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Availability of Browse Plants to Goats Fed with Napier Grass: Voluntary Feed Intake and Effects on Body Weight

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Abstract: ***Plants with varying level of tannins were offered to goats 4-6 months old fed with napier grass (Pennisetumpurpureum) and palm kernel cake (PKC)-based pellet. Voluntary feed intake (VFI) of offered plants on the 3rd week of feeding was highest for Artocarpusheterophyllus and Leucaenaleucocephala (48 and 36 g/kg0.75 body weight (BW)). Sapiumbaccatum, Brachiariadecumbens, Micaniamicrantha and Musa sp. had VFI of 34, 33, 33 and 31 g/kg0.75 BW respectively whereas VFI for Cyprus kyllinga, Melastomamalabathricum and Dilleniasuffruticosa were amongst the lowest (24, 22 and 20 g/kg0.75 BW respectively). Animals offered with L. leucocephala and A. heterophyllushad increased BW gain(8.8 and 7.9 kg respectively; p<0.05) whereas M. malabathricum and D. suffruticosafed animals had reduced BW gain (5.6 and 5.8 kg respectively; (p<0.05)) compared to the BW gain of napier grass fed animals (6.9 kg).A.heterophyllus, L.leucocephala, S. baccatum, C. kyllinga, and M. malabathricumcontain measurable condensed tannin (7.4, 2.6, 6.8, 5.6 and 2.7 mg/gDM respectively) whereas hydrolysable tannin was highest in M. malabathricumand D. suffruticosa (187 and 143 mg/g DM respectively).The use of browse plants containing tannins to manipulateVFI and growth may be beneficial if consumed between 3-7 weeks to avoid cumulative negative effects of plant secondary compounds on BWG.***

Keywords: browse plants, condensed tannin, hydrolysable tannin, feed intake, body weight gain

1. Introduction

Given choice goats in the tropics will consume forage with less fibre and higher crude protein (CP)content such as leaves of browse. The selection criteria of browsing goats toselect certain plants species or plant parts are many and may not be restricted to the contents of crude protein or fibre (Hadjigeorgiou*et al*., 2003), presence of tannin (Kumar and Vaithiyanathan, 1990) or fibre digestibility (Hadjigeorgiou*et al*.,2003, Alonso-Diaz, 2008). Plants containing secondary factors may positively affect microbial degradation of fibre, ammonia nitrogen formation and bypass protein **(**Mueller-Harvey, 2006**).** The optimum level of feeding on tannin containing plants varies between plants with values ranging from 0.7-3.5% considered to be safe (Sharma *et al*, 2008) whereas consumption at a level of over 6% are not advisable as this may affect feed utilization (Min *et al*, 1999).

Rumen microbes require sufficient N to enable the synthesis of microbial proteins necessary for the growth of these microbes and efficient digestion of fibers (Madsen *et al*, 1997; Shem *et al*, 2003). Sufficient N provision under moderate to high in developing countries may be met through diet rich in CP (commercial concentrate) or traditional methods (e.g. homemade concentrate based on *G. sepium*, maize bran and cotton seed cake (Kabi*et al*, 2005). There is currently an increased interest in the utilisation of plants with secondary compounds especially in view of the fact that consumption of tanniniferous plants can help protect against extensive rumen degradation of feed CP and increasing amino acid absorption (Waghorn*et al*., *1987*), control antimicrobial (Lentz *et al*, 1998), prevent bloat in ruminants (Tanner *et al*., 1995) and suppress nematodes (Alen*et al*, 2000) and other intestinal parasites (Min and Hart, 2003).

It is important to evaluate the performance of animals fed plants with varying level of phenolic compounds because long term consumption of plants with these secondary compounds can affect the rumen microbial flora and fauna (Odenyo*et al*, 2003; Mlambo*et al*, 2007) such that the degradation of fibre (Molina, *et al*, 1999), microbial growth and energy availability in the form of short chain fatty acids are also altered. Thus the objectives of the current experiments were: (1) to evaluate the intake of plants with different nutritional properties over extended period of time by goats already obtaining sufficient amount of N, 2) to quantitate the intake of CP and fiber during the feeding trial and 3) to determine the benefits of offering these plants in relation to growth performance.

2. Materials and Methods

2.1 Experimental plants

Plants used in this study were obtained within the University of Malaya campus, Kuala Lumpur (altitude m, rainfall 650 - 247 mm). *Cyperuskyllinga* was harvested by cutting the whole plant at 5 cm above the ground whereas *Pennisetumpurpureum* and *Brachiariadecumbens* were harvested at 5 and 2 weeks respectively after previous cutting.*Artocarpusheterophyllus, Leucaenaleucocephala, Sapiumbaccatum, Melastomamalabathricum and Dilleniasuffruticosa* were offered in the form of twigs (max diameter 0.5 cm) and leaves. *Musa sp.* was offered in the form of whole leaves whereas *Micaniamicrantha* (mile-a-minute weed) was offered in the form of stems, petioles and leaves.

2.2. Animals, diets and treatments

Male 4-6 months old Jermasia crossKatjang goats, with initial body weights between 11.0 and 13.0 (11.6 ± 0.19 kg; n=40), were allocated according to body weight in groups of four. Animals were weighed on a weekly basis before morning feeding. The goats were penned (1.5m x 2.0m) individually on wooden slated floors. Napier grass was harvested daily and offered in the morning (0800 – 0900 hr) to the animals at 2% of body weight (BW). Tested pants were also harvested daily in the morning and left to wilt under the shed and these were offered at 2% of BW together with 200g palm kernel cake (PKC) based concentrate (18% CP)in the evening (1500-1600 hr).Control animals received a second Napier grass ration in the evening. The goats had free access to fresh clean water and mineral block throughout the trial period. The treatment period consisted of 10 days for adaptation followed by 12 weeks of growth period. Representative samples of plants consumed were collected thrice weekly, oven (50ºC) dried, pooled and subsequently ground to pass through 1.0mm screen for further analysis.Refusals of supplement and napier grass were separately weighed each morning before feeding and samples were taken during digestibility period for analysis.

Plant samples were analysed for contents of dry matter (DM), organic matter (OM) and nitrogen (N) (AOAC, 1990). Sodium sulphite was used for the analysis of neutral detergent fibre (NDF) (Van Soest and Robertson, 1985) and values were corrected for their ash content.

2.3 Chemical analysis

Neutral (NDF) and acid (ADF) detergent fibre analysis were carried out as described by Van Soest*et al*, (1991). The weight of plant samples and sintered glass crucibles for fibre analysis were determinedcorrect to four decimal places (in gram; Sartorius Analytic). The plant samples were dried (100ºC, 24hr) to remove residual water content. Nitrogen (N) content in samples was determined by Macro-N analysis (Foss Electric (UK) Ltd.) and N values obtained in %DM was multiplied by 6.25 to yield % crude protein (CP).

2.4 Extractable phenolic compounds

Analysis of phenolic compound in the plants was carried out in four replicates as described by Khazaal*et al*, (1993). Total extractable condensed tannins (CT; as catechin equivalent), were determined using the vanillin assay (Jones *et al*, 1976) and in unit absorbance at 550nm (Total phenol) using the proanthocyanidins assay (Porter *et al*, 1986). Total extractable tannin (TETa; in tannic acid equivalent) was calculated by the difference between total extractable phenolics (Julkunen-Tiito, 1985) and amount of phenolic compounds remain after absorption onto polyvinylpolypyrrolidone (PPVP) (Makkar and Singh, 1992). Hydrolysable tannin was analysed using rhodanine reagent (Inoue and Hagerman, 1988).

2.5 Calculation and statistical analysis

Browse plants nutrient and secondary compound contents, nutrient intake and growth performance were analyzed by analysis of variance using the SPSS (1999) package. Significant differences between means ($p<0.05$) were tested using the Duncan multiple range test (DMRT).

3. Results and Discussion

3.1 Nutrient and anti-nutrient characteristics of browse plants.

CP was highest in *L. leucocephala* (26.2%) whereas other plants ranged 10-16% (Table 1). The CP contents of the plants used in the present studies (10-26%) were higher than 8%, the minimum level required for maintenance of animals (Norton, 1998). The CP attributed to each plant may also vary since there is variation in CP contents within plant when shoots leaves and twigs were compared (Ben Salem *et al*, 2005). The NDF content which ranged 34-57% in most plants indicate low fibre content compared to 66 and 70% in *P. purpureum*and *Musa sp.* respectively.Except for *P. purpureum*, the ADF fraction for all plants were more than 50% of the NDF which is indicative of high levels of hemicellulose.The CT determined ranged between <1.0 – 7.5 mg/gDM. The relatively low CT determined in the present studies could be explained by the use of only one CT compound (catechin) as reference for CT whilst the use of extracted CT from the plants (Waghorn, 2008) under study would be more appropriate. Nevertheless appreciable increase in gas production in the presence of PEG (*M. malabathricum*, *S. baccatum*and *C. kyllinga* $p<0.05$; *L. leucocephala* and *A.heterophyllus; p>0.05*)indicate the presence of biologically active CT in these plants (Makkar, 2003b).Two plant species (*M. malabathricum* and *D. suffruticosa*) contained the highest amount of hydrolysable tannins (187.2 and 143.8 *g/kg DM respectively)* but these are comparable to those reported in oak, acacia species and other browse plants (up to 200 gHT /kgDM; Reed, 1995).The differences in the contents of total tannins/condensed tannins in the plants arecomparable to other reports (Rodriguez *et al*, 2008), which highlight the variation in potential feed quality used in the present studies. It is interesting to note that *M. Micrantha*, considered as one of the most invasive plants in the world (Zhang *et al*, 2002) has comparable NDF and ADF values as *B.decumbens*.Its low DM content however may restrict intake.

3.2 Feed and Nutrient Intake

Napier (*P. purpureum*) and signal (*B. decumbens*) grasses, despite categorically classed as poorer C4 grass than temperate C3 grasses (Lewandowski*et al.* 2003) can be used successfully to feed small ruminants (Archimede*et al*, 2000, Axtmayer, *et al*. 194O). The intake of *B. decumbens*was thus used in the present study to compare with the intake of other offered plants in the evening. Napier grass intake by goats offered browse plantsranged 30-41 $g/kg^{0.75}$ BW as compared to napier grass consumed by *B. decumbens*-offered goats (33-34 $g/kg^{0.75}$BW). The browse plants were consumed between 20 and 40 $g/kg^{0.75}$BW/day with the intake of *C. kyllinga*, *M. Malabathricum*and *D. suffruticosa* being lower (24-27, 22-28 and 20-30 $g/kg^{0.75}$BW/day respectively, $P>0.05$) compared to the intake of *B. decumbens* (27-32 $g/kg^{0.75}$BW/day*).D. suffruticosa* (20±2.3 $g/kg^{0.75}$BW/day) was consumed less than *B. decumbens* (27±3.1 $g/kg^{0.75}$BW/day; $p<0.05$) in week 3 (Stage 1) but the amount eaten increased gradually to 24 ±

3.5 g/kg$^{0.75}$BW/day (week 6, Stage 2) and 30 ± 2.4 g/kg$^{0.75}$BW/day by the end of the feeding study (Week 12, Stage 3). Regardless of reduced intake for certain browse plants compared *to B. decumbens* intake, total dry matter intake (TDMI) of treated goats in Stage 1 (78 – 108 g/kg$^{0.75}$BW/day) were on average higher than TDMI of control group (76±2.9 g/kg$^{0.75}$BW/day) with significant (p<0.05) effects seen *in M. micrantha-, L. lecocephala-, S. baccatum-* and *A. heterophyllus*-offered groups.

Intake of CP was higher in goats which consumed *S.baccatum* (14.0-14.9g/kg$^{0.75}$BW; P>0.05), *L.leucocephala* (19-20g/kg$^{0.75}$BW; P<0.05) and *A.heterophyllus* (15.3-16.4g/kg$^{0.75}$BW; P<0.05) compared to control group (*P.purpureum*, 11.6-12.7 g/kg$^{0.75}$BW) at all three experimental stages. The consumption of *C.kyllinga, M.micranthaand M.malabathricum* resulted in lower (p>0.05) CP intake than Napier grass-fed goats. The intake of NDF and ADF in *M.sepiantum*and*A.heterophyllus*-offered goats were higher (P<0.05) than those in control group. *M.micrantha*-offered goats had reduced NDF intake only in the 3rd stage whereas *C.kyllinga-, M.malabathricum*-and*D.suffruticosa*-offered goats had significantly reduced NDF intake by stage 2. ADF intake was increased in *L.leucocephala* (p<0.05, stage 1) and in *S.baccatum* (p<0.05, all 3 stages) offered goats whereas NDF intake was not affected. The ratio of fibre:CP in the diet consumed by control goats range between 4.3 to 4.7 (Table 4). This ratio was reduced for *L.leucocephala-, D. suffruticosa-* and *M.malabathricum*-fed goats (3.0-3.1, 3.6-3.9 and 4-4.3 respectively; P<0.05) but was increased for *M.sepiantum*-(4.9-5.2; P>0.05) and *A. heterophyllus*- (5.2-5.3; P<0.05) fed goats.

The presence or absence of phenolic compounds in the plants used in the present studies did not influence VFI in a uniform manner (Table 2). The calculated amount of CT in the plants (0.15 – 0.46% DMI) was low compared to other reports (Jones *et al*, 1976)and thus may not be contributing to the formation of ruminalundegradable protein and subsequent potentially higher amino acid flow to the small intestine. Tannin contents in browse plants of less than 1% of total DM intake are considered not likely to have substantive adverse effects on ruminants (Getachew*et al.,* 2002). Two plants with relatively high HT had VFI that remained unchanged (*M. malabathricum*) or even increased with time(*D. suffruticosa*) suggesting the animals have adapted to eating these plants.

Goats are excellent in selecting feed that are highly digestible, which is usually not dependent on the tannin levels in the plants (Alonso-Diaz, 2009). The increased consumption of such feed high in tannin may lead to slow degradation of DM and CP in the rumen (Kaitho*et al*., 1998) and subsequent reduction in intake in the next feeding session. Such cyclic pattern observed in goats consuming its tannin rich meal have been described by Silanikove*et al*, (1997). Most plants in the present studies showed tendency of higher TDMI in certain week (e.g. week 6) than in others (e.g. weeks 3 and 12). It is apparent that for several browse plants species, other feed nutritive values (e.g water content, digestibility and palatability) may have determining effects on the voluntary intake apart from the tannins contents (Fahey and Jung 1989).

3.3 Growth performance and feed conversion ratio

The LBW gain on the 12th week of study increased for *L. leucocephala-, A. heterophyllus-* and *S. baccatum-* fed goats (8.8±0.67, 7.9±0.36 (P<0.05) and 7.2±0.54 kg (p>0.05) respectively) compared to control animals (6.5±0.15kg). Goats fed with the two plants rich in HT, *D. suffruticosa* and *M.malabathricum*, had lowest LBW gain (5.6±0.17 and 5.8±0.24kg respectively, p<0.05). This could be explained by the adaptation to these two plants (either unchanged (*M. malabathricum*) or increased (*D. suffruticosa*) VFI with time) resulting inpossible adverse negative effects to the breakdown products of HT (e.g. gallic acid) on body protein metabolism (Murdiati*et al,* 1991).*A.heterophylus*showed increased ADG (94.0-102.4 gDM/gLWG) and also improved FCR (1.2 gCP/gLWG; P<0.05) during the 3rd stage of eating compared to control goats. When compared to control goats, *L. luecocephala*-offered goats, which had similar feeding performance as *A.heterophyllus*-offered goats, had improved ADG (100–105 gDM/gLWG; P<0.05 for all three feeding stages) and FCR for DM (8.3gDM/gLWG; P<0.05 stage 3 of feeding) but not FCR for CP (1.6-1.7gCP/gLWG; P<0.05 stages 2 and 3 of feeding). On the other hand goats consuming *C.kyllinga, M.micrantha,M.malabathricum* or *D.suffruticosa* showed reduced (p<0.05) ADG throughout the experiment. There was no increase in BW, ADG and FCR in *M. sepiantum*-offered goat at stage 1 (one) of feeding, despite higher intakes of CP (p>0.05) and NDF (p<0.05).

The plants/foliages which are widely used as feed supplements in the tropics potentially contain a wide array of secondary compounds and the present studies showed that these need to be properly evaluated. *L. leucocepahala,* a commonly used legume in the tropics (Adejumo and Ademosum, 1991) appeared to be uneconomical in the present studies when consumed over long period of time. High dietary protein intake by the consumption of this plant (CP= 26.2%; FCR=1.7 kgCP/kgLWG) for 12 weeks was not used to support live body weight gain (LWG) as efficient as *A. heterophyllus* (CP=15.9%, FCR= 1.2kgCP/ kgLWG). Goats in the present studies can be regarded have adapted to the tanniniferous plants after 3 months feeding on these plants (Pell *et al*., 2000). The poor performance of *C. kyllinga-, M. micrantha-, M. malabathricum-* and *D. suffruticosa*-fed goats as evidenced from the lower ADG (Table 5) cannot be explained by tannin contents alone. Reduced total nutrient intake may be partially responsible since CP and NDF intakes (Table 4) from these plants were generally lower than napier grass-fed goats with profound reduced fibre:CP ratio for *M. malabathricum-* and *D. suffruticosa*-fed goats, particularly in week 6 and 12 (p<0.05).

In practice, the use of browse plants tremendously improved the quality of diets for ruminants in the tropics if they can provide both fermentable carbohydrates and N, especially when readily nutrient availability are suppressed during the dry season (Leng, 1997; Fondevila*et al.,* 2002). In addition these plants can be beneficial to animal production because the secondary plant compounds may provide protection to dietary protein against extensive rumen microbial digestion (Makkar, 2003a). Despite this potential benefit,plants

containing considerably small amount of tannins, either in the form of CT or HT, may have negative consequences to animal growth performance when consumed over long period of time (longer than 6 weeks). Such concern is demonstrated in the present studies if the plants (*C. kyllinga*,and*M. malabathricum*with CP 10.4 and 11.4% respectively) can not contribute as much CP as *L.leucocephala*and*A. heterophyllus* (CP 26.2 and 15.9% respectively).

One of the main concerns of allowing goats to browse in the evening under extensive management (e.g. Baba et al 1998) as routinely practiced in the tropics is the risk of consuming plants that may be deleterious to growth performance. This could happen particularly if the purpose of free browsing in the evening is to allow consumption of additional greens as supplements to that offered in the shed. The fact that several plants in the present studies (e.g. *D. suffruticosa*, *M. malabathricum*, *C. kyllinga*) may not be suitable to be consumed at high levels or as single supplement for more than 6 weeks does not mean that they are not suitable to be consumed as periodically browsed (i.e. part of a mixed ration with other plants). In this regard, it is very important for the farmers to be given adequate information on the feed resources and nutrient potential of plants that are available in abundance around the shed.

4. Conclusions

The feeding values of nine tropical browse were evaluated by determining levels of nutrients and secondary compounds, as well as feed intake and growth performance of goats. The eating values of these plants in relation of body weight gain cannot be evaluated based on fibre:CP intake, tannin composition, or even on biological tannin assay. *M. malabathricum*and,*D. suffruticosa* which contain high HT content are not suitable for long term feedings. Plants with high CP, high CT and high VFI can be safely consumed over long period of time without a negative effect on body weight gain provided the total daily CP intake is higher than 15%.

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Table 1: Proximate analysis of browse plants and grasses offered to goats.

Browse plants/ grasses	DM (%)	CP (%)	EE (%)	Ash (%)	*NDF(%)*	ADF (%)
P. purpureum (Np)	18.7[a]	14.5[a]	3.6[a]	12.6[a]	66.4[a]	30.14[a]
M. sepientum (MS)	24.8[a]	14.4[a]	3.8[a]	9.2[b]	70.4[a]	41.50[a]
B. decumben (Bd)	19.4[a]	14.5[a]	3.6[a]	10.7[a]	56.6[a]	29.70[cd]
C. kyllinga (Ck)	16.2[a]	10.4[a]	2.3[a]	8.3[b]	47.9[bc]	31.70[c]
M. micrantha (Mmi)	15.3[a]	11.4[a]	4.5[a]	11.2[a]	53.0[b]	33.69[bc]
L. leucocephala (Ll)	33.4[b]	26.2[b]	4.3[a]	7.8[b]	37.6[cd]	25.60[d]
S. baccatum (Sb)	38.0[b]	14.3[a]	4.0[a]	9.9[b]	46.9[b]	40.60[a]
M. malabatricum (Mm)	36.5[b]	11.4[a]	2.8[a]	10.7[a]	35.6d	28.99[cd]
D. suffoticosa (Ps)	35.2[b]	10.9[a]	2.a	12.5[a]	34.6[d]	28.99[cd]
A. heterophyllus (Ah)	39.3[b]	15.9[a]	4.5[a]	10.7[a]	48.4[bc]	38.04[ab]
s.e.d.	9.6	4.4	0.8	1.4	11.9	5.3

Analysis was carried out in duplicate and the coefficient of variation was less than 5%
DM:dry matter; CP:crude protein; EE : fat (ether extract); NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre
[ab]Different superscripts in the same column differ significantly with P. purpureum at p<0.05

Table 2: Phenol and tannin contents (mg/g) in tropical grasses and browse plants

Grass/ Browse plant	Total Phenol[1]	TETa[2]	CT[3]	HT[4]	Gas (ml) [5](-PEG)	Gas (ml) (+ PEG)
P. purpureum (Pp)	13.30	12.80			55.5[a]	57.9 [a]
M. sepiantum (Ms)	9.10	7.40	<1.0	<5.0	58.0[a]	59.7 [a]
B. decumben (Bd)	12.90	16.00	<1.0	8,9	50.9[a]	56.4 [a]
C. kyllinga (Ck)	34.00	12.40	<1.0	8,5	36.2[a]	49.9 [a]
M. micrantha (Mmi)	10.00	8.60	5,60	<5.0	42.7[a]	52.6 [a]
L. leucocephala (Ll)	46.80	22.20	<1.0	<5.0	51.3[a]	72.4 [a]
S. baccatum (Sb)	254.20	33.10	2,65	24,1	46.9[a]	69.9 [b]
M. malabathricum (Mm)	121.20	22.00	6,83	40,8	41.4[a]	52.2 [a]
D. suffoticosa (Ds)	99.40	20.10	2,76	187,2	34.6[a]	38.7 [a]
A. heterophyllus (Ah)	43.40	30.80	<1.0	143,8	49.7[a]	71.4 [b]
s.d.			7,48	<5.0	7.6	10.2

Analysis of phenolic compound was carried out in four replicates and the coefficient of variation is less than 5%
Total extractable phenolics (Julkunen-Tiito, 1985) Total extractable proanthocyanidins (absorbance @ 550 nm/g DM);
[2]TETa: in tannic acid equivalent. (Total phenol – phenolic compounds [after PPVP absorption; Makkar et al, 1992].
[3]CT: condensed tannin (Catechin equivalent; mg/g DM; using vanillin assay Broadhurst and Jones, 1978)
[4]HT: hydrolysable tannin(gallic acid equivalent; mg/g DM)
[5]Gas produced from Hohenheim gas test (Baba et al, 2002) in the absence (-PEG) or presence (+PEG) of polyethylene glycol (PEG)
[ab]Means in a row with different superscripts differ (P < 0.05).

Table 3: Nutrient intake(g/kg$^{0.75}$BW/day) by goats offered grasses or browse plants as additional evening meal (Mean±sem)

Nutrient intake (NI; (g/kg$^{0.75}$/day)	Diets									
	P.p	*M.sep*	*B.d*	*C.k*	*M.mic*	*L.l*	*S.b*	*M.mal*	*D.s*	*A.h*
Napier grass(P.p) [1] intake										
3 weeks	52 ± 3.5	31 ± 4.4 [a]	33 ± 2.2 [a]	29 ± 5.1 [a]	33 ± 5.2 [a]	36 ± 5.4 [a]	40 ± 4.6 [a]	31 ± 3.0 [a]	33 ± 4.3 [a]	32 ± 2.4 [a]
6 weeks	60 ± 2.0	33 ± 3.6 [a]	34 ± 2.4 [a]	31 ± 4.8 [a]	34 ± 3.6 [a]	36 ± 4.0 [a]	41 ± 3 [b]	33 ± 3.2 [a]	36 ± 3.8 [a]	31 ± 2.2 [a]
12 weeks	61 ± 1.4	32 ± 2.4 [a]	33 ± 2.2 [a]	32 ± 3.9 [a]	32 ± 2.8 [a]	34 ± 2.6 [a]	40 ±1.8[b]	33 ± 2.6 [a]	36 ± 2.6 [a]	30 ± 1.9 [a]
Browse plants (BP) [1] intake										
3 weeks	-	32 ± 4.3 [a]	27 ± 3.1 [a]	24 ± 2.4 [a]	29 ± 1.5 [a]	36 ± 5.4 [a]	34 ± 7.6 [a]	22 ± 3.0 [a]	20 ± 2.3 [b]	48 ± 5.7 [b]
6 weeks	-	32 ± 1.9 [a]	31 ± 2.3 [a]	26 ± 2.4 [b]	29 ± 1.8 [a]	42 ± 5.7 [b]	34 ± 4.8 [a]	27 ± 2.5 [a]	24 ± 3.5 [a]	51 ± 2.0 [b]
12 weeks	-	32 ± 0.8 [a]	32 ± 2.4 [a]	27 ± 2.3 [a]	28 ± 1.7 [a]	42 ± 3.6 [b]	32 ± 2.4 [a]	28 ± 3.0 [a]	30 ± 3.8 [a]	50 ± 2.8 [b]
Total Feed Intake[2]										
3 weeks	76 ± 2.9 [a]	86 ± 6.1 [a]	85 ± 5.5 [a]	78 ± 6.1 [a]	87 ± 5.2 [b]	95 ± 11.0[b]	98 ± 11.4[b]	78 ± 6.2 [a]	81 ± 3.9 [a]	108±5.9[b]
6 weeks	85 ± 1.5 [a]	89 ± 5.5 [a]	89 ± 4.9 [a]	82 ± 6.3 [a]	88 ± 4.4 [a]	102±10.2[b]	99 ± 8.3[b]	84 ± 5.6 [a]	86 ± 6.3 [a]	108±3.6[b]
12 weeks	84 ± 1.9 [a]	85 ± 3.4 [a]	87 ± 5.0 [a]	82 ± 5.8 [a]	89 ± 3.5 [a]	97 ± 6.4 [b]	94 ± 4.7[b]	83 ± 5.1 [a]	89 ± 5.7 [a]	103±2.5[b]
%CP in diet										
3 weeks	15.1±0.0 [a]	15.0±0.1 [a]	15.0±0.0 [a]	13.8±0.1 [b]	14.0±0.1[a]	19.2±0.3 [a]	14.0±0.1[a]	14.1±0.1[a]	15.5±0.1 [a]	15.3±0.1[b]
6 weeks	15.0±0.0 [a]	14.9±0.0 [a]	15.0±0.0 [a]	13.7±0.1 [b]	14.0±0.1 [a]	19.7±0.2 [b]	14.9±0.0 [a]	14.0±0.1 [a]	15.4±0.0 [a]	16.2±0.1 [b]
12 weeks	15.0±0.0 [a]	14.9±0.0 [a]	15.0±0.0 [a]	13.7±0.1 [b]	13.9±0.1 [b]	20.0±0.2 [b]	14.9±0.0 [a]	14.0±0.1 [a]	15.4±0.0 [a]	16.5±0.1 [b]
% contribution by BP[3]										
DM (3 weeks)	-	36±5.7 [a]	31±1.7 [a]	31±3.2 [a]	33±3.1 [a]	37±2.7 [b]	34±3.8 [a]	30±2.4 [a]	27±2.1 [b]	46±2.4 [b]
(6 weeks)	-	36±2.4 [a]	34±0.7 [a]	32±2.8 [a]	33±2.4 [a]	41±2.0 [b]	34±2.1 [a]	32±1.6 [a]	28±2.2 [b]	47±1.2 [b]
(12 weeks)	-	37±1.5 [a]	36±0.8 [a]	33±2.1 [a]	34±2.3 [a]	43±1.3 [b]	34±0.7 [a]	33±2.1 [a]	33±2.3 [a]	48±2.1 [b]
CP (3 weeks)	-	34±5.5 [a]	30±1.7 [a]	23±2.7 [b]	27±2.7 [b]	50±3.1 [b]	32±3.8 [a]	25±2.1 [b]	28±2.1 [a]	38±2.3 [b]

(6 weeks)	-	35±2.3 [a]	33±0.7 [a]	24±2.3 [b]	27±2.1 [b]	54±2.1	33±2.0 [a]	26±1.4 [b]	29±2.2 [a]	39±1.1 [b]
(12 weeks)	-	36±1.5 [a]	35±0.9 [a]	25±1.7	28±2.1 [b]	57±1.2	33±0.7 [a]	27±1.9 [b]	34±2.4 [a]	40±2.0 [b]

[abc]Means in a row with different superscripts (a–c) differ (P < 0.05). Mean values calculated from n=4 goats.
[1]*P.purpureum*and Browse plants intake were compared with *B.decumbens* fed goats.
[2]Total Feed Intake include palm kernel cake as concentrate (178g DM/ animal)
[3]% contribution of DM or CP by browse plants were compared with *B.decumbens* fed goats.
P.p, P. purpureum; M.sep, M. sepiantum; B.d, B. decumben; C.k, C. kyllinga; M.mic, M. micrantha; Ll, L. leucocephala; S.b, S. baccatum; M.mal, M. malabathricum; D.s, D. suffruticosa; A.h, A. heterophyllus

Table 4: Nutrient intake(g/kg$^{0.75}$BW/day) by goats offered grass or browse plants as additional evening meal (Mean±SEM)

	Diets									
	P.p	*M.sep*	*B.d*	*C.k*	*M.mic*	*L.l*	*S.b*	*M.mal*	*D.s*	*A.h*
Crude protein intake										
3 weeks	11.6±0.4 [a]	13.1±1.0 [a]	12.9±0.8 [a]	11.0±0.9 [a]	12.3±0.8 [a]	18.5±2.3 [b]	14.7±1.7 [b]	11.1±0.8 [a]	12.6±0.6 [a]	14.4±0.7 [a]
6 weeks	12.7±0.2 [a]	13.2±0.8 [a]	13.4±0.7 [a]	11.2±0.9 [a]	12.3±0.6 [a]	20.0±2.1 [b]	14.7±1.2 [b]	11.7±0.8 [a]	13.2±1.0 [a]	14.2±0.5 [b]
12 weeks	12.6±0.3 [a]	12.8±0.5 [a]	13.1±0.7 [a]	11.2±0.8 [a]	11.6±0.5 [a]	19.4±1.3 [b]	14.0±0.7 [b]	11.6±0.7 [a]	13.8±0.9 [a]	13.5±0.3 [b]
NDF intake										
3 weeks	34.3±2.4 [a]	42.7±3.9 [b]	37.2±3.1 [a]	30.8±3.5 [a]	37.1±3.1 [a]	37.4±5.2 [a]	42.2±6.0 [a]	28.6±2.9 [a]	29.5±2.6 [a]	45.7±3.2 [b]
6 weeks	40.1±1.3 [a]	44.3±3.2 [a]	39.7±2.9 [a]	32.7±3.5 [b]	37.7±2.2 [a]	39.9±4.4 [a]	42.9±4.0 [a]	31.4±2.7 [b]	32.2±3.2 [b]	45.5±2.2 [bc]
12 weeks	40.6±0.9 [a]	43.4±1.9 [a]	39.7±2.8 [a]	34.1±3.1 [b]	36.2±1.6 [b]	38.2±2.8 [a]	41.3±2.2 [a]	32.0±2.4 [b]	34.1±2.5 [b]	44.0±1.3 [bc]
ADF intake										
3 weeks	15.8±1.1 [a]	22.4±2.1 [b]	17.9±1.5 [a]	16.4±1.7 [a]	19.7±1.3 [b]	20.0±2.8 [b]	25.6±4.1 [b]	16.1±1.7 [a]	16.3±1.1 [a]	29.0±2.2 [b]
6 weeks	18.2±0.6 [a]	23.2±1.6 [b]	19.2±1.4 [a]	17.4±1.7 [a]	20.0±1.0 [b]	21.7±2.4 [b]	26.0±2.7 [b]	17.7±1.4 [a]	17.9±1.8 [a]	28.9±1.2 [b]
12 weeks	18.8±0.4 [a]	22.7±0.9 [b]	19.3±1.4 [a]	18.2±1.6 [a]	19.2±0.7 [a]	20.9±1.5 [a]	25.0±1.4 [b]	18.1±1.3 [a]	19.4±1.6 [a]	28.0±0.9 [b]
Total (Fibre:CP) ratio										
3 weeks	4.3±0.2 [a]	4.9±0.2 [bc]	4.2±0.1 [a]	4.3±0.2 [a]	4.6±0.1 [a]	3.1±0.1 [b]	4.6±0.2 [a]	4.0±0.2 [a]	3.6±0.2 [b]	5.2±0.1 [bc]
6 weeks	4.6±0.1 [a]	5.1±0.1 [bc]	4.4±0.1 [a]	4.5±0.1 [a]	4.7±0.0 [a]	3.1±0.1 [b]	4.7±0.1 [a]	4.2±0.1 [b]	3.8±0.1 [b]	5.2±0.5 [bc]
12 weeks	4.7±0.1 [a]	5.2±0.1 [bc]	4.5±0.1 [a]	4.7±0.1 [a]	4.8±0.0 [a]	3.0±0.1 [b]	4.7±0.1 [a]	4.3±0.1 [b]	3.9±0.1 [b]	5.3±0.5 [bc]

Means in a row with different superscripts (a–c) differ (P < 0.05). Mean values calculated from n=4 goats.
[1]Nutrient intakes were compared with *P.purpureum*fed goats.
P.p, P. purpureum; M.sep, M. sepiantum; B.d, B. decumben; C.k, C. kyllinga; M.mic, M. micrantha; Ll, L. leucocephala; S.b, S. baccatum; M.mal, M. malabathricum; D.s, D. suffruticosa; A.h, A. heterophyllus

Table 5: Body weight gain and feed conversion ratio of goats fed with tropical browse plants

	Tropical browse plants offered									
	P.p	*M.sep*	*B.d*	*C.k*	*M.mic*	*L.l*	*S.b*	*M.mal*	*D.f*	*A.h*
Goat body weight (kg)										
Initial	12.1±0.7 [a]	12.5±1.3 [a]	11.6±0.6 [a]	12.0±0.8 [a]	11.9±0.5 [a]	12.7±0.7 [a]	12.1±0.7 [a]	13.3±0.8 [a]	11.5±0.5 [a]	11.4±0.3 [a]
After 3 weeks	13.9±0.6 [a]	14.5±1.2 [a]	13.8±0.9 [a]	13.5±0.6 [a]	13.6±0.8 [a]	14.9±1.2 [a]	14.2±1.2 [a]	14.7±1.0 [a]	13.2±0.5 [a]	13.4±0.1 [a]
After 6 weeks	15.7±0.6 [a]	16.4±0.7 [a]	15.6±0.8 [a]	15.0±0.7 [a]	15.2±0.8 [a]	16.9±0.9 [a]	15.8±1.2 [a]	16.0±0.7 [a]	14.6±0.2 [a]	15.4±0.4 [a]
After 12weeks	18.6±0.7 [a]	19.3±1.1 [a]	18.4±0.8 [a]	18.1±1.0 [a]	18.3±0.9 [a]	21.5±0.6 [b]	19.4±1.1 [a]	19.0±0.9 [a]	17.1±0.5 [a]	19.3±0.4 [a]
LBW gain (kg)	6.5±0.2 [a]	6.9±0.4 [a]	6.7±0.2 [a]	6.1±0.3 [a]	6.3±0.5 [a]	8.8±0.7 [b]	7.2±0.5 [a]	5.8±0.2 [c]	5.6±0.2 [c]	7.9±0.4 [b]
ADG (3 weeks; g/day)	86.9±5.0 [a]	97.6±4.8 [a]	81.8±3.3 [a]	70.2±10.6 [a]	75.0±29.2 [a]	105.9±25.3 [a]	96.4±24.1 [a]	70.2±9.0 [b]	77.4±23.8 [b]	102.4±11.3 [a]
ADG (6 weeks; g/day)	85.1±9.6 [a]	92.9±14.1 [a]	86.9±2.4 [a]	72.6±6.3 [a]	76.2±12.4 [a]	100.0±6.7 [a]	85.7±12.4 [a]	64.9±3.6 [b]	73.8±8.7 [a]	100.0±12.8 [a]
ADG (12 weeks; g/day)	77.0±1.8 [a]	81.9±4.2 [a]	81.9±3.3 [a]	72.8±3.0 [a]	74.9±5.5 [a]	104.6±7.9 [b]	85.9±6.4 [a]	68.8±2.9 [b]	66.9±2.0 [b]	94.2±4.3 [b]
FCR(3wk;gDM/g LWG)	6.8±2.7 [a]	6.4±0.4 [a]	5.9±0.8 [a]	7.8±1.1 [a]	8.5±3.1 [a]	7.0±2.1 [a]	7.7±2.3 [a]	8.3±1.0 [a]	7.9±3.4 [a]	7.3±0.8 [a]
FCR(6wk;gDM/g LWG)	7.4±0.8 [a]	7.4±1.5 [a]	6.9±0.3 [a]	8.1±0.8 [a]	8.4±1.5 [a]	7.8±0.8 [a]	8.7±1.8 [a]	9.7±0.3 [a]	8.2±0.7 [a]	8.2±1.5 [a]
FCR(12wk;gDM/g LWG)	9.1±0.2 [a]	9.0±0.5 [a]	9.0±0.3 [a]	9.2±0.5 [a]	9.2±0.6 [a]	8.3±0.4 [b]	9.3±0.9 [a]	10.4±0.8 [b]	10.6±0.6 [b]	9.1±0.5 [a]
FCR (3wk; gCP/gLWG)	0.9±0.2 [a]	1.0±0.1 [a]	0.9±0.1 [a]	1.1±0.2 [a]	1.2±0.4 [a]	1.3±0.4 [a]	1.1±0.4 [a]	1.2±0.1 [a]	1.0±0.1 [a]	1.0±0.1 [a]
FCR (6wk; gCP/gLWG)	1.1±0.1 [a]	1.1±0.2 [a]	1.0±0.1 [a]	1.1±0.1 [a]	1.2±0.2 [a]	1.6±0.2 [b]	1.3±0.3 [a]	1.4±0.0 [b]	1.3±0.1 [a]	1.1±0.2 [a]
FCR (12wk; gCP/gLWG)	1.4±0.0 [a]	1.3±0.1 [a]	1.4±0.1 [a]	1.3±0.1 [a]	1.3±0.1 [a]	1.7±0.1 [b]	1.4±0.1 [a]	1.5±0.1	1.6±0.1 [b]	1.2±0.1 [b]

Means in a row with different superscripts (a–c) differ (P < 0.05). Mean values calculated from n=4 goats.
P.p, P. purpureum; M.sep, M. sepiantum; B.d, B. decumben; C.k, C. kyllinga; M.mic, M. micrantha; Ll, L. leucocephala; S.b, S. baccatum; M.mal, M. malabathricum; D.s, D. suffruticosa; A.h, A. heterophyllus