NUTRITIONAL AND ANTI-NUTRITIONAL QUALITY OF RANGE VEGETATION IN SOUTHERN ETHIOPIA AND SUPPLEMENTARY VALUES OF SELECTED BROWSE LEAVES TO GOATS

Philosophiae Doctor (PhD) Thesis

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All the Glory be to God!

Aster Abebe
Ås, October 2010

List of Papers

This thesis is based on the following papers referred to their Roman numerals in the text.

I. Aster Abebe, Adugna Tolera, Øystein Holand, Tormod Ådnøy, Lars Olav Eik. Seasonal variations in nutritive value of some browse and grass species in Borana rangeland, southern Ethiopia. (Submitted to Tropical and Subtropical Agroecosystems)

II. Aster Abebe, Adugna Tolera, Øystein Holand, Tormod Ådnøy, Lars Olav Eik. Feed intake, digestibility, nitrogen balance and body weight change of Borana goats fed grass hay supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol addition.

III. Aster Abebe, Adugna Tolera. Girma Abebe. Concentrate replacement value of *Balanites aegyptiaca* leaves in goats fed a basal diet of barley straw.

IV. Aster Abebe, Lars Olav Eik, Øystein Holand, Tormod Ådnøy, Adugna Tolera. Pastoralists' perceptions of feed scarcity and livestock poisoning in southern rangeland, Ethiopia. (Accepted in Tropical Animal Health and Production)

Summary

Livestock are reared in all agroecological zones of Ethiopia under various production systems. Goats, although found in all agroecological zones, are popular in the drier environments since they adapt well in harsh condition better than sheep and cattle. Natural vegetation comprised of both woody and herbaceous species provides the feed base year round in such environments. Due to seasonal variations, a marked fluctuation in feed resource exists in quantitative and qualitative terms. The herbaceous particularly the grasses, are faster in deteriorating while most of the woody (browse) species maintain greenness and are able to provide higher level of crude protein and minerals to animals. In areas where crops and livestock are integrated, crop residues provide substantial amount of feed to animals. However, cereal straws are inherently low in crude protein and high in fibre which results in low intake and digestibility. Thus such feeds cannot even meet maintenance requirement of animals and should be supplemented to enhance their nutritive value. Supplementation with browse foliage and fruits could be a viable alternative in smallholder livestock-crop mixed production systems.

The study was comprised of four individual works. In experiment I, nutritional quality of some important browse and grass species collected from Borana rangeland during the hot dry and main rainy seasons were evaluated in terms of chemical composition, in vitro digestibility and *in sacco* degradability potentials. In experiment II, the effect of polyethylene glycol (PEG) on feed intake, digestibility, ammonia nitrogen concentration, nitrogen balance and body weight gain of Borana goats was evaluated. Goats were fed a basal diet of Rhodes grass (*Chloris gayana*) hay supplemented with either *Acacia brevispica* or *Acacia seyal* leaves with or without PEG addition. The concentrate replacement value of *Balanites aegyptiaca* leaves was evaluated in experiment III. The concentrate was replaced at 25, 50, 75 and 100 percent by *Balanites aegyptiaca* and feed intake, digestibility, nitrogen balance, excretion of purine derivatives and microbial nitrogen supply and average daily body weight gain were evaluated using Arsi-Bale goats fed barley straw as a basal diet. The fourth component of the study was a survey

conducted in the southern rangelands to assess the perception of pastoralists towards dry season feed shortage and associated livestock poisoning in the rangeland.

The browse foliage had higher crude protein content (>10%) during both seasons with higher values in the main rainy season (except for *A. seyal*). On the other hand, crude protein content of grass species was only slightly above the critical limit required to maintain proper functioning of rumen microbes. The fibre content was lower in the browses and higher in the grasses. The concentration of condensed tannins was variable among the browses ranging between negligible levels to over 30%. The *in vitro* and *in sacco* digestibility values were generally higher for browses, which shows their potential to be used as supplements to poor quality fibrous feeds. Experiment II showed that addition of PEG did not result in significant differences in feed intake, digestibility of dry matter, organic matter, and neutral detergent fibre as well as in nitrogen excretion and retention, and average daily weight gain. However, goats receiving PEG had higher crude protein digestibility, ammonia nitrogen concentration, and urinary nitrogen excretion. Goats without PEG addition had higher faecal nitrogen loss. When the type of Acacia was considered, *A. seyal* supplemented goats had higher feed intake while crude protein digestibility and ammonia nitrogen concentration were higher for *A. brevispica* supplemented goats. Higher average daily body gain was recorded for *A. seyal* supplemented goats. Experiment III showed that *B. aegyptiaca* had a potential to be used as supplement to cereal straw based diets. This was evident from the performance of the animals even when the concentrate was replaced completely by *B. aegyptiaca*. All animals had positive average daily body weight gain although it was lowest in animals supplemented with sole leaves of *B. aegyptiaca*. The survey revealed that the pastoralists in the southern rangelands are knowledgeable in allocation of resources, animal husbandry and ethnoveterinary practices. It also showed the concern of pastoralists about the changes in vegetation that favors woody and some unpalatable herbaceous species. Twenty two plants were identified by pastoralists as causes of livestock poisoning when ingested which usually occurs when animals are hungry and thirsty.

Samandrag

Husdyrhald er vanleg under ulike produksjonssystem i alle agroøkologiske soner i Etiopia. Sjølv om geiter er finst over heile landet, er dei mest vanlege i tørre strok. Dei kan, betre enn sau og storfe, utnytta ein stor del av vegetasjonen, inkludert gras, urter og lauvfôr og har difor lettare for å livnæra seg gjennom heile året. Sesongvariasjonar med regn- og tørketid, gjer at det er stor variasjon i fôrtilgang og fôrkvalitet gjennom året. Normalt vil kvaliteten på fôr frå urter og spesielt gras avta mykje raskare enn for lauvfôr.

I område med både åkerbruk og husdyrhald er halm og andre biprodukt ein viktig fôrressurs. Men halm er eit proteinfattig fôr med høgt trevleinnhald. Det har difor låg næringsverdi og opptaket er avgrensa. Dyra kan knapt dekka vedlikehaldsbehovet på ein slik rasjon. Tilskotsfôring med lauvverk og frukter frå tre og buskvegetasjon kan difor vera eit viktig tiltak for å auka produktiviteten i husdyrhaldet i små driftseiningar med åkerbruk.

Dette arbeidet er samansett av fire artiklar. I forsøk I samla vi inn fôrprøvar i den varme tørketida og i hovedregntida frå viktige tre- og grasartar i beite i Borana-regionen i det sørlege Etiopia. Fôrverdien vart bestemt ved analysar for kjemisk innhald, in vitro fordøyingsgrad og *in sacco* nedbrytingsgrad.

I forsøk II såg vi på verknaden av polyethylene glycol (PEG) på fôropptak, fordøyingsgrad, konsentrasjon av ammonium-nitrogen, nitrogenbalanse og levandevektendring hos boranageiter. Geitene fekk høy laga av Rhodes-gras (*Chloris gayana*) med tilskot av enten *Acacia brevispica* eller *Acacia seyal* lauv med og utan tilskot av PEG.

Fôrverdien til lauv frå *Balanites aegyptiaca* samanlikna med kraftfôr vart studert i forsøk III. Kraftfôret vart erstatta med lauv i forholdet 25, 50, 75 and 100% i ein fôrrasjon med bygghalm til Arsi-Bale geiter. Effekten av behandlinga vart studert med omsyn til

fôropptak, fordøyingsgrad, nitrogenbalanse, ekskresjon av purin-derivat, tilgang på mikrobiell nitrogen og fôropptak.

I del fire av dette arbeidet gjennomførte vi ei spørjeundersøking for å finna ut kva utfordringar pastoralistar i dei sørlege heieområda har med å skaffa fôr til buskapen i tørketida og om giftige planter er eit problem for husdyr.

Proteininnhaldet i lauvfôr var høgt (>10%) både i tørke- og regntid. Med unntak av *A. seyal*, var innhaldet av protein høgast i hovedregntida. For grasartane derimot var proteininnhaldet lågt og berre tilstrekkeleg for å dekka vedlikehaldsbehovet til dyra. Fiberinnhaldet i lauv var også lågare enn for gras. Innhaldet av kondenserte tanniner varierte frå nesten ingenting til over 30%. Generelt var verdiane for fordøyingsgrad (*in vitro* og *in sacco)* høgre for lauv enn for gras. Lauvfôr har difor eit potensiale som tilskotsfôr i trevlerike fôrrasjonar. Tilskot av PEG i fôrrasjonen hadde ingen effekt på fôropptak, fordøyingsgrad av tørrstoff, organisk materiale, eller trevler (NDF), eller på nitrogenekskresjon og retensjon, eller middel dagleg tilvekst hos dyra (Forsøk II). Men geiter med PEG i fôrrasjonen hadde høgre fordøingsgrad med omsyn til råprotein, konsentrasjon av ammonium-nitrogen og utskiljing av nitrogen i urinen. Geiter utan PEG i rasjonen hadde høgare tap av nitrogen i møkka.

Vi fann også skilnad i fôrverdi mellom ulike akasie-treslag. Geiter med tilskot av *A. seyal* i fôret hadde høgre fôropptak, medan fordøyingsgrad for råprotein og konsentrasjon av ammonium-nitrogen var høgast for geiter som fekk tilskot av *A. brevispica.* Tilveksten var også større for geiter som fekk *A. seyal.*

Forsøk III syner at *B. aegyptiaca* har eit potensiale som tilskotsfôr til halmbaserte fôrrasjonar, til og med når alt kraftfôret i rasjonen vart erstatta med lauvfôr. Alle dyra hadde positiv middel dagleg tilvekst, men vektendringane var minst for geiter som berre fekk tilskot av lauv frå *B. Aegyptiaca.*

Spørjeundersøkinga synte at pastoralistane Borana-regionen sit inne med stor kunnskap om resursallokering beitebruk og -planter, husdyrhald og sjukdomsbehandling basert på lokal kunnskap. Dei uttrykte uro over at vegetasjonen har endra seg, frå opnare beitemark til tettare buskvegetasjon med større innslag av beiteplanter som ikkje høver til fôr. Pastoralistane identifiserte 22 planteslag som kan vera giftige for husdyr dersom dei blir etne. Forgifting er vanlegast i periodar med fôrmangel og når dyra er tørste.

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Papers I-IV

1. Introduction

1.1 Livestock and feed resources

Globally the contribution of livestock reaches up to 40 percent of the agricultural output and livestock production is a means of livelihood for about a billion people (FAO, 2009). In Africa more than 200 million people depend on livestock through the incomes obtained from sale of animals and animal products such as meat and milk and direct consumption of the products. Moreover, animals provide draught power and are important to fulfill ritual and spiritual needs in some societies (Hoffman and Vogel, 2008).

Livestock production in Africa can be broadly categorized into three: Industrial livestock production, pastoral and agropastoral and smallholder production systems (Hoffman and Vogel, 2008). The later two production systems are of great importance as they are the major production systems in Africa. The pastoral and agropastoral system which is mainly found in the arid and semiarid regions depends largely on natural pasture comprising herbaceous and woody perennials while in the smallholder system crop residues contribute substantial amount of the ruminant feed. However, there is often shortage of feeds in the dry season as grasses dry up quickly and become very scarce in quantity and decline in quality (Tolera et al., 1997). In the mixed crop-livestock smallholder production system crop residues which are usually available for the dry season feeding are of low quality and hardly support maintenance requirement of animals. Nutrient deficiencies in the available feeds in the dry season hamper animal production (Kaitho et al., 1998b). On the other hand, most browse species have the ability to remain green and maintain their nutritive value throughout the dry period (Tolera et al., 1997). Browse species are high in protein and mineral content (Kibon and Ørskov, 1993; Kadzere, 1995) and thus important in supplementing low quality feeds like mature grasses or cereal straws.

Ethiopia has diverse agroecological zones and a wide range of climatic features which made the country suitable for various farming systems. Ethiopia is known for its large livestock populations in Africa. The contribution of the livestock sector in terms of products like meat, milk and hides accounts for 40 percent of the country's agricultural gross domestic product (GDP) and 20 percent of total GDP (Aklilu, 2002). If other benefits were added such as provision of draught power, transport services, manure for fertilizer and fuel, this percentage would be even higher. In Ethiopia, livestock are kept for different functions and purposes both in the highland crop-livestock mixed production system as compared to in the lowland pastoral and agropastoral production system. The lowland area which covers 61 percent of the land mass is inhabited by various pastoral and agropastoral communities like the Borana, Afar, Somali, Kereyyu, Hamar etc. whose livelihood is mainly based on livestock. The pastoral areas of Borana, Afar and Somali are the main sources of livestock destined for export market (Getachew et al., 2008).

In Ethiopia, goats are kept in all agroecological zones and contribute to food security through production of milk, meat and cash incomes to the owners. However, production and productivity of goats in east Africa is low due to various constraints among which nutritional constraint can explain much of the low performance of goats in the region (Tolera et al., 2000). The low production and productivity is manifested through stunted growth of young animals; high mortality and morbidity rates and longer time taken to reach market weight and reproductive age. In the arid and semiarid areas where the pastoral and agro pastoral production system prevails, browse species contribute substantial amount of feed ingested by goats (Hove et al., 2001; Ramirez, 1999) while in the smallholder production system browse species can supplement low quality roughages such as cereal crop straws. In line with this, Yayneshet et al. (2008) reported that 69 percent of feed ingested by goats in the northern Ethiopia was composed of various browse species. Similarly Landau et al. (2000) reported that browse makes much of feeds ingested by goats in the Mediterranean woodland/scrubland even when herbaceous species are abundant. Goats maintain the amount of browse in their ingesta in a way that they do not face dramatic change in the different seasons (Silanikove, 2000). However, most browse species are known to contain compounds which are potentially antinutritional or toxic to animals consuming them. These include polyphenols, saponins, alkaloids and others among which polyphenols are most important (Kaitho et al., 1998b).

Tannins are one group of compounds in the broad category of plant polyphenols and of great interest in animal nutrition.

1.2. Tannins: significance in animal nutrition

Tannins are compounds which are grouped under plant polyphenols. They are widely distributed among forbs, shrubs and trees and are found in different parts of the plant such as leaves, flowers, twigs, barks, roots, fruits (Woodward and Reed, 1989). They are diverse in terms of molecular weights and complexity (Makkar, 2003). Tannins can be classified mainly into two categories: hydrolysable tannins (HT) and condensed tannins (CT) (Landau et al., 2000; Makkar, 2003; Goel et al., 2005) depending on their structure and reactivity towards hydrolytic reagents. The hydrolysable and condensed tannins have basic differences in their structure. In the case of HT, there is a central sugar which is attached to several gallic acid groups while CT are polymers of flavanol units linked by carbon-carbon bonds (Waghorn, 2008). It is not yet well understood why plants are synthesizing these compounds, the main hypotheses being that they provide i): protection for the plant against herbivores, ii) defense against pathogen and that they are iii) means of energy and nitrogen conservation (Waghorn, 2008).

Condensed tannins are also known as proanthocyanidins due to the fact that bright red anthocyanadin chloride is released upon treatment with acid (Waghorn, 2008). They are more abundant in forages than HT (Min et al., 2003) and are known to have both beneficial and harmful effects in nutrition of animals depending on the nature and concentration level (Makkar, 2003; Min et al., 2003; Waghorn, 2008). As reviewed by Waghorn (2008), the positive effect of CT is primarily related to its ability to reduce excess protein degradation in the rumen by forming CT-protein complexes and thus more dietary protein enters small intestine. Most of the complexes formed are believed to be hydrolyzed in the acidic environment of abomasum. This phenomenon is particularly useful when the CP content of the feed is beyond the requirement of rumen microorganisms. However, it becomes detrimental to the animal if the feed is low in CP content but high in fibre. Condensed tannins may also prevent bloat formation in animals on legume pastures particularly in temperate regions. Bloat is caused by high solubility of proteins and leads to formation of stable foams (Min et al., 2003).

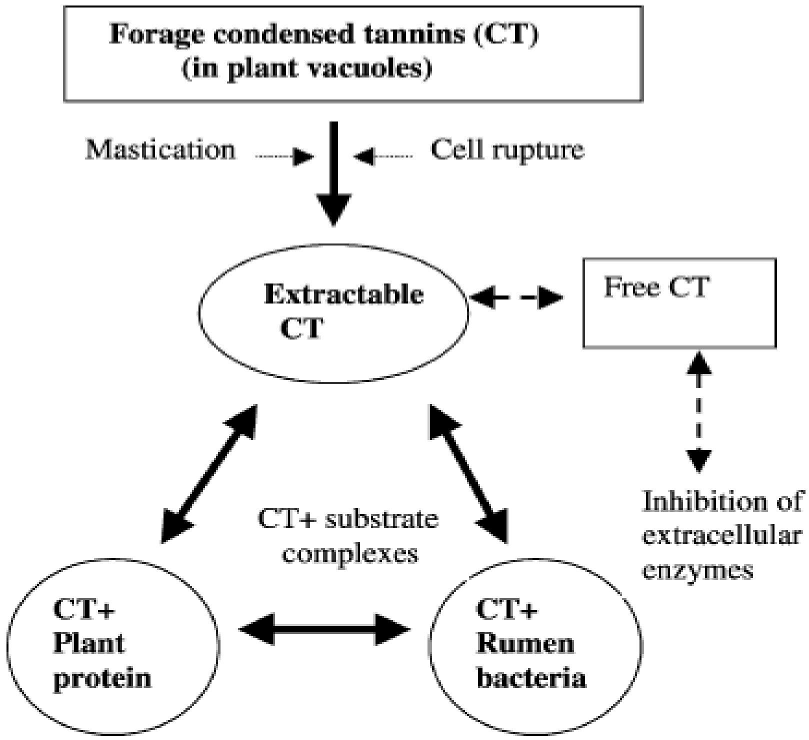

Figure 1: Proposed effect of condensed tannins (CT) on rumen bacteria and their interactions. Source: Min et al. (2003).

Furthermore, condensed tannins are also known to have anthelmintic effect which provides alternatives in areas where availability of drugs or drug resistance have become a challenge (Min et al., 2003; Min and Hart, 2003).

Condensed tannins affect negatively ruminant nutrition in various ways and Waghorn (2008) described it as ‘’double edged sword’’. They reduce feed intake and palatability due to the astringency effect produced during chewing as plant cells rupture and release CT and complexes are formed with salivary protein (Figure 1). Astringency is the sensation/feeling created due to dryness in the oral cavity (Goel et al., 2005). Feed intake could be depressed also as result of impaired digestion and irritation of the digestive tract epithelium (Silanikove et al., 1997a) due to CT. Indeed, an inverse relationship exists between concentration of CT and feed intake. Digestibility of protein is limited because of the complexes formed with CT and becomes unavailable for rumen microbes. This could be detrimental depending on CP content of the feed and animals requirement for nutrients. The complexes formed in the rumen may dissociate in the more acid environment of abomasum (Jones and Mangan, 1977). However, many will not get hydrolyzed for digestion and absorption in the intestine (Makkar, 2003). Condensed tannins have also ability to bind bacterial enzymes (Figure 1) and thereby depress their accessibility and activity. This action coupled with their ability to form complexes with cell wall carbohydrates further affects digestibility of the fibre fraction (Min et al., 2003; Waghorn, 2008).

1.3. Use of polyethylene glycol (PEG) to deactivate tannins

Polyethylene glycol is a synthetic polymer with no nutritional value (Makkar et al., 1995) and has been used to alleviate the negative effects of CT due to its strong affinity for tannins (Getachew et al., 2001). It can form irreversible complexes with tannins and thereby minimize binding of tannin to proteins (Jones and Mangan, 1977). Positive results have been reported by application of PEG to browse based diets of sheep and goats. In an earlier study Pritchard et al. (1992) reported increase in DM intake, N digestibility and wool growth in sheep consuming Mulga (*Acacia aneura*) and supplemented with PEG. More recently, several other workers have reported increased DM intake (Bhatta et al., 2002; Decandia et al., 2000; Priolo et al., 2000), N digestibility (Ben Salem et al., 1999; Bhatta et al., 2002; Decandia et al., 2000; Priolo et al., 2000) and live wight gain (Ben Salem et al., 1999; Bhatta et al., 2002; Gilboa et al., 2000; Priolo et al., 2000). Moreover, increased consumption of browse leaves with high tannin content has been observed in goats supplemented with PEG (Decandia et al., 2000). In contrast to the above reports, Mlambo et al. (2004) concluded that deactivation of *Dichrostachys cinerea* CT rich fruits with PEG has no beneficial effect and thus these fruits can be used effectively by goats without addition of PEG. Such differences in results with application of PEG could occur due to diversity in structure and bioactivity of tannins. The effect of tannins in browse species might be affected by the presence of other anti-nutritional compounds, diet composition and the types (and ages) of animal.

1.4. Rationale of the study

The Ethiopian lowlands which comprise more than half of the country's land mass are home for valuable breeds of livestock including goats. In these areas which are characterized as arid and semiarid, the livestock population is dependent mainly on natural vegetation composed of herbaceous and woody species. There is a marked seasonal fluctuation in the availability and quality of the natural vegetation. The shrubs and trees are known to maintain better nutrient content than most herbaceous species and thus are considered as alternative supplements to roughages such as low quality hay and crop residues. Therefore, it was hypothesized that the use of leaves of indigenous browse species as a supplement to low quality roughages could alleviate the problem of loss of body condition of animals particularly in the dry season. On the other hand, most browse species are known to contain various compounds considered as anti-nutritional compounds which limit their potential use as supplements and thus addition of polyethylene glycol was considered to deactivate tannins.

1.5. The objectives:

1. To evaluate the nutritive quality (chemical composition, *in vitro* DM digestibility, *in sacco* DM degradability) of important browse and grass species in the Borana rangelands during two main seasons: hot dry and main rainy seasons (Paper I).
2. To evaluate effect of *Acacia brevispica* or *Acacia seyal* leaf supplementation with or without polyethylene glycol (PEG) addition on performance of Borana goats fed a basal diet of grass hay (Paper II).
3. To evaluate concentrate replacement value of *Balanites aegyptiaca* leaves when supplemented to Arsi-Bale goats fed a basal diet of barley straw (Paper III).
4. To assess the feed resource and management, strategies in dry periods and problem of livestock poisoning in the southern rangelands of Ethiopia (Paper IV).

2. Materials and methods

2.1. Field site description

In Paper I, seasonal variation in nutritive quality of indigenous forage species was evaluated. Forage samples were collected from Borana rangeland. The climate in the area is generally semiarid with annual rainfall average of 500 mm in the south to 700 mm in the north. The rainfall pattern is bimodal, with the main rains falling between March and May while the short rains fall between September and November (Coppock, 1994). Generally the rain in the area is erratic and variable which makes crop production unreliable activity. The Acacia leaves used as a supplement in Paper II were also collected from the same area.

2.2. Forage sampling and analysis

Forage sampling was undertaken in four pastoral associations selected from Yabello and Dire woreda (districts). Sixteen transects, each with length of about 1.5 km were constructed and followed while sampling. The samples were collected both during the hot dry season and main rainy season in the area. There were eight and 10 browse and three grass species that were collected during both seasons. The samples were dried, ground and analyzed for chemical composition, *in sacco* DM degradability and *in vitro* DM digestibility.

2.3. Experiments and survey procedures

Feed intake, digestibility, nitrogen balance and body weight changes of Borana goats fed on Rhodes grass (*Chloris gayana*) hay and supplemented with either *A. brevispica* or *A. seyal* leaves with or without addition of polyethylene glycol were evaluated in Paper II. In this experiment 32 growing Borana goats were used. The experiment was conducted in Hawassa in the University farm where animals were kept in individual pens with feeding trough and watering bucket. During the digestibility trial animals were kept in individual metabolism cages with feeding trough and watering bucket. There were four animals in each treatment. The acacia leaves were collected from Borana rangeland by hand plucking and were dried under shade. The growth experiment lasted for 70 days while digestibility trial was undertaken for 7 days of collection period after the growth experiment. The feeds and feeding management were the same for both growth experiment and digestibility trial. Polyethylene glycol was provided to the goats in concentrate mixture. Feed intake, digestibility, nitrogen balance, ammonia nitrogen concentration and body weight changes of goats were evaluated.

In Paper III, the concentrate replacement value of *B. aegyptiaca* leaves was evaluated using 20 Arsi-Bale goats fed barley straw as basal diet and supplemented with varying levels of concentrate and *B. aegyptiaca* leaves. The *B. aegyptiaca* leaves replaced 25 (T2), 50 (T3), 75 (T4) and 100 (T5) % of the concentrate in the diet whereas those in T1 received 100% concentrate mixture as a supplement. Feed intake, digestibility, and nitrogen balance, microbial nitrogen supply and body weight changes of goats were evaluated. The *B. aegyptiaca* leaves were collected and dried under shade while the barley straw was obtained from Kofale and Qore districts West Arsi Zone, Oromia Regional State and transported to Hawassa University. The concentrate mixture was prepared from equal proportions of wheat bran and linseed cake. The growth and digestibility experiments lasted for 84 and 7 days, respectively. The experiment was conducted in the same farm unit as in Paper II. Data were analyzed using SAS (2003).

The survey (Paper IV) was conducted in the southern rangelands which included the Borana and Garri pastoralists. The survey involved individual interviews and focused group discussion. One hundred and nineteen household heads took part in the interview which included young and elderly as well as women. During the survey, dry season forage conditions and coping strategies, vegetation changes, and the problem of livestock poisoning in relation to dry season feed shortage was assessed. Data collected were analyzed using SPSS (version 15.0).

3. Summary of results

The summary of the results in the present work is given for individual papers referred by Roman numerals (I to IV)

3.1. Paper I: Chemical composition and digestibility

The nutritive quality of forage species collected from Borana rangeland during the hot dry and main rainy seasons were evaluated on the basis of chemical composition, IVDMD and *in sacco* DM degradability. The browse species had higher CP content in both seasons while it was lower than 10% for grasses. The CP content of the browse species was higher during the main rainy season except for *Acacia seyal*. The ash content was found to be higher in grasses than in browse species. The fibre content of the browse species was variable during both seasons and no clear trend was observed. In general, the fibre content was higher in the grasses than in the browse species. The concentration of condensed tannins was higher during the main rainy season which could be associated with the growth of new leaves, which need protection from damages, at this season. The IVDMD of browses were higher particularly for *Acacia nilotica, A. seyal, Acacia tortilis, Grewia tembensis* and *Vernonia cinerascens*, while the remaining browses had IVDMD values similar to grasses in the main rainy season. The *in sacco* DM degradability study was done on four browse and one grass species. Two of the browse species (*Acacia nilotica* and *Balanites aegyptiaca*) had the highest degradability values in both seasons, whereas the other two species (*Grewia bicolor* and *Rhus natalensis*) had moderate degradability. The lowest DM degradability values were observed in the grass species, *Chrysopogon aucheri*, in the dry season.

3.2. Paper II: Use of Polyethylene glycol to deactivate tannins

The effect of polyethylene glycol was tested in a factorial design where growing goats were either supplemented or not given PEG when either *Acacia brevispica* or *A. seyal* was as a supplement to a basal diet of Rhodes grass (*Chloris gayana*) hay. Effects of PEG supplementation were observed on intake of DM, CP and neutral detergents. Compared with goats receiving *A. brevispica*, animals supplemented with *A. seyal* had significant higher daily DM intake and body weight gains. Digestibility of CP was affected by both presence of PEG and type of Acacia supplemented. Crude protein digestibility was higher ($P<0.05$) in PEG supplemented goats. Also *A. brevispica* supplemented goats had higher CP digestibility than those provided with *A. seyal* whereas no differences were found in digestibility of DM, OM, and NDF. Excretion of nitrogen in faeces was higher ($P<0.05$)

in goats without PEG while those receiving PEG had higher (P<0.05) nitrogen in urine while total nitrogen excreted and nitrogen retained remained unaffected. Average daily body weight gain was higher (P<0.05) in *A. seyal* supplemented goats than those supplemented with *A. brevispica* leaves. However, addition of PEG did not have a significant effect on the body weight gain of the goats.

3.3. Paper III: Concentrate replacement value of *B. aegyptiaca*

Concentrate replacement value of *B. aegyptiaca* leaves was evaluated using Arsi-Bale goats fed barley straw as a basal diet. No significant differences (P>0.05) were observed in DM intake among the treatments. However, DM intake tended to be significant (P=0.06) with higher intakes recorded in T2, T3 and T4. On the other hand, there were significant differences in OM (P<0.05), CP (P<0.001), NDF and ADF (P<0.05) intakes. The highest digestibility of DM, OM and CP were recorded for T1 which was similar to T2 and T3 but different from T4 and T5 While digestibility values for T2, T3, T4 and T5 did not differ significantly (P>0.05). A decreasing trend in digestibility occurred as proportion of *B. aegyptiaca* was increased in the diet. Neutral detergent fibre digestibility was unaffected. There were no significant differences in nitrogen balance of the animals, although there were differences in nitrogen intake and digestibility. Further, no significant differences were recorded in excretion of purine derivatives and microbial nitrogen supply. All animals gained modest body weight with significant differences (P<0.001) between the treatments. The highest daily gain was recorded for T2 (28.7 g) which was similar to T1 but different from all others. Animals in T1, T3 and T4 had similar daily gain but different from T5. The sole *B. aegyptiaca* leaves supplemented animals (T5) had the lowest daily gain (11.3 g) compared to others. However, in such areas where concentrate supplementation is not practical *B. aegyptiaca* could be a viable option to improve or maintain body condition of animals particularly in dry periods.

3.4. Paper IV: Pastoralists’ perception on feed shortage and livestock poisoning

The survey showed that livestock remains to be main livelihood source in the southern rangeland, although there is an increasing trend of crop farming. The area is endowed with diverse vegetation comprising both herbaceous and woody species which sustains valuable breeds of livestock for the nation. The pastoralist indicated that diversity of the vegetation is useful as it acts as a natural feed security for the animals during scarcity because there is a potential of supplying forage at different times of the year. However, the respondents also indicated the on-going gradual changes in vegetation composition, in favor of expansion of woody species and some herbaceous unpalatable forbs at the expense of some very valuable perennial grasses. Some plants were mentioned as potential toxic to young animals or certain species of livestock. During the survey, 22 plants were reported to have toxic effects upon ingestion by animals. It was also indicated that most of the poisoning occur during periods of feed and water scarcity. The respondents mentioned various ways of dealing with poisoning as veterinary services are limited. This includes use of herbs, milk, local mineral salt, branding and water.

4. General discussion

The first step in feed evaluation is to determine its chemical composition and undertake degradability or digestibility studies. Paper I deals with the chemical composition, *in vitro* digestibility and *in sacco* degradability of some indigenous browse and grass species in the Borana rangelands. The CP content of most herbaceous species including grasses, are low during the dry seasons. The grasses had low CP content, which is below the minimum level required for optimum rumen microbial function during the dry season. According to Bondi (1987), animals receiving feeds which contain crude protein less than six percent cannot maintain a positive nitrogen balance. On the other hand, the CP content of the browse species is well above this critical level during both seasons with slightly higher values in the wet season except for *A. seyal*. The lowest CP value (109 g/kg DM) was recorded in the dry season for *Rhus natalensis*. This difference in CP between the browse and grasses is the basis for using browses as a supplement to poor quality roughages. Several experiments have shown the supplementary value of browse species to cereal straw based diets (e.g. Reed et al., 1990; Woodward and Reed, 1995; Kaitho et al., 1998a; Solomon et al., 2004). On the other hand, most shrubs and trees are known to contain varying levels of secondary plant metabolites such as tannins. Condensed tannin is widely distributed in nature and could affect feed intake and digestibility. In this study the concentration of CT ranged from negligible concentration in *Balanites aegyptiaca* to 332 g/kg DM in *Acacia tortilis*. Tannin content can vary with plant species, stage of maturity and plant parts, level of harvesting or browsing and the environmental conditions (Roberts et al., 1993). Several factors are also known to affect the analysis of tannins particularly CT which include initial harvesting of forage samples, drying and extraction methods employed (Schofield et al., 2001). Fibre is important in nutritive value of forages as its characteristics can have great impact on the extent of digestion of organic matter (Huhtanen et al., 2006). The fibre contents were generally lower in the browse species compared to the grasses. The *in vitro* dry matter digestibility (IVDMD) of the browse species was affected by species but unaffected by season and remained high both in the dry and main rainy seasons. In grasses IVDMD was affected by species and season. The values were lower during the dry season but improved in the main rainy season and were comparable to *G. bicolor*, *A. brevispica* and *R. natalensis*. Similarly the *in sacco* degradability results support the trend seen in the IVDMD. *Acacia nilotica* and *B. aegyptiaca* had the highest values in both seasons while *R. natalensis* and *G. bicolor* were intermediate during the dry season followed by the grass specie *Chrysopogon aucheri*. The lower digestibility/degradability of grasses during the dry season could be as a result of advancement in maturity and thus accumulation of cell wall components.

As supported by the findings in Paper I, there exists a variation in quality of forages between seasons and species and it is more pronounced in herbaceous species particularly grasses while most of the browse species have high CP and digestibility. Thus it becomes appropriate to supplement dry grasses and also cereal crop residues with leaves (fruits) of browse species or concentrates whenever possible. Shrubs and trees contribute significantly to feed ingested by goats in the drier regions of the world (Devendra, 1991; Ramirez, 1999). In the southern rangelands the population of woody vegetation has increased tremendously in the past few decades and can make significant contribution to browsers like goat and camel (Paper IV). On the other hand, most of the browses are known to contain secondary plant metabolites which include condensed tannins (Getachew et al., 2001; Bhatta et al., 2002). Due to the anti-nutritional effect of CT, contribution of browse may be hampered and thus requires deactivation of CT to enhance their nutritive value and animal productivity. Paper II investigates the effect of PEG in deactivating the condensed tannins in two indigenous Acacia species, *A. brevispica* and *A. seyal*, when fed to growing goats as a supplement to grass hay.

Condensed tannins are abundant in nature and can negatively affect feed intake and digestion. In this regard, Silanikove et al. (1996a) reported the reduction in feed intake and digestibility due to CT in the leaves of carob (*Ceratonia siliqua*). They also observed reduction in the activity of ruminal and intestinal enzyme in both sheep and goats. The application of polyethylene glycol to such kind of feeds has demonstrated the potential of improving utilization of forages high in CT. A study by Ben Salem et al. (1999) showed increased CP and NDF digestibility, increased N retention and daily body weight gain in sheep consuming PEG-treated *A. cyanophylla* Lind. foliage compared to those given fresh or air-dried foliage. Bhatta et al. (2002) also reported increased feed intake of *Prosopis* leaves upon administering five g PEG per day to individual kids. The PEG group had also higher CP digestibility, increased rumen ammonia nitrogen concentration. In earlier study Pritchard et al. (1992) showed positive effect of PEG on feed intake, CP digestibility, N retention and wool growth in sheep fed *Acacia aneura*. However, there are contrasting results regarding the effect of PEG in deactivating tannins. Mlambo et al. (2004) reported low N digestibility and retention and less body weight gains in goats receiving PEG treated *Dichrostachys cinerea* fruits compared to those receiving either NaOH treated or untreated fruits or commercial protein supplements. Decandia et al. (2000) did not find differences in digestibility of CP, nitrogen retention and body weight gains of the goats receiving or not receiving PEG. In our study, there was higher CP digestibility and ammonia nitrogen concentration for goats receiving PEG compared to groups without PEG supplementation. Nevertheless, there were no differences in nitrogen retention and body weight gain between the two groups. The ambiguous results in the various experiments undertaken with PEG addition to tannin rich foliages could be due to the differences in concentration of tannins, their structure and bioactivity (Hagerman et al., 1992; Waghorn, 2008) and also presence of other secondary compounds such as saponins (Makkar, 2003). Moreover, the species difference between sheep and goat could explain part of the differences in the results obtained by various workers. Sheep are grazers and less adapted to browse compared to goats and thus show pronounced effects of polyethylene glycol when supplemented to browse based diets. Min et al. (2003) showed that two species of *Lotus* with similar concentration of tannin had different effects on the animals. This demonstrates the fact that concentration alone cannot be used to judge the effect of tanniniferous feeds and that other attributes should be considered. Therefore, overall recommendation of PEG in deactivation of tannin in browse species has to be considered with caution. The two *Acacia* species used in this study differed in their effect. *Acacia seyal* supplemented goats had higher feed intake, N retention and daily weight gain although CP and ammonia nitrogen concentration were lower than *A. brevispica* supplemented goats. The lack of effect of the increased CP digestibility and ammonia nitrogen concentration recorded in *A. brevispica* could be due to uncoupling of energy source for maximum utilization.

Cereal crop residues are important feed resources in the tropics and contribute much to the feed availability, particularly in the dry season, in mixed crop-livestock and agropastoral production systems. Cereal crop residues are low in quality because of low CP and mineral contents, and low digestibility. Supplementation is thus required to alleviate such deficiencies and improve animal performance. Concentrates are costly and in short supply in most parts of Ethiopia. Thus in our study, we evaluated the concentrate replacing value of *B. aegyptiaca* leaves in barley straw based diets using Arsi-Bale goats. *Balanites aegyptiaca* grows well in pastoral and agropastorl areas of Ethiopia and is known to maintain its green leaves in the dry season. It has moderate CP content but moderate condensed tannins. In this experiment, it substituted concentrate mixture at 25, 50, 75 and 100 percent. Animals in the different treatments had similar DM intake but differed in nutrient intakes, which could be due to differences in nutrient content of the concentrate mixture and *B. aegyptiaca* leaves. The digestibility of DM, OM and CP were higher for diets containing more concentrate mixture and lowest when sole *B. aegyptiaca* was used as a supplement. *Balanites aegyptiaca* has lower CP content compared to the concentrate mixture and also it has substantial concentration of CT which could hamper CP digestibility. However, DM and CP digestibility of diet with sole *B. aegyptiaca* agrees with reports of Woodward and Reed (1995) for tef straw based diet supplemented with *A. brevispica*. Furthermore, the DM digestibility of *Albizia harveyi* and *Grewia similis* in *Cenchrus ciliaris* based diet reported by Goromela et al. (1997) and that of *Leucaena leucocephala* and *Sesbania sesban* (accession 1190, 2024) supplements in tef straw based diets reported by Kaitho et al.(1998a) compares well with our results. Diet with more *B. aegyptiaca* resulted in higher fecal N but lower urinary N loss. High N loss in urine is considered more harmful to the environment and less beneficial to the farmer who depends on manure as a fertilizer. Excretion of purine derivatives and microbial nitrogen supply also remained similar across treatments. All animals gained weight, including those fed *B. aegyptiaca* as a sole supplement, with varying magnitude. Cereal straws without supplements are not able to meet maintenance requirements of animals due to the inherent deficiencies which limit microbial growth and activity. The positive weight gains in the present study are much the role of concentrate and *B. aegyptiaca* in supplying nutrients deficient in the straw. A number of studies (e.g. Reed et al., 1990; Woodward and Reed, 1995; Kaitho et al., 1998; Solomon et al., 2004) have reported positive weight gains in straw based diets supplemented with foliages from trees and shrubs. Therefore, *B. aegyptiaca* could be considered as a potential dry season supplement to poor quality feeds in smallholder farming situations.

The survey conducted in the southern rangelands of Ethiopia, showed that livestock remain to be the main source of livelihood despite the increasing interest in crop cultivation. The pastoralists have embarked on food crop cultivation to cope with the food insecurity they are facing due to frequent drought. This action may be a threat to dry season grazing pattern as both compete for the bottomlands. A study in Borana area by Angassa and Oba (2008) showed that the majority of the respondents in their study were involved in bottomland cultivation as opposed to upland. The area has experienced frequent drought in the past few decades. This combined with other factors like ban on range burning has resulted in dramatic change in vegetation composition particularly in Borana area. According to the respondents the change has favored woody species and some unpalatable forbs, while amount of perennial grasses with higher feeding potential is declining. This is a great challenge to Borana pastoralists who largely depend on cattle. Moreover, certain plants in the rangeland have the ability to cause toxic effect when ingested by animals. According to the respondents the incidence is encounted more in the dry season because these plants maintain greenness and apparent palatability. Twenty two such plants were identified by the respondents in the study area to have toxic effects. The effect on animal production ranges from stunted growth in young ones, reduced milk production and loss of weight in adult and deaths in severe instances. The pastoralists use their knowledge of ethnoveterinary to treat poisoned animals using various items including herbs, local mineral salts, milk, water and antibiotics.

5. Conclusion and recommendation

The browse species evaluated had medium to high CP and relatively low fibre contents and high in IVDMD digestibility while the grasses were low in CP, high in fibre contents and relatively low IVDMD values. The CP content of the browse species was above 10 percent even during the dry season, which shows their potential role as supplements to animals fed poor quality roughages as basal diet. However, this should be considered with caution since some of the browses contain substantial amounts of tannins which could be affecting palatability, feed intake and digestion. Addition of polyethylene glycol to diet of goats based on grass hay and supplemented with either *A. brevispica* or *A. seyal* did not affect feed intake, DM and fibre digestibility, N excreted and retained and body weight gain but had influenced CP digestibility, concentration of ammonia N, and route of excretion of N. All animals supplemented with *B. aegyptiaca* gained live weight throughout the study period, including the treatment where *B. aegyptiaca* leaves replaced 100% of the concentrate mixture. Hence, smallholder farmers who cannot afford to buy commercial concentrates or provide home-grown grains to their animals can use sole leaves of *B. aegyptiaca* as a supplement to crop residues. The gain in live weight was improved when *B. aegyptiaca* was used in combination with concentrate mixture with the highest gain occurring when the concentrate mixture and *B. aegyptiaca* leaves were used as supplements in a 3:1 ratio. The choice of feeding strategy depends on the objective and also the availability of these supplements in the area. Dry season feed shortage is closely associated with livestock poisoning in the southern rangelands. A number of plants have been identified by the pastoralists as being toxic to livestock when ingested. Range livestock poisoning could be a potential threat in the changing climatic conditions. Therefore, it is critical to identify the principal compounds responsible for toxicity and undertake possible preventive and treatment measures. The existing vegetation has to be utilized through appropriate livestock species combined with various strategies to suppress proliferation of bushes.

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Paper I

Seasonal variations in nutritive value of some browse and grass species in Borana rangeland, southern Ethiopia

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Abstract

The Borana rangeland has diverse species of woody and herbaceous plants which are useful as forage. Chemical analysis, *in vitro* dry matter digestibility (IVDMD) and *in sacco* degradability study were conducted on feed samples collected from browse and grass species during the hot dry and main rainy seasons. Chemical analysis and IVDMD were done for *Acacia brevispica*, *Acacia nilotica*, *Acacia seyal*, *Acacia tortilis*, *Balanites aegyptiaca*, *Grewia bicolor*, *Grewia tembensis*, *Rhus natalensis*, *Vernonia cinerascens* and *Maracaa* (native name) and grass species *Cenchrus ciliaris*, *Chrysopogon aucheri* and *Pennisetum mezianum* while *in sacco* degradability was undertaken for *A. nilotica, B. aegyptiaca*, *G. bicolor*, *R. natalensis* and *C. aucheri*. The crude protein content (CP) of the browse species was higher in the rainy season except for *A. seyal* which had higher value in the dry season (210 g/kg DM). The condensed tannin (CT) concentration ranged from 1.18 to 332 g/kg DM in *B. aegyptiaca* and *A. tortilis*, respectively. The NDF and ADF were highest in *G. tembensis* and *G. bicolor* while lowest values were in *A. nilotica* and *A. seyal* in the dry season, respectively. During the rainy season *G. tembensis* had highest NDF (750 g/kg DM) and lowest was in *A. nilotica* (128 g/ kg DM). The ADF ranged from 84 to 347g/ kg DM in *A. nilotica* and Maracaa, respectively. The IVDMD among the browse varied from 0.965 to 0.718 and 0.974 to 0.676 in the dry and rainy seasons, respectively. In grass species CP was low (57–84 g/kg DM) compared to browse species. The NDF ranged from 728 to 749 g/kg DM and from 673 to 709 g/kg DM in dry and rainy seasons, respectively. The highest (654) and lowest (405) ADF values were recorded for *C. ciliaris* and P. *mezianum* in the dry season while the IVDMD was higher (0.698–0.811) in the rainy season compared to the dry season (0.577–0.620). The *in sacco* DM degradability was highest for *A. nilotica* throughout the incubation time followed by *B. aegyptiaca* and lowest was in *C. aucheri*. The browse species had high feed potential based on chemical and digestibility/degradability values recorded in this study while grasses could be considered as moderate.

Key words: Borana pastoralists; Digestibility; Hot dry season; Main rainy season

1. Introduction

The Ethiopian lowlands are situated below 1500 m above sea level and comprise about 61% of the national land area. The Borana rangelands of southern Ethiopia covers about 95,000 km^2 and it is predominantly inhabited by the Borana pastoralists (Coppock, 1994). The Borana pastoral system has traditionally been based on cattle husbandry for wealth accumulation and milk production while small ruminants provide quick cash income (Desta and Coppock, 2004). The Borana rangelands support livestock that are valuable as sources of food and cash income for the pastoral and agropastoral communities. They are source of foreign currency earnings for the nation and cattle are particularly important to provide draught power for smallholders in the highlands (McCarthy, *et al.,* 2002).

Cossins and Upton (1987) described the Borana rangeland as one of the most productive systems of traditional pastoral lands in East Africa, which supports diverse valuable vegetation. The dominant herbaceous plants in the study area are perennial grasses which include *Cenchrus, Cynodon, Themeda, Pennisetum, Entropogon, Bothriochloa, Brachiaria, Sporobolus, Panicum, Chloris, Aristida, Dactyloxenium, Leptothrium, Heteropagon* and *Hyparrhenia* (Coppock, 1994). Browse constitutes substantial amount of the diet of goats, camels and sheep in the Borana rangelands (Coppock, 1994) and a similar trend is observed in other arid and semi-arid regions of Ethiopia. Trees and shrubs (browse) are important sources of fodder for livestock in the tropics and dry environments and withstand harsh climatic conditions better than herbaceous species (Silanikove *et al.*, 1996a). Browse species maintain their green leaves longer into the dry season (Coppock, 1994; Tolera et al., 1997) and are known to supply better crude protein (CP) and minerals (Coppock, 1994; Kadzere, 1995). According to Coppock (1994) the most common woody genera in the study area include: *Acacia, Commiphora, Combretum, Cordia, Terminalia, Aspilia, Albizia, Juniperus, Rhus, Boscia, Boswellia, Cadaba, Balanites, Salvadora, Dobera, Pappea, Grewia, Delonix* and *Boswellia* spp. Gemedo *et al.* (2006) reported a total of 327 plant species in Borana lowlands among which 118 species were identified as useful forage plants.

However, the widespread encroachment of woody plants in the Borana rangelands has become a serious concern of the pastoralists, researchers and development workers in the area. According to Angassa (2007) 83% of the Borana rangelands have been threatened by a combination of bush encroachment and invasion by unpalatable forbs while only 17% of the rangelands were free from either bush encroachment or invasion by unpalatable forbs. This situation has negative impact on herbaceous growth and biomass production. In support of the above statement, the report of Van Wijigaarden (1985) reveals that in savanna ecosystem of East Africa an increase in bush cover by 10% reduces grazing by 7%. The grazing capacity could be lost entirely when bush cover reaches 90%.

Due to the change in vegetation, the composition of livestock species in the area is changing. Desta and Coppock (2000) reported increasing number of browsers like camels in Borana pastoral system in response to increased woody plants though the Borana are traditionally cattle pastoralists. The population of small ruminants and particularly that of goats is believed to increase in recent years (personal communication with pastoralists). While it is critical to maintain the balance of the ecosystem in the Borana rangelands to sustain the pastoral production system, it is important to utilize the wide range of woody and herbaceous plants as sources of forage. The availability and quality of the different browse and grass species is believed to vary from season to season due to marked seasonality in rainfall distribution that affects the growth and development of the plant species, particularly that of the grasses and other herbaceous species. Therefore, the present study was undertaken to evaluate the seasonal variations in nutritive value of some important native browse and grass species in the area.

2. Materials and methods

2.1. Description of study area

The study was conducted in Dirre and Yabello districts of Borana zone, Oromia National Regional State, southern Ethiopia. The area receives bi-modal rainfall, with the main rains (*ganna*) falling between March and May, and short rains (*hagayya*) falling between October and November (Cossins and Upton, 1987) followed by the hot dry season (*bona hagayya*). The cool dry season (*adolesa*) comes after the main rains between June and August. However, the actual length of the rainy season is getting shorter and shorter through time and the area is prone to more frequent drought (Tolera and Abebe, 2007).

2.2. Sampling, sample preparation and chemical analysis

Sampling of forage material was conducted in two major seasons, hot dry and main rainy seasons. Four sites were selected in the above mentioned two districts which included two ranches and two communal grazing lands in four pastoral associations[1]. Four transects were constructed in each site and it covered areas between 1350 to 1780 m above sea level. Transects were about 1.5 km in length and sampled at 50 m interval. The leaves of the selected browse species were hand plucked when available along transects while grass samples were harvested at about 5 cm above the ground. Samples were air dried until transported to laboratory.

The forage samples collected were oven-dried at 50^0C for 72 h and ground to pass through 1 mm sieve for chemical analysis and *in vitro* digestibility and 2 mm sieve size for *in sacco* degradability study. The ground samples were kept in air-tight containers until used for analysis. The determination of dry matter (DM), ash and nitrogen (N) was done according to AOAC (1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analyzed following the procedure of Van Soest and Robertson (1985).

[1] Smallest administrative unit in pastoral areas

Digestion was undertaken using ANKOM Fibre Analyzer^{220} (ANKOM Technology 05/03, Macedon, NY USA) using F57 ANKOM filter bags. Condensed tannins was analyzed according to Maxson and Rooney (1972).

2.3. *In vitro* dry matter digestibility (IVDMD)

The IVDMD was determined following the procedure of Van Soest and Robertson (1985). Feed samples were incubated in Daisy Incubator (ANKOM Technology 05/03, Macedon, NY USA) using F57 ANKOM filter bags and subsequent digestion was carried out in ANKOM Fibre Analyzer^{220}. Rumen fluid used in this study was obtained from two rumen fistulated sheep fed 600 g Rhodes grass (*Chloris gayana*) hay; 200 g fresh alfalfa (*Medicago sativa*) and 200 g concentrate mixture on daily basis in two equal portions.

2.4. *In sacco* degradability study

To determine the *in sacco* DM degradation and degradability characteristics of feed samples, about 2.5 g feed sample in nylon bags were incubated in the rumen of three rumen-fistulated sheep. The sheep were kept in individual pens and fed 600 g Rhodes grass hay; 200 g fresh alfalfa and 200 g concentrate mix daily in two equal portions. Clean drinking water was provided everyday. Nylon bags were withdrawn at 4, 8, 16, 24, 72 and 96 h of incubation and immediately rinsed in tap water. This was followed by machine washing in three cycles which lasted 15, 10 and 5 minutes. The 0 h measurement was obtained by washing and drying duplicate bags with samples which were not incubated in the rumen. The data were fitted to the exponential equation $p = a+b(1-e^{-ct})$ of Ørskov and McDonald (1979), where p is DM degradation at time t. Since the washing loss (A) was higher than the estimated rapidly soluble fraction (a), the lag time was estimated according to McDonald (1981) by fitting the model $p = A$ for $t \leq t_0$, $p = a+b(1-e^{-ct})$ for $t>t_0$ and the degradation characteristics of the forage samples were defined as A= washing loss (represents the soluble fraction of the feed); B = (a+b)-A, representing the insoluble but slowly degradable fraction; c = the rate of degradation of B and the lag phase (L) = (1/c)loge[b/(a+b-A)] (Ørskov and Ryle, 1990). Potential degradation (PD) was estimated as (A+B), while effective degradability (ED) of DM calculated according to Dhanoa (1988) using the formula ED = A+ [Bc/(c+k)] at rumen outflow rates (k) of 0.05 h^{-1}.

2.5. Statistical analysis

Analysis of variance was carried out on chemical composition, IVDMD and *in sacco* degradability using General Linear Model procedure of Statistical Analysis System (SAS, 2001). The model included the effects of species, season and their interaction.

3. Results

3.1. Chemical composition and IVDMD of browse species

Chemical composition and IVDMD of the browse species are presented in Table 1. The chemical composition of the browse species, except the ADF content, was influenced by both the species of the plants and the season while the ADF content and IVDMD were not influenced (P>0.05) by season. Among the browse species total ash content was lowest in *Acacia nilotica* both in dry (60 g/kg DM) and rainy (42 g/kg DM) seasons while the highest was recorded for *Grewia tembensis* (114 g/kg DM) in the wet season. The CP content of the browse species ranged from 109 g/kg DM in *Rhus natalensis* to 210 g/kg DM in *Acacia seyal* in the dry season and corresponding values for rainy season ranged from 134 to 196 g/kg DM in *R. natalensis* and *Acacia brevispica*, respectively. The CP content of the browse species, except for *A. seyal*, was higher in the rainy season than in the dry season. A very wide variation was recorded in condensed tannins (CT) concentration between the browse species within the seasons. It ranged from 1.18 g/kg DM in *Balanites aegyptiaca* to 196 g/kg DM in *R. natalensis* in the dry season. In the rainy season, *G. tembensis* and *B. aegyptiaca* had the lowest (2 g/kg DM) while *Acacia tortilis* had highest (332 g/kg DM). A higher concentration of CT was recorded in the rainy than in the dry season for most of the browse species except *G. bicolor* and *G. tembensis*.

The NDF content of the browse species varied between species and seasons (P<0.05). The highest NDF content was recorded for *G. tembensis* in the dry and rainy seasons while *A. nilotica* had lowest in both seasons. In both dry and rainy seasons, *Acacia brevispica, A. nilotica* and A. *tortilis* had lower NDF contents while *B. aegyptiaca, G. bicolor, G. tembensis* and *R. natalensis* had relatively higher NDF contents. In the dry season, the lowest ADF contents were recorded for *A. seyal* followed by *A. nilotica* and highest value was recorded for *G. bicolor.* In the rainy season as well *A. nilotica* and *A. seyal* had the lowest ADF content while *Maracaa* had the highest. The IVDMD ranged from 0.718 in *G. bicolor* to 0.965 in *A. nilotica* in the dry season. *Grewia tembensis* had the second highest (0.921) IVDMD next to *A. nilotica*. In the rainy season, the highest IVDMD was in *A. nilotica* (0.975) followed by *Vernonia cinerascens* (0.934) while the lowest values were recorded for *G. bicolor* (0.676) and second lowest *Maracaa* (0.741).

3.2. Chemical composition and IVDMD of grass species

The chemical composition and IVDMD of the grass species are presented in Table 2. The ash content varied from 108 g/kg DM in *Pennisetum mezianum* to 133 g/kg DM in *Cenchrus ciliaris* in the dry season while in the rainy season, the ash content varied from 120 g/kg DM in *P. mezianum* to 128 g/kg DM in *C. ciliaris* although the differences were not significant. The total ash recorded for grass species were higher than for browses except for *G. tembensis*. The CP content of the grass species was lower than those recorded for the browse species (Table 1) in both seasons. The lowest CP was in *P. mezianum* (57 g/kg DM) in the rainy season while the highest was in the dry season for *Chrysopogon aucheri* (84 g/kg DM).

The NDF content of the grass species varied from 673 g/kg DM in *C. ciliaris* in the rainy season to 749 g/kg DM in same species in the dry season. The ADF content varied from 405 to 654 g/kg DM in the dry season. *Pennisetum mezianum* had the lowest IVDMD in both seasons while *C. aucheri* and *C. ciliaris* had the highest in the dry and rainy seasons, respectively. Generally the IVDMD of the grass species was lower than that of the browse species except for *G. bicolor* and *Maracca*.

3.3. *In sacco* dry matter degradability of forage species

The dry matter disappearance of five forage species (four browse and one grass species) during the dry and rainy seasons at different incubation time are presented in Figure 1 and 2. Significant variations were observed in DM degradability between the species throughout incubation time. *Acacia nilotica* had the highest degradability values followed by *B. aegyptiaca* at all incubation time during both seasons while *C. aucheri* had the lowest values. DM degradability of browse in dry season was higher than the corresponding values in the rainy season up to 24 h incubation time. After 48 h incubation time *A. nilotica* and *B. aegyptiaca* had higher degradability in the rainy season compared to values in dry season while *R. natalensis* attained higher value at after 96 h in rainy season. Among the browse, *G. bicolor* had the lowest (0.634) DM degradability value.

Table 3 presents DM degradability at 48 h incubation time and degradability characteristics during the dry and rainy seasons. During the dry season DM degradability after 48 h incubation ranged from 0.810 to 0.417 in *A. nilotica* and *C. aucheri*, respectively. The washing loss varied between 0.166 in *C. aucheri* to 0.427 in *A. nilotica*. The values for the insoluble, but fermentable, fraction (B) ranged from 0.385 in *C. aucheri* to 0.484 in *R. natalensis*. *Chryospogon aucheri* scored lowest potential (A+B) and effective degradability (ED) values (0.548; 0.309), respectively while the highest values were recorded for *A. nilotica* (0.843; 0.665) for both parameters. The rate constant c was highest in *B. aegyptiaca* (0.089) and lowest in *R. natalensis* (0.020). The lag phase ranged from 3.092 to 0.169 in R. *natalensis* and *C. aucheri*, respectively.

During the rainy season, DM degradability after 48 h incubation varied from 0.512 in *C. aucheri* to 0.837 in *A. nilotica*. The second lowest value was recorded in *G. bicolor* (0.529) whereas *B. aegyptiaca* had the second highest value after *A. nilotica*. It is important to note that *A. nilotica* had the highest DM degradability in both season followed by *B. aegyptiaca*. The washing loss (A) was highest in *B. aegyptiaca* (0.434) and lowest in *C. aucheri* (0.204). *Rhus natalensis* and *B. aegyptiaca* had the highest and lowest insoluble fraction, respectively. The potential degradability varied from 0.871 in *R. natalensis* to 0.625 in *C. aucheri* while effective degradability was highest in *A. nilotica* and lowest in *C. aucheri*. The rate constant was similar for *A. nilotica* (0.0789) and *B. aegyptiaca* (0.0791) but lowest in *G. bicolor*. The lag phase was highest in *R. natalensis* (5.067) followed by *G. bicolor* (2.117).

4. Discussion

4.1. Chemical composition

Several factors which include species, plant part, stage of maturity and climatic variables affect the nutritive value of forages. The wide variation in chemical composition between browse and grass species was as expected. The CP content of browses was high as compared to grasses in both seasons in this study. Most browse species have the ability to maintain their greenness and nutritive value through the dry season when grasses dry up and deteriorate both in quality and quantity (Tolera *et al*., 1997). However the CP values of browse species in this study are lower than values reported by Abdulrazak *et al.* (2000), Woodard and Coppock (1995) and Gemedo (2004) with only few comparable values. Variations in CP content between the browses may result from differences in protein accumulation in them during growth (Salem *et al.,* 2006). In Sahelian and Sudanian areas of West Africa variation in CP was estimated to range between 100 and

206 g/kg DM (Breman and Kessler, 1995). In the present study none of the browse species fell below this low margin as opposed to grass species. The low CP content of grasses reported in this study agrees with reports of Woodward and Coppock (1995) for herbaceous species and Berhane and Eik (2006) and Yayneshet *et al.* (2009) for grasses although the magnitude is not same.

The total ash values reported for browse species in current study are slightly lower than the values reported by Gemedo (2004) which may be due to differences in soil from areas samples were harvested. Browses had lower ash value than the values recorded for grasses in this study. The individual mineral elements that are supplied by a given feed are more important than just total ash. Therefore it is important to further investigate the mineral content of browses in the study area.

A very wide variation in CT content was recorded in this study between browse species. The variation ranged from 1.18 in B. *aegyptiaca* in the dry season to 332 g/kg DM in *A. tortilis* in rainy season. Concentration of tannins can vary widely between and within species. The growth stage and part of the plant and management conditions have impact on tannin concentration. Moreover, environmental factors may influence synthesis of tannins (Hagerman, 1988; Roberts *et al.,* 1993). Furthermore, several factors are known to have significant effect on condensed tannin analysis. Such factors include initial harvesting, drying and extraction method of the forage material. The variation within species in condensed tannin concentration can be over at least a 4 to 6 fold range depending on plant provenance (Schofield *et al.,* 2001). Abdulrazak *et al.* (2000) reported a very low TCT (total condensed tannin) values for *A. brevispica, A. nilotica, A. seyal* and *A. tortilis* than the values obtained in the present study. However, the trend was similar in both studies that *A. brevispica* had the lowest concentration followed by *A. nilotica, A. seyal* and *A. tortilis*. Max *et al.* (2007) reported CT content of *A. tortilis* (307.4 g/kg DM) in the wet season which is quite similar with value reported in this study for same species in rainy season. The values reported by Larbi *et al.* (1998) for multipurpose tree and shrubs are also in agreement with the present report. The variation in CT content between seasons observed in this study is consistent with reports of Max *et* *al.* (2007) and Larbi *et al.* (1998). Contents of CT were higher in wet season than in dry season although there are some inconsistencies.

Fibre in forages is considered as the major source of energy for ruminant animals (Graham and Åman, 1991). The mean NDF value for the individual browse species reported in this study is lower than the values reported by Larbi et al. (1998), Merkel *et al.* (1999) and Gemedo (2004) except for *G. tembensis*. However there is similarity with values reported by El hassan *et al.* (2000), Abdulrazak *et al.* (2000), Yayneshet *et al.* (2009) and Tefera *et al.* (2008). The NDF value reported by Tolera *et al.* (1997) for the introduced multipurpose tree into Ethiopian highlands, Tagasaste (*Chamaecytisus Palmensis*), favorably compares with present report. The ADF values in this study agree with previous reports of Merkel *et al.* (1999) Abdulrazak *et al.* (2000), Yayneshet *et al.* (2009) and Tefera *et al,* (2008). Higher NDF and ADF values were recorded for grasses compared to the browse species in this study. Similar values have been reported by Yaynshet *et al.* (2009). Coupled with low CP content particularly during the dry season, such high fibre content may impair digestibility and voluntary intake by ruminants. Digestibility of fibre is an important parameter of forage quality.

4.2. *In vitro* dry matter digestibility (IVDMD)

The IVDMD values recorded in this study are generally higher for browse species as compared to grasses. This could be due to high CP and low fibre content in browse species. This phenomenon is particularly important in the dry season. The values reported by Yaynshet *et al.* (2009) for browse is consistent with the present study while the values for grasses in the dry season are lower. The report of Woodward and Coppock (1995) on browse and herbaceous species agrees with the present data although some inconsistencies exist. When the overall IVDMD is considered browse species will be in the decreasing order of: *A. nilotica, Vernonia cinerascens, A. seyal, A. tortilis, G. tembensis, B. aegyptiaca, R. natalensis, A. brevispica, Maracaa* and *G. bicolor*. However, this rank may not hold when the real situation in Borana area is taken into consideration.

Fruits from *A. tortilis* and *A. nilotica* are highly appreciated and regarded as valuable feeds by Borana pastoralist but the leaves of these trees including *A. seyal* are not on top list. In semiarid areas like Borana lowlands where drought is frequent, feed availability during such times is critical. G*rewia tembensis* and *V. cinerascens* are among top forages (both from this data and pastoralists knowledge) but their abundance and availability during dry periods may limit their contribution. On the other hand, *R. natalensis* which is considered as less nutritious and has moderate digestibility value could provide large proportion of forage consumed by goats and camels in the dry season. Woodward and Coppock (1995) reported high selection by goats for this species during the dry season. It is also one of the forages fed to kids during the dry season. Nutritive value is dependant on voluntary feed intake by the animal and the efficiency by which the animal extracts nutrients from the feed during digestion process (Mandal, 1997).Therefore, such results from laboratory should be combined with animal experiments and indigenous knowledge of pastoralists.

4.3. *In sacco* degradability study

The *in sacco* degradability was carried out for four browse and one grass species. The large variation in ruminal degradation recorded for *A. nilotica* and *B. aegyptiaca* during both seasons compared to other species could be attributed to their CP and fibre contents. The grass species which had very low soluble fraction and slow degradation rate for the insoluble fraction scored the lowest value during both seasons. Dry matter degradability value reported for *A. nilotica* by Abdulrazak *et al.* (2000) was extremely low than in the present study. This difference could be due to low soluble fraction and rate of degradation of the insoluble fraction and high fibre content recorded for this specie in their study which could be also amount of twigs and fine stems included. However, DM degradability reported for *Acacia nubica* in their study compares with that of *A. nilotica* and *B. agyptiaca* in the present study. The high dry matter degradability of *A. nilotica* and *B. agyptiaca* in the present study could be attributed to the high soluble fraction, potential degradability and rate of degradation of the insoluble fraction. *Rhus* *natalensis*, on the other hand, with high potential degradability like *A. nilotica* and *B. aegyptiaca* had low degradability due to its low degradation rate of the insoluble fraction and prolonged lag phase. The dry matter degradability reported by Balogun *et al.* (1998) for *Albizia lebbeck, A. richardiana* and *Combretum apiculatum* are comparable to the values reported for *G. bicolor* in the present study while *Leucaena leucocephala* had similar dry matter degradation with that of *R. natalensis*. The high to medium dry matter degradability of browse species in the present study suggests that they are of great value as livestock feed in the dry environments of the country. On the other hand, Balogun *et al.* (1998) reported very high dry matter degradability (81.6/83.2) for *Panicum maximum* which contrasts with value for *C. aucheri* in our study. This may be attributed to genetic differences, maturity level and proportion of leaf to stem and management conditions.

5. Conclusion

The browse species evaluated have good potential as livestock feed and particularly as supplement for low quality roughages during the dry season. The grass species also showed to have moderate potential based on their digestibility values. However, the results need to be further confirmed in animal experiments whether the potential could be translated into animal performance. The wide range of woody species available in the region should be utilized to increase livestock production while undertaking some bush control measures to maintain the balance between the woody and the herbaceous species.

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Table 1
Chemical composition and IVDMD of some browse species in the Borana rangeland during the hot dry and main rainy seasons

Species by season	Chemical components (g/kg DM)						
	DM (g/kg)	Ash	CP	CT	NDF	ADF	IVDMD (Coef.)
Hot dry Season							
Acacia brevispica	937	65	172	83	483	257	0.808
A. nilotica	937	60	132	110	168	111	0.965
A. seyal	919	73	210	121	171	109	0.948
A. tortilis	917	66	144	182	219	160	0.908
Balanites aegyptiaca	937	108	137	1.18	346	249	0.843
Grewia bicolor	935	89	146	136	436	277	0.718
G. tembensis	922	95	160	79	574	243	0.919
Rhus natalensis	925	108	109	196	331	272	0.853
Main rainy Season							
Acacia brevispica	938	61	196	105	318	191	0.818
A. nilotica	944	42	154	114	128	84	0.974
A. seyal	936	78	158	210	230	153	0.914
A. tortilis	931	62	177	332	217	154	0.886
Balanites aegyptiaca	935	112	160	2	459	250	0.846
Grewia bicolor	935	78	155	110	517	288	0.676
G. tembensis	924	114	195	2	750	281	0.889
Rhus natalensis	943	77	134	253	460	312	0.825
Vernonia cinerascens	939	84	144	3.36	462	251	0.933
Maracaa[1]	935	86	136	5.42	444	347	0.736
SEM	0.2903	5.1432	7.6847	17.9565	37.0855	19.6891	0.0158
Species	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Season	<0.0001	0.0938	0.0009	0.0072	0.0364	NS	NS
Interaction	<0.0001	<0.0001	0.008	0.0001	0.0006	0.0004	NS

[1]=Local name; DM = dry matter; CP = crude protein; CT = condensed tannins; NDF = neutral detergent fibre; ADF = acid detergent fibre; IVDMD = in vitro DM digestibility; NS = not significant; Coef. = Coefficient

Table 2
Chemical composition and IVDMD of three grass species in the Borana rangelands during the hot dry and main rainy seasons

Species by season	DM g/kg	Chemical component (g/kg DM)				IVDM D (Coef.)
		Ash	CP	NDF	ADF	
Hot dry season						
Cenchrus ciliaris	926	133	83	749	654	0.597
Chrysopogon aucheri	930	126	84	728	481	0.620
Pennisetum mezianum	927	108	80	732	405	0.577
Main rainy season						
Cenchrus ciliaris	923	128	72	673	504	0.811
Chrysopogon aucheri	926	126	82	709	555	0.715
Pennisetum mezianum	911	120	57	705	573	0.698
SEM	0.2058	10.8730	3.0161	9.0126	35.3196	0.0202
Species	0.0070	NS	0.0004	NS	0.0678	0.0276
Season	0.0116	NS	0.0001	<0.0001	Ns	<0.0001
Interaction	NS	NS	0.0057	0.0015	0.0005	0.0039

DM = dry matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; IVDMD = in vitro DM digestibility; NS = not significant; Coef. = coefficient

Table 3
DM disappearance (DMD) from nylon bag after 48 h incubation and DM degradability characteristics of some selected forage plants in Borana rangeland during hot dry and main rainy seasons

Species by season	DMD 48 h	A[b]	B[c]	A+B[d]	c[e]	L[f]	ED[g]	RSD[h]
Hot dry season								
Acacia nilotica	0.810	0.427	0.416	0.843	0.0737	0.592	0.665	1.6667
Balanites aegyptiaca	0.778	0.413	0.388	0.828	0.089	2.238	0.641	1.5050
Grewia bicolor	0.567	0.294	0.404	0.696	0.035	0.776	0.429	1.4257
Rhus natalensis	0.597	0.332	0.484	0.816	0.0207	3.092	0.453	1.5045
Chrysopogon aucheri	0.417	0.166	0.385	0.548	0.0273	0.169	0.309	8.4795
Main rainy season								
Acacia nilotica	0.837	0.414	0.454	0.868	0.0789	0.6704	0.676	1.619
Balanites aegyptiaca	0.784	0.434	0.404	0.842	0.0791	2.117	0.635	1.4788
Grewia bicolor	0.529	0.263	0.464	0.729	0.024	2.198	0.389	1.766
Rhus natalensis	0.591	0.335	0.540	0.871	0.017	5.067	0.441	1.762
Chrysopogon aucheri	0.512	0.204	0.421	0.625	0.0390	0.9345	0.370	1.2484
S.E.M[a]	1.1029	0.5866	1.774	1.829	0.0055	0.549	0.841	
Species	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	
Interaction	<.0001	<.0001	NS	NS	NS	NS	<.0001	

NS= not significant
a Standard error of the means
b Washing loss
c Insoluble but fermentable fraction
d Potential degradability
e Rate of degradation of B (fraction/h)
f Lag phase (h)
g Effective degradability at an outflow rate of $0.05h^{-1}$
h Residual standard deviation

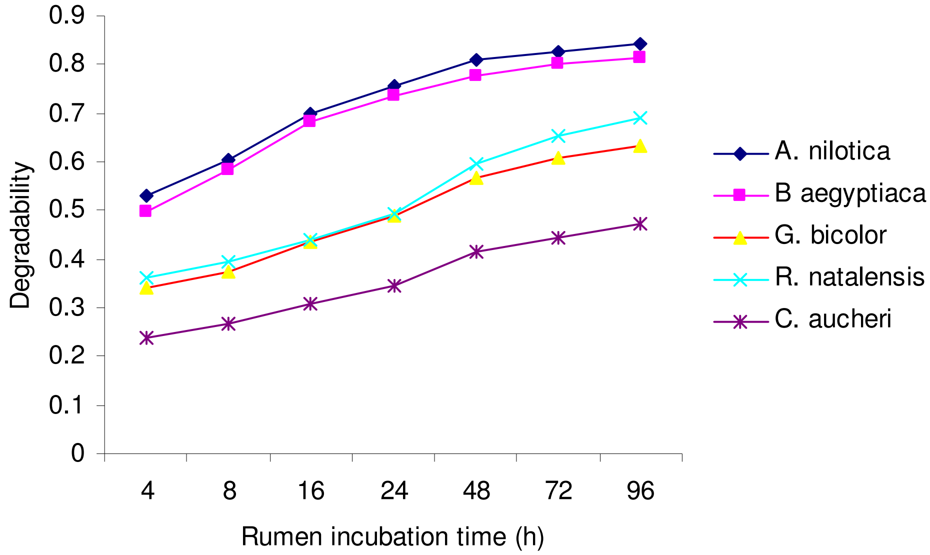

Figure 1: DM disappearance of forage samples taken in the hot dry season at different rumen incubation times

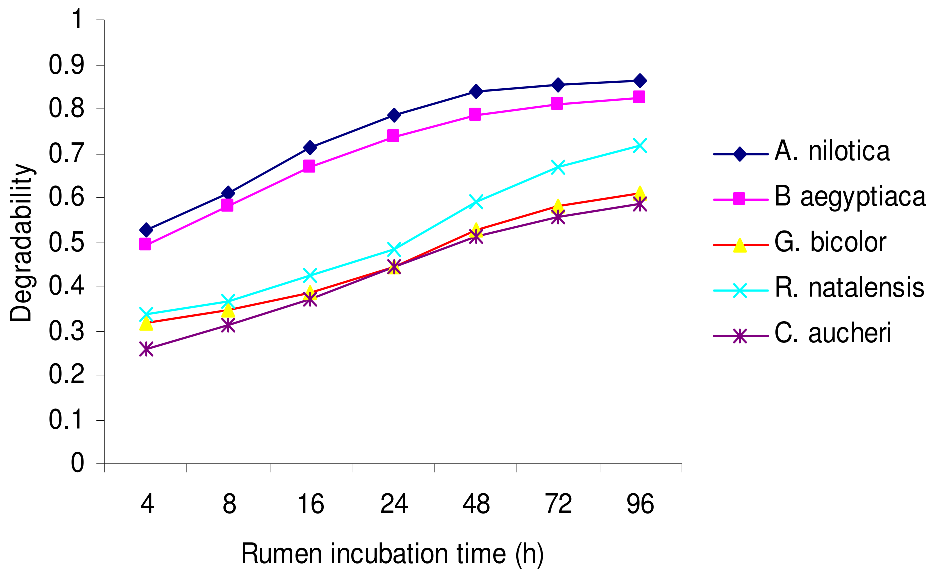

Figure 2: DM disappearance of forage samples taken in the main rainy season at different rumen incubation times

Paper II

Feed intake, digestibility, nitrogen balance and body weight change of Borana goats fed grass hay supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol addition

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Abstract

An experiment was conducted to evaluate the effect of supplementation with *Acacia brevispica* or *A. seyal* leaves with or without polyethylene glycol (PEG) addition on feed intake, digestibility, nitrogen balance and body weight gain of yearling Borana goats fed Rhodes grass (*Chloris gayana*) hay as basal diet. The hay was prepared from semi-cultivated pasture while Acacia leaves were collected from Borana rangeland in southern Ethiopia and air dried under shade. All animals were offered 600 g grass hay, 300 g Acacia leaf and 100 g concentrate mixture both during growth and digestibility experiments. Additionally feeding one of Acacia types and no or 7 g PEG led to four treatment groups: hay + *A. brevispica* + concentrate + PEG (T1), or without PEG (T2), hay + *A. seyal* + concentrate + PEG (T3) or without PEG (T4). Addition of PEG did not affect feed intake, nitrogen (N) intake, N excreted, N retained and average daily gain. However, CP digestibility, rumen ammonia-N concentration and urinary N excretion were higher ($P<0.05$) for goats receiving PEG. The type of Acacia leaves supplemented significantly affected DM and OM intake, rumen ammonia-N concentration as well as route of N excretion. Goats supplemented with *A. seyal* had higher ($P<0.05$) intakes of DM and OM compared to *A. brevispica* supplemented goats. Urinary N excretion was also significantly higher ($P<0.05$) in goats supplemented with *A. brevispica* while *A. seyal* supplemented goats lost more N in faeces. Nitrogen retention and average daily gain were higher ($P<0.05$) for *A. seyal* supplemented goats. The results of the experiment show that PEG had little effect in improving the performance of goats supplemented with tanniniferous foliage. *Acacia seyal* was found to be superior to *A. brevispica* in terms of feed intake, nitrogen retention and average daily gain.

1. Introduction

The dry areas in African and Middle Eastern countries are not suitable for crop production but can be used for extensive livestock production (Degen et al., 2010). Goats are well adapted to arid and semiarid environments and utilize a wide range of vegetation available in such areas. The arid and semiarid areas are characterized by long dry period, erratic rainfall and drastic changes in availability of resources (Silanikove, 2000). Most of the world's goat population is found in these areas. In Ethiopia, more than half of the goat population is located in the arid and semiarid agroecological zones under pastoral and agropastoral production systems. They are kept mainly for meat and milk production as well as to generate cash income for immediate use. The Borana rangeland in southern Ethiopia is among the major suppliers of goats for export as live goats and goat meat and also supplies domestic markets.

Coppock (1994) noted an increasing trend in population of goats, sheep and camels in Borana rangeland primarily due to expansion of woody vegetation in the area at the expense of grasses. Most shrubs and trees have ability to tolerate drought (Woodward and Reed, 1989) and can maintain their green leaves long into the dry season while grasses become poor in nutritive quality faster and less abundant (Tolera et al., 1997). The foliages of shrubs and trees are important as sources of nitrogen to enhance the nutritive value of low quality feeds such as mature grasses and crop residues (Tolera et al., 1997; Woodward and Reed, 1997). On the other hand, the foliages of most shrub and tree species contain tannins and other phenolic compounds which are known to reduce their feeding value. Tannins have multiple phenolic hydroxyl groups in their structure which enable them to form complexes mainly with proteins and to some extent with metal ions, polysaccharides and amino acids (Makkar, 2003). As a result, the use of many browse species as supplement to low quality roughages based diets may have limited impact on increasing the productivity of animals (Makkar et al., 1995). High tannins concentration in foliages reduce palatability (Goel et al., 2005), decreases voluntary feed intake, nutrient digestibility and nitrogen retention (Kumar and Vaithiyanathan, 1990; Silanikove et al., 1996a; Goel et al., 2005). However, several previous works showed that the negative effect of tannins could be neutralized by addition of polyethylene glycol (PEG) into diets of goats and sheep consisting browse leaves. In earlier studies conducted *in vivo* and *in vitro* (Jones and Mangan, 1977) and (Kumar and Vaithiyanathan, 1990), respectively reported an increase in the digestibility of tanniniferous feeds by addition of polyethylene glycol (PEG). There are reports suggesting use of PEG to treat tannin rich foliages to improve their nutritive values and animal productivity (e.g., Pritchard et al., 1992; Ben Salem et al., 1999; Gilboa et al., 2000; Bhatta et al., 2002). With this background the present study was conducted to investigate the feed intake, digestibility, nitrogen metabolism and growth performance of growing goats fed Rhodes grass (*Chloris gayana*) hay supplemented with *Acacia brevispica* or *A. seyal* leaves with or without PEG addition.

2. Materials and methods

2.1. Experimental animals and management

Thirty two yearling male Borana goats were used in the growth study (8 goats per treatment) and 16 out of the 32 were used in the subsequent digestibility trial (4 goats per treatment). The animals were purchased from the Borana pastoral area about 300 km south of Hawassa, where the experiment was conducted on station in the University farm. The mean initial weight of the animals was 15.1±1.47 kg. Goats were housed in individual pens equipped with feeding trough and watering bucket. They were vaccinated against sheep pox, anthrax and contagious caprine pleuro-pneumonia (CCPP) and treated against internal and external parasites. The animals were accustomed to experimental feed and facilities for two months before start of the experiment.

2.2. Experimental feeds

Rhodes grass (*Chloris gayana*) hay was used as a basal feed while two Acacia species (*Acacia brevispica* and *Acacia seyal)* and a concentrate mixture were used as supplements. The leaves of the two Acacia species were collected by hand plucking from Borana rangeland. The collected leaves were air dried under shade and stored in perforated bags in barn until transported to Hawassa. To ensure uniformity, leaves were mixed thoroughly before use. The Rhodes grass used for making hay was grown in Hawassa University campus, harvested and dried in the field for few days, chopped and stored in sacks in barn. Cutting of the grass for hay was delayed due to prolonged heavy rains experienced in the area. The concentrate mixture was prepared from 48% wheat bran, 24% maize, 25% noug (*Guizotia abyssinica*) cake, 1% common salt and 2% *bole* (locally produced mineral soil used as a mineral supplement).

2.2. Growth experiment

Each animal was offered 600 g hay, 300 g Acacia leaves (*A. brevispica* for treatments 1 and 2 and *A. seyal* for treatments 3 and 4) and 100 g concentrate mixture. In addition, animals in treatments 1 and 3 were given 7 g PEG per animal per day. Animals were offered the morning feed at 8:00 h after refusals from the previous day were collected while the second portion of the feed was offered at 13:00 h in the afternoon. The feeds were offered in the following sequence both during the morning and afternoon feedings: concentrate with or without PEG, Acacia leaves, and hay. Clean water was made available at all times. Body weight measurements were recorded fortnightly throughout the study period.

2.3. Digestibility experiment

Digestibility trial was carried out for seven days using 16 goats previously used in the growth experiment with four animals in each treatment. The feeds, amount and feeding management were similar to the growth study. Animals were kept in individual metabolic cages equiped with feeding trough and water bucket. The cages were convenient for collection of faeces and urine separately. Faeces were collected into faeces collection bags attached to each animal and every morning the faeces was emptied from the bags, weighed and 10% of total daily output was kept in deep freezer. A sample of faeces was also taken and oven dried at 105^0C for the purpose of determining DM content on daily basis. Urine was collected into glass bottles containing 100 ml of 10% HCl and every morning daily output was measured and 10% sample taken and stored in deep freezer. After the collection period, faecal and urine samples were pooled for each animal and sub-samples taken for chemical analysis. A portion of faecal samples was dried at 65^0C for 48 h for chemical analysis other than nitrogen. Faecal samples were ground to pass through 1 mm sieve size and kept in air-tight containers pending chemical analysis.

2.4. Chemical analysis

Dry matter content of feed, refusals and faeces were determined by oven drying the samples at 105^0C for 12 h. Total ash was determined by igniting samples in a muffle furnace at 550^0C for 5 h. Total nitrogen from feed, faeces and urine were analyzed by Kjeldahl method (AOAC, 1990). The crude protein content (CP) was calculated as N x 6.25. The frozen faeces samples, after thawing, were used for determination of nitrogen content. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest and Robertson (1985). Extractions were carried out by ANKOM 220 fibre analyzer (ANKOM Technology 05/03, Macedon, NY, USA) using F57 filter bags. Condensed tannin (CT) in the two Acacia species was analyzed according to Maxson and Rooney (1972). Ammonia nitrogen in rumen fluid was determined using a Kjeltic System Distilling Unit.

2.5. Statistical analysis

The general linear model (GLM) procedure of Statistical Analysis System (SAS 2003, version 9.1) was used to analyze mean feed intake, digestibility, ammonia nitrogen concentration, N retention and average daily body weight gain. The model included Acacia type, PEG and their interaction while initial body weight of the goats was used as covariate in the model. Duncan's multiple range test was used when there was significant difference between means.

3. Results

3.1. Chemical composition of experimental feeds

The chemical composition of feeds used in the experiment is presented in Table 1. The Rhodes grass hay was very low in CP but high in NDF and ADF contents. On the contrary, the Acacia leaves had high CP content but low NDF and ADF contents. The concentrate mixture had an intermediate CP and NDF contents compared to the grass hay and Acacia leaves. *Acacia seyal* had higher concentration of condensed tannins (CT) (142.8 g/kg DM) compared to *A. brevispica* (64.3 g/kg DM).

3.2. Feed intake

Addition of PEG to the diet of goats supplemented either with *A. brevispica* or *A. seyal* did not have significant ($p>0.05$) effect on DM, OM, CP or NDF intakes. On the other hand, significantly higher ($P<0.05$) DM and OM intakes were observed in goats supplemented with *A. seyal* leaves irrespective of PEG addition. However, Acacia type did not affect CP and NDF intakes significantly (Table 2).

3.3. Digestibility

Table 3 presents digestibility of DM, OM, CP and NDF. The digestibility of DM, OM, and NDF were not affected either by addition of PEG or by Acacia type supplemented. Digestibility of CP was higher ($P<0.05$) in goats supplemented with *A. brevispica* leaves than those supplemented with *A. seyal* leaves and it was higher ($P<0.05$) in diets to which PEG was added than diets without PEG. Addition of PEG increased CP digestibility from 0.60 to 0.66 while the digestibility of CP in *A. brevispica* leaves supplemented goats was higher (0.70) than those supplemented with *A. seyal* (0.56) leaves.

3.4. Rumen ammonia nitrogen concentration

Addition of PEG to the diet resulted in higher ($P=0.05$) NH_3-N concentration compared to diet without PEG (Table 4). Also Ammonia nitrogen (NH_3-N) concentration was higher ($P<0.05$) in *A. brevispica* supplemented goats than *A. seyal* supplemented goats (162.2 vs. 121.54 mg/L). The interaction between Acacia type and PEG was not significant. Figure 1 shows rumen NH_3-N concentration at different times of rumen fluid sampling where morning feeding was taken as a reference point. Ammonia nitrogen concentration increased from 0 h to 4 h after morning feeding and thereafter declined progressively through 8 h to 12 h after morning feeding.

3.5. Nitrogen balance

Table 5 shows nitrogen balance of goats fed a basal diet of grass hay and supplemented with *A. brevispica* or *A. seyal* leaves with or without PEG. Nitrogen intake, total nitrogen excreted and nitrogen retained were unaffected by addition of PEG to the diet. However, the nitrogen retention tended to be higher ($P=0.056$) for goats which did not receive PEG (3.2 g/day) as compared to those which were given PEG (1.6 g/day). Addition of PEG to the diet increased excretion of nitrogen in the urine while decreasing its excretion in the faeces. Nitrogen excretion in the faeces was higher (P<0.05) in goats supplemented with *A. seyal* leaves whereas goats supplemented with *A. brevispica leaves* excreted more nitrogen in the urine. Nitrogen retention was higher (P<0.05) in goats supplemented with *A. seyal* leaves than those supplemented with *A. brevispica* leaves (3.3 vs. 1.5 g/day).

3.6. Body weight change

Table 6 shows average daily body weight gain of goats fed a basal diet of grass hay and supplemented with *A. brevispica* or *A. seyal* with or without PEG. Body weight gain of goats was unaffected by addition of PEG to the diets. However, the type of Acacia supplement had significant effect (P<0.05) on daily body weight gain of the goats with higher value recorded for *A. seyal* supplemented goats compared to goats supplemented with *A. brevispica*.

4. Discussion

4.1. Chemical composition of experimental feeds

The low CP and higher fibre contents in the hay was due to the advanced stage of maturity of the grass at harvesting time. The CP content of the hay was similar to that of tef (*Eragrostis tef*) straw (tef is a staple cereal crop in Ethiopian highlands) reported by Reed et al. (1990), Woodward and Reed (1995) and Solomon et al. (2004). The grass was harvested at late maturity stage. It could not be harvested at earlier stage of maturity because of rainy weather prevailing in the area at the time the grass was supposed to be harvested. The CP content of the hay was below the minimum amount (7% CP) required for optimum function of rumen microorganisms. However, browse species such as Acacia are good sources of CP and certain minerals that are relatively low in grasses and herbaceous species. The CP content of *A. brevispica* and *A. seyal* in this study was similar to findings of Woodward and Reed (1995) and Reed et al. (1990), respectively and Abdulrazak et al. (2000) for both species. Moreover, the low fibre content of the Acacia species used in this experiment confirms their supplementary value to low quality roughages. On the other hand, presence of condensed tannins in browse species limits their contribution by reducing intake and digestibility of the feeds. The report of Abdulrazak et al. (2000) for CT concentration for the two Acacia species was far lower than our results. Such differences could be due to differences in method of extraction, stage of maturity of the leaves and climatic condition at time of sampling (Hagerman, 1988; Roberts et al., 1993). The concentrate mixture was used mainly as a means of providing PEG for treatment groups to which PEG was added, although all animals received same amount and benefited from relatively high CP and low fibre content of the concentrate mixture.

4.2. Feed intake

The lack of effect on DM and nutrient intake due to PEG addition in the diets of goats in the present study is in contrast to previous works reported by Prichard et al. (1992), Silanikove et al. (1996a), Moujahed et al. (2000) and Bhatta et al. (2005). However, it is in agreement with the works reported by Decandia et al. (2000) and Debela (2008). In their work, Decandia et al. (2000) reported no significant difference in lentisk (*Pistacia lentiscus* L.) and total diet intake between goats supplemented with 0, 25 and 50 g PEG/day/head. They argued that the allowance of metabolisable energy was higher than their requirement and that could explain why goats supplemented with PEG were not aimed at increasing their total intake of DM. However, they observed that goats with PEG supplement tended to consume forages with higher CT compared to those without PEG. In our study the goats used in the experiment were purchased from Borana rangeland area where they were free to forage various browse species of varying tannin contents. The Acacia leaves used as supplement were also collected from same area although the experiment was conducted in a different locality and setting. This could partly explain that these animals were familiar with tanniniferous diets and capable of utilizing tanniniferous foliages even in the absence of PEG. The report of Odenyo et al.

(1999) indicated that indigenous African ruminants might harbour more tannin-tolerant/tannin-degrading microorganisms compared to animals from different feeding strategies. Indigenous Ethiopian goats were among animals used in their study and the rumen fluid collected from the goats produced substantial amount of gas when used to incubate various feeds next to Gunther's dik-dik. On the other hand, a significant difference was observed for DM and OM intake between the Acacia types used as supplements. Despite the relatively low CP and higher CT concentration in *A. seyal*, it resulted in higher intake values. This reveals that nutritive value of forage may not be predicted by gross chemical composition alone (Reed et al., 1990).

4.3. Digestibility

The positive effect of PEG on CP digestibility in the present work is consistent with the work of Decandia et al. (2000) where goats supplemented with 25 and 50 g PEG per day had higher CP digestibility compared to those without PEG. According to Decandia et al. (2000), the increase in CP digestibility was 90 and 30 % for indoor and outdoor experiments, respectively. But the increase is far lower in the present work (0.60 to 0.66). The positive effect on CP digestibility due to addition of PEG in diets of goats is of greater importance than increased intakes. The lack of difference in DM, OM, and fibre digestibility in the presence of PEG observed in this study is contrary to the results of earlier studies reported by Silanikove et al. (1996a) and Moujahed et al. (2000). The higher CP digestibility of *A. brevispica* is consistent with its relatively higher CP content and low CT concentration compared to *A. seyal*.

4.4. Ammonia-N concentration

The mean NH_3-N concentration obtained in the present work is similar but slightly higher than previous works by Perez-Moldanado and Norton (1996) for *Desmodium* and *Calliandra* supplemented animals and by Tolera and Sundstøl (2000) for *Desmodium* *intortum* hay supplemented sheep. The values reported by Solomon et al. (2004) for *Sesbania sesban* (accession 1198 and 15019) and *Acacia angustissima* foliage supplemented animals favorably compares with this study but that of *Leucaena pallida* was far lower. Nevertheless the NH_3-N concentration in Acacia leaf supplemented goats in the current study was well above the minimum level (50 mg/L) required to ensure microbial growth and protein synthesis. The higher value observed for *A. brevispica* could be due to the low concentration of condensed tannins available to complex protein coupled with relatively high CP content compared to *A. seyal.* Even in the presence of PEG, the improvement in NH_3-N concentration in *A. seyal* was minimal and suggests that the type and amount of CT might be important aspects in deactivation process as a result of PEG-tannin complex formation. However, it is noteworthy that presence of PEG increased NH_3-N concentration in both Acacia species and that even adapted rumen microbes may not be able to fully deactivate the tannins in the diets.

The trend in the concentration of rumen NH_3-N at different sampling times in the present study agrees with the results reported by Solomon et al. (2004) for *Sesbania sesban* 1198, *Sesbania sesban* 1198 + *Leucaena pallida* 14203, *Sesbania sesban* 15019 + *Leucaena pallida* 14203, *Sesbania sesban* 1198 + *A. angustissima* 15132*, Sesbania sesban* 15019 + *A. angustissima* 15132 and wheat bran supplemented lambs fed tef straw as a basal diet. Such high NH_3-N concentration shortly after feeding and decline in the subsequent sampling times indicates inadequate energy availability during early hours for the rumen microorganisms to utilize the released NH_3-N. The high fibre content of the basal feeds requires more time for chewing and production of volatile fatty acids could be low at the early stage. Moreover, the presence of condensed tannins may affect negatively activity of some fibre degrading bacteria (Waghorn, 2008).

4.5. Nitrogen retention

Addition of PEG to the diets did not affect nitrogen intake and total nitrogen excreted but significantly affected the route of excretion. The high proportion faecal nitrogen loss in goats without PEG indicates that tannin-protein complexes formed in the rumen were not fully hydrolyzed in the lower tract and thus lost in the faeces. Whether the complex between protein and tannin dissociates or remains is determined by affinity of tannin for protein and other macromolecules (Makkar, 2003). On the other hand, low proportion of nitrogen lost in faeces of goats that received PEG could be as a result of complex formation between tannin and PEG making nitrogen available for rumen microbes and lower tract digestion and absorption. The opposite was observed when urinary nitrogen excretion is considered. Animals supplemented with PEG had higher nitrogen loss in urine. This could be explained by higher ammonia concentration in the rumen (Moujahed et al., 2005). Contrary to our results Decandia et al. (2000) did not find significant difference in urinary nitrogen excretion between goats that received 0, 25 and 50 g PEG daily. But goats with 50 g PEG had highest excreted nitrogen in urine followed by those receiving 25 g indicating the effect of PEG in the route of nitrogen excretion. Similarly Debela (2008) did not find significant differences in amount of nitrogen excreted in faeces and urine between goats with and without PEG.

Nitrogen retention did not differ significantly between PEG supplemented and un-supplemented animals although a relatively higher value was recorded for goats without PEG. This is not consistent with increased CP digestibility and NH_3-N concentration observed in goats supplemented with PEG. The benefits obtained by increased CP digestibility and NH_3-N concentration were not translated into tissue but rather excreted as a waste. The nutrients made available as result of addition of tannin deactivating compounds could be wasted without being utilized efficiently for microbial protein synthesis as a result of lag in energy released (Makkar, 2003). It is recommended that provision of supplement at appropriate time could enhance synthesis of microbial protein in such circumstances (Getachew et al., 2001). In agreement with present work Decandia et al. (2000) and Debela (2008) reported no significant difference in nitrogen retention between goats that received PEG or no PEG in their diet. Decandia et al. (2000) found relatively low nitrogen figures retained in goats receiving 50 g PEG than those given 25 g although the difference was not significant. In contrast to our results, Moujahed et al. (2000) reported significantly higher nitrogen retention in sheep fed *Acacia cyanophylla* foliage-based diet and given feed block containing PEG. This could probably be due to the fact that sheep are less adapted to browsing tanniniferous foliages and thus addition of PEG to the diet might have reduced the negative effect of tannin on digestion and absorption of protein.

The two Acacia species used as a supplement affected route of nitrogen excretion differently probably due to differences in the concentration and structure of condensed tannins present. *A. seyal* resulted in higher nitrogen retention despite high condensed tannin content. This indicates that tannins from different plants may have different detrimental effects on herbivores. Hagerman et al. (1992) have showed that structure and molecular weights of tannins are important in determining their biological activity.

4.6. Body weight change

Addition of PEG did not have significant effects on average daily gain of the experimental goats. All goats gained weight irrespective of presence or absence of PEG in the diet. Similar to our results, Bhatta et al. (2002), Bhatta et al. (2005) and Debela (2008) did not find differences in body weight gain between PEG supplemented and unsupplemented goats. However, the average daily gain reported by Debela (2008) was lower than the result obtained in this study whereas Bhatta et al. (2005) reported almost twice our results. On the other hand, a higher average daily gain was reported by Gilboa et al. (2000) in Mamber goats at mid-pregnancy and heavier birth weights and higher daily gain of kids born to PEG supplemented does compared to controls. Similarly Bhatta et al. (2004) reported higher weight gain when kids were given PEG compared to the controls and their performance was similar to kids given high protein diet. Results obtained with lambs are dramatic as sheep are generally known to be less adapted to browses than goats. Priolo et al. (2000) reported a threefold increase in weight gain in lambs supplemented with PEG compared to unsupplemented ones fed carob (*Ceratonia siliqua*) pulp while Ben Salem et al. (1999) observed 39 percent increase in daily gain of growing sheep fed PEG-treated *Acacia cyanophylla* Lind. leaves. Such contrasting results could be attributed to the difference in species (sheep vs. goats), breeds of goats, type and handling of tanniniferous feeds used in the different studies and environmental factors under which the experiments were conducted.

When the effect of Acacia type is considered *A. seyal* resulted in significantly higher daily gain than *A. brevispica*. This is consistent with higher nitrogen retained in *A. seyal* supplemented goats despite similar amounts of nitrogen ingested by the two groups. This seems unlikely when the chemical composition of the two species is taken into account. Based on a survey in the southern rangelands, Tolera and Abebe (2007) reported that *A. brevispica* is highly palatable and good for milk and butter production when consumed by lactating goats. However, they did not report whether the same holds true for growing animals.

5. Conclusion

The study revealed that addition of PEG did not have effect on daily body weight gain of goats although positive effects were seen in CP digestibility and NH_3-N concentration. It also showed the superiority of *A. seyal* over *A. brevispica* leaf supplements in terms of nitrogen retention and daily body weight gain. Further research in the range condition has to be conducted to support the present findings.

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Table 1

Chemical composition of feeds used in the experiment

Chemical component	Hay	*Acacia brevispica* leaves	*Acacia seyal* leaves	Concentrate mixture
DM (g/kg)	917.0	928.5	920.3	866.8
(g/kg DM)				
Ash	117.3	80.3	100.5	105.0
Organic matter	882.7	919.8	900.0	895.1
Crude protein	37.5	221.2	201.8	172.5
Neutral detergent fibre	726.4	322.1	244.1	404.4
Acid detergent fibre	419.0	204.5	162.9	184.7
Condensed tannins	nd*	64.3	142.8	nd*

* = not determined

Table 2
Feed intake of goats fed a basal diet of grass hay supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol (PEG) addition

Variable	Acacia leaf supplement	Presence or absence of (PEG)		Mean	S.E.
		With PEG	Without PEG		
Total DM intake	*Acacia brevispica*	506.0	510.0	508.0[b]	16.2
(g per head per day)	*Acacia seyal*	537.0	575.0	556.0[a]	16.1
	Mean	521.5	542.2		
	S.E.	16.4	15.8		
Total DM intake	*Acacia brevispica*	62.0	63.0	62.5[b]	1.7
(g/kg $W^{0.75}$ per day)	*Acacia seyal*	65.0	68.0	66.6[a]	1.7
	Mean	63.5	65.5		
	S.E.	1.7	1.6		
Total DM intake	*Acacia brevispica*	3.1	3.1	3.1[b]	0.08
(% of body weight)	*Acacia seyal*	3.2	3.4	3.3[a]	0.08
	Mean	3.1	3.3		
	S.E.	0.05	0.05		
OM intake	*Acacia brevispica*	443.0	449.0	446.0[b]	14.7
(g per head per day)	*Acacia seyal*	467.0	502.0	484.5[a]	14.6
	Mean	455.0	475.5		
	S.E.	14.9	14.3		
CP intake	*Acacia brevispica*	78.0	78.0	78.0	2.7
(g per head per day)	*Acacia seyal*	78.0	84.0	81.0	2.7
	Mean	78.0	81.0		
	S.E.	2.8	2.7		
NDF intake	*Acacia brevispica*	226.0	235.0	230.5	10.0
(g per head per day)	*Acacia seyal*	243.0	249.0	246.0	10.0
	Mean	234.5	242.0		
	S.E.	10.2	9.8		

Means with different letters within a row or column are significantly different ($P<0.05$).

Table 3
Dry matter and nutrient digestibility in goats fed a basal diet of grass hay and supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol (PEG) addition

Variable	Acacia leaf supplement	Presence or absence of Polyethylene glycol (PEG)			
		With PEG	Without PEG	Mean	S.E.
DM digestibility	*Acacia brevispica*	0.48	0.50	0.49	0.026
	Acacia seyal	0.45	0.51	0.48	0.026
	Mean	0.46	0.50		
	S.E.	0.025	0.025		
OM digestibility	*Acacia brevispica*	0.50	0.54	0.52	0.023
	Acacia seyal	0.52	0.58	0.55	0.023
	Mean	0.51	0.56		
	S.E.	0.022	0.022		
CP digestibility	*Acacia brevispica*	0.72	0.68	0.70[a]	0.017
	Acacia seyal	0.60	0.52	0.56[b]	0.017
	Mean	0.66[a]	0.60[b]		
	S.E.	0.016	0.016		
NDF digestibility	*Acacia brevispica*	0.32	0.40	0.36	0.039
	Acacia seyal	0.28	0.37	0.32	0.039
	Mean	0.30	0.38		
	S.E.	0.038	0.038		

Means with different letters within a row or column are significantly different (P<0.05).

Table 4
Effect of PEG on ammonia-N concentration (mg/L) in rumen fluid of goats fed a basal diet of grass hay and supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol (PEG) addition

Variable	Acacia leaf supplement	Presence or absence of Polyethylene glycol (PEG)			
		With PEG	Without PEG	Mean	S.E.
Ammonia-N	*Acacia brevispica*	173.3	152.5	162.9[a]	7.34
	Acacia seyal	133.4	109.7	121.5[b]	7.34
	Mean	153.4[a]	131.1[b]		
	S.E.	7.34	7.34		

Means with different letters within a row or column are significantly different (P<0.05).

Table 5
Nitrogen balance (g/day) in goats fed a basal diet of grass hay and supplemented with *Acacia brevispica* or *Acacia seyal* leaves with or without polyethylene glycol (PEG) addition

Variable	Acacia leaf supplement	Presence or absence of PEG			
		With PEG	Without PEG	Mean	S.E.
N intake	*Acacia brevispica*	11.2	10.4	10.8	0.61
	Acacia seyal	11.3	12.2	11.8	0.61
	Mean	11.3	11.3		
	S.E.	0.60	0.60		
N excreted in faeces	*Acacia brevispica*	3.2	3.4	3.3^{b}	0.25
	Acacia seyal	4.3	5.7	5.0^{a}	0.25
	Mean	3.8^{b}	4.5^{a}		
	S.E.	0.24	0.24		
N excreted in urine	*Acacia brevispica*	7.8	4.2	6.0^{a}	0.63
	Acacia seyal	4.1	2.9	3.5^{b}	0.63
	Mean	5.9^{a}	3.6^{b}		
	S.E.	0.62	0.62		
Total N excreted	*Acacia brevispica*	11.0	7.6	9.3	0.78
	Acacia seyal	8.3	8.6	8.5	0.78
	Mean	9.7	8.2		
	S.E.	0.77	0.77		
N retained	*Acacia brevispica*	0.16	2.7	1.5^{b}	0.55
	Acacia seyal	3.0	3.7	3.3^{a}	0.55
	Mean	1.6	3.2^{*}		
	S.E.	0.54	0.54		

Means with different letters within a row or column are significantly different (P<0.05).
* There was tendency of significance (P=0.06).

Table 6

Body weight gain (g per head per day) of goats fed a basal diet of grass hay and supplemented with *Acacia brevispica* or *Acacia seyal* with or without polyethylene glycol (PEG) addition

Acacia leaf supplement	Presence or absence of PEG			
	With PEG	Without PEG	Mean	S.E.
Acacia brevispica	25.5	24.9	25.2[b]	4.13
Acacia seyal	43.5	52.3	47.9[a]	4.09
Mean	34.6	38.6		
S.E.	4.18	3.93		

Means with different letters within a row or column are significantly different (P<0.05).

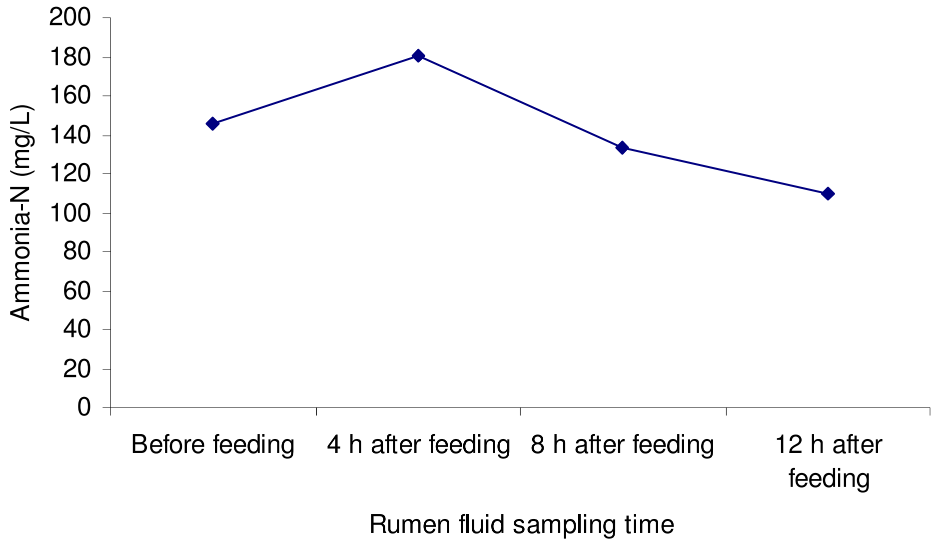

Figure 1: Ammonia-N concentration (mg/L) in rumen fluid of goats before and after morning feeding

Paper III

Concentrate replacement value of *Balanites aegyptiaca* leaves in goats fed a basal diet of barley straw

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Abstract

This study evaluated the potential of *Balanites aegyptiaca* leaves in replacing concentrate supplement in barley straw based diet using 20 Arsi-Bale yearling goats. The treatments were: Barley straw + 240 g concentrate mixture (T1), Barley straw + 180 g concentrate mixture +60 g *B. aegyptiaca* leaves (T2), Barley straw + 120 g concentrate mixture +120 g *B. aegyptiaca* leaves (T3), barley straw + 60 g concentrate mixture +180 g *B. aegyptiaca* leaves (T4) and Barley straw + 240 g *B. aegyptiaca* leaves (T5). There were no significant differences (P>0.05) in dry matter (DM) intake among the treatments. However, the DM intake tended to be higher (P<0.06) in T2, T3 and T4 than in T1 and T5. The crude protein (CP) intake was highest (P<0.001) in T1 (56 g/day) and lowest (42.5 g/day) in T5 and showed a decrease with increasing amount of *B. aegyptiaca* leaves in the diet. Significant (P<0.05) differences were noticed in organic matter (OM), neutral detergent fibre (NDF) and acid detergent fibre (ADF) intakes as well. These were either influenced by DM intake or the proportion of the two supplements. Digestibilities of DM, OM and CP were significantly higher (P<0.05) in T1 than in T4 and T5. The NDF digestibility also showed a decreasing trend with increasing proportion of *B. aegyptiaca* leaves in the diet although the differences were not significant. There were no significant differences in nitrogen balance of the animals although there were differences in nitrogen intake and digestibility. Further, no significant differences were recorded for excretion of purine derivatives and microbial nitrogen supply. All animals gained live weight with significant differences (P<0.001) between the treatments. The highest daily gain (28.7 g) was recorded for T2 which was similar to T1 but different from all others. Animals in T1, T3 and T4 had similar daily gain but different from T5. The sole *B. aegyptiaca* leaves supplemented animals (T5) had the lowest daily gain (11.3 g) compared to others. However, because of its contribution towards positive gain, *B. aegyptiaca* could be regarded as potential forage and can be used as a supplement to cereal straw based diets.

1. Introduction

Inadequacy and seasonal variation in the quantity and quality of feed supplies are the main constraints facing livestock development in most tropical countries. Cereal crop residues and poor quality natural pastures are used as basal feeds for a large number of ruminants especially during the dry season. In the medium and high altitude areas of Ethiopia, where smallholder mixed crop livestock production is the main production system, various cereal and pulse crops are produced. Large quantities of crop residues are produced as by-products of the different cereal and pulse crops. These crop residues can be used for different purposes but their use as livestock feed is by far the most important. According to Zinash and Seyoum (1991) 70 percent of the crop residues are used for livestock in the highland areas. However, when they are fed alone, fibrous crop residues cannot sustain effective animal production, and most unsupplemented and untreated crop residues cannot even maintain an animal because of their low nutrient content, low digestibility and limited intake (Mosi and Butterworth, 1985; Owen, 1985).

Thus appropriate supplementation is one way of improving the utilization of such crop residues in smallholder mixed farming systems of the tropics and sub-tropics. Concentrate supplements are costly and in short supply in most developing countries. Thus the supplementation strategy would be more viable if it could be based on locally available feed resources such as forage legumes, tree leaves and pods from leguminous trees. In the semiarid Rift Valley areas of southern Ethiopia, Acacia pods and leaves from various trees are used as supplementary feedstuffs for ruminants, especially small ruminants. Thus the objective of this study was to assess the potential of *Balanites aegyptiaca* leaves in replacing concentrates in the diet of goats fed a basal diet of barley straw.

2. Materials and methods

2.1. Experimental animals and management

Twenty male Arsi-Bale goats with average initial weight of 14.28 ± 1.32 kg were purchased from Bulbula market, about 90 km north of Hawassa. The animals were transported to Hawassa where the experiment was conducted. Animals were sprayed against external parasites and treated against internal parasites during the adaptation period which lasted for a month. Animals were kept in individual pens provided with feed troughs and watering buckets. Clean water and mineral lick were supplied free choice throughout the experimental period.

2.2. Experimental feeds and treatments

The leaves of *B. aegyptiaca* used in the experiment were collected from Hawassa, particularly near Lake Hawassa and from the compound of the College of Agriculture of Hawassa University. The leaves were collected by hand plucking and air dried under shade. The barley straw was purchased from Kofale and Qore districts West Arsi Zone, Oromia Regional State and transported to Hawassa. The straw was chopped and mixed thoroughly to obtain uniform material. The concentrate mixture was prepared from equal proportions of wheat bran and linseed cake.

2.3. Growth experiment

During the growth experiment, which lasted for 84 days, animals were allocated to the five treatments with four animals in each treatment. The treatments included supplementing goats fed barley straw with concentrate mixture only (treatment 1), and replacing 25, 50, 75 and 100% of the concentrate mixture with *B. aegyptiaca* leaves in treatments 2, 3, 4, and 5, respectively. The concentrate and *B. aegyptiaca* leaves were provided separately at 8:00 and 15:00 while barley straw was offered free choice for *ad libitum* intake. The treatment combinations were as follows:

1. Barley straw *ad lib* + 240 g concentrate mixture (T1)
2. Barley straw *ad lib* + 180 g concentrate mixture +60 g *B. aegyptiaca* leaves (T2)
3. Barley straw *ad lib* + 120 g concentrate mixture +120 g *B. aegyptiaca* leaves (T3)
4. Barley straw *ad lib* + 60 g concentrate mixture +180 g *B. aegyptiaca* leaves (T4)
5. Barley straw *ad lib* + 240 g *B. aegyptiaca* leaves (T5)

2.4. Digestibility experiment

Digestibility trial was conducted following the growth study using 15 of the goats after a few days rest period. During this rest period animals were allowed to familiarize with the metabolism crates and faeces and urine collection harnesses. This was followed by a collection period of seven days. Accumulated faeces during previous 24 h were collected everyday before morning feeding, weighed and recorded while a subsample of 10% was taken and kept in a freezer. A separate sample was dried at 105^oC for 12 h for determination of dry matter (DM). At the end of the collection period faecal samples for each animal were pooled over the seven days and a portion was dried at 65^oC for 48 h and then ground to pass through 1 mm sieve size for chemical analysis while fresh faecal samples were kept in freezer for nitrogen (N) analysis. Ground samples were kept in air-tight sample bottles until used for analysis. Urine was collected into glass bottles of 2.5 L capacity containing 100 ml (10%) HCl by a funnel attached to the genitalia of the animals. The total amount of urine voided was collected and measured daily at same time of faeces collection, diluted to 2 L and 10% subsample was taken and stored in a freezer (-20^oC) for analysis of N and purine derivatives.

2.5. Chemical analysis

Dry matter content of feed, refusals and faeces were determined by oven drying the samples at 105^0C for 12 h. Total ash was determined by igniting samples in a muffle furnace at 600^0C for 6 h. Total nitrogen from feed, faeces and urine were analyzed by Kjeldahl method and crude protein (CP) was calculated as N x 6.25. The frozen faeces samples, after thawing, were used for determination of nitrogen content. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985). Condensed tannin (CT) and soluble tannins (ST) were analyzed according to Porter et al. (1986). Allantoin was determined by a colorimetric method following the method of Chen and Gomez (1995) while uric acid and xanthine plus hypoxanthine were analysed according to Chen et al. (1990b). The amounts of microbial purine derivatives (PD) and absorbed purine derivatives (PDa) corresponding to the PD excreted (PDe) in mmol per day was calculated based on Chen et al. (1990a) using the model: PDe= 0.84 PDa + ($0.15W^{0.75} e^{-0.25PDa}$). The constant 0.84 represents the recovery of absorbed purines as purine derivatives in urine and the components in the parentheses of the formula account for the contribution of endogenous purines. The contribution of endogenous purines decrease as that of exogenous purines becomes available for the animal (Chen et al., 1992). The amount of microbial N (MN) supplied was calculated as: MN (g/day) = (PDa x 70)-(0.83 x 0.116 x 1000) = 0.727 PDa; where 70, 0.83 and 0.116 are assumed to be the N content of purines (mg/mmol), the digestibility of microbial purines and the ratio of purine N to total N in mixed rumen microbes, respectively (Chen et al., 1992; Chen and Gomez, 1995).

2.6. Statistical analysis

The general linear model (GLM) procedure of Statistical Analysis System (SAS, version 9.1) was used to analyze the feed intake, digestibility, N excretion and retention, body weight gain, PD and MN. The model included treatment effect while initial body weight of the goats was used as covariate in the model. Duncan's multiple range tests was used for mean separation when there was significant difference between means.

3. Results

3.1. Chemical composition

The chemical composition of the experimental feeds is presented in Table 1. The CP content of barley straw was low and insufficient to meet minimum requirements of rumen microbes if fed alone. On the contrary the concentrate mixture and *B. aegyptiaca* leaves had high to medium level CP content, respectively. The fibre fraction particularly NDF and ADF were higher in barley straw compared to the other two feeds. But ADL was highest in *B. aegyptiaca* leaves. The condensed tannins (CT) and soluble tannins (ST) were determined for B. aegyptiaca only as these components are less important in straws and concentrates.

3.2. Feed intake

The average daily DM, OM, CP and NDF intake of goats is shown in Table 2. There were no significant differences ($P>0.05$) between treatments in DM intake. However, there was a tendency of higher intake ($P=0.06$) in animals supplemented with a combination of concentrate and *B. aegyptiaca* leaves. There was higher ($P<0.05$) OM intake by goats in T2, T3 and T4 than those in T5. The CP intake was higher ($P<0.001$) in T1 than in T2 and T3, which in turn had higher CP intake than T4, whereas animals supplemented with sole *B. aegyptiaca* leaves (T5) had the lowest CP intake. The intake of fibre fraction was also significantly different between treatments. The NDF intake was higher ($P<0.05$) for T2, T3 and T4 compared to T1 and T5. Similarly ADF intake was higher ($P<0.05$) in T3 and T4 than in T1 and T2 while T5 had intermediate intake.

3.3. Digestibility

Table 3 shows the DM and nutrient digestibility of the experimental diets. The apparent DM, OM and CP digestibility were higher ($P<0.05$) for T1 compared to T4 and T5. The OM and CP digestibility for T2 and T3 did not differ ($P>0.05$) from T1, T4 and T5.

There were no significant differences (P>0.05) in NDF digestibility although it showed a declining trend from T1 to T5.

3.4. Nitrogen balance

Table 4 shows average daily intake, excretion and retention of nitrogen. The N intake was higher (P<0.01) in animals supplemented with sole concentrate mixture (T1) but similar to T2. The animals in T2 and T3 had similar but higher (P<0.01) N intake than T4 and T5, where animals supplemented with sole *B. aegyptiaca* leaves (T5) had the lowest N intake. Faecal and urinary N excretion, total N excreted and N retained were not significantly different (P>0.05) between treatments. However, there was some pattern when faecal and urinary N excretions were considered. Faecal N excretion increased from T1 through T5 as the level of *B. aegyptiaca* increased in the diet and the opposite was true with urinary N excretion.

3.5. Excretion of purine derivatives and microbial N supply

Table 5 shows excretion of purine derivatives and microbial N supply. There were no significant (P>0.05) differences between treatments regarding excretion of allantoin, uric acid, xanthine plus hypoxanthine and total PD. Although not significant, there exists a clear trend in excretion of allantoin and total PD. In both cases T1 had higher values but declined progressively to T5. Such trend was not observed in excretion of uric acid and xanthine plus hypoxanthine. No significant (P>0.05) differences recorded for absorbed purines and microbial N supply between treatments. But it is important to note the pattern between treatments and both parameters.

3.6. Body weight changes

Figure 1 shows the average daily weight gain of goats. All animals had a positive body weight change with varying magnitudes during the whole period. Animals in T2 which received 180 g concentrate mixture and 60 g *B. aegyptiaca* supplement had the highest

(28.7 g) gain per day while those in T1 (sole concentrate supplement) had similar gain to T2 and also to T3 and T4. The lowest gain (11.3 g) was recorded for animals in T5 which had sole *B. aegyptiaca* as supplement.

4. Discussion

4.1. Chemical composition of feeds

The low CP and high fibre content of the barley straw is characteristics of most crop residues such as cereal straws. The CP value recorded for barley straw in this study is similar to the reports of Lulseged and Jamal (1988) and Owen (1994). Bogale et al. (2008) reported similar but slightly lower values from two sub-districts in highlands of Bale. The values reported by Bogale et al. (2008) for fibre fraction from the Sinana sub-district well agree with our results except ADL while values from Dinsho sub-district were higher. But the NDF value reported by Lulseged and Jamal (1988) is slightly lower than our result and far less than that reported by Bogale et al. (2008). Such differences could arise as result of differences in management and the variety of barely grown in these areas. The leaves of *B. aegyptiaca* used to substitute concentrate mixture had an intermediate CP content compared to several multipurpose trees reported by earlier workers. These include *Albizia harveyi* and *Delonix elata* (Goromela et al., 1997), *Sesbania sesban* (Woodward and Reed, 1995; Kaitho et al., 1998b; Solomon et al., 2004; Mekoya et al., 2008), *Gliricidia sepium* (Merkel et al., 1999), *Leucaena leucocephala* (Abdulrazak et al., 1997; Kaitho et al., 1998a; Solomon et al., 2004) and *Acacia brevispica* (Woodward and Reed 1995). On the other hand, the CP values reported by Chriyaa et al. (1997) and Ben Salem et al. (1999) for *Acacia cyanophylla* and Chriyaa et al. (1997) for *Atriplex nummularia* Lindl. were lower than values obtained for *B. aegyptiaca*. The CP value reported for *Grewia similes* by Goromela et al. (1997) was comparable with *B. aegyptiaca*. The highest ADL recorded for *B. aegyptiaca* could be attributed to the tannin present in this feed. Due to the existence of structural similarity between condensed tannins and lignin, they are measured as lignin and thus exaggerate the value (Reed, 1986).

4.2. Feed intake

The barley straw with its low CP content cannot provide sufficient N to rumen microorganisms. In the present study additional N was supplied from concentrate mixture and *B. aegyptiaca* leaves. The similarity in DM intake between the treatments with varying levels of supplements could be an indication of a potential of *B. aegyptiaca* to replace concentrate mixture in straw based diets. The tendency of higher DM intake with combination of the two supplements at varying amounts reveals improvement in utilization of readily available energy and nitrogen than when animals were supplemented with either concentrate or *B. aegyptiaca* leaves alone. The differences in OM intake between treatments could result from DM intake. But the low OM intake by animals in T5 which received sole *B. aegyptiaca* as a supplement was as a result of high ash content of the supplement. On the other hand, CP intake was largely affected by the type of supplement whereby animals receiving sole concentrate mixture had the highest intake of CP. The NDF and ADF intakes were enhanced when combination of the supplements were fed to animals as in T2, T3 and T4. Since animals consumed all concentrate mixture on offer and almost all *B. aegyptiaca* leaves, their chemical composition had influenced nutrients ingested. Thus the low NDF and ADF intakes were observed for animals supplemented with concentrate mixture alone. The tannins in *B. aegyptiaca* leaves seem to be less detrimental to feed intake as no significant differences were observed in DM intake between treatments. The effect of tannin on feed intake is dependent on the concentration of tannin in feeds (Provenza et al., 2000). However, this should be considered with caution since factors such as structure and molecular weights determine their biological activity (Hagerman et al., 1992, Waghorn, 2008).

4.3. Digestibility

The decreasing trend in DM, OM and CP digestibility with increasing level of *B. aegyptiaca* could be associated with the presence of tannin in this feed. This is more evident when digestibility values for animals receiving either concentrate mixture or *B. aegyptiaca* as sole supplement is considered. Tannins are known to lower digestibility of feeds and thereby limit production potential of animals (Reed et al., 1990; Silanikove et al., 1996a; Makkar, 2003). The digestibility of DM reported by Woodward and Reed (1995) for sheep fed tef straw and supplemented with sole *A. brevispica* compares with the present result obtained when varying amounts of *B. aegyptiaca* was supplemented to goats on barley straw basal diet. Similarly Kaitho et al. (1998a) reported DM digestibility of various multipurpose trees as supplement to tef straw comparable to our result for *B. aegyptiaca* leaves as a sole supplement (T5) but slightly lower than other treatments. Reed et al. (1990) reported higher OM digestibility for animals given tef straw as basal diet and supplemented with noug (*Guizotia abyssinica*) cake, which is similar to animals consuming concentrate mixture as sole supplement in the present study although the magnitudes were different. The higher CP digestibility for animals receiving sole concentrate mixture could be due to the type of protein in such conventional feeds which is highly digestible. The decreasing trend in CP digestibility with increasing level of *B. aegyptiaca* leaves could be due to lower CP content and the interference of tannins in CP digestibility. Such interactions between protein and tannin may limit production of ammonia nitrogen and thereby affect overall digestibility.

4.4. Nitrogen metabolism

There was a positive N balance in all the treatments although there were differences in intake of N between treatments. The N content of the diets clearly affected the amount of N ingested by animals whereby the amount decreased with decreasing concentrate mixture. However, the differences recorded in N intake were not reflected in total N excreted and retained. Although the differences were reported to be not significant, there was a clear difference in the route of excretion of N. An increase in *B. aegyptiaca* leaves in the diet resulted in higher faecal N which could be attributed to the complex formation between tannins and proteins, which render it unavailable for digestion. Solomon et al. (2004) who used wheat bran and three multipurpose tree leaves either single or their mixture as supplement to tef straw basal diet reported higher faecal N excretion in rams supplemented with multipurpose tree leaves compared to those supplemented with wheat bran. The N loss in faeces could be regarded beneficial than loss in urine as in the former case it could be utilized to fertilise crop lands and cause less pollution to the environment (Kaitho et al., 1998b).

4.5. Excretion of purine derivatives and microbial N supply

Despite the significant difference in N intake between treatments, excretion of PD and microbial N supply did not differ significantly. Furthermore, the difference recorded in CP digestibility of the diets between treatments did not result in significant differences in excretion of PD and microbial N supply. Although the differences were not significant, there was a tendency that animals that had higher CP intake and digestibility had increased excretion of PD and microbial N supply. The microbial N supply of goats reported in the present study is higher than the values reported by Debela (2008), Solomon et al. (2004) and Tolera and Sundstøl (2000). Such disagreement between the present and previous works could be attributed to diets used in these studies. In the present study the diet was composed of concentrate mixture, leaves of *B. aegyptiaca* and barley straw as basal feed except in T1 and T5, which had concentrate mixture and *B. aegyptiaca* leaves as sole supplements, respectively. However, the values obtained for T5 (animals with sole *B. aegyptiaca* supplement) agrees with the reports of above authors. Low N intake and digestibility were recorded for animals receiving sole *B. aegyptiaca* as supplement. Therefore, the presence of highly digestible CP in the concentrate mixture could be responsible towards increased excretion of PD and microbial N supply.

4.6. Body weight changes

The positive changes in live weight of goats across the treatments could be an indication that *B. aegyptiaca* could substitute concentrate mixture, although the body weight gain was small in animals receiving *B. aegyptiaca* as sole supplement. The daily gain of goats in the present study was lower than the values reported by Kaitho et al. (1998a) for sheep fed tef straw as basal feed and supplemented with various multipurpose trees, which could be due to species difference in growth rate related to their mature sizes. But the daily gains of ewes reported by Solomon et al. (2004) is comparable to our observation except for animals supplemented with sole *B. aegyptiaca* leaves.

5. Conclusion

All animals had gained live weight throughout the study period and this demonstrates the potential of *B. aegyptiaca* to be used as a supplement to straw or low quality forage based diets. Smallholder farmers who cannot afford to provide either commercial concentrates or home grown concentrate supplements or do not have access to other high quality forage supplements can use sole leaves of *B. aegyptiaca* as a supplement to crop residues. The gain in live weight was improved when *B. aegyptiaca* was used in combination with concentrate mixture with the highest gain when the concentrate mixture and *B. aegyptiaca* leaves were used as supplements in a 3:1 ratio. The choice of feeding strategy depends on the objective and also the availability of these supplements in the area.

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Table 1

Chemical composition of feeds used in the experiment

Chemical component	Barley straw	Concentrate mixture	*Balanites aegyptiaca* leaves
Dry matter (%)	91.6	90.5	90.9
Ash (g/kg DM)	109.2	57.6	137.4
Organic matter (g/kg DM)	890.8	942.4	862.6
Crude protein (g/kg DM)	51.0	210.2	163.7
Neutral detergent fibre (g/kg DM)	743.5	378.4	445.1
Acid detergent fibre (g/kg DM)	495.3	122.8	288.1
Acid detergent lignin (g/kg DM)	60.0	23.7	108.6
Soluble tannins (%)	nd	nd	10.8
Condensed tannins (Abs/g DM)	nd	nd	32.5

nd = not determined

Table 2
Feed intake of goats fed barley straw and supplemented with varying levels of concentrate and *Balanites aegyptiaca* leaves

Variables	Treatments					P	SEM
	T1	T2	T3	T4	T5		
DM intake (g/day)	380.3	420.9	424.5	424.5	367.7	NS	16.25
DM intake (g/kg $W^{0.75}$)	48.9	53.4	54.5	54.7	48.6	NS	2.01
DM intake (% BWt)	2.5	2.7	2.7	2.8	2.5	NS	0.10
OM intake (g/day)	347.7^{ab}	379.9^{a}	377.7^{a}	375.9^{a}	319.9^{b}	*	14.58
CP intake (g/day)	56.0^{a}	$54.8a^{b}$	52.3^{b}	47.2^{c}	42.5^{d}	***	0.90
NDF intake (g/day)	196.9^{b}	$231.6a^{b}$	237.1^{a}	249.1^{a}	205.2^{b}	*	12.49
ADF intake (g/day)	102.3^{b}	$130.8a^{b}$	136.4^{a}	150.8^{a}	127.4^{ab}	*	8.82

Means with different letters within a row differ significantly
*P<0.05; ‘**P<0.01; ***P<0.001; NS=not significant; SEM= Standard error of the means

Table 3

Dry matter and nutrient digestibility coefficients in goats fed barley straw and supplemented with varying levels of concentrate and *Balanites aegyptiaca* leaves

Variables	Treatments					P	SEM
	T1	T2	T3	T4	T5		
DM digestibility	0.702^{a}	0.649^{ab}	0.623^{ab}	0.605^{b}	0.562^{b}	*	0.023
OM digestibility	0.719^{a}	0.672^{ab}	0.640^{ab}	0.615^{b}	0.569^{b}	*	0.023
CP digestibility	0.737^{a}	0.682^{ab}	0.646^{ab}	0.590^{b}	0.553^{b}	*	0.028
NDF digestibility	0.626	0.583	0.563	0.564	0.522	NS	0.027

Means with different letters within a row differ significantly (P<0.05); NS= not significant; SEM= Standard error of the means

Table 4
Nitrogen balance (g/day) of goats fed barley straw and supplemented with varying levels of concentrate and *Balanites aegyptiaca* leaves

Variable	Treatments					P	SEM
	T1	T2	T3	T4	T5		
N intake	8.93[a]	8.44[ab]	8.43[b]	7.88[c]	7.29[d]	**	0.183
Faecal N	2.35	2.70	2.99	3.24	3.26	NS	0.229
Urinary N	1.81	1.82	1.20	1.03	0.67	NS	0.365
Total N excreted	4.16	4.52	4.19	4.27	3.93	NS	0.367
N retained	4.76	3.92	4.24	3.62	3.36	NS	0.373

Means with different letters within a row differ significantly ($P<0.01$); NS= not significant; SEM= Standard error of the means

Table 5

Excretion of purine derivatives and microbial N supply of goats fed barley straw and supplemented with varying levels of concentrate and *Balanites aegyptiaca* leave

Variables	Treatments					P	SEM
	T1	T2	T3	T4	T5		
PD excretion (mmol/day)							
Allantoin	7.55	6.89	6.09	5.25	3.45	NS	1.52
Uric acid	1.09	1.39	0.99	0.85	0.68	NS	0.28
Total uric acid	1.17	1.44	1.03	0.81	0.67	NS	0.29
Total PD	10.7	10.3	8.1	6.70	3.92	NS	2.35
Microbial N (g/day)							
Absorbed purine	12.7	12.1	9.5	7.8	4.2	NS	2.92
Microbial N supply	8.9	8.6	6.9	5.7	4.1	NS	2.18

Means without letters within a row do not differ significantly (P>0.05); NS= not significant; SEM= Standard error of the means

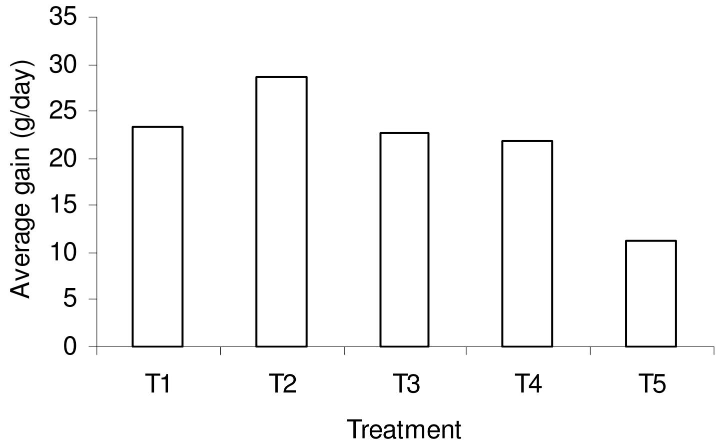

Figure 1: Average daily gain of goats fed barley straw and supplemented with varying levels of concentrate and *Balanites aegyptiaca* leaves

Paper IV

Pastoralists' perceptions of feed scarcity and livestock poisoning in southern rangelands, Ethiopia

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Abstract

The pastoral areas in Ethiopia support about 12% of human population and serve as sources of livestock both for domestic and export markets. A survey was conducted between April and July, 2007 using semi-structured questionnaire to generate information on dry season feeding management and livestock poisoning in the southern rangeland of Ethiopia. A total of 119 pastoralists were interviewed. Moreover, additional information was obtained through focused group discussions. The study revealed that pastoralists have rich knowledge on natural resource management and utilization. This is evident from the various strategies they employ such as migration, collection of grasses and pods and cutting branches to overcome feed scarcity during dry/drought periods. Migration of livestock and people to areas with better grazing is the widely used strategy by pastoralists in the area. However, the implementation of this strategy is diminishing as a result of changes that are taking place such as bush encroachment, expansion of settlements and crop cultivation in dry season grazing lands. The respondents also indicated the presence of poisonous plants in the rangeland and about 22 such plants were reported to exist in the study area. Various species and classes of livestock are reported to be affected by toxic plants particularly in the dry and early rainy seasons when feed is in short supply. Veterinary services are inaccessible and thus pastoralists use a wide range of materials including herbs to treat animals poisoned by toxic plants. The efficiency of the materials used for treatment of poisoned animals, however, is not established and calls for further investigation

Keywords: Dry season, Feed shortage, Pastoralists, Poisonous plants, Southern rangeland

1. Introduction

The pastoral areas of Ethiopia are located around the periphery of the country and mostly below 1500 m above sea level. They cover vast areas (about 61%) of the country and are categorized under arid and semiarid agroecologies. The pastoral areas experience a relatively harsh climate with low, unreliable, and erratic rainfall as also high temperature (Beruk and Tafesse, 2000). Pastoralism and agro-pastoralism are the dominant types of land use in these areas. The southern rangeland of Ethiopia is among the major pastoral areas of the country and supports livestock that are valuable to the nation. They provide food and income for the pastoral and agropastoral population and contribute to the nation's foreign currency earnings. Moreover, they provide draught power to smallholders in the highlands (McCarthy et al., 2002).

Diverse herbaceous and woody species are known to exist in the southern rangeland. However, some of the plant species existing in the region have a potential to cause poisoning to livestock as well as humans. Livestock poisoning caused by plants and secondary compounds they produce is one of major economic losses to the livestock industries throughout the world (Panter et al., 2007). Economic losses due to livestock poisoning can be divided into direct and indirect losses. Direct losses occur due to negative effects of poisonous plants on livestock productivity and health. Indirect losses include costs incurred to prevent poisoning and costs of medication to treat poisoned animals (Pfister et al., 2002). Animals are exposed to consumption of poisonous plants particularly during dry periods when palatable forages become less abundant in the grazing land (Botha and Penrith, 2008; Hart and Carpenter, 2001). During drought most palatable plants dry up while many of the poisonous plants maintain greenness and become the only option for animals to consume. These problems may be aggravated when animals suffer from deficiencies of minerals such as phosphorus or vitamin A. The grazing behavior of the animals could be affected due to such deficiencies (Hart and Carpenter, 2001).

The effect of poisonous plants is complex and can affect various organ systems as a result of presence of several toxic principles in some plants that affect different systems. The dominant effect depends on several factors such as condition, growth stage or part of the plant, the amount ingested and the species and susceptibility of the animal (Botha and Penrith, 2008). Poisoned animals show various symptoms which include death, chronic illness, stunted growth in young, abortions, birth defects and photo-sensitizations. These symptoms have been attributed to the active ingredients in such plants, which include nitrates, oxalates, fluroacetate, selenium and others (Agaie et al., 2007). However, poisoning by plants occurs when animals ingest large quantity too fast or graze it over a prolonged period of time (Panter et al., 2007).

The southern rangeland of Ethiopia is facing critical shortage of palatable forages due to frequent droughts that the area is experiencing. Although studies regarding ethnoveterinary practices (Sori et al., 2004) and ethnobotany (Gemedo-Dalle et al., 2005) have been conducted in the area, there is no adequate information on poisonous plants and livestock poisoning. Thus this study was conducted to understand the perception of pastoralists on livestock feed shortage and poisoning and document toxic plants in the area.

2. Materials and methods

2.1. Description of the study area

The study was conducted in four pastoral associations[1] of Borana zone of Oromia Regional State and Moyale area where Lay Volunteers International Association (LVIA) operates. The pastoral associations in Borana zone are Dida-Hara, Dubuluk, Madhacho and Melbana while Moyale area covers some part from Borana Zone and some from Liben zone of Somali Regional State. The Borana and Garri are the dominant pastoralist groups in the southern rangeland. Borana are the eldest branch of the Oromo ethnic group

[1] Smallest administrative unit in the area

while Garri are a clan of Somali ethnic group in Ethiopia. Extensive livestock production is the main means of livelihood of both pastoral communities. The Borana have high preference for cattle while camel is the top priority for the Garri.

Water is one of the key production limiting resources in the area. The area experiences bimodal rainfall thus dividing the year into four seasons: two wet and two dry seasons. However, the rainfall pattern is very erratic and unpredictable, making crop production unreliable. The actual length of the rainy season is getting shorter through time and the area is more prone to frequent droughts (Tolera and Abebe, 2007). The study area lacks surface water, thus their important water sources are permanent and temporary ponds, traditional deep and shallow wells, springs, and bore holes. Traditional deep wells which are locally known as *tula* are particularly important in Borana rangeland.

2.2. Data collection and analysis

Information on household livelihood sources, feed resource base, presence of poisonous plants and associated symptoms and treatments of poisoned animals were collected using semi-structured questionnaire between April and June 2007. Two enumerators from Borana and Guji Zones Pastoral Development Project, the former Southern Rangeland Development Unit (SORDU), and two enumerators from LVIA were involved in data collection. Prior to the survey, training was given to the enumerators on data collection. Elders as well as young respondents were included in the survey to obtain more representative information from the community. A total of 119 pastoralists were interviewed, including six female household heads. In addition there were focused group discussions in Moyale area. Among the poisonous plants mentioned four were collected, pressed and brought to National herbarium in Addis Ababa, for botanical classification while some of the botanical names were obtained from previous works. The collected data were analyzed using descriptive statistics (SPSS, 2007).

3. Results

3.1. Household livelihood sources

All the respondents own cattle although the number varies greatly. Goats represent the second most important species, owned by 93.3% of the respondents followed by sheep. Only about half of the respondents own camel which could be attributed to low popularity of camel among the Borana, although there is a gradual increasing trend recently due to changes in vegetation composition of the rangeland as grasses are replaced by bushes and shrubs in most parts of the rangeland. Horses and mules are so few but nearly half of the respondent own donkeys. Keeping of scavenging chicken was reported by 45% of the respondents, which indicates that chicken are gaining importance. Crop production is the second largest activity in which 68.9% of the respondents are engaged next to livestock rearing. This activity is particularly undertaken by large number of pastoralists in Dida-Hara (92.6%) and Melbana (91.7%). Other activities like petty trade, charcoal making, collection of natural products like incense and gum, wage employment are undertaken by few respondents (Figure 1).

3.2. Feed Resources

Range plants which comprise browses, grasses, herbaceous legumes and forbs make nearly 100% of the livestock feed in the study area. Some of the forage species are very useful in the beginning of rainy season because they grow fast or produce leaves early in the season. These include *Chlorophytum gallabatense, Cyperus sp, Commelina africana* from the herbaceous category and *Commiphora erythrae, Commiphora habessinica* and *Acacia bussei* from the browse category. The most common grasses in the rangeland include: *Chrysopogon aucheri, Cenchrus ciliaris, Digitaria milanjiana, Pennisetum mezianum, and Heteropogon contortus* both during dry and rainy seasons.

The trees and shrubs that are regarded as most useful livestock feed include: *Grewia tembensis, Grewia bicolor, Vernonia cinerascens, Acacia brevispica, Acacia tortilis,* *Acacia nilotica, A. bussei, Lannea rivae, C. habessinica*, *Boswellia neglecta, C. erythraea, Premna schimperi, Bidens hildebrandtii,* and *Rhus natalensis*. Some species however contribute much to feed pool during dry period as they have ability to maintain green leaves/produce fruits; they include *Pappea capensis, Boscia mossambicensis, R. natalensis, Balanites aegyptiaca, A. tortilis* (leaves and fruits), *A. nilotica* (leaves and fruits), *A. brevispica,* and *G. tembensis.*

The availability and quality of feed in the rangeland are very variable due to variability in rainfall. The pastoralists regard the months of January and February as period of critical feed and water shortage whereas April and May are considered as months of plenty (Figure 2). The pastoralists have developed traditional coping strategies through generations and sustain their animals during dry periods. Movement of animals to areas with better pasture is by far the most important strategy to address the problem of feed shortage. However, several other means of tackling the problem were mentioned by the pastoralists, which include cutting branches of trees, collection of grass from bottomlands, collection of fruits, use of *kalo* (reserve grazing or standing hay), chopping and feeding roots of certain plants like *Entada leptostachya* and *Sesamothamnus rivae*, provision of mineral salts which is usually synchronized with watering days, taking animals for grazing early in the morning, adults strategically take part in herding instead of youth and children to select areas with better grazing such as with *P. mezianum*, and to treat animals against internal and external parasites.

3.3. Changes in vegetation cover in the rangeland

Majority of the respondents have noticed significant changes in vegetation cover of the rangeland over the past decades. The respondents emphasized that some species particularly grasses are decreasing in abundance while some woody species are increasing from year to year. Among grass species that are reported to be decreasing are *C. ciliaris, C. aucheri, Digitaria milanjiana, P. mezianum*. The reasons cited by the respondents include insufficient rainfall, increase in livestock number, and increase in woody plants, crop cultivation and action of termites (Table 1). The woody species that are recorded to be increasing in decreasing order of importance include *Commiphora africana, A. drepanolobium, A. mellifera, A. bussei, A. nilotica, A. seyal, A. tortilis, Euphorbia nubica* and *Gurbi. Gurbi* represents a group of shrubby plants. However, it should be noted that the abundance of these plants is not the same across the study area. *Acacia drepanolobium* constitutes a major problem for the rangeland cover in Dida-Hara and Melbana areas while *C. africana* is more abundant in Dida-Hara and Dubuluk areas. In Madhacho, it was reported that *A. tortilis* and *A. nilotica* are increasing whereas in other areas these species are less abundant considering their feed value particularly in the dry season. On the other hand, in areas close to Moyale town *A. tortilis* and *A. nilotica* have been used extensively for charcoal production to the extent of endangering the species. Considering the reason for the increase of woody plant species, the majority of the respondents believe that it is due to ban on periodic burning of the rangeland, the practice they used for centuries. However, some consider that seeds of woody plants can be disseminated easily by animals and wind (Table 1).

3.4. Poisonous plants and livestock poisoning in the rangeland

Some range plants are reported to cause illness/death to livestock. Majority of the respondents have knowledge of poisonous plants in their area. Botanical classification was obtained for some plants. Hence, the native names and botanical names when applicable, growth forms, parts toxic to livestock, symptoms upon ingestion, and traditional/local treatments are presented in Table 2. The 22 poisonous plants reported in this study include both woody and herbaceous species. Three of the herbaceous species were grasses; *Sorghum bicolor, Ardaa* and *Finchoo* (native name). Most of the poisonous plants remain green and attractive during dry periods and ingested by hungry and thirsty animals. However, *Ardaa* was reported to be toxic during the rainy season particularly when grown on heaps of manure in abandoned villages. Similarly *Tabari* and *Euphorbia sp (Qorsa dida)* are reported to be poisonous in the rainy season although some respondents believe that these plants are toxic year round. Donkeys are the most affected animals by *Tabari* than other livestock species. The distribution of these plants varies from one site to the other. For instance *Qorsa dida* was reported only in Madhacho, *Gladiolus boranensis (Marra dhigaa)* in Dubuluk, while *Gaaddalla* was reported in Moyale area, Dida-Hara and Madhachoo.

The magnitude of the economic losses due to poisoning is unknown in the area. But it was reported that death and chronic illness and associated decline in milk yield and growth rate are responsible for economic losses to the households. Various items ranging from flood and *tula* water to antibiotics were reported to be used for treatment of poisoned animals (Table 2). Pastoralists have a wealth of knowledge on ethnoveterinary medicines and the community benefits from such practices as most of the areas are remote and veterinary services are not accessible.

4. Discussion

4.1. Household livelihood sources

All the respondents own cattle even though the number may vary from a few heads to several hundreds. The Borana are known to be cattle pastoralists (Desta and Coppock, 2002; Tolera and Abebe, 2007). The population of camels, however, is increasing in Borana area as a response to increase in woody vegetation and frequent drought. Desta and Coppock (2000) reported an increase in camel population from 15,000 in 1987 to 75,000 in 1996-7 in the Borana plateau. This explains the pastoralists' adaptation strategy to changes in the rangeland cover and pasture availability. On the other hand, although the Garri have more preference for camels, they also keep cattle. The Garri cows are known for good milk yield (pastoralists, personal communication, 2008). The Garri prefer camel's milk to cow's milk and believe that one who consumes camel's milk regularly has good health and strength. Goats are popular because of their ability to utilize woody vegetation which is less favored by cattle and sheep. Sheep have similar function as goats but less important for milk. Another species of livestock gaining importance among the pastoralists is chicken even though consumption of eggs and chicken meat is uncommon among pastoral households. Therefore they are meant for sale and their contribution to households who have lost their animals to drought should not be undermined.

Crop production has become second important economic activity next to livestock rearing which is evident from the number of respondents engaged in cultivation. However, initially it was limited around towns by migrants from the highlands (Coppock, 1994). According to Desta and Coppock (2000) cultivation started to become widespread on central Borana plateau after the 1983-84 droughts when people opportunistically planted maize and cowpea to temporarily tackle food shortages created by huge cattle mortality. Crop cultivation is considered as one means of economic diversification. Angassa and Oba (2008) reported that less than 15% of Borana households depend directly on the products of their livestock alone. Crop production is a response to food insecurity as loss of livestock herds due to frequent drought made it difficult for the pastoralists to depend on livestock alone for food (Tolera and Abebe, 2007). However, the sites that are chosen for crop production are those with fertile soil and good moisture which are also good for grass growth and particularly serve as dry season grazing lands. Angassa and Oba (2008) reported that a greater proportion of respondents (90%) in their study were involved in farming bottomlands as opposed to uplands (10%) in Borana zone. This is a direct competition between crop and livestock production. Moreover, since the rainfall in the area is unreliable, crop failure is a common phenomenon and such cultivated plots of land might be abandoned and become grounds for proliferation of weeds or toxic plants. A good example is an annual weed known as *Parthenium* which is spreading in crop fields near Yabello town in Borana zone (personal observation; communication with farmers, 2008). This weed was believed to be introduced to the country through grain entering the country for food aid. It was also reported that *Sorghum bicolor*; *Ricinus communis, Finchoo* and *Halakuu ajoo* are appearing recently with expansion of cropping in the rangeland. Crop cultivation may not only compete for the land with forage production but may introduce or facilitate growth of unpalatable weeds and poisonous plants into the rangeland. Although it may not be practical to completely ban cultivation, its expansion should not be left uncontrolled. As long as crop cultivation is undertaken, crop residues should be wisely utilized to support feed resource base. Pastoralists are new to this activity and thus need some technical support. During the survey only two respondents mentioned that they store crop residues and use them for dry season feeding.

Other activities such as trading of livestock are limited to those who can afford the capital required to undertake it. Few also engage in brokering of livestock when not able to raise the capital for trading. On the one hand, participation in collection and selling of natural products like gum and resins is low although useful species like *Acacia senegal* and *Boswellia* are available in the area. Facilitation of market channels could improve participation and thereby income. Income from selling of charcoal, firewood, wage labor and handicrafts are negligible in the area. Charcoal production and wooden handicrafts are considered illegal.

4.2. Feed resources and change in vegetation

The southern rangeland has diverse species of plants which support large livestock and wildlife populations. The bimodal nature of the rainfall in the area enhanced growth of perennial grasses like *Cenchrus, Chloris, Panicum* and *Pennisetium*. However, the availability and contribution of both woody and herbaceous forages vary greatly with season and from site to site. Because of such variations pastoralists developed a strategy of moving their herds to areas where there is better grazing. The respondents indicated that mobility was the most widely used grazing strategy in the area. However, it was pointed out that such movements are currently curtailed due to increasing human population and settlements, cultivation, and bush encroachment in the rangeland. Collection of grass for calves and weak/sick animals is a duty left to women. This activity may require more time during dry seasons. On the other hand, collection, drying and storing of grass for dry season feeding are not usual practices among the pastoralists. An extension program was started by CARE-Borana on how to make hay and utilize in dry periods in its projects sites (Coppock, 1994). Further efforts were made by other institutions such as LVIA, Hawassa University and Ethiopia Sanitary and Phytosanitary Standards and Livestock Marketing Program (SPS-LMM) in collaboration with Oromia

Pastoral Areas Development Commission to train the pastoralists and development workers of the area on fodder conservation principles and practices. Conserved grasses may have better crude protein and digestibility compared to standing hay usually collected by women during dry periods. Although the adoption of the technology was slow at the beginning, it is showing a gradual progress. This may call for continued awareness creation and technical support to the pastoralists. Strategies like treatment against parasites and provision of mineral salts have been mentioned. However the benefits should be confirmed by further investigations. Kabaija and Little (1991) reported non-significance in average daily gain between steers supplemented either with copper (Cu) or phosphorus (P) and the non-supplemented groups in southern rangeland despite the fact that there were low Cu and P concentrations in grasses during the study period. The experimental animals were drinking water from traditional deep well *(tula*) which is known to have high concentration of Cu and P and concluded that it might have suppressed the effect of supplementation. Borana pastoralists in *tula* water area claim that animals drinking *tula* water have longer lifespan and their meat is tasty compared to animals drinking from ponds.

The change in vegetation in the rangeland is a great threat to the ecological balance as well as to the welfare of the livestock and wildlife population of the area. Pastoralists reflected their concerns and fears about the trend of the ever increasing woody species and the decreasing valuable grasses. The increased livestock numbers combined with drought and tremendous decrease in grazing lands have placed much pressure on valuable perennial grasses with little chance of flowering and seed setting. The decrease in grazing land was caused by expansion cultivation for crop production, settlements and woody encroachment. The effect of woody plants is more than only competing for space. Previous studies conducted in the area showed that *Acacia horrida, A. seyal* and *A. brevispica* have negative effect on growth of grasses due to their extensive lateral root system (Coppock, 1994). Angassa and Oba (2008) reported varying responses of woody species to bush encroachment control methods in Did-Tuyuraa and Dambala-Wachu ranches in Borana zone. They also reported that bush encroachment control methods significantly improved the recovery of herbaceous vegetation although individual responses varied. However, the interaction between grasses and woody species is complex and requires site and species specific research. In Melbana, termites were reported to be problematic in destroying seeds of grasses in addition to the above mentioned problems.

The increase in the woody species is a recent phenomenon which is mainly attributed to the ban of the rangeland burning practices. Fire is considered to be a cost effect tool to control woody vegetation and it has been employed for this purpose for centuries by pastoralists (Stoddart et al., 1975). Until it was banned by the government in 1970s it was part of range management practice in the southern rangeland as well. Use of fire under current situation might be challenging due to scarce fuel load, increased settlements and scattered crop lands. However, it could be re-introduced with careful planning. In addition to lack of burning, expansion of woody plants was aided by dispersion of seeds by wind and browsing animals. Some of the seeds are resistant to enzymes in digestive tract and voided intact in feces which in turn facilitates their germination.

4.3. Poisonous plants and livestock poisoning in the rangeland

The presence of poisonous plants in the rangeland is an issue which also requires an attention. It is known that the livestock industry world-wide is encountering large economic losses as a result of range livestock poisoning caused by poisonous plants (Panter et al., 2007). Most of the poisonous plants remain green and attractive during dry periods and thereby they are readily ingested by hungry and thirsty animals. It is important to note that the quantities of poisonous plants that cause poisoning upon ingestion by animals are not uniform.

The poisonous plants reported in this study comprised of both herbaceous and woody plants including three grass species. It is believed that in East Africa no species of grass is intrinsically poisonous. But several have been known to develop toxic properties under certain environmental conditions. *Aristida* and *Cymbopogon* species as well as *Themeda triandra* and *Cynodon dactylon* have all been known to be capable of building up quantities of hydrocyanic acid in their tissues (Verdcourt and Trump, 1969). The poisoning of *Sorghum bicolor* was reported to occur in the dry season when there are new growths. This observation of pastoralists concurs well with the explanation on production of hydrocyanic acid in grass species. However, the poisoning in *Ardaa* might be due to accumulation of excess nitrates during the rainy period particularly when grown on heaps of manure in abandoned encampments. Similarly, *Tabari* and *Qorsa dida* are reported to be poisonous in the rainy season although some respondents believe that these plants are toxic year round.

Poisonous plants and their toxic principles are not documented in the study area and thus no proper treatment is available. However, the pastoralists employ various materials to treat poisoned animals within their reach. In Moyale area, treatment of animals poisoned by *Gaaddalla* is not possible because they believe that animals show no symptoms before death. The poisoning due to *Gaaddalla* is confirmed when fruits of the plant are found in the gastro-intestinal tract upon slaughtering the animal; while in Dida-Hara and Madacho it was reported that such animals are treated because symptoms like bloat and diarrhea are associated with its poisoning which could be due to differences in concentrations of toxic principle when grown in different sites. The amount of toxic principles, and even its presence and absence depends on climate or soil condition. A plant may be poisonous at a certain stage of growth and not at another (Verdcourt and Trump, 1969). The botanical name for *Gaaddalla* was obtained based on specimen collected from Moyale area thus those in other sites remain to be classified botanically in future study.

Pastoralists are using their traditional veterinary knowledge to treat sick animals in the areas where it is hard to access conventional services. The effectiveness of the herbs as well as the other materials used for treatment should be confirmed and supported by scientific methods. The herbs reported to be used for treatment in this work however were not reported by Sori et al. (2004) who reported 43 medicinal plants used by Borana pastoralists. More extensive survey is required to document all poisonous plants in the southern rangeland as some plants may have specific ecological distribution. It was not possible to reach the vast area of southern rangeland, although the respondents indicated presence of some toxic plants like *lochisaa, garbicha, qajima, doli hilensa* and *mara busawa* (native names) in neighboring pastoral associations.

Among the plants reported in this study, *Sorghum bicolor* and *Ricinus communis* were also reported in Sokoto state, Nigeria (Agaie et al. 2007) and in East Africa by Verdcourt and Trump (1969) while *Acokanthera schimperi,* known as arrow poison, was reported by Verdcourt and Trump (1969) and Watt and Breijer-Brandwijik (1962) in East Africa. However, the poisoning of *A. schimperi* has little effect when administered orally. Watt and Breijer-Brandwijik (1962) also reported occurrence of *Euphorbia heterophylla* in other East African countries. In Ethiopia in the Middle Awash valley area, Abule et al., (2005) reported presence of poisonous plants including woody and herbaceous species.

It is important to understand why animals ingest plants that are poisonous to them. Animals may ingest toxic plants due to lack of past experience. In this study it was reported that young animals consume *Qorsa dida* (*Euphorbia sp*) because of lack of experience as they first start grazing outside. But older animals were not reported to ingest or get poisoned of this plant. Animals may ingest toxic plants when hungry and in poor condition even if they had past experiences. Animals in poor body condition may become less selective and thus consume plants less palatable and with toxic potential (Pfister et al., 2002). Animals under nutritional stress may be less able to detoxify plant toxins and may suffer relatively greater harm from the metabolic effects of the toxins. This has a very practical implication in the southern rangeland where there is risk of frequent droughts. It was reported that between 1980-81 and 1998-2000 the pastoral areas of Ethiopia has encountered three major droughts (Desta and Coppock, 2000). When dry season is prolonged or during drought years, animals become unproductive; they lose condition and market value and eventually die due to inadequate feed and water supply and the very low nutritive value of the available feed (Tolera and Abebe, 2007). Animals under such condition are easily exposed to ingestion of poisonous plants but less capable to detoxify the effects of toxicity.

Quantifying the magnitude of economic loss from poisonous plants to livestock production is not an easy task. This is because separation between losses due to diseases, accidents and predators from losses caused by ingestion of poisonous plants can be difficult. Low reproductive performance and weight loss can be caused by disease and inadequate nutrition as well as by consumption of poisonous plants. Moreover, some negative effects due to poisonous plants such as birth defects occur long after the animal has ingested the poisonous plants (Holchek, 2002).

5. Conclusion and recommendation

The pastoralists in the southern rangeland are knowledgeable in range management and are aware of the changes taking place in vegetation cover, land use pattern and climatic conditions. The ban of range burning was cited as major cause for the proliferation of woody vegetation, which is believed to suppress growth of grasses. Increase in woody vegetation and decline in grasses, expansion of cultivation coupled with the frequent drought has caused a serious threat to the livestock production in the rangeland. If the area has to continue to support the pastoral communities and supply livestock to the export and domestic market, the prevailing constraints and potentials should be considered in designing pastoral development programs with active participation of the pastoralists.

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Table 1: Reasons for decline in grasses and increase in woody plants in the southern rangeland, Ethiopia

Parameter	Reasons	No of respondents ranking			Index*
		1st	2nd	3rd	
Decline in grass	Increased livestock	44	10	1	0.39
	drought	34	14	2	0.34
	Increased woody plants	11	0	4	0.09
	Settlement and cultivation	8	5	3	0.09
	Termites	7	3	1	0.07
	Do not know	2	0	0	0.02
Increase in woody	Ban on range burning	55	17	1	0.51
	Dispersion[1]	20	6	1	0.19
	Failure in Tradition	11	1	1	0.09
	drought	11	0	0	0.08
	Less browsed	7	1	1	0.06
	Do not know	8	0	0	0.06

* Index= sum of single reason ranks (3 for rank 1) + (2 for rank 2) + (1 for rank 3) divided by sum of all weighed reasons mentioned by the respondents for each category

[1] by wind and animals

Table 2: Summary of poisonous plants in southern rangelands, Ethiopia

Local name	Botanical name	Growth form	Season	Harmful part	Livestock affected	Symptoms	Treatment (local/traditional)
Gaaddallaa	*Pavetta gardeniifolia*	shrub	dry	fruit leaf	camel goat sheep cattle	no symptoms bloat diarrhea	no treatment provide drinking water give anthelmentic
Marra dhigaa	*Gladiolus boranensis*	herb	dry	leaf stems		blood in urine	drench a solution prepared from *walda* and water injection of oxytetracycline
Qorsa dida	*Euphorbia sp*	herb	Year round rainy	leaf/ stem	young animals	bloat diarrhea (with blood sometimes) stunted growth	drench a solution prepared with *walda* and water butter milk mixed with *magado* branding on belly and tail
Bosoqee	*Euphorbia hetrophylla*	herb	dry	leaf fruit	sheep	bloat diarrhea	give excess water
Mishingaa (sorghum)	*Sorghum bicolor*	herb	dry	leaf stem	cattle	bloat	inject oxytetracycline
Ardaa	---	herb	rainy	stem leaf	cattle	bloat bellowing foam comes out	drench a solution prepared with *walda* and water fumigate with *walda*
Tabari	---	herb	early rainy dry	leaf stem	Donkeys, horses cattle sheep goat	Animals unable to stand	give flood or tula water brand on legs, joints and back injection with oxytetracycline
Ogora gaalaa	--	shrub	dry	leaf fruit	camels	Bloat diarrhea	no treatment
Hadha	--	shrub	dry	leaf fruit	goat sheep	bloat diarrhea	drench milk fumigate with *walda/andaad* oxytetracycline injection
Bobiya	--	herb	dry	leaf stem	camel goat	fever bloat and diarrhea protrude lips droopy head	drench camel's milk, honey

Table 2: (continued)

Local name	Botanical name	Growth form	Season	Harmful part	Livestock affected	Symptoms	Treatment local/traditional
Finchoo	---	herb	dry	stem leaf	cattle	bloat, usually sudden death	drench a solution prepared with *walda* and water fumigate with *walda*
Annoo worabessaa	*Euphorbia nubica*	shrub	dry	leaf stem	cattle, camel goat, sheep	diarrhea sap irritates eye	brand on belly
Hidii qixii	*Solanum sp*	shrub	dry	leaf fruit	goat, camel	blindness, deafness nervousness, death	provide excess water
Qobboo	*Ricinus communis*	Shrub/tree	dry	fruit leaf	cattle	bloat, diarrhea, weight loss, death	no treatment
Qararuu	*Acokanthera schimperi*	tree	dry	leaf	cattle goat sheep	meat has bitter taste	no treatment as the effect is mild
Halakuu ajoo	--	herb	dry	leaf stem	cattle	diarrhea	fumigate with *andaad* give tetracycline capsules
Banya	--	shrub	dry	leaf	camel, goat	diarrhea	no treatment
Buri	--	shrub	dry	stem	camel, goat	diarrhea, weight loss	give milk, root of *dhaqaba*
Dhallaa	--	herb	dry	stem/leaf		fever, diarrhea, death few days	no treatment
Qanxxallaa	--	herb	dry	stem/leaf	goat, sheep	bloat, kills few days	inject oxytetracycline, give *walda*, tobacco
Wardele	--	shrub	rainy	Fruit leaf	goat sheep	abortion	no treatment
Babalaa	--	shrub	dry, early rainy	stem	cattle	bloat diarrhea	no treatment, there is medicine but did not want to mention (one respondent)

Walda, dhaqabaa and *andaad* are plants used for treating various sicknesses in animals
Magado is a type of salt extracted from one of crater lakes in Borana zone.

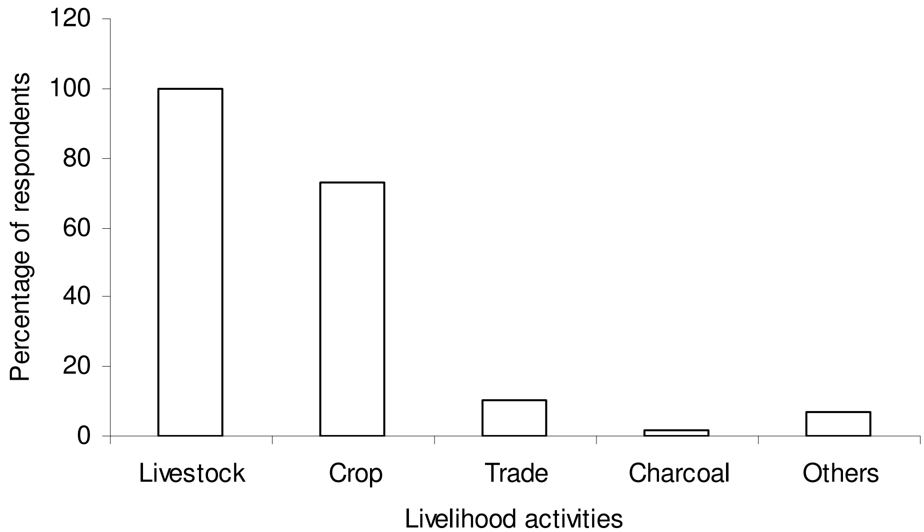

Figure 1: Sources of respondents' livelihood, southern rangelands

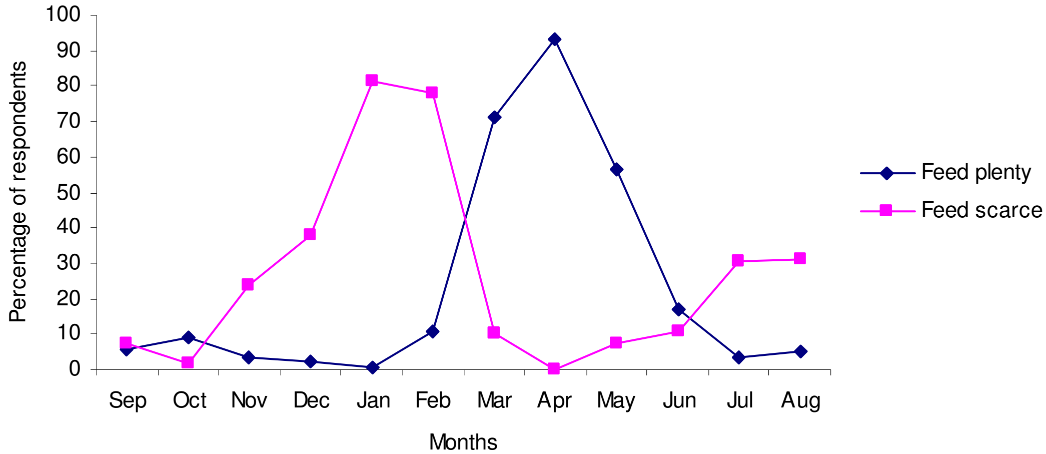

Figure 2: Pattern of feed availability in the southern rangeland