FEEDING VALUE OF SELECTED INDIGENOUS BROWSE SPECIES FOR GOATS IN KENYA

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DECLARATION

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

B.K. Wanyama.............................. Date ....07/12/2005.............

This thesis has been submitted for examination with my approval as a university supervisor.

Prof. S.A. Abdulrazak (Ph.D. in Animal Science) ....

Date ....7TH DEC. 2005.............................

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DEDICATION

This work is dedicated to my mother, Neddy Nandaha Wanyama.

ABBREVIATIONS

ADF – Acid detergent fibre

ADF-I – Acid detergent fibre intake

ADG – Average daily gain

ADL – Acid detergent lignin

ARNAB – African Research Network for Agricultural By-products

CP – Crude protein

DM – Dry matter

DMD – Dry matter digestibility

DMI – Dry matter intake

DOMI – Digestible organic matter intake

MPTs – Multipurpose trees and shrubs

N – Nitrogen

N – I - Nitrogen intake

NDF – Neutral detergent fibre

NDF-I – Neutral detergent fibre intake

OM – Organic matter

OMI – organic matter intake

PANESA – Pastures Network for Eastern and Southern Africa

PEG – Polyethylene glycol

ABSTRACT

A large number of legume shrubs and tree species have been documented as useful livestock fodder. Supplementing grass diets containing <7% crude protein with legume forages improves both feed intake and animal performance. With a wide variation in nutritive value, it is important to screen these MPTS to ascertain their nutritional value. A study was carried out to address the above problem using five indigenous fodder species in two experiments. The five tree fodders selected for this study were: 1. *Acacia nilotica*, 2. *Acacia senegal*, 3. *Albizia amara*, 4. *Balanites aegyptiaca* and 5. *Bridelia micrantha*. In the first experiment, chemical composition of the selected tree forages was analysed. The CP content ranged from 11.2% in *B. micrantha* to 25.0% in *A. senegal*. Maize stover, which was used as basal diet, had a CP of 3.3%. The NDF levels ranged from 29.0% DM in *A. nilotica* to 60.1% DM in *A. amara*. Although *A. nilotica* had a high *in sacco* degradability at 76.3% ($p<0.05$), it had a low degradation rate. *Bridelia micrantha* had a significantly low degradation rate compared to the other forages. *Balanites aegyptiaca* showed the highest degradability (62.2%) at the fractional outflow rate of 0.05. The forages were also subjected to *in vitro* gas production and *B. aegyptiaca* showed the highest OMD% at 48hrs. During the palatability trial, *B. aegyptiaca* had the highest indices while *B. micrantha* was consistently ranked last over the entire period of 15 days. Based on chemical composition, degradation characteristics and palatability trial, *B. aegyptiaca* was selected for the feeding trial in experiment two. In the second experiment, twenty Small East African male goats were used in a CRD, with four animals per treatment. Increasing levels of *B. aegyptiaca* leaves at 0, 5, 10, 15 and 20 g DM/kg$W^{0.75}$ were used as supplements to maize stover. Although supplementation had a positive effect on the total DMI and N intake, it only had a mitigating effect on weight loss. DMI improved from 295 g to 358 g/day while weight loss was reduced from 102 g to 44 g/day. There was no effect on stover intake. Apparent DMD of the feeds improved from 12.6% without supplementation to 61.2% at the highest level of supplementation. The species studied showed potential as protein supplements. *Balanites aegyptiaca* leaves can be used as supplement to poor quality roughages but higher levels than 20 g DM/kg$W^{0.75}$ may be required for maintenance during the dry season.

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CHAPTER ONE

1.1 INTRODUCTION

Animal production contributes substantially to the income of farming communities. However, in Sub-Saharan Africa, availability of good quality feed is a major constraint to animal production. This is common in the semi arid regions where grass production is characterised by short seasonal growth, rapid deterioration in quality with advancing stage of maturity and scarcity of herbage during the dry season (Leng, 1990). Animals are offered natural pasture, crop residues or grown fodder, which are low in digestible nutrients and do not supply adequate nutrients to meet the requirements of the animals (Leng, 1990). Since the native pastures and browse are the main forages and in most cases the only components of livestock nutrition, there is inadequate supply of good quality feed to animals throughout the year. The productivity of such animals in terms of meat, milk and other products is, therefore, sub-optimal. Consequently, poor nutrition is one of the major causes of low livestock productivity in tropical areas. The low productivity is caused by the imbalanced nature of the nutrients that arise from digestion of the available forages when these are fed without supplements (Leng *et al.*, 1992).

Supplementation with commercial concentrates is one way of improving roughage utilisation. However, for smallholder livestock farmers, these concentrates are not readily available or are too expensive. An alternative to these concentrates is to use on-farm supplements, and multipurpose tree and shrub (MPTS) forages. Supplementing grass diets containing <7% crude protein with legume forages improves both feed intake and animal performance (Minson and Milford, 1967). When fed, tree forage supplements create a rumen environment more capable of fermentatively digesting poor quality forage (Leng *et al.*, 1992). There is evidence of beneficial responses to production due to the use of some tree fodder supplements in terms of live weight gain (Abdulrazak *et al.*, 1996, 1997, Sawe *et al.*, 1998) and milk production (Ondiek *et al.*, 2000).

A large number of legume shrubs and tree species have been documented as useful livestock fodders (Topps, 1992). With a wide variation in nutritive value, it is important to screen these MPTS using simple techniques like *in sacco* and *in vitro* methods. Some of the species contain antinutritive factors like tannins and these abound in tree species like the *Acacias* (Woodward and Reed, 1997). Tannins may compromise the nutritive value of the fodders (Swain, 1979) since they precipitate protein by forming tannin-protein complexes (Reed *et al.*, 1990, Reed, 1995), thereby reducing the digestibility of protein and dry matter (Hangerman *et al.*, 1992).

1.2 Statement of The Problem

There are basically two classes of trees and shrubs, namely the indigenous and the introduced ones. A lot of studies have been done on the introduced species but information on the nutritional value of forage from indigenous trees and shrubs is scanty. The feeding of these fodders is likely to improve the animals' intake and the digestibility of the diet, which will lead to improved animal productivity. Indigenous trees and shrubs are highly productive and adapted to local conditions, especially the arid and semi-arid lands where the larger livestock populations are found.

1.3 Justification

Most studies on MPTS have been on the agronomic performance, identification, propagation and management (ICRAF, 1992). To some extent the basic chemical composition (dry matter, ash, and nitrogen) have been reported. There is a need for more work on evaluation of these MPTS and their nutritional role in livestock production. The use of legume trees and shrubs as livestock feed is increasingly becoming important especially in the tropics where the protein feed sources are few, costly and competitive in their use. International Livestock Research Institute (ILRI) work on evaluation of MPTS have been summarised and indicated the potential of the indigenous tree forages (Osuji and Odenyo, 1997).

1.4 Objectives

The main objective of this study was to identify and examine the potentials and limitations of some common indigenous trees and shrubs as livestock feeds.

Specific objectives

(i) To determine the nutritive value, degradation characteristics and palatability of selected indigenous browse species.

(ii) To determine the effects of supplementation of tree forage on the performance of goats.

1.5 Hypotheses

(i) The nutritive value of indigenous tree forages is the same.

(ii) Supplementation with MPTS does not improve feed intake and performance of goats.

CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 Importance of the goat in the Tropics

Goats constitute an important component of the livestock resources of the world (Table 1). The largest populations are found in Asia and Africa which together account for about 91.3% of the total (FAO, 2001).

Table 1. Goat Statistics

	Numbers ('000)	meat (tons)	milk (tons)	goatskins ('000)
World	738246	3759	12455	838
Africa	218625	851	2773	146
Kenya	9000	32	96	10

Source: FAO. Production YearBook, Vol. 55 - 2001.

The value of goats to man is emphasised by the fact that next to the dog, goats were the first animals to be domesticated by man (Payne, 1990). Goats are valued primarily for the production of meat, milk, skins and fibre. They also meet man's social, cultural and recreational needs (Gall, 1981).

Goats are kept by over 90% of the households in the arid and semi-arid regions where other domestic species may not survive (Devendra and Burns, 1983). Here, they contribute to the health and nutrition of several million people in the developing countries especially those on/or below the poverty line. This source of food and milk makes the difference between adequate nutrition and malnutrition for many rural people who cannot afford to buy these foods and are unable to produce them by rearing cattle (Devendra and Burns, 1983). Goat production is also attractive due to the low initial investment required relative to cattle production and the corresponding small financial loss incurred with the death of individual animals. Their labour requirements are relatively low and their manure can be used to enhance crop production or as fuel (Devendra and Burns, 1983).

2.1.2 Nutrition and management of goats in the tropics

In the tropics, there is a serious shortage of meat (FAO series, 2002), which contributes to a general deficit of protein in the human diet. Given the high growth rate and reproduction of goats, it is possible to substantially increase the supply of meat in a short period with improved nutrition and disease control. Goats have a short reproductive cycle and a high twinning rate with an optimum interval of three parturitions in two years. However, rapid reproduction entails the danger of overstocking and in most areas where goats are kept, overgrazing is apparent (Gall, 1981). Goats in the arid and semi-arid areas breed throughout the year with seasonal peaks being dependent on feed availability. Bucks exhibit high libido, high fertility and early sexual maturity (Devendra and Burns, 1983).

Animal feeding is limited by the quality and quantity of nutrients available from indigenous grass and shrub species throughout the year. Tropical grasses are low in energy and protein and high in fibre content largely as a result of their more rapid physiological growth and early maturity as influenced by temperature, water stress and light (Gall, 1981). Shrubs and trees often retain high levels of nutrients during the dry season. At the time of the year when the nutrients available from grass and herbaceous legumes are inadequate, forage trees and shrubs become a valuable source of feed especially for goats. Free roaming livestock consume a wide variety of materials from grasses, herbs, shrubs and trees (Gall, 1981) and the selection made depends on plant availability, season and the livestock species involved. The wide distribution of goats is partially due to their habit of feeding on a variety of feedstuffs mainly tree leaves, browse, forbs and grasses (Devendra and Burns, 1983). This habit shows variation with season, environment and production level and these also determine the selection for particular plants or plant parts.

In the arid and semi-arid lands, goats scavenge in free roaming village flocks with no special provision of forage or housing and with animal management limited only to herding (Devendra and Burns, 1983), supplements are rarely given and veterinary care is limited to occasional treatments of the sick. In the dry areas where the extensive pastoral systems are common, browse is the major feed for goats especially when the quantity and quality of pastures are low. Goats are opportunistic generalists and tend to consume the most palatable and nutritious forage that is available (Gall, 1981), hence their diet is determined more by the availability of feed than preference. Goats prefer to select from a variety of feeds such as a combination of grasses, shrubs or tree leaves and are said not to thrive well when kept on a single type of feed for any length of time (Devendra and Burns, 1983).

2.1.3 Factors affecting voluntary food intake in Ruminants

Voluntary food intake (VFI) is the weight eaten by an animal or group of animals during a given period of time during which they have free access to food (Forbes, 1986). Consumption of food initiates several events important for eventual development of satiety. Absorbed nutrients, gut hormones and sensory nerves are believed to mediate feedback mechanisms (Forbes, 1986) and since animal productivity is largely dependent on the intake of food, the stockman strives to increase the voluntary intake of farm animals. The importance of the quantity of food an animal consumes is emphasised by the fact that higher food intake is associated with a greater opportunity for increased daily production.

Ruminant intake is controlled by a combination of physical, chemical and psychological factors. In the tropics, performance of ruminant livestock is largely limited by voluntary intake and digestibility of the basal feed, which mainly consists of low quality roughages and crop residues (Premaratne *et al.*, 1998). Leng (1987) reported that when roughages of low nitrogen concentration are given to ruminants, a supplementation with protein often results in an increase in voluntary food intake caused by increased availability of fermentable nitrogen. Although Van Hao and Ledin (2001) found that increasing levels of gliricidia resulted in an increase in the total intake but a depression in intake of the basal rice straw diet, Dutta *et al.* (1999) showed that provision of leucaena at the rate of 30% of total DMI as a protein supplement significantly increased total DMI and the digestibility of the rice straw diet. This was in contrast to Kaasschieter *et al.* (1988) who found no increase in straw intake while supplementing rice straw with legumes *L. leucocephala* and *G. maculata.* Improved intake of low protein foods is not necessarily accompanied by increased digestibility since the nitrogen content of the digesta is the major factor limiting rate of fermentation in the rumen and also the rate of passage through the digestive tract (Ramirez-Perez *et al.*, 2000).

(a) Physical Factors

The type of feed affects the rate of eating since dry feed is eaten more slowly than the same feed in wet form. A decrease of food intake during water deprivation is mainly due to an increase of quantitative thirst level, and the act of feeding itself induces thirst more than the length of water deprivation periods in goats fed on dry feeds (Bambang *et al.*, 2000). The intake of roughage diets with a low outflow rate from the rumen is limited by the capacity of the reticulo-rumen (McDonald *et al.*, 1988), as there are limits to which the rumen distension will not go beyond though the animal's energy requirements have not been satisfied. But this is of less importance with concentrate diets where the chemostatic mechanism will play a bigger role (Forbes, 1986). Forages containing high cell wall content show restricted voluntary intake due to their slow degradability and accumulation of fibre in the rumen (Leng, 1990). Higher digestibility and degradability may be linked to higher CP content which provides more N for microbial utilisation.

Voluntary intake is positively affected by increased forage digestibility as rate of passage is increased. Mean retention time of fluid and of digesta particles in the reticulo-rumen is generally related to the reticulo-rumen capacity, the level of intake and the digestibility of the diet ingested. The rate of passage of feed through the rumen will affect intake since high passage leads to high intake. High forage availability does not necessarily mean greater forage consumption by the animals (Ramirez-Perez *et al.*, 2000) as intake is inversely related to the fibre contents of the plants and hence its maturity. As a result, a high concentration of structural carbohydrates, which are fermented more slowly than other substrates, will lead to a higher degree of rumen fill and probably to a limitation of food intake. Whereas digestibility increases food intake, with highly digestible roughage, differences in digestibility may have a relatively smaller effect on intake than with less digestible materials. Islam *et al.* (2000) found that although high food intakes reduce nutrient digestibility, this could be used to reduce the energy and nitrogen losses and to maximise digestible nutrient intake as well as ruminant productivity.

Voluntary food intake in the adult sheep could also be affected if the development of the alimentary tract is impaired by nutritional restriction during a period of rapid growth and differentiation of the digestive organs (Sibbald and Davidson, 1998) and hence, treatment effects on VFI might be seen in older animals when body condition begins to play a role in intake regulation.

(b) Chemical Factors

Low energy high bulk diets tend to affect food intake physically, whereas on high-energy low bulk diets, the control of food intake is mainly chemical (Bondi, 1987). There is likely to be reduction in intake with good sources of energy. Grains, which generate a lower heat increment than roughage, tend to improve food intake by lowering the overall heat increment of the diet. Mahgoub *et al.* (2000) observed progressive food intake with increasing grain fed.

In ruminants, protein deficiency may inhibit bacterial fermentation in the rumen reducing food intake (Bondi, 1987). Crude protein requirements for moderate levels of production in ruminants are met at dietary DM concentrations of 11-12% (NRC 1981). Negesse *et al.* (2000) found that increasing the crude protein content in the diet of kids increased the average daily dry matter intake from 448g (CP 80g/kg DM) to 608g (CP 155g/kg DM), an improvement of 36%. Sarwar and Mahr-Un-Nisa (1998) reported that a crude protein concentration of less than 8% limited dry matter intake, while Orden *et al.* (2000) observed an increased intake with the addition of either leucaena or gliricidia to the diet. Although they did not observe an improvement in straw intake, they concluded that the increased outflow rate may have led to the higher DM consumption.

Goodchild and McMeniman (1994) found that browse foliage could increase the voluntary DOMI of sheep consuming low quality roughages by providing nitrogen and sometimes minerals and organic matter of greater digestibility. In their study, Premaratne *et al.* (1998) concluded that protein rich supplements from tree forages may result in similar or increased intakes of the basal feeds, while energy rich supplements often result in a partial or complete substitution of roughage intake. Protein quality of both the basal diet and the supplement are important in determining the response to supplementation. Increased intake of low quality material can only be achieved if the high protein forage supplement, which provide extra nutrients, is itself very degradable in the rumen (Ahn *et al.*, 1989).

(c) Animal Factors

In very fat animals, the deposition of fat in the abdominal cavity may reduce the space into which the rumen can expand during feeding (Forbes, 1986). In pregnant animals, voluntary food intake may be affected by two opposing factors. The increased demand for nutrients for foetal growth may lead to increased intake while the increase in size of the foetus reduces the available space for rumen expansion during feeding (McDonald *et al.* 1988). Decreased food intake is observed during oestrus since less time is spent eating (Forbes, 1986).

Changes in food intake occur to reflect the changing nutrient requirements of animals during growth and reproduction (Forbes, 1986). If the intake level does not meet requirements, then either the rate will be reduced, the process stopped or the animal resorts to depleting body reserves to meet these requirements. Voluntary food intake could also be affected if the development of the alimentary tract is impaired by nutritional restriction during a period of rapid growth (Sibbald and Davidson, 1998).

(d) Environmental Factors

Very low environmental temperatures increase intake. This is as a result of increased energy requirements to meet demand for increased heat production to maintain internal body temperature (Payne, 1990). On the other hand, high environmental temperature reduces intake in order to reduce heat production associated with feeding. The overall feeding pattern has shown more frequent meals during the day than at night. This may be modified during times when days are too hot so that feeding is concentrated at the cool of day and at night (Forbes, 1986).

Animals tend to eat at the same time so that those fed in groups tend to eat less than those fed in individual pens. Forbes (1986) states that the size of the group does not seem to affect daily intake.

Diseases of most types depress intake. Whereas internal parasites either compete with the host animal for nutrients from the ingested food or extract nutrients from the host animal, external parasites either extract nutrients from the host animal or cause distractions through irritation reducing the time spent feeding (Forbes, 1986).

2.1.4 Nutritive value of tree forages

To maintain high animal productivity from the poor quality pastures and crop residues, the nutritive value of these feedstuffs must be improved. The nutritive value of crop residues is influenced by stage of maturity at the time of harvesting, harvesting and handling losses, plant morphological components and the length of time and the degree of weathering in the field between crop harvest and residue collection. Tolera *et al.* (1998) reported that maize harvested at stage I and II (grain moisture content ranging from about 20 to 30%) gave higher leaf: stem ratio, higher CP and lower NDF in stover without significant change in grain and stover yield. However, maize harvested at stage III (grain moisture content of 10–12%) was the least in stover yield and nutritive value of the stover. Leguminous fodder trees have been found to be potentially suitable for supplementing basal roughages (Abdulrazak *et al.*, 1996, 1997, Odenyo *et al.*, 1999). The nutritive value of forages depends on the voluntary intake of the feed consumed and the extend to which the quantity of dry matter eaten by the animal supplies dietary energy, proteins and minerals.

While using *Leucaena leucocephala* and *Gliricidia sepium* in concentrate formulation, Ondiek *et al.* (2000) found that the two tree forages can be used as cheap nitrogen sources in commercial type concentrates without causing any detrimental effects on performance of dairy goats. The concentrate formulations contained 30% of either leucaena or gliricidia meal with the CP ranging from 174 to 175 g/kg DM. Kaitho and Kariuki (1998) using either desmodium, calliandra or sesbania as supplements to either young or old napier grass (*Pennissetum pupureum*) concluded that a low level supplementation rate (1 – 1.5kg DM/day) was adequate to maintain good growth rates when basal feed quality was poor i.e. in dry season feeding.

The insolubility of nitrogen in acacia was found to be associated with the high proportions of nitrogen bound to fibre (Ben Salem *et al.*, 1997). Increasing the level of acacia in the diet increased DM, digestible organic matter, and digestible crude protein intake. This led to the conclusion that response in terms of organic matter digestibility to shrub supplementation seems to be mediated by their nutritional characteristics rather than their level in the diet.

Chemical composition alone cannot be used to assess nutritive value of tree forages. Although *Acacia angustissima* was found to be a high protein supplement with 33.2g/kg DM nitrogen, it was also found to be highly toxic to sheep when fed at levels higher than 50g/day without adaptation (Odenyo *et al.,* 1997). However, gradual adaptation allows rumen microorganisms to develop the capability to detoxify the anti-nutrition factor. Tolera *et al.* (1997) found that although Tagasaste contained a higher concentration of total extractable phenolics and total extractable tannins than broom and gorse, its gas production without polyethylene glycol (PEG) treatment was relatively high and did not respond to PEG treatment. This led them to conclude that it is the condensed tannins that are the main factors depressing the *in sacco* degradability and *in vitro* gas production potential of browse plants. The chemical composition of some forage species is shown in Table 2.

Table 2. Chemical composition of some tree forages (g/kg DM).

Forage	DM	OM	CP	NDF	ADF	ADL	Source
Acacia brevispica	915	-	214	511	411	-	Sawe *et al.*, '98
Acacia nilotica	918	-	135	227	207	-	Sawe *et al.*, '98
Acacia seyal	-	957	134	230	168	121	Abdulrazak *et al.*, '00
Acacia tortilis	904	924	181	511	337	85	Nyangaga '01
Acacia senegal	905	904	219	424	221	61	Nyangaga '01
Balanites aegyptiaca	867	-	145	430	335	90	Kitilit '03

2.1.5 Factors affecting palatability of browse

Palatability is a complex phenomenon influenced by animal, plant and environmental factors. It can be defined as a plant characteristic eliciting a proportional choice among two or more forages conditioned by plant, animal or environmental factors which stimulate a selective intake response by the animal (Kaitho *et al.,* 1996). To assess the palatability of tree forages, observation of preference and measurement of intake in confinement is recommended (Kaitho *et al.,* 1997) rather than the cafeteria method, which gives an observation on the selection only.

Plant factors that influence forage palatability are, species, intra-specific variation, chemical composition, physical traits, maturation and availability in a non-controlled situation and form of the forage (Kaitho, 1997). Free roaming livestock consume a wide variety of materials from grasses, herbs, shrubs and trees. The selection made depends on plant availability, season and the livestock species involved (Kaitho, 1997). If a forage is given *ad libitum*, the level of intake depends on refusals rate that is frequently higher in goats than in other ruminants (Devendra and Burns, 1983). A meal of the goat fed on forages alone at the trough is divided into three phases: a phase of exploration, where the goat takes stock of the feed offered, a phase of intense feed intake where the animal satisfies most of its hunger and a phase of slower intake where the goat selects the plant fractions to be ingested (Devendra and Burns, 1983). Goats select the most nutritive fractions of forages, the leaves more than the stems, the thin stems more than the thick ones and the fractions richest in proteins and poorest in cell-wall carbohydrates (Devendra and Burns, 1983).

Animals tend to develop some tolerance over time so that multipurpose trees and shrubs (MPTS) that appear unpalatable at first contact end up being quite palatable. Abdulrazak *et al.* (1996) observed that animals offered gliricidia encountered palatability problems during the early stages of the adjustment period. They suggested that the unusual odour in the leaves of gliricidia could be the most plausible reason for its poor acceptability. Stewart *et al.(*1998) showed that accustomisation may be a stronger determinant of acceptability of the different *G. sepium* provenances than genetic variation in taste and odour. Nutritional wisdom dictates that animals are able to identify harmful plants and avoid them during browsing. This may be through smell before eating or after the first bite. Kaitho *et al.* (1996) observed that intake for some of the MPTS in their study decreased with time over the twelve experimental study period suggesting that animals could have developed some reflex against inhibitory factors.

The form in which the forage is given (dry vs fresh) also has an effect on palatability. Although in controlled feeding situations the animal's feed choice is limited, the palatability of the plant forage provided can be improved by altering the form offered. Kaitho *et al.* (1997) observed a 37% difference in intake of wilted vs dried calliandra.

2.1.6 Anti-nutritional factors in tree legume forages

A major factor limiting the use of many tropical tree forages is the occurrence of a diverse range of natural compounds capable of precipitating deleterious effects in animals. Although several legume trees and shrubs have been documented as useful livestock fodder (FAO, 1992, Topps, 1992) their use has been limited by the presence of anti-nutritional factors. The levels of deleterious substances in tropical legumes vary with the species of plant, cultivar, season and post harvest treatment (D'Mello, 1992). Most of these compounds have no role in the nutrition of the plant but have been developed as a defence mechanism against predators (D'Mello, 1992). The significance of anti-nutritional factors becomes more evident when tree forage is the only feed consumed (Mandal, 1997) where manifestations of toxicity range from reduction in animal performance and nutrient utilisation to increased mortality.

Tannins may contribute to differences in feed utilisation by animals whereby feed intake may be reduced, which then affects livestock weight gains (Reed *et al.*, 19890). Tannins are natural repellants to predators, their low palatability resulting from their ability to precipitate salivary proteins leading to reduced feed intake (Makkar, 1993). Polyphenolics also have the capacity to prevent excessive degradation of high quality leaf protein in the rumen. Ruminants fed a high tannin legume may have an overall shortage of rumen-degradable nitrogen and it is this insufficiency, which impairs the digestibility of structural carbohydrates (D'Mello, 1992). Tannins form stronger complexes with polyethylene glycol (PEG) than they do with proteins. The effect of PEG on condensed tannins in tropical legumes has been noted with improvements in nutritional value of the feed (D'Mello, 1992). Tolera *et al.* (1997) found that depression in *in vitro* gas production and improvement in gas production as a result of PEG treatment are mainly dependent on the condensed tannin content of the browse species rather than the content of total phenolics and total tannins. In the presence of antinutritive factors, the nylon bag technique and gas production will tend to overestimate the nutritive value of forages (Khazaal *et al.*, 1993).

Condensed tannins are known to decrease protein degradation either by altering the forage proteins or by inhibiting microbial proteases. The beneficial effect of tannins may occur where the high affinity of tannins to complex with protein prevents their excessive degradation in the rumen and thus increases protein supply to the lower gut. Kaitho *et al.* (1997) found that increasing tannin content is beneficial to an optimum level upon which when exceeded, animal performance is severely affected. They also found that manifestation of adverse effects depends on the level of intake of browse and on the extent and rate of ruminal metabolism of the anti-nutritive constituents.

Tannins are anti-oxidants and could possibly have beneficial effects on rumen microbes by decreasing the oxidation potential of the rumen ecosystem (Makkar and Becker 1998). They may also be beneficial where they increase the availability of rumen undegradable nitrogen and/or by-pass nitrogen, digestible energy and minerals when fed to livestock (Ash, 1990). Although tree forages contain condensed tannins, their behaviour as well as effects on digestion, differ with plant species (Reed, 1986). It is expected that the higher the tannin content in the fodder, the lower the digestibility and/ or degradability of the material. However, Ash (1990) found that although albizia and gliricidia species contained more tannin than sesbania, gliricidia showed higher rumen degradation. Fibre digestion in goats fed on tannin rich diets may not be impaired because goats secrete proline-rich protein in saliva, which has a higher affinity for tannin than for dietary protein (D'Mello, 1992).

While looking at the relationships among soluble phenolics, insoluble proanthocyanidins and fibre in East African browse species, Reed (1986) reported that the content of insoluble proanthocyanidins is positively correlated with neutral detergent fibre (NDF) and fibre bound nitrogen. *Acacia nilotica* leaves with a NDF of 23.7% OM had insoluble proanthocyanidins of 2.7A_{550}/g NDF as compared to *Acacia senegal* leaves with NDF of 41.2% OM and proanthocyanidins of 4.1A_{550}/g NDF. He further observed that differences between browse species in content of NDF were related to differences in content of soluble phenolics and insoluble proanthocyanidins.

Tropical legumes contain a diverse range of toxic non-protein amino acids often in substantial concentrations to contribute significantly to the poor nutritional value of their forages (D'Mello, 1992). Manifestation of toxicity range from simple reductions in food and nutrient utilisation to lethal neurological disorders. The aromatic amino acid mimosine accounts for the toxicity of *Leucaena leucocephala* leaves and seeds to ruminants (D'Mello, 1992). Toxicity depends upon the concentration of the deleterious compounds in the fodder and the rate at which the forage is eaten. One approach to reducing toxicity is to feed the toxic plant in mixture with other plants, thus diluting the effective level of each compound (Lowry, 1989, Melaku *et al.*, 2005).

2.1.7 Effect of tree legume forages on animal performance

Available literature on response curve experiments using napier grass and maize stover as basal diets and *Gliricidia sepium* and *Leucaena leucocephala* forages as supplements offered to crossbred cattle indicate positive responses in intake and weight gain and that forage from MPTS are a cheap source of nitrogen (Abdulrazak *et al.*, 1996, 1997). Sawe *et al.* (1998) showed that goats browsing on predominantly acacia bushland and supplemented with 150g of acacia leaf and pods had significantly higher liveweight gains and feed intake than those which were not supplemented.

The productivity of ruminants is closely associated with the capacity of a feed to promote effective microbial fermentation in the rumen and to supply the quantities and balances of nutrients required by the animal tissues for different productive states (Mandal, 1997). Van Eys *et al.* (1986) found no effect of legume supplementation on total DMI, intake of cell wall constituents and gross energy with napier grass. This led them to conclude that the improvement in weight gain observed with legume supplementation may probably be associated with the proportion and degradation characteristics of the rumen-degradable protein and its effect on microbial protein production. One important attribute of legume fodder is their positive effect on intake and digestibility. Ondiek *et al.* (1999) showed that supplementation of hay diets with *L. leucocephala* and *G. sepium* increased dry matter intake and improved digestibility of the diet and the total intake of digestible dry matter. Hence the importance of tree fodder lies in the fact that their feeding is likely to improve the animal's intake and the digestibility of the diet, which will lead to improved animal productivity.

CHAPTER THREE

EXPERIMENT ONE

Chemical composition, *in vitro* gas production, *in sacco* degradation and palatability ranking of Kenyan indigenous browse species

3.1.1 Introduction

The potential value of a forage can be predicted by an analysis of its chemical composition. Whereas organic matter and dry matter gives an indication of the quantity of forage that will be available on intake, the nitrogen component is an indicator of the value of the forage as a protein supplement.

The rumen degradation characteristics and chemical composition can be used to predict the voluntary dry matter intake of a forage (Carro *et al.*, 1991). Whereas a high correlation has been established between *in vitro* gas production and *in sacco* degradation in temperate feeds, this has not been conclusively done with the tropical feeds. The parameters characterising the extent and rate of rumen degradation are; (a) the rapidly washed out fraction, (b) the slowly degradable fraction and (c) the degradation rate constant of the slowly degradable fraction (b) (Abdulrazak and Fujihara 1999).

3.1.2 Objectives

The objectives of this study were to determine the chemical composition [i.e. organic matter (OM), dry matter (DM), nitrogen (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL)], *in sacco* degradation and *in vitro* gas production characteristics and palatability rating among goats of the selected indigenous browse species.

3.1.3 Materials and Methods

Forages

This study was done using five common indigenous browse species that were identified based on information given by farmers in Baringo district as the most utilised tree forages. The five species are; *Acacia nilotica, Acacia senegal, Albizia amara, Balanites aegyptiaca* and *Bridelia micrantha.*

The forages were harvested at Chemeron Field Station of Egerton University during the wet season. The station is located in Baringo district in the lower midland agro-ecological zone (LM 5), at an altitude of 1080 m above sea level with an annual mean temperature of 23°C. The area receives 700 mm to 950 mm of rainfall per year with peaks in the April/May and July/August rain seasons. The forages, which consisted of leaves, were harvested by hand and air-dried under shade for five days. They were then stored in gunny bags for latter use.

The chemical analysis, *in vitro* gas production, *in sacco* degradation and palatability experiments were carried out at Tatton Farm of Egerton University. This is in the Central Rift Valley of Kenya at an altitude of 2,238 m above sea level, mean day temperatures of 21°C and a mean annual rainfall of 900 to 1020 mm.

3.1.4 Experimental Procedures

(a) Chemical composition

The DM of the forages was determined by drying the samples at 135°C for 2 hrs while the OM was determined by ashing the samples at 550°C for 4 hrs according to procedures described by Abdulrazak and Fujihara (1999). Total N was determined by micro Kjeldahl digestion (AOAC, 1984) and CP worked out as Nx6.25. NDF, ADF and ADL were determined by the methods of Van Soest *et al.* (1991).

(b) *In sacco* degradation

Two 48 (±2) months old fistulated Friesian steers weighing 460kg (±30) were used. The steers were treated against external parasites by a weekly spray of Triatix® dip wash. The diet of the steers consisted of Rhodes grass hay supplemented with a grain concentrate. They were also provided with a mineral lick (Maclik Plus®) composed of NaCl 27%; Ca 15.42%; P 6.47%; Mg 1.5%; Fe 0.40%; Cu 0.14%; S 0.3% Mn 0.20%; Zn 0.30% Co 0.016%; I 0.0125%; Se 0.0005%;

Mo 0.0002% with a Ca:P ratio of 2.38:1. The degradation characteristics of the forages were determined by placing 5gm of dry sample milled to pass through a 2.5mm screen in nylon bags (140x75mm; pore size 40-60μm) obtained from Shimane University, Japan. The bags in duplicate were then placed in the rumen of the fistulated steers and withdrawn (in duplicate) after periods of 3, 6, 12, 24, 48, 72 and 96 hrs. The zero hour was obtained by soaking the bags in a water bath maintained at 39°C (± 0.5) for one hour. All the bags were then hand washed under a running tap until the water coming through was clear (for 3-5 minutes), the bags were then oven dried at 60°C for 48 hrs to determine the DM disappearance. The disappearance values of the DM over time were fitted to the exponential equation of McDonald (1981) where the degradation curve is described as: within a lag time T, $y=a+b\ (1-e^{-ct})$ where y = degradation after t hours and a, b, and c are degradation constants.

(c) *In vitro* gas production

The gas production technique of Menke and Steingass (1988) as described by Abdulrazak and Fujihara (1999) was used. Rumen fluid from the two fistulated Friesian steers was sampled using a hand pump and strained through a double layer of surgical gauze. The rumen fluid was then mixed with buffer (2:1 v/v) earlier prepared. Thirty millilitres (30 ml) of the mixture was used to inoculate 200 mg each of the five forage samples in 100 ml gas-tight graduated glass syringes in triplicate. The syringes' pistons were lubricated with Vaseline® (pure petroleum jelly) to ease their movement and prevent escape of gas. The syringes were prewarmed to 39°C prior to the inoculation of the buffer mixture. After inoculation, the syringes were incubated in a water bath maintained at 39°C (± 0.5). Gas volumes were recorded at 0, 3, 6, 12, 24, 48, 72 and 96 hrs of incubation. The net gas volume (NGV) was calculated by subtracting gas production in the blank syringes i.e. those with rumen fluid plus buffer without forage samples, from the gas volume recorded in syringes containing forage samples. The NGV data was then fitted to the exponential equation $Y=a+b\ (1-e^{-ct})$ (Ørskov and McDonald 1979) using Neways' computer program (X. B. Chen, Rowett Research Institute, Aberdeen) where:

Y= the volume of gas produced at time t, a+b = the potential extent of the gas production, c = the rate of gas production.

(d) Palatability of the tree forages

The relative palatability of the five tree forages i.e. *A. nilotica, A. senegal, Albizia amara, B. aegyptiaca and B. micrantha* was determined using ten male goats weighing 20kg (± 2.5) and aged six months (±15 days) confined to individual well ventilated pens. An adaptation period of five days was allowed followed by a data collection period of 15 days. Each goat was provided with an individual feed trough subdivided into five separate compartments to contain each of the five test forages. Each goat was also provided with a separate trough for the basal diet of Rhodes grass hay and a water trough. Clean drinking water and mineral licks were provided at all times. One hundred and fifty grams (150gm) of each forage was placed in the compartments and 250gm of basal diet was provided. The forages and basal diet were offered between 8.00 hrs and 12.00 hrs after which left overs were removed and weighed. After this hay was offered *ad libitum*. The amount of feed offered and refused was recorded for each animal. The palatability of the different forages was measured and calculated using variables as described by Kaitho *et al.* (1996).

The relative palatability indices (RPIs) were calculated as follows:

RPI 1= (LegInt1/LegOff1)/ (HayInt1/HayOff1)

RPI2= (LegInt2/LegOff2)/ (HayInt2/HayOff2)

RPI 3= (LegInt3/LegOff3)/ (HayInt3/HayOff3)

RPI4= (LegInt4/LegOff4)/ (HayInt4/HayOff4)

RPI 5= (LegInt5/LegOff5)/ (HayInt5/HayOff5)

Where:

LegInt 1: Average legume intake on day 1

LegOff 1: Average legume offered on day 1

LegInt 2: Average legume intake between day 2 and 5

LegOff 2: Average legume offered between day 2 and 5

LegInt 3: Average legume intake between day 6 and 12

LegOff 3: Average legume offered between day 6 and 12

LegInt 4: Average legume intake between day 13 and 15

LegOff 4: Average legume offered between day 13 and 15

LegInt 5: Average legume intake between day 1 and 15

LegOff 5: Average legume offered between day 1 and 15

HayInt 1: Average hay intake on day 1

HayOff 1: Average hay offered on day 1

HayInt 2: Average hay intake between day 2 and 5

HayOff 2: Average hay offered between day 2 and 5

HayInt 3: Average hay intake between day 6 and 12

HayOff 3: Average hay offered between day 6 and 12

HayInt 4: Average hay intake between day 13 and 15

HayOff 4: Average hay offered between day 13 and 15

HayInt 5: Average hay intake between day 1 and 15

HayOff 5: Average hay offered between day 1 and 15

3.1.5 Data analysis

The data from *in sacco* degradation and *in vitro* gas production was subjected to analysis of variance (ANOVA) (Steel and Torrie, 1980), using the General Linear Model of SAS (1997) and means separated by Least Significant Difference (LSD) (Steel and Torrie, 1980). Data on forage palatability was analysed using the linear models of Statistica (2000) and means separated by Duncan's multiple range test of the same programme.

Plate 1: Nylon bag degradation

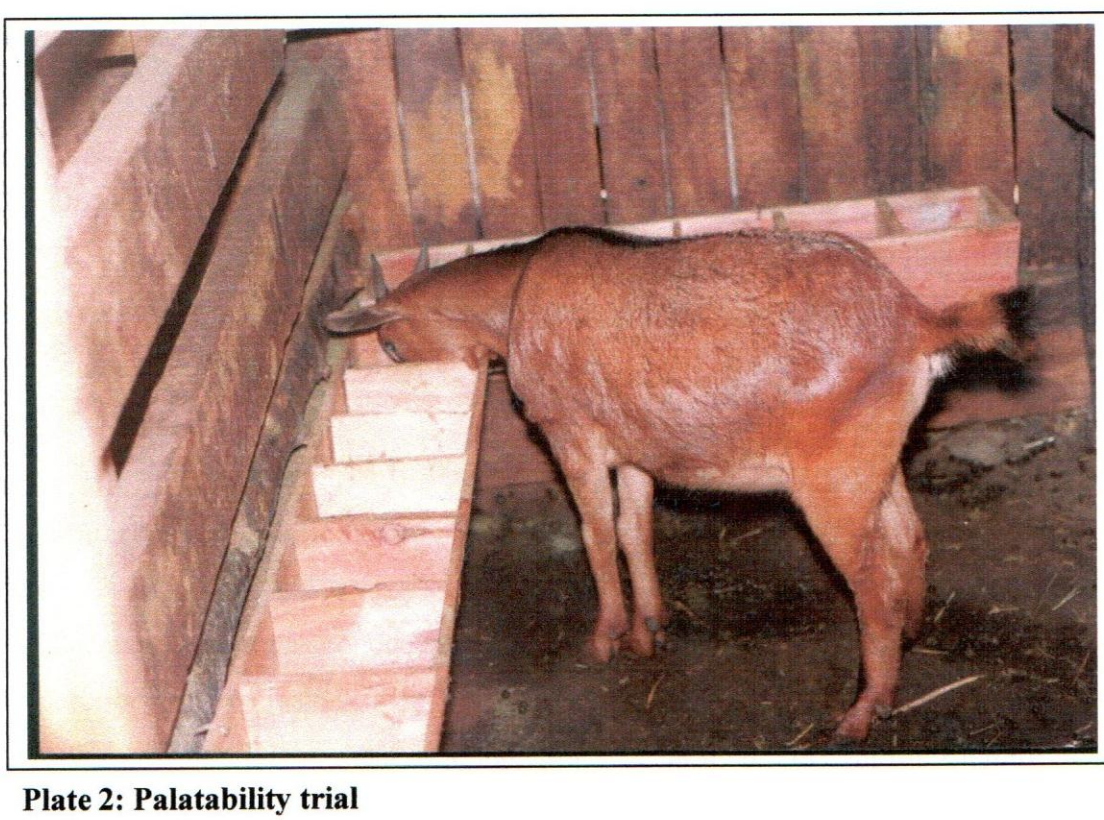

Plate 2: Palatability trial

EXPERIMENT TWO

The Effect of Supplementing Maize Stover with *Balanites aegyptiaca* leaves offered to Goats

3.2.1 Introduction

Feed shortages are prevalent in the arid and semi-arid lands for most parts of the year. These periods are characterised by poor quality feeds, which lead to low feed intakes and reduced animal performance. To mitigate the effects of these low quality feeds, use of tree forages as protein supplements is recommended. Besides their high CP content, legume tree forages also contain minerals, which they supply to the animal.

This experiment was done using *B. aegyptiaca* that was selected from experiment one. Although *B. aegyptiaca* leaves had moderate CP of 13.7%, it was selected due to its high palatability to goats and potential degradability. *Balanites aegyptiaca* is also abundant in the arid and semi-arid lands and remains green throughout the year.

3.2.2 Objectives

The objective of this study was to assess the effect of supplementing incremental levels of *B. aegyptiaca* to maize stover offered to goats on DMI, and DM and OM digestibility and average daily gain (ADG).

3.2.3 Materials and Methods

(a) Site

The experiment was conducted on Tatton Farm of Egerton University whose conditions are as described in experiment one. The goats were housed in individual pens constructed in a house with a corrugated iron sheet roof and both wire mesh and off-cut timber walls. The house was well lit and ventilated.

(b) Animals

Twenty weaner Small East African entire male goats aged between 6 and 8 months with average liveweight of 14 kg (±3.5) were used. These had been purchased from farmers around Marigat Town in Baringo district.

(c) Experimental procedures and design

The experimental design was a completely randomised design (CRD) with five treatments and four animals per treatment. The goats were drenched against internal parasites before the start of the experiment and were sprayed fortnightly for the control of external parasites. The animals were given a ten days adaptation period, followed by 56 days of data collection. The animals were also offered a complete mineral lick (Maclik Plus®) and clean drinking water. The mineral lick was mixed with maize bran to allow for its complete consumption.

For the digestibility study, the animals were put into metabolic cages at the end of the seventh week for total but separate collection of faeces and urine. The total amount of faeces excreted each day for a period of five days was recorded and a sample taken for analysis.

(d) Diets

Ground maize stover milled through a 5mm screen was offered as the basal diet and supplemented with different levels of *B. aegyptiaca*. Grinding of the maize stover was done to reduce diet selection and wastage through spillage and trampling. The leaves of *B. aegyptiaca* supplement were harvested by hand and dried under shade for five days then stored in gunny bags for latter use. The supplement was not ground. The maize stover and supplement were offered in separate troughs. Plenty of clean drinking water was provided *ad lib* and a mineral lick was provided on alternate days. The treatments are shown in the Table 3:

Table 3. Treatment diets for the feeding trial

Treatment	Diets
1	Maize stover + maize bran (control)
2	Control + 5 g DM *B. aegyptiaca* /$kgW^{0.75}$
3	Control + 10 g DM *B. aegyptiaca* /$kgW^{0.75}$
4	Control + 15 g DM *B. aegyptiaca* /$kgW^{0.75}$
5	Control + 20 g DM *B. aegyptiaca* /$kgW^{0.75}$

Both the basal diet and the supplement were offered twice daily at 0830 hrs and 1600 hrs in two equal portions. The amount of maize stover offered was dependent on the previous day's refusals ensuring at least 10% refusal while the amount of supplement was adjusted weekly after weighing the animals.

All animals received an equal amount of maize bran (100g) and molasses (200mls) diluted with water at the rate of 1:4 was sprinkled on the maize stover to improve its intake.

(e) Measurements

The amounts of maize stover, *B. aegyptiaca* and maize bran offered, refused and eaten by each individual goat were recorded on a daily basis. The goats were weighed once a week on a specific day and at between 0730hrs and 0830hrs before commencement of the day's feeding. Weekly feed refusals were bulked per animal and sampled for DM, OM and N analysis. Dry matter was analysed according to procedures described by AOAC (1984) while N was determined by micro Kjeldahl digestion (AOAC, 1984). OM was determined by ashing the samples at 550°C for 4 hrs according to procedures described by Abdulrazak and Fujihara (1999). NDF and ADF were determined by the methods of Van Soest *et al.* (1991).

(f) Statistical Analysis

All the data collected was subjected to ANOVA using SAS (1997). The initial liveweights were used as covariates in the analysis of the effects of the treatments on the ADG.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Experiment One

4.1.1 Chemical Composition

The results of the chemical analysis are as shown in Table 4. There were wide variations in nutrient composition of the various browse species. Crude protein ranged from 11.2 % in *Bridelia micrantha* to 24.9% in *Acacia senegal*. Leaves of *Albizia amara* had the highest NDF (60.1% DM). Whereas *B. micrantha* had the highest ADF at 42.1%, *A. amara* showed the highest levels of ADL at 25.0% of DM. Individual mineral content was not analysed, but the OM levels showed ash contents of between 4.7% DM in *A. amara* and 13.3% DM in *B. aegyptiaca*.

Table 4. Chemical composition of the leaves of selected indigenous browse species

Forage	DM%	OM	CP	NDF	ADF	ADL
		% DM				
A. nilotica	89.9	93.5	12.1	29.0	21.2	10.8
A. senegal	88.4	90.4	24.9	42.3	26.6	12.5
A. amara	89.8	95.3	16.7	60.1	41.3	25.0
B. aegyptiaca	86.7	86.7	13.7	34.9	26.6	15.4
B. micrantha	90.3	94.0	11.2	48.1	42.1	21.2
Maize stover	93.0	90.7	3.3	73.1	44.3	3.3

CP: = crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin.

4.1.2 *In sacco* DM degradation

The DM degradation characteristics are shown in Table 5. The degradation characteristics of the DM exhibited a wide variation in the A and B portions and the fractional degradation rates in the forage species. *Balanites aegyptiaca* had the highest degradation at 24 hrs but was similar to *Acacia senegal* and *A. nilotica* at 48hrs. *Albizia amara* was least degraded at both 24 hrs and 48 hrs.

Balanites aegyptiaca had the highest proportion of the potentially degradable (B) fraction (40.4) and a high degradation rate 'c' (0.080). The leaves of *A. amara* were the least degradable with a low water soluble fraction (A) of 21.6, and the lowest 'B' fraction (15.0) with a slow fractional degradation rate 'c' of 0.017 and a low effective degradability (ED) of 24.7%. *Balanites aegyptiaca* had the highest ED of 62.2% at an outflow rate of 0.05. Figure 1 shows the degradation trends. *Albizia amara* and *B. micrantha* were least degradable at all times.

Table 5. Dry Matter *in sacco* degradation characteristics of selected indigenous browse species

	Total degradation (%)		Degradability parameters				Deg. at	
Species	24 hrs	48 hrs	A	B	A+B	*c* (%/hr)	*k* =0.05	RSD
A. nilotica	65.6^{c}	76.3^{c}	41.8^{c}	36.5^{b}	78.3^{b}	0.054^{b}	57.9b^{b}	1.67
A. senegal	63.8^{c}	77.9^{c}	40.9^{c}	38.8^{b}	79.7^{b}	0.037^{b}	58.9^{b}	2.18
A. amara	25.1^{a}	29.9^{a}	21.6^{a}	15.0^{a}	36.6^{a}	0.017^{a}	24.7^{a}	1.28
B. aegyptiaca	71.7^{c}	76.9^{c}	37.6^{b}	40.4^{b}	77.9^{b}	0.080^{b}	62.2^{b}	2.58
B. micrantha	33.7^{b}	43.7^{b}	28.7^{a}	37.2^{b}	65.9^{b}	0.015^{a}	33.3^{a}	0.93
SEM	3.015	1.569	0.47	8.097	7.99	0.0067	0.893	

^{a}Means with the same letter superscript in a column are not significantly different ($p<0.05$).

SEM: Standard error of the means;

A-washing loss (%), B-degradability of water insoluble fraction (%), c-rate constant.

RSD- residual standard deviation

Deg: Degradability, and *k:* fractional outflow rate

4.1.3 *In vitro* Gas Production

The results from *in vitro* gas production are presented in Table 6. Total gas production shows variations in the forages' degradability and digestibility potential, with *A. nilotica* leaves showing the highest potential, followed by *A. senegal* and *B. aegyptiaca*. Leaves of *A. amara* had the least gas production (17.1ml) at both 24 hrs and 48 hrs. However, there was no difference between the degradation potential of *A. nilotica* (28.65 ml) and that of *A. senegal* (29.12 ml) at 48 hrs. *Balanites aegyptiaca* had the highest rate of gas production, 'c', at 0.094. The mean gas production at 48hrs for *A. Senegal, A. nilotica* and *B. aegyptiaca* were similar but significantly ($P<0.05$) different from *B. micrantha* and *A. amara*, which were similar. The browse with the highest production at 24 and 48 hrs was *B. aegyptiaca*. The gas production trends are shown in Figure 2.

Table 6. *In-vitro* gas production (ml/200 mg DM) of leaves of selected indigenous browse species

	Gas Production at		Degradation potential		48hrs	
Species	24 hrs	48 hrs	a + b (ml)	*c (%/h)*	OMD%	RSD
A. nilotica	28.7^{b}	38.7^{b}	43.9^{d}	0.044^{ab}	55.00^{b}	1.430
A. senegal	29.1^{b}	35.1^{b}	37.8^{c}	0.058^{b}	52.22^{b}	1.431
A. amara	12.6^{a}	17.1^{a}	18.9^{a}	0.045^{b}	35.23^{a}	0.679
B. aegyptiaca	31.9^{c}	35.4^{b}	37.8^{c}	0.094^{c}	51.98^{b}	2.104
B. micrantha	12.1^{a}	19.4^{a}	27.2^{b}	0.024^{a}	37.13^{a}	0.458
SEM	0.631	0.616	0.862	0.003	0.577	

SEM: standard error of the means; a, b, c are constants in the equation (Ørskov and McDonald, 1979).

[a]Means with the same letter superscript in a column are not significantly different ($p<0.05$).

OMD48: *In vitro* organic matter digestibility calculated from the equation: OMD (%) = 18.53 + 0. 9239 gas production (at 48hrs) + 0.0540 CP (Menke and Steingass, 1988).

4.1.4 Palatability Trial

Results for the palatability trial are shown in Table 7. Throughout the trial, *B. aegyptiaca* was the highest ranked with an index of 0.803 on day one and 1.6846 for day 1-15. *Bridelia micrantha* consistently remained at the bottom of the rankings except between days 2-5 when *A. nilotica* was ranked last. There was a high correlation between Day 1 and Days 1-15 (0.96) but lower between Day 1 and Days 6-12 (0.61) (Table 8). All clusters had high correlation with Day 1-15 except Days 13-15, which was slightly lower than the others.

Table 7. Palatability ranking of selected indigenous browse species

	Indices				
Species	**Day 1**	**Day 2-5**	**Day 6-12**	**Day 13-15**	**Day 1-15**
B. aegyptiaca	0.8028^{Ca}	1.1067^{Ca}	2.366^{Aa}	2.0281^{Aa}	1.6846^{ABa}
A. senegal	0.6758^{Ca}	0.9686^{BCa}	1.7913^{Ab}	1.1562^{Bb}	1.2604^{Ba}
A. amara	0.2536^{Bb}	0.4748^{B}	1.0274^{Ac}	0.7705^{ABb}	0.699^{ABb}
A. nilotica	0.1812^{Ab}	0.217^{Ab}	0.3676^{Ad}	0.4365^{Ac}	0.3092^{Ab}
B.micrantha	0.1442^{Ab}	0.2833^{Ab}	0.3522^{Ad}	0.217^{Acd}	0.2769^{Ab}

^{A}Means with the same letter superscript in a row are not significantly different ($p<0.05$)

^{a}Means with the same letter superscript in a column are not significantly different ($p<0.05$)

Table 8. Correlation coefficients of the cluster periods

	Day 1	Day 2-5	Day 6-12	Day 13-15	Day 1-15
Day 1	1	0.85*	0.61*	0.83*	0.96*
Day 2-5		1	0.71*	0.88*	0.90*
Day 6-12			1	0.87*	0.71*
Day 13-15				1	0.89*
Day 1-15					1

*Coefficients with the superscript are significant ($p< 0.05$)

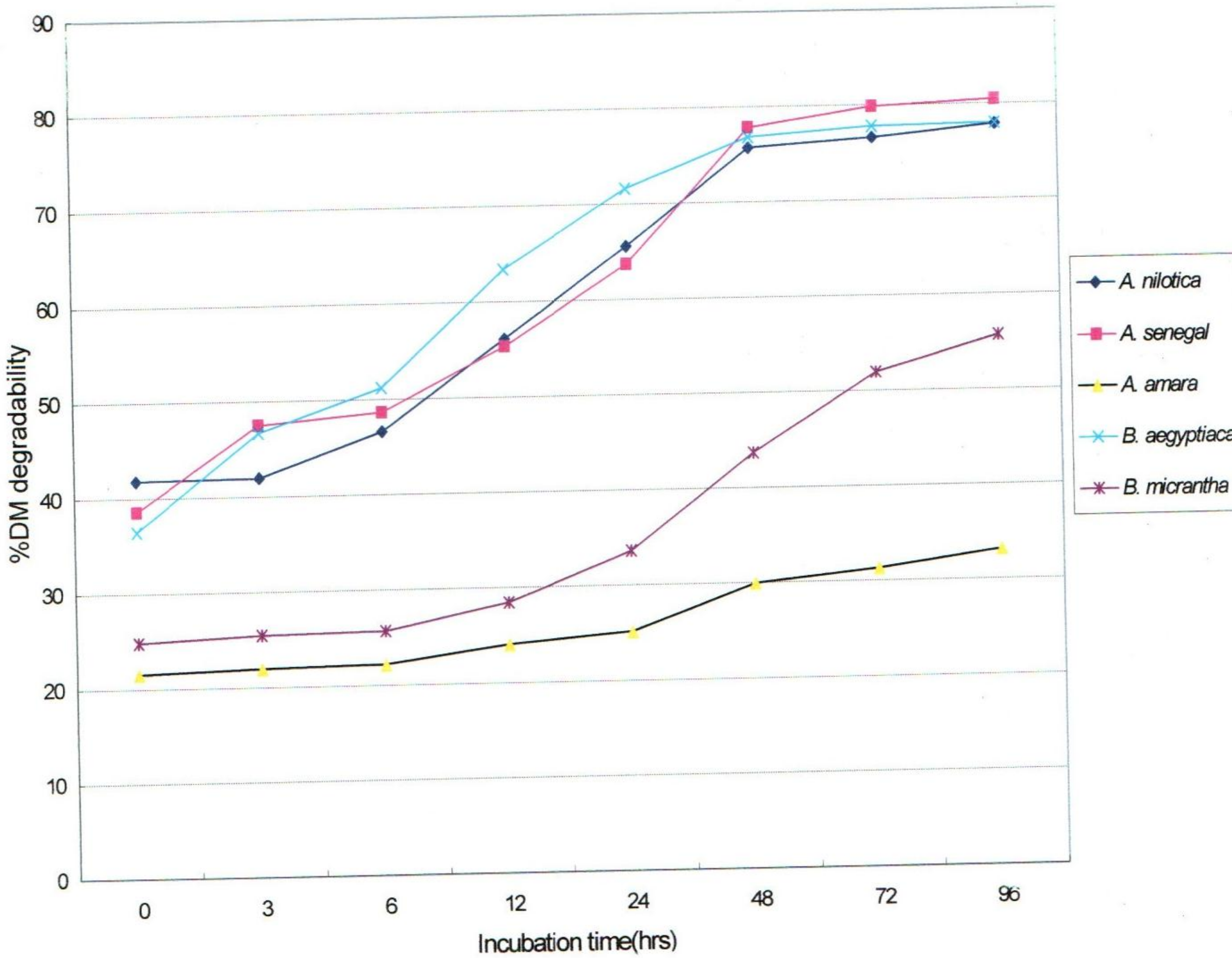

Figure 1. Dry matter degradability for selected indigenous browse species

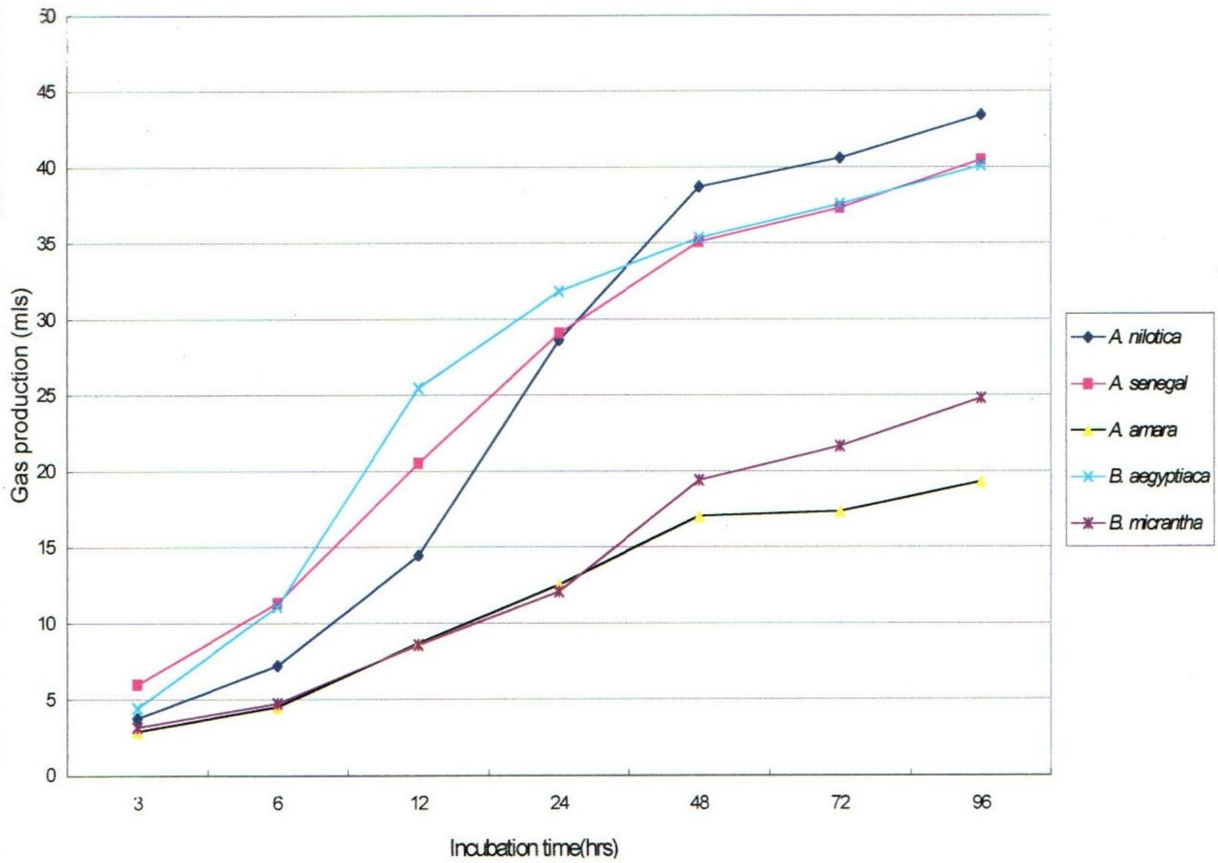

Figure 2. Corrected gas production (mls/200 mg DM) for selected indigenous browse species over time

4.2 Experiment Two

4.2.1 Composition of the feeds

The chemical composition of the feeds is presented in Table 9. *Balanites aegyptiaca* leaves contained 20.5 g N/kg DM while maize stover contained 5.3g N/kg DM. The NDF content in maize stover at 730 g/kg DM was almost double that of *B. aegyptiaca* at 387g/kg DM.

Table 9. Chemical composition of the feeds fed to the goats

	DM g/kg	Total N	OM	NDF	ADF	ADL
		g/kg DM				
B. aegyptiaca	927.5	20.5	864.8	386.6	233.9	126.7
Maize stover	930.2	5.3	907.1	730.5	442.9	33.1

4.2.2 Feed Intakes and Liveweight Changes

The intakes of DM, OM, N, fibre and average weight changes are shown in Table 10. Although addition of *B. aegyptiaca* tended to increase total DMI, the intake of the basal diet, i.e. maize stover tended to decrease with increasing levels of *B. aegyptiaca*. At higher levels of supplementation, *B. aegyptiaca* had a replacement effect on the maize stover. The digestibility of the diets increased with increasing levels of supplementation from a low value of 12.6% for unsupplemented stover to 61.2% for the highest level of supplementation. Supplementation significantly ($p<0.05$) reduced the weight losses from 102g to 44g (Figure 3), a 56% improvement between the control and the highest level of supplementation.

Table 10. Intakes of dry matter, organic matter, crude protein, NDF, ADF and average daily gain of the goats

Supplementation level (g/kgW $^{0.75}$)	0	5	10	15	20	SEM
DMI (g/day)						
Maize stover	252.4^{a}	202.1^{b}	172.4^{d}	190.9^{c}	174.2^{d}	3.11
B. aegyptiaca	0.0	36.0	65.3	102.5	126.9	nd
Maize bran	56.9	56.9	56.9	56.9	56.9	nd
Total	309.3^{b}	295.0^{a}	294.6^{a}	350.3^{c}	358.0^{c}	24.42
OMI (g/day)	279.2^{b}	264.7^{c}	263.1^{c}	312.1^{a}	318.0^{a}	3.41
N-I (g/day)	2.2^{e}	2.7^{d}	3.1^{c}	3.9^{b}	4.4^{a}	0.14
NDF-I (g/day)	184.4^{a}	161.6^{b}	151.2^{c}	179.1^{a}	176.3^{a}	3.15
ADF-I (g/day)	111.8^{a}	97.9^{d}	91.6^{e}	108.5^{b}	106.9^{c}	0.33
ADG (g/day)	-102.3^{e}	-86.1^{d}	-73.1^{c}	-67.0^{b}	-44.9^{a}	0.306
DMD (g/kg DM)	126^{a}	258^{b}	395^{c}	400^{c}	612^{d}	1.403

SEM =Standard error of the mean

Nd – Not done

[a]values with different letter superscripts in the same row are significantly different at p<0.05

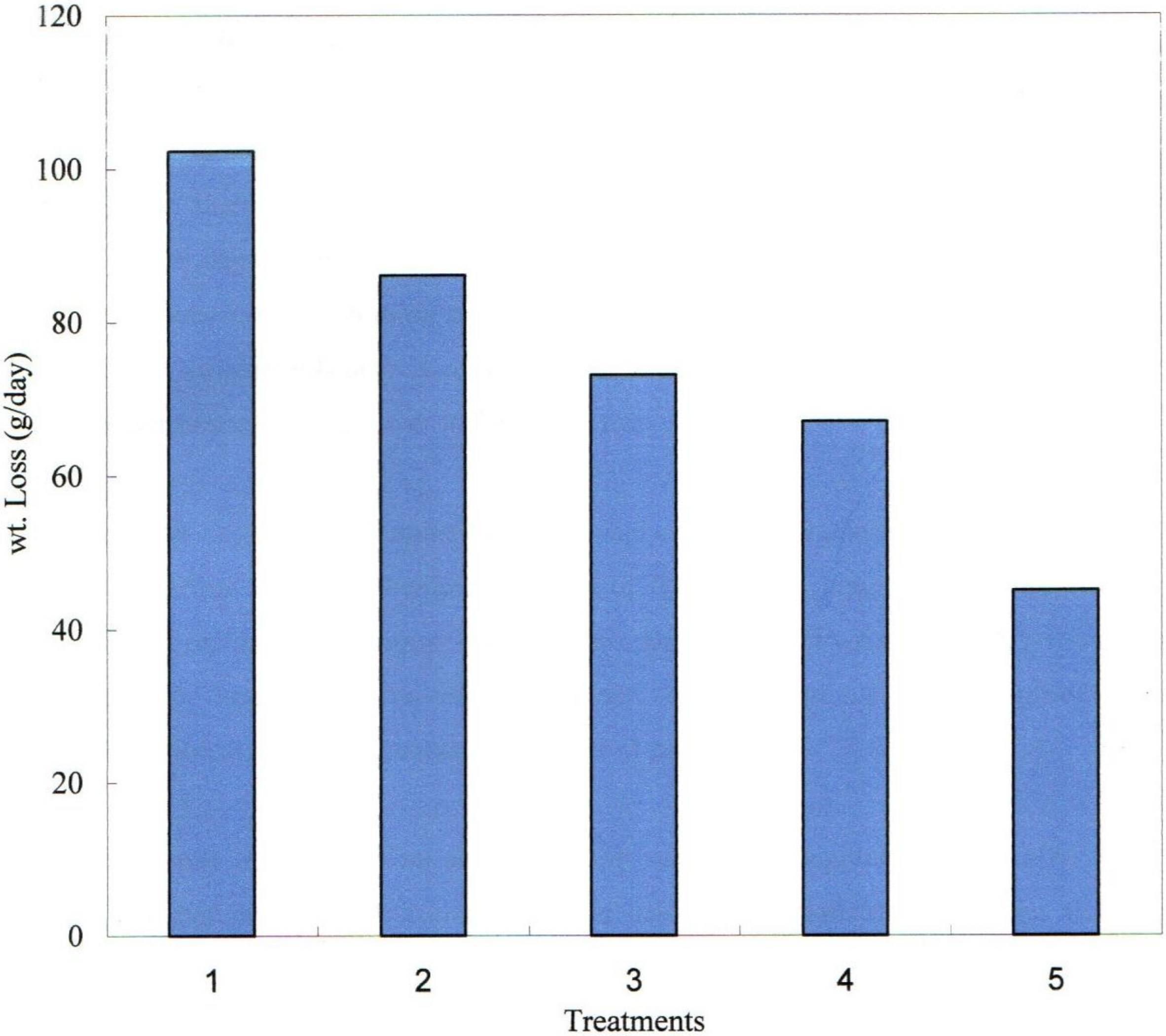

Figure 3. **Average weight changes in goats offered maize stover supplemented with *Balanites aegyptiaca* leaves**

4.3 DISCUSSION

The high dependence of ruminants in the tropics on poor quality plant material, natural pastures and crop residues calls for ways of improving the rumen environment to enable these animals utilise such feeds more efficiently. This can be achieved by providing a source of nitrogen, where supplementing these feeds with tree forages has been one of the approaches. These forage supplements increase protein supply to the animal and improve microbial protein synthesis. The supplements also increase total feed intake and improve diet digestibility because they are richer in protein and lower in fibre than tropical grasses.

The first experiment examined the chemical composition and degradation characteristics of the selected tree forages. Chemical analysis of feedstuffs is aimed at understanding why a given feedstuff exhibits its nutritional peculiarities. But as stated by Kaitho (1997), the true value of a feedstuff is dependent on its voluntary intake and ability to supply the required nutrients. Feeds of high nutritive value promote high levels of production.

The results of the chemical analysis of the various tree legume leaves (Table 4) showed they had nutrient potential for ruminants. This has been demonstrated in other tree legume browse in various studies (Abdulrazak *et al.*, 1997; Ben Salem *et al.*, 1997; Ebong, 1995). The CP content in *B. aegyptiaca* was similar to that reported by Kitilit (2003) while *A. Senegal* and *A. nilotica* showed slight differences from those reported by Nyangaga (2001).

Since cell contents are more rapidly digested, the duration for the breakdown of forages depends on proportion of cell walls in the forage and on the rate of degradation of the cell walls (Ørskov, 1994). The NDF contents ranged from 290 to 601g/kgDM while ADL fraction ranged from 108 to 250g/kgDM. These fractions have an implication on the energy content of a feed since they determine the portion of digestible organic matter. Metabolizable energy is a function of DOM in forages. NDF and ADF may have a pointer to the energy content of the forages while lignin is the key element that limits cell wall digestibility.

The *in sacco* degradation results showed all forages except *A. amara* had high potential degradability. The soluble fraction (A) was low in *A. amara* and the potentially degradable (B) fraction was high in *A. nilotica* and *B. aegyptiaca*. However, these were lower than figures reported by Abdulrazak *et al.* 2001. Potential degradability represents the fraction that would be degraded if samples were incubated during an infinite time but does not reflect the *in vivo* situation. The forages had degradabilities ranging from 65.9 to 78.3%, which were within the ranges reported for other forages (Abdulrazak *et al.*, 2001). The low degradability of *A. amara* could have been caused by its composition that had a high proportion of shoots and petioles. The results for *in vitro* gas production showed a similar trend as *in sacco* degradation.

However, since the presence of high levels of polyphenolic compounds in the forage could restrict preference and intakes of the forages, the palatability tests were conducted to determine which among the test legumes had the highest taste preference. Moreover, chemical composition alone may not determine the suitability of a tree forage as a supplement hence the digestibility and palatability which varies with the type of animal (Kaitho, 1997) are of great importance. The palatability ranking resulting from the indices used shows significant differences in palatability rating among the legume species. There were some slight changes in the palatability indices of all the forages when using different time lengths. This indicated tolerance or acceptability of certain browse after a period of exposure since none of the goats used in this trial had had previous exposure to the test forages. Similar changes in palatability have been described by various authors (Reed *et al.*, 1990; Odenyo *et al.*, 1997; Kaitho, 1997) in previous studies using tree forages of different species.

Factors that determine palatability of forage have been identified as the animal and the forage. Different animal species have different taste and the taste of a forage species varies with age and chemical composition. The animal effect in this study could be seen in the goat's eventual adaptation to the legume leaves after a period of time. The forage's effect can be observed from the differing chemical compositions and their impacts on the potential degradation levels. The higher palatability of *A. senegal* compared with *A. nilotica* agrees with findings of Abdulrazak *et al.* (2001) using sheep.

The high correlation between the palatability indices of day 1 and day 2-5 may have been caused by the adaptation period of five days during which time the animals developed a preference of specific forages. The low correlation between day 1 and the longer periods (5-12) was caused by reduced intakes of the less palatable forages. Although Kaitho (1997) advocates for palatability periods of upto twelve days, there was little difference between the cluster periods. Hence with fewer forage species to be compared, shorter periods of upto five days can be used.

Thus the nutrient make up of the tree forage leaves, their palatability ratings using goats and potential degradation levels are an indication of the latent value in these forages either as entire diets or as supplements providing a source of N to poor quality forages. The only limitations to the use of some of the species are the polyphenols that are part of their make-up. Though tannins exert their anti-nutritive effect by binding with proteins the overall effect has been said to vary depending on the level of tannin in the forage (D'Mello, 1992; Makkar, 1993). It has been pointed out that at low levels tannins may actually positively contribute to overall diet protein utilization by providing means of ruminal degradation by-pass (Ørskov, 1994). Therefore, the supplementation level of the indigenous leave browse in a roughage diet may be important.

Although *B. aegyptiaca* has moderate levels of CP, Fadel *et al.* (2002) observed its leaves to show little variation in the CP, organic matter, and minerals (calcium, phosphorus and magnesium) concentration between seasons making it a good source of CP supplement during the dry season. This coupled with its high degradation and palatability led to its choice in the feeding trial.

The results of experiment two show an increase in total DMI. The higher levels of the supplement, which tended to replace the maize stover, caused the increase in DMI. Ramirez and Ledezma (1997) found that inclusion of shrubs of *Acacia regidula* and *Acacia farnesiana* did not adversely affect forage intake by goats. Sawe *et al.* (1998) also reported that supplementation did not affect estimated forage intake. There was no significant difference in total DMI between treatments 2 and 3 and between treatments 4 and 5 of experiment 2 ($p>0.05$). Increasing levels of the supplement caused an increase in DMI. However, this had little effect on the intake of maize stover (Table 10). This was in contrast with Leng (1987) who reported that when roughages of low N concentration are given to ruminants, a supplementation with protein often results in an increase in voluntary food intake caused by increased availability of fermentable nitrogen. But this compares with Smith *et al.* (1988) who found that although supplementation with tree legumes increased total DMI ($P<0.001$), digestibility ($P<0.05$) and nitrogen retention, the intake of maize stover was not increased. Kaasschieter *et al.* (1988) also found no increase in straw intake while supplementing rice straw with legumes *L. leucocephala* and *G. maculata*. The NDF intake was similar between treatment 4 and 5 but significantly different ($p<0.05$) from the other treatments.

The nitrogen content of the digesta is the major factor limiting rate of fermentation in the rumen and also the rate of passage through the digestive tract. Small ruminants may be able to rapidly remove poorly digested material from the rumen by increasing intake (Ramirez and Ledezma, 1997) as seen in the control group which had higher total DM intakes than treatments 2 and 3. However, Campling and Balch (1961) observed that with low protein foods, improved intake may not necessarily be accompanied by increased digestibility.

The Dry matter digestibility (DMD) of the diet increased significantly ($p<0.05$) with higher levels of supplementation. Although maize stover alone had a high DMI, it had a low digestibility, which led to high loss of body weight. Supplementation even at the lowest level of $5g/kgW^{0.75}$ doubled the DMD of the diet. This is in agreement with Chowdhury (1997) who observed an increase in the DMD of rice straw when supplemented with tree forages. Improved digestibility may be attributed to enhanced microbial yield due to increased nitrogen supply (Goodchild and McMeniman, 1994). The increased digestibility of the diet could be explained by the improved supply of nitrogen from the supplement that improved the rumen environment for microbial activity. The digestibility of the diets increased from 12% with no supplementation to 61% at the highest level of supplementation. This is in agreement with findings of Ben Salem *et al.* (1997) and Premaratne *et al.* (1998), who observed positive responses in digestibility when supplementing low quality feeds with tree forages. Considering the low digestibility of maize stover (126g/kg DM) and low level of supplementation of nitrogen from *B. aegyptiaca*, the greater part of increased digestibility at higher levels of supplementation can be attributed to the substitution effect of *B. aegyptiaca* on maize stover. Although the digestibility of *B. aegyptiaca* was not determined, it must have contributed to the high digestibility observed at higher levels of supplementation.

Although even animals at the highest level of supplementation (20g/kgW$^{0.75}$) lost weight, the weight loss was greatly reduced (by 65%) by supplementation. At higher levels of supplementation, there was improved digestibility of the diets supplying more nutrients to the animals. However, this could not meet the animals' requirements for maintenance. The animals therefore continued losing weight.

The factor that most limits the nutritive value of cereal straw is its unbalanced nature. Maize stover has a low digestibility due to its low content of nitrogen (5.3g/kg) and deficiency of readily available carbohydrates, which limit microbial activity in the rumen. Post-harvest handling causes great variability in nutritive value of stover. Any form of handling that encourages loss of leaf and leaf sheath will lead to consequent reduction in nutritive value of the stover. This will lead to its low intake due to its low metabolisable energy and nitrogen content (Owen and Aboud, 1988). In this study, the delay between maize harvesting and stover collection may have led to its deterioration and low quality (CP 3.3%). Whereas the CP requirement for maintenance is 52g/day the diet was only able to supply 27.2g/day at the highest level of supplementation. This led to loss of weight at all levels of supplementation.

Stovers are often chopped in order to reduce bulk, increase consumption and reduce wastage through selection. This practice forces the animal to eat more of the low quality parts and reduces the nutritive value of that actually consumed. Van Soest (1988) observed that chopping stover greatly affects goats by reducing their intake due to their selective feeding and small metabolic size. The milling of the maize stover in this experiment through a 5mm screen completely eliminated the possibility of selecting leaves in preference to the stems.

The addition of *B. aegyptiaca* caused an overall increase in N intake, which doubled from 2.17g in control to 4.35g at the highest level of supplementation. This may have improved the rumen environment leading to improved DMD with supplementation. The Total digestible nutrient (TDN) requirements for maintenance for goats is 367g/day (NRC, 1981), while the CP requirement is 52g/day (NRC, 1981). The animals in this experiment were unable to meet their maintenance requirements from their intake even at the highest level of supplementation where TDN intake was 219g/day while CP intake was 27.2g/day. The feed intake was 2.2% of body weight, which was below the 2.4% recommended (NRC, 1981) for poor quality roughage for maintenance. The intake of the control diet was 1.9% of body weight, which led to higher weight loss. However, increasing levels of supplementation improved diet digestibility leading to better supply of nutrients and lower weight losses. Supplementation of the stover with *B. aegyptiaca* reduced the weight loss caused by the low quality stover by 56% from 104g to 44g/day.

CHAPTER FIVE

5.1 CONCLUSIONS

- Based on the chemical composition and the degradation characteristics, the species studied i.e. *Albizia amara, Acacia nilotica, Acacia Senegal, Balanites aegyptiaca* and *Bridelia micrantha,* have shown potential as protein supplements to low quality feeds.

- Evaluation following palatability rating of the five tree fodders under study, *Balanites aegyptiaca* showed the best potential as a forage supplement and hence can be used as a supplement.

- The main constraints to the use of maize stover remains, its bulkiness, which renders transportation and storage difficult and its low protein content, which greatly reduces its intake and digestibility. To be utilised therefore, maize stover requires a good protein supplement.

5.2 RECOMMENDATIONS

- Some of the tree forages used in this experiment had low palatability especially *Albizia amara* and *Bridelia micrantha*. Further work should be done to establish if there are any chemical compounds responsible for their low palatability.

- Supplementing *Balanites aegyptiaca* at $20g/kgW^{0.75}$ failed to support the animals' maintenance requirements. Higher levels will therefore be required, but the energy source will also need to be reconsidered.

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5.4 APPENDICES

Appendix 1

ANOVA for maize stover intake (g/day)

Source	DF	Sum of squares	Mean square	F value	Pr>F
Model	7	17162.0313	2451.7187	63.36	0.0001
Error	12	464.3732	38.6977		
Corrected total	19	17626.4045			
r^2		C.V.	Root MSE	Total mean	
0.973655		3.135112	6.22075	198.422	

Source	DF	Type III SS	Mean square	F value	Pr>F
Treatment	4	16990.3499	4247.5875	109.76	0.0001
Replicates	3	171.6814	57.2271	1.48	0.2699

Means with the same letter superscript are not significantly different (P>0.0001).

Treatment	Mean stover intake
1	252.43^a
2	202.12^b
3	172.44^d
4	190.89^c
5	174.23^d

Appendix 2

ANOVA for apparent Dry Matter Digestibility (%)

Source	DF	Sum of squares	Mean square	F value	Pr>F
Model	7	3950.188	658.365	111.50	0.0001
Error	12	47.236	5.905		
Corrected total	19	3997.424			

r^2	C.V.	Root MSE	Total mean
0.988183	6.78369	2.429918	35.82

Source	DF	Type III SS	Mean square	F value	Pr>F
Treatment	4	3944.184	986.046	167.00	0.0001
Replicates	3	6.004	3.002	0.51	0.6196

Means with the same letter superscript are not significantly different (P>0.0001).

Treatment	Mean apparent DMD%
1	12.60^{a}
2	25.80^{b}
3	39.50^{c}
4	40.00^{c}
5	61.20^{d}

Appendix 3

ANOVA for Nitrogen intake (g/day)

Source	DF	Sum of squares	Mean square	F value	Pr>F
Model	7	12.51976	1.78854	22.17	0.0001
Error	12	0.96792	0.08066		
Corrected total	19	13.48768			

r^2	C.V.	Root MSE	Total mean
0.928237	8.776485	0.28401	35.82

Source	DF	Type III SS	Mean square	F value	Pr>F
Treatment	4	12.48928	3.12232	38.71	0.0001
Replicates	3	0.03048	0.01016	0.13	0.9429

Means with the same letter superscript are not significantly different (P>0.0001).

Treatment	Mean Nitrogen intake
1	2.17^{c}
2	2.66^{d}
3	3.13^{c}
4	3.87^{b}
5	4.35^{a}

Appendix 4

ANOVA for Average Daily Gain (ADG) (g/day)

Source	DF	Sum of squares	Mean square	F value	Pr>F
Model	9	7418.7875	824.3097	11590.6	0.0001
Error	10	0.7112	0.0711		
Corrected total	19	7419.4987			

r^2	C.V.	Root MSE	Total mean
0.999904	-0.357041	0.266681	-74.692

Source	DF	Type III SS	Mean square	F value	Pr>F
Treatment	4	4877.8869	1219.472	1747.00	0.0001
Replicates	3	0.6151	0.205	2.88	0.0891
Intake	1	3.2162	3.216	45.22	0.0001
IN*INWT	1	3.4698	3.469	48.79	0.0001

IN*INWT – Intake corrected for initial weight (covariate).

Means with the same letter superscript are not significantly different (P>0.0001).

Treatment	Mean ADG
1	-102.29^{e}
2	-86.14^{d}
3	-73.14^{c}
4	-67.00^{b}
5	-44.86^{a}