

**EFFECTS OF SUPPLEMENTING RHODES GRASS HAY WITH
Acacia tortilis LEAVES AND / OR PODS, MAIZE BRAN ON GROWTH
PERFORMANCE OF SMALL EAST AFRICAN GOATS**

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A thesis submitted to Graduate School in partial fulfilment of the requirements of the Master of Science Degree in Animal Production (Animal Nutrition Option) of Egerton University

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DECLARATION AND APPROVAL

I declare that this thesis is my original work and has not been presented for the award of a degree elsewhere.

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DEDICATION

This work is dedicated to my parents, wife Jane, daughter Njeri, ASAL farmers and anybody else who may find the information useful.

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LIST OF ABBREVIATIONS

ADG	-	Average daily gain
ANF	-	Anti-nutritive factor
AOAC	-	Association of Analytical Chemist
CP	-	Crude protein
CT	-	Condensed tannin
DM	-	Dry matter
EP	-	Empty pods
FAO	-	Food and Agriculture Organization
FNO	-	Faecal Nitrogen Output
GP	-	Gas production
HDMI	-	Hay dry matter intake
MB	-	Maize bran
MOALD	-	Ministry of Agriculture and Livestock Development
MOALDM	-	Ministry of Agriculture, Livestock Development and Marketing
N	-	Nitrogen
NDF-N	-	Nitrogen bound in Neutral detergent fibre
NH ₃ -N	-	Ammonia nitrogen
PA	-	Proanthocyanidin
PD	-	Potential degradability
PL	-	Pods and Leaves
SPHEN	-	Soluble phenolics
TDMI	-	Total dry matter intake
TNI	-	Total Nitrogen Intake
TNR	-	Total Nitrogen Retention
UNO	-	Urinary Nitrogen Output
VFAs	-	Volatile fatty acids
W ^{0.75}	-	Metabolic body weight
WF	-	Whole fruit
VFI	-	Voluntary feed intake

ABSTRACT

Two experiments were conducted at Naivasha Sheep and Goat station to investigate the effects of supplementing with single or mixed *Acacia tortilis* components (leaves and pods) with or without maize bran on growth performance of Small East African goats (SEAG). In first experiment, twenty-four (24) SEAG, 9 months old were divided into equal six groups and used in a completely randomised design (CRD) experiment. Six different diets which included hay alone (Control) or control supplemented with 19g pods-P, 19g leaves-L, 9.5g-P:9.5g-L (PL), 14g-P:5g-L (PPL) and 5g-P:14g-L (PLL) DM/kg $W^{0.75}$ were fed. Results indicated that the CP of feeds offered ranged between 72 to 168 g / kg DM. Total dry matter intake ranged from 591 to 784 (Se 11.17) g DM/d and was ($p < 0.05$) higher for supplemented groups. Supplementation with pods ($p < 0.05$) depressed hay dry matter intake. The average daily gains for animals fed on hay, L and PLL diets were ($p < 0.05$) lower in comparison to those fed diets containing P, PL and PPL. Rumen ammonia nitrogen was similar across the diets whereas nitrogen retention was ($p < 0.05$) higher only in PL supplemented group. In the second experiment, twenty SEAG, 12 months old were used to investigate the effects of different levels of maize bran (MB) on growth performance of goats. The control diet constituted of hay plus *Acacia tortilis* (pods / leaves; 1:1 - PL), best treatment diet in experiment one. In the other four diets, the control was supplemented with MB at 3g (MB1), 6g (MB2), 9g (MB3) and 12g (MB4) DM / kg $W^{0.75}$. From the results, inclusion of maize bran in the diets at levels exceeding 9g DM / kg $W^{0.75}$ significantly ($p < 0.05$) increased total dry matter intake, average daily gains, Ammonia nitrogen and dry matter, organic matter, and Neutral detergent fibre digestibilities. Digestible organic matter intake ($p < 0.05$) increased at all maize bran inclusion levels. However, the rumen pH and nitrogen retention was unaffected by supplementation. *In-sacco* dry matter degradability and *in-vitro* gas production conducted to evaluate the quality of feeds offered indicated the highest potential degradability and total volume of gas produced (63.7ml) in MB4 diet. It was concluded from the two experiments that the use of pods / leaves (1:1- PL) can sufficiently be used as nitrogen source for growing goats. In addition, inclusion of maize bran at levels above 9g DM / kg $W^{0.75}$ to a mixture of pods / leaves enhance utilisation of *Acacia tortilis* nitrogen improving the weight gain.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Agriculture forms the backbone of Kenya's economy. It contributes 30% of gross domestic product (GDP), with 75% of Kenyans' deriving their livelihood from farming (Uwechue, 1996). However, Kenya's population growth rate of 3.4% is among the highest in Sub-Saharan African countries (CBS, 1994). Majority of this population is concentrated in the high potential areas, resulting in reduction of the arable land, thus a decline in food production. This pose a major challenge to Agriculture Scientists in developing appropriate technologies geared towards increasing food production (animals and crops) in face of ever decreasing agricultural land size per rural household.

The larger part of Kenya (80%) is arid and semi-arid land (ASAL), mainly suitable for livestock production (FAO, 1992). Fortunately, much of this area is dominated by trees of acacia species (browse) that are rich in crude protein (12-30%) compared to grasses 3-15% (Devendra, 1995; Abdulrazak et al., 2000). The values of these fodder trees increase with increasing aridity, accounting for 40 % of available animal feed resources (Devendra, 1990). Supplementation of ruminants' diet with fodder from these trees is expected to increase nitrogen and metabolisable energy intake, improve palatability, rumen function, and availability of vitamins, minerals and animal performance. They could therefore be harvested in times of plenty to complement grasses especially during the non-growing season. Other diverse use of browses include stabilizing soil structures, fixing nitrogen, provision of fencing and construction materials while the roots, barks and leaves of some are used for medicinal purposes.

Unfortunately the role of browses in ruminant nutrition is limited by presence of inherent anti-nutritive substances, which may produce toxic effects in animals or compromise their nutritive value by depressing nutrients intake and utilization (D'Mello, 1992; Nguyen et al., 2002). However, low levels of these substances enhance high quality by-pass protein supplies to duodenum that are beneficial to ruminants (Mangan, 1988).

Livestock sector plays a crucial role in national development by contributing 10% of the country's GDP and 30% of GDP within the Agriculture sector (MOALDM, 1999). In Kenya, meat goat production, a sub-sector in livestock industry has been neglected for long time, yet it contributes 30% of total red meat consumed in the country (MOALD, 2001). ASAL ecology favours goat farming as they resist the harsh environmental conditions

(Devendra and Burns, 1976). Unlike beef or mutton, chevon is believed to be leaner (Devendra and Burns, 1983) and highly demanded, especially by the urban population (Devendra, 1987; FAO, 1996). In addition, low initial investment, less labour requirements and easier marketing characterize this industry (MOALD, 2001). Consequently, resource poor families can afford to initiate small-scale goat production enterprise.

This scenario suggests urgent need of revolutionising goats farming in ASAL to meet the growing demand for animal protein. This work was undertaken to seek ways on how best to utilise alternative feed resources with promising nutritional impact on performance of ruminants.

1.2 Problem statement

Prolonged dry spells are common occurrence in ASAL, hence inadequate nutrition is a major constraint to ruminants' productivity. Available feedstuffs are seasonal and characterized by high fibre content, low nitrogen and digestible energy containing nutrients. These attributes have negative impact on dry matter intake, diet digestibility and growth performance of small ruminants. Browsers (CP 12 – 30%) are abundant in these regions and form valuable components in goats' diets. Digestible energy required by rumen microbes is limiting and goats walk long distance to obtain sufficient quantity to cater for maintenance and production. Moreover, the knowledge of how best to effectively utilize different parts (pods and leaves) of browsers and their synchronization with energy to improve growth performance of goats is limited.

1.3 Broad objective

To evaluate the effects of supplementing Rhodes grass hay with single or mixed *Acacia tortilis* components with or without maize bran on voluntary feed intake (VFI) and growth performance of Small East African Goats (SEAG).

1.4 Specific objectives

(i) To investigate the effects of supplementing Rhodes grass hay with single or mixed *Acacia tortilis* components (pods and leaves) on voluntary feed intake (VFI), diet digestibility, nitrogen balance, ammonia nitrogen ($\text{NH}_3\text{-N}$), pH and growth performance of SEAG.

(ii) To examine the effects of different levels of maize bran (MB) on VFI, diet digestibility, nitrogen balance, $\text{NH}_3\text{-N}$, pH and growth performance of SEAG fed Rhodes grass hay plus *Acacia tortilis*.

1.5 Hypotheses

Ho: Supplementing Rhodes grass hay with single or mixed *Acacia tortilis* components have similar effects on VFI, diet digestibility, nitrogen balance, $\text{NH}_3\text{-N}$, pH and growth performance of SEAG

Ho: Supplementing Rhodes grass hay plus *Acacia tortilis* with different levels of maize bran have similar effects on VFI, diet digestibility, nitrogen balance, $\text{NH}_3\text{-N}$, pH and growth performance of SEAG

1.6 Justification

Availability of high potential land in Kenya is already a constraint while the demand for animal protein is on the increase. The deficit in supply of this protein can be overcome by enhancing utilization of the unexploited ASAL resources (goats and browse) to improve animal productivity. Meat goats get most of their nutrients requirements from existing forages by either consuming the pods, leaves or mixture of the two depending on availability. However limited information exists on the potential and nutritional value on wider usage of these components in feeding system for growing goats. There is need to investigate the potential and limitations of feeding goats with either single or mixtures of these components.

The production of sorghum, millets and maize grain in ASAL is inadequate, despite being major sources of energy for both human and livestock. Maize bran, a by-product of maize processing is rich in energy (Mjema Mweta et al., 1995; Ondiek et al., 1999), although unfit for human consumption. It may form an alternative energy source for livestock in ASAL rather than using the little available cereal grains or losing the animals through starvation. Limited studies have been done on synchronization of nitrogen from *Acacia tortilis* with energy from maize bran in ruminants. There is need to examine its effects when supplemented at different levels on growth rate of goats fed on *Acacia tortilis*. Knowledge on how best to effectively utilize these browse components with or without energy will build on existing scientific knowledge in Kenya and elsewhere in the tropics. It will also go along way in improving the general productivity and profitability of ASAL farmers.

CHAPTER TWO

1.0 LITERATURE REVIEW

2.1 Introduction

Arid and semi arid regions of Kenya normally experience prolonged dry spell. The areas receives less than 500mm of annual rainfall, inadequate for crop production unless under irrigation (Ojany, 1983). Natural pastures, trees and shrubs (browse) dominate much of these areas with livestock farming being the fundamental economic activity. The 1999 livestock census in Kenya indicated a population of 3.6M dairy cattle, 10M beef cattle, 9.6M sheep and 10.6M goats (FAO, 1999). However, majority of the goats (98.9%) are meat type, mainly concentrated in ASAL areas under extensive management system (MOALD, 2001).

2.2 Feeding behaviour of goats

The availability and quality of vegetation on which ruminant animals evolved influence their feeding habits. Naturally, goats evolved as browsers, consuming 32 – 50% of browses (woody species) in their diet (Devendra and Burns, 1976; Kaitho, 1997). This results from their high threshold for bitter taste (tanniferous diets) due to presence of rumen microflora (bacteria), capable of degrading tannins without detrimental physiological effects (Nelson et al., 1995; Nherera et al., 1998). It is hypothesized that consumption of tannin rich diets by goats is related to higher urea recycling and secretion of saliva containing proline rich protein (PRP) (Provenza and Malechek, 1984; Austin et al., 1989). This special protein (PRP) interacts with CT to form complexes resistant to digestive attack (Mehanso et al., 1987). Goats are therefore used as efficient and economic tool for bush clearing as they effectively utilize trees and shrubs dominating much of the rangelands (Malechek and Provenza, 1981).

In times of feed scarcity, goats reduce the levels of feed intake that is compensated by selection of most nutritious plant parts to obtain sufficient nutrients for maintenance and production. Schwartz et al. (1984) noted an increase in number of plants species (32.1) of higher metabolizable energy (6.5MJ kg / DM ME) in goats with restricted intake of poor quality diet. Dominique et al. (1991) and Ebong (1995) found higher nutrients digestibility in goats and attributed it to large rumen volume relative to body size leading to increase in mean rumen retention. In another study, goats feeding on fibrous roughages were noted to increase saliva production and urea concentration (Alam et al., 1985), a mechanism stabilizing rumen ammonia concentration for optimal utilization of fibrous diets. Moreover, goats exhibit

flexibility in their feeding habit with grass / browse mixed diets, browse alone or unpalatable forage forming major components in their diets depending on availability (Le Houerou, 1980). They maximize utilization of the limited organic matter available in poor quality feeds during the dry seasons, hence high survival rate. However, supplementation of these poor roughages with low cost protein and energy source can boost their productivity in times of feed scarcity.

2.3 Nutritive value of tropical grasses

Mature tropical grasses form major feed resource for ruminants in developing countries. However, their nutritive value reported in the literature is extensive and diverse. This was associated with variation among the species, varieties, climate, soil fertility (Minson, 1989) and stage of maturity (Nogueira et al., 2000). These factors influence the chemical compositions (Table 1), thus palatability, intake and degradation rate by animals and rumen microbes. Generally, the crude fibre and calcium content of forages improves while protein and phosphorus deteriorate with advancing plant maturity or drought.

Table 1 Chemical composition of *Chloris gayana*

Grass type	DM	OM	CP	CF	NDF	Source
	g /kg DM					
<i>Chloris gayana</i> Mature	949	870	40	-	-	1
Mid age	952	855	63.7	-	-	''
<i>Chloris gayana</i>	917.6	903.1	52.2	386.5	-	2
''	939.6	858	44.6	372.6	-	''
''	934	837	48	-	705	3
''	916	911	56.3	-	725	4

Source: 1; Coppock (1993) 2; Mtenga and Shoo (1990)
3; Ondiek et al. (1999) 4; Nyangaga (2001)

2.4 Nutritive value of maize bran

Maize is a cereal crop grown in almost every part of Kenya. It is used both for human consumption as well as a main energy source in formulation of non-ruminant and ruminant feedstuff. However, the priority is to use maize grain for human consumption than as a livestock feed hence its high market price. Sub division of agricultural land is a major constraint to maize production and it's unlikely that its production can be increased to cater for human and livestock. Inadequate production of this crop has therefore been cited as a major challenge to livestock production in the country (Republic of Kenya, 1994).

Energy is the most limiting nutrient in livestock production (Van Soest, 1982). Maize bran, a by-product of maize processing is a suitable source of energy (Munthali, 1987) and could substitute for maize grain in supplying ruminant energy. Earlier work done by Abdulrazak et al. (1997) and Ondiek et al. (1999) on this product indicated a CP of 95g / kg DM, with NDF ranging from 299 to 546g/kgDM respectively. In another study, supplementation of Napier grass plus 2kg of *Leuceana leucocephala* offered to crossbred cattle (Ayrshire / Brown Swiss x Sahiwal) with 1kg of maize bran was noted to significantly increase milk yield and VFA production pattern (Muinga, 1993). However, less work has been done to establish the effects of different levels of maize bran in diet of growing goats.

2.5 Potential of *Acacia tortilis* as a supplement in dry areas

Acacia tortilis grow extensively in ASAL areas of Kenya and has more value than simply being a source of livestock feed. The empty pods and immature seeds from this species are used by the Turkana and Maasai communities as human food (Fagg and Stewart, 1994). Moreover, the value of this browse increases in the dry season when the pastoralists' economy depends entirely on browsing of trees and shrubs by camels, sheep and goats (Woodward and Reed, 1989). On average, an *A. tortilis* tree has the potential of producing 2.5 kg of foliage on dry matter and 20-210 kg of pods / year depending on locality, season, age and tree size (Gupta and Molan, 1982). Pods are collected and sold in organized markets, contributing 30% of total diet consumed by cattle, sheep or goats in times of feed scarcity (Scolte, 1992).

Diverse and extensive literature on nutritive value of different parts (leaves and pods) of this species has been reported (Table 2). This variation in chemical composition may be explained by stage of maturity, parts harvested, variety, site (Topps, 1992), phenolic concentration or pre-feeding treatments (Mupangwa et al., 2000; Nogueira et al., 2000). Despite these variations, *Acacia tortilis* forages are rich in CP (Tanner et al., 1990;

Abdulrazak et al., 2000), calcium and phosphorous (Sawe et al., 1998) compared to ASAL grasses, hence qualify as protein supplement.

Variable responses on intake and live weight gains have been reported in literature on offering *Acacia tortilis* as protein supplement to ruminants. Live weight gains of browsing goats were noted to increase from 49 to 68.5 g per day on supplementing with 150g DM/d of *A. tortilis* pods, though TDMI was not affected (Sawe et al., 1998). In an earlier study, supplementing *Cenchrus ciliaris* hay with 350g DM / d of *Acacia tortilis* pod fed to sheep, significantly ($p < 0.05$) increased total DM intake, although hay DM, OM intakes and digestibility were ($p < 0.05$) depressed (Bitende and Ledin, 1996). Increase in feed intake arising from supplementation with browse legume is manifested by significant increase in animal performance (Abdulrazak et al., 1997; Orden et al., 2000). The difference noted in TDMI is associated with the effect of DM intake from the supplements.

Tanner et al. (1990) observed similar nitrogen retention in sheep fed on maize stover diet plus high quality, non-tanniferous feeds (*Guizotia abyssinica*) and those fed on *Acacia tortilis* pods. This was attributed to reduction in protein digestibility and urinary nitrogen loss by tannins present in *Acacia tortilis* pods but not the case with animals fed on non-tanniferous feeds. In another study, supplementing dairy cows with sunflower cake and *Acacia tortilis* pods resulted in similar hay and total DM intake (Shayo et al., 1997), although the later supplement was higher in phenolic. Therefore the types and concentration of tannins present in *Acacia tortilis* pods do not confer any negative effect on animals' response.

Table 2 Chemical composition of *Acacia tortilis* components

Parts of	DM	OM	CP	ASH	NDF	CT	SPHEN	Source
<i>Acacia</i>								
<i>Tortilis</i>	%							
Seed	-	-	18.06	3.7	42.8	15.06	40.14	1
	-	-	30.5	4.59	33.7	13.00	46.4	2
	95.3	95.3	26.2	4.7	26.3	3.5	46	3
EP	-	-	9.3	4.5	45	7.78	42.93	1
	-	-	12.5	6.89	39.4	3.8	32.9	2
	93.2	95	11.7	5.1	35.0	4.0	43	3
WF	-	-	13.4	4.1	44	11.04	41.77	1
	89.4	-	21.7	4.66	32.4	3.14	37.3	2
	89.3	93.7	15.0	6.3	34.6	6.2	45.9	3
	95.6	90.1	20.7	-	-	-	-	4
Leaves	-	95.5	17.2	-	29.6	2.8	-	5

EP – Empty pods WF – Whole fruits

Source: 1; Shayo et al. (1997) 2; Tanner et al. (1990) 3; Bitende and Ledin (1996)
 4; Coppock (1993) 5; Abdulrazak et al. (2000)

2.6 Limitation of browses as sole ruminant feedstuff

Most browse plants contain secondary compounds, which act as deterrents to insects, fungus and animals (Robbin et al., 1987). Tannins, classified as either hydrolysable or condensed tannins (CT) are documented as the most widespread (Kumar, 1983; Makkar, 1995). These compounds react with feed protein and other macromolecules to form rumen undegradable complex (Kumar and Singh, 1984). The interaction between these substances is influenced by nature of protein molecules, digestive contents, size and structure of tannins and conditions of reaction (pH, temperatures) (Hagerman et al., 1992).

Browse tannins have been shown to have either negative or positive effects on the nutritive value of ruminant feeds. High levels of condensed tannins (>20g DM / kg or 5% DM) affects palatability and rumen microbes, depressing feed intake, CP and structural carbohydrates apparent digestibility (Mangan, 1988; Nguyen et al., 2002). Concentration of 2-4% CT in leguminous forage is ideal (Barry and Duncan, 1984) as it prevents excessive protein degradation in the rumen, subsequently released as by-pass protein. This improves the quantity and quality of post-ruminal amino acid absorbed from the intestines (Jackson et al., 1996; Waghorn et al., 1987). In addition, low levels reduce occurrence of bloat by destabilizing protein foam in the rumen, improving protein utilization efficiency (Makkar, 1993).

In the field, farmers reduce palatability and toxicity problems associated with anti-nutritive factors through wilting, drying or dilution. Usually dilution involves feeding browse forage mixtures at different suitable levels with or without sun drying. This approach is cheap, extends the choice of available feeds and reduces chances of animal poisoning by phenolics (Le Houerou, 1980; Rosale and Gills, 1997), thus commonly adopted by tropical farmers (Devendra, 1990).

2.7 Factors affecting voluntary feed intake and diet digestibility in ruminants

Voluntary feed intake (VFI) is an essential tool in assessing forage quality in terms of nutrients input for animal production. The quantity of digestible nutrients consumed by an animal is a function of daily feed intake and relates directly to production (Islam et al., 2000). In ruminants, forage intake is regulated by communication between hunger and satiety centres in brain and rumen wall receptors (Forbes, 1995). These centres are stimulated by multiple factors under the influence of the plant, animal and the environment.

2.7.1 Plant factors

Forage choice by an animal is dependant on its abundance, nutrient content and stage of maturity. Fibre contents in plants increases with age rendering them more resistant to particle size reduction, subsequently reducing the onward passage of rumen digesta and feed intake (Forbes, 1995).

Dutta et al. (1999) found that sheep offered leuceana (NDF 32.1%) exhibited a higher intake ($34.5 \text{ g / kgW}^{0.75}$) for the rice straw than those offered *Prosopis cineraria* ($27.8 \text{ g / kgW}^{0.75}$, NDF 44.6%) or Oat ($19.8 \text{ g / kgW}^{0.75}$, NDF 57.3%). The difference in straw intake was an influence of increased rumen fill resulting from fibrous nature of Oat and *Prosopis* (Baumont et al., 1997; Mawuenyega et al., 1997). However, grinding of fibrous feeds results in reduction of particle size, hence increasing the passage rate and intake (Inou'e et al., 1994), though tract digestibility is reduced (Sutton, 1980).

Tropical legume forages normally supplements grass / cereal crop residue diets (< 7% CP) fed to ruminants. They improve palatability, nitrogen and energy of the basal diets, thus cellulolysis and feed intake are enhanced (Dutta et al., 1999; Devendra and Burns, 1983). Study comparing the intake of young and mature grass by calves demonstrated higher intake (2.3 kg DM / d) of the young relative to 2.1 kg DM / d of mature grass (Coppock, 1993). This variation could be explained by increase in rumen fill attributed to slow fermentation and microbial growth resulting from inadequate nitrogen in mature grass (Van Soest, 1994). In another study, Nyangaga (2001) indicated ($p < 0.01$) increase in total DM intake on supplementing a diet of ad libitum barley straw (49 g N / kg DM) offered to sheep with 0, 10, 20 or 30% DM of *A. brevispica*. High levels of legume forage increases digesta outflow rate, allowing less time for microbes to act on feeds (Van Soest, 1982; McMeniman et al., 1988) leading to reduced fibre digestibility (Mtenga and Shoo, 1990; Bonsi et al., 1995; Kaitho, 1997).

Palatability of forages relates to their chemical composition, morphological and physical traits and maturation. Tannins in leguminous browses have been observed to reduce palatability and feed intake by precipitating salivary muco-protein or digestive enzymes (Bae et al., 1993). Sheep fed on high tannin browse (*A. brevispica*) consumed less straw than those on low tannin browse (*S. sesban*) (Woodward and Reed, 1997).

2.7.2 Animal factors

The volatile fatty acid (VFA) production is a function of organic matter fermented in the rumen and its molar proportion positively relates to feed energy and appears to control the intake (Islam et al., 2000). Meissner et al. (1991) reported a case where addition of 200g of maize meal to sheep fed mature rye grass hay increased total VFA from 11.6 to 13.4 mmol / 100ml accompanied by a decline (53.4 to 32.5 g/kg $W^{0.75}$) in organic matter intake. In an earlier study infusion of acetate but not propionate or butyrate in the rumen of sheep was indicated to reduce feed intake (Armstrong et al., 1958). However, rumen osmotic pressure fluctuates with rumen VFAs and controls rumen motility and pH both involved in regulation of VFI (Hoover, 1986; Funk et al., 1987).

Restriction of feed intake in ruminants during the growth period reduces the energy expended on maintenance. On resuming *ad libitum* feeding, the animal exhibits compensatory growth, accompanied by an increase in intake per unit body weight (McDonald et al., 1988). This could be explained by aspect of energy balance, usually regulated through increased voluntary feed intake (Faverdin and Barcille, 1999). The amounts of protein and amino acids profile available at animals' tissue level are reported to control VFI (Bonsi et al., 1995; Oosting et al., 1995) and growth rate (Preston and Leng, 1987). However, under tropical environments goats offered Rhodes grass hay plus leuceana were found to consume 2.2 to 4.0 % (Mtenga and Shoo, 1990) or 2.5 to 3.9% of their body weight (Devendra and Burn, 1983).

2.7.3 Environmental factors

Ambient temperatures play a central role in determining the amount of feed and water intake by an animal. Normally animals eat to keep warm and increase their intake during cold weather to provide for metabolizable energy, a compensatory mechanism for heat loss. However, heat stress depresses VFI in cattle and is more severe in less adapted compared to well adapted animals, which lower their metabolism reducing the rate of heat production (Silanikove, 1985). Kennedy et al. (1986) noted a 23 % increase in VFI and rumination time on reducing the ambient temperatures from 26°C to 5°C. In another study, increasing ambient temperature from 32°C to 38°C reduced the DMI by $-26 \text{ g} / \text{kg} W^{0.75} / \text{h}$ in *Bos taurus* and corresponded to $-0.06 \text{ g} / \text{kg} W^{0.75} / \text{h}$ in *Bos indicus* for every 1°C increase in ambient temperature (Ahmed and El Amin, 1997). Reduction in intake in *Bos taurus* reduces the body temperature offset heat production.

Increasing the temperature to levels exceeding 40°C had minimal effects on VFI but significantly depressed growth performance of Zebu cattle (Bartha, 1971). In conclusion, 87 % of variation in DM intake in *Bos taurus* was influenced by difference in daily ambient temperatures whereas only 7 % in *Bos indicus*.

2.8 Supplementation effects on rumen pH, NH₃-N and microbial growth

Digestion in ruminants can be maximized through creation of a favourable rumen microbial ecosystem. This is achieved by steady supply of energy, nitrogen and minerals including sulphur for growth of rumen microbes and maintenance of pH (Ørskov, 1982).

Normally, H ions in the rumen move as free acids towards the blood side while rumen urea, phosphate and bicarbonate ions secreted in saliva flows in reverse direction (Van Soest, 1982; McDonald et al., 1988). These stabilize the rumen pH within 6.2 – 7.0, indicated as optimum for cellulolytic growth (Ørskov, 1982). Work done has shown that supplementation of rice straw with 30 g / kg DM of *L. leucocephala*, *G. sepium* or *T. diversifolia* had no effect on rumen pH (Premaratne et al., 1997). Feeding crossbred steers with 15 or 30g / kg DM of *G. sepium* or *L. leucocephala*, increased rumen microbial protein supply without any significant effect on pH (6.72 - 6.99) (Abdulrazak et al., 1997). Addition of carbohydrate (corn) to a diet of Italian rye grass plus Soya bean meal fed to sheep reduced the pH from 6.85 to 6.32 (Islam et al., 2000). This was an indication of enhanced rumen fermentation associated with high starch energy in corn.

Among other factors, the amounts of energy released from rumen organic matter influence microbial growth and nitrogen synthesis. Chikunya et al. (1996) observed significant increase in bacterial counts and microbial nitrogen supply (MNS) on offering molasses sugar beet pulp (SBP) plus 9g N/kg of casein to sheep but not with grass hay plus equal amount of nitrogen. This attribute relates to differences in fibre degradability as slowly degraded fibre (grass) limit carbohydrate digestion compared to fast degraded fibres (SBP). Microbial nitrogen supply increased on adding starch concentrate (maize plus barley starch 0, 15.5 and 31%) to untreated barley straw offered to sheep (Gomes et al., 1994).

Dietary protein provides ammonia nitrogen (NH₃-N), which limit microbial growth if supplied with adequate energy. Levels as high as 100 to 200mg NH₃-N / l has been reported for optimal intake and digestibility of low quality roughage (Perdok et al., 1988), though 50-80mg NH₃-N / l is indicated as minimum for an active rumen fermentation (Satter and Slyter, 1974; Abdulrazak et al., 1997). Mehrez and Ørskov (1977) reported 238 mg NH₃-N / l as optimal for degradation and microbial growth in high-energy diets such as barley.

Despite the high protein content in most browses, rumen $\text{NH}_3\text{-N}$ release varies with degradability, form offered, types and levels of tannin. *S. sesban* and *A. nilotica* fed to sheep promoted more rumen $\text{NH}_3\text{-N}$ release relative to *A. brevispica* and *A. seyal* (Woodward and Reed, 1997; Ebong, 1995). Low $\text{NH}_3\text{-N}$ level in the later browse associated with reduced rumen degradable nitrogen (RDN) resulting from high tannin levels. In an *in-vitro* study, *G. sepium* was found to generate more $\text{NH}_3\text{-N}$ (221.5mg / l) compared to *L. leucocephala* (182.6mg / l), although the later contained relatively more nitrogen (28g / kg DM) than the former 25.5g / kg DM (Richard et al., 1994). This was attributed to faster rate and greater size of ruminally degraded nitrogen fraction in gliricidia compared to *L. leucocephala* resulting in greater proportion of *G. sepium* N being ruminally degraded.

The form in which browse is offered appears to be an important determinant of animals' response. Dry *L. leucocephala* ($p < 0.001$) depressed $\text{NH}_3\text{-N}$ release compared to fresh *L. leucocephala* (Bonsi et al., 1995). It is possible that drying increased tannin content forming complex with plant protein, thus reducing rumen fermentation. Any excess $\text{NH}_3\text{-N}$ is absorbed through the rumen wall and converted into urine urea (Buttery and Lewis, 1982). This route of ammonia wastage can be avoided by adequate supply of fermentable carbohydrates.

2.9 Supplementation effects on live weight gain

Supplementation aims at sustaining or maximizing weight gain by improving or maintaining utilization of the lesser expensive, low quality roughages. Supplementation of poor quality roughages requires steady ruminal energy supply, proper nitrogen / energy ratio or their synchronization for optimum microbial growth. The effect of legume browse on animal's weight gain depends on the quantity and quality of forage supplements, form of offering, quality and quantity of the basal feed. Devendra (1987) and Kaitho (1997) recommended that when used as supplements, browse and shrubs should constitute 30 – 50 % of total ration on DM basis for normal growth.

Work done on *Acacia tortilis* pods indicates that 0.5kg DM/d was adequate to convert weight loss of -78g / d to a gain of 40g / d in calves fed *Cenchrus ciliaris* hay (Coppock, 1993). Premaratne et al. (1998) noted that 13g / kg $W^{0.75}$ of *L. leucocephala*, *G. sepium* or *T. diversifolia* was adequate in converting a weight loss of -1.7 in sheep fed rice straw plus 9g DM / kg $W^{0.75}$ of cassava to a gain of 5.4g / kg $W^{0.75}$. Moreover, addition of 0, 100, 200 g/d of *L. leucocephala* increased weight gain of goats feeding on natural pasture by 3, 9 and 10 g / d over the unsupplemented goats (Mtenga and Shoo, 1990).

Addition of a by-product source of energy to diet containing tree legumes improves animal performance at a lower cost (Richard et al., 1994). Ondiek et al. (1999) reported a case where goats fed Rhodes grass hay supplemented with 120g of *G. sepium* / maize bran (1:1) per day gained 26g / d more than those supplemented with *G. sepium* alone. This was ascribed to synchronization of fermentable energy with degradable nitrogen enhancing microbial growth and animals' growth rate (Sinclair et al., 1995).

Table 3 summarizes results of experiments carried out by various to investigate the effects of supplementing low quality roughages with *G. sepium*, *L. leucocephala*, *L. pallida*, *P. cineraria* and *S. sesban* or mixtures of *L. leucocephala* / *Calliandra* and *G. sepium* / *L. leucocephala* for goats, sheep and steers. Generally, supplementation with forage legumes improved the intakes and animals' weight gains. Higher dry matter intakes and weight gains were also realised on supplementing with forage mixtures as opposed to single forages.

Table 3 Effects of legumes on dry matter intake and weight gains

Basal feed	Animal species	Supplement	Total Intake g/d	LWG	Source
Maize husks	Goats	<i>Leuceana/Calliandra</i> (1:1)	317	22.6	1
	”	<i>Calliandra</i>	315	19	”
Rice straw	Goats	<i>P. cineraria</i>	407.5	-4.40	2
	”	<i>Leuceana</i>	459.3	-4.40	”
Ricestraw (UT)	Sheep	-	445.4	19.3	3
	”	<i>Leuceana</i>	525	34.6	”
Maize stover	Goats	<i>Gliricidia</i>	490.6	33.9	”
	”	<i>L. pallida</i>	385.7	41.3	4
	”	<i>Calliandra</i>	365.0	42.0	”
Maize stover	Steers	-	2300	81	5
	”	<i>Gliricidia</i>	4100	355	”
	”	<i>Leuceana</i>	4300	396	”
Teff straw	Sheep	-	536	-17.5	6
	”	<i>Leuceana</i>	703	43.8	”
	”	<i>S. sesban</i>	742	39.9	”

UT – Untreated stover

Source: 1; Phiri et al. (1992) 2; Dutta et al. (1999) 3; Orden et al. (2000)
 4; Nherera et al. (1998) 5; Abdulrazak et al. (1997) 6; Kaitho (1997)

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was conducted at Naivasha Sheep and Goats Station, in Nakuru district, located at the floor of Rift Valley Province of Kenya. The station lies at latitude of $0^{\circ} 43'S - 36^{\circ} 25'E$ and an altitude of 1905 to 2012 metres above the sea level, falling under ecological zone IV (ASAL). The work was carried out between April and November 2002, and mean rainfall and daily temperatures ranged between 66.4 mm, 82.0 mm and $27.3^{\circ}C, 28.6^{\circ}C$ respectively.

3.1 Experiment one: Effects of single or mixed *Acacia tortilis* components (pods and leaves) on growth performance of SEAG

3.1.1 Objective

To investigate the effects of supplementing Rhodes grass hay with single or mixed *Acacia tortilis* components (pods and leaves) on voluntary feed intake (VFI), diet digestibility, nitrogen balance, ammonia nitrogen (NH_3-N), pH and growth performance of SEAG.

3.1.2 Experimental diets

Six experimental diets were formulated to contain (1) Rhodes grass hay (Control) or Control supplemented with (2) 19g Pods - P, (3) 19g leaves - L (4) 9.5P + 9.5L - PL (5) 14g P + 5g L - PPL or (6) 5g P + 14g L - PLL DM/kgW^{0.75}. Amount of supplements offered was designed to supply 4.3g N/d. Daily intake of all the supplements plus 0.4kg of hay offered would supply 8.9g N/d, sufficient to meet the dietary N requirements (8.3 - 13.3g N) for maintenance of goat (NRC, 1981). These values were expressed in metabolic body weight, which is more appropriate as opposed to live weight in comparing values for animals of different sizes. Hay was purchased from local farm in Naivasha (Nakuru district) and chopped to a length of about 4 - 6cm using a chaff cutter to minimize wastage and selection. Leaves and pods were harvested from Chemeron, Egerton University field station in Baringo district. Harvesting of leaves was done manually by pruning the lower branches and air-drying under shade for three (3) days before removal of leaflets. Pods were harvested dry using hooked sticks and milled to pass through a 6-mm screen. The collected leaflets and resulting pods meal were stored in gunny bags for later use in the experiment.

3.1.3 Experimental animals and design

Twenty-four Small East African goats (SEAG) aged 9 months (270 ± 5 days) with mean initial weight of 18 ± 4 kg were used. Animals were dewormed and sprayed with Nilzan plus® and Triatix® at the start of the experiment to control both the external and internal parasites. They were sorted into six similar groups of four animals each (minimum number for reliable statistic results) based on live weight. They were later confined individually in well-ventilated pens measuring 1.5m x 2m x 1.5m with timber slatted floors and allocated to above-mentioned treatment diets in a complete randomised design (CRD). The experimental lasted for 63 days with 7-day adaptation period and 56-day of data collection.

3.1.4 Experimental procedure and measurements

Hay was offered *ad libitum* (08.30h and 14.30h) allowing for 15 – 20 % feed refusals (DM basis). Supplements were thoroughly mixed and offered in plastic containers twice per day (08.00h and 14.00h) and amounts adjusted weekly based on animal's live weight. The refusals (hay and supplements) from individual pens were separately weighed following morning before fresh feeds were offered. Daily intake was computed as the difference between the amount offered and refusals. Feeds were sampled and bulked for chemical analysis fortnightly while animal weighing was on weekly base before morning feeds. Clean drinking water and multi-mineral mix (Maclik plus: NaCl, 27; Ca-15.4; P-6.5; Mg-1.5; Fe-0.4; Cu-0.1; S-0.3; Mn-0.2; Zn-0.3; Co-0.02; I-0.01; Se-0.0005; Mo-0.0002) were provided free choice to all goats during the entire feeding period.

3.1.5 Digestibility and N-balance trial

On completion of the feeding trial, three intact bucks were randomly selected from each treatment diet and used in the study of apparent dry matter, organic matter and fibre digestibilities and nitrogen balance. The bucks were individually housed in metabolic cages that allowed for separate collection of total faecal and urine production. Animals were maintained on same treatment diets used during the feeding trial, though the supplements were offered once (08.00h) for proper monitoring of diets effects on rumen pH and $\text{NH}_3\text{-N}$ with changing time. However, the basal diet (hay) was offered twice (08.30h and 14.00h) per day. Faecal and urine samples were collected in separate plastic buckets with urine buckets containing 75ml of 10% H_2SO_4 . Total daily (24h) faecal and urine production were recorded and a 10% aliquot of each collected daily. Daily faecal samples from individual animals were oven dried at 60°C for 48h for easier storage. Collected samples were milled to pass through

2 mm screen and stored in polythene bags while urine samples were stored in plastic containers and frozen at -20°C pending analysis. The trial lasted for 12 days, with five-day cage adaptation phase followed by a 7-day collection phase. Nutrients digestibilities were estimated from the difference between nutrient intake and faecal nutrient output divided by nutrients intake (Digestible nutrients divided by nutrients intake). Nitrogen balance was calculated from the difference between total nitrogen intake and total nitrogen output.

$$\text{Nitrogen balance} = \text{Total nitrogen intake} - (\text{faecal nitrogen} + \text{urine nitrogen})$$

3.1.6 Rumen pH and ammonia-nitrogen ($\text{NH}_3\text{-N}$)

Rumen liquor samples were taken from individual animals using a stomach tube and a vacuum pump in the last two days of digestibility trial. Sampling was done at 0, 3, 6, 9, and 12 h after offering the supplements. Forty millilitres of the liquor samples were taken and the pH immediately determined using an ionisable pH meter. The samples were later strained through a clean double layer of cheesecloth and sub-samples of 20ml of liquor fractions taken, acidified with 2mls of 10% H_2SO_4 and frozen at -20°C for $\text{NH}_3\text{-N}$ analysis.

3.1.7 *In-vitro* gas production

In-vitro organic matter digestibility of the treatment diets was assessed by use of gas production technique (Menke and Steingass, 1988). Rumen fluid (liquor) was collected from rumen of two fistulated Friesian steers fed *ad libitum* Rhodes grass hay, 4 kg concentrate, molasses and mineral mix with free access to clean drinking water. The liquor was collected using hand-pump and strained through double layer cheesecloth. Rumen buffer mixture was prepared using 4g of sodium bicarbonate and 35g of ammonium bicarbonate per 100ml and mixed with the rumen liquor. A 200 ± 5.0 mg of air-dried, ground (1.0mm) samples were then weighed in duplicates and put into 100ml calibrated glass syringes, whose pistons were lubricated with Vaseline petroleum jelly to ease their movement and prevent gas escape. The syringes were pre-warmed in a water bath at 38.5°C for 1hr and 30 ± 0.1 ml of rumen-buffer mixture added to each syringe. They were incubated together with two blanks (rumen-buffer mixture without sample) in the water bath set at $38.5 \pm 0.5^{\circ}\text{C}$. The readings of syringes were recorded at 0, 3, 6, 12, 24, 48, 72, and 96h of incubation.

Gas production was calculated as the difference between the volume recorded in sampled syringes and volume in blank syringes. Mean gas values were fitted in the exponential equation: $P = a + b(1 - e^{-ct})$ of Ørskov and McDonald, (1979), where P was the gas

produced at time t , $(a+b)$ are the potential gas production and c the rate of gas production. *In-vitro* organic matter digestibility (OMD) at 48hrs was calculated from the equation: $\text{OMD g/kg DM} = 185.3 + 9.239\text{GP} + 0.540\text{CP}$ (Menke and Steingass, 1988), where GP= gas production (ml/200mg), CP = Crude protein g/kg DM.

3.1.8 *In-sacco* degradability

All the feed samples were air dried at 60°C for 48h and milled to pass through a 2.5-mm screen. Five grams of each sample were weighed in duplicates into nylon bags (140mm x 75mm, pore size 40-60µm). The weights of bags with samples were recorded and incubated in the rumen of two fistulated Friesian steers on grass hay, concentrate, molasses, mineral mix and had free access to clean drinking water. The feed samples were incubated in Steers rather than in goats, as the aim was to evaluate the quality of feeds offered based on rumen microbial activity. Moreover, rumen fermentation, thus ruminal microbial activity actually depends on the diet consumed and not the animal species. Bags were withdrawn at an interval of 3, 6, 12, 24, 48, 72 and 96 h after incubation and 0-hour measurement was obtained by soaking duplicate bags of each sample in warm water at 38.5°C for 1h. Immediately after withdrawal, the bags were hand washed in cold running tap water till the water coming out was clean. The washed bags with the residues were oven-dried at 60°C for 48h, cooled in a desiccator and finally weighed to determine the DM disappearance, which was fitted in the model $Y = a + b(1 - e^{-ct})$ of McDonald (1981). The degradation curve was described as a lag time T , where $Y=A$ (initial washing loss beyond the time T ; a , b and c in the model were degradation constants. The effective degradability was calculated using Ørskov and McDonald, (1979) equation: $\text{ED} = (a+b) c/(c+k) e^{-ct}$ where k was the estimated rumen outflow rate, and a , b and c as described above.

3.1.9 Chemical analysis

Chemical compositions of collected samples were determined at Egerton University, Animal Science laboratory. Rhodes grass hay, supplements and faecal samples were milled to pass through a 1mm screen before analysis. Dry matter (DM) was determined by oven drying the samples at 105°C for 24 h, organic matter by ashing the samples in a muffle furnace at 550°C for 4h and nitrogen by micro-Kjeldah digestion (CP calculated as $\text{N} \times 6.25$). All these procedures were done according to the method of (AOAC, 1990). Neutral detergent fibre (NDF) and ADF were determined as described by Van Soest et al. (1991). Rumen liquor was thawed and analysed for $\text{NH}_3\text{-N}$ as described by Abdulrazak and Fujihara (1999).

3.1.10 Statistical analysis

Intakes and average daily gain means were subjected to analysis of covariance (ANCOVA). Initial live weights were used as covariate to control the wide variation in body weights. Ammonia nitrogen (NH₃-N), pH and digestibility were analysed using one-way analysis (ANOVA) of the General Linear Model (GLM) procedure of statistical analysis system package (SAS, 2000). Separation of means was done using Duncan New multiple range test (Steel and Torrie, 1980).

Models: ANCOVA; $Y_{ij} = \mu + t_i + \beta(X_{ij} - x_{ij}) + e_{ij}$

ANOVA; $Y_{ij} = \mu + t_i + e_{ij}$

Y_{ij} – Observation due to i^{th} treatment and j^{th} animal

μ - Overall mean

t_i – Effect due to i^{th} treatment

β - Linear regression coefficient of Y_{ij} and X_{ij}

X_{ij} – Measurement of covariant corresponding to X_{ij}

x_{ij} – Mean of X_{ij}

e_{ij} – Random error component

3.2 Experiment two: Effects of supplementing Rhodes grass hay plus *Acacia tortilis* components with different levels of maize bran on VFI and growth performance of SEAG

3.2.1 Objective

To examine the effects of different levels of maize bran (fast degraded source of energy) on VFI, diet digestibility, N- balance, $\text{NH}_3\text{-N}$, pH and growth performance of SEAG.

3.2.2 Experimental diets

Five experimental diets were computed to contain (1) Rhodes grass hay plus leaves / pods (1:1) (MB0) or MB0 supplemented with (2) 3g MB1, (3) 6g MB2, (4) 9g MB3 or (5) 12g MB4 DM maize bran / $\text{kgW}^{0.75}$. All the animals received 140g /d of LP (1:1), enough to ensure that protein was not limiting. Preparation for Rhodes grass hay and leaves / pods (1:1) was carried out as described under experimental diets in previous experiment. Maize bran was purchased from a local posho mill in Naivasha town.

3.2.3 Animals and experimental design

Twenty (20) SEAG with mean initial body weight of $19 \pm 0.6\text{kg}$, 12 months (360 ± 5 days) old were used. All were dewormed with Nilzan plus® one week before the trial commenced and thereafter on monthly intervals. Spraying was done weekly with Triatix® to control the external parasites. The animals were sorted into five similar groups of four animals each based on live weight. They were individually confined in same pens used in experiment one, allocated to above-mentioned diets in a complete randomised design (CRD). The trial lasted for a period of 63 days, which comprised of 7-day for adaptation and 56-day for data collection.

3.2.4 Experimental procedures and measurements

Pods and leaves (1:1) plus maize bran were thoroughly mixed and fed at 08.00 and 14.00h. Hay was offered *ad libitum* (at 8.30h and 14.30h) allowing a proportional refusal of 0.20 of the amount offered. Refusals were collected from individual pens and separately weighed the following morning before fresh feeds were offered. The collected data was used in computing daily feed intake. Clean drinking water and multi-mineral mix (composition indicated in experiment one) were provided free choice to goats during the entire feeding trial. Representative samples of feed offered were hand picked fortnightly, bulked and sub-

sampled for dry matter and chemical analysis. Animals were weighed weekly before morning feed, individual weights recorded and used in calculating amount of *Acacia tortilis* and maize bran offered in subsequent week.

The rest of the procedures including *in-sacco* degradability, *in-vitro* gas production, chemical and statistical analysis were conducted as described under the previous experiment.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Experiment one

4.1.1.1 Proximate analysis of hay and *Acacia tortilis* components

Chemical composition of feeds offered is shown in Table 4. All samples were analysed in duplicates and results presented as means. However, means were not statistically analysed as the samples were few to give reliable information. Nevertheless, this did not affect the findings of the study since the data was mainly used in computing nutrients intake and output by animals. It was noted from the results that Rhodes grass hay contained 718 g/kg DM and pods 357 g/kg DM, the highest and lowest NDF content respectively. The amounts of CP in supplements were more than twice that in hay. The NDF content in leaves decreased while its CP value slightly increased on mixing with pods. However, the high ash value in leaves was a reflection of low organic matter. Generally, the low CP and high NDF of Rhodes grass hay indicates its low nutritive value.

Table 4 Proximate analysis of hay and *Acacia tortilis* components

Feed	DM	Ash	CP	ADF	NDF	ME
	g/kg	g/kg DM				MJ/kgDM
Hay	946.8	103.2	71.6	226	718.3	11.46
Pods	915.1	56.8	162.1	290	356.5	10.52
Leaves	934.2	106.3	164.7	275	449.5	10.74
PL	922.4	79.8	163.7	286	402.8	10.58
PPL	914.3	64.8	165.9	292	379.8	10.49
PLL	926.7	90.5	167.8	281	426.3	10.65

PL – Pods + Leaves, PPL – 3/4 Pods + 1/4 Leaves, PLL – 1/4 Pods + 3/4 Leaves

4.1.1.2 Diets effects on intakes, diet digestibility and average daily gain (ADG)

Means of DM, ME and CP intakes, diet digestibility and ADG are shown in Table 5. Leaves were most fibrous in respect to NDF leading to reduced palatability, hence its low intake. On average, the control group consumed 591g DM/d of hay. However, this was ($p < 0.05$) depressed on supplementing with pods but not with rest of the supplements. Supplementation ($p < 0.05$) increased total dry matter intake (TDMI).

Inclusion of browse had no ($p > 0.05$) effect on DM and NDF digestibility though the later was lowest (598 g/kg DM) in pods supplemented group. Organic matter digestibility (OMD) was similar across the diets except for leaves supplemented where it was ($p < 0.05$) depressed. General increase in weight gain was realised in all the groups, with control group recording the lowest gain. Moreover, the gains were ($p < 0.01$) higher in P, PL, and PPL supplemented groups. The groups supplemented with mixed browse components were noted to gain slightly more weight than those supplemented with corresponding single components. The general trend for average weekly weight gains for entire feeding trial is shown in Figure 1.0.

Table 5 Effects of supplementing with single or mixed *Acacia tortilis* components on mean intakes, diet digestibility and ADG

DMI (g / d)	DIET						SEM
	H	P	L	P L	PPL	PLL	
Hay	591 ^a	483 ^b	579 ^a	558 ^a	531 ^{ab}	557 ^a	11.06
Supplements	-	233	187	226	235	224	-
Total	591 ^b	716 ^a	766 ^a	784 ^a	766 ^a	781 ^a	11.17
ME (MJ/kgDM) intake (suppl)	-	2.5	2.0	2.4	2.5	2.4	-
ME (MJ/kg DM) intake	6.8	8.0	8.6	8.8	8.5	8.8	-
CP intake g/d	4.0	7.4	7.6	7.8	7.5	7.6	-
Digestibility							
DM (g/kg)	560 ^a	576 ^a	575 ^a	603 ^a	611 ^a	579 ^a	1.05
OM (g /kg DM)	759 ^a	736 ^{ab}	690 ^b	755 ^a	739 ^{ab}	722 ^{ab}	1.19
NDF (g /kg DM)	644 ^a	598 ^a	620 ^a	636 ^a	636 ^a	613 ^a	1.28
N (g/kg DM)	388	424	389	424	464	394	-
ADG (g / d)	14.5 ^b	33.1 ^a	27.1 ^{ab}	38.1 ^a	33.9 ^a	32.8 ^{ab}	3.58

*^{a,b} Means on the same row with different superscript are significantly different

*SEM- Standard error of the mean

Suppl. - Supplements

4.1.1.3 Effects of supplementing with *Acacia tortilis* components on rumen pH, NH₃-N and N-balance

Table 6 presents means of rumen pH, NH₃-N and N-balance are shown in. From the results, the pH values ranged from 7.10 to 6.92 with means of 6.99 and 7.10 for supplemented and control groups respectively. The values were ($p < 0.05$) lower in PLL supplemented group. NH₃-N concentrations ranged from 126 to 167mg/l for the control and supplemented groups respectively and were insignificant across the diets.

Supplementation ($p < 0.05$) increased total nitrogen intake (TNI) and faecal nitrogen loss (FN) but the effect on urinary nitrogen (UN) loss was insignificant. FN as a fraction of total nitrogen intake (TNI) tended to decline with decreasing proportion of leaves in the mixture, with L and PLL registering the highest (61.2 % and 60.3 %) values. UN as a fraction of TNI was higher in the control group whereas nitrogen retention (NR) was ($p < 0.05$) higher in PL supplemented group. The percent nitrogen retained as a fraction of TNI increased on mixing the components with PPL and PL with the highest respective values.

Table 6 Effects of supplementing with *Acacia tortilis* components on rumen pH, NH₃-N and N-balance

Parameters	DIET						SEM
	H	P	L	PL	PPL	PLL	
Rumen pH	7.10 ^a	6.98 ^{ab}	7.04 ^{ab}	7.03 ^{ab}	6.98 ^{ab}	6.92 ^b	0.04
NH ₃ -N (mg/l)	126 ^a	167 ^a	136 ^a	142 ^a	146 ^a	150 ^a	7.82
<i>Nitrogen balance (g/d)</i>							
TNI	6.4 ^b	11.80 ^a	12.10 ^a	12.50 ^a	11.20 ^a	12.10 ^a	0.74
FN	3.7 ^b	6.8 ^a	7.4 ^a	7.2 ^a	6.0 ^{ab}	7.3 ^a	0.51
UN	1.15 ^a	1.59 ^a	1.60 ^a	1.55 ^a	1.53 ^a	1.62 ^a	0.23
NR	1.55 ^b	3.35 ^{ab}	3.17 ^{ab}	3.76 ^a	3.69 ^{ab}	3.22 ^{ab}	0.50
<i>% of TNI</i>							
FN	57.8	57.6	61.2	57.6	53.6	60.3	-
UN	18.0	13.5	13.2	12.4	13.7	13.4	-
NR	24.2	28.4	26.2	30.1	32.9	26.6	-

*^{a, b} Means on the same row with different superscript are significantly different

SEM- Standard error of the mean

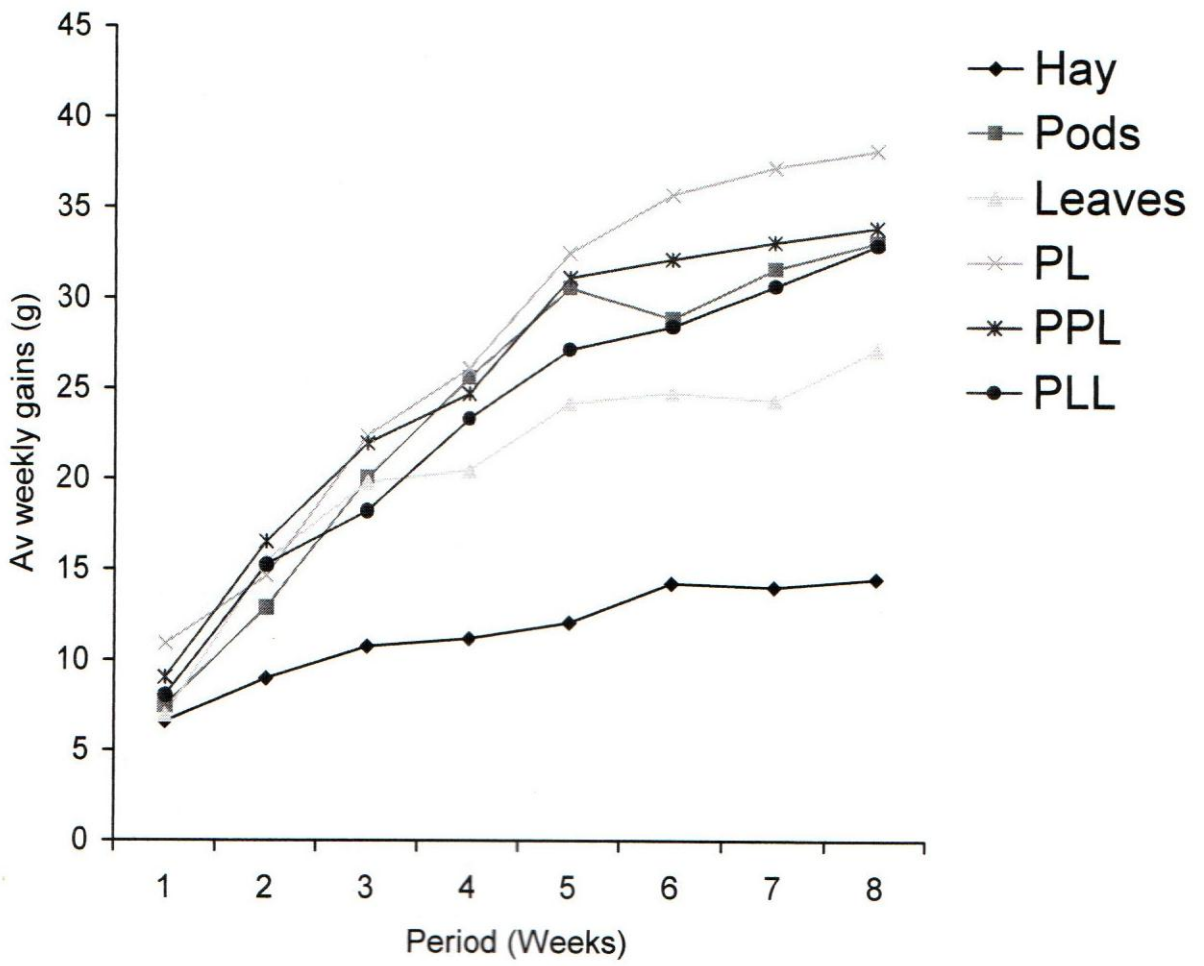


Fig 1 Average weekly weight gains for SEAG fed Rhodes grass hay supplemented with single and mixed *Acacia tortilis* (pods and leaves) components

4.1.1.4 In-sacco degradability and In-vitro gas production of hay, single and mixed

Acacia tortilis components

Table 7 presents the dry matter (DM) degradation characteristics of feeds offered during the trial. Degradability of *A* soluble fractions varied from 225 to 410 g/kg DM. Lowest degradation rate 'c' (0.025 %/h) was noted with Rhodes grass hay followed by 0.032 %/h for L and PLL diets. Pods were degraded fastest (0.041 %/h) with an *A* fraction of 410 g/kg DM. The potential (*A+B*) and effective degradability of the feeds varied from 715 to 803 and 385 to 559 g/kg DM respectively. On descending order, the feeds could be ranked as P > PL > PPL > PLL > H > L based on potential degradability (PD). However, hay and leaves had the highest *B* fractions of 508 and 477 g/kg DM respectively.

Table 7 *In sacco* DM degradation characteristics of hay and *Acacia tortilis* components

DIET	Total degradation (g/kg DM)		Degradability parameters					ED k=0.05	RSD
	24hrs	48hrs	A	B	A+B	c (%/h)			
							(g/kg DM)		
H	469	573	225	508	733	0.025	385	1.42	
P	653	700	410	393	803	0.041	559	2.50	
L	509	583	238	477	715	0.032	402	2.37	
PL	614	671	345	450	795	0.035	508	2.47	
PPL	609	665	304	477	781	0.038	512	2.87	
PLL	547	655	289	457	746	0.032	484	2.38	

A – Highly degraded, B – slowly degraded, (A+B) – potential degradability

c – Rate of degradation, ED – effective degradability

Mean volume of gas produced is presented in Table 8. Organic matter digestibility (OMD) calculated from gas produced at 48h was highest in pods and lowest in hay respectively. Gas production, *in-vitro* OM digestibility and DM degradation values of mixtures were moderate and within values of corresponding individual single components.

Table 8 *In-vitro* gas production of hay and *Acacia tortilis* components

DIET	Gas production at (ml/ 200mg DM)		(a + b) ml	c (% / h)	OMD g/kg DM (48h)
	24h	48h			
H	26.3	28.4	65.0	0.013	486
P	41.6	54.9	68.0	0.044	780
L	24.9	34.7	41.2	0.040	595
PL	32.7	42.7	52.4	0.042	668
PPL	34.8	45.2	56.1	0.042	692
PLL	27.3	39.1	47.6	0.041	637

a b c – are constants in the equation (Ørskov and McDonald, 1979)

OMD (48h) g/kg DM= 185.3 + 9.239GP + 0.540CP (Menke and Steingass, 1988)

ME (MJ/kg DM) = 14.78 – 0.0147 ADF (Menke and Steingass, 1988)

a – Intercept of gas production curve, b– Asymptote of gas production curve $b(1 - e^{-ct})$,

(a + b) – Potential of gas production, c – rate of gas production, OMD – organic matter digestibility

4.1.2 Experiment two

4.1.2.1 Proximate analysis of hay, maize bran and *Acacia tortilis* components

All animals remained health and in good body condition during the entire feeding trial. Chemical compositions of feed offered are shown in Table 9. Mean DM content of hay, maize bran, pods and leaves were 903, 883, 884 and 903g/kg DM respectively and their respective CP contents were 65, 109, 145 and 152g/kg DM. Mean NDF was lowest in pods and highest in hay. Maize bran recorded the highest organic matter as reflected by its low ash content.

Table 9 Chemical composition of hay, maize bran and *Acacia tortilis* components

	DM	CP	Ash	ADF	NDF	ME
Feed	g /kg	g/kg DM				MJ/kg DM
Hay	903.1	65.4	112.3	225.0	718.0	11.5
Maize bran	883.0	109.3	37.9	85.0	382.8	13.5
Pods	884.2	145.3	57.1	241.0	309.8	11.2
Leaves	902.7	152.0	149.4	314.1	452.6	10.2
PL	896.7	149.7	113.9	278.0	401.0	10.7

4.1.2.2 Effects of different levels of maize bran on intakes, nutrients digestibility and ADG

Means of DM, DOM, ME and CP intakes, diet digestibility and average daily gains are shown in Table 10. Control group (MBO) had the highest (12g DM/d) supplement refusal, thus less consumption of the same. Supplementing with bran partially depressed hay DM intake. Nevertheless, total DM intake improved on inclusion of maize bran and was ($p<0.05$) higher at levels above 9g DM/kgW^{0.75} (MB2). Similar trend was noted with DOM intake, though the values were significantly higher for all supplemented groups. MBO group consumed the least and MB4 group the highest amount of DOM and the later was ($p<0.05$) higher in comparison to rest of the groups.

Dry matter (DM), organic matter (OM) and neutral detergent fibre (NDF) digestibilities improved at each level of maize bran. Moreover, all parameters were ($p<0.05$) higher at levels exceeding 9g DM/kg W^{0.75} (MB2). Digestibilities for the control were comparable to group supplemented with least amount of maize bran (MB1). Live weight gains were evident with increasing levels of maize bran and 6, 10, 15 and 22 g/d were recorded with MB1, MB2, MB3 and MB4 in excess of the control group (MB0). Growth rate of 45 g/d observed in MB4 was ($p<0.05$) higher but similar to that of MB3. The trends for average weekly gains during the entire feeding trial are shown on figure 2.0.

Table 10 **Effects of different levels of maize bran on intakes, diet digestibility and ADG**

	DIET					SEM
	MBO	MB1	MB2	MB3	MB4	
DMI (g/d)						
Hay	510 ^a	502 ^a	466 ^a	448 ^a	483 ^a	11.33
<i>Acacia tortilis</i>	128	132	138	138	140	-
Maize Bran	-	35	65	96	120	-
Total	638 ^b	669 ^b	669 ^b	682 ^{ab}	743 ^a	10.12
DOMI (g/d)	365 ^c	408 ^b	413 ^b	435 ^b	488 ^a	6.30
ME (MJ/kg DM)						
intake (Maize Bran)	-	0.47	0.88	1.30	1.62	-
ME intake	7.2	7.6	7.7	7.9	8.2	-
(MJ/kg DM)						
CP intake (g/d)	6.5	7.0	7.1	7.3	7.3	-
Digestibility						
DM (g/kg)	547 ^b	554 ^b	591 ^{ab}	603 ^{ab}	625 ^a	1.10
OM (g/kg DM)	635 ^c	672 ^{bc}	677 ^b	699 ^{ab}	719 ^a	0.71
NDF (g/kg DM)	529 ^c	545 ^{bc}	574 ^{ab}	579 ^{ab}	592 ^a	0.86
N (g/kg DM)	599	609	648	630	638	-
ADG (g/d)	23 ^c	29 ^{bc}	33 ^{bc}	38 ^{ab}	45 ^a	1.68

a,b,c Means on the same row with different superscript are significantly different

SEM- Standard error of the mean

4.1.2.3 Diets effects on rumen pH, NH₃-N and N-balance

Means of rumen pH, NH₃-N and N-balance are presented in Table 11. The pH and NH₃-N values are means for all values taken at different time intervals. Partial decline in pH (7.14 to 6.98) was observed on inclusion of maize bran, though the values were similar across the treatments. NH₃-N concentrations increased from 116 to 159 mg/l on supplementing with maize bran, with an average of 142 mg/l for supplemented groups. Supplementation had no ($p > 0.05$) effect on nitrogen intake, thus urinary nitrogen, faecal nitrogen and nitrogen retention remained similar across the diets. However, there was tendency for nitrogen retained to improve with increasing maize bran, with MB4 and MB0 groups recording the highest and lowest respective values.

Table 11 Effects of different levels of maize bran on rumen pH, NH₃-N and N-balance

Parameters	DIET					SEM
	MBO	MB1	MB2	MB3	MB4	
Rumen pH	7.14 ^a	7.02 ^a	7.03 ^a	6.96 ^a	6.92 ^a	0.04
NH ₃ -N (mg/l)	116 ^b	119 ^b	142 ^{ab}	147 ^{ab}	159 ^a	5.82
<i>Nitrogen balance (g/d)</i>						
TNI	10.4 ^a	11.2 ^a	11.3 ^a	11.7 ^a	11.6 ^a	0.27
FN	4.17 ^a	4.38 ^a	3.98 ^a	4.33 ^a	4.20 ^a	0.18
UN	1.84 ^a	2.10 ^a	2.30 ^a	2.40 ^a	1.80 ^a	0.25
TNL	6.01 ^a	6.49 ^a	6.28 ^a	6.74 ^a	6.00 ^a	0.28
NR	4.34 ^a	4.68 ^a	5.06 ^a	4.91 ^a	5.63 ^a	0.32

^{abc} Means on the same row with different superscript are significantly different

SEM- Standard error of the mean

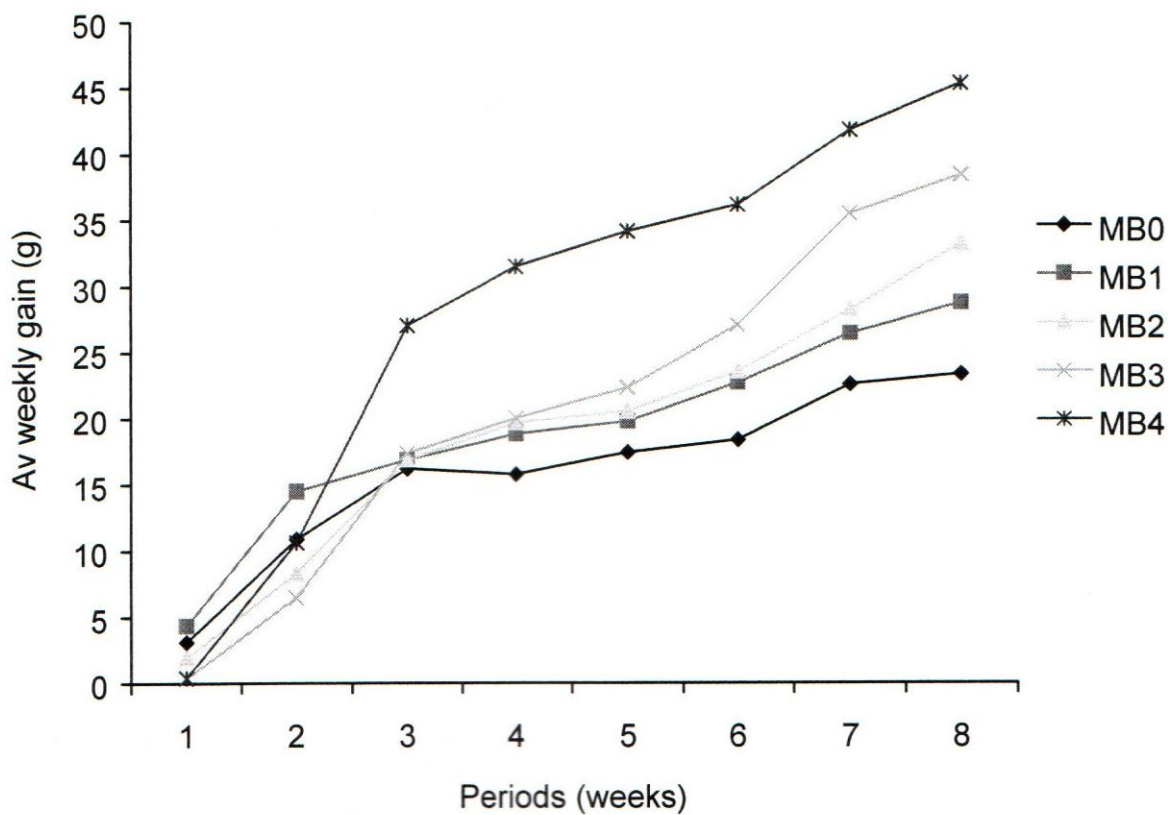


Fig 2 Average weekly weight gains for goats fed Rhodes grass hay plus *Acacia tortilis* supplemented with different levels of maize bran

Table 12 *In sacco* DM degradation characteristics of different levels of maize bran

DIET	Total degradation (g/kg DM)		Degradability parameters					
	24hrs	48hrs	A	B	A+B	c	ED	RSD
				(g/kg DM)			(%/Hr)	k=0.05
MB0	506	628	287	383	670	0.022	470	1.77
MB1	523	654	290	403	693	0.023	477	2.95
MB2	531	654	300	441	741	0.023	480	2.42
MB3	565	660	321	488	809	0.038	482	2.95
MB4	586	668	328	491	819	0.047	494	2.84

A – Highly degraded, B – slowly degraded, (A+B) – potential degradability

c– Degradation rate, ED – effective degradability

Table 12 presents the dry matter (DM) degradation characteristics of *Acacia tortilis* leaves / pods (1:1) with different levels of maize bran. Amount of DM degraded improved with increasing levels of maize bran. The rate of degradation also enhanced on increasing the levels of maize bran, with MB4 recording the highest 'c' value of 0.047%/h. Similar trend was noted for potential degradability (A+B), degradation rate (c) and effective degradability (ED).

Table 13 present the gas production values for *Acacia tortilis* components (1:1) with increasing levels of maize bran. Total volume of gas produced (a+b), production rate 'c' and *in-vitro* organic matter digestibility (IVOMD) improved with increasing levels of maize bran

Table 13 *In-vitro* gas production (ml / 200mg DM) of different levels of maize bran

DIET	CP g / kg DM	Gas production (ml/200mg)		(a + b) ml	c (% / h)	OMD g/kg DM (48h)
		24h	48h			
MB0	148	29.4	41.8	52.0	0.034	651.0
MB1	150	32.5	46.8	55.9	0.037	699.8
MB2	150	33.9	47.0	56.2	0.038	701.0
MB3	151.3	36.9	52.3	63.4	0.038	750.2
MB4	151.7	38.5	53.9	63.7	0.043	765.2

a,b,c – are constants in the equation (Ørskov and McDonald, 1979)

OMD (48h) g/kg DM= 185.3 + 9.239GP + 0.540CP (Menke and Steingass, 1988),

a – Intercept of gas production curve, b– Asymptote of gas production curve $b(1 - e^{-ct})$,

(a + b) – Potential of gas production, c – rate of gas production

4.2 Discussion

4.2.1 Experiment one

The NDF content of Rhodes grass hay was within the range 705 – 725g /kg DM reported by other workers (Ondiek et al., 1999; Nyangaga, 2001). Its CP was slightly above 70g /kg DM (4g CP/kgW^{0.75}), level indicated as minimum for ruminal microbial activity (Minson, 1981, NRC, 1981). However, The CP of *A. tortilis* leaves was slightly below the range 172 - 181g /kg DM reported in earlier work by Abdulrazak et al. (2000) and Nyangaga (2001) respectively. This variation was partly due to site, variety and stage of maturity at harvesting. The observed CP value of pods was between the range 134 - 207g /kg DM reported in the studies of Shayo et al. (1997) and Coppock (1993). Naturally, the seeds of *Acacia tortilis* are tiny (Tanner et al., 1990) but have more CP compared to empty pods (Shayo et al., 1997). This emphasizes the need of grinding the fruits before feeding to improve utilization efficiency of available nutrients, which would otherwise escape digestion.

Woodward and Reed (1997) established a positive relationship between NDF and proanthocyanidin concentrations in leguminous tree fodder. Higher levels (> 5%) of proanthocyanidin were noted to relate negatively with palatability, thus voluntary feed intake (Mangan, 1988; Kaitho, 1997). *Acacia tortilis* leaves were most fibrous in respect to NDF, contributing to its low acceptability in present trial. It is apparent that improvement in palatability and acceptability of the supplement on mixing the components was more of dilution of fibre levels.

Substitution of hay on supplementation with pods resulted from high supplement intake accompanied by low NDF digestibility. The high amount of pods consumed possibly displaced more of the rumen volume. This may have led to reduction in rumen space for hay intake, as rumen capacity is a determinant of total DM intake. This conform to the findings of Tanner et al. (1990) and Bitende and Ledin (1996) who noted depression in intake of maize stover and grass hay respectively on supplementing with unmilled *Acacia tortilis* pods

Total DM consumed was ($p < 0.05$) higher for supplemented groups compared to the control group. On average, the later group consumed 591g DM/d of hay, equivalent to 3.1% of body weight. Highest DMI for supplemented groups was 784 g DM/d, equivalent to 3.9 % of body weight. These values were within 2.5 - 3.9 %, intake range documented for tropical goats by earlier workers (Devendra and Burns, 1983). Contrary to increase in TDMI on supplementation, contribution by hay either decreased or was insignificant.

Protein supplements had varying effects on nutrient intake in goats. Some of the animals consumed slightly below (40 – 78g CP/kg DM/d) their requirement levels, which range from 52 – 83g CP/kg DM/d (NRC, 1981). Total energy intake found in this study agree with those reported by Mtenga and Shoo (1990), varying from 7.0 to 9.9 MJ/d. Several factors may have contributed to improvement in DMI. Protein status in the rumen is postulated to be an important limitation to forage intake (Kempton et al., 1978). This suggests enhanced digesta outflow rate from additional nitrogen supply from browse, stimulating the intake. Another possibility for increase in DMI was substitution of hay especially with pods supplemented group. Browsers provide some by-pass protein, improving amino acids supply to the small intestines whose uptake elicits higher consumption (Oosting et al., 1995; Premaratne et al., 1998). Dilution of leaves fibre level when mixed with pods improved diet palatability and may be responsible for the relatively higher DMI in groups on mixed compared to single browse components. Similar responses have been reported in other studies on supplementing poor quality roughage with single (Mtenga and Shoo, 1990; Shayo et al., 1997) or mixed (Le Houerou, 1991; Bosman et al., 1995) legume forage.

Variations in OMD observed with supplemented groups reflect the differences in NDF levels of. Presence of high NDF levels in leguminous browse interferences with true availability of organic matter and this negatively affects OMD of feeds (Dutta et al., 1999). This explains the depression effects noted with OMD in leaves supplemented group.

Supplementation with browse had no significant effect on rumen pH and the levels remained within the range 6.2 – 7.0, suggested as optimum for cellulolytic bacterial growth and fibre digestion (Ørskov, 1982). The increase in rumen NH₃-N release on supplementation in the current study indicates enhanced ruminal degradable nitrogen (RDN). Pods were more degraded than leaves and their inclusion in mixtures improved NH₃-N levels for groups supplemented with mixed components in relation to leaves alone. Nevertheless, the concentrations for all the groups remained above 50-80 mg/l, suggested range for active rumen fermentation (Satter and Slyter, 1974; Abdulrazak et al., 1997). The NH₃-N release in the group fed on hay alone was relatively higher than expected from such a diet. Alam et al. (1985) noted that goats increase urea production, hence concentration in their saliva when fed fibrous roughage.

Nitrogen intake and faecal nitrogen loss tended to increase on supplementing with browse, implying additional nitrogen supply in the diet. When expressed as percentage (%) of TNI, faecal nitrogen output from L and PLL groups were relatively higher compared with rest of the groups. Low DM degradability of leaves resulting from high anti-nutritive factor

(NDF) may be responsible for higher N loss in the two diets through formation of indigestible NDF-N complex with dietary nitrogen. Similar responses were observed on supplementing low quality roughage with different types of browses (Kibon and Maina, 1993; Ebong, 1995; Woodward and Reed, 1997). Studies with different tropical legumes have demonstrated that browse enhance nitrogen retention (Nherera et al., 1998; Orden et al., 2000). Amount of nitrogen retained in present trial improved on mixing browse components. This probably resulted from positive associative effects of highly degradable organic matter from pods as indicated by high gas production and *in-vitro* OM digestibility.

The weight gains improved on supplementing with P, L, PL, PPL and PLL, and the animals gained 18.6, 12.6, 23.6, 19.4 and 18.3 g/d respectively in excess of the control group. This demonstrates that hay alone was inadequate to cater for nutrients requirement of growing goats even when availed in abundance.

Protein supplementation improves performance of animals consuming low quality forages through stimulation of voluntary forage intake (Kaitho, 1997). This is an attribute of legumes overcoming the depression effect that low nitrogen has on intake (Minson and Milford, 1967) and providing ruminally degradable nitrogen (Van Eys et al., 1986). Supplemented animals groups consumed more protein and energy intake. These nutrients probably improved ruminal microbial growth and protein synthesis, later digested and absorbed in the lower gut improving the weight gains. Dutta et al. (1999), Nyangaga (2001) and Sawe et al. (1998) noted similar response in studies involving feeding goats and sheep on variety of browses. Individual components in the mixtures contributed differently in consumed nutrient resulting to synchronization of fermentable organic matter and nitrogen in the mixtures. This was responsible for the relatively higher weight gains for mixed in relation to single supplemented groups. This conform with Phiri et al. (1992) who indicated improvement in weight gain on supplementing maize stover fed to goats with mixed forages.

The nutritional value of browse lies in their OM and NDF content that would contribute to the overall feeds' energy content. *In-vitro* organic matter digestibility calculated from gas production shows the potential of feed to supply metabolisable energy. Variation in DM degradation and gas production amongst feeds offered was due to variation in chemical composition. The high organic matter and low NDF present in pods contributed to the high DM degradability and gas production thus greater energy for microbial activity. On the other hand, low OM and high NDF in leaves may have limited rumen microbial growth, hence fermentation indicated by low DM degradability and gas production. Studies conducted with

other browse species (Kaitho, 1997) highlighted negative NDF effects on DM degradability and gas production.

In conclusion, result from this experiment indicate that *Acacia tortilis* components can be used successfully as a nitrogen source for growing goats consuming Rhodes grass hay. However, utilisation of these components should be optimised by mixing them. Present study suggest that supplementing the components at a ratio of 1:1 result in higher DMI and nitrogen retention leading to a more desirable weight gain. Therefore, this treatment was selected to form the base of the objective of experiment two.

4.2.2 Experiment two

The NDF content (718g DM/kg) of hay in this trial was similar to that used in experiment one. Maize bran CP compared well with 103 and 98g /kg DM obtained by Ndemanisho et al. (1995) and Abdulrazak et al. (1997) whereas that of pods was similar to values reported in the previous experiment. Leaves CP and NDF content were slightly deviated from values reported by Abdulrazak et al. (2000). The stage of maturity has been recognized as a major factor affecting chemical composition of browse legumes (Orden et al., 2000). The variation in chemical composition could reflect the age of the vegetative parts (leaves), which was not considered at time harvesting. In the present trial, mixture of pods and leaves (1:1) was included as part of the basal feed to minimize weight loss resulting from nutrients deficient in hay.

Rumen capacity and energy value of a diet are factors most recognized in determining feed intake by ruminants. Contrary to this, past studies, have shown that supplementation of high quality forage (NDF < 50 – 60%) with energy depress fibre digestibility with severe cases reducing the intake (Meissner et al., 1991). The high NDF value of hay in present study reflects advanced age and possibly the cause of insignificant depression effect on hay intake. On average, the animals consumed 482 g/d, which fairly conformed to 468 g/d reported by Ondiek et al. (1999). Total DM intake ranged from 3.0 to 3.2 % of body weight and improved on supplementing with maize bran. The values were within the intake range 2.2 - 4.0% of body weight reported by Mtenga and Shoo (1990). The increase in TDMI was attributed partly to insignificant maize bran effect on hay intake. Meissner et al. (1991) and Gomes et al. (1994) noted similar findings on supplementing low quality grass hay with protein and energy. According to Gomes et al. (1994) and Mawuenyegah et al. (1997), increasing dietary energy improves fractional outflow rates of both the liquid and solid phase with stimulating effect on intake.

The NDF digestibility and corresponding increase in digestible organic matter consumption improved at each inclusion level of MB. This associates with increased DMI in conjunction with enhanced organic nutrients digestibility. The improvement in DM degradability, gas production and *in-vitro* digestibility on inclusion of maize bran resulted from fast degradable nature of it compared to browses. Therefore ruminal energy status improved on adding maize bran resulting to enhanced fermentation, microbial growth and improved digestibility. Similar response has been observed in other studies where corn or starch was added to straw based diets (Mawuenyegah et al., 1997; Islam et al., 2000).

The rumen pH tended to decline on inclusion of maize bran, though the effect was not significant. This could be explained by improvement in rumen fermentation resulting from increased energy intake from maize bran. Nevertheless, the pH values were above 6.3, suggested as lower limit for cellulolysis (Ørskov and Ryle, 1990). According to Cruz Soto et al. (1994), two phases are recognized in the growth of rumen microbes. Energy and $\text{NH}_3\text{-N}$ are the nutrients identified as limiting during the initial and final phase respectively. In the present study, $\text{NH}_3\text{-N}$ concentrations was not limiting as the values were above minimum (50 – 80 mg/l) range for microbial growth and fibre digestion (Abdulrazak et al., 1997). However, $\text{NH}_3\text{-N}$ concentrations higher than this are required to maximize digestion of high-energy diets (Mehrez and Ørskov, 1977). Energy released from maize bran probably synchronized with nitrogen from *Acacia tortilis*, creating a favourable rumen environment for increased microbial activity and $\text{NH}_3\text{-N}$ release.

Nitrogen retention was ($p>0.05$) across the diets and lowest in control group. Ruminal energy supply from maize bran could have enhanced nitrogen utilization efficiency resulting to the insignificant effect. However, higher faecal nitrogen loss in supplemented groups associates with enhanced feed intake that was expected to increase digesta passage rate.

Rumen microbial growth is a function of fermentable organic matter in the rumen and highly degradable feeds supplies more organic matter thus more microbial yield and protein flow (Chikunya et al., 1996). The groups supplemented with maize bran consumed more DOM, which translated to greater energy supply. This improved ruminal protein / energy ratio for microbial growth and nitrogen flow to the small intestine, hence enhancing the weight gain (Sinclair et al., 1995).

In conclusion, the results indicated that total intake and weight gain could significantly improve on supplementing Rhodes grass hay plus pods and leaves (1:1) with maize bran at levels above $9\text{g DM/ kg W}^{0.75}$.

4.2.3 General discussion

Tropical livestock solely depends on low quality pasture and crops residues for dry season feeding. The materials are almost devoid of critical digestible nutrients required for efficient rumen microbial ecosystem to effectively utilize poor quality feeds, thus sustenance of high animal production levels (Preston and Leng, 1987). Supplementation with materials adequate in nitrogen, energy and minerals can be used to rectify this problem.

Most leguminous browse forages including *Acacia tortilis* are rich in protein and minerals (Sawe et al., 1998). In addition, they are drought tolerant, high yielders, supply rumen by-pass protein and could be used to enhance utilization of fibrous roughage by ruminants. However, they are rarely used as sole animal feeds due to wide variation in their chemical composition particularly the anti-quality factors as affected by stage of maturity and part harvested. Simple management practices including use of forage mixtures (Devendra, 1990) or addition of energy can improve nutritive value of these forages.

4.2.3.1 Effects of supplements on dry matter intake

Forage intake in ruminant is a function of fibre digestion and outflow rate (Waldo et al., 1972), both influenced by ruminal nitrogen and energy supply (Mawuenyegah et al., 1997). Palatability is as well important in determining browse intake, though it has been noted to relate negatively with amount of NDF (Kaitho, 1997; Woodward and Reed, 1997). In present study, animals offered supplement with high amount of leaves encountered some palatability problem as reflected by low intake of the supplement (Table 5.0). The decline in supplements refusals on mixing the browse components indicates improvement in palatability. This probably resulted from dilution of leaves' fibre levels.

Substitution of hay was evident in animals supplemented with pods, which may be an effect of levels of DM intake from the supplements. Tanner et al. (1990) and Abdulrazak et al. (1997) reported similar responses on supplementing maize stover with higher levels of *A. tortilis* pods and gliricidia respectively. Supplementation with maize bran had insignificant depression effect on hay intake. The plausible reason may be that maize bran contributed less than 30% of total carbohydrate in the ration (DM) as levels above this are known to depress fibre digestion and forage intake (Uden, 1984).

On average, animals in experiment 1 and 2 consumed 66.9 and 78.3 g DM/kgW^{0.75} respectively. The values were within the intake range 43.2 – 101.7g DM/kgW^{0.75} reported for

tropical goats (Kumar et al., 1987). Ruminants increase their intake in response to energy and / or protein demand (Fujihara and Nakao, 1984). The difference in intake between the two experiments may be explained by the variation in nutrient contents of feeds offered. Increase in *in-vitro* OM and NDF digestibilities (Table 10) indicated higher energy levels in maize bran and its addition to the diet enhanced energy intake reducing the amount of feed consumed.

4.2.3.2 Supplementation effects on rumen pH, NH₃-N and N-balance

In both experiments, supplementation had no effect on rumen pH and the values remained above 6.2, indicated as the lower limit for any adverse effect on cellulolysis (Mould et al., 1983).

Rumen microbial synthesis requires adequate nitrogen supply, although the efficiency may be reduced by low or high NH₃-N concentrations. Nonetheless, NH₃-N values ranging from 50 to 80mg/l are indicated as minimum for optimal microbial growth and fibre digestibility (Satter and Slyter, 1974; Abdulrazak et al., 1997). Perdok et al. (1988) reported higher values (100 to 200mg / l) for optimum intake and digestibility of low quality roughages. Therefore, NH₃-N concentrations for maximum digestion may vary with availability of substrate, fermentation rate and microbial yield (Russel et al., 1993).

The 126 and 116mg NH₃-N/l concentrations observed in respective control groups were above minimum values for optimum fibre digestibility. Moreover, rumen NH₃-N concentration in both experiments increased with supplementation, reflecting improvement in rumen fermentation. This relates to additional nitrogen intake from browse supplements (experiment 1) and enhanced urea entry into the rumen (experiment 2) resulting from higher energy intake (Armstrong, 1980). The difference in rumen NH₃-N concentration noted between experiment 1 and 2 was attributed to capturing of most rumen nitrogen by energy supplied by maize bran.

Supplementation with fibrous diets (L and PLL) increased faecal nitrogen loss as a percentage of total nitrogen intake (experiment 1). This presumably resulted from the low DM degradability of these diets (Table 6), hence passing out most of feed nitrogen in faeces. Licitra et al. (1996) and Orden et al. (2000) obtained similar response on supplementing with slowly degraded forage (leuceana) as opposed to rapidly degraded forages (gliricidia). The insignificant nitrogen retention in experiment 2 suggests that ruminal energy production matched with nitrogen release from the diets. This was consistent with the findings of

Richard et al. (1994) where no difference in nitrogen retention was noted on adding energy to leguminous browse.

4.2.3.3 Supplementation effect on diet digestibility

The nature of structural components of the supplements and composition of other food ingredients offered are major determinant of diet digestibility (McDonald et al., 1988; Nherera et al., 1998; Orden et al., 2000). Except for the depression in OM digestibility with leaf-supplemented groups, the NDF and DM digestibilities were not affected by browses. The tendency for browse fibre to bind with OM making it unavailable for digestion, could explain the depression effect observed with the fibrous supplements (leaves). Similar response in OM digestibility was noted on supplementing goats' diet with fibrous *Prosopis cineraria* and Oat (Dutta et al., 1999). Though insignificant, digestibilities tended to improve on mixing, suggesting reduction (dilution) in fibre levels.

In experiment 2 diet digestibility improved with increasing levels of bran and reached significant level at 9g DM / kg W^{0.75}. The low, highly degraded NDF in maize bran improved digestible organic matter in the rumen as shown by enhancement in potentially degraded fraction *A + B* (Table 12) with increasing bran.

4.2.3.4 Supplementation effect on weight gain

The animals used in this study were relatively older but gave reliable results, as the aim was to compare the effects of different treatment diets on growth performance of goats. The positive weight gains (14.5 and 23g / d) noted in the control groups of respective experiments were associated with sufficient nutrients supply by the basal diets for maintenance of the rumen microbes. The surplus weight gain realized on supplementing with browse was contributed by enhanced microbial growth from improved nitrogen intake or increased rumen undegradable nitrogen absorbed in the lower guts. Maintenance of higher DMI (earlier mentioned) required continuous influx of feed in the rumen and may have improved the efficiency of tissue protein synthesis through increased microbial nitrogen synthesis and absorption in the lower gut (Fujihara et al., 1999). The increase in DM and DOM intake on supplementation could have promoted higher weight gains.

Comparison in experiment 1 revealed more weight gains in groups supplemented with mixtures compared with those on single browse components. This presumably resulted from the slight increase in nitrogen retention for the former compared to the later groups. However, weight gains improved on inclusion of maize bran to browse based diets reaching

significant level at $9\text{g DM} / \text{kgW}^{0.75}$. This indicates energy but not nitrogen was the limiting nutrient in experiment 2. The energy from MB synchronized with nitrogen from browse (experiment 2), improving the efficiency of microbial growth and protein synthesis (Sinclair et al., 1995), with corresponding increase in weight gains. This was in agreement to the findings of Ondiek et al. (1999) where addition of energy to gliricidia positively enhanced the growth rates of goats. However, the observed growth rates were lower than expected from the amount of nitrogen retained. A source of this discrepancy could be underestimation of faecal nitrogen loss, resulting to overestimation of nitrogen balance. In this trial, all the faecal samples were dried at 60°C for 48h and this may have contributed to underestimation of faecal nitrogen as a result of volatile N loss.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

The present work indicates that *Acacia tortilis* components are rich in crude protein and could successfully be used as nitrogen source for goats fed on poor quality roughages (hay). The results show that provision of leaves / pods (1:1) as protein supplement will significantly increase total dry matter intake, nitrogen retention and weight gains. However, inclusion of maize bran at levels above 9gDM/kg W^{0.75} to the mixture enhanced dry matter intake and diet digestibility, which translated to improved weight gain.

Mixture of browses components (leaves / pods) at 1:1 with inclusion of maize bran at levels above 9g DM / kg W^{0.75} can form part of goats feeding strategies to increase and sustain weight gains. It is advisable for ASAL farmers to harvest both the leaves and pods of *Acacia tortilis* when in plenty and use them as protein supplement for growing goats.

Future studies

- Should explore the effects of browse mixtures with indigenous grasses and other sources of energy available in marginal areas.
- Should investigate the effects of mixing browse with varying anti-nutritive factors on production performance of goats.

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5.2 Appendices

Experiment 1 dry matter intake

Ani No	Treatment	Hay	<i>A.tortilis</i>	Total
1	1	460	0	460
2	1	594	0	594
3	1	653	0	653
4	1	658	0	658
5	2	402	204	606
6	2	523	235	758
7	2	559	247	806
8	2	447	247	693
9	3	626	252	879
10	3	573	138	711
11	3	528	208	736
12	3	586	224	810
13	4	494	194	688
14	4	541	163	704
15	4	612	248	860
16	4	583	261	744
17	5	546	238	784
18	5	547	242	788
19	5	547	264	807
20	5	485	202	686
21	6	512	229	741
22	6	448	208	656
23	6	652	203	855
24	6	616	257	873

Treatments 1 – Control 2 – Pods (P) 3 – Leaves (L) 4 – PL 5 – PPL 6 - PLL

Experiment 2 Dry matter intake

Ani No	Treatment	Hay	Bran	A.tortilis	Total
1	1	587	0	115	702
2	1	439	0	131	570
3	1	398	0	94	492
4	1	610	0	177	787
5	2	360	35	110	505
6	2	608	37	125	768
7	2	422	35	127	584
8	2	615	35	166	817
9	3	553	67	132	752
10	3	375	64	127	566
11	3	434	65	140	651
12	3	448	65	155	705
13	4	353	94	115	562
14	4	497	97	149	743
15	4	344	92	113	549
16	4	596	105	175	876
17	5	499	129	159	787
18	5	479	122	160	762
19	5	453	114	115	682
20	5	497	114	130	741

Treatments 1 - MB0 2 - MB1 3 - MB2 4 - MB3 5 - MB4

Experiment 1 Weekly Live weight (kg)

Ani.No	Treatment	WEEKS							
		1	2	3	4	5	6	7	8
1	1	14.1	14.1	13.8	13.8	13.6	13.8	14.0	13.9
2	1	16.2	16.4	16.7	17.1	17.2	16.9	17.3	17.3
3	1	20.7	20.7	20.3	21.1	21.2	21.3	21.1	21.2
4	1	22.4	22.8	23.0	22.5	22.7	22.9	23.2	23.0
5	2	14.9	15.6	16.0	16.4	15.9	16.5	16.3	16.4
6	2	18.5	19.1	19.3	19.5	19.9	19.7	20.0	20.1
7	2	20.3	21.5	20.9	21.4	21.6	21.6	22.1	21.8
8	2	20.1	19.9	21.1	21.1	21.2	20.9	21.0	21.5
9	3	20.8	21.4	22.2	21.6	22.3	21.7	21.9	22.4
10	3	16.9	17.5	17.8	17.4	17.6	17.4	17.3	17.6
11	3	15.5	16.0	16.1	16.6	16.7	17.0	16.6	17.0
12	3	20.8	21.1	21.3	21.6	21.9	22.0	21.8	21.8
13	4	15.9	16.1	16.4	16.8	17.3	17.5	17.8	17.7
14	4	16.0	16.0	16.6	17.0	17.2	17.7	17.6	17.8
15	4	20.1	19.9	20.7	20.3	20.5	20.8	20.9	20.7
16	4	22.2	22.8	23.2	23.7	24.2	24.0	24.1	24.4
17	5	18.4	19.1	19.6	20.2	20.4	20.5	20.8	20.7
18	5	19.7	20.3	19.7	19.6	20.4	20.2	20.8	20.0
19	5	22.2	22.4	23.5	24.0	24.2	23.5	24.1	24.0
20	5	15.1	15.6	16.1	15.8	15.9	15.5	15.7	15.5
21	6	17.8	18.1	18.3	18.2	18.9	18.8	19.3	19.2
22	6	16.4	15.9	16.6	16.2	16.4	16.1	16.3	16.0
23	6	20.8	21.5	22.5	22.3	21.1	21.1	22.4	21.9
24	6	21.6	21.8	21.9	22.6	22.8	23.0	22.9	22.5

Treatments 1 – Control 2 – Pods (P) 3 – Leaves (L) 4 – PL 5 – PPL 6 - PLL

Experiment 2 Weekly Live weight (kg)

Ani No	Trts	WEEKS								
		1	2	3	4	5	6	7	8	9
1	1	12.7	13.0	13.1	13.3	13.5	13.4	13.6	13.5	14.3
2	1	25.5	26.0	26.6	26.5	26.5	27.0	27.5	27.1	27.3
3	1	22.3	23.9	24.6	24.2	24.4	24.2	24.5	24.3	23.9
4	1	17.9	18.0	18.3	18.5	18.6	18.6	18.9	19.1	19.3
5	2	21.6	23.7	23.3	23.2	23.4	23.6	24.0	24.0	24.2
6	2	18.0	18.3	18.5	18.7	18.5	18.7	19.5	18.9	19.0
7	2	23.2	23.9	25.4	25.6	25.5	25.9	26.0	26.7	26.6
8	2	15.5	16.5	15.9	16.2	19.4	16.7	16.6	17.0	16.9
9	3	17.9	18.7	19.1	19.4	21.6	19.5	19.8	20.0	20.5
10	3	21.0	21.0	21.6	21.4	24.4	21.8	22.0	22.4	22.3
11	3	21.5	22.5	23.9	24.5	18.7	24.7	25.4	26.0	25.8
12	3	17.4	18.1	18.3	18.5	27.5	19.0	19.3	19.6	19.4
13	4	25.1	25.8	26.9	27.0	16.9	27.9	28.5	28.4	28.1
14	4	15.6	16.2	16.6	17.0	24.6	17.3	17.8	17.3	17.7
15	4	21.9	22.3	23.9	24.4	15.6	25.0	25.6	26.0	25.9
16	4	14.5	15.3	15.5	15.3	21.5	15.8	16.6	16.9	17.7
17	5	19.0	19.6	20.9	21.7	25.4	21.9	22.5	21.7	21.3
18	5	22.6	23.0	24.1	24.5	22.8	25.0	25.5	25.6	26.0
19	5	21.4	21.7	22.5	23.0	18.3	23.6	24.0	24.4	24.6
20	5	15.4	16.7	18.4	18.1	18.3	18.3	18.6	19.2	19.0

Treatments 1- MB0 2-MB1 3 – MB2 4 – MB3 5 – MB4

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