiaria species adapts well to a variety of soil types, management, and weather conditions (Daniela *et al.,* 2014). When properly managed, they can produce high-quality fodder with high dry matter production, providing the nutritional needs of animals, particularly during the dry season (Brighenti *et al.,* 2011). Although this may change with age and species, Brachiaria species typically have excellent digestibility. These changes may be caused by the various concentrations of crude protein, which may be linked to improved nitrogen utilization efficiency via biological nitrification inhibition (BNI) (Lascano *et al.,* 1996; Mureithi *et al.,* 2016). In Tanzania, Brachiaria brizantha yield rose from 6 to 26.5 t/ha.

Table 2.2 Nutritive value of different species of Brachiaria

Species	CP%	IVDMD%	References
B. *brizantha* cv. Marandu	9.74–13.41	63.75 -75.5	Payan *et al.* (2007)
B. *decumbens*	9.02-13.68	57.90-69.95	Payan *et al.* (2007)
B. *ruziziensis*	8.88—13.40	59.30-69.43	Payan *et al.* (2007)
B. *decumbens* cv. Basilisk	9–20	60- 70	Cook *et al.* (2005)
B. *humidicola*	5–17	59– 66	Cook *et al*. (2005)
B. hybrid Mulato II	10.6-13.1	70-70.6	Cook *et al.* (2005)
B. *brizantha*	4.6-7.6	48-59	Urio *et al.* (1988)

In subtropical conditions, however, production declines sharply during the dry season and eventually stops in the winter. In Brazil, *Brachiaria brizantha* cv. Marandu is one of the most frequently planted species. Its IVDMD values range from 63.75% to 75.5% (Table 2.2), which is higher than the average (55%) for fodder grasses in the tropics (Payan *et al.,* 2007). The CP fluctuates between 9.74 and 13.41%. IVDMD was 57.90–69.95% and CP was 9.02–13.68% for *Brachiaria decumbens*. IVDMD was 59.30–69.43% and CP was 8.88–13.40% for *B. ruziziensis* (Payan *et al.,* 2007). An IVDMD of 48–59% was maintained in Africa (Tanzania) using *B. brizantha,* which is within the average (55%) for tropical environments. For *Brachiaria brizantha* and *Brachiaria ruziziensis*, respectively, the CP ranges from 4.6-7.6% and 6.77.7%, which are typical in tropical environments (Urio *et al.,* 1988). According to Cook *et al.* (2005), this can fall quickly to 5% at 90 days, depending on the age of the plant, soil quality, and management.

In Kenya, an experiment on average daily weight gain (ADWG) of bucks fed on B.var. MG4, Mulato II, Piata and *Chloris gayana* showed gains that were statistically different ($P<0.05$). Bucklings fed on Piata (45.21 g/day) and MG4 (41.28 g/day) had the highest while those given Mulato II and Rhodes grass had the lowest ADWG (1.99 g/day) and ADWG (9.64 g/day) respectively. In each of the four diets, there were noticeable differences in the feed conversion ratios (FCR) for DM, OM, and CP. The fact that Piata and MG4 had the lowest FCR indicates that the animals were effective feeders, as seen by the considerable body weight gain. For the duration of the experiment, goats fed Piata and MG4 maintained their maximum weights (Ngila *et al.,* 2016). Milk yield increased by 15–40% in cows fed Brachiaria grasses (*B. brizantha* cvs. Piata, Xaraes, and MG4 or *B. decumbens* cv. Basilisk) in an on-farm feeding trial in the Kangundo sub-County of Machakos County in the mid-altitude eastern region of Kenya compared to local feeds, which were varied mixtures of Napier grass and maize stover (Muinga *et al.,* 2016). According to the same author, farmers in coastal Kenya should be encouraged to produce more Brachiaria in order to boost milk production because Brachiaria species have the ability to complement Napier grass in dairy feeding.

2.4.2 Brachiaria *(Brachiaria ruziziensis)*

Commonly known as Congo signal grass *(Brachiaria ruziziensis)* is native to Central Africa. It is highly palatable and nutritive forage for livestock (Ceccon *et al.,* 2014; Lima *et al.,* 2014). It can grow from sea level to a height of 2000 meters, according to FAO (2015). It may be harvested for hay or fed freshly to stalled ruminants (Cook *et al.,* 2005). *B. ruziziensis* is one of species that has been tested in Kenya which can yield up to 140 Kg/ha of viable seeds (Ndikumana *et al.,* 1996). The author further reveals that *B. ruziziensis* is one of the most relatively persistent forages under heavy grazing during the dry season (Ndikumana, 1985). Agronomic studies done in Kitale Kenya, showed that *B. ruziziensis* took 147 days to flowering after sowing, while it took less than 21 days for the regrowth to head. Its crude protein and NDF levels range from 8% to 15% and 61 to 67% of DM (Herrero *et al.,* 2001; Meale *et al.,* 2012). Studies conducted in Cameroon showed that between the wet and dry seasons, NDF and ADF increased from 71 to 76% of DM and 34 to 48% of DM, respectively, whereas protein content decreased from 16 to 5% (Tedonkeng *et al.,* 2007). With a protein concentration of roughly 5% of DM, Congo signal grass hay has a lower nutritional quality (Kawashima *et al.,* 2006; Kawashima *et al.,* 2007).

Meale *et al. (*2012) found that *in vitro* DM digestibility ranged from 38% to 66% but declined with growth stage. *In situ* DM and protein digestibility of fresh Congo signal grass in sheep have been reported to be 57% and 53%, respectively (Khanum *et al.,* 2010). Ibrahim *et al.* (1995) and Lopes *et al.* (2010) reported degradability of 47%, 51%, and 65% on OM, DM, and protein, respectively. Congo grass can be stored as hay or silage. Congo grass hay's OM and protein digestibility varied from 55% in cattle to 47% in sheep, respectively (Kawashima *et al.,* 2006; Kawashima *et al.,* 2007). Soybean meal added to Congo grass hay increased the amount of DM consumed and the ability of cattle and sheep to digest nutrients (Kawashima *et al.,* 2007). The voluntary feed consumption of hay made from Congo grass was higher in goats than it was for silage. With sufficient N supplies, up to 20 t/ha DM output has been reached, while in poor soils with no N fertilizer, Congo grass only produced 6 t DM/ha (Cook *et al.,* 2005). However, after fertilization with 150 kg/ha of N fertilizer, the yields can increase to 12 t DM/ha (Cook *et al.,* 2005).

2.4.3 Anti-nutritive aspects of Brachiaria

The primary lithogenic steroidal saponin present in the various species of Brachiaria is protodioscin, which is known to possess toxic compounds (Castro *et al.*, 2011; Mustafa *et al.,* 2012; Santos Jr., 2008). Hepatogenous photosensitization signs can be seen in sick animals (Souza *et al.,* 2010). Cattle, sheep, and goats have all been known to become ill from Brachiaria poisoning. Sheep are more vulnerable to poisoning than cattle (Riet-Correa *et al.,* 2011). The toxicity threshold for sheep has not been determined, claims the same author. But in sheep that have just been brought to the pasture, saponins with a concentration of greater than 1% may be hazardous (Riet-Correa *et al.,* 2011). According to the information that is currently available, budding pastures have higher saponin concentrations than mature ones (Castro *et al.,* 2011; Santos Jr., 2008), and young, green leaves have higher saponin concentrations than older, senescent leaves. According to Souza *et al.* (2010), *Brachiaria decumbens* is responsible for the majority of recorded outbreak instances of poisoning, while *B. brizantha* has less cases (Brum *et al.*, 2007). Animals that are affected by outbreaks should be taken out of the dangerous pastures and kept under shade with food and water. Additionally, the processes of ensiling and producing hay can lower the amounts of the steroidal saponin protodioscin (Flavia *et al.,* 2012). Animals displaying photosensitization symptoms should receive treatment. Preventive actions should be based on the cultivation of Brachiaria species or varieties with low saponin contents and the selection of resilient or resistant animals (Riet-Correa *et al.,* 2011).

2.5 Rhodes grass *(Chloris gayana)*

Tropical grass native to Africa called "Rhodes grass" *(Chloris gayana)* is now found all over the world in tropical and subtropical environments and is the most extensively planted grass (Moore, 1970). Rhodes grass, as it is widely called, is a tufted leafy perennial grass that typically spreads by stolons and runners and reaches a height of 0.9 to 2 meters (Loch *et al.,* 2004). Both seeds and splits can be used to sow Rhodes grass. Although seeds are fluffy and challenging to handle, they sprout readily when planted. It is advised to sow at a rate of 0.5-1 Kg/ha to get more quick cover (Cook *et al.*, 2005; Loch *et al.*, 2004). Since feeding value rapidly decreases as blooming progresses, it is crucial to keep the stand in a leafy condition by defoliating it fairly frequently. In extremely young leaves, crude protein levels can reach 17%, but they drop to 3% in older leaves (Loch, 2004). The same source goes on to say that soil phosphorus levels can vary based on the material's age and can range from 0.1 to 0.4% accessible phosphorus. According to variety, soil fertility, environmental factors, and cutting frequency, dry matter digestibility (IVDMD) ranges from 40 to 80%, and dry matter yields are between 2 and 25 tons per hectare (Mbwile *et al.,* 1997). Yields may range from 10 to 16 tons of dry matter per hectare, depending on management and environmental factors (Ecocrop, 2014; Murphy, 2010). Five steers per hectare in Zimbabwe were sustained by Rhodes grass that had been fertilized with 220 kg of superphosphate and 440 kg of ammonium sulphate during the summer, when they gained 117 kg per head or 234 kg/ha. When just 220 Kg/ha of sulphate of ammonia was utilized, the stocking was reduced to 2.5 steers/ha with the same amount of live-weight gain (Cook *et al.,* 2005). Rhodes grass has not been linked to any toxicities.

2.6 Role of multipurpose tree legumes

It is impossible to overstate the importance of multipurpose tree legumes. This is due to the fact that they are naturally versatile and may be utilized to produce high quality animal feed, mulch for crops, fuel wood and lumber, improve the microclimate, stabilize the ecosystem, and supply food for people (Gutteridge *et al.,* 1993; Le Houérou, 1980). They are appealing to both smallholder and large-scale livestock enterprises because of their distinctive nature. In recent years, a lot of research and development has focused on expanding the resource base by assessing a wider range of tree legume genera, identifying ideal management practices, and creating appropriate systems that take use of these species' advantages (Gutteridge *et al.,* 1993; Wambugu *et al.,* 2011)

2.6.1 Advantages of multipurpose tree legumes

Tropical grasses mostly utilise the C4 photosynthetic pathway, whose growth pattern is regulated by hot temperatures, intense sun radiation, and recurrent drought stress. Higher fibre content related to cell walls and lower cell content related to plasma are related to it (Humphreys, 1994). Tropical grasses are thought to be less digestible than temperate ones since the contents of the cell are more easily absorbed by animals than the cell walls. Tropical grasses have a reduced protein content when compared to temperate grasses (which mostly utilise the C3 photosynthetic pathway). This is especially true following a dry period. When grass is in short supply, cattle and other livestock kept by pastoralists which consume primarily grass during the rainy season can adapt to eating the leaves and twigs of woody trees during the dry season. The nomadic tribes of west and east Africa frequently rely on browsing to survive during the dry season and times of drought, according to Gutteridge *et al.*

(1993). According to the same author, legume trees, and shrubs maintain their green colour for a longer period of time than grass during dry spells. This is most likely because they have deeper root systems that can access underground water supplies.

2.6.2 Increased production and income from cattle supplemented with Calliandra leaves

One kilogram of dried Calliandra leaves (CP 24% and 60% DMD given fresh), according to Roothaert *et al.* (1999), contains roughly the same amount of digestible protein as one kilogram of dairy meal (16% crude protein and 80% digestibility). Two kilograms of dried Calliandra leaves serve as a useful protein supplement for a basal feed of Napier grass and crop residue in on-farm feeding trials in Kenya's Embu District and Malawi's Masaka District (Kabirizi *et al.,* 2006; Paterson *et al.,* 1996). The same authors also stated that under farmer management, milk production improved by 0.6-0.75 kg milk for every kg of dried Calliandra. A mean response of 0.80 kilograms of milk per kilogram of dried Calliandra was obtained in a survey conducted among the same farmers (Franzel *et al.,* 2007). According to the study, farmers substitute dairy meal with caliandra as well as utilize it as a supplement to boost milk output (Tuwei *et al.,* 2003). Wambugu *et al.* (2006), reports that a farmer with 500 trees in Kenya and Uganda might expect net returns ranging from USD 62 to USD 122 annually at four sites. According to a survey carried out in the Chikwaka District of Zimbabwe, the use of fodder trees *(L. leucocephala, A. angustissima, L. diversifolia,* and *L. pallida)* in small-scale dairy operations resulted in gross margins between 13 and 334 dollars and benefit-to-cost ratios between 1.12 and 3.03 dollars (Moyo *et al.,* 2001).The efficiency of *L. leucocephala* as a dry season supplement for grazing steers was confirmed by a research done in semi-arid western Tanzania to investigate the effect of fodder trees on non-dairy cattle (Kakengi *et al.,* 2001).

2.6.3 Increased production and income from small ruminants supplemented with Calliandra leaves

Dairy goats fed fodder trees have a big impact on milk production (Niang *et al.,* 1996). The author further observed an ADG of 50 grams per day in goats supplemented with *Mimosa scabrella* in the highlands of Rwanda compared to 31 grams per day for grass alone. In comparison to ewes supplemented with concentrates, *Sesbania sesban*-fed ewes in Ethiopia produced 13% more milk, according to Mekoya *et al.* (2008). When given Calliandra, sheep in Kenya increased 79–90 grams of live weight each day. This suggested that Calliandra leaf meal has a high potential to replace soybean meal in compounded feeds for feeding goats reared for meat production (Ebong *et al.,* 2009). Favourable opinions on the impact of tree legumes on weight gain and reproductive efficiency in sheep in Ethiopia were reported by Hess *et al.* (2006) and Mekoya *et al.* (2008).

2.7 Calliandra *(Calliandra calothyrsus)*

Calliandra belongs to the subfamily Mimosoideae of the family Leguminosae (Fabaceae). In addition to the humid and sub-humid tropics of Mexico and Central America, it is native to Indonesia. In 1036, it moved from Indonesia to Java and has subsequently spread to other parts of South-East Asia (Palmer *et al.*, 1996). It was first used to give shade on Indonesian coffee farms, but it later turned out to be more valuable for other things including land reclamation, fodder, and fuel wood. Calliandra can produce up to 18.2 tons of dry matter per hectare when grown for fodder. It produces slightly less than other fodder trees like Leucaena (21.8 ton DM/ha) and Gliricidia (19.2 ton DM/ha) (Catchpoole *et al.*, 1990).
Calliandra, however, outperforms Leucaena in its ability to tolerate acidic soils and protect itself from psyllid attack because adult psyllids cannot feed or lay their eggs on it (Vandesschricke *et al.,* 1992). Similar to the majority of legume trees, the Calliandra has substantially higher concentrations of micronutrients and crude protein than grasses do. Calliandra meets the criteria for a good feed supplement because of its high crude protein content, especially when it comes to grasses and crop residues, which are the main sources of protein for animals consuming low quality forages. The high quantities of tannin, which have a tendency to bind protein, fibre, and minerals, result in reduced digestion despite the food's high protein content. Low nutritional digestibility and protein availability might result from high tannin concentrations (>5% DM). The review offers the nutritional composition of Calliandra and its effects on animal growth, which provides a summary of current understanding.

2.7.1 Palatability and acceptance of Calliandra leaves by animals

According to research from Indonesia and Australia, Calliandra is best used fresh rather than dry or wilted. In studies where sheep were fed freshly obtained Calliandra leaves, voluntary intake was 59 g dry matter/Kg W $^{0.75}$ as opposed to 37 g dry matter/Kg W $^{0.75}$ for dried materials (Palmer *et al.,* 1996). Calliandra leaves are typically quite tasty to ruminant animals that have previously consumed the fodder**.** High levels of Calliandra leaves supplementation (wilted or dried) will reduced palatability. Supplementation of (20–40%) had no impact on intake (Phiri *et al.*, 1992). Reports on acceptability of Calliandra compared with other leguminous trees are conflicting. Fresh Calliandra's acceptance was higher than *Sesbania sesban* and *Gliricidia sepium,* but lower than Leucaena, according to Phiri *et al.* (1992). However, according to reports from Nigeria, Gliricidia had the greatest preference index, followed by Leucaena and Calliandra. According to the paper, the reason behind Gliricidia's high preference index was because it was the forage that goats were most accustomed to at the time of the study. Even though Gliricidia is of great grade, animals initially find it to be unappealing (Norton, 1994).

2.7.2 Crude protein content of Calliandra leaves

According to Patterson *et al.* (1996), Calliandra has a protein concentration between 20 and 30%, which is comparable to other forage tree legumes as *Gliricidia sepium* (20–30%) and Leucaena (25.9%). Calliandra's crude protein concentration varies depending on the cultivar, plant component, cutting interval, and season (Rusdy, 2016). Younger Calliandra shoots and leaves contain more tannin than older shoots. When the cutting period was extended from 6 to 12 weeks, crude protein dropped from 22.4 to 21.6%, according to Tuwei *et al.* (2003). Calliandra has a high protein content (> 7%), which is necessary to supply the minimal ammonia levels (70 mg NH3/L) needed for optimal rumen microbial activity (Norton, 1994). Because of this, Calliandra makes an excellent feed supplement for animals fed with forages of poor quality. However, feeding large doses of tannins may reduce protein degradability in the rumen due to complexes formed with protein, resulting in lower rumen nitrogen ammonia concentrations and more protein being absorbed outside of the rumen (Rusdy, 2016).

2.7.3 Tannin content of Calliandra leaves

The level of condensed tannin (CT) contents of Calliandra varies depending on species, variety, stage of maturity, season and sampling method (Table 2.3). However, it ranges from 6.00 to 16.0%, with an average of 9.5% (Palmer *et al.*, 1996; Rusdy, 2016). Condensed tannin in Calliandra is much higher than found in Gliricidia (3.79%) and Leucaena (3.51%).

Table 2.3 Condensed tannin content of Calliandra leaves

CT (%)	References
7.43	Setyawati *et al.* (2016)
8.08	Abqoriyah *et al.* (2014)
19.4	Salawu *et al.* (2002)
11.2 – 16.0	Premaratne *et al.* (1999)

Depending on the amount taken, tannins in ruminant diets can have both positive and negative consequences. While moderate concentrations of tannins prevent protein from being broken down in the rumen and make the protein available for enzymatic digestion in the lower stomach, low levels of tannins are totally destroyed in the rumen by the microorganisms (Perera *et al.*, 1996). Tannins bind dietary protein during chewing and shield it from microbial attack in the rumen at a CT level of 2–4% DM, which increases nitrogen retention and boosts growth rates and milk production (Barry, 1983; D'Mello, 1992). According to Barahona *et al.* (2003), protein complexes with CT at greater concentrations (>5% DM) are anti-nutritive because they reduce voluntary intake and digestibility. With a CT higher than 5%/Kg DM, Calliandra has been classified as high Tanniniferous forage (Rusdy, 2016).

2.7.4 Digestibility

Different authors have reported different values regarding Calliandra's *in-vitro* dry matter digestibility (IVDMD) and *in-vitro* organic matter digestibility (IVOMD) in comparison to other fodder trees like Leucaena, Gliricidia, and Sesbania, (Table 2.4). According to Dzowela *et al.* (1995), the IVDMD and IVOMD values are influenced by the drying technique, ADF, and tannin concentration. In Calliandra, the freeze drying procedure produced the greatest IVDMD values, followed by sun drying and oven drying. The low IVDMD and IVOMD value of Calliandra may be caused by its high tannin content, despite the fact that it has a relatively low ADF concentration (about 25%) (Premaratne *et al.*, 1999). Since Calliandra has a poor rate of digestion, it should only be consumed as a supplement and not as a main feed.

Table 2.4 IVDMD and IVOMD of Calliandra in relation to other fodder trees

Fodder	IVDMD (%)	IVOMD (%)	References
Calliandra	19.5 – 40.2	26.6	Dwozela *et al.* (1995)
Calliandra	25.3	26.6	Perera *et al.* (1996)
Calliandra	27.3	36.1	Premaratne *et al.* (1999)
Calliandra	38.9	36.5	Tuwei *et al.* (2003)
Calliandra	-	48.4	Santoso *et al.* (2013)
Calliandra	35.88	-	Barrios (2016)
Leucaena	65.2	67	Datt *et al.* (2008)
Gliricidia	54.0	52	Barrios (2016)
Sesbania	60.5	76.1	Dzowela *et al.* (1995)

2.7.5 Tannins and their effect on ruminants

Tannins are polyphenolic secondary metabolites that can be found in a variety of plant species that ruminants frequently eat. Depending on their content, chemical make-up, molecular weight, the type of animal involved, and the amount consumed, they may have either a positive or negative effect. They can be divided essentially into two categories: condensed tannins (CT) and hydrolysable tannins (HT). While moderate tannin concentrations may improve by-pass protein mostly because of a decrease in protein degradation in the rumen and an increase in amino acid transport to the small intestine, high tannin concentrations decrease voluntary feed intake and nutrient digestibility. Animal performance is thus improved as a result of these consequences. Trees and bushes contain both types of tannins, which have different nutritional and harmful effects. Condensed tannins are more tolerable for goats than for cattle and sheep.

Herbivores have evolved many methods over the course of evolution to cope with ingesting tannin-rich plants (Alonso-Daz *et al.*, 2010; Frutos *et al.,* 2004). While sheep only create proline-rich proteins when ingesting plants high in tannins, goats and other browsers do so regularly (Lamy *et al.,* 2008; Vaithiyanathan *et al.,* 2001). Some rumen microorganisms have adaptable mechanisms that allow them to break down hydrolysable tannins more quickly or to reduce their activity by methylating phenolic hydroxyl groups. These microbes can work well in situations with a lot of tannic acid. Tannins are prevented from having a negative impact on rumen bacteria by the production of extracellular polysaccharides with a high affinity for binding tannins and the development of thick glycoprotein with a high tannin affinity. The defence of important membrane proteins by deliberate use of lipids may be the adaptive mechanism by which the rumen bacteria could tolerate and function effectively in the face of high tannin levels (Pell *et al.,* 2000**).**

2.8 Alleviation of anti-nutritional effects of tannins

Various methods devised to counteract the deleterious effects of high tannin content in tropical forages (>5 % of dry matter) to improve their nutritional value.

2.8.1 Grinding

Grinding improves surface area while reducing particle sizes. This makes it easier for plant phenolic oxidases and tannins to interact, which lowers the level of tannin (Manach *et al.,* 2004; Vitti *et al.,* 2005).

2.8.2 Storage

Storage lowers the concentration of tannin. Total phenols and condensed tannins (CTs) decrease when newly chopped leaves with 40% moisture are stored at 37°C, followed by 50°C and room temperature. Several authors have noted that storage has caused the tannins to diminish (Ben *et al.,* 2005; Vitt *et al.,* 2005).

2.8.3 Chopping

Chopping increases, the contact of tannins with plant phenolic oxidases, which results in their oxidation, chopping and grinding diminish the tannin content (Ben *et al.,* 2005; Wina *et al.,* 2005).

2.8.4 Drying

This can take place under the shed or green house for 24 to 72 hr or in the sun for 24 to 48 hr. Cassava and Leucaena leaves' tannin levels decreased after drying (Makkar, 2003). In order to ensure that moisture is removed from the feed during feeding, this drying environment is more effective for feedstuffs with higher moisture content.

2.8.5 Chemical means

To reduce the tannin concentration, chemicals created in a lab must be used. It uses 30% acetone, 50% methanol, and 40% ethanol as aqueous organic solvents, which may remove up to 70% of the tannins from leaves. Due to the oxidation of phenolics by oxygen at higher pH values, the use of alkalis such sodium hydroxide (0.05 M) is beneficial in treatment. The tannin level was reduced by almost 95% by the oxidizing agents and potassium permanganate (0.02 M). Additionally, used to lower tannin levels is ferrous sulphate, a tannin-complexing agent. The inclusion of urea is crucial for the release of ammonia, which is required for tannin inactivation.

2.8.6 Use of wood ash

This is a good source of alkali that will help reduce the amount of total phenols in the product. Some cultures prepare high-tannin sorghum and millet for human consumption using wood ash solutions. Tannin-rich feedstuffs may be de-tanned with the use of wood ash, a cheap supply of alkali.

2.9 Role of supplementation in ruminant nutrition

Low digestibility, energy, and protein are all characteristics of poor quality roughages. To maximize their output, rumen microorganisms need fermentable metabolizable energy (FME) and metabolizable protein (MP), which is crucial for guaranteeing a high output in animals. Feeds with less than 7% crude protein produce a negative nitrogen balance, which inhibits the growth of rumen microorganisms (Ondiek *et al.,* 2000). So, in order to increase intake of basal diets, supplementation is required to make up for any deficiencies. According to Gatenby (1986), the most popular types of dietary supplements are protein sources like soy meal, cotton seed cake, and groundnut cake, energy sources like molasses, maize bran, and rice, non-protein nitrogen (NPN), and minerals (Table 2.5)

Table 2.5 Types of protein supplements available in Kenya

By-product	CP (% DM)	References
Sunflower cake	29.3 -37.9	FAO (2012)
Cotton seed cake	38.7 – 49.8	FAO (2012)
Pymarc	20.2 - 23.5	Maina *et al.* (2012)
Cotton seed cake	39.8- 45.6	NRC (1984)
Sunflower cake	28.6 - 34.8	NRC (1984)

Concentrates are expensive, thus their use should be supported by the anticipated increase in production. Roughages that are less expensive can be used by ruminants to meet their nutritional needs for growth, maintenance, and reproduction. Both the soluble and insoluble portions of the plant matter that is consumed are digested by rumen microbes (Van Soest, 1991). Some of these forages fed to ruminants have significant fibre percentages but low protein levels (Ibrahim *et al.,* 1995). By boosting the rumen's ecology through supplementation with high nitrogen feeds, an animal's capacity to digest the fibrous components of these forages is increased (Preston *et al.,* 1987). Supplementation is linked to increased intake of dry matter (DM) from low-quality base foods such grass hay and crop wastes (wheat, rice, barley, straw and maize stover). After giving goats *Tithonia diversifolia* supplements, Wambui *et al.* (2006) showed an increase in DM consumption of maize stover from 271 gKg^{-1} DM to 336 gKg^{-1} DM. This might be because Tithonia supplements can supply the N and energy that microorganisms in the rumen need to degrade food. A good supplement is one that either maintains or improves the intake of the basal diets, according to Kaitho (1997).

CHAPTER THREE

NUTRITIVE VALUE AND DEGRADATION OF BRACHIARIA AND RHODES GRASS HAY SUPPLEMENTED WITH CALLIANDRA LEAVES

Abstract

Twelve diets consisting of Brachiaria and Rhodes grass hay supplemented with (0%, 10%, 20%, and 30%) levels of Calliandra leaves were evaluated for chemical composition and *in-vitro* degradability. Chemical composition including (polyphenols) condensed tannin (CT) and *in-vitro* gas production characteristics were determined. Rumen liquor collected from six Red Maasai sheep was used to determine the *in-vitro* degradation. The data was analysed by general linear model of ANOVA using SAS (2002) software (version 9.0). Results from chemical composition showed that Calliandra leaves had the highest protein (CP) content of 21.1% and (CT) content of 8%. The CP content in the supplemented diets increased ($p<0.05$) ranging from 5.8% to 12.6% (Brachiaria + Calliandra) and 4.2% to 10% (Rhodes + Calliandra), respectively. The relatively high CP in Calliandra leaves indicates its potential use as a protein source for sheep. The ether extract (EE) increased ($p<0.05$) with supplementation while NDF and ADF decreased ($p<0.05$) with supplementation. The CT in the diets ranged from 0.9% to 3.5% which is lower than 5% considered detrimental to intake. The mineral profile likewise improved ($p<0.05$) with supplementation. The *in-vitro* gas production after 24 and 48-hour incubation period, showed significant difference ($p<0.05$) between the basal diets and the supplemented diets. The potential (a + b) and the rate (c) ranged between 14 to 40 ml and 0.02 to 12.6 /hr. Brachiaria supplemented with 30% Calliandra recorded the highest rate of gas production (12.6%/hr.) and gas production (40/ml/200mg). The *in-vitro* organic matter digestibility (IVOMD) increased ($p<0.05$) ranging from 34.6% to 54.1% with increased levels of supplementation. Brachiaria supplemented with 30% Calliandra had the highest *in–vitro* organic matter digestibility (54.1%). The study therefore concluded that Brachiaria grass supplemented with 30% Calliandra has a great potential as a forage diet for growing Red Maasai sheep.

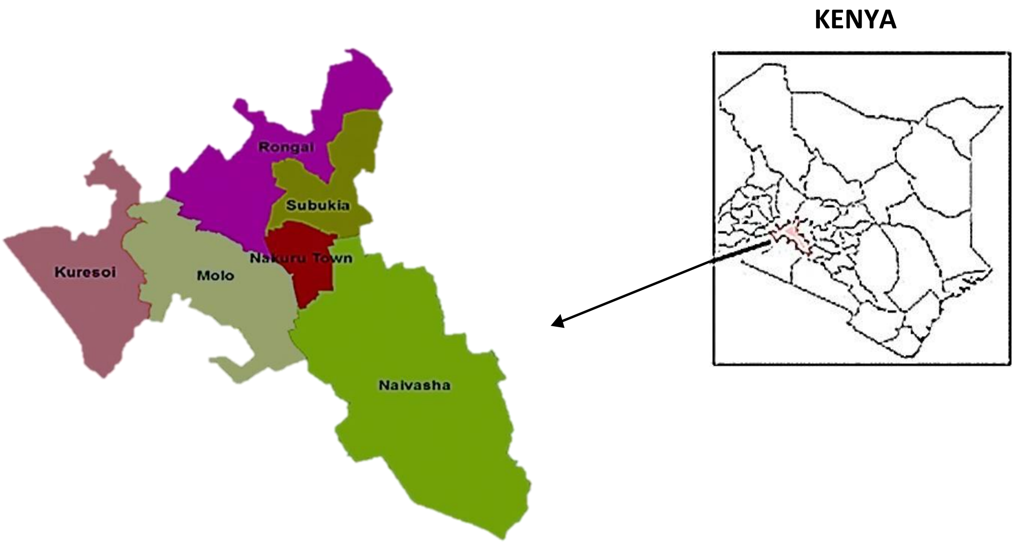
3.1 Introduction

Forages are a crucial part of ruminants' diets because they supply the crude fibre essential for rumen function. Brachiaria is a major tropical grass that is becoming quite liked among Kenyan farmers (Maass *et al.,* 2015). It can be made into hay or fed fresh to stalled ruminants (Cook *et al.,* 2005). It contains 8% to 15% crude protein and 61 to 67% NDF by DM, respectively (Herrero *et al.*, 2001; Meale *et al.*, 2012). Brachiaria is a climate-smart pasture with many desirable qualities, including the ability to sequester carbon, increase nitrogen use efficiency through biological nitrification inhibition (BNI), reduce greenhouse gas emissions, and pollute ground water. It is also adapted to marginal soils, water stressed, and shade tolerance, high biomass production potential, highly palatable, and nutritious (Mutai *et al.*, 2017; Subbarao *et al.*, 2009). Rhodes grass (*Chloris gayana)* is a grass whose seeds are widely available and simple to plant and manage, they have been utilized extensively to improve pastures. In very young leaves, crude protein levels can reach 17%, but in older leaves, they fall to 3% (Loch, 2004). Varieties grown in Kenya provide a considerable quantity of herbage for grazing and hay. They are readily eaten by livestock even when they are mature although the nutritive value is very low at old age (Mero *et al.*, 1997; Mtenga *et al.*, 1990; Mupangwa *et al.*, 2000; Osuga *et al.*, 2012). Brachiaria and Rhode grass hay if fed solely, may not sufficiently supply nutrients required for maintenance, growth and production (Lowe *et al.*, 2015; Mudzengi *et al.*, 2014). Calliandra is a leguminous fodder shrub with (200–300 gKg^{-1} DM) crude protein content, which is rich in minerals (Paterson *et al.*, 1996). Animals find it to be delicious and accept it (Palmer *et al.*, 1996). It has been shown that dairy cattle fed with Calliandra produce more milk and faster growth of calves. Calliandra leaves have been demonstrated to enhance goats' dry matter intake (DMI) and growth (Ebong 1996; Kaitho, 1997). However, there is little available information in Kenya about Calliandra supplementation in sheep. The diets of ruminants must also include vitamins and minerals. Although they rarely lacking in forages, their content may vary because of several factors like forage species and environment. The objective of this study was to evaluate the nutritive value and *in-vitro* degradation of Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra leaves.

3.2 Materials and methods

3.2.1 Study site

This study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) Lanet in Nakuru County, in Kenya. The Center is situated at a height of 1920 m above sea level between the longitudes of 36° 09' E and 00° 18' S. The Center is located on 1418 hectares of land that is divided into two agro ecological zones (AEZs). 20% of the land is in AEZ III, while 80% is in AEZ IV (Jaetzol *et al.*, 2010). In this region, the rainy season is bimodal, with the long rains beginning in March and lasting until June and the short rains beginning in November and ending in December. Temperatures range from 10°C to 30°C, and there is an average annual rainfall of 600–1000 mm (Jaetzol *et al.*, 2010). The soils are deep sandy loam with a pH of 5.5 to 6.5 (FAO).



Source: **https://goo.gl/images/HBS7Fe**

Figure 3.1 Map of Nakuru County showing the study site

3.3.2 Feed preparation

The basic feed ingredients used in the study were Brachiaria *(Brachiaria ruziziensis)* hay, Rhodes grass *(Chloris gayana)* hay, and Calliandra (*Calliandra calothyrsus)* leaves. The KALRO, Lanet farm supplied the Brachiaria and Rhodes grass hay. Since there wasn't enough Calliandra at the institution farm, the bulk was obtained from nearby farmers. The leaves were packaged and stored in a well-ventilated barn after being dried in the greenhouse. Before the experiment began, grass hay and dried

Calliandra leaves were ground to pass through a 4 mm sieve for feeding trials and a 1 mm screen for chemical analyses (AOAC, 2005). The feeds were then formulated into 12 diets along a CRD (3x4) factorial design consisting of three basal diets Brachiaria grass hay, Rhodes grass hay and a (50:50 mixtures of Brachiaria and Rhodes grass hay) as the main effects and supplementation of Calliandra leaves (0%, 10%, 20%, and 30%) as interaction levels, treatment one (T1) (0% Calliandra supplementation) served as the control (Table 3.1).

Table 3.1 Experimental diets

Diets		Levels of Calliandra leaves (%)			
		T1	T2	T3	T4
Brachiaria hay	Calliandra	0	10	20	30
	Brachiaria	100	90	80	70
Rhodes hay	Calliandra	0	10	20	30
	Rhodes	100	90	80	70
Brachiaria & Rhodes hay	Calliandra	0	10	20	30
(50: 50) mixture	Brachiaria & Rhodes	100	90	80	70

3.3.3 Chemical analysis

Dietary samples were examined in accordance with the method outlined by Van Soest *et al.* (1991). The proximate analysis was established using AOAC (2005) procedures. According to Julkunen-Titto (1985) and Warly *et al.* (2004), the Folin Ciocalteu technique was used to extract phenolic compounds using 70% aqueous acetone and total extractable phenols (TEPH). The method prescribed by Porter *et al.* (1986), was used to measure and determine condensed tannin (CT). Macro and micro minerals: Calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) were analysed using atomic absorption spectrophotometer (AAS).

3.3.4 *In-vitro* gas production

The *in-vitro* gas production was determined according to Menke *et al.* (1988). This was carried out at the end of the (12 weeks) of the feeding trial. About 300 ml of rumen liquor was extracted by use of a suction pump from six sheep before morning feeding. The liquor was then immediately transferred into a thermos flask, after being filtered through two layers of cheese-cloth to obtain strained rumen fluid which was then flushed with carbon dioxide (CO_2). Triplicate samples (0.2 g) of the diets were accurately weighed into 100 ml calibrated glass syringes fitted with plungers. The syringes were then filled with 30 ml of rumen-buffer (1:2) mixture consisting of 10 ml of rumen fluid and 20 ml of buffer solution. Three blank samples were then prepared containing 30 ml of medium (inoculum and buffer only) then incubated at the same time with the other samples. The syringes were incubated in a thermostatically controlled water bath at 39^{o}C for 0-96 hours. The gas production readings were recorded at 0, 3, 6, 9, 12, 18, 24, 36, 48, 72 and 96 hr. The average gas volume produced from the blanks was deducted from the volume of gas produced from sample. The calculated values of gas production were fitted into the model developed by Ørskov *et al.* (1979) to determine the degradability of the feed. *In-vitro* organic matter digestibility was calculated from the equation: OMD (%) = 18.53 + 0. 9239 (gas production at 48 hr) + 0.0540 CP (Menke *et al.,* 1988). The metabolizable energy (ME) was estimated using the equation of the Australian Agricultural Council (AAC, 1990) for tropical forages as follows:

$$\text{ME MJ/Kg DM} = \text{DOM gKg}^{-1}\ \text{DM} \times 18.5 \times 0.81$$

Where ME is the metabolizable energy (MJ/Kg DM), MJ is mega joules, DM is dry matter and DOM is digestible organic matter (gKg^{-1} DM)

3.3.5 Statistical analysis

The data was analysed by general linear model of ANOVA (SAS, 2002) software (version 9.0). Means were separated using LSD at ($P<0.05$).

Statistical model

Yijk =μ + Ai +Bj + (BR) ij + eijk

where

Yijk = (Nutrient content, minerals and degradation)

μ = overall population mean

Ai = effect of level of factor A (Diets 1, 2 and 3)

Bj = effect of level of factor B (Treatments 1, 2, 3 and 4)

(BR) ij = effect of interaction between Factor A and B.

eijkl = random error associated with Yijk

3.4 Results and discussion

3.4.1 Chemical composition

The chemical composition of the feed ingredients is presented in Table 3.2 Dry matter (DM) content ranged from the highest 940.1 gKg^{-1} DM (Rhodes grass) to the lowest 893.8 gKg^{-1} DM (Calliandra). Brachiaria had the highest OM content (918 gkg^{-1} DM) followed by Calliandra (915 gKg^{-1} DM) and Rhodes (911 gKg^{-1} DM) having the least. Rhodes grass had the lowest CP content (42.4 gKg^{-1} DM) followed by Brachiaria (58.3 gKg^{-1} DM), while Calliandra leaves had the highest (211.5 gKg^{-1} DM).

Table 3.2 The proximate composition of Brachiaria, Rhodes grass hay and Calliandra leaves

Nutrients (gKg^{-1} DM)	Brachiaria hay (gKg^{-1} DM)	Rhodes hay (gKg^{-1} DM)	Calliandra leaves (gKg^{-1} DM)
Dry matter	930	940	893
Organic matter	918	911	915
Crude Protein	58.3	42.4	211
Crude fibre	398	392	256
Neutral detergent fibre	713	724	556
Acid detergent fibre	388	411	358
Ash	82.0	89.0	85.0
Ether Extract	8.5	9.2	118
TEPH	31.2	31.3	151
CT	9.6	9.2	80.1

The CP in the grasses is lower than the threshold of (7% or 70 gKg^{-1} DM) required for proper rumen function but within the range of 40 to 112 gKg^{-1} DM for tropical grasses (Van Soest *et al.,* 1991). The CP content of Calliandra was within the range of (200-300 gKg^{-1} DM) reported by Paterson *et al.* (1996). The CP levels of Calliandra reported in Kenya ranged between 160-210 gKg^{-1} DM (Kariuki, 1998; Odongo *et al.,* 1999). Rhodes grass had the highest NDF and ADF content (724 gKg^{-1} DM and 411 gKg^{-1} DM) followed by Brachiaria (713 gKg^{-1} DM and 388 gKg^{-1} DM) while Calliandra had the lowest (556 gKg^{-1} DM and 358 gKg^{-1} DM) respectively. The lower NDF in Calliandra in comparison with Rhodes grass and Brachiaria hay is in agreement with the general observations of lower NDF in legumes than grasses (Minson, 1990). Calliandra leaves had the highest content of condensed tannins (80.1 gKg^{-1} DM) while Brachiaria and Rhodes had the lowest (9.6 gKg^{-1} DM and 9.2 gKg^{-1} DM) respectively. This is in agreement with reports by Ahn *et al.* (1989) and Alonso-Diaz *et al.* (2011). Calliandra (118 gKg^{-1} DM) had the highest EE while and Brachiaria and Rhodes had the lowest (67.2 gKg^{-1} DM and 96.0 gKg^{-1} DM). Table 3.3 presents the chemical composition of the 12 experimental diets.

Table 3.3 Nutrient composition of experimental diets (gKg^{-1} DM)

Feed	DM	OM	CP	EE	ME (MJ)	NDF	ADF	ASH	CT
Brachiaria hay									
T1	930^{b}	917^{c}	58.3^{d}	8.5^{d}	5.79^{d}	713^{a}	388^{a}	87.2^{d}	9.6^{d}
T2	927^{c}	918^{b}	87.5^{c}	10.5^{c}	6.99^{c}	708^{b}	369^{b}	87.6^{c}	18.2^{c}
T3	932^{a}	918^{b}	112^{b}	45.8^{b}	7.29^{b}	703^{c}	356^{c}	88.9^{b}	26.4^{b}
T4	917^{d}	919^{a}	126^{a}	65.4^{a}	8.11^{a}	698^{d}	348^{d}	89.0^{a}	32.4^{a}
Brachiaria and Rhodes mixture hay (50:50)									
T1	931^{b}	918^{b}	45.2^{d}	7.8^{d}	5.22^{d}	722^{a}	403^{a}	81.3^{d}	10.6^{d}
T2	933^{a}	918^{b}	77.3^{c}	11.5^{c}	6.34^{c}	716^{b}	396^{b}	81.5^{c}	18.6^{c}
T3	927^{c}	918^{b}	94.8^{b}	46.2^{b}	7.09^{b}	711^{c}	378^{c}	81.7^{b}	26.3^{b}
T4	906^{d}	919^{a}	115^{a}	65^{a}	7.60^{a}	708^{d}	363^{d}	81.8^{a}	33.3^{a}
Rhodes grass hay									
T1	911^{c}	902^{d}	42.4^{d}	9.2^{d}	5.2^{d}	724^{a}	411^{a}	81.3^{d}	9.2^{d}
T2	911^{c}	904^{c}	70^{c}	11.8^{c}	5.26^{c}	721^{b}	406^{b}	81.6^{c}	19.5^{c}
T3	912^{b}	915^{a}	81.7^{b}	50.1^{b}	6.86^{b}	714^{c}	398^{c}	82.0^{b}	25.4^{b}
T4	913^{a}	914^{b}	99.8^{a}	72.1^{a}	7.52^{a}	710^{d}	369^{d}	82.6^{a}	35.4^{a}
SEM	1.67	0.97	4.50	4.34	0.17	1.29	3.52	0.54	1.66

[abcd]Means with different subscript in a column are significantly different at 5% (p<0.05)

DM: Dry Matter; CP: Crude Protein; EE: Ether Extracts; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre; OM: Organic Matter; CF Crude Fibre; TFPH: Total extractable Phenolic; CT: Condensed Tannins SEM: Standard Error of Means, (MJ/Kg DM): Estimated from OMD %, T1 :(0% Calliandra); T2:(10% Calliandra); T3:(20% Calliandra); T4: (30% Calliandra).

The CP content was significantly ($p<0.05$) higher for the supplemented diets than the control. The CP content ranged from 42.4 gKg^{-1} DM for Rhodes grass (T1) to 126.9 gKg^{-1} DM for Brachiaria (T4). The energy level also increased with supplementation. The estimated energy in Brachiaria increased from 5.79 ME (MJ)/Kg DM to 8.11 ME

(MJ)/Kg DM, while Rhodes grass increased from 5.20 ME (MJ)/Kg DM to 7.52 ME (MJ)/Kg DM. Supplementation reduced NDF and ADF levels due to the lower levels of NDF and ADF in Calliandra. The CT in the diets varied and ranged between 9.6 gKg^{-1} DM to 35.4 gKg^{-1} DM which is lower than 50 gKg^{-1} DM considered detrimental to intake (Barry *et al.*, 1984; Waghorn *et al.,* 1994). The diets supplemented with 30% Calliandra had the highest levels of Calcium and Phosphorus. These compositional variations of the diets reflected the composition of Calliandra and the level of supplementation.

3.4.2 *In-vitro* gas production

The different gas production levels are recorded in (Table 3.4). Brachiaria (T4) had the highest gas production of 21.47 ml/200 g DM and 31.13 ml/200 g DM after 24 and 48 hr respectively. It was followed by Mix (T4) and Rhodes (T4) with (20.42 ml/200g and 28.15 ml/200 g) and (19.82 ml/200 g and 28.39 ml/200 g) respectively. The lowest gas production recorded was from the basal diets Rhodes (T1), Mix (T1) and Brachiaria (T1) which had (4.83 ml/200 g and 15.02 ml/200 g), (10.38 ml/200 g and 15.02 ml/200 g) and (12.87 ml/200 g and 18.39 ml/200 g) respectively. There was significant difference ($p<0.05$) in gas production between the basal diets (main effect) and the levels of supplementation (interactions).

The potential (a + b) and the rate (c) ranged between 14 to 40 ml and 0.02 to 12.6/hr. The rate of gas production (c) mostly explains the rate of passage of feed through the rumen, whereas the potential gas production ($a + b$), is associated with potential degradability of feed (Khazaal *et al.*, 1995). This indicates that the higher values obtained for the potential gas production in the Brachiaria (T4), Mix (T4) and Rhodes (T4) might be due to a better nutrient availability for rumen microorganisms. The calculated organic matter digestibility (OMD) ranged from 34.7 to 54.1%. Brachiaria (T4) had the highest (54.1%) whereas Rhodes (T1) had the lowest (34. 1%). IVOMD of basal diet of Brachiaria hay in this study was lower than 47% to 55% reported by Kawashima *et al.* (2006). This may have been due to the lower quality of Brachiaria hay used in this study. Metabolizable energy (ME) was estimated from OMD%. The calculated energy values ME (MJ/Kg DM) in the diets, ranged from 5.22 to 8.11 ME (MJ/Kg DM). There was a positive correlation between the level of energy and supplementation rate. This indicated that supplementation increased the supply of metabolizable energy in the diets. However, some of the values are moderate and lower than the recommended minimum energy level of 8 to 10 MJ/Kg DM of minimum protein level of about 80 gKg^{-1} DM for maintenance by sheep (Gatenby, 1986; Minson, 1990; NRC, 2007).

Table 3.4 *In-vitro* gas production (ml/200 g DM) of the experimental diets

Diets	Reading Hour			Estimated Parameters	
	24.00	48.00	a + b	c(%h)	OMD 48(%)
Brachiaria hay					
T1	12.9^{d}	18.4^{d}	27.7^{d}	0.02^{d}	38.7^{d}
T2	14.6^{c}	25.3^{c}	31.6^{c}	0.13^{c}	46.7^{c}
T3	18.4^{b}	26.0^{b}	32.9^{b}	7.01^{b}	48.6^{b}
T4	21.5^{a}	31.1^{a}	40.4^{a}	12.6^{a}	54.1^{a}
Brachiaria and Rhodes mixture hay (50:50)					
T1	10.4^{d}	15.0^{d}	16.6^{d}	7.02^{d}	34.8^{d}
T2	14.2^{c}	21.2^{c}	31.2^{c}	0.03^{c}	42.3^{c}
T3	17.5^{b}	25.6^{b}	32.9^{b}	0.15^{b}	47.3^{b}
T4	20.4^{a}	28.2^{a}	39.1^{a}	7.24^{a}	50.8^{a}
Rhodes hay					
T1	4.8^{d}	15.2^{d}	14.9^{d}	0.18^{d}	34.7^{d}
T2	12.8^{c}	13.8^{c}	28.9^{c}	0.05^{c}	35.1^{c}
T3	15.6^{b}	24.7^{b}	31.7^{b}	0.06^{b}	45.8^{b}
T4	19.8^{a}	28.4^{a}	33.9^{a}	7.11^{a}	50.2^{a}
CAL	16.8	20.4	22.1	4.31	37.1
SEM	0.83	1.45	1.28	0.71	1.13

^{abcd}Means with different subscript in a column are significantly different at 5% ($p<0.05$)

OMD 48: In vitro organic matter digestibility calculated from the equation: OMD (%) = 18.53+0.9239 Gas production + 0.0540 Crude protein (Menke and Steingass, 1988). a, b, c are constants as described by Ørskov and McDonald (1979). CAL: Calliandra SEM=standard error of the mean

3.4.3 Mineral content of feed ingredients and formulated diets

Ash, macro and micro mineral concentration contents of the feed ingredients and the formulated experimental diets are presented in Table 3.5. Minerals both macro and micro play a very important role in the nutrition of animals. They are required for almost all chemical processes in the animals' body.

Table 3.5 Mineral content of the experimental diets

Major elements, (gKg^{-1} DM)						Trace elements, ($mgKg^{-1}$DM)			
Diets	ASH	P	K	Ca	Mg	Fe	Cu	Zn	Mn
Feed ingredients									
Brachiaria	89.0	0.09	11.30	0.16	1.80	43.00	0.45	38.00	154.0
Rhodes	82.0	0.05	9.43	0.15	1.29	24.00	0.40	22.00	108.0
Calliandra	85.0	2.47	14.60	9.50	2.86	87.00	1.42	84.00	288.0
Brachiaria hay									
T1	87.2^{d}	0.09^{d}	11.3^{d}	0.16^{d}	1.80^{d}	43.0^{c}	0.45^{d}	38.0^{d}	154.0^{d}
T2	87.6^{c}	0.33^{c}	11.6^{c}	1.09^{c}	1.91^{c}	47.4^{c}	0.55^{d}	42.4^{c}	166.8^{c}
T3	88.9^{b}	0.57^{c}	11.9^{b}	2.03^{b}	2.01^{b}	51.8^{b}	0.64^{d}	47.2^{b}	180.8^{b}
T4	89.0^{a}	1.37^{a}	12.3^{a}	2.96^{a}	2.12^{a}	56.2^{a}	0.75^{a}	51.8^{a}	194.2^{a}
Brachiaria and Rhodes mixture (50:50)									
T1	81.3^{d}	0.08^{d}	10.5^{d}	0.16^{d}	1.55^{d}	33.5^{d}	0.43^{d}	30.0^{d}	131.0^{d}
T2	81.6^{c}	0.32^{c}	10.9^{c}	1.09^{c}	1.68^{c}	38.9^{c}	0.52^{c}	35.4^{c}	146.7^{c}
T3	81.7^{b}	0.57^{b}	11.3^{b}	2.02^{b}	1.81^{b}	44.2^{b}	0.62^{b}	40.8^{b}	162.4^{b}
T4	81.8^{a}	0.82^{a}	11.7^{a}	2.96^{a}	1.94^{a}	49.6^{a}	0.73^{a}	46.2^{a}	178.1^{c}
Rhodes hay									
T1	81.3^{d}	0.05^{d}	9.43^{d}	0.15^{d}	1.29^{d}	24.0^{d}	0.40^{d}	22.0^{d}	108.8^{d}
T2	81.6^{c}	0.29^{c}	9.95^{c}	1.09^{c}	1.45^{c}	30.3^{c}	0.50^{c}	28.2^{c}	126.8^{c}
T3	82.0^{b}	0.53^{b}	10.5^{b}	2.02^{b}	1.60^{b}	36.6^{b}	0.60^{b}	34.4^{b}	144.0^{b}
T4	82.6^{a}	0.78^{a}	10.9^{a}	2.96^{a}	1.76^{a}	42.9^{a}	0.71^{a}	40.6^{a}	162.0^{a}
SEM	0.54	0.06	0.14	0.18	0.04	1.56	0.02	1.43	4.13

[abcd]Means with different subscript in a column are significantly different at 5% ($p<0.05$)

DM: Dry Matter; P: Phosphorous; K: Potassium; Ca: Calcium; Mg: Magnesium; Fe: Iron; Cu: Copper; Zn: Zinc; Mn: Manganese. Tannins SEM: Standard Error of Means *P*: *P*-value. T1:(0% Calliandra); T2:(10% Calliandra); T3:(20% Calliandra); T4: (30% Calliandra).

In this study, there was significant difference (p<0.05) in ash content across the feed ingredients and the formulated diets. Brachiaria grass had the highest (89.0 gKg^{-1} DM) ash content followed by Calliandra (85.0 gKg^{-1} DM) and Rhodes (82.0 gKg^{-1} DM) having the least. The ash content in the diets reflected the composition in the main ingredients which increased depending on the level of supplementation. The level of supplementation improved significantly (p<0.05) the mineral concentration in of the diets. According to

Miles *et al.* (2000), Calcium (Ca) and phosphorus (P) are important minerals in the diet of animals because they are involved in the growth of bones. Although these minerals are rarely deficient in forages (Nguku *et al.,* 2016), the amount of Ca (0.15 gKg^{-1} DM) and P (0.09 gKg^{-1} DM) in Brachiaria and Ca (0.16 gKg^{-1} DM) and P (0.16 gKg^{-1} DM) Rhodes grass in this study fell below (2.0 gKg^{-1} DM Ca) and (2.0 gKg^{-1} DM P) required for a (70 Kg) ewe fed on forages (NRC, 2007). Although supplementation with 30% Calliandra was able to raise the Calcium level of the basal diets to 2.96 gKg^{-1} DM, Phosphorous (1.37 gKg^{-1} DM) still fell short of the recommendation of NRC (2007). This is an indication that when sheep are fed on grass hay there is need for supplementation with suitable mineral supplements in the animal's diet. The macro mineral concentration (P, K, Ca and Mg) for Rhodes grass in this study is lower than reported by Deng *et al.* (2017) who reported higher levels of P, K, Ca except for Mg which was lower. However, the micro minerals Fe, Mn, Cu and Zinc were higher. The concentration of P, K, Ca, and Mg in Brachiaria reported in this study are consistent with those reported in earlier by Nguku *et al.* (2016). The Calcium and Phosphorous levels in Calliandra were consistent with those reported by Kinuthia *et al.* (2007). Generally, the mineral content in this study was higher in Brachiaria than in Rhodes grass. This concurs with the findings of Urio *et al.* (2006) in studies on mineral status of some grass species at Morogoro in Tanzania, reported high mineral content of *Brachiaria brizantha* as compared to *Chloris gayana* and other grass species. The mineral profile (macro-elements and micro-elements) in Calliandra was superior to that of the Brachiaria and Rhodes grass. This was reflected in the diets whereby there was a positive correlation between the level of supplementation and the mineral content.

3.5 Conclusion

The results from chemical analysis indicates that Brachiaria hay supplemented with 30% Calliandra has the highest crude protein content (126.9 gKg^{-1} DM) and superior mineral profile. Results from the *in-vitro* degradability indicates that Brachiaria hay supplemented with 30% Calliandra has the highest organic matter digestibility (OMD) of (54.1%) indicating that Calliandra is a suitable supplement for low quality forages. This study concludes that Brachiaria supplemented with 30% Calliandra leaves has a great potential as a dry season forage diet for sheep in the arid and semi-arid lands.

3.6 Recommendation

This study recommends the use of 30% supplementation of Calliandra leaves to improve the quality of both Brachiaria and Rhodes grass hay basal diets for sheep.

CHAPTER FOUR

RELATIVE PALATABILITY AND PREFERENCE BY RED MAASAI SHEEP OFFERED BRACHIARIA AND RHODES GRASS HAY SUPPLEMENTED WITH CALLIANDRA LEAVES

Abstract

A study was conducted to evaluate the effect on palatability and preference of supplementing Brachiaria (*Brachiaria ruziziensis)* hay and Rhodes *(Chloris gayana)* hay with different levels of Calliandra *(Calliandra calothyrsus)* leaves on Red Maasai Sheep. Nine male sheep averaging one year and weighing (22.0 ± 2.5 Kg) were used in a 3x4 factorial completely randomized design (CRD). Three animals in three replicates, were used to measure feed intake and palatability. Twelve experimental diets were formulated consisting of Brachiaria, Rhodes and a (50:50 mix) of Brachiaria and Rhodes grass hay as the basal diets, supplemented with (0%, 10%, 20% and 30%) of Calliandra leaves. Supplemental rates were used as treatments (T1, T2, T3 and T4) respectively. Treatment one (T1) served as the control. 200 g of each diet was offered daily in the morning at 08:00 hr (8 am) (EAT) with an allowance of 60 minutes feeding time. The feed left over were weighed and recorded each day and intake determined by difference. Palatability was calculated for each feed diet based on the daily feed intake divided by that of the highest feed intake and expressed as a percentage and then ranked in separate preference classes of high (>60%), medium (35-55%) and low palatability (<25%). The feeding trial lasted for 21 days. The data was analysed by general linear model of ANOVA using SAS (2002) software (version 9.0). Results showed that supplementation improved (p<0.05) crude protein, average daily intake and palatability of the experimental diets. Brachiaria grass supplemented with 30% Calliandra proved to be the most preferred diet with a dry matter intake (113.9 gKg^{-1} DM) and palatability index of (RPI=100%). The relative palatability indices according to treatments were as follows :(T4>T3>T2>T1). The study concluded that Brachiaria grass supplemented with 30% Calliandra has a great potential as a dry season forage diet for Red Maasai sheep.

4.1 Introduction

Availability of feeds both in quality and quantity is a major challenge faced by pastoralists during the dry season in the arid and semi-arid lands (ASALs) of Kenya. Due to the effects of climate change, these areas experience lower and unreliable rainfall which has aggravated the existing poor status of feed availability. During the dry season, pastoralist communities are forced to move from place to place in search of pasture or purchase feeds (mostly hay) from commercial farms. Generally, most of the hay available in the tropics is of low quality and if fed solely does not meet the basic nutrients requirements of the animals (Lowe *et al.,* 2011; Mekuriaw *et al.,* 2012; Mudzengi *et al.,* 2014). Protein and energy are the most deficient nutrients in the dry season, protein often being the most limiting (Mudzengi *et al.,* 2014; Wambui *et al.,* 2006). There is therefore need to look for alternative sources of protein to supplement the low-quality pasture and crop resides that may be available during the dry season. Leguminous fodder trees or multipurpose trees (MPT) are locally available and are rich in protein and can be used to supplement low quality pastures (Abdulrazak *et al.,* 2001; Rahmani *et al.,* 2005). Apart from being rich in protein and minerals, most of the MPTs are also known to contain high levels of anti-nutritive factors (ANFs) such as alkaloids, phenolic, tannins and aromatic compounds which bind nutrients especially proteins rendering them indigestible (Makkar *et al.,* 2003; Piluzza *et al.,* 2010; Waghorn, 2008). Most of these ANFs are also known to affect palatability and voluntary intake due to their astringent properties (Waghorn 2008).

Palatability and preference are parameters that can be used to evaluate the acceptability of a given feed to animals. The term palatability refers to those characteristics of a feed that provoke a sensory response (Baumont 1996; Yusmadi *et al.,* 2008). Preference on the other hand refers to the choice the animal makes when offered a variety of feeds (Baumont, 1996; Hussain *et al.,* 2009). Selection of feeds by animals depends on their palatability which are dependent on plant and animal factors. Plant factors that influence palatability include: species, chemical composition, physiological age, presence of ANFs. Animal factors include: species or breeds, organoleptic senses, individual differences and familiarity to the feed (Baumont, 1996). There are other techniques for assessing palatability such as oesophageal fistula technique and stomach content and faecal analysis (Ngwa *et al.,* 2003). However, they are not convenient because they are laborious, costly, complicated and considered as invasive. Direct feeding on pasture or stall feeding seems to be more suitable for palatability studies (Ben Salem *et* *al.,* 1994; Kaitho *et al.,* 1996; Ngwa *et al.,* 2003). Sheep are known to feed on a wide range of forages and select those that meet their nutritional requirements and to evade those that are toxic (Provenza, 1995). The objective of this study was to evaluate the effect on palatability and preference of supplementing Brachiaria *(Brachiaria ruziziensis)* hay and Rhodes *(Chloris gayana)* hay with different levels of Calliandra *(Calliandra calothyrsus)* leaves by Red Maasai sheep in Kenya.

4.2 Materials and methods

4.2.1 Experimental site

This study was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) Lanet in Nakuru County, Kenya. The Centre lies between longitude 36° 09’ E and latitude 00° 18’ S at an altitude of 1920 m above sea level. The Centre occupies 1418 hectares. The land is within two agro ecological zones (AEZs), where 20% of it lies within AEZ III and 80% in AEZ IV (Jaetzol *et al.,* 2010). The area has a bimodal rainfall season with the (long rains) starting from March to June and the (short rains) falling from November to December. The annual rainfall ranges between 600-1000 mm and temperatures between 10°C and 30°C (Jaetzol *et al.,* 2010). Soil pH ranges from 5.5 to 6.5. Soils are deep sandy loam with good water holding classified as Humic nitosols under Food and Agricultural Organization of the United Nations (FAO) classification.

4.2.2 Feed preparation

The main feed ingredients used in the study were Brachiaria *(Brachiaria ruziziensis)* hay and Rhodes grass *(Chloris gayana)* hay and Calliandra *(Calliandra calothyrsus)* leaves. Brachiaria and Rhodes grass were sourced from the KALRO, Lanet farm. Most of the Calliandra *was* sourced from local farmers since there was not enough in the institute farm. The leaves were dried in the green house, packaged and stored in a well aerated barn. Before the start of the experiment the grass hay and the dried Calliandra leaves were ground to pass through a 4 mm sieve for feeding trials and 1mm for chemical analysis (AOAC, 1990). The feeds were then formulated into 12 rations along a CRD (3x4) factorial design consisting of three basal diets Brachiaria grass hay, Rhodes grass hay and a (50:50 mixtures of Brachiaria and Rhodes grass hay) as the main effects and supplementation of Calliandra leaves (0%, 10%, 20%, and 30%) as interaction levels (Table 3.1). Treatment one (0% Calliandra supplementation) served as the control.

4.2.3 Experimental design, feeding and housing

Nine (n=9) male Red Maasai Sheep with an initial mean body weight (22.0±2.5 Kg) of about 1 year were used in a completely randomized design (CRD) replicated three times. They were confined in separate individual pens of (1.5 m x 2.5 m). Before the start of the experiment, sheep were all drenched using de-wormers to control internal parasites. Sheep were all sprayed with acaricides to control external parasites. The sheep were fed in two phases. Phase one: fourteen (14) days for adaptation to the different diets. Phase two: seven (7) days data collection involving daily feed offered and left over. The palatability study was conducted in a cafeteria feeding method as described by Abdulrazak *et al.* (2001). Each pen was provided with four feed troughs at 30 cm height to accommodate each of the four treatments (T1, T2, T3 and T4) respectively (Table3.1). They were offered 200 g each day in the morning at 8:00 hr (8 am) (EAT) with an allowance of 60 minutes feeding time. The refusals were collected, weighed and intake determined by difference. Each day, the physical positioning of the tested feed in the troughs was altered to eliminate possible biasness from preferences for one side. The sheep were then removed from the pens and allowed to graze for the rest of the day. Water and mineral supplements were offered *ad libitum*

4.2.4 Data collection

To determine the amount of feed consumed each day, the feed offered and refused was weighed using a digital weigh scale (with an accuracy of ±1 g). This was used to determine the relative palatability of the diets. Palatability was calculated for each feed diet based on the daily feed intake divided by that of the highest feed intake and expressed as a percentage as described by Abdulrazak *et al.* (2001) and then ranked in separate preference classes of high (>60%), medium (35-55%) and low palatability (<25%) (Lambart *et al.,* 1989; Obour *et al.,* 2015).

4.2.5 Chemical analysis

Samples of feeds offered and refused were collected daily and pooled for each sheep then sub-sampled for proximate and analysis. Proximate analysis was determined according to AOAC (2005) methods. The extraction of phenolics was carried out by using 70% aqueous acetone and total extractable phenols (TEPH) determined using Folin Ciocalteu procedures as described by Julkunen- Titto (1985) and Warly *et al.* (2004). Condensed tannin (CT) was measured and calculated as leucocyanidin equivalent, following the method of Porter *et al.* (1986).

4.2.6 Statistical analysis

The data was analysed by general linear model of ANOVA (SAS 2002) software (version 9.0). Means were separated using LSD at ($p<0.05$).

Statistical model

Yijk =μ + Ai +Bj + (BR) ij + eijk

where

Yijk = (dietary nutrient content, feed intake)

μ = overall population mean

Ai = effect of level of factor A (Diets 1, 2 and 3)

Bj = effect of level of factor B (Treatments 1, 2, 3 and 4)

(BR) ij = effect of interaction between Factor A and B.

eijkl = random error associated with Yijk

4.5 Results and discussion

Dry matter (DM) intake, palatability and preference of the experimental diets are represented in Table 4.1. The DM intake varied throughout the experimental period. The intake of diets T1 and T2 initially increased during the first 10 days of the experimental period but dropped drastically during the last 7 days, while the reverse trend was observed in T3 and T4. Rhodes (T1) recorded the lowest DM daily intake of 19.34 g/sheep/day. Brachiaria (T4) registered the highest daily DM intake (113.90 g/sheep/day). The level of supplementation greatly influenced feed intake in all treatments. There was an increase in intake with increased in the levels of crude protein in the diets. Intake was inversely proportional to the concentration of CF, NDF and ADF in that diets with high fibre registered low intake. Likewise, the Relative palatability indices followed the same trend whereby the diets with low CF, NDF, ADF were ranked high. In terms of preference, Brachiaria (T4) was ranked the highest *(*100%) and Rhodes grass (T1) the lowest (16. 62%).The preference class for Brachiaria, Rhodes and their mixture were similar at 30% supplementation with Calliandra. They were all ranked high. The lowest preference class recorded was from Rhodes (T1). Sheep in this study initially consumed more of the basal diet which they were more familiar to than those supplemented with Calliandra.

Table 4.1 DM intake, palatability index and preference ranking

Rations/Diets	Daily intake (gKg^{-1} DM)	Daily intake (g/sheep/day)	RPI(%)	Preference class
Brachiaria hay				
T4	113^{a}	124^{a}	100	High
T3	73.9^{b}	79.3^{b}	63.9	High
T2	67.1^{c}	72.4^{c}	58.3	Medium
T1	49.6^{d}	53.4^{d}	43.0	Medium
Brachiaria and Rhodes mixture (50:50)				
T4	103^{a}	113^{a}	91.7	High
T3	67.0^{b}	72.3^{b}	58.3	Medium
T2	58.3^{c}	66.0^{c}	53.2	Medium
T1	38.2^{d}	52.6^{d}	42.4	Medium
Rhodes hay				
T4	101^{a}	108^{a}	87.6	High
T3	50.4^{b}	54.7^{b}	44.0	Medium
T2	35.2^{c}	25.3^{c}	20.4	Low
T1	19.3^{d}	20.6^{d}	16.6	Low
SEM	0.63	5.82	4.70	
p	0.0001	0.0001	0.0001	

T1:(0% Calliandra); T2:(10% Calliandra); T3:(20% Calliandra); T4: (30% Calliandra).
SEM: Standard Error of Means P: P-value.
^{abcd}Means with different subscript in a column are significantly different at 5% ($p<0.05$)
High:(>60%), Medium: (35-55%) Low palatability (<25%)

A similar trend was also observed and reported by Ngwa *et al.* (2003). This pattern of intake was explained in a study by Provenza *et al.* (1995) which reported that ruminants prefer familiar to new or strange feeds and that they sample strange feeds with much caution. The increase in the levels of Calliandra in the diets increased DM intake and palatability (Kaitho, 1997). This may be due to the increased level of protein in the diets. This justifies Calliandra as a forage supplement due to its influence on feed intake and efficient utilization of poor-quality hay (Kaitho, 1997; Nyeko *et al.,* 2004). Although Calliandra is regarded as highly tanniniferous forage plants, the condensed tannin (CT) inclusion levels in the diets in this study were below (<50 gKg^{-1} DM) normally considered detrimental to intake and palatability due to its astringent property (Barry *et al.*, 1984; Waghorn *et al.*, 2008). This suggests that by supplementing Calliandra to low tannin basal diets, concentration of tannin in the diets decreased. This may explain why the CT content did not negatively influence intake and palatability of the diets. The order in which the diets were ranked according to treatments from the most palatable combination to the least based on daily DM intake and relative palatability index is as follows: (T4>T3>T2>T1). In this study Brachiaria grass (T4) was the most superior in terms of palatability and preference ranking while Rhodes grass (T1) had the poorest (Figure 4.1).

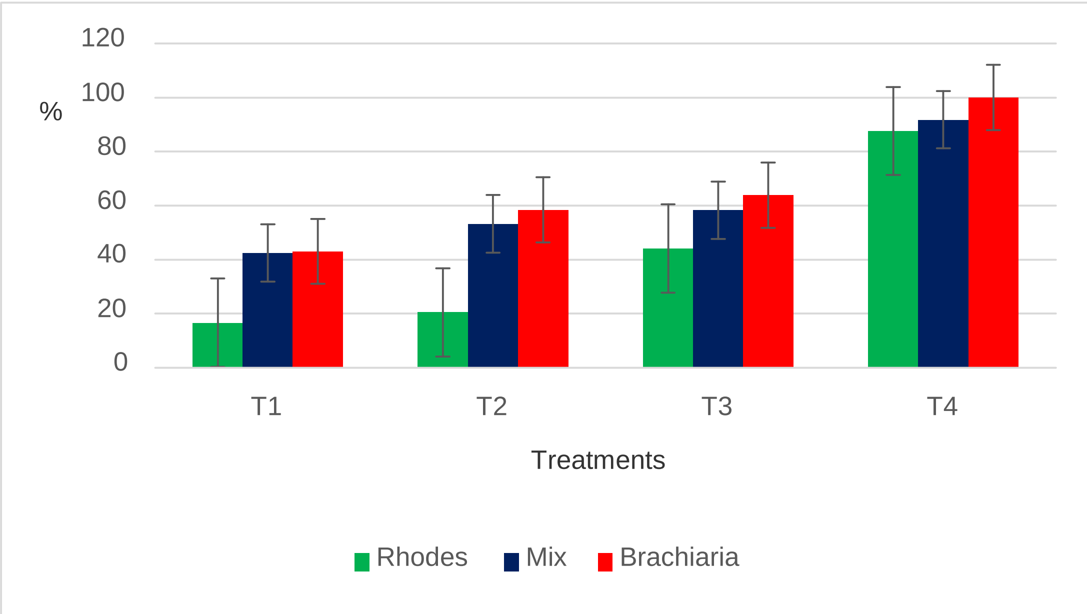


Figure 4.1 Ranked palatability indices of the experimental diets according to treatments

4.6 Conclusion

Supplementing Brachiaria and Rhodes grass with Calliandra leaves greatly improves the CP content of the diets. Supplementing Brachiaria and Rhodes grass with Calliandra leaves greatly improved DM intake, palatability and preference. Brachiaria hay supplemented with 30% Calliandra leaves had the highest in DM intake, palatability and preference. Brachiaria grass supplemented with 30% Calliandra had the great potential as a forage diet for Red Maasai sheep.

4.7 Recommendation

This study recommends feeding of Brachiaria hay supplemented with 30% Calliandra during the dry season in the arid and semi-arid areas of Kenya.

CHAPTER FIVE

INTAKE, DIGESTIBILITY AND LIVE WEIGHT CHANGE OF SHEEP FED ON BRACHIARIA AND RHODES GRASS HAY SUPPLEMENTED WITH CALLIANDRA LEAVES

Abstract

A study was conducted to evaluate the effect of feeding Red Maasai lambs with Brachiaria *(Brachiaria ruziziensis)* and Rhodes grass hay *(Chloris gayana)* supplemented with Calliandra *(Calliandra calothyrsus)* leaves at different levels. The specific objectives were to determine the voluntary feed intake, digestibility and weight change the lambs. Thirty-six (n=36) male sheep with a mean weight of 22 ± 2.5 Kg at 1 year were used in a completely randomized design (CRD) with a factorial arrangement, having 3 sheep per treatment replicated three times. Twelve (12) diets were formulated to constitute Brachiaria hay, Rhodes hay and 50:50 mix of Brachiaria and Rhodes hay, supplemented with Calliandra leaves at different levels. Treatments (T) were based on the level of Calliandra supplementation on DM basis where: (T1=0%), (T2=10%), (T3=20%) and (T4=30%), respectively. Proximate analysis and condensed tannin were determined. Sheep were kept in individual metabolic cages. Daily feed offered, left-over and faeces were weighed and recorded. The apparent nutrient digestibility was determined by difference in content in faeces and nutrient intake expressed as a percentage of feed intake. Weekly body weight measurements were taken after overnight fasting until the completion of the experiment. Sheep were allowed a 14-day adaptation period prior to the actual feeding trial. The feeding trial lasted 12 weeks. Data on feed intake, digestibility and weight gain was analysed by the general linear model of analysis of variance using SAS (2002, version 9.0). Results showed that supplementation increased ($p<0.05$) intake across the treatments whereby sheep on 30% supplementation recorded highest intake (78.68 gKg^{-1} DM $W^{0.75}$, 71.29 gKg^{-1} DM $W^{0.75}$ and 74.47 gKg^{-1} DM $W^{0.75}$) respectively. The nutrient digestibility of crude protein (CP), organic matter (OM) and dry matter (DM) followed a similar trend where supplemented diets recorded higher ($p<0.05$) values. The average daily gain (ADG) of sheep increased ($p<0.05$) after supplementation. Sheep fed on 30% supplementation recorded the highest gain (52.8g/d, 42g/d and 45.0g/d), respectively. Sheep fed Brachiaria hay supplemented with 30% Calliandra leaves showed superior performance in all parameters tested (intake, digestibility and weight gain),

leading to the conclusion that Brachiaria hay supplemented with 30% Calliandra leaves has a good potential for dry season feeding of growing Red Maasai sheep.

5.1 Introduction

Red Maasai sheep is one of the most prominent native breeds commonly found across Kenya and Tanzania among the Maasai communities. They are preferred by the Maasai communities because they are well adapted to arid and semi-arid areas and are known to be tolerant to internal and external parasites (Mugambi *et al.,* 1996; Ojango *et al.,* 2013). Apart from cows and goats, sheep are a major source of food and revenue. However, they are often faced by severe feed deficits (quantity and quality) especially during the dry season, which leads to weight loss, low productivity or death in extreme cases. Protein and energy are the most deficient nutrients in the dry season, protein often being the most limiting (Mudzengi *et al.,* 2014; Wambui *et al.,* 2006). Conservation of pastures in form of hay is one strategy of ensuring feed availability during the dry period. Rhodes grass *(Chloris gayana)* has been extensively used for hay making especially by large scale commercial farm in Kenya. Brachiaria *(Brachiaria ruziziensis)* is another important tropical grass that is gaining a lot popularity among farmers in Kenya (Maass *et al.,* 2015). This is because of its high biomass production potential, high palatability, nutritious and relatively tolerant to drought. The nutritive value of Brachiaria and Rhodes hay is relatively low and may not meet the basic nutrient requirements of animals during the dry season (Lowe *et al.,* 2011; Mekuriaw *et al.,* 2018; Mudzengi *et al.,* 2014). Nutrients, especially energy and protein are the major factors that determine productivity of all animals. Sheep require a minimum of 8 to 10 MJ/Kg DM of ME in order not to lose weight and a minimum protein of about 80 gKg^{-1} DM for maintenance (Gatenby, 1986; Minson, 1990; NRC, 2007). These energy and protein levels are considerably higher than the average values found in natural pastures and hay (Afzal *et al.,* 2007; CIAT, 2007).

Leguminous fodder trees such as Calliandra are generally rich in protein and minerals. Besides being available in the dry season, they have a reasonable content of CP ranging between 10-30% (Olafadehan *et al.,* 2016). Therefore, supplementing grass hay using leguminous fodder trees instead of commercial concentrates, provides a cheaper way of enhancing the quality of feed offered to ruminant animals during the dry season (Olafadehan *et al.,* 2016; Place *et al.,* 2009). Moreover, leguminous fodder trees being high in soluble protein have the potential of improving voluntary feed intake and digestibility when used to supplement low quality basal diets (Widiawati, 2002). This study aims at evaluating the effect of feeding (Brachiaria and Rhodes grass hay) supplemented with Calliandra leaves on feed intake, digestibility and weight gain of growing Red Maasai sheep.

5.2 Materials and methods

5.2.1 Study site

This study was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) Lanet in Nakuru County, Kenya. The Centre lies between longitude 36° 09’ E and latitude 00° 18’ S at an altitude of 1920 m above sea level. The Centre occupies 1418 hectares of land that lies within two agro ecological zones (AEZs), where 20% of the land lies within AEZ III and 80% in AEZ IV (Jaetzol *et al.,* 2010). The area has a bimodal rainfall season with the (long rains) starting from March to June and the (short rains) falling from November to December. The annual rainfall ranges between 600-1000 mm and temperatures between 10°C and 30°C (Jaetzol *et al.,* 2010). Soil pH ranges between 5.5- 6.5. Soils are deep sandy loam with good water holding classified as Humic nitosols under Food and Agricultural Organization of the United Nations (FAO, 1974) classification. The experiment was conducted from March to June 2020.

5.2.2 Feed preparation

The main feed ingredients used in the study were Brachiaria *(Brachiaria ruziziensis)* hay and Rhodes grass *(Chloris gayana)* hay and Calliandra *(Calliandra calothyrsus)* leaves. Brachiaria and Rhodes hay was sourced from the KALRO, Lanet farm. Most of the Calliandra was sourced from local farmers since there was not enough on the Institute farm. The leaves were dried in the green house, packaged and stored in a well aerated barn. Before the start of the experiment the grass hay and the dried Calliandra leaves were ground to pass through a 4 mm sieve for feeding trials and 1 mm for chemical analyses, respectively (AOAC, 2005). The feeds were formulated into 12 rations consisting of three basal diets: Brachiaria hay, Rhodes hay and a (50:50 mixtures of Brachiaria and Rhodes hay) supplemented with Calliandra leaves (0%, 10%, 20%, and 30%) levels (Table 3.1). Treatment 1 (0 % Calliandra supplementation) served as the control.

5.2.3 Experimental animals and management

Approximately 1-year-old Red Maasai male sheep (n=36) weighing 22.0 ± 2.5 Kg were purchased from pastoralists in Narok County. Information from the owners was used to determine the age of the sheep and confirm by dentition. Before the start of the experiment, sheep were all drenched using appropriate de-wormers to control internal parasites. Sheep were all sprayed with acaricides to control external parasites. The sheep were housed individually in metabolism crates with provisions for collecting faeces, free access to feed, fresh water and minerals.

5.2.4 Experimental design

The sheep were randomly assigned treatments in a (3x4) factorial arrangement in a completely randomized designed (CRD). Three sheep were randomly assigned to each treatment then replicated three times. The diets consisted of three basal feed ingredients of Brachiaria hay, Rhodes and a 50:50 of Brachiaria and Rhodes hay (Table 3.1). The daily feed offered was based on 3-4% body weight offered each morning at 8.00 am. (EAT). Mineral licks and drinking water were offered *ad libitum*. The initial body weight of the sheep was taken as the mean of two consecutive weighing after overnight fasting. Weekly body weight measurements were taken after overnight fasting until the completion of the experiment. Sheep were allowed a 14-day for adaptation period prior to the feeding trial which lasted 12 weeks.

5.2.5 Digestibility

Digestibility experiment was carried out at the end of the 12 weeks of the feeding trial. This involved seven (7) days of data collection involving daily feed offered, left over feed and faecal collection. Feed was offered every day at 8.00 am. The daily feed offered, left over and faeces were weighed and recorded after every 24 hours. Daily feed offered and left over for each sheep for the seven days were pooled together. A sub sample was collected milled to pass through a 1 mm sieve and packed in airtight bottles pending laboratory analysis. Likewise, faecal samples for the seven days were pooled together, sub sampled and then kept in airtight plastic containers. This was followed by drying at 60^{o}C for 72 hr, milled through a 1 mm sieve and packed in airtight bottles pending laboratory analysis. This was followed by drying at 60^{o}C for 72 hr, milled through a 1 mm sieve and packed in airtight bottles pending laboratory analysis.

5.2.6 Chemical analysis

Samples of feeds offered and leftover were collected daily and pooled for each sheep then subsampled for proximate and fibre analysis. Proximate analysis was determined according to AOAC (2005) methods. The extraction of phenolics was carried out by using 70% aqueous acetone and total extractable phenols (TEPH) determined using Folin Ciocalteu procedures as described by Julkunen- Titto (1985) and Warly *et al.* (2004). Condensed tannin (CT) was measured and calculated as leucocyanidin equivalent, following the method of Porter *et al.* (1986).

5.2.7 Statistical analysis

The values of the measured parameters (DMI, ADG, crude fibre, minerals, IVOMD, ME) were determined by analysis of variance (ANOVA) using the general linear model (GLM) procedure of statistical analysis system (SAS, 2002). Significant differences in means were separated using the least significance difference (LSD) at (*p*< 0.05).

Statistical model

Yijk =μ + Ai +Bj + (BR) ij + eijk

where

Yijk = (Nutrient intake, digestibility and wt change)

μ = overall population mean

Ai = effect of level of factor A (Diets 1, 2 and 3)

Bj = effect of level of factor B (Treatments 1, 2, 3 and 4)

(BR) ij = effect of interaction between Factor A and B.

eijkl = random error associated with Yijk

5.3 Results and discussion

5.3.1 Chemical composition

Values on intake, digestibility and weight gain of sheep fed on Brachiaria and Rhodes grass hay supplemented with different levels of Calliandra are represented in Table 5.1. The total dry matter intake (TDMI) gkg^{-1} DM and gKg^{-1} DM $W^{0.75}$ of the three basal diets increased significantly (p<0.05) with supplementation. Brachiaria (T4) had the highest intake of 920.59 gKg^{-1} DM and 78.68 gKg^{-1} DM $W^{0.75}$ while Rhodes grass (T1) had the lowest (420.00 gKg^{-1} DM and 46.67 gKg^{-1} DM $W^{0.75)}$. Total organic matter intake (TOMI) showed the same trend to that of TDMI across the diets. The increased TDMI with supplementation (30%) was due to the improved level of CP as a result of supplementation. The CP percentages of the basal diets improved by 45.9%, 42.5% and 39.2% for Brachiaria, mix and Rhodes grass respectively. The increased CP improved rumen microbial protein leading to enhanced microbial activity and multiplication which resulted in improved digestibility, increased rate of passage of the digesta, which increased intake of the basal diet (Lamidi, 2014; McDonald *et al.*, 1995; Van Soest *et al.*, 1991). Similar reports on increased basal feed intake with supplementation have been documented by many authors (Deng *et al.*, 2017; Kaitho, 1997; Kemboi *et al.*, 2017; Ngila *et al.*, 2016; Wambui *et al.*, 2006). Dry matter intake expressed as percentage body (% BW) were different (p<0.05) among the treatments. Basal diets supplemented with (30%) showed a higher percentage body weight. These were

Brachiaria (T4), Mix (T4) and Rhodes (T4) which had percentage body weight intakes of 3.47 %, 3.29 % and 3.18 % respectively.

Table 5.1 Intake, digestibility and weight gain of sheep fed on experimental diets

DIET	IBW Kg	FBW Kg	BWG Kg	TDMI gKg^{-1} DM	TDMI gKg^{-1} DM $W^{0.75}$	DM % BW	ADG g	Apparent Nutrient digestibility		
								CP %	OM %	DM %
Brachiaria hay										
T1	22.1^{a}	20.1^{d}	-1.98	510^{d}	53.71^{d}	2.54^{d}	-22.0	35.0^{d}	49.7^{d}	49.2^{d}
T2	21.3^{c}	21.8^{c}	0.54^{c}	583^{c}	57.78^{c}	2.67^{c}	6.0^{c}	38.0^{c}	56.7^{c}	53.5^{c}
T3	20.9^{d}	24.2^{b}	3.33^{b}	720^{b}	66.69^{b}	2.97^{b}	37.0^{b}	40.6^{b}	58.6^{b}	58.8^{b}
T4	21.8^{a}	26.6^{a}	4.75^{a}	920^{a}	78.68^{a}	3.47^{a}	52.8^{a}	43.7^{a}	61.1^{a}	60.2^{a}
Brachiaria and Rhodes hay mixture (50:50)										
T1	21.4^{c}	19.1^{d}	-2.34	444^{d}	48.82^{d}	2.33^{d}	-26.0	33.0^{d}	48.8^{d}	47.0^{d}
T2	21.6^{b}	21.9^{c}	0.36^{c}	540^{c}	53.47^{c}	2.46^{c}	4.00^{c}	34.9^{c}	51.3^{c}	49.5^{c}
T3	20.4^{d}	23.2^{b}	2.80^{b}	680^{b}	64.21^{b}	2.93^{b}	31.1^{b}	40.0^{b}	57.3^{b}	56.5^{b}
T4	22.0^{a}	26.1^{a}	4.05^{a}	856^{a}	74.47^{a}	3.29^{a}	45.0^{a}	41.3^{a}	59.6^{a}	58.5^{a}
Rhode grass hay										
T1	21.8^{b}	18.7^{d}	-3.15	420^{d}	46.67^{d}	2.25^{d}	-35.0	32.4^{d}	47.7^{d}	46.3^{d}
T2	22.5^{a}	22.6^{c}	0.14^{c}	524^{c}	50.43^{c}	2.32^{c}	1.50^{c}	33.8^{c}	49.1^{c}	48.1^{c}
T3	20.9^{c}	23.1^{b}	2.21^{b}	669^{b}	63.78^{b}	2.90^{b}	24.5^{b}	36.9^{b}	53.8^{b}	52.3^{b}
T4	21.8^{b}	25.6^{a}	3.78^{a}	812^{a}	71.29^{a}	3.18^{a}	42.0^{a}	39.5^{a}	58.2^{a}	55.5^{a}
SEM	0.10	0.44	0.45	27.24	1.77	0.07	4.97	0.61	0.79	0.82

IBW: (Initial body weight); FBW: (Final body weight); BWG: (Body weight gain); TDMI: (Total dry matter intake); DM (% BW): (Dry matter % body weight); ADG: (Average daily gain),^{abcd}Means with different subscript in a column are significantly different at 5% ($p<0.05$) with different subscript in a column differ at $p<0.05$

Basal diets without supplementation showed lower percentage body weight gains (2.54%, 2.33% and 2.25%) respectively (Table 5.1). These values were lower than those reported by Yulistiani (2016) who reported average DMI of 3.89% BW in the response of sheep fed on corn cob silage or Elephant grass basal diet with or without Calliandra leaf meal supplementation. However, the values reported in this study were higher than the recommended 2.6% BW for 30 Kg sheep (NRC, 2007), but similar to those reported by

Ondiek *et al.* (1999) who reported 2.9-3% BW DMI in goats supplemented with *Gliricidia sepium* and *Leucaena leucocephala* to a basal diet of Rhodes grass hay

5.3.2 Apparent nutrient digestibility

Apparent nutrient digestibility is present in Table 5.1. The apparent digestibility of (CP, OM and DM) was significantly different among the treatments ($p<0.05$). It was lower for the un-supplemented diets in all parameters (CP, OM, and DM) and was highest in the supplemented diets. The DM digestibility among the basal diets ranged from 46.3% to 49.2%. Rhodes grass hay had the lowest digestibility (46.3%), while Brachiaria had the highest (49.2%). The Brachiaria and Rhodes grass mixture had 47.0% digestibility. These values were lower than average range of 55% DMD of tropical grasses reported by Cook *et al.* (2005) but within the range of 48-59% reported by Urio *et al.* (1988) and 49% observed by Widiawati (2002). However, they are within the range of 40-80% reported by Mbwile *et al.* (1997) who stated that digestibility will vary due to age and frequency of harvesting.

According to Bell (2006), digestibility of a diet is a useful indicator of its quality. It is positively related to the energy and protein content of feed. Feeds high in energy and protein content are equally high in digestibility. The lower DM, CP, OM digestibility in this study among the un-supplemented diets, could be attributed to low level of CP, energy and high cell wall contents. Supplementation increased DMD in Brachiaria from 49.2% (T1) to 60.2% (T4) and Rhodes from 46.3% (T1) to 55.5% (T4). This may have been because supplementation increased total nitrogen (N) supplied which increased not only rumen microbial activity but also tissue metabolism of volatile fatty acids. This, together with an increase in diet digestibility, would have contributed to the better performance with the supplemented diets. This is in agreement with the report that digestion of feed in ruminant animals is highly influenced by the level of protein and fibre in the diet (Peyraud *et al.*, 1998). Supplementation also increased organic matter digestibility (OMD) and digestible crude protein (DCP) of the basal diets. OMD of Brachiaria increased from 50.67% (T1) to 61.10% (T4) while Rhodes from 47.70% (T1) to 58.15% (T4). This was similar to the findings of Palmer *et al.* (1992) who reported increased in OM digestibility in sheep when hay was supplemented with Calliandra at 16, 28 and 35% of the total diet on DM basis, from 48 to 58, 62 and 63% respectively for the same levels of supplementation. DCP in Brachiaria increased from 35% (T1) to 43.7% (T4) while Rhodes from 32.4% to 39.5% which is higher than 24% in Brachiaria

(Kawashima *et al.,* 2006; Kawashima *et al.,* 2007). As explained earlier the condensed tannin (CT) inclusion levels in the diets in this study were below (<50 gKg^{-1} DM) normally considered detrimental to intake, palatability and digestibility which may explain why it did not negatively influence intake and digestibility of the diets.

5.3.3 Average daily gain

In terms of weight change, there were significant ($p<0.05$) differences in average daily gain (ADG) across the treatments. Supplemented sheep showed higher ADG compared to non-supplemented. Basal diets that were supplemented with the highest level of supplementation (30%) showed a higher ADG. These were Brachiaria (T4), Mix (T4) and Rhodes (T4) which had ADG of 52.8 g/d, 45.0 g/d and 42.0 g/d respectively (Figure 4.2). The higher ADG recorded in supplemented diets could have been as a result of higher protein (CP) and energy as a result of supplementation which was responsible for improved growth compared to non-supplemented diets. Supplementation improved intake by supplying fermentable carbohydrates and proteins for the cellulolytic microbes upon degradation in the rumen (Kariuki, 1998; Osuji *et al.,* 1995). However basal diets that had no supplementation recorded negative gains. Brachiaria (T1), Mix (T1) and Rhodes (T1) recorded negative weights (-22.0 g/d, -26.0 g/d and -35.0 g/d) (Figure 5.1). This was probably due to the low CP and ME together with a high NDF in the basal diets which may be as a result late harvesting of the grasses. Mature or older grasses tend to accumulate more of structural carbohydrates and less of soluble carbohydrates (Van Soest *et al.,* 1991) leading to low digestibility and energy (Kaitho, 1997). Low CP is also associated with the older mature grasses which if they are solely fed to ruminants may not be adequate to meet the minimum threshold of 70 gKg^{-1} DM required for proper rumen function and production (Mudzengi *et al.,* 2014; Ondiek *et al.,* 1999; Wambui *et al.,* 2006). Several cases of weight losses as a result of unsupplemented basal diets have been reported. Kemboi *et al.* (2017), reported weight loss of 47.8 g/d in small east African goats fed a basal diet of *C. gayana* hay and daily body weight gain of 21.4-22.3 g/d when the same goats were supplemented with *Acacia brevispica* and *Berchemia discolor.* Also, Ondiek *et al.* (2010), reported weight loss of 4.91g/d in small east African goats fed a basal diet of Rhodes grass hay and daily body weight gain of 12.9-28.1 g/d when the same goats were supplemented with *Maerua angolensis* and *Ziziphus mucronata* mixed Yirga *et al.* (2011) also reported body weight loss as a result of un supplemented diets. Results from the current study indicate that intake and digestibility of *B. ruziziensis* was higher than those of *C. gayana* which is in agreement with the findings of Urio *et al.* (1988).

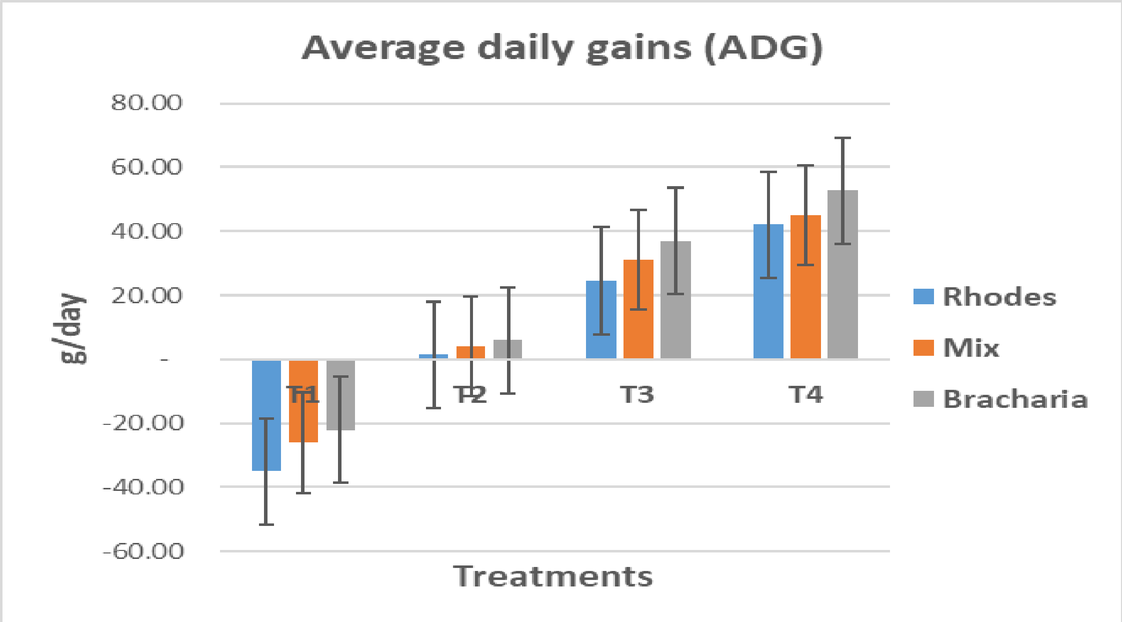


Figure 5.1 Average daily gain of sheep fed on various treatments

5.5 Conclusion

Supplementation of Brachiaria and Rhodes grass hay with Calliandra leaves improves feed intake, nutrient digestibility and growth rate of sheep. Results from the study indicates that Brachiaria grass hay supplemented with 30% Calliandra proved the most suitable diet for sheep especially during the dry season when there is scarcity of feed.

5.6 Recommendation

Results from this study indicate that Calliandra leaves can effectively be utilized as a protein supplement to improve poor quality basal diets. Based on the findings, it is recommended that farmers should be encouraged to feed Brachiaria hay supplemented with 30% Calliandra leaves to their sheep especially, during the dry season

CHAPTER SIX

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 General Discussion

The experimental diets had a crude protein content ranging from 4.2 to 12.6%. The relatively high CP content in Calliandra (21.1%) demonstrates its potential value as a protein source for small ruminants, particularly in arid and semi-arid areas. Calliandra leaves can be added to fibrous crop wastes or low-quality natural pasture during the dry season to boost animal performance. Calliandra's relatively high crude protein content makes it a suitable supplement for hay or crop waste like straw and poor-quality natural pastures (Osuga *et al.,* 2006). Calliandra leaves had a high cell content that an animal can use, as evidenced by the fact that their NDF and ADF concentration was lower than that of grasses. This explains why supplementation caused both NDF and ADF to decline. Leguminous fodder trees have proven to be easier for animals to digest than crop residue and mature grass (El Hassan *et al.,* 2000). The amount of total extractable phenolic and total extractable condensed tannins (TEPH and CT) in the diets was within the threshold of 50 gkg^{-1} DM, which is typically regarded as harmful to intake and digestibility. The mineral content of the diets varied significantly and the trend observed showed that the mineral profile improved with supplementation. The diets supplemented with 30% Calliandra had the highest gas production hence were highly degradable at 24 and 48 hours. The gas is produced by the fermentation of organic matter (OM) in the feed (Blümmel *et al.,* 2002). This shows that Calliandra leaves have a great potential of improving low quality feeds fed especially for sheep.

The energy in the diets ranged from 5.20 ME (MJ)/Kg to 8.11 ME (MJ)/Kg. The estimated energy in the basal diets was less than the 8–10 (MJ)/Kg DM of ME needed to prevent sheep from losing weight (Gatenby, 1986; Minson, 1990; NRC, 2007). Since rumen bacteria need energy for microbial protein synthesis, the increase in energy with the increase in supplementation rate is essential (McDonald *et al.,* 1995; Van Soest, 1991). This energy is released as a result of organic matter (OM) fermentation in the rumen, which primarily produces volatile fatty acids (VFAs), which are important sources of energy for ruminants (Mackie *et al.,* 1995). The diets' relative palatability indices varied greatly and were ranked as follows: (T4>T3>T2>T1). In comparison to the control diet, which had no supplements at all, the supplemented meals displayed better preference and palatability indices. Despite the fact that Calliandra leaves are thought to be extremely tanniniferous, the low levels found in the diets were under 5%, which is typically viewed as being harmful to intake and digestion

(Barry *et al.,* 1984; Waghorn *et al.,* 2008). The average daily gain (ADG) of sheep fed on basal diets (Brachiaria, Rhodes and 50:50 mix) were low with a negative values (-22g/d, -36g/d and -26g/d) respectively. This negative growth may have been caused by the low energy and protein in the basal diet. The low nutritional value of the basal diet may have been as a result of late harvesting of the grasses when they are overgrown. Some cases of weight losses as a result of unsupplemented basal diets have been reported (Kemboi *et al.,* 2017; Ondiek *et al.,* 2010; Yirga *et al.,* 2011). Sheep fed on supplemented diets recorded positive gains whereby sheep on 30% supplementation recorded the highest (52.8g/d, 45.0g/d and 42g/d) respectively. Supplementation improved the rumen environment by enhancing rumen microbial activity which resulted in improved digestibility and intake of digestible nutrients, hence increased gains. It was observed that DM digestibility among the basal diets ranged from 46.3% to 49.2%.

The digestibility Rhodes grass hay was the lowest (46.3%) while Brachiaria had the highest (49.2%) among then basal diets. The Brachiaria and Rhodes grass mixture (50:50) had 47.0 % digestibility. Supplementation increased DMD in Brachiaria from 49.2% (T1) to 60.2 % (T4), Rhodes from 46.3% (T1) to 55.5% (T4) and the mix from 47.0 to 58.5%. This may have been as a result of enhanced total nitrogen (N) supplied which led to the increased digestibility of the diets. This is consistent with observations by Peyraud *et al.* (1998) that the amount of protein and fibre in the diet has a significant impact on how well ruminant animals digest feed. The organic matter digestibility (OMD) and digestible crude protein (DCP) of the basic diets were both improved by supplementation. Brachiaria's organic matter digestibility grew from 50.67% (T1) to 61.10% (T4), whereas Rhodes went from 47.70% (T1) to 58.15%. (T4). This was consistent with findings by Palmer *et al.* (1992), which showed an increase in OM digestibility in sheep when hay was supplemented with Calliandra at 16, 28, and 35% of the total diet on DM basis, from 48% to 58%, 62%, and 63% correspondingly for the same levels of supplementation. The apparent digestibility of protein in Brachiaria rose from 35% (T1) to 43.7% (T4), while Rhodes rose from 32.4% to 39.5%, which is greater than Brachiaria at 24% (Kawashima *et al.,* 2006; Kawashima *et al.,* 2007). Condensed tannin (CT) inclusion levels in the diets in this study were below the threshold (50 gKg^{-1} DM), which is typically regarded harmful to intake, palatability, and digestibility. This may account for why it had no adverse effects on intake and digestibility of the diets. It was clear from the study's findings that a diet consisting solely of Brachiaria and Rhodes grass hay was insufficient to give sheep the nutrients they needed for development and maintenance. Rhodes grass had a lower CP content than Brachiaria (5.8% vs. 4.2%), but their estimated ME contents were nearly the same. This meant that Brachiaria would have a greater CP content at any amount of Calliandra supplementation. Most likely, this helped the animals that were fed Brachiaria to perform better. It is necessary to conduct further feeding research on the elements that influence the sheep's acceptance and, consequently, preference for the diets.

6.2 Conclusions

i. Supplementation of the basal diets with Calliandra improved the nutritive content, *in-vitro* digestibility and fermentation characteristics of the basal diets.
ii. Supplementation of the basal diets with Calliandra improves palatability and preference of the basal diets.
iii. Supplementation of the basal diets with Calliandra improved animal performance (feed intake and weight gain).

6.3 Recommendations

i. Feeding of Brachiaria and Rhodes grass hay supplemented with 30% Calliandra leaves to sheep during the dry season.
ii. Feeding of Brachiaria and Rhodes grass hay supplemented with 30% Calliandra leaves to sheep during the dry season.
iii. Feeding of Brachiaria and Rhodes grass hay supplemented with 30% Calliandra leaves to sheep during the dry season.

6.4 Further Research

i. Studies on the effects of the diets on carcass quality (organoleptic characterization).
ii. More research can be done on nutrient composition especially amino acids and vitamins of the various diets.
iii. Processing the best ration into feed blocks for ease of dissemination and adoption

REFERENCES

AAC. (1990). *Feeding standards for Australian livestock.* Australian Agricultural Council. Ruminant sub-committee, CSIRO, Australia.

Abdulrazak, S.A., Nyangaga, J.N., & Fujihara, T. (2001). Relative palatability, *in-sacco* degradation and *in-vitro* gas production of some multipurpose fodder trees. *Asian- Australasian Journal of Animal Science, 14*(11), 1580–1586.

Abqoriyah, Utomo, R., & Suwignyo, B. (2014). Effect of Different Tannin Caliandra *(Calliandra calothyrsus)* on *in vitro* Digestibility in the Different Defoliation. *In: 16th AAAP Animal Science Congress,* 10-14 November 2014, Gadjah Mada University, Yogyakarta, Indonesia.

Ademosun, A. A. (1994). Constraints and prospects for small ruminant research and development in Africa. *In: Small Ruminant Research and Development in Africa. Proceeding of the 2^nd^ Biennial Conference of SRNET*, A1CC, Arusha, Tanzania, 1–6.

Afzal, J., & Ullah, M.A. (2007). Assessment of productive potential and utilization of rangelands and sown pastures in Peshawar Plateau. In: *Annual Report of the National Agriculture Research Centre,* Islamabad, pp. 10

Ahn, J.H., Robertson, B.M., Elliott, R., Gutteridge, R.C., & Ford, C. W. (1989). Quality assessment of tropical browse legumes: Tannin content and protein degradation. *Animal Feed Science and Technology, 27,* 147–156.

Alonso-Diaz, M. A., Torres-Acosta, J. F. J., Sandoval-Castro, C.A., & Hoste, H. (2011). Comparing the sensitivity of two *in vitro* assays to evaluate the anthelmintic activity of tropical tannin rich plant extracts against *Haemonchus contortus*. *Veterinary Parasitology*, *181*(2–4), 360–364.

ANKOM Technology, (2014). Method for determining neutral detergent fiber in feeds (ANKOM^{200} fibre analyser operator`s manual).

AOAC. (2005). *Official methods of analysis. Association of Official Analytical Chemists,* Gaithersburg, MD, USA .18th Ed.

Baker, R. L., Mugambi, J. M., Audho, J. O., Carles. A. B., & Thorpe, W. (2004). Genotype by environment interactions for productivity and resistance to gastro-intestinal nematode parasites in Red Maasai and Dorper sheep. *Journal of Animal Science*, *79,* 343–353.

Baker, R. L., Nagda S., Rodriguez-Zas, S. L., Southey B. R., & Audho, J. O. (2003). Resistance and resilience to gastro-intestinal nematode parasites and relationships with productivity of Red Maasai, Dorper and Red Maasai x Dorper crossbred lambs in the subhumid tropics. *Journal of Animal Science*, *76*, 119–136.

Barahona, R., Lascano, C.E., Narvaez, N., Owen, N., Morris, P., & Tehodorou, M.K. (2003). *In-vitro* digestibility of mature and immature leaves of tropical forage legumes differing in condensed tannin and non-starch polysaccharide content and composition. *Journal of Science Food and Agriculture, 83,* 1256 – 1266.

Barrios, E. (2016). *The in-vitro dry matter digestibility method*. Tropical Soil Biology and Fertility Institute of CIAT, Cali, Columbia.

Barry, T. N., & Duncan, S. J. (1984). The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 1. Voluntary intake. *British Journal of Nutrition*, *51*, 485– 491.

Barry, T. N., & Manley, T. R. (1984). The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 2. Quantitative digestion of carbohydrates and proteins. *British Journal of Nutrition*, *51*, 493–504.

Barry, T.N. (1983). The condensed tannin content of vegetative *Lotus pedunculatus,* its regulation by fertilizer application, and effect upon protein solubility. *Journal of Science Food and Agriculture*, *34* (10), 1047 – 1056.

Baruch, Z., & Merida, T. (1995). Effects of drought and flooding on root anatomy in four tropical forage grasses. *International Journal of Plant Sciences, 156,* 514–521.

Baumont, R. (1995). Palatability and feeding behaviour in ruminants. A review. Annales dezootechnie. *INRA/EDP Sciences, 45*(5), 385–400.

Bell, A. (2006). Pasture assessment and livestock production. *Prime Facts*, *323*, 1–6.

Benchaar, C., & Pomar, C. (2001). Evaluation of dietary strategies to reduce methane production in ruminants: a modelling approach. *Canadian Journal of Animal Science, 81,* 563–574.

Ben Salem, H., & Saghrouni, L. N. A. (2005). Attempts to deactivate tannins in fodder shrubs with physical and chemical treatments. *Animal Feed Science Technology, 122*(10), 9–12.

Bishop, S. C. (2012). Consideration of resistance and tolerance for ruminant nematode infections. *Front Genetics, 3,* 168.

Blümmel, M., & Fernandez-Rivera, S. (2002). *In vitro* gas techniques and efficiency of microbial substrate degradation. *Animal Nutrition and Feed Technology*, 2, 93-115.

Brighenti, A.M., Sobrinho, F.S., Rocha, W.S.D., & Martins, C.E. (2011). Suscetibilidade diferencial de espécies de braquiária ao herbicida glifosato. *Pesquisa. Agropecuária Brasileira, 46*(10), 1241–1246.

Brum, K.B., Haraguchi M., Lemos, R.A.A., Riet-Correa, F., & Fioravante, M.C. (2007). Crystal associated cholangiopathy in sheep grazing *Brachiaria decumbens* containing the saponin protodioscin. *Pesquisa Veterinaria Brazileira*, *27,* 39–42.

Castro, M.B., Santos, H.L.Jr., & Mustafa, V.S. (2011). Brachiaria spp. poisoning in sheep in Brazil: experimental and epidemiological findings. In *Poisoning by Plants, Mycotoxins and Related Toxins* (pp. 110-117). Wallingford UK: CABI.

Catchpoole, D.W., & Blair, G. (1990). Forage Tree Legumes. I. Productivity and N economy of Leucaena, Gliricidia, Calliandra, and Sesbania and tree/Panic mixtures. *Australian Journal of Agricultural Research, 41,* 521 – 530.

Ceccon, G., & Concenço, G. (2014). Mass yield and burn down of perennial forages for crop-livestock integration. *Planta Daninha,* 32(2), 319–326.

Chapman, S.C., Chakraborty, S., Dreccer, M.F., & Howden, S.M. (2012). Plant adaptation to climate change: opportunities and priorities in breeding. *Crop Pasture Science, 63,* 251–268.

CIAT. (2007). Annual Report 2006. *Project IP-5Tropical grasses and Legumes: Optimizing genetic diversity for multipurpose use,* pp. 228.

Close, W., & Menke, K.H (1986). *Selected Topics in Animal Nutrition, a manual prepared for the 3rd Hohenheim course on animal nutrition in the tropics and semi-tropics.* 2nd (edn), University of Hohenheim, Stuttgart, Germany.

Cook, B.G., Pengelly, B.C., Brown, S.D., & Donnelly, J.L. (2005). Tropical forages: an interactive selection tool. [CD-ROM], CSIRO, DPI&F (Qld) Brisbane, Australia: CIAT and ILRI. CIAT (2007). *Annual Report 2006. Project IP-5 Tropical grasses and Legumes: Optimizing genetic diversity for multi-purpose use.*

Daniela, M. A., Alexander, M.A., Marcy, G.F., & Melissa, V. L. (2014). *Brachiaria ruziziensis* Responses to Different Fertilization Doses and to the Attack of *Mahanarva spectabilis* (*Hemiptera: Cercopidae*) Nymphs and Adults. *Scientific World Journal*, Article ID 543813, 8 pages, 2014. https://doi.org/10.1155/2014/543813

Datt, C. Datta, M., & Singh, N.P. (2008). Assessment of fodder quality of leaves of multipurpose trees in subtropical humid climate of India. *Journal Forestry Research, 19* (3), 209 – 212.

Deng, M. T, Ondiek, J. O. & Onjoro, P. A. (2017). Intake, relative palatability index and preference class of selected Bor, South Sudan browse species fed to crossbred growing goat. *Livestock Research for Rural Development, 29, Article #171.* http://www.lrrd.org/lrrd29/9/mame29171.html

D'Mello, J. P. F. (1992). Nutritional potentialities of fodder trees and fodder shrubs as protein sources in monogastric nutrition. *Legume trees and other fodder trees as protein sources for livestock (A Speedy and PL Pugliese, editors) FAO Animal Production and Health Paper, 102,* 145-160.

De Souza-Kaneshima, A.M., & Simioni, C., F. (2010). Meiotic behaviour in the first interspecific hybrids between *Brachiaria brizantha* and *Brachiaria decumbens*. *Plant Breeding*, *129*, 186–191.

Devendra, C. (1986). Feeding systems and nutrition of goats and sheep in the tropics. In: Adeniji, J. A. & Kategile, K.O. (Eds.), *Proceedings. workshop on the improvement of small ruminants in Eastern and Southern. Africa* (Printed by Modem Lithographic (k) Ltd. pp. 91–109.

Dwozela, B.H., Hove, L., & Mafongoya, P.L. (1995). Effect of drying method on chemical composition and *in vitro* digestibility of multi-purpose tree and shrub fodder. *Tropical Agriculture*, *29* (263 – 269).

Ebong, C. (1996). Calliandra leaf meal in goat rations. Effects on protein degradability in the rumen and growth in goats. Small Ruminant Research and Development in Africa. *Proc. 3rd Biennial Conf. SRNET, L1CC, Kampala, Uganda, 5th - 9th, Dec., 1994*. Lebbie, S.H.B & Kagwini, E. (Eds.), 227–229.

Ecocrop, (2014). Food and Agriculture Organization (*FAO)*. Rome, Italy.

FAO. (2015). *Grassland Index.* A searchable catalogue of grass and forage legumes.

FAO. (1986). *Livestock in food security.* Food and Agriculture Organization of the United Nations, Rome Italy.

FAO. (2012). *Livestock in food security.* Food and Agriculture Organization of the United Nations, Rome Italy.

FAO. (2011). *Livestock in food security*. Food and Agriculture Organization of the United Nations, Rome Italy.

Flavia, G.L., Carolina, S., Ribeiro. Diogo, D. F., & Andrade, G. (2012). Effects of *Brachiaria brizantha* Hay Containing a Steroidal Saponin in Lambs. *International Journal of Poisonous Plant Research*, *2*(1).

Franzel, S., Wambugu, C., Nanok, T., Kavana, T., Njau, P., Aithal, A., & Muriuki, J., K. A. (2007). The Production and Marketing of Leaf Meal from Fodder Shrubs in Tanga, Tanzania. *A Pro-Poor Enterprise for Improving Livestock Productivity* (No. 50).

Frutos, P., Hervás, G., Giráldez, F.J., & Mantecón, A. R. (2004). Review. Tannins and ruminant nutrition. *Spanish Journal of Agricultural Research*, *2,* 191–202.

Ganskopp, D., & Bohnert, D. (2003). Mineral concentration dynamics among 7 Northern Great Basin grasses. *Journal of Range Management*, *56,* 174–184.

Gatenby, R.M. (1986). *Sheep production in the tropics and sub-tropics.* Tropical Agricultural Series, Longman Group Ltd, Essex.

Gitunu, A. M., Mnene, W. N., & Muthiani, E. N., (2003). Increasing the productivity of livestock and natural resources in Semi-Arid areas of Kenya: A case study from the Southern Kenya rangelands. *For End of Programme Conference, Agriculture/Livestock Research Support Programme, Phase II,* Held on 11 – 12 November.

GoK. (2015). *National Policy for the Sustainable Development of northern Kenya and other Arid Land. (Draft).* Ministry of Devolution and Planning.

Gutteridge, R.C., & Shelton, H. (1993). The scope and potential of tree legumes in agroforestry. *Agroforest Systems*, *23,* 177–194.

Hatfield, J., Boote, K., Fay, P., Hahn, L., Izaurralde, C., Kimball, B.A., & Mader, T. (2008). Agriculture. In: *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States.* A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC., USA, pp. 362.

Herlocker, D.J. (1999). *Rangeland Resources in Eastern Africa*: Their Ecology and Development. German Technical Cooperation, Nairobi.

Herrera, R. S. (2004). *Photosynthesis: Tropical Grasses, Contribution to Physiology, Establishment, and Biomass Yield, Biomass Production, Seed Production and Recycling of Nutrients.* ICA, La Habana: editions EDICA pp. 37.

Herrero, M., Valle, C. B., Hughes, N. R., & Jessop, N. S. (2001). Measurements of physical strength and their relationship to the chemical composition of four species of Brachiaria. *Animal Feed Science and Technology*, *92*(3–4), 149–158.

Hess, H.D., Tiemann, T.T., Noto, F., Franzel, S., & Lascano, C. K. M. (2006). The effects of cultivation site on forage quality of Calliandra calothyrsus var. Patulul. *Agroforestry System*, *68*, 209–220.

Hollmann, F., Argel, P., Rivas, L., White, D., & Medina, A. (2004). Benefits and costs of rehabilitation of degraded pastures in Honduras. *Pasturas Tropicales*, *26*(3), 13–18.

Huhtanen, P., Nousiainen, J., & Rinne, M. (2006). Recent developments in forage evaluation with special reference to practical applications. *Agriculture Food Sciences*, *15*, 293–323.

Humphreys, L. (1994). *Tropical forages*: Their role in sustainable agriculture. Harlow, UK. Longman, 414.

Hussain, F., & Durrani, M. J. (2009). Seasonal availability, palatability and animal preference of forage plants in Harboi Arid Range Land Kalat, Pakistan. *Pakistan Journal of Botany, 41*(2), 539–955.

Ibrahim, M. N. M., Tamminga, S., & Zemmelink, G. (1995). Degradation of tropical roughages and concentrate feeds in the rumen. *Animal Feed Science Technology*, *54*(1–4), 81–92.

IFAD. (2010). Rural Poverty Report 2011. *New Realities, New Challenges: New Opportunities for Tomorrow's Generation.* The International Fund for Agricultural Development (IFAD), IFAD, Rome, Italy, 319 pp.

ILRI. (2013). Ruzi grass *(Brachiaria ruziziensis)* for livestock feed on small-scale farms. Nairobi, Kenya: ILRI.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin & G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1535, doi: 10.1017/CBO9781107415324.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2010). (2nd Ed). *Farm Management Handbook of Kenya: Subpart B1a*, *Southern Rift Valley Province*, Vol II. Nairobi: Ministry of Agriculture.

Jank, L., Barrios, S.C., Valle, C.B., Simeão, R.M., & Alves, G. F. (2014). The value of improved pastures to Brazilian beef production. *Crop Pasture Science*, *65,* 1132–1137.

Jančík, F., Koukolová, V., Kubelková, P., & Čermák, B. (2009). Effects of grass species on ruminal degradability of silages and prediction of dry matter effective degradability. *Czech Journal Animal Science*, *54*, 315–323.

Jones, W.T., & Anderson, L.B. (1973). Bloat in cattle: detection of protein Precipitants (flavolans) in legumes. *New Zealand Journal of Agricultural Research*, *16*(4), 41–46.

Julkunen-Titto, R. (1985). Phenolic constituents in the leaves of northern willows: methods for analysis of certain phenolic. *Journal of Agricultural Food Chemistry*, *33*, 213–217.

Kabirizi, J., & Mpairwe, D. (2006). Improving dairy cattle productivity in smallholder farms in Uganda: incorporating leguminous forages in farming systems Uganda. *Journal of Agriculture Science*, *12*, 1–12.

Kahi, A.K., Wasike, C.B., & Rewe, T. O. (2006). Beef production in the arid and semiarid lands of Kenya: constraints and prospects for research and development. *Animal Feed Science and Technology*, *35,* 217–225.

Kaitho, R. J., Umunna, N. N., Nsahlai, I. V., Tamminga, S., Bruchem, J., & Hansona, J. (1997). Palatability of wilted and dried multipurpose tree species fed to sheep and goats. *Animal Feed Science and Technology*, *65*, (1–4), 151-163.

Kaitho, R. J. (1997). *Nutritive value of browses as protein supplement(s) to poor quality roughages.* PhD Thesis. Wageningen Agricultural University, The Netherlands.

Kakengi, M. S., M.N., & Mtengeti, E. P. (2001). *Leucaena leucocephala* leaf meal as a supplement to diets of grazing dairy cattle in semiarid western Tanzania. *Agroforestry System*, *52*, 73–82.

Kariuki, J. N. (1998). *The potential of improving Napier grass under smallholder dairy farmer's conditions in Kenya. PhD Thesis.* Wageningen Agricultural University, The Netherlands.

Katiku, P.N., Kimitei, R.K. & Korir, B. (2013). Value chain assessment of small ruminant production, challenges and opportunities: The case of southern rangelands of Kenya. *Livestock Research for Rural Development*, *25*, *Article #1.* http://www.lrrd.org/lrrd25/1/kati25001.htm

Kawashima, T., Sumamal, W., Pholsen, P., Chaithiang, R., & Terada, F. (2007). Comparative study on energy and nitrogen metabolism of Brahman cattle and sheep given ruzi grass hay with different levels of soybean meal. *Japan Agricultural Research*, *41*(3), 253–260.

Kawashima, T., Sumamal, W., Pholsen, P., Chaithiang, R., & Kurihara, M. (2006). Comparative study on energy and nitrogen metabolisms between Brahman cattle and swamp buffalo Fed with low quality diet. *Japan Agricultural Research*, *40*(2), 183–188.

Kemboi, F, Ondiek J.O., & Onjoro, P.A. (2017). Evaluation of nutritive value and *in-vitro* degradation of selected indigenous browses from Semi-Arid areas of Kenya. *Livestock Research for Rural Development*,*33*(6), 74-85. http://www.lrrd.org/lrrd29/5/kemb29092.html.

KARI. (2004). Transformation of Agricultural Research in Africa. In: Ndiritu, C.G., Lynam, J. K., & Mbabu, A. N. (eds), *Lessons from Kenya,* Michigan State University Press.

KMT. (2014). Kenya Livestock and Meat Market Analysis: For Cattle, Sheep and Goat.

Khan, Z. I., Ashraf, M., & Valeem, E. E. (2006). Forage mineral status evaluation: The influence of pasture. *Pakistan Journal of Botany*, *38*, 1043–1057.

Khanum, S. A., Hussain, H. N., Hussain, M., & Ishaq, M. (2010). Digestibility studies in Sheep fed sorghum, sesbania and various grasses grown on medium saline lands. *Small Ruminant Research*, *91*(1), 63–68.

Khazaal, K. A., Dentino, M. T., Ribeiro, J. M., & Ørskov, E. R. (1995). Prediction of apparent digestibility and voluntary intake of hays fed to sheep: comparison between using fibre components, *in-vitro* digestibility or characteristics of gas production or nylon bag degradation. *Animal Science, 61,* 527–538.

Kinuthia, M. N., Wanyoike, M. N., Gachuiri, C. K., & Wakhungu, J. W. (2007). Effect of supplementing weaner goats with graded levels of *Calliandra calothyrsus* and Lucerne

Medicago sativa on feed intake and weight gain. *Livestock Research for Rural Development, 19*(115).

KNBS. (2009). Kenya Population and Housing Census, Kenya National Bureau of Statistics.

Koech, O. K., Kinuthia, R. N., Mureithi, S. M., Karuku, G., & Wanjogu, R. (2015). Water Stress Tolerance of Six Rangeland Grasses in the Kenyan Semi-Arid Rangelands. *American Journal of Agriculture and Forestry, 3*(5), 222–229.

Kosgey, I.S., Rowlands, G.J., Van Arendonk, J.A.M., & Baker, R. L. (2008). Small ruminant production in small holder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research, 77*, 11–24.

Lambert, M. G., Jung, G. A, Fletcher, R. H., & Budding, P. J. (1989). Forage shrubs in North Island hill country. 2. Sheep and goat preferences. *New Zealand Journal of Agricultural Research, 32*, 485–490.

Lamidi, A.A., & Ologbose, F. I. (2014). A Threat to Sustainable Ruminant Animal Production in Nigeria. *Journal of Agriculture and Social Research*, *4*(1).

Lamy, E., Costa, G., Capela, S.F., Potes, J., Coelho, A.V., & Baptista, E. S. (2008). Comparison of electrophoretic protein profiles from sheep and goat parotid saliva. *Journal of Chemistry Ecology, 2*(34), 388–397.

Lascano, C.E., & Euclides, V. B. P. (1996). Nutritional quality and animal production of Brachiaria pastures. In: Miles, J.W., Maass, B.L., & do Valle, C.B. (Eds.), *Brachiaria: Biology, Agronomy and Improvement*; CIAT: Cali, Colombia, pp. 106–123.

Le Houérou, H. N. (1980). *Browse in Africa, the Current State of Knowledge*. ILCA.

Lebbie, S.H., Mukasa-Mugerwa, B., & Wilson, R. T. (1996). Impact of disease and reproductive wastage on productivity of tropical small ruminants. In: *Proceedings from. 6th International Conference. on Goats* 6th-11th May, 1996 Beijing, 727.

Lima, S. F. I., Timossi, P. C. I., & Almeida, D. P. (2014). Weed suppression in the formation of Brachiaria under three sowing methods. *Planta Daninha, 32*(4), 699–707.

Loch, D. S., Rethman, N. F., & Van Niekerk, W. A. (2004). Rhodesgrass. *Warm-Season (C4) Grasses, Agronomy Monograph, 45*, 833-872.

Lopes, F. C. F., Paciullo, D. S. C., & Mota, E. F. (2010). Chemical composition and *in situ* Ruminal degradability of four Brachiaria species. *Arquivo Brasileirode Medicina Veterinária e Zootecnia*, *62*(4), 883–888.

Lowe, K. F., Hume, D. E., & Fulkerson, W. J. (2015). Forages and Pastures | Perennial Forage and Pasture. In *Crops – Species and Varieties Encyclopaedia of Dairy Sciences* (pp. 576– 585).

Mackie, R. I., & Morrison, M. (1995). Nitrogen metabolism in the rumen: biotechnological problems and prospects. In *Workshop on Rumen Ecology Research Planning, Addis Ababa (Ethiopia), 13-18 Mar 1995*. ILRI.

MacOpiyo, L., Irungu, P., & Elhadi, Y. M. (2013). *Study of Livestock, Fodder, Milk Production and Marketing in Arid and Semi-Arid Lands of Kenya Under - "Promotion and Strengthening Enterprises and Market Systems in Drought-Prone ASAL Areas"* Baseline Report for Kajiado, West Pokot and Narok Counties.

Makkar, H. P. S. (2003). Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Ruminant Research, 49*(3), 241–256.

Maina, I., Osuga, Abdulrazak, S., Muleke, C.I., & Fujihara, T. (2012). Potential nutritive value of various parts of wild sunflower *(Tithonia diversifolia)* as source of feed for ruminants in Kenya. *Journal of Food, Agriculture & Environment, 10*(2): 632-635.

Manach, C., Scalbert, A., Morand, C., Re´me´sy, C., & Jimenez, L. (2004). Polyphenols food sources and bioavailability. *American Journal of Clinical Nutrition*, 79, 727–747.

Maass, B.L., Midega, A. O., Mutumura, M., Rahetla, V.B., Salgado, P., Kibirizi, J. M., & Rao, I. (2015). Home coming of Brachiaria: Improved hybrids prove useful for African Animal Agriculture. *East African Agricultural and Forestry Journal, 81*(1), 71–78.

Mbogoh, S.G., & Shaabani, S.B. (1999). *Socio-economic study on characterization of recommendation domains for pasture improvement in pastoral and agro-pastoral production systems in Kenya.* Part II Consultancy Report. KARI/EU ARSP II. KARI, Nairobi, Kenya.

Mbwile, R. P., & Udén, P. (1997). The effect of feeding level on intake and digestibility of Rhodes grass (*Chloris gayana,* cv Kunth) by dairy cows. *Animal Feed Science Technology, 66* (1-3), 181-196.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., & Morgan, C. A. (1995). *Animal nutrition 5th Edition*. Longman Group Ltd. Edinburg gate, Harlow Essex CM20 2JE UK. pp. 444 - 510.

McDowell, L. R. (1997). Mineral deficiencies and toxicities and their effect on beef production in developing countries. In *Symposium: Beef cattle production in developing countries University of Edinburgh, Scotland* (pp. 216-241).

Mc Manus, C., Paim, T.P., Melo, C.B., Brasil, B.S.A.F., & Paiva, S.R. (2014). Selection methods for resistance to and tolerance of helminths in livestock. *Journal/Parasite, 21,* 56.

Meale, S. J., Chaves, A. V., Baah, J., & McAllister, T. A. (2012). Methane production of different forages in *in vitro* ruminal fermentation. *Asian-Australasian Journal of Animal Science, 25*(1), 86–91.

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S., & Zijpp, A.J. (2008). Farmers' perceptions about exotic multipurpose fodder trees and constraints to their adoption. *Agroforestry Systems.* 73(2):141-153.

Menke, K.H., & Steingass, H. (1998). Estimation of the Energetic Feed Value obtained from chemical analysis and *in-vitro* gas production using rumen fluid. *Animal Resource Development, 28*, 7–55.

Mekuriaw, Y., Asmare, B., Urge, M., & Animut, G. (2012). Intake, digestibility, live weight changes and rumen parameters of Washera sheep fed mixtures of lowland bamboo *Oxytenanthera abyssinica* leaves and natural pasture grass hay at different ratios. *Pakistan Journal of Nutrition*, *11*(3), 22–31.

Mero, R. N., & Udén, P. (1997). Promising tropical grasses and legumes as feed resources in Central Tanzania. I. Effect of different cutting patterns on production and nutritive value of six grasses and six legumes. *Tropical Grasslands*, *31*(6), 549–555.

Mganga, K.Z., Musimba, N.K R., Nyangito, M.M., Nyariki, D.M., & Mwangombe, A. W. (2010). Improving hydrological properties of degraded soils in semi-arid Kenya. *Journal of Environment Science Technology*, *3,* 217–225.

Miles, N., & Manson, A.D. (2000). Nutrition of planted pastures. In: Tainton N.M. (ed.), *Pasture management in South Africa.* Pietermaritzburg: University of Natal Press. pp. 180–232

Minson, D.J. (1990) *Forage in Ruminant Nutrition*. Academic Press, San Diego, pp. 483.

MLFD. (2004). Ministry of Livestock and Fisheries Development. Annual report.

MLFD. (2005). Ministry of Livestock and Fisheries Development. Annual report.

Moore, R. (1970). *Australian Grasslands*. Canberra: ANU Press.

Moyo, S., & Ayuk, E.T. (2001). Costs and benefits of tree fodder with small-scale dairy farmers in Zimbabwe. *Living Trees of South Africa*, *6,* 1–3.

Mtenga, L.A., & Kitaly, A. J. (1990). Growth performance and carcass characteristics of Tanzanian goats fed Chloris gayana hay with different levels of protein supplement. *Small Ruminant Research*, *3*(1), 1–8.

Mudzengi, C. P., Taderera, L. M., Tigere, A., & Kapembeza, C. S. (2014). Adoption of urea treatment of maize stover technology for dry season supplementation of cattle in Wedza, Zimbabwe. *Livestock Research for Rural Development*, *26,* 160.

Muia, J. M. K. (2000). *Use of Napier grass to improve smallholder milk production in Kenya*. PhD Thesis, Wageningen Agricultural University, The Netherlands.

Mugambi, J.M., Wanyangu, S.W., Bain, R.K., & Owango, M.O. (1996). Response of Dorper and Red Maasai lambs to trickle *Haemonchus contortus* infections. *Research Veterinary of Sciences*, *6,* 218–221.

Muinga, R.W., Njunie, M., Gatheru, M., & Njarui, D. M. (2016). The effects of Brachiaria grass cultivars on lactation performance of dairy cattle in Kenya. *The Proceedings of the Workshop Held in Naivasha, Kenya, 14th -15th September, 2016.* (pp. 229-237).

Mupangwa, J. F., Ngongoni, N. T., Topps, J. H., & Hamudikuwanda, H. (2000). Effects of supplementing a basal diet of *Chloris gayana* hay with one of three protein-rich legume hays of *Cassia rotundifolia*, *Lablab purpureus* and *Macroptilium atropurpureum* forage on some nutritional parameters in goats. *Tropical Animal Health Production, 32*(4), 245– 256.

Mutai, C., Njuguna, J., & Ghimire, S. (2017). Brachiaria Grasses (*Brachiaria spp*.) harbor a diverse bacterial community with multiple attributes beneficial to plant growth and development. *Microbiology Open, 6*(5), https://doi.org/10.1002/mbo3.497

Mureithi, J.G., & Djikeng, A. (2016). Overview of the climate smart Brachiaria grass programme. In: *Climate smart Brachiaria grasses for improving livestock production in East Africa: Kenya Experience (*Njarui, D.M.G., Gichangi, E.M., Ghimire, S.R. & Muinga, R.W. (Eds.): *Proceedings of a workshop, Naivasha, Kenya, 14th – 15th September 2016*. Nairobi, Kenya: Kenya Agricultural and Livestock Research Organization: pp. 1-2.

Murphy, S.R., Lodge, G.M., & Brennan, M.A. (2010). Tropical grasses capture winter rainfall. In: *The Proceedings of the 25th Annual Conference of the Grassland Society of NSW*. Eds C Waters, D Garden. NSW Grassland Society Inc., Orange. pp. 137–140

Mustafa, V. S., Moscardini, A. R. C., & Borges, J. R. J. (2012). Intoxicação natural por Brachiaria spp. em ovinos no Brasil Central. *Pesquisa Veterinária Brasileira*, v. 32, n. 12, p. 1272–1280.

Nardone, A. (2000). Weather conditions and genetics of breeding systems in the Mediterranean area. *XXXX International Sysmposium of Societa Italiana per Il Progresso Della Zootecnia,* Ragusa, Italy, pp. 67–92.

NRC. (1984). *Nutrient Requirements for various classes of sheep and goat,* Washington, D.C.: National Academies Press.

NRC. (2007). Committee on the Nutrient Requirements of Small Ruminants, Board on Agriculture, Division on Earth, and Life Studies. *Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids*. National Research Council

Naumann, H. D., Tedeschi, L.O., Zeller, W. E., & Huntley, N. F. (2017). The role of condensed tannins in ruminant animal production: advances, limitations and future directions. *Brazilian Journal of Animal Science*, *79,* 727–747.

Ndikumana, J. (1985). *Etude de l'hybridation entre espèce apomictiques et sexuées dans le genre Brachiaria. Louvain-La-Neuve, Beligium:* PhD. Dissertation. Université Catholique de Louvain.

Ndikumana, J., & Leeuw, P.N. (1996). Regional Expertise with Brachiaria: Sub-Saharan Africa. In: Miles B.J.W. (ed), *Brachiaria: Biology, Agronomy, and Improvement*. CIAT & EMBRAPA. pp. 245–257.

Ngila, P., Njarui D. M., Musimba, N. K., & Njunie, M. (2016). Performance of Galla Goats Fed Different Cultivars of Brachiaria in the Coastal Lowlands of Kenya. *Journal of Fisheries Livestock Production, 5:* 210.

Ngwa, A. T., Nsahlai, I.V., & Bonsi, M. L. K. (2003). Feed intake and dietary preferences of sheep and goats offered hay and legume-tree pods in South Africa. *Agroforestry Systems*, *57*, 29–37.

Niang, A., Ugiziwe, J., & Styger, E. (1996). Forage potential of eight woody species: intake and growth rates of local young goats in the highland region of Rwanda. *Agroforestry Systems* 34, 171–178.

Nguku, S., Musimba, N., Njarui, D., Mwobobia, R., & Kaindi, E. (2016). Effects of acid scarification on germination of the genus Brachiaria grass Cultivars. *International Journal of Science Research Innovation and Technology, 3*, 45–50.

Njarui, D. M. G., Gatheru, M., & Wambua, J. M. (2010). Challenges in milk processing and marketing among dairies in the semi-arid tropical Kenya. *Livestock Research for Rural Development, 22*(2), 35. http://www.lrrd.org/lrrd22/2/njar22035.htm

Norton, B. W. (1994). The nutritive value of tree legumes. *Forage tree legumes in tropical agriculture.* CAB International, U K. pp. 177-191.

Norton, B.W., & Waterfall, M. H. (2000). The nutritive value of *Tipuana Tipu* and *Calliandra calothyrsus* as supplements to low–quality straw for goats. *Small Ruminant Research*, *38,* 178–182.

Nyeko, P., Stewart, J., Franzel, S., & Barklund, P. (2004). *Farmer's experiences in the management and utilisation of Calliandra Calothyrsus, a fodder shrub, in Uganda* (network paper, No. 140).

Obour, R., Oppong, S. K., & Abebrese, I. K. (2015). Forage palatability of *Broussonetia papyrifera* an invasive species in Ghana: Relative preference and palatability by sheep and goats. *Journal of Energy and Natural Resource Management, 2,* 63–70.

Odhiambo, M. O. (2013). The ASAL policy of Kenya: releasing the full potential of arid and semi-arid lands — an analytical review. *Nomadic Peoples, 17*(1), 158–165. http://www.jstor.org/stable/43123928

Odongo, J.A., Muyekho, F.N., Kute, C.A., Magothe, M., & Buyu, G. (1999). Evaluation and management of forages in the originally non-traditional dairy producing areas of Kenya. *Proceedings of 6th Biennial Scientific Conference. Kenya Agricultural Research Institute (KAR1). 9th-13th Nov., 1998,* pp. 18-24.

Ojango, J.M.K., Oyieng, E.P., Audho, J., & Okeyo, A.M. (2014). *Indigenous sheep to help improve market access and livelihood security among pastoralists in Kenya*: Results of a baseline survey. Nairobi, Kenya: International Livestock Research Institute.

Olafadehan, O.A., & Okunade, S. A. (2016). Fodder value of three browse forage species for growing goats. *Journal of the Saudi Society of Agricultural Sciences, 17*(1). http://dx.doi.org/10.1016/j.jssas.2016.01.001.

Ondiek, J. O., Abdulrazak, S. A., Tuitoek, J. K., & Bareeba, F. T. (2010). Use of *Leucaena leucocephala* and Gliricidia as nitrogen source in supplementary concentrates for dairy goats offered Rhodes grass hay. *Asian-Australasian Journal of Animal Science, 3,* 1246– 1254.

Ondiek, J.O., Abdulrazak, S.A., Tuitoek, J.K., & Bareeba, F. (1999). The effects of *Gliricidia sepium* and maize bran as supplementary feed to Rhodes grass hay on intake, digestion and live weight of dairy goats. *Livestock Production Science, 61*, 27–38.

Ondiek, J.O., Abdulrazak, S.A., Tuitoek, J.K., & Bareeba, F. T. (2000). Use of *Leucaena leucocephala* and Gliricidia as nitrogen source in supplementary concentrates for dairy goats offered Rhodes grass hay. *Asian-Australasian Journal of Animal Science, 13,* 1249– 1254.

Ørskov, E.R., & McDonald, I. (1979). The estimation of protein degradation in the rumen from incubation measurements weighted according to the rate of passage. *Journal Agricultural Science, 92,* 499–503.

Osuga, I. M., Abdulrazak, S. A., Muleke, C. I., & Fujihara, T. (2012). Effect of supplementing Rhodes grass hay *(Chloris gayana)* with *Berchemia discolor* or (*Zizyphus mucronata)* on the performance of growing goats in Kenya. *Journal of Animal Physiology and Animal Nutrition, 96*(4), 634–639.

Osuji, P.O, Nsahlai, I.V., & Khalili, H. (1993). *Feed evaluation.* ILCA Manual. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

Owen, E., Kitalyi, A., Jayasuriya, N., & Smith, T. (2005). *Improving the husbandry of animals kept by resource-poor people in developing countries.* Nottingham University Press, Nottingham, England (pp. 74).

Palmer, B., & Ibrahim, T. (1996). Calliandra calothyrsus forage for the tropics - a current assessment. *International Workshop on the Genus Calliandra. 23rd-27th Jan., 1996,* 183–194.

Paterson, J.A., Belyea, R.L., Bowman, J.P., Kerley, M.S., & Williams, J.E. (1994). The Impact of Forage Quality and Supplementation Regimen on Ruminant Animal Intake and Performance. *Forage Quality, Evaluation and Utilization,* American Society of Agronomy, Inc. Crop Science Society of America, Soil Science Society of America, Inc., Madison, 59-114.

Paterson, R.T., Roothaert, R.L., Nyaata, O.Z., Akyea, V. E., & Hove, L. (1996). Experience with Calliandra calothvrsus as a feed for livestock in Africa. *International Workshop on the Genus Calliandra. 23rd -27th Jan., 1996,* 195–209.

Patra, A. K. (2010). Effects of supplementing low-quality roughages with tree foliage on digestibility, nitrogen utilization and rumen characteristics in sheep: a meta-analysis. *Journal of Animal Physiology and Animal Nutrition*, *94*, 338–353.

Pedreira, C.G.S, Braga, G.J., & Portela, J. (2017). Herbage accumulation, plant-part composition and nutritive value on grazed signal grass *(Brachiaria decumbens)* pastures in response to stubble height and rest period based on canopy light interception. *Crop and Pasture Science*, *68*(1), 62–73. https://doi.org/DOI 10.1071/CP16333.

Payan, A., Jimenez, F., Ibrahim, M., & Casanoves, F. (2007). Improved pastures for cattle rising in the Jucuapa river subwatershed, Nicaragua. *Recursos Naturales y Ambiente*, *51*(52), 167–174.

Payne, W. J. A. (1978). *Cattle Production in the Tropics*. London: Longman group, UK, 257-359.

Payne, W.A.J. 1990. *An Introduction to Animal Husbandry in the Tropics*. 4th Ed. Longman group UK. Scientific and technical, 472-536.

Pell, A.N., Woolston, T. K., Nelson, K.E., & Schofield, P. (2000). Tannins: biological activity and bacterial tolerance. In: *Proceedings of an international workshop,* Adelaide, Australia, 31st May–2nd June 1999, pp. 123–126.

Perera, A.N.F., Perera, E.R.K., & Gunasena, H.P.M. (1996*).* Nutritive value and degradation characteristics of *Calliadra calothyrsus*. In: *Proceedings. International workshop on the genus Calliandra*. Ed. D.O. Evans. Bogor, Indonesia, Jan. 23rd – 27th pp. 251 – 259.

Peyraud, J. L., & Astigarraga, L. (1998). Review of the effects of Nitrogen fertilization on the intake and nutritive value of fresh herbage. Consequences on animal nutritive and nitrogen balance. *Animal Feed Science Technology*, *72*, 235–239.

Phiri, D.M., Coulman, B., Steppler, H.A., Kamara, C.S., & Kwesiga, F. (1992). The effect of browse supplementation on maize husk utilization by goats. *Agroforestry System*, *17*(2), 153–158.

Piluzza, G., & Ullitta, S. (2010). The dynamics of phenolic concentration in some pasture species and implications for animal husbandry. *Journal of the Science of Food and Agriculture, 90,* 1452–1459.

Place, F., Roothaert, R., Maina, L., Franzel, S., Sinja, J., & Wanjiku, J. (2009). *The Impact of Fodder Trees on Milk Production and Income among Smallholder Dairy Farmers in East Africa and the Role of Research* (Occasional Paper No. 12). http://impact.cgiar.org/pdf/217.pdf.

Polley, H. W., Morgan, J. A., & Fay, P. A. (2011). Application of a conceptual framework to interpret variability in rangeland responses to atmospheric CO_2 enrichment. *The Journal of Agricultural Science*, *149*(1), 1-14.

Porter, L.J., Hrstich, L.N., & Chan, B. (1986). The conversion of proanthocyanidins and prodelphinidins to cyanidin and delphinidin. *Phytochemistry, 25,* 223–230.

Premaratne, S., & Perera, H.G.D. (1999). Evaluation of provenance variation in condensed tannin content of fresh leaves of *Calliandra calothyrsus*. *Australian Journal of Animal Science*, *12* (6), 891 -894.

Preston, T. R. (1986). *Better utilization of crop residues and by-products in animal feeding. 2. A practical manual for research workers*. Animal Production and Health Paper 50/2, FAO Paper 50/2), Rome Italy.

Preston, TR., & Leng, R. (1987). *Matching Ruminant Production Systems with available resources in the Tropics and sub tropics.* CTA publication, Armidale, Australia pp 245.

Preston, R. (1990). Future strategies for livestock production in the tropical 3rd world countries. *Ambio*, *19,* 390–393.

Provenza, F. D., Lynch, J. J., & Chene, C. D. (1995). Effects of a flavor and food restriction on the response of sheep to novel foods. *Applied Animal Behaviour Science*, *43,* 83–93.

Provenza, F. D. (1995). Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management, 48*, 2–17.

Quraishi, M. A. (1999). *Range Management in Pakistan.* Faisalabad University of Agriculture.

Reid, R. L. (1994). Milestones in forage research *(1969-1994). Forage Quality, Evaluation, and Utilization,* ASA, CSSA, SSSA. (pp. 1–58).

Renvoize, S.A., Clayton, W.D., & Kabuye, C. H. (1996). Morphology, Taxonomy, and Natural Distribution of Brachiaria. In: *Biology, Agronomy, and Improvement*, B. A. J.W. Miles (Ed.), CIAT & EMBRAPA, pp. 1–12

Riet-Correa, B., Castro, M.B., Lemos, R.A., Riet-Correa, G., Mustafa, V., & Riet-Correa, F**.** (2011). Brachiaria spp. poisoning of ruminants in Brazil. *Pesquisa. Agropecuária Brasileira, 31*(3), 183-192.

Robbins, C. T., Hanley, T. A., Hagerman, A. E., Hjeljord, O., Baker, D. L., Schwartz, C. C., & Mautz, W. W. (1987). Role of Tannins in defending plants against ruminants: Reduction in protein availability. *Ecology, 1*(98–107).

Roothaert, R.L. (1999). Feed intake and selection of tree fodder by dairy heifers. *Animal Feed Science and Technology, 79,* 1-13.

Roothaert, R.L., Arimi, H.K., & Kamau, E. N. (1997). *Improving Indigenous Fodder Trees and Shrubs in Kenya: Starting with Farmers' Knowledge,* No 1 11 Agroforestry Research Network for Africa (AFRENA) report. Published by ICRAF. In Starting with Farmers' Knowledge No 1 11.

Rosegrant, M.W., Fernandez. M., Sinha. A., Alder, J., Ahammad, H., de Fraiture, C., Eickhout, B., Fonseka, J., Huang, J., Koyama, O., & Omizzene, A.M. (2009). Looking into the future of agriculture and AKST. *Agriculture at a crossroad*. Island Press, Washington D.C., USA.

Rusdy, M. (2016). (*Calliandra calythorsus)* leaves as tanniferous fodder for ruminant animals. *International Journal of Scientific and Research Publications*, *6*(12), 286. www.ijsrp.org

SAS, (2002). *Statistical Analysis System Institute*. *SAS User's Guide. Statistics, Software Version 9.00*, SAS Institute, Cary, North Carolina, USA.

Santos, J. H. L. (2008). Estudo da toxicidade de diferentes estágios de crescimento de Brachiaria decumbens em ovinos. *Dissertação de Mestrado em Saúde* Animal, Faculdade de Agronomia e Veterinária. Universidade de Brasília, Brasília.

Santoso, B., Saragih, E.W., & Hariadi, B.T. (2013). Effect of water extract of plants containing tannin on in vitro methanogenesis and fermentation characteristics of the grass *Pennisetum purpureophoides*. *Journal of Tropical Animal Agriculture, 38* (1), 47 – 54.

Sanz-Saez, A., Erice, G., Aguirreolea, J., Muñoz, F., & Sanchez-Diaz, M. (2012). Alfalfa forage digestibility, quality and yield under future climate change scenarios vary with *Sinorhizobium meliloti* strain. *Plant Physiology*, *169,* 782–788.

Semenye, P. P., & Hutchcroft, T. (1992). *On-farm research and technology for dual-purpose goats*. Small Ruminant Collaborative Research Support Program.

Semenye, P. P., Onim, J. F. M., Conelly, W. T., & Fitzhugh, H. A. (1989). On-farm evaluation of dual-purpose goat production systems in Kenya. *Journal of animal science*, *67*(11), 3096-3102.

Setyawati, I., Putra, I.G.N.A.D., Wiratmini, N.I., & Sudatri, N.W. (2016). Liver histology of female rat *(Rattusnovergicus)* fed diet containing Calliandra leaf and pineapple peel during gestation. *International Journal of Advance Pharmacy Biology and Chemistry, 5* (1). 9 – 14.

Solomon, B., Leeuw P. N., Grandin, B. E., & Neate, P. J. (1991). *Maasai herding: An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya.* ILCA Systems Study 4. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 172 pp.

Souza, R.I.C., Riet-Correa, F., Barbosa-Ferreira, M., Brum, K.B., Fernandes, C.E., & Lemos, R.A.A. (2010). Intoxicação por Brachiaria spp. em bovinos no Mato Grosso do Sul. *Pesquisa Veterinaria Brazileira*, *30*(12), 1036-1042.

Subbarao, G.V., Nakahara, K. Hurtado, M. P., Ono, H., Moreta, D. E., Salcedo, A. F., & Ito, O. (2009). Evidence for biological nitrification inhibition in Brachiaria pastures. *Proceedings of the National Academy of Sciences Oct 2009,* 106 (41).

Saturnino, K.C., Mariani, T. M., Barbosa-Ferreira, M., & Brum, K. B. (2010). Intoxicação experimental por Brachiaria decumbens em ovinos confinados. *Pesquisa Veterinaria BrazileiraVeterinária Brasileira*, *30*(3), 195–202.

Taweel, H.Z., Tas, B.M., Smit, H.J., Elgersma, A., Dijkstra, J., & Tamminga, S. (2003). Improving the quality of perennial ryegrass *(Lolium perenne L.)* for dairy cows by selecting for fast clearing and/or degradable neutral detergent fibre. *Livestock Production Sciences*, *141*, 113–127.

Tedonkeng, P.E., Boukila, B., Fonteh, F. A., Tendonkeng, F., Kana, J. R., & Nanda, A. S. (2007). Nutritive value of some grasses and leguminous tree leaves of the Central region of Africa. *Animal Feed Science Technology*, *135*(3–4), 273–282.

Temu, V.W., Rude, B.J., & Baldwin, B.S. (2014). Nutritive value response of native warm-season forage grasses to harvest intervals and durations in mixed stands. *Plants*, 3, 266–283.

Thomas, C.D., Cameron, A., & Green, R.E. (2004). Extinction risk from climate change. *Nature*, *427*, 145–148.

Thornton, P.K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society, 365*, 2853–2867.

Tiffany, M. E., McDowell, L. R., Connor, G. A. O., Nguyen, H., Martin, F. G., & Cardoso, N. S. W. (2000). Effects of pasture applied bio solids on forage and soil concentration over a grazing season in North Florida. I. Macro minerals, Crude protein and *in vitro* digestibility. Community Soil Science. *Plant Analysis, 31*, 201–203.

Tuwei, P.K., Kang'ara, J.N.N., Mueller-Harvey, I., Poole, J., Ngugi, F.K., & Stewart, J.L. (2003). Factors affecting biomass production and nutritive value of Calliandra calothyrsus leaf as fodder for ruminants. *Journal of Agricultural Science, 141*, 113–127.

UNEP. (2012). *Reduction in Sulphur in Fuels.* Partnership for Clean Fuels and Vehicles. United Nations Environment Programme, Nairobi.

Urio, N.A., Sarwat, S.V., & Mtengeti, E.J. (1988). A review of the potentialof Brachiaria species as forage crop for livestock in Tanzania. In: *Proceedings of the third PANESA workshop,* Addis Ababa, Ethiopia, ILCA. pp. 74–80.

Urio, N.A., Sarwat, S.V., & Mtengeti, E.J. (2006). A review of potential of Brachiaria species in Tanzania.

Vaithiyanathan, S., Mishra, J.P., Sheikh, Q., & Kumar, R. (2001). Salivary glands tannins binding proteins of sheep and goat. *Indian Journal of Animal Science, 71,* 1131–1134.

Van Soest, P.J., Robertson, J.B., & Lewis, B. A. (1994). Methods for dietary fibre, Neutral detergent fibre and non-starch polysaccharides in relation to Animal nutrition. *Journal of Dairy Science*, *74,* 3588–3597.

Van Soest, P.J., Robertson, J.B., & Lewis, B. A. (1991). Methods for dietary fibre, neutral detergent fibre, and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74,* 3583–3597.

Vandesschricke, F., Quilici, S. G., & Roederer, Y. (1992). The Leucaenapsyllid in Reunion: the extent of damage and prospect of biological control. *Bois et Forest des Tropiques*, *234*, 47–59.

Verbeek, E., Kanis, E., Baker, R.L., & Kosgey, I. S. (2006). Socio-economic factors influencing small ruminant breeding in Kenya. *Livestock Research for Rural Development, 19*(6).

Vigna, B.B.Z., Jungmann, L., Francisco, P.M., Zucchi, M.I., Valle, C.B., & Souza, A. P. (2011). Genetic diversity and population structure of the *Brachiaria brizantha* germplasm. *Tropical Plant Biology*, 4, 157–169.

Vitti, D.M.S.S., Nozella, E.F., Abdalla, A.L., Bueno, I.C.S., Silva, F. J.C., & Costa, C. (2005). The effect of drying and urea treatment on nutritional and anti-nutritional components of browses collected during wet and dry seasons. *Animal Feed Science Technology, 122,* 123–133.

Waghorn, G. C. (2008). Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production – progress and challenges. *Animal Feed Science Technology, 147,* 116–139.

Wambugu, C., Place, F., & Franzel, S. (2011). Research, development and scaling up the adoption of fodder shrub innovations in East Africa. *International Journal of Agriculture Sustain*, *9,* 100–109.

Wambui, C., Abdulrazak, S., & Noordin, Q. (2006). The effect of supplementing urea treated maize stover with Tithonia, Calliandra and Sesbania to growing goats. *Livestock Research for Rural Development.* 18, 5. http://www.lrrd.org/lrrd18/5/abdu18064.htm.

Warly, E.L., Fariani, A., Ichinohe, T., Abdulrazak, S.A., & Fujihara, T. (2004). Comparative Rumen Degradability of Some Legume Forages between Wet and Dry Season in West Sumatra, Indonesia. *Asian-Australian Journal of Animal Science, 17*(8), 1107–1111.

Widiawati, Y. (2002). *The utilization of Tropical Shrub Legumes: Leucaena Leucocephala, Gliricidia sepium and Calliandra calothyrsus by Ruminant Animals.* PhD Thesis. James Cook University, Australia.

Wilson, R. T. (1991). *Small Ruminant Production and the Small Ruminant Genetic Resource in Tropical Africa, FAO.* Animal Production and Health Paper, No. 88. FAO, Rome.

Wilson, R. T. (1992). Goat and sheep, skin and fibre production in selected sub-Saharan countries. *Small Ruminant Research*, *8,* 13–22.

Wilson, R. T. (1995). *Livestock production systems.* CTA/Macmillan Education: London.

Wilson, R. T. (1997). Animal genetic resources and domestic animal diversity in Nepal. *Animal Genetic Resources and Domestic Animal Diversity in Nepal, 6,* 233–251.

Wina, E., Tangendjaja, B., & Susana, I. W. (2005). Effects of chopping, and soaking in water, hydrochloric acidic and calcium hydroxide solutions on the nutritional value of *Acacia villosa* for goats. *Animal Feed Science Technology*, *122,* 79–92.

Wymann von Dach, S., Romeo, R., Vita, A., Wurzinger, M., & Kohler, T. (2014). *Mountain Farming Is Family Farming: A Contribution from Mountain Areas to the International Year of Family Farming*; Food and Agriculture Organization. FAO. Rome, Italy. http:// www.fao.org/docrep/019/i3480e/i3480e.pdf.

Yirga, H., Melaku, S., & Urge, M. (2011). Effect of concentrate supplementation on live weight change and carcass characteristics of Hararghe Highland sheep fed a basal diet of urea-treated maize stover. *Livestock Research for Rural Development*, *23*(12), 245.

Yusmadi, N., & Ridla, M. (2008). Quality and palatability of silage and hay based Rations Complete primer organic waste on Etawah goat. *Journal of Agriculture Pet, 8,* 31–38.

Yulistiani, D. (2016). Response of sheep fed on corn cob silage or elephant grass basal diet with or without Calliandra leaf meal supplementation. *Jurnal Ilmu Ternak Dan Veteriner, 21*(3), 165–173.

APPENDICES

Appendix A. Evidence of Publication

International Journal of Veterinary Sciences and Animal Husbandry 2020; 5(5): 18-22

International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2020; 5(5): 18-22

www.veterinarypaper.com
Received: 15-07-2020
Accepted: 18-08-2020

RS Kenana
Egerton University, Department of Animal Science, PO Box, Egerton, Kenya

PA Onjoro
Egerton University, Department of Animal Science, PO Box, Egerton, Kenya

MK Ambula
Egerton University, Department of Animal Science, PO Box, Egerton, Kenya

Relative palatability and preference by red Maasai sheep offered brachiaria and Rhodes grass hay supplemented with calliandra leaves in Kenya

RS Kenana, PA Onjoro and MK Ambula

Abstract
A study was conducted to evaluate the effect on palatability and preference of supplementing Brachiaria (*Brachiaria ruziziensis*) hay and Rhodes *(Chloris gayana)* hay with different levels of Calliandra *(Calliandra calothyrsus)* leaves on Red Maasai Sheep. Nine male sheep averaging one year and weighing (22.0 ± 2.5 kg) were used in a 3x4 factorial completely randomized design (CRD). Three animals in three replicates, were used to measure feed intake and palatability. Twelve experimental diets were formulated consisting of Brachiaria, Rhodes and a (50:50 mix) of Brachiaria and Rhodes grass hay as the basal diets, supplemented with (0%, 10%, 20% and 30%) of Calliandra leaves. Supplemental rates were used as treatments (T1, T2, T3 and T4) respectively. Treatment one (T1) served as the control. 200g of each diet was offered daily at 8:00am (East African time) with an allowance of 60 minutes feeding time. Results showed that supplementation improved ($p<0.05$) crude protein, average daily intake and palatability of the experimental diets. Brachiaria grass supplemented with 30% Calliandra emerged the most preferred with a dry matter intake (113.9 g/kg^{-1} DM) and palatability index of (RPI=100%). The relative palatability indices according to treatments were as follows: (T4>T3>T2>T1). The study concluded that Brachiaria grass supplemented with 30% Calliandra has a great potential as a forage diet for ruminants in the arid and semi-arid lands.

Keywords: Crude protein, diets, dry matter, intake

Appendix B. NACOSTI Permit

License No: NACOSTI/P/20/6589

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 599849

Date of Issue: 09/September/2020

RESEARCH LICENSE

This is to Certify that Mr.. Richard Suyianka Kenana of Egerton University, has been licensed to conduct research in Nakuru on the topic: EVALUATION OF THE EFFECTS OF FEEDING BRACHIARIA (Brachiaria ruziziensis) AND RHODES GRASS (Chloris gayana) HAY SUPPLEMENTED WITH CALLIANDRA (Calliandra calothyrsus) ON THE PERFORMANCE OF RED MAASAI SHEEP for the period ending : 09/September/2021.

License No: **NACOSTI/P/20/6589**

599849

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
5. The License does not give authority to tranfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix C. Research Ethics Clearance

EU/RE/DVC/009
Approval No. EUREC/APP/111/2021

EGERTON UNIVERSITY

TEL: (051) 2217808
FAX: 051-2217942

P. O. BOX 536
EGERTON

EGERTON UNIVERSITY RESEARCH ETHICS COMMITTEE

EU/RE/DVC/009
Approval No. EUREC/APP/111/2021

27th January, 2021

Richard Kenana
Animal Science Department
Egerton University.
P. O. Box, 536-20115
Egerton
Telephone.0725430801
E-mail rskenana@gmail.com

Dear Richard,

RE: ETHICAL CLEARANCE APPROVAL: EVALUATION OF THE EFFECT OF FEEDING BRACHIARIA (BRACHIARIA RUZIZIENSIS) AND RHODES GRASS (CHLORIS GAYANA) HAY SUPPLEMENTED WITH CALLIADRA (CALLIADRA CALLOTHYRSUS) ON THE PERFORMANCE OF RED MASAAI SHEEP

This is to inform you that ***Egerton University Research Ethics Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUREC/APP/111/2021.*** The approval period is ***27th January, 2021 –28th January, 2022.***
This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. You are required to adhere Institutional Experimental Animals use and Care policy.
iii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Research Ethics Committee***.
iv. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Research Ethics Committee*** within 72 hours of notification
v. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Research Ethics Committee*** within 72 hours
vi. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.

"Transforming Lives through Quality Education"

vii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

viii. Submission of an executive summary report within 90 days upon completion of the study to ***Egerton University Research Ethics Committee***.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

EGERTON UNIVERSITY
Date 27/01/2021
RESEARCH ETHICS

Prof. R. Ngure,

CHAIRMAN, EGERTON UNIVERSITY RESEARCH ETHICS CTTEE

RN/BK/BK

Appendix D. Research Pictorial

Plate 1. Brachiaria *(B. ruziziensis)*

Plate 2. Rhodes grass *(C. gayana)*

Plate 3. Calliandra *(C. calothyrsus)*

Plate 4. Red Maasai sheep

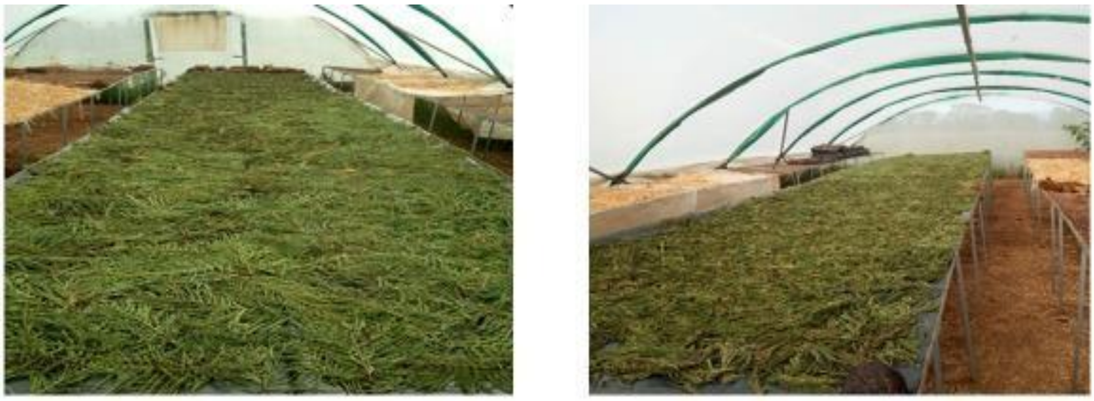


Plate 5. Drying of fresh Calliandra leaves in a green house

Plate 6. Mixing of the feed ingredients

Pate 7. Weighing and de-worming of sheep

Plate 8. Accurate weighing of feed

Plate 9. Palatability trials

Plate 10. Metabolism cages

Plate 11. Extraction of rumen liquor

Plate 12. Tannin and fibre extraction

Appendix E. ANOVA Tables

The SAS System 15:13 Saturday, August 14, 2020 2

The GLM Procedure

Dependent Variable: **DM**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	3311.000000	301.000000	33.44	<.0001
Error	24	216.000000	9.000000		
Corrected Total	35	3527.000000			

R-Square	Coeff Var	Root MSE	DM Mean
0.938758	0.325792	3.000000	920.8333

The SAS System 16:33 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **OM**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	1116.000000	101.454545	8.78	<.0001
Error	24	277.440000	11.560000		
Corrected Total	35	1393.440000			

R-Square	Coeff Var	Root MSE	OM Mean
0.800896	0.371585	3.400000	915.0000

The SAS System 16:48 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable**: EE**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	22342.58750	2031.14432	17570.5	<.0001
Error	24	2.77440	0.11560		
Corrected Total	35	22345.36190			

R-Square	Coeff Var	Root MSE	EE Mean
0.999876	1.010151	0.340000	33.65833

The SAS System 17:03 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **ME**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	34.33707500	3.12155227	49.94	<.0001
Error	24	1.50000000	0.06250000		
Corrected Total	35	35.83707500			

R-Square	Coeff Var	Root MSE	ME Mean
0.958144	3.784534	0.250000	6.605833

The SAS System 17:16 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **NDF**

Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	11	1976.000000	179.636364	1.15	0.3695
Error	24	3750.000000	156.250000		
Corrected Total	35	5726.000000			

R-Square	Coeff Var	Root MSE	NDF Mean
0.345093	1.754796	12.50000	712.3333

The SAS System 17:30 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **ADF**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	14678.75000	1334.43182	18.47	<.0001
Error	24	1734.00000	72.25000		
Corrected Total	35	16412.75000			

R-Square	Coeff Var	Root MSE	ADF Mean
0.894350	2.224646	8.500000	382.0833

The SAS System 17:40 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable**: CT**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2833.687500	257.607955	1272.14	<.0001
Error	24	4.860000	0.202500		
Corrected Total	35	2838.547500			

R-Square	Coeff Var	Root MSE	CT Mean
0.998288	2.038505	0.450000	22.07500

The SAS System 20:16 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **ASH**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	330.6675000	30.0606818	95.86	<.0001
Error	24	7.5264000	0.3136000		
Corrected Total	35	338.1939000			

R-Square	Coeff Var	Root MSE	ASH Mean
0.977745	0.666865	0.560000	83.97500

The SAS System 20:50 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **P**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	4.80290000	0.43662727	174.65	<.0001
Error	24	0.06000000	0.00250000		
Corrected Total	35	4.86290000			

R-Square	Coeff Var	Root MSE	P Mean
0.987662	10.60071	0.050000	0.471667

The SAS System 21:08 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **K**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	29.02550000	2.63868182	21.54	<.0001
Error	24	2.94000000	0.12250000		
Corrected Total	35	31.96550000			

R-Square	Coeff Var	Root MSE	K Mean
0.908026	3.264418	0.350000	10.72167

The SAS System 21:26 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Ca**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	39.36860000	3.57896364	159.07	<.0001
Error	24	0.54000000	0.02250000		
Corrected Total	35	39.90860000			

R-Square	Coeff Var	Root MSE	Ca Mean
0.986469	9.635974	0.150000	1.556667

The SAS System 21:58 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Mg**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model 11 2.41260000 0.21932727 1.79 0.1127

Error 24 2.94000000 0.12250000

Corrected Total 35 5.35260000

R-Square Coeff Var Root MSE Mg Mean

0.450734 20.95808 0.350000 1.670000

The SAS System 22:18 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Fe**

Sum of
Source DF Squares Mean Square F Value Pr > F Model 11 3567.680000 324.334545 42.89 <.0001

Error 24 181.500000 7.562500

Corrected Total 35 3749.180000

R-Square Coeff Var Root MSE Fe Mean

0.951589 7.081545 2.750000 38.83333

The SAS System 22:31 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Cu**

Sum of
Source DF Squares Mean Square F Value Pr > F

Model 11 0.48187500 0.04380682 17.52 <.0001

Error 24 0.06000000 0.00250000

Corrected Total 35 0.54187500

R-Square	Coeff Var	Root MSE	Cu Mean
0.889273	8.810573	0.050000	0.567500

The SAS System 22:47 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Zn**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2942.270000	267.479091	13.21	<.0001
Error	24	486.000000	20.250000		
Corrected Total	35	3428.270000			

R-Square	Coeff Var	Root MSE	Zn Mean
0.858238	12.56398	4.500000	35.81667

The SAS System 23:04 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Mn**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	23985.39000	2180.49000	15.14	<.0001
Error	24	3456.00000	144.00000		
Corrected Total	35	27441.39000			

R-Square	Coeff Var	Root MSE	Mn Mean
0.874059	8.094435	12.00000	148.2500

The SAS System 16:10 Sunday, September 19, 2020 2

The GLM Procedure

Dependent Variable: **Palatability**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	27960.80000	2541.89091	40670.3	<.0001
Error	24	1.50000	0.06250		
Corrected Total	35	27962.30000			

R-Square	Coeff Var	Root MSE	Palatability Mean
0.999946	0.386598	0.250000	64.66667

Dependent Variable: **DMI**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	883260.9391	80296.4490	2753.65	<.0001
Error	24	699.8400	29.1600		
Corrected Total	35	883960.7791			

R-Square	Coeff Var	Root MSE	DMI Mean
0.999208	0.843444	5.400000	640.2325

Dependent Variable: **DCP**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	1019.126475	92.647861	164.71	<.0001
Error	24	13.500000	0.562500		
Corrected Total	35	1032.626475			

Dependent Variable: **FBW**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	316.8410750	28.8037341	235.13	<.0001
Error	24	2.9400000	0.1225000		
Corrected Total	35	319.7810750			

R-Square	Coeff Var	Root MSE	FBW Mean
0.990806	1.573682	0.350000	22.24083