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ORIGINAL ARTICLE

Effect of supplementing Rhodes grass hay (*Chloris gayana*) with *Berchemia discolor* or *Zizyphus mucronata* on the performance of growing goats in Kenya

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Summary

Twenty growing Small East African goats were used to determine the effects of feeding sun-dried leaves of the browse forages *Berchemia discolor* and *Zizyphus mucronata* as supplements to low-quality basal diet, Rhodes grass (*Chloris gayana)* hay, on voluntary feed intake (VFI), digestibility and growth performance. The grass hay and maize bran were used as a control. The dried leaves were then included at the rates of 15% and 30% of the dry matter intake (DMI). *Berchemia discolor* had the highest crude protein (CP) content of 195.5 g/kg DM, while *Z. mucronata* had CP content of 169.5 g/kg DM. The grass hay had the lowest CP content of 50.9 g/kg DM. The browse forages had low fibre content [Neutral detergent fibre (NDF); 257.9–369.5 g/kg DM], while the grass hay had high fibre content (NDF; 713.1 g/kg DM). Goats in the groups supplemented with either of the browse forages had higher total DMI, nitrogen (N) intake and retention and live-weight gains than those in the control diet group. The digestibility of DM and organic matter (OM) was not affected by supplementation, but the CP digestibility increased with supplementation. The use of the browse forages as supplements for goats fed on poor-quality basal diets would enhance the performance of the animals.

Introduction

Most areas of the tropics, including Kenya, are classified as arid or semi-arid and are always prone to prolonged drought. During such times, the common scenario is a decrease in productivity from animals and, in worst cases, death of the animals mainly because of feed shortage. To tackle the situation, there is a need to explore ways of alleviating such losses, especially through the use of locally available feed resources which may be of high nutritive value. Hence, identification of nutritious feed resources is important so that farmers can be advised to harvest and keep such feeds in times of plenty (rainy season) for use during the lean periods (Osuga et al., 2007). *Berchemia discolor* and *Z. mucronata* are some of the browse species available in the tropics, which can be used for feeding ruminants.

Berchemia discolor, also known as 'wild almond', is a shrub or a tree up to 20 m high with erect spreading branches making a heavy rounded crown. The leaves are alternate or subopposite, shiny dark green above, dull and glaucous below, sticky at early stage and oval with the widest part towards the apex. *Zizyphus mucronata* is a semideciduous shrub or tree up to 15 m high, sometimes scrambling over other plants with branches and spreading, often drooping, branching well above ground or near the base. The leaves are hairless and shiny and alternate.

Despite the presence of such browse species in the arid and semi-arid ecosystem of East Africa, there is limited information available on their nutritive value. Previous studies have shown their potential nutritive value for the supplementation of poor-quality diets consumed by animal (Osuga et al., 2006). The species had good palatability when they were offered with other species such as *Acacia mellifera* and *Maerua angolensis* (Osuga et al., 2008). Wambui et al. (2010) improved the degradability of the browse forages *in vitro* by including yeast. Therefore, the objective of this study was to determine the effect of supplementing a low-quality basal diet (hay) with either *B. discolor* or *Z. mucronata* on intake, digestibility and growth performance of growing goats in Kenya.

Materials and methods

Study site

The study was conducted at Egerton University's Tatton Farm in Njoro, Kenya. The area is situated at an altitude of 2250 m above sea level. The area has a mean annual temperature and rainfall of 21 °C and 900 mm, respectively.

Animals

A total of 20 male Small East African growing goats (12–15 months old), with a mean body weight of 16.6 ± 1.1 kg, were used in the growth performance trial. The experiment was preceded by a 2-week preliminary period to accustom the animals to the premises, treatment diets and conditions. The animals were kept indoors on slatted floor in individual pens throughout the experimental duration and fed in individual feed troughs. The animals were dewormed using a broad-spectrum anthelmintic before starting the experiment and sprayed every 3 weeks with acaricide to control external parasites.

Feeds and treatment diets

Leaves from *B. discolor* and *Z. mucronata* were used in this study. The leaves were harvested from Egerton University's Chemeron Field Station in Baringo District, Kenya. The area is located at an altitude of 1066 m above sea level with an average annual rainfall and temperature of 700 mm and 24 °C, respectively. The leaves were dried under a shade until dry (about 1 week) and stored for use during the experiment. Maize bran was bought from local commercial millers. Rhodes grass (*Chloris gayana*) hay was purchased from a nearby farm in bulk and stored for use during the experiment. The hay was chopped using an electric chopper to pieces of about 30–40 mm to minimize wastage before being fed to the animals. Water and mineral block for licking were provided *ad libitum*. The treatment diets were:

- **T1.** Rhodes grass hay *ad libitum* plus 60 g maize bran (control).
- **T2.** Control plus 15% *B. discolor*.
- **T3.** Control plus 30% *B. discolor*.
- **T4.** Control plus 15% *Z. mucronata*.
- **T5.** Control plus 30% *Z. mucronata*.

Experimental design and procedures

A completely randomized design was used with four animals for each of the five treatment diets. The supplement and basal diets were offered separately. The browse supplement and maize bran were weighed and placed in the feed troughs every morning at 08:30 h. The hay was then introduced at 09:30 h after the supplement, and bran has been completely consumed by the animals. The amounts of supplements offered were adjusted weekly based on the previous week's intake. The basal diet (hay) was offered *ad libitum* by ensuring that the refusals were 15% more than the previous day's intake. The amount of basal diet and browse DM offered, refused and consumed by each individual animal was recorded every day. The goats were weighed on weekly intervals at 07:00 h for two consecutive days prior to accessing their daily feed or water. However, at the start and finish of the experiment, the goats were weighed for three consecutive days and the average taken as the initial and final weights of the animals, respectively. The data were collected for 10 weeks.

During the tenth week of the trial, three animals from each treatment diet were introduced to metabolic cages for total but separate collection of faeces and urine. The total amount of faeces excreted each day (24 h) was recorded, and a sample (10%) was taken for DM and chemical analysis. The urine was collected in plastic containers to which had been added 50 ml of 0.01 M sulphuric acid, the total volume measured and a sample taken for analysis of N. The Rhodes grass hay, maize bran and browse forages were sampled weekly, bulked and mixed at the end of the experiment and subsampled for DM and chemical analysis. DM, organic matter (OM) and crude protein (CP) contents were measured according to the official methods of the Association of Official Analytical Chemists (AOAC, 1984). Neutral detergent fibre (NDF) and acid detergent fibre were determined according to the methods of Van Soest et al. (1991). During the last 2 days of the experiment, rumen liquor was extracted from the goats using a stomach tube at 0, 3 and 6 h post-feeding for pH and ammonia nitrogen determination (AOAC, 1984).

Statistical analysis

All data were subjected to analysis of variance using the General Linear Model procedure of the STATISTICAL ANALYSIS SYSTEM (SAS) Version 8.1 (SAS Institute, NC, USA). Significance between means was tested using Fisher's least significance difference.

Results and discussion

The chemical compositions of the feeds are shown in Table 1. The CP content ranged from 50.9 g/kg DM in grass hay to 195.5 g/kg DM in *B. discolor,* while *Z. mucronata* had a CP content of 169.5 g/kg DM. The CP content of *B. discolor* and *Z. mucronata* was comparable with the reported CP content of similar browse forages (Ondiek et al., 1999; Osuga et al., 2006; Wambui et al., 2006). The maize bran used in the experiment was purchased from local commercial millers, who during milling used mechanical de-hullers, and therefore, the bran had considerable amounts of the endosperm. This may have contributed to the higher CP content of maize bran (156.9 g/kg DM) than that reported by other workers (Ondiek et al., 1999; Wambui et al., 2006). However, the low CP content of the hay was within the range reported (Ondiek et al., 1999; Osuga et al., 2006). The hay had numerically high fibre content (713.1 g/kg DM) than the other feeds used in the experiment. However, considerable amount of the fibre is hemicellulose, which could be digested in the rumen by the rumen microbes to release energy.

Table 1 Chemical composition of the experimental diet ingredients (g/kg DM)

Feed	DM†	OM	CP	NDF	ADF
Rhodes grass hay	905.6	919.0	50.9	713.1	382.7
Maize bran	894.4	920.4	156.9	257.9	219.6
B. discolor	902.7	926.1	195.5	347.0	196.1
Z. mucronata	874.1	927.0	169.5	369.5	200.6

ADF, acid detergent fibre; CP, crude protein; OM, organic matter; NDF, neutral detergent fibre.
†Expressed as g/kg fresh weight.

The results on the DM intake (DMI), digestibilities and live-weight gain (LWG) are presented in Table 2. There was a general depression in the basal diet intake associated with supplementation, though only significant ($p < 0.05$) for T5 (30% *Z. mucronata*). However, supplementation with either of the forages significantly ($p < 0.05$) increased the total DMI except at 15% *B. discolor* supplementation. The goats fed on 30% *B. discolor* had significantly ($p < 0.05$) the highest LWG (63.6 g/day) followed by the group supplemented with 30% *Z. mucronata* (38.0 g/day). However, there were no significant ($p < 0.05$) differences among the groups fed at lower rate of supplement. The control group gained the least weight at 4.6 g/day.

Leng (1990) defined low-quality forages as forages with CP <80 g/kg DM and suggested supplementation of such forages with appropriate nutrients to achieve high levels of animal production. Nutritional studies have generally shown that the use of forage legumes as protein supplements enhanced the nutritive value of low-quality fibrous feeds (Abdulrazak et al., 1997; Ondiek et al., 1999; Hove et al., 2001; Wambui et al., 2006; Kahindi et al., 2007).

The results of this study show that the use of dried *B. discolor* or *Z. mucronata* forages as a protein supplement to a basal diet of grass hay results in higher total DMI. All the supplements were readily eaten by the animals, and the animals showed no apparent health problems. Increasing the level of

Table 2 Mean DM intake, digestibility and live-weight gain (LWG) of growing goats

Treatment	T1	T2	T3	T4	T5	SEM
Intake (g/day)						
Hay	458.7[a]	388.8[ab]	402.1[ab]	406.1[ab]	374.2[b]	20.7
Maize bran	53.7	53.7	53.7	53.7	53.7	-
Forage	_	77.7	183.3	84.5	167.6	21.6
Total	516.1[b]	520.1[b]	639.1[a]	544.3[ab]	595.4[ab]	34.0
CP	31.8	43.4	65.1	43.8	56.3	
Digestibility						
DM	647.9	559.5	600.8	663.2	604.1	2.6
OM	633.8	548.0	582.5	576.2	607.9	2.4
CP	834.8[b]	884.8[ab]	920.2[a]	886.8[ab]	923.4[a]	6.2
LWG (g/day)	4.6[d]	28.1[c]	63.6[a]	24.3[c]	38.0[b]	5.8

CP, crude protein; OM, organic matter.
Means with different superscripts in a row differ significantly ($p < 0.05$).
T1, treatment 1; T2, treatment 2; T3, treatment 3; T4, treatment 4; T5, treatment 5.

either *B. discolor* or *Z. mucronata* resulted in increased total DMI, which is in agreement with the previous studies from Kenya involving similar forages (Sawe et al., 1998; Abdulrazak et al., 2005). However, the intake of the basal diet tended to decline with supplementation especially in T5. These results are in agreement with the results of Kahindi et al. (2007) and Wambui et al. (2006). Ondiek et al. (1999) reported a decline in basal diet (*Choris gayana* hay) intake when maize bran was included in the supplementation with *Gliricidia sepium* for growing goats. Hove et al. (2001) noted a depression in intake of natural pasture hay by goats when supplemented with browse forages, although the depression was only significant at higher levels of supplementation (320 g/day).

Protein supplementation has been found to increase total DMI in diets with low-quality roughage, resulting in a simple additive effect – sum of basal diets and supplements (Sánchez and Ledin, 2006) as found in this study. Goodchild and McMeniman (1994) found that inclusion of 20–50% of plants rich in protein in the diet resulted in a 10–45% increase in total intake. The increase in DMI with browse forage supplementation can be because of improved microbial activity as a result of the increase in essential nutrients available to rumen microbes. In addition, the energy supplied by maize bran could have contributed to higher microbial activity compared with hay alone owing to an improved energy–N ratio in the rumen (Sinclair et al., 1993) stimulating the growth and cellulolytic activity of ruminal bacteria.

Depressed intake of basal diets owing to supplementation has also been attributed to reduced cellulolysis in the rumen because of tannins binding with nutrients and enzymes. However, the forages used in this study had earlier been shown to have low levels of tannins (Osuga et al., 2008), which would be unlikely to affect the total DMI. The activity of the tannins present in the forages had also been shown to be low (Osuga et al., 2008). The depressed intake of the basal diet may also have been attributed to the substitution of the browse forages for hay, since the total DMI increased. This may be due to the high palatability of the browse forages (Osuga et al., 2008) and low fibre (NDF) content of the forages (Hove et al., 2001).

The apparent digestibility of DM and OM was not statistically affected by supplementation with *B. discolor* or *Z. macronata* forages. At higher levels of supplementation, the CP digestibility increased with 30% inclusion of either forage. Sánchez and Ledin (2006) also reported similar results when dairy cows fed on sorghum silage basal diet (CP; 72.5 g/kg DM) were supplemented with *Cratylia argentea* forage (CP; 177.3 g/kg DM) and sugarcane molasses.

The rumen pH and NH_3-N are shown in Table 3. The rumen pH was not significantly ($p < 0.05$) different among the treatment diets except after 6 h post-feeding in T3, which decreased. After supplementation, the rumen pH tended to decline for all the treatment diets. Before supplementation and feeding, the rumen NH_3-N ranged from 21.0 to 27.4 mg/l. However, after 6 h post-feeding, the rumen NH_3-N ranged from 45.3 to 65.3 mg/l.

The dietary treatments had no effect on the rumen pH, which is in agreement with other studies involving browse forages (Wambui et al., 2006; Krebs et al., 2007). Ruminal microbes are quite sensitive to changes in rumen pH and most prefer a range of 6.5–6.8 (Russell et al., 1979). Cellulolytic bacteria, in particular, are generally more sensitive to low pH than are amylolytic species (Therion et al., 1982). Cellulolysis has been shown to be inhibited by pH below 6.0 both *in vitro* and *in vivo* (Terry et al., 1969; Ørskov and Fraser, 1975). Thus, fibre digestion may be depressed at low pH because of negative effects of pH on cellulolytic bacteria (Grant and Mertens, 1992). In the current study, the rumen pH was maintained above 6.2, which would indicate favourable conditions for microbial activity in the rumen.

There were no significant differences in the rumen NH_3-N concentrations However, in the browse forage supplemented groups, the maximum NH_3-N concentrations exceeded 50 mg/l considered as the minimum concentration required to maximize microbial growth in the rumen (Satter and Slyter, 1974). Krebs et al. (2007) noted that the rumen NH_3-N concentrations were highest at 4 h post-feeding and that the

Table 3 Rumen pH and ammonia-N concentration

Treatments	T1	T2	T3	T4	T5	SEM
Rumen pH						
0 h	6.9	6.9	6.9	6.8	6.8	0.04
3 h	6.4	6.5	6.3	6.5	6.5	0.03
6 h	6.5^{ab}	6.6^{ab}	6.3^{b}	6.5^{ab}	6.8^{a}	0.06
Rumen NH_3-N (mg/l)						
0 h	21.0	23.9	23.8	26.4	27.4	1.18
3 h	35.7	44.5	63.6	36.2	45.8	2.87
6 h	45.3	51.3	65.3	55.1	52.2	4.12

Means with different superscripts in a column differ significantly ($p < 0.05$).

T1, treatment 1; T2, treatment 2; T3, treatment 3; T4, treatment 4; T5, treatment 5.

concentrations were above the minimum concentrations for a period of 8–11 h. The rumen NH_3-N concentration in this study exceeded the minimum concentrations at 6 h post-feeding. Animals in the control group had lower concentration of rumen NH_3-N than 50 mg/l.

Goats supplemented with browse forages had higher live-weight (LW) gains, suggesting that the various browse forages had beneficial effects on the animals. The LW gains in this study followed the trend of CP intake (Table 2) with the highest gains being in the animals consuming T3 (65.1 g CP/day) and least gain being from the control group (T1). These weight gains are comparable to those of Sawe et al. (1998) especially as regards to *B. discolor* supplementation (59.1 g/day). McSweeney et al. (2002) noted that annual growth rates of animals in the tropical regions of Africa are restricted by the low N and high fibre content of the native grasses and crop residues that form the basis of the diets in these regions. However, supplementation with either *B. discolor* or *Z. mucronata* in this study supplied the deficient nutrients especially N, and this led to the increased LW gains in the animals supplemented with the forages. The inclusion of maize bran as an energy source in the diets of the animals improved the energy status of the animals, and this may have resulted in the animals in the control group also gaining some weight.

High tannin levels in forages generally tend to depress voluntary feed intake and nutrient utilization in animals (Barry and McNabb, 1999), but a low content of tannins is beneficial to ruminants as it produces a bypass protein effect (Barry et al., 1986). Both forages used in this study were reported to contain low tannin levels of 20.2–34.8 g/kg DM (Osuga et al., 2008), which could be beneficial to animals consuming them through the production of bypass protein effects. Bypass protein has been noted to improve the N availability to the gut (Barry and McNabb, 1999) with subsequent improvement in weight gains.

Conclusion

Inclusions of either *B. discolor* or *Z. mucronata* forages in the diet of the goats increased LW gains. The increase in animal performance was because of the increase in DMI, provision of deficient nutrients in the basal diet especially N and provision of favourable rumen environment. The performance of the animals was greater at higher level (30%) of leaf supplement inclusion than that at the lower level (15%).

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