EVALUATION OF NUTRITIVE VALUE OF LOCAL BROWSES FROM KENYA ON PERFORMANCE OF GROWING GOATS (SMALL EAST AFRICAN X TOGGENBURG CROSSES)

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DECLARATION AND RECOMMENDATION

Declaration

I hereby 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.

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Recommendation

This thesis has been submitted with our approval as university supervisors

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DEDICATION

This work is dedicated to my beloved wife Vivien, my daughter Whitney, my sister Jackline and my mother Miriam for their support and prayers.

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ABSTRACT

The feeding value of five browse forages (*Balanites aegyptiaca, Maerua angolensis, Acacia brevispica, Grewia hostii* and *Berchemia discolor*) from semi-arid area were evaluated to check their potential as feed supplements. Rhodes grass (*Chloris gayana)* hay *ad-libitum* was used as control. The objectives of the study were to determine the feeding value of selected browses, their palatability and performance when growing goats (Small East African x Toggenburg) were offered the browse forages. Chemical composition including polyphenols and *in-vitro* gas production characteristics were determined. The Crude protein (CP) content ranged from 41.4gkg^{-1}DM to Rhodes grass and 161.8 gkg^{-1}DM in *Berchemia discolor*. The relative high CP content range (111.5 to 161.8 gkg^{-1}DM) of browse forage shows the possible contribution as protein source for goats. Total extractable phenolics (TEPH) and condensed tannins (CT) contents ranged from 6.1 to 52.3 gkg^{-1}DM and 2.0 to 43.8 gkg^{-1}DM, respectively. Relative palatability index of local browse species and control, differed widely with the following ranking: *Acacia brevispica >Balanites aegyptiaca >Grewia hostii >Berchemia discolor >Maerua angolensis >Chloris gayana*. For animal performance, the intake of Rhodes grass hay (53.4, 33.0 and 37.6g/d) varied across the diets, but supplementation significantly increased total dry matter intake (53.4, 117.7 and 125.2 g/d) for those supplemented with *Acacia brevispica* and *Berchemia discolor* respectively. The apparent nutrient digestibility differed ($P<0.05$) among the treatments. The average daily gain (ADG) of the control animals were low with a negative value (-47.8g/d) with the supplements *Acacia brevispica* and *Berchemia discolor* having a positive gain of 21.4g/d and 22.3g/d, respectively. The supplemented diets resulted in significant changes in ADG. However, *Berchemia discolor* was superior among the supplements with a lot of potential as a protein supplement to low quality roughages in the arid and semi-arid areas during the dry season. In conclusion, these browses being high in nutritive value, moderate palatability and enhanced feed intake, diet digestibility and average daily gains of growing goats can be used in dry season to supplement poor quality natural pasture or fibrous crop residues to improve animal performance in the arid and semi-arid regions.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
Ad libitum	Free feeding
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
CO_2	Carbon dioxide
CP	Crude protein
CRD	Completely randomized design
DM	Dry matter
EE	Ether Extract
HCL	Hydrochloric acid
In vitro	A test done in artificial environment in glass in the laboratory
In vivo	A test done within a living organism
NDF	Neutral Detergent Fibre
RPI	Relative palatability index
SAS	Statistical analysis system

CHAPTER ONE

INTRODUCTION

1.1 Background information

Kenyan livestock sector is dominated by small-scale farmers. The livestock population is concentrated in the arid and semi-arid lands (ASALS) which cover about 75 percent of the total land surface (FAO, 2005). In Kenya like many other tropical arid regions, livestock is an important source of household livelihoods among which goats are outstanding due to their adaption to the harsh environmental conditions prevalent in arid and semi-arid regions of the world. The productivity of goats maintained in resource poor environments are usually low due to seasonal fluctuations in the supply and quality of animal feeds. This could be overcome by using locally available natural resources such as the different local browse species (Aregawi *et al.,* 2008).

Browse (shrubs and tree forage) plays a significant role in providing fodder for ruminants in many parts of the world. The browse fodder is generally rich in protein and minerals and can be used during the dry season to supplement poor quality natural pasture or fibrous crop residue to improve animal performance (Devendra *et al*., 1990). Besides being available in the dry season, the browse species have a reasonable content of crude protein (CP) ranging from 12.7-14.7%, medium to high *in-vitro* dry matter digestibility of 66.6-80.8% and *in-sacco* potential degradability of 86-95% (Aregawi, 2006). However, the presence of tannins and other phenolic compounds in a large number of shrubs and tree leaves hampers their utilization as animal feeds.

Browse species are receiving increasing attention as potential livestock feeds in arid regions and a number of studies have proved that the different local browse species are rich in the nutrients and improve the performance of animals, particularly that of small ruminants (Melaku *et al.,* 2004). Fodder from browses is often available throughout the year, especially in the dry periods when pastures and crop residues are depleted (Aregawi *et al*., 2008). It is possible and most appropriate to supplement grazing with local browse such as *Grewia hostii, Balanites aegyptiaca, Acacia brevispica, Berchemia discolor* and *Maerua angolensis* to make up for deficiency of some nutritional component and to improve performance.

These browses are adapted to grow in arid and semi-arid areas and usually remain green throughout the year. Therefore, the objective of this study was to evaluate the effect of

supplementing a basal diet of grass hay with dried forage of local browse on feed intake, diet digestibility and growth performance for growing goats (Small East African x Toggenburg) during the post- weaning period.

1.2 Statement of the problem

Livestock are an important source of household livelihoods in arid and semi-arid regions of Kenya. However, the major constrain to goats rearing in these areas is deterioration of the range land from overgrazing of palatable grasses and shrubs leaving behind less palatable and inadequate quality of feed that become prominent under drought or dry season and can barely meet the maintenance and reproduction requirement of livestock especially the goats. Goats are also selective feeders. Browse (shrubs and tree forage) plays a significant role in providing fodder for ruminants. Supplementation of low quality roughage diets with browse has been shown to increase dry matter (DM) intake and to improve animal performance. There is no sufficient data that can be used to recommend to the farmers the most appropriate browses to be utilized for better performance of goats in the dry seasons.

1.3 Objectives

1.3.1 General objective

To contribute to increasing goat production through the utilization of selected local browse fodders as supplements to growing goats.

1.3.2 Specific objectives

i) To determine the feeding value of the selected local browses.
ii) To determine the palatability and preference of the selected browses.
iii) To determine the effects of supplementation of the selected browses on feed intake, average daily weight gain and feed digestibility on growing goats.

1.4 Hypotheses

i) There is no significant difference in feeding value of the selected local browses.
ii) There is no significant difference in palatability and preference of the selected browses.
iii) There is no significant difference in the effects of supplementation of the selected browses on feed intake, average daily weight gain and feed digestibility on growing goats.

1.5 Justification

The productivity of animals maintained in feed resource poor environments is usually low due to seasonal fluctuations in the supply and quality of animal feeds, which could be overcome by using locally available natural feed resources such as the different local browse species in the arid and semi-arid regions. Fodder from browses is often available throughout the year especially, in the dry and drought periods when pastures and crop residues are depleted in the arid and semi-arid regions. A number of studies have proved that the different browse species have acceptable digestibility, are rich in their nutrient content, and improve the performance of animals, particularly that of small ruminants. Supplementation with browse to low quality roughage diets has been shown to increase dry matter (DM) intake and to improve animal performance. The browses are well fermented in the rumen and improve the rumen environment in the ruminants especially the goats. It is therefore important to rank the available fodders in terms of preference and nutritional suitability, and to recommend to the farmers the most appropriate browses they can use to attain maximum performance, especially during the dry spells.

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CHAPTER TWO

LITERATURE REVIEW

2.1. Goat production systems in semi-arid regions of Kenya

In arid and semi-arid regions of Kenya, goats are normally kept under an extensive system of grazing and the major land use form in these areas is migratory pastoralism which is mainly for subsistence production. The nutrition of livestock in these areas has been a problem because of lack of basal feeds (Hernandez *et al*., 1998). When available even in limited amount the poor quality mature grasses and the fibrous feeds such as crop residues cannot maintain the animals during dry spells, therefore affecting animal performance. Supplementation of browse to low quality roughage diets with browse has been shown to increase dry matter (DM) intake and to improve animal performance (Reed *et al.,* 1990). The browse is well fermented in the rumen and improves the rumen environment in the ruminants, especially the goats. Browse fodder contains protein and minerals and can be used in the dry season to supplement poor quality natural pasture or fibrous crop residue to improve animal performance in the arid and semi-arid regions.

2.2 Distribution and production of browse species

Browse (shrubs and tree forage) is important in livestock production systems of semi-arid areas of Kenya which depend on natural pasture and crop residues. These natural pastures are severely overgrazed and nearly depleted in the dry season; therefore, local browse plants become an important component of the grazing animal diet especially the small ruminants. Local browse species have high persistence in their respective areas of arid and semi-arid regions (Woodward and Coppock, 1995). They are, however, at risk of extinction due to overuse (e.g. medicinal uses, charcoal making and browsing by ruminants), shifting cultivation and deforestation linked activities.

Not all local browse species are preferred by browsing animals (Kuria *et al*., 2005), and free from anti-nutritional factors. The local livestock keepers may have their own favourites for local browse plant species, depending on numerous uses (Alemu *et al.,* 1998). The screening work is important in highlighting potential local multipurpose shrubs and trees to preserve as early as possible in the respective sites to ensure maximum utilization and to improve animal performance.

2.3 Chemical composition of local browse species

Poor nutrition in ruminants is caused by both lower quantity and poor quality of the major grass forages that are of poor digestible and cannot meet animal requirements (Leng, 1990). This is one of the major causes of low productivity in livestock in the tropics in the arid and semi-arid regions, including Kenya.

Animals consuming basal diets containing less than 7% crude protein (CP) will require supplementation for improved performance and maximum production (Ondiek *et al.*, 2000). Therefore, there is need to exploit and encourage the use of these forage resources especially the legume browses which can improve CP intake during supplementation. Some Acacia species including *Acacia brevispica*, *Acacia nubica* and *Acacia mellifera* have been reported to contain appreciable CP (Abdulrazak *et al.,* 2000). Useful forage varies in their nutritive values and, therefore, the necessity to assess the local species using simple techniques like proximate analysis, *in-vitro* gas production and nylon bag method in determining the potential nutrition significance especially herbs, tree and shrub legume forage having anti-nutritional factors such as polyphenols, polyphenolics and tannins (Woodward and Reed, 1997). Tannins precipitate and bind protein by forming tannin protein complex (Reed, 1995), thereby decreasing the digestibility of protein and feed dry matter (DM) (Hangermarman *et al*., 1992). However, tannins may increase the availability of rumen undegradable nitrogen, minerals and digestible energy (Ash, 1990).

The contribution of browse as fodder is significant in difficult environmental conditions, where the available grazing is not sufficient to meet the maintenance requirements of the animal especially in the dry periods. During the dry period, farmers traditionally feed local fodder species to meet nutritional requirements of the animal. Apart from being available in the dry season, the browse species have a reasonable content of CP ranging between 12.7-14.7%, *in-Sacco* potential degradability of 86-95% and medium to high *in-vitro* dry matter digestibility of 66.6-80.8% (Aregawi, 2006). The relatively high CP of browse ranges from (112 to 321gkg^{-1}DM) shows the potential contribution as protein feed resources for ruminants, especially browsing goats. This has also been demonstrated in other tree legume browse in various studies (Ebong, 1995; Ondiek *et al.,* 1999; Abdulrazak *et al.,* 2000; Ondiek *et al.,* 2000; Abdulrazak *et al.,* 2001). They found both *Maerua angolensis* and *Balanites aegyptiaca* to be low in total extractable tannins 3 and 3gkg^{-1}DM and 114 and 152gkg^{-1} DM in total extractable phenolics, respectively. They also found *Acacia tortilis, Zizyphus spina-*

christi, Balanites aegyptiaca and *Acacia mellifera* to be potentially valuable for dry season feeding and as protein and energy supplements that can improve animal performance.

Elseed *et al*., (2002) in a study of Sudanese local browses reported variations between the early and late dry season with some nutrients (OM, NDF, ADF) being higher in the late dry season. The mineral content of the local tree browses varies from moderate to high (Abdulrazak *et al.*, 2000). According to their findings acacia species was rich in the micro-elements Mn, Mo, Zn, Co, Cu, Fe and Se showing that animals may consume adequate amounts and may only require specific supplementation in the diet during feeding. The highest mineral levels of browses for the macro elements Ca, P and Mg was at 28, 3.2 and 8.7gkg^{-1}DM and lowest levels at 7, 0.8 and 0.4gkg^{-1}DM, respectively (McDowell, 1985). The values are adequate to meet the requirement for growth to improve the animal performance especially during the dry periods when the availability of pasture is limited in the arid and semi-arid regions.

2.4 Effects of tannins in ruminant animals

Tannins from various plants affect the rate of gas production by decreasing the attachment of microbes to feed particles. Condensed tannins cause a considerable detachment of *Fibrobacter succinogenes*. The adaptation of microbes to tannins with a delay in degradation of tannins does appear to be responsible, at least for condensed tannins as they are not degraded by rumen microbes (Makkar *et al*., 1995). The lower intake of tannin-rich feeds is generally attributed to their astringent taste as well as, their lower rate of digestion (Makkar *et al*., 1995).

The condensed tannins are not absorbed into the blood stream (Terrill *et al*., 1994), therefore, under normal physiological conditions, are not likely to damage organs such as liver, kidney and spleen, have been observed for hydrolysable tannins. However, under the situation of intestinal damage due to consumption of high levels of tannins or of other intestinal membrane irritants, condensed tannins may get absorbed into blood and can cause organ damages similar to hydrolysable tannins.

Infestation by the interior parasites is one of the main constraints in ruminant production which affects animal performance and an increase in the supply of digestible protein improves the resistance and resilience of gastrointestinal nematodes (Van Houtert and Sykes, 1996). Condensed tannins (CT) bind strongly to protein and protect them from degradation

by rumen microbes. Condensed tannins containing in forages have been reported to minimize the detrimental effects including diarrhoea due to heavy load of internal parasites (Niezen *et al*., 1995). Forages containing CT can therefore be used in management of internal parasite.

2.5 Adaptation of ruminants to tannins

Very high levels of tannin intake by animals can produce toxicity and can even cause death (Garg *et al.,* 1992). Animals normally consuming tannin-rich feeds appear to develop defensive mechanism against tannins. In some animals, the salivary glands are considered to be the first line of defense against dietary tannins and therefore less protein is required to bind all the tannins, resulting in a quantitative saving of nitrogen from the feed (Pell *et al*., 2000). Saliva is rich in non-essential amino acids which are excreted instead of essential amino acids from dietary proteins, providing a qualitative saving of nitrogen which is a source of protein in nature (Pell *et al*., 2000).

The microorganisms present however, have some adaptive mechanism, which enables them to degrade hydrolysable tannins faster (Odenyo *et al.,* 1999) or decrease the activity of hydrolysable tannins through methylation of phenolic hydroxyl groups. These microbes are capable of working efficiently in high concentrations of tannins. The secretion of extracellular polysaccharides which has a high affinity for binding tannins and the formation of thick high-tannin affinity glycoprotein which prevent tannins from causing adverse effects on rumen microbes. The adaptive mechanism through which the rumen microbes could tolerate and work efficiently in presence of high tannin levels could be the protection of key membrane proteins by strategic deployment of lipids (Pell *et al*., 2000).

2.6 Importance of browse species

Browse (shrubs, herbs and tree forage) plays a significant role in providing fodder for ruminants in many parts of the world. Trees and shrub forage are of importance in animal production because they do not compete with human for food. Supplementation with browse to low quality roughage diets has been shown to increase dry matter (DM) intake and to improve animal performance (Reed *et al.,* 1990). The browse is well fermented in the rumen and improves the rumen environment in the ruminants especially the goats. The fodder is generally rich in protein and minerals and can be used in dry season to supplement poor quality natural pasture or fibrous crop residue. Though, the presence of tannins and other

phenolic compounds in a large number of shrubs and tree leaves hampers their utilization as animal feeds.

Browse species are receiving increasing attention as potential livestock more importantly in arid regions. A number of studies have proved that the different browse species are rich in nutrient and improve the performance of animals, particularly that of small ruminants (Melaku *et al.*, 2004). Browses are adapted to grow in arid and semi-arid areas and usually remain green throughout the year.

Trees and shrubs are increasingly recognized as important components of animal feeding, especially as suppliers of protein and their contribution is significant in difficult environmental conditions, where the available grazing is not sufficient to meet the maintenance requirements of the animal. They are readily accepted by livestock and contain high levels of digestibility, minerals and crude protein that improve animal performance especially during the dry period of the year.

2.7 Performance of goats fed on selected browse fodders

The animals raised on natural pastures are characterized by early maturity and fast growth during the wet season followed by rapid decline in nutritive value in the dry season due to changes in the nutritional value of the pasture. Therefore, changes in the nutritional value of these feed resources result in irregular growth patterns and low milk yields in the goats (Das and Sendalo, 1991). Supplementation with browses to low quality roughage diets has been shown to increase DM intake and to improve animal performance (Reed *et al*., 1990). There are many trees and shrubs in the tropics and subtropics that can supply fodder and most of them have been shown to be of high nutritive value (Abdulrazak *et al*., 2001). Forbs and shrubs are well fermented and improve the rumen environment. The fodder is generally rich in protein and minerals and can be used in dry season to supplement poor quality natural pasture or fibrous crop residue (Devendra *et al*., 1990).

Goats kept under extensive system on rangeland pastures are deficient in nitrogen and digestible nutrients for optimum rumen digestion (Van Soest, 1982), therefore, low intake can be improved by fodder supplementation (Topps, 1992; Abdulrazak *et al.*, 2000). Kanjanapruthipong and Leng, (1998) reported improving performance of rams fed on poor quality grass and supplemented with local browse species.

Tree browse however, contain tannins that may affect utilization (Makkar, 1993) and hence the mixture of browse forage may help to dilute the concentration of these anti-nutritive agents. The browse species have shown to increase palatability and intake (Devendra, 1990) as well as digestibility of the diet (Phiri *et al*., 1992) and growth (Bosman *et al*., 1995). This helps to improve and optimize on the nutritional intake to meet the requirement of the animal. Supplementation with leaf forage significantly improves the digestibility of the proximate constituents. Mixing of forage led to synchronization of fermentable individual chemical constituents leading to associative effects in dry matter intake and digestibility (Sinclair *et al*., 1995).

Protein status of poor quality roughage has limiting effects on the intake, and supplementing with browse which is high in crude protein increases the rumen outflow rate that stimulates the intake of the feedstuff. Mixing of leaf forage improve diet palatability through dilution of anti-nutritive factors with fiber resulting to an associated improved dry matter digestibility and intake (Devendra, 1990).

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CHAPTER THREE
MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at Egerton University; Njoro in Kenya. The area is situated at an altitude of 2238 meters above sea level with the mean annual rainfall and temperature of 900 - 1200 mm and 17 to 22ºC respectively (Egerton University, Department of Agricultural Engineering Meteorological station, 2009).

3.2 Forage collection site

The forage collection of *Grewia hostii, Balanites aegyptiaca, Acacia brevispica, Berchemia discolor* and *Maerua angolensis* was done in Marigat Sub-County, a semi-arid area in Baringo County which lies at 1080m above sea level. Rainfall is generally very erratic in nature 700 – 950mm per year with peaks in the April/May and July/August rain seasons and annual mean temperature of 23ºC.

3.3 Collection and preparation of experimental diets

Leaves of local browses namely *Grewia hostii, Balanites aegyptiaca, Acacia brevispica, Berchemia discolor* and *Maerua angolensis* was harvested by hand stripping from the browse trees on communal grazing ranges in Marigat Sub-County during the dry season. After harvesting, the forage was spread on a sheet and air dried under the shed for 2 to 4 days. The dried forages were put in sacks and stored in a well-ventilated shade until used. The basal diet consisted of Rhodes grass hay (*Chloris gayana)* that was purchased from a local supplier. The forages were ground to pass through 1mm sieve for chemical analysis and *in-vitro* digestibility and through 4mm sieve for feeding trials.

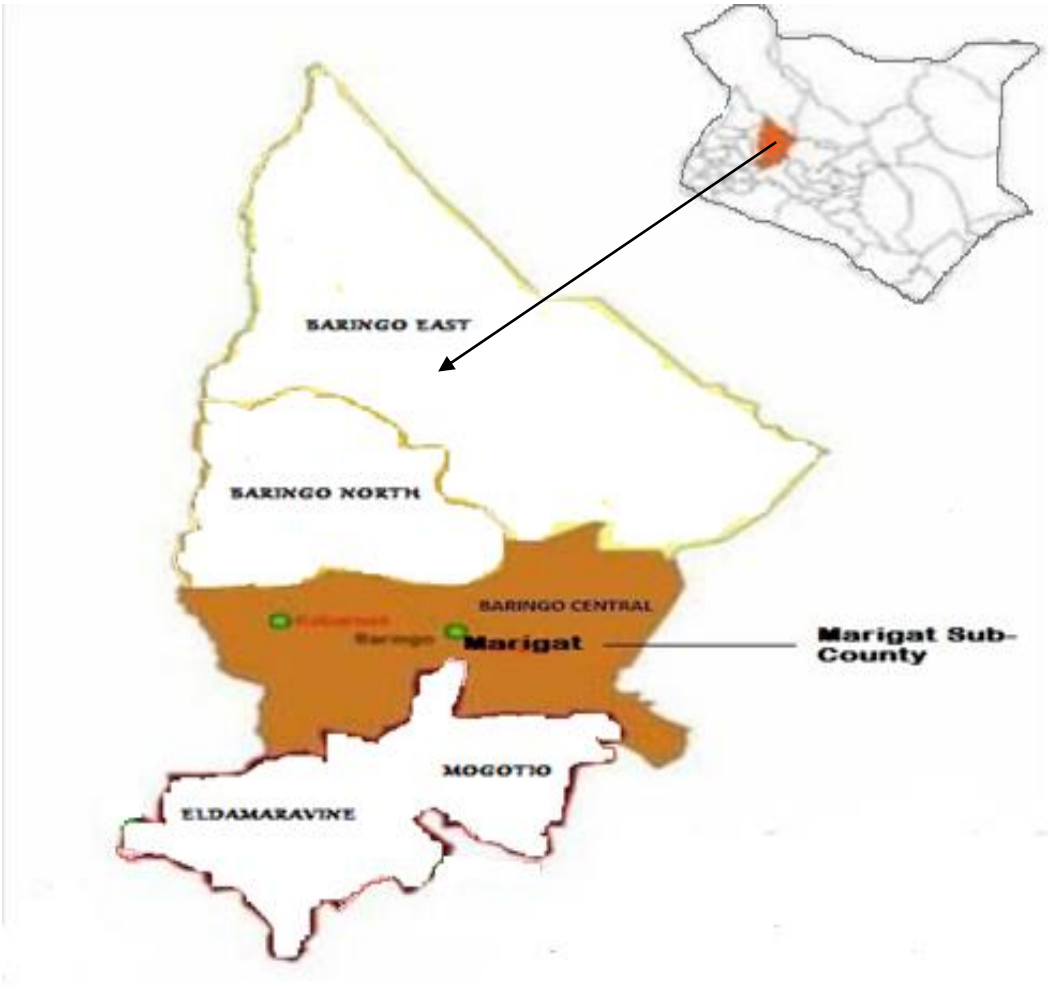

Figure 1. Map of Baringo County showing Marigat Sub-County where forages were collected.

Source: Google maps.

3.4 Chemical analysis

Proximate analysis was done to determine the dry matter (DM), nitrogen (N) and ash. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed to determine fibre and lignin content. Total extractable phenolics (TEPH) and condensed tannins were also determined, and analysis of minerals was done.

3.5 Determination of *in-vitro* degradability of selected browses

Four growing goats (Small East African x Toggenburg) of about 12 ± 2.2 kg live weight were used to obtain the rumen fluid. Rumen fluid extracted by use of a stomach tube was used in combination with buffers to simulate the action of saliva. A sample (1mm screen) of browse species weighing 200 mg was placed into a 100 ml glass syringes in duplicate.

The fermentative activity of the mixed microbial population was determined using the gas production technique described by Menke and Steingass, (1988).

Finally, the syringes were incubated in a thermostatically controlled water bath at 39^{o}C for 0-96 hours. Both the samples and blank (rumen fluid + buffer) were run in triplicates. The calculated values of gas production were fitted into the model developed by Ørskov and McDonald, (1979) to determine the degradability of the feed.

3.6 Experimental design and procedures

The three-dietary treatments were offered in a completely randomized design (CRD) with three replications and four goats per treatment. The basal diet (control) and supplements were offered individually in the study. The supplements were offered daily at 200 g / head on DM basis at 07:30h to let the goats eat the supplements before offering the control diet. The refusals from supplements were collected before offering the basal diet, weighed and recorded. The Rhode grass hay (control) was introduced at 09:00h after the supplement has been consumed by goats. The hay was offered at 750g / head on DM basis to ensure it was *ad-libitum*. Feed refusals were collected, weighed and recorded every day in the morning before offering fresh hay. Initial body weight of the goats was taken as the mean of two consecutive weighing after overnight fasting. Subsequent body weight measurements were taken every 7 days after overnight fasting until the completion of the experiment. The data was collected for 8 weeks.

3.7 Digestibility trial

During the eight weeks of the feeding trial, total daily fecal output of the 12 goats was collected for seven consecutive days. The daily fecal material of each animal was mixed thoroughly, a 50 g sample collected and kept in airtight plastic containers. This was followed by drying at 60^{o}C for 72 hours, grinding and storing in airtight containers pending chemical analysis.

3.8 Statistical analysis

Collected data on feed intake, digestibility and average daily gain (ADG) was subjected to the analysis of variance using the General linear model procedure of statistical analysis system (SAS, 2002) version 9.0, where initial live weight was fitted as a covariate in the analysis of feed intake and live weight changes.

Significant means was separated using Tukeys HSD (Tukeys Honestly Significant Difference Test) at 5% significance. The model used for statistical analysis was:

$Y_{Ijk} = \mu + \tau_i + (\text{ɛ}J) + \varepsilon_{ijk}$, where:

$Y_{IJ}k$ = observation from the i^{th} treatment,

μ= overall mean,

τ_i= effect of the i^{th} treatment (*Chloris gayana*, *Acacia brevispica* and *Berchemia discolor*),

$\text{ɛ}J$ = Fixed effect of the individual goat's induction body mass used as covariates,

ε_{ijk}= random error term.

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CHAPTER FOUR

RESULTS AND DISCUSSION

Objective 1: Evaluation of nutritive value and *in-vitro* degradation of selected local browses from semi-arid areas of Kenya

Abstract

The feeding value of five browse forages (*Balanites aegyptiaca, Maerua angolensis, Acacia brevispica, Grewia hostii and Berchemia discolor)* from the semi-arid area of Marigat, Baringo were evaluated to check their potential as feed supplements. Rhodes grass (*Chloris gayana)* hay *ad-libitum* supplemented with browse forage was used as the control. Chemical composition including polyphenols and *in-vitro* gas production characteristics were determined. The crude protein (CP) content ranged from 112gkg^{-1}DM in *Grewia hostii* and 162gkg^{-1}DM to *Berchemia discolor.* The relative high CP content range (112 to 162gkg^{-1}DM) of the browse forages show their potential as protein sources. The EE content range was from 17.7gkg^{-1}DM in *Grewia hostii* to 53.4gkg^{-1}DM for *Acacia brevispica. Chloris gayana, Grewia hostii, Acacia brevispica, Balanites aegyptiaca* and *Berchemia discolor* had higher NDF, ADF and ADL contents, respectively. *Maerua angolensis* had the lowest fibre content among the test species. The TEPH and CT contents ranged from 6.11 to 52.3gkg^{-1}DM and 2.0 to 43.8gkg^{-1}DM, respectively. The major mineral P, K, Ca and Mg were in the ranges of 1.8-3.4, 9.1-24.8, 2.5-20.5 and 1.3-13.1gkg^{-1}DM, respectively. Trace elements (mg kg^{-1}DM) varied in the range of Co (3224-5397), Cu (81.3-160), Zn (69.1-134), Mn (0.04-65.4) and Fe (20.2-86.9). It is concluded that these browses can be used in dry season to supplement poor quality natural pasture or fibrous crop residues to improve animal performance in semi-arid areas.

Keywords: *Acacia brevispica, Balanites aegyptiaca, Berchemia discolor,* crude protein, goats, *Grewia hostii, Maerua angolensis* and Rhodes grass.

Introduction

The performance of animals maintained in resource-poor surroundings is usually poor due to seasonal fluctuations in the quality and supply of animal feeds especially in the arid and semi-arid regions, which could be overcome by using locally available natural resources such as the different local browse species (Aregawi *et al.,* 2008). When accessible even in limited quantities, the fibrous feeds such as cereal crop residues and poor quality mature grasses cannot maintain animals during much of the year (Osuga *et al.*, 2008).

The browse fodder is generally rich in protein and minerals and can be used in dry season to supplement poor quality natural pasture or fibrous crop residue to improve animal performance (Devendra *et al.,* 1990). However, the presence of tannins in shrubs and tree leaves hampers their utilization as animal feeds by exhibiting anti-nutritional effects or positive nutritional merits (Osuga *et al.,* 2008). Goats can tolerate condensed tannins better than cattle and sheep during feeding.

It is possible and most appropriate to supplement grazing with local browse such as *Grewia hostii, Balanites aegyptiaca, Acacia brevispica, Berchemia discolor* and *Maerua angolensis* to make up for deficiency of some nutritional component and to improve performance.

Materials and methods

Browse foliages

Leaves from five browse species (*Grewia hostii, Acacia brevispica, Balanites aegyptiaca, Berchemia discolor and Maerua angolensis)* that grow in the semi-arid region of Kenya were harvested by hand stripping from the trees on communal grazing ranges in Marigat sub-county of Baringo county during the dry season. The browse forages were selected based on local farmers' knowledge of the species consumed by animals in the region. The area is located at an altitude of 1080m above sea level with an average annual rainfall and temperature of 700mm and 24^{o}C, respectively.

Chemical analysis

Proximate analysis was done to determine the dry matter (DM), nitrogen (N) and ash according to the standard methods of AOAC (1990). The crude protein (CP) was calculated as N×6.25. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to the procedure described by Van Soest *et al*., (1991).

Phenolics were extracted using 70% aqueous acetone following the procedures described by Makkar (2003). Total extractable phenolics (TEPH) were determined using Folin-ciocalteu procedures were the concentration of TEPH was calculated using regression equation of tannic acid standard. Condensed tannins were determined according to the method described by Porter *et al.,* (1986). Analysis of minerals was determined using atomic absorption spectrophotometer (AAS) following wet digestion with 1:1 nitric acid and 1:4 HCl.

***In-vitro* gas production**

Four growing goats (Small East African x Toggenburg) of about 12 ± 2.2 kg live weight were used to obtain the rumen fluid after feeding with the experimental diets. Rumen fluid was collected before morning feeding from the four goats by mouth siphoning through a stomach tube that was inserted through the mouth into the rumen of the goat. One litre of rumen fluid from the donor goat was kept in a warm flask after being filtered through two layers of cheese-cloth to obtain strained rumen fluid which was then flushed with carbon dioxide (CO_2).

Rumen fluid extracted by use of a stomach tube was used in combination with buffers to simulate the action of saliva. A sample (1mm screen) of browse species weighing 200 mg was placed into a 100 ml glass syringes in duplicate. The syringes lubricated with petroleum jelly to ease the sliding of the piston and prevent gas escape then the silicon rubber closed with a plastic clip. The fermentative activity of the mixed microbial population was determined using the gas production technique described by Menke and Steingass, (1988). The rumen fluid and buffer medium were mixed in the ratio of 1:2 (v/v). 30 ml of buffer-rumen fluid mixture was passed into syringes holding samples, shaken gently and any air bubbles released.

Finally, the syringes were incubated in a thermostatically controlled water bath at 39^{o}C for 0-96 hours. Both the samples and blank (rumen fluid + buffer) were run in triplicates. Then the volume of gas produced was determined at 0, 3, 6, 9, 12, 18, 36, 48, 72, and 96 hours by reading the calibration of the syringe. Therefore, gas produced was the total increase in volume minus the mean blank value from the recorded gas production of all samples to give the net gas production. The calculated values of gas production were fitted into the model developed by Ørskov and McDonald, (1979) to determine the degradability of the feed: $Y= a + b (1-e^{-ct})$, where:

Y = the volume of gas produced with time (t)

a = initial gas production

b = gas produced during incubation

c = gas production rate constant (fraction /hour)

Then (a+b) represents the potential extent of the gas production.

Results and discussion

Chemical composition

Table 1 presents the chemical composition of the browse forages. The OM content ranged from 873gkg^{-1}DM in *Maerua angolensis* to 945gkg^{-1}DM in *Berchemia discolor.* The CP content ranged from 41.4gkg^{-1}DM in Rhodes grass to 162gkg^{-1}DM in *Berchemia discolor.* The relative high CP content range (112 to 162gkg^{-1}DM) of *Balanites aegyptiaca, Maerua angolensis, Berchemia discolor, Acacia brevispica* and *Grewia hostii* show the possible contribution as protein source. The EE content range was from 17.7gkg^{-1}DM in *Grewia hostii* to 53.4gkg^{-1}DM for *Acacia brevispica.* Rhode grass*, Grewia hostii, Acacia brevispica, Balanites aegyptiaca* and *Berchemia discolor* had the highest ADF and ADL contents, respectively compared to *Maerua angolensis.*

Table1. Chemical compositions (gkg-1DM) of five browse species and *Chloris gayana* as control

Sample	**DM**	**OM**	**CP**	**EE**	**NDF**	**ADF**	**ADL**	**TEPH**	**CT**
Acacia brevispica	926.0^{a}	937.8^{a}	132.0^{ab}	53.4^{a}	295.0^{cb}	216.0^{c}	254.0^{c}	37.6^{b}	32.1^{b}
Balanites aegyptiaca	915.0^{a}	873.5^{b}	114.0^{b}	48.8^{a}	279.0^{c}	218.0^{c}	243.0^{c}	16.4^{d}	9.7^{c}
Berchemia discolor	918.0^{a}	926.3^{a}	162.0^{a}	21.3^{b}	171.0^{d}	155.0^{d}	144.0^{d}	49.2^{a}	4.8^{d}
Chloris gayana	920.0^{a}	920.8^{a}	41.4^{c}	21.0^{b}	693.0^{a}	503.0^{a}	478.0^{a}	6.1^{e}	2.0^{d}
Grewia hostii	929.0^{a}	914.0^{ab}	112.0^{b}	17.7^{b}	299.0^{b}	253.0^{b}	336.0^{b}	52.3^{a}	43.8^{a}
Maerua angolensis	871.0^{b}	872.7^{b}	123.0^{ab}	43.0^{a}	103.0^{e}	80.2^{e}	88.8^{e}	27.3^{c}	10.8^{c}
SEM	0.217	8.13	0.803	0.253	0.292	0.292	0.326	0.218	0.070
P	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001

abc Means in the same column with different superscripts are different at (P<0.05). DM=dry matter; OM=organic matter; CP=crude protein; EE=ether extracts; ADF=acid detergent fibre; NDF=neutral detergent fibre; CT=condensed tannin; TEPH =total extractable phenolics; ADL=acid detergent lignin; SEM-standard error of the mean.

Maerua angolensis had the lowest fiber contents among the species. Osuga *et al.*, (2008) also reported *Maerua angolensis* to be low in fiber. TEPH and CT contents ranged from 6.1 to 52.3gkg^{-1}DM and 2.0 to 43.8gkg^{-1}DM, respectively. Abdulrazak *et al.*, (2000), reported high total extractable condensed tannins (100-480mgkg^{-1}DM) and total extractable phenolics (104-512mgkg^{-1}DM) for *Acacia nilotica, Acacia tortilis* and *Acacia seyal* used as livestock browse in the arid and semi-arid regions.

To improve performance, animal consuming basal diets containing less than 7% CP will require supplementation to achieve maximum production, (Ondiek *et al.*, 2000). According to Abdulrazak *et al*., (2000) some Acacia species including *Acacia brevispica*, *Acacia nubica* and *Acacia mellifera* have been shown to contain appreciable crude protein content. The relative high CP content of the browses (150-249g/kg DM) provides adequate ground for the use of the browse leaves to supplement crop residues such as straw and low-quality natural pastures (Osuga *et al.,* 2006). The NDF content of the browse species was low to moderate, which indicates that the browses have high cell content, that is related with high digestibility (Osuga *et al.,* 2005). Browse fibre has been shown to be digestible more than crop residue and mature grass hence can be utilized by animal easily (El Hassan *et al.,* 2000). The major and microelement composition of the forages and Rhodes grass is shown in Table 2.

Table 2. Major and trace elements in five Kenyan local browse and Rhodes grass

	Major elements, ($gkg^{-1}DM$)				Trace elements, ($mgkg^{-1}DM$)				
sample	**P**	**K**	**Ca**	**Mg**	**Co**	**Cu**	**Zn**	**Mn**	**Fe**
Acacia brevispica	2.7^{c}	9.1^{e}	13.6^{d}	6.2^{c}	5397.0^{a}	81.3^{f}	84.6^{e}	65.4^{a}	20.2^{e}
Balanites aegyptiaca	2.1^{d}	22.0^{b}	20.5^{a}	9.2^{b}	3224.0^{f}	86.0^{e}	69.1^{f}	1.4^{e}	86.9^{a}
Berchemia discolor	3.4^{a}	12.5^{d}	10.8^{e}	5.7^{d}	4528.0^{c}	114.0^{d}	104.0^{b}	21.7^{d}	51.1^{b}
Grewia hostii	3.1^{b}	13.7^{c}	15.5^{c}	6.5^{cd}	4680.0^{b}	160.0^{a}	96.2^{c}	24.4^{c}	51.1^{b}
Maerua angolensis	1.8^{e}	24.8^{a}	18.4^{b}	13.1^{a}	3940.0^{e}	123.0^{c}	94.9^{d}	32.7^{b}	46.1^{c}
Chloris gayana	3.3^{ab}	22.1^{b}	2.5^{f}	1.3^{e}	4504.0^{d}	141.0^{b}	134.0^{a}	0.0^{f}	40.0^{d}
SEM	0.027	0.179	0.224	0.166	0.299	0.284	0.247	0.146	0.193
P	.0001	.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

^{abc} Means in the same column with different superscripts are different at ($P<0.05$). SEM-standard error of the mean

The major minerals P, K, Ca and Mg were in the ranges of 1.8-3.4, 9.1-24.8, 2.5-20.5, and 1.3-13.1gkg^{-1}DM, respectively. Trace elements (mgkg-1DM) varied in the range of Co (3224.0-5397.0), Cu (81.3-160.0), Zn (69.1-134.0), Mn (0.0-65.4) and Fe (20.2-86.9). Earlier studies on analysis of the mineral content of the local tree browses showed a variation from moderate to high as reported by Abdulrazak *et al.,* (2000). The authors found that although Acacia species was rich in the micro-elements Mn, Mo, Zn, Co, Cu, Fe and Se, the level of P and Ca showed variability with the tree browses, suggesting that animals may consume adequate amounts and may only require specific supplementation in the diet. The current study reported the highest levels for major elements P, K, Ca and Mg at 3.4, 24.8, 20.5 and 13.1 gkg^{-1}DM and lowest level at 1.8, 9.1, 2.5, 1.3gkg^{-1}DM respectively. This is similar to results of McDowell, (1985) who reported the highest mineral levels for the major elements Ca, P and Mg at 28, 3.2 and 8.7 gkg^{-1}DM and lowest levels at 7, 0.8 and 0.4 gkg^{-1}DM, respectively. The values are adequate to meet the requirement for growth to improve the animal performance especially during the dry periods when the availability of pasture is limited in the arid and semi-arid regions.

The *in-vitro* degradation characteristics of the browse DM varied widely among the 5 selected local species. The total gas production (ml/200mg DM) at 24hrs and 48hrs as shown in Table 3, point variations in the digestibility potential and forage degradability with *Balanites aegyptiaca* (14.1 ml) being the highest and *Acacia brevispica* (8.2 ml) the lowest at 48hrs. The degradation of some of the forages improved from 24 to 48 hours indicating that they require more time for effective degradation (6.0-14.1) for *B. aegyptiaca* and (8.6-13.5) for *C. gayana*.

Table 3. In-vitro gas production (ml/200mg DM) of 5 local browses and Rhodes grass as control

	Fermentation characteristics						
Sample	**24**	**48**	**a**	**b**	**c**	**a+b**	**RSD**
Balanites aegyptiaca	6.0	14.1	3.6	3.7	0.4	7.3	3.5
Maerua angolensis	12.0	10.9	-0.5	7.8	48.9	7.3	3.7
Berchemia discolor	16.2	10.3	0.5	8.1	0.2	8.5	4.7
Chloris gayana	8.6	13.5	0.0	4.6	13.6	4.6	4.9
Acacia brevispica	9.2	8.2	0.0	4.2	12.6	4.2	3.2
Grewia hostii	11.9	13.5	-0.7	8.4	0.1	7.7	4.1

a, b, c are constants as described by Ørskov and McDonald (1979)

Maerua angolensis, Berchemia discolor and *Acacia brevispica* were highly degraded at the 24 hours compared to the 48hours. The variations in gas production between the local browse species could be due to the amount of substrate fermented. The gas is produced by the fermentation of organic matter (OM) in the feed (Blümmel and Fernandez-Rivera, 2002).

This indicates that these local browses are potentially degradable and can become potential supplements in improving low quality feeds fed especially to goats. The phenolic compound present in the browses could have contributed towards the low gas production under study especially *Acacia brevispica, Berchemia discolor* and *Maerua angolensis* at 48 hours. This is similar to the results of Osuga *et al.,* (2008) who reported that all the browse forages had high gas production potential except *Maerua angolensis*. These browses contain low to moderate phenolic constituents, rich in protein and are highly fermented in the rumen from the study with *Balanites aegyptiaca* and *Grewia hostii* showing high potential degradability at the 48 hour.

Conclusion

From the results of chemical composition and *in-vitro* gas production, the local browse fodder was found to be generally rich in protein (112 to 162gkg^{-1}DM) and moderate to high minerals which can be used in dry season to supplement poor quality natural pasture with low crude protein or fibrous crop residue, especially in the arid and semi-arid areas.

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Objective 2: Palatability and preference by goats of selected local browses from semi-arid areas of Kenya

Abstract

The palatability of five browses forages (*Balanites aegyptiaca, Maerua angolensis, Acacia brevispica, Grewia hostii and Berchemia discolor)* from the semi-arid area were evaluated for their potential as supplements to Rhodes grass (*Chloris gayana)* hay. The five-dietary treatments were offered in a completely randomized design (CRD) with four crossed growing goats (23.0 ±0.2 kg) housed individually with individual feeding. Palatability test was performed to determine acceptability and preference by goats. The selected leaves were offered together with the Rhodes grass hay as the control. Feed offered and refusals (left overs) was recorded every day to determine the feed intake which was used to predict palatability. Ranking of the local browse species was based on intake and preference by the goats. Relative palatability indices and preference ranking were: *Acacia brevispica* > *Balanites aegyptiaca* > *Grewia hostii* > *Berchemia discolor* > *Maerua angolensis* > *Chloris gayana. Maerua angolensis* was of low palatability compared to other browse species. It is concluded that local browse *A. brevispica* had high palatability and was preferred by goats.

Keywords: crude protein, goats, Rhodes grass, supplement

Introduction

Ruminant production in tropical regions such as Kenya is affected by the inadequate supply of feeds in terms of quantity and quality (Osuga *et al.,* 2005). Fibrous feeds such as cereal crop residues and poor quality mature grasses cannot maintain animals during much of the year (Osuga *et al.,* 2008). To improve performance, animals consuming forages with less than 7% crude protein (CP) will require supplementation to achieve maximum production (Ondiek *et al.,* 2000). Browse fodder is generally rich in protein and minerals and can be used in the dry season to supplement poor quality natural pasture or fibrous crop residue to improve animal performance (Devendra *et al.,* 1990). However, the presence of tannins in shrubs and tree leaves hampers their utilization as animal feeds by exhibiting anti nutritional effects or poor nutritional merits (Osuga *et al.,* 2008).

It is possible and appropriate to supplement grazing with local browse such as *Grewia hostii, Balanites aegyptiaca, Acacia brevispica, Berchemia discolor* and *Maerua angolensis* to make

up for deficiency of some nutritional components and to improve performance of goats in arid and semi-arid areas of Kenya.

Materials and methods

Palatability evaluation

Study site

The experiment was conducted at Egerton University Tatton Agriculture Park in Njoro, Kenya. The area is situated at an altitude of 2238 meters above sea level with the mean annual rainfall and temperature of 900-1200 mm and 17 to 22^{o}C respectively (Engineering meteorological Station, 2009).

Animals, housing and feeding

The selected leaves were offered together with the Rhodes grass hay as the control in a completely randomized design (CRD). A period of 7 days was allowed for adaptation to confinement during which the test forage was randomly fed. Four crossed growing goats (23.0 ±0.2 kg) of similar age (about 1-year-old) housed individually with individual feeding trough subdivided into five separate sections to contain each of the test browses in addition to a separate feeding trough for a basal diet of chopped Rhodes grass were adopted. The test local browse was offered at 200g each at the same time using suitable feed troughs for 60 minutes daily for a period of 14 days then fed 750g chopped Rhodes grass hay for the rest of the day. Mineral salt licks and water were provided *ad libitum* throughout the experimental time.

Each day, before feeding the position of browse forages in the feed trough partitions were randomly changed to remove expected biasness from goats' innate preferences for one side of feed trough partition. Feed offered and refusals (left overs) was recorded every day to determine the feed intake which was used to predict palatability. The intake data was used to determine the relative palatability of the local browse species. A relative palatability index (RPI) was calculated for each species by dividing the amount consumed by that of the highest value, and multiplied by 100 as described by Abdulrazak *et al.,* (2001). Ranking of the local browse species was based on intake and preference by the goats.

$$\text{Relative Palatability Index} = \frac{\text{Daily feed intake}}{\text{Highest feed intake}} \text{X } 100$$

Results and discussion

The control had the lowest palatability compared to the browses (Table 4). It was also observed that *Maerua angolensis* leaves had a stronger smell than the other local browse species even after drying. This suggests that smell, taste, or physical texture of feed may relate to the acceptability or liking by the animal (Ngwa *et al.,* 2003). Spines were present in *A. brevispica* but had little effect on the acceptability and preference for local browse. Palatability differences in the local browse species tested for the study were manifested in the variation in the dry matter intake of the tested browse forages. It is noted that those browse species with the highest dry matter intake were most preferred by the goats. In the current study *A. brevispica* had the highest DM intake with *M. angolensis* having the least. This value was similar to those reported by Osuga *et al.*, (2008) who reported *A. brevispica* having the highest DM intake with *M. angolensis* having the least.

The levels of anti-nutritive factors such as tannins affect the palatability of forage and hence preference by the animals (Osuga *et al.,* 2008). Although *M. angolensis* was low in condensed tannins compared to *A. brevispica* it still exhibited the lowest palatability. Total extractable phenolics were relatively higher in *A. brevispica* than *M. angolensis*. Therefore, the low palatability index can be as a result of tannins and other factors responsible for low palatability and hence preference to browse forage by animals. Kalio *et al.*, (2006) reported that the intakes of forages are influenced by plant type, period of maturity, method of presentation, chemical components of the fodder and ways of processing. Although *A. brevispica and M. angolensis* had similar CP contents of 132 and 123 gkg^{-1}DM, respectively, *A. brevispica* was more palatable than *M. angolensis. Berchemia discolor* regardless of having highest CP was fourth in the preference ranking, lower than *A. brevispica*, *Balanites aegyptiaca* and *Grewia hostii* (Figure 2).

Table 4. Dry matter intake, palatability index and preference ranking of browses relative to Rhodes grass

Species	Intake (gDM)	Palatability index (%)	Preference ranking
Acacia brevispica	190.0[a]	96.7	1
Balanites aegyptiaca	108.0[b]	55.2	2
Grewia hostii	67.9[c]	52.2	3
Berchemia discolor	67.2[c]	33.62	4
Maerua angolensis	28.5[d]	33.57	5
Chloris gayana	29.8[d]	27.1	6
SEM	5.76	3.50	
P	<0.0001	<0.0001	

[abcd] *Means with different subscript in a column differ at P<0.05*

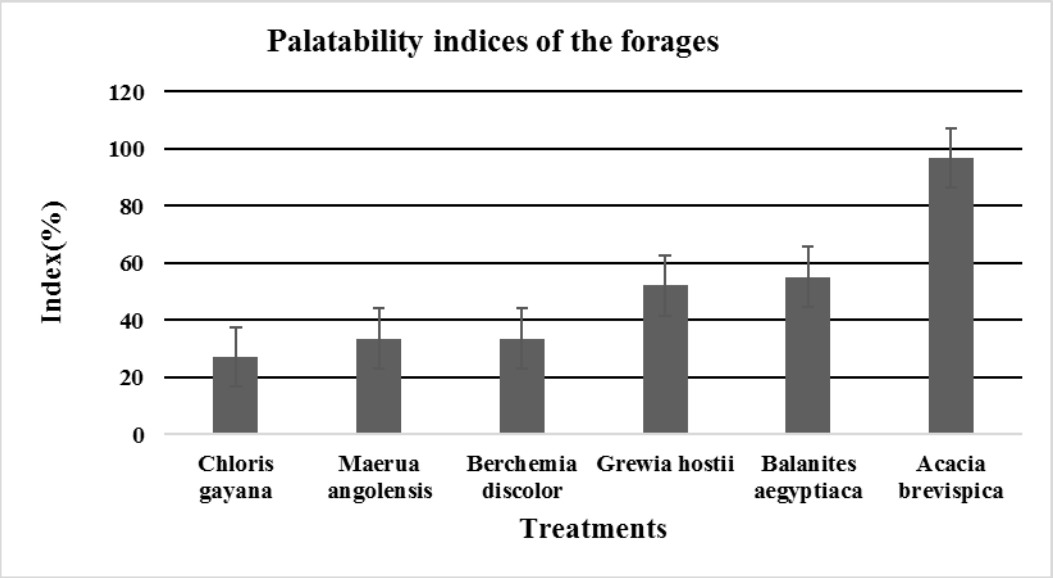

Figure 2. Ranked palatability indices of the experimental forages.

Conclusion

1. The local browse *A. brevispica* had high palatability and was preferred by goats.
2. The low palatability index of some browse species may be attributed to anti-nutritive factors including smell.

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Objective 3: Effects of supplementing Rhodes grass hay with selected local browse species on voluntary feed intake, feed digestibility and live weight changes

Abstract

The study consisted of 60 days feeding trial and 7 days' digestibility trial using 12 goats with mean initial body weight and age of 17.6 ±1.2 kg and 6 months old, respectively. The objectives were to examine the effects of supplementing with selected local browse species of *Acacia brevispica* and *Berchemia discolor* on voluntary feed intake, feed digestibility and live weight change in Rhodes grass hay based feeding of goats. The three-dietary treatments were offered in a completely randomized design (CRD) with three replications and four goats per treatment. The CP content ranged from 41.4, 131.7 and 161.8gkg^{-1}DM for Rhodes grass, *Acacia brevispica* and *Berchemia discolor*, respectively. The intake of Rhodes grass hay (53.4, 33.0 and 37.6g/d) varied across the diets, but supplementation significantly increased total dry matter intake (53.4, 117.7 and 125.2 g/d) for those supplemented with *Acacia brevispica* and *Berchemia discolor*. The apparent nutrient digestibility differed ($P<0.05$) among the treatments. The average daily gain (ADG) of the control animals were low with a negative value (-47.8g/d) with the supplements *Acacia brevispica* and *Berchemia discolor* having a positive gain of 21.44g/d and 22.34g/respectively. The supplemented diets resulted in significant changes in ADG, with both supplements having a considerable effect. However, *Berchemia discolor* was superior among the supplements with a lot of potential as a protein supplement to low-quality roughages in the arid and semi-arid areas during the dry season. In conclusion, *Acacia brevispica* and *Berchemia discolor* supplements enhanced feed intake, diet digestibility and average daily gains of growing goats important especially in the arid and semi-arid regions.

Key words*:* *Acacia brevispica, Berchemia discolor,* goat and performance

Introduction

The insufficiency and poor quality of the existing protein and energy feedstuffs, particularly during the dry season is the most challenging limitation in small ruminant production in the tropics (Njoya *et al.,* 2005; Olafadehan *et al*., 2009). In the dry and scarcity times, forage from browses is often obtainable throughout the year particularly when grasses and crop remains are depleted (Aregawi *et al.,* 2008). Legume tree forages have high crude protein, organic matter and mineral content that can be used as supplements to mitigate the effects of the low quality feeds (Ondiek *et al.,* 2013).

Therefore, keeping of small ruminants especially the goats in the arid and the semi-arid areas frequently depends on natural local browse for survival throughout the year. The *Berchemia discolor* and *acacia brevispica* leaf browse was selected due to high palatability, high crude protein, potential degradability and their large quantity in arid and semi-arid areas. The objective of this study was to evaluate the effect of supplementation with dry forages of *Berchemia discolor* and *acacia brevispica* to Rhodes grass hay offered to goats on voluntary dry matter intake, feed digestibility and live weight changes.

Materials and methods

Site

Leaves from two browse species (*Acacia brevispica* and *Berchemia discolor)* that grow in the semi-arid region of Kenya were harvested by hand stripping from the trees on communal grazing ranges in Marigat Sub-county of Baringo County during the dry season. The area is located at an altitude of 1080m above sea level with an average annual rainfall and temperature of 700mm and 24^{o}C, respectively. The experiment was conducted at Egerton University Tatton Agriculture Park in Njoro, Kenya. The area is situated at an altitude of 2238m above sea level with the mean annual rainfall and temperature of 900- 1200 mm and 17 to 22^{o}C respectively (Engineering meteorological Station, 2009).

Animals

Twelve goats with initial average live weight and age of 17.6±1.2kg at 6 months of age, respectively were used in the study. The goats were allocated to individual pens. Salts licks and water were offered *ad- libitum*. Before the start of the experiment all the animals were treated against internal parasites using one of the dewormers in the market and sprayed with a given acaricide for external parasites. The animals were assigned to three diets each with four goats per treatment.

Diets

The basal diet consisted of Rhodes grass (*Chloris gayana*) hay that was purchased from a local supplier in Njoro. Leaves of local browses (*Berchemia discolor* and *acacia brevispica*) were collected in Marigat sub-county, Baringo, by hand stripping and were spread on gunny sheet and air dried under the shade for 2 to 4 days. The dried forages were put in sacks and stored in well ventilated shed. The forages were milled to pass through 4mm sieve for feeding trial. Additionally, the animals were offered salt licks.

Experimental design and procedures

The three-dietary treatments, *Acacia brevispica, Berchemia discolor* and Rhodes grasses (control) were offered in a completely randomized design (CRD) with three replications and four animals per treatment. The basal diet (control) and supplements were offered individually in the study. The supplements were offered daily at the rate of 200g/head on DM basis at 07:30h to let the goats eat the supplements before offering the basal diet. The refusals from supplements were collected before offering the basal diet, weighed and recorded. The Rhodes grass hay was introduced at 09:00h after the supplement had been consumed by goats. The hay was offered at 750g/head on DM basis to ensure it was *ad-libitum*. Feed refusals were collected, weighed and recorded every day in the morning before offering fresh hay. Initial body weight of the goats was taken as the mean of two consecutive weighing after overnight fasting. Subsequent body weight measurements were taken every 7 days after overnight fasting until the completion of the experiment. The data was collected for 8 weeks.

Digestibility trial

During the eight weeks of the trial total daily fecal output of the 12 goats was collected for seven consecutive days. The daily fecal material of each animal was mixed thoroughly and kept in airtight plastic containers. This was followed by drying at 60^{o}C for 72 hours, grinding and storing in airtight containers pending chemical analysis.

Results and discussion

Table 5. Feed dry matter intake, average daily gains (ADG) and apparent nutrient digestibility of goats fed Rhodes grass hay and supplemented with *Acacia brevispica* and *Berchemia discolor*

Treatments	Control	*A. brevipica*	*B. discolor*	SEM
Dry matter intake(g/d)				
Rhode grass	53.4^{a}	33.0^{c}	37.6^{b}	0.69
Supplement	0.0^{c}	84.7^{b}	87.6^{a}	0.61
Total DMI	53.4^{c}	117.7^{b}	125.2^{a}	0.78
ADG	-47.8^{b}	21.4^{a}	22.3^{a}	
Apparent nutrient digestibility(g/kgDM)				
CP	78.9^{a}	70.1^{ab}	64.9^{c}	2.7
OM	9.3^{a}	9.1^{a}	9.0^{a}	0.79
DM	3.6^{a}	2.7^{b}	3.7^{a}	0.19

^{abc} values in a row with different superscript differ at P<0.05, SEM-standard error of the mean

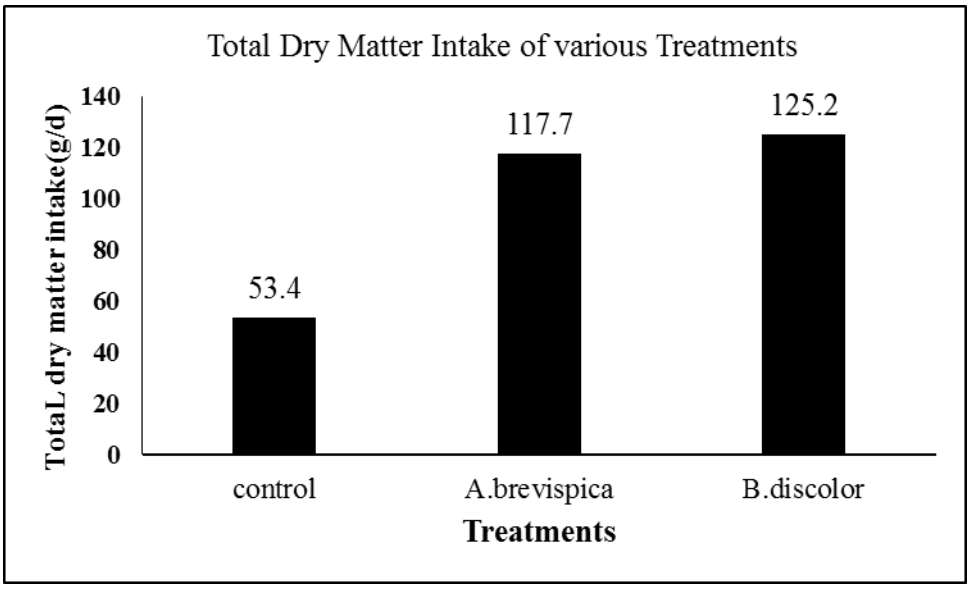

Figure 3. Total dry matter intake of various treatments

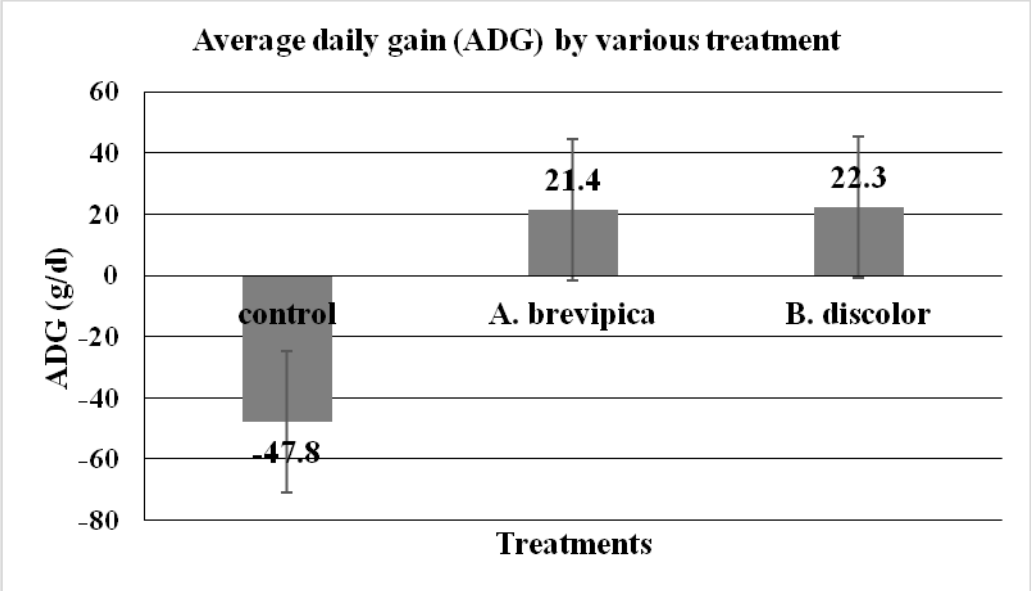

Figure 4. Average daily gain of goats on various treatments

The goats feeding on the non-supplemented Rhodes grass hay had a higher dry matter intake (DMI) compared to those supplemented with browse leaves of *Acacia brevispica* and *Berchemia discolor* which is in agreement with the findings reported by Weldemariam *et al.,* (2014) in Abergelle goats fed hay and supplemented with browse species. Solomon *et al.,* (2008) and Abdulrazak *et al.,* (2005) also reported the non-supplemented goats having a relatively high quantity of hay intake compared to those supplemented.

Among the local browse species, the intake of *Berchemia discolor* was higher than that of *Acacia brevispica* with significant difference in total DM intake. Supplementation with *Acacia brevispica* and *Berchemia discolor* increased the total DM intake. This is in agreement with findings of Osuga *et al.,* (2011) and Abdulrazak *et al.,* (2005) who reported increased total DM intake from supplementation with browse forages. Goats supplemented with *Berchemia discolor* consumed 125.2g/d compared to 117.7g/d and 53.4 g/d for goats consuming *Acacia brevispica and* Rhodes grass as control, respectively. The results of this study confirm that the use of *Acacia brevispica* and *Berchemia discolor* as a supplement to low quality basal diet of grass hay results in higher total DM intake especially when used as a protein supplement in arid and semi-arid areas. Protein supplementation to low quality roughage increases total DM intake in diets (Sanchez and Ledin, 2006).

Availability of important nutrients to rumen microorganisms from supplementation with local browse species might have resulted to increase in DM intake. The low intake of the control diets may be as a result of replacement of the local browse forages for hay (Osuga *et al.,* 2011) and high palatability of the browse forages (Osuga *et al.,* 2008). The growing rates of the goats feeding on hay alone were negative, and positive with all supplements with the best result from *Berchemia discolor.* The ADG of the control animals were low with a negative value (-47.8g/d) with the supplements *Acacia brevispica* and *Berchemia discolor* having a positive gain of 21.44g/d and 22.34g/d, respectively. The supplemented diets resulted in significant changes in ADG, with both supplements having considerable effect, signifying that the different local browse forages had useful effects on the goats especially in the arid and semi-arid areas. Weight gain findings are in agreement with those of Osuga *et al.,* (2011) and Sawe *et al.,* (1998) especially results of Berchemia *discolor* as a supplement. The increase in weight gain is linked to the supply of rumen fermentable nitrogen (N) which offers a substrate for improved microbial growth and protein synthesis (Ondiek *et al.,* 2010).

Apparent nutrient digestibility was different among the diets. The CP and OM for the control were higher which is in contrast to the results reported by Ondiek *et al.,* (2013). The digestibility of OM and DM was not statistically affected by supplementation using *Acacia brevispica* and *Berchemia discolor* forages in the study. The current results are in agreement with the findings of Osuga *et al.,* (2011) who reported apparent digestibility of DM and OM being not statistically affected by supplementation with *Berchemia discolor* or *Zizyphus mucronata* on the performance of growing goats in Kenya. This is because Rhodes hay is low

in tannins levels which tend to lower voluntary feed intake and nutrient utilization during feeding. The DM digestibility differed across the diets and was higher with supplementation from *Berchemia discolor* (3.7g/kg DM) which was not significantly different from the control (3.6g/kg DM). *Acacia brevispica* had a lower DM digestibility compared to the other diets. Lower nutrients and anti- nutritive factors especially tannins in the control diet might have made the goats to extract entirely the available nutrients therefore increasing nutrient digestibility of the hay in the study.

Conclusion

Supplementation of goats with local browse species such as *Acacia brevispica* and *Berchemia discolor* forages improved feed intake, nutrient digestibility and growth rates. Therefore, supplementation of hay with browse forages especially with *Berchemia discolor* which exhibited more distinct effects in goats is more useful to small ruminants especially in the dry period with insufficiency and poor quality feedstuffs in the arid and semi-areas.

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CHAPTER FIVE
GENERAL DISCUSSION

The CP content ranged from 41.4gkg^{-1}DM in Rhodes grass to 162gkg^{-1}DM in *Berchemia discolor*. The relative high CP content range (112 to 162gkg^{-1}DM) of *Balanites aegyptiaca, Maerua angolensis, Berchemia discolor, Acacia brevispica and Grewia hostii* show the potential contribution as protein source significant for the use of the small ruminants especially in the arid and semi-arid regions. The local browses can be used in dry season to supplement poor quality natural pasture or fibrous crop residues to improve animal performance during a dry spell. The relative high crude protein content of the browse (150-249g/kg DM) provides adequate ground for the use of the browse leaves to supplement crop residues such as straw and low-quality natural pastures (Osuga *et al.,* 2006).

According to Abdulrazak *et al*., (2000) some Acacia species including *Acacia brevispica*, *Acacia nubica* and *Acacia mellifera* have shown to contain appreciable crude protein. The NDF content of the local browse species was low to moderate, which shows that the browses have high cell content which can be utilized by the animal due to increased digestibility. *Maerua angolensis* had the lowest fiber contents among the species but with a lower acceptability to the animal during palatability test. Osuga *et al.,* (2008) also reported *Maerua angolensis* to be lowest in fiber. Browse fiber has been shown to be digestible more than crop residue and mature grass hence can be utilized by animal easily (El Hassan *et al.,* 2000).

The total extractable phenolics and total extractable condensed tannins contents were high in browse species compared to the control. TEPH and CT contents ranged from 6.11 to 52.3gkg^{-1}DM and 1.98 to 43.8gkg^{-1}DM, respectively. The mineral content of the local browse species varied from moderate to high. Earlier studies on the mineral content of local tree browses showed variation from moderate to high as reported by Abdulrazak *et al.,* (2000). The authors found that although Acacia species was rich in the micro-elements Mn, Mo, Zn, Co, Cu, Fe and Se, the level of P and Ca showed variability with the tree browses, suggesting that animals may consume adequate amounts and may only require specific supplementation in the diet in order to meet the requirement for growth to improve the animal performance.

Maerua angolensis, Berchemia discolor and *Acacia brevispica* were highly degraded at the 24 hours compared to the 48 hours. This shows that these local browses are actually degradable and can become potential supplements in improving low quality feeds fed especially to goats. The phenolic compound present in the browses could have contributed

towards the low gas production in this study especially *Acacia brevispica*, *Berchemia discolor* and *Maerua angolensis* at 48 hours. The gas is produced by the fermentation of organic matter (OM) in the feed (Blümmel and Fernandez-Rivera, 2002).

This is similar to the results of Osuga *et al.* (2008) who reported all the browse forages with generally high gas production potential except *Maerua angolensis*. These local browses contain low to moderate phenolic constituents, are rich in protein and are highly fermented in the rumen, hence can be used as supplements in dry spell in the arid and semiarid areas especially *Balanites aegyptiaca* and *Grewia hostii* with high potential degradability at the 48 hours. Relative palatability index of local browse species and control, differed widely with the following ranking: *Acacia brevispica* >*Balanites aegyptiaca* >*Grewia hostii* >*Berchemia discolor* >*Maerua angolensis* >*Chloris gayana*. *Maerua angolensis* appears to be of low palatability compared to other local browse species.

The control had the lowest palatability compared to the browse forages. It was also observed that *Maerua angolensis* leaves had the strong smell than the other local browse species even after drying may have related to the acceptability or preference by the animal. This suggests that smell, taste, or physical texture of feed may relate to the acceptability or liking by animal as reported by Ngwa *et al.,* (2003). Spines were present in *A. brevispica* but had little effect in determining the acceptability and preference of the browse. The levels of anti- nutritive factors such as TEPH and CT affected the palatability of the browse forages and hence preference by the goats. *Maerua angolensis* was low in condensed tannins compared to *Acacia brevispica* and still exhibited the lowest palatability. Therefore, the low palatability index can be as a result of tannins and other factors responsible for low palatability by the goats. The levels of anti- nutritive factors such as tannins affect the palatability of forages and hence preference by the animals (Osuga *et al.,* 2008).

The intake of Rhodes grass hay (53.4, 33.0 and 37.6g/d) varied across the diets, but supplementation significantly increased total dry matter intake (53.4, 117.7 and 125.2g/d) for those supplemented with *Acacia brevispica* and *Berchemia discolor.* This is in agreement with findings of Osuga *et al.,* (2011) and Abdulrazak *et al.,* (2005) who reported increased total DM intake from supplementation with browse forages. The goats feeding on the non-supplemented Rhodes grass hay had a higher dry matter intake (DMI) compared to those supplemented with browse leaves of Acacia *brevispica* and *Berchemia discolor* which is in agreement with the findings reported by Weldemariam *et al.,* (2014) in Abergelle goats fed

sward natural pasture hay and supplemented with *Ziziphus spina-christi*, *Sterculia africana* and *Terminalia brownii* browse species.

Among the local browse species, the intake of *Berchemia discolor* was higher than that of *Acacia brevispica* with significant difference in total DM intake. Supplementation with *Acacia brevispica* and *Berchemia discolor* increased the total DM intake. Goats supplemented with *Berchemia discolor* consumed 125.2g/d compared to 117.7g/d and 53.4 g/d for goats consuming *Acacia brevispica and* Rhodes grass as control, respectively. The apparent nutrient digestibility differed ($P<0.05$) among the treatments. The digestibility of OM and DM was not statistically affected by supplementation using *Acacia brevispica* and *Berchemia discolor* forages in this study. The average daily gain (ADG) of the control animals were low with a negative value (-47.8g/d) while supplementation with *Acacia brevispica* and *Berchemia discolor* had a positive gain of 21.4g/d and 22.3g/d respectively.

The supplemented diets resulted in significant changes in ADG, with both supplements having considerable effect, signifying that the different local browse forages had useful effects on the goats especially in the arid and semi-arid areas. Weight gain findings are in agreement with results of Osuga *et al.*, (2011) and Sawe *et al.*, (1998) especially results of Berchemia *discolor* as a supplement. To improve performance, animal consuming basal diets containing less than 7% crude protein (CP) will require supplementation to achieve maximum production, (Ondiek *et al.,* 2000).

The supplemented diets resulted in significant changes in ADG, with both supplements having a significant effect. *Berchemia discolor* was superior among the supplements, therefore *Acacia brevispica* and *Berchemia discolor* can be utilized as potential protein supplements, enhanced feed intake, diet digestibility and average daily gains of growing goats important especially in the arid and semi-arid regions during a dry spell.

CONCLUSIONS

1. Results of chemical composition and *in-vitro* gas production showed the local browse species to be generally rich in protein (112 to 162gkg^{-1}DM), moderate digestibility and moderate to high minerals which can be used in dry season to supplement poor quality natural pasture especially in the arid and semi-arid areas.
2. Local browse species such as *Acacia brevispica* had the highest palatability hence preference by goats. The relative low palatability index in some browse species especially *Maerua angolensis* may be attributed to anti-nutritive factors including smell.
1. Supplementation of goats with local browse species such as *Acacia brevispica* and *Berchemia discolor* forages improved feed intake, nutrient digestibility and growth rates. Hence, supplementation of hay with browse forages especially with *Berchemia discolor* which displayed more distinct effects in goats is more useful especially to small ruminants in dry period with insufficiency and poor quality feedstuffs.

RECOMMENDATIONS

1. Supplementation of goats with local browses especially *Berchemia discolor* can be done improve to feed intake, nutrient digestibility and growth rates.
2. Natural dry grass pastures are low in nutrients composition therefore require supplementation to meet animal requirement for growth especially in dry spell.
3. Local browse species have moderate to high mineral content and will only require specific supplementation, therefore can supply minerals required by goats for growth.

FURTHER RESEARCH

1. More feeding studies need to be done on factors that affect acceptability and hence preference of the browse species by the goats as a protein supplement.
2. Studies on the effects of browse species at different inclusion levels on carcass quality (organoleptic characterization).
3. Research to determine the effect of local browse species by mixing with other feed ingredients for the ruminants.
4. More research on whether different season affect nutrient composition of various local browse species.
5. More research can be done on nutrient composition especially amino acids and vitamins of the various local browse species.

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APPENDICES

Appendix 1: List of publications from this thesis

1. Kemboi, F., Ondiek, J.O and 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. Volume 29, Article #92.* Retrieved December 7, 2017, from http://www.lrrd.org/lrrd29/5/kemb29092.html

2. Kemboi, F., Ondiek, J.O and Onjoro, P.A (2017). Nutritive value and acceptability by goats of selected indigenous browses from semi-arid areas of Kenya. *Livestock Research for Rural Development.Volume29,Article#118.*RetrievedJune2,2017,fromhttp://www.lrrd.org/lrrd29/6/kemb29118.html

3. Kemboi, F., Ondiek, J.O and Onjoro, P.A (2017). Effects of supplementing Rhodes grass hay (*Chloris gayana*) with selected indigenous browse species on voluntary feed intake, feed digestibility and live weight change of goats. *Livestock Research for Rural Development. Volume 29, Article#222.*RetrievedDecember7, 2017, from http://www.lrrd.org/lrrd29/12/kemb29222.html

Appendix 2: Analysis of variance (ANOVA)

Dependent Variable: intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1027775.479	205555.096	110.62	<.0001
Error	330	613195.875	1858.169		
Corrected Total	335	1640971.354			

R-Square	Coeff Var	Root MSE	intake Mean
0.626321	52.63575	43.10649	81.89583

The GLM Procedure

Tukey's Studentized Range (HSD) Test for intake

Alpha	0.05
Error Degrees of Freedom	330
Error Mean Square	1858.169
Critical Value of Studentized Range	4.05391
Minimum Significant Difference	23.352

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	diet
A	190.125	56	5
B	107.786	56	1
C	67.857	56	2
C			
C	67.232	56	4
D	29.839	56	6
D			
D	28.536	56	3

Dependent Variable: Basal

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	55261.9372	27630.9686	240.28	<.0001
Error	717	82450.1161	114.9932		
Corrected Total	719	137712.0532			

R-Square	Coeff Var	Root MSE	Basal Mean
0.401286	25.93689	10.72349	41.34454

Dependent Variable: supplement

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1189055.532	594527.766	6644.89	<.0001
Error	717	64150.995	89.471		
Corrected Total	719	1253206.526			

R-Square	Coeff Var	Root MSE	supplement Mean
0.948811	16.46539	9.458932	57.44736

Dependent Variable: Total dry matter intake (TDMI)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	747362.4672	373681.2336	2552.33	<.0001
Error	717	104974.5086	146.4080		
Corrected Total	719	852336.9758			

R-Square	Coeff Var	Root MSE	TDMI Mean
0.876839	12.24791	12.09992	98.79171

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Basal

Alpha	0.05
Error Degrees of Freedom	717
Error Mean Square	114.9932
Critical Value of Studentized Range	3.32140
Minimum Significant Difference	2.2991

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	diet
A	53.4368	240	Rhodes
B	37.6355	240	Bdisc
C	32.9613	240	Acacia

The GLM Procedure

Tukey's Studentized Range (HSD) Test for supplement

Alpha	0.05
Error Degrees of Freedom	717
Error Mean Square	89.4714
Critical Value of Studentized Range	3.32140
Minimum Significant Difference	2.028

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	diet
A	87.6027	240	Bdisc
B	84.7394	240	Acacia
C	0.0000	240	Rhodes

The GLM Procedure

Tukey's Studentized Range (HSD) Test for TDMI

Alpha	0.05
Error Degrees of Freedom	717
Error Mean Square	146.408
Critical Value of Studentized Range	3.32140
Minimum Significant Difference	2.5942

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	diet
A	125.238	240	Bdisc
B	117.700	240	Acacia
C	53.437	240	Rhodes

Dependent Variable: Daily Gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	103574.1134	34524.7045	26.70	<.0001
Error	92	118958.0961	1293.0228		
Corrected Total	95	222532.2096			

R-Square	Coeff Var	Root MSE	Daily gain Mean
0.465434	-2709.598	35.95863	-1.327083

The SAS System
The GLM Procedure

Tukey's Studentized Range (HSD) Test for DG

Alpha	0.05
Error Degrees of Freedom	92
Error Mean Square	1293.023
Critical Value of Studentized Range	3.36901
Minimum Significant Difference	21.416

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Treat
A	22.344	32	bdisc
A			
A	21.438	32	acacia
B	-47.763	32	rhodes

Appendix 3: Browse forages used in the study

Maerua angolensis ***Berchemia discolor*** ***Balanites aegyptiaca***

Acacia brevispica ***Grewia hostii***

Appendix 4: Growing goats (Small East African x Toggenburg) used in the study

Goats eating browse species

Goats eating Rhodes grass