Chemical Composition, Degradation Characteristics and Effect of Tannin on Digestibility of Some Browse Species from Kenya Harvested during the Wet Season

I. M. Osuga, S. A. Abdulrazak[1], T. Ichinohe and T. Fujihara*
Laboratory of Animal Science, Faculty of Life and Environmental Science, Shimane University
Matsue-shi 690-8504, Japan

ABSTRACT : A study was conducted with the objective of evaluating the nutritive value of some browse species from Kenya. The species evaluated included: *Bauhinia alba*, *Bauhinia variegata*, *Bridelia micrantha*, *Calliandra calothyrsus*, *Carisa edulis*, *Cratylia argentea*, *Gliricidia sepium*, *Lantana camara*, *Maerua angolensis*, *Sesbania micrantha* and *S. sesban*. The browses were evaluated by their chemical composition including phenolics, *in vitro* gas production and tannin activity (tannin bioassay). All the species had high crude protein content (149-268 g/kg DM) and low NDF content (239-549 g/kg DM). The feeds had varying contents of total extractable tannins (TET) ranging from low (3-22 mg/g DM), moderate (42-58 mg/g DM) and high (77-152 mg/g DM). *Calliandra calothyrsus* had the highest tannin content. Significant ($p<0.05$) variation in gas production was recorded among the species. *Sesbania micrantha* had the highest ($p<0.05$) potential gas production while *Gliricidia sepium* had the highest ($p<0.05$) rate of gas production. Use of polyethylene glycol (PEG 6000), to assess the adverse affect of tannins, indicated that tannins in browse species with high tannin content had inhibitory effects on rumen microbial fermentation as indicated by the gas production. Estimated organic matter digestibility and metabolizable energy also increased with PEG addition. The results of this study indicate that such Kenyan browse species have the potential to be used as feed supplements for ruminant animals. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 1 : 54-60)***

Key Words : Browse, Chemical Composition, Gas Production, PEG, Digestibility

INTRODUCTION

Ruminant production in tropical regions such as Kenya is constrained by inadequate supply of feeds in terms of quality and quantity. The native pastures and crop residues are the major feed sources available in these areas for the ruminants. With the increase in human population, more land is being dedicated to crop production and hence unavailable for pasture production. This has resulted in animals increasingly being fed on crop residues. The intake and digestibility of such feeds is low for productive animal production. The cause the low intake and digestibility of such feeds has been suggested to be due to their low content of essential nutrients such as proteins, minerals and vitamins and coupled with high lignifications of their structural carbohydrates (Nair et al., 2002), which slows rumen fermentation. It has been suggested that supplementing these feed resources with nitrogenous feeds such as multipurpose trees and shrubs (MPTS) is one way of alleviating the nitrogen (McSweeny et al., 1999) and mineral deficiencies (Abdulrazak et al., 2000).

There are many trees and shrubs in the tropics and subtropics that can supply fodder. Most of them have been shown to be of high nutritive value (Abdulrazak et al., 2001; Viengsavanh et al., 2002). The MPTS is rich in most nutrients such as proteins and are more digestible. However, use of the MPTS is limited by the presence of antinutritional compounds such as tannins, which are toxic to rumen microbes or the animal. The phenolic compounds also reduce digestibility and availability of protein, contribute to unpalatability and hence, reduce intake (Kibon and Ørskov, 1993).

Rubanza et al. (2003) showed that the *in vitro* digestibility of browse leaves declines with increase in tannin content. Abdulrazak et al. (2000) reported a negative correlation between concentration of phenolics and *in vitro* gas production of some Kenyan browse species. This negative influence of phenolics on digestibility has been attributed to their toxic effects on rumen microbes (Tolera et al., 1997). However, when they occur in low quantities (less the 5% DM), they tend to increase the rumen by-pass of nutrients such as proteins, which increases nutrient flow to the intestines (Abdulrazak et al., 2001). In Kenya, there is generally scanty information available on the nutritive value of the trees and shrubs and especially on indigenous species. The objective of this study was to investigate the nutritive value of multipurpose trees and shrubs as feed for ruminants and the effect of tannins on estimated *in vitro* organic matter digestibility and metabolizable energy.

MATERIALS AND METHODS

Browse samples

Browse leaves from eleven species were used in this

* Corresponding Author: T. Fujihara. Fax: +81-852-32-6537, E-mail: fujihara@life.shimane-u.ac.jp
[1] Division of Research and Extension, Egerton University, P.O. Box 536, Njoro, Kenya.
Received January 26, 2004; Accepted June 16, 2004

study. They include: *Bauhinia alba*, *Bauhinia variegata*, *Bridelia micrantha*, *Calliandra calothyrsus*, *Carisa edulis*, *Cratylia argentea*, *Gliricidia sepium*, *Lantana camara*, *Maerua angolensis*, *Sesbania micrantha* and *Sesbania sesban*. All the samples except *Maerua angolensis* were harvested from around World Agroforestry centre (ICRAF)-Maseno (0° 0'; 34° 35'E) in western Kenya. The area is located at an altitude of 1600m above sea level with average annual rainfall and temperature of 1,500-2,000 mm and 20°-23°C respectively. *Maerua angolensis* was harvested from Marigat area (0° 31'S; 35° 78'E) Baringo district, Kenya. The area is located at an altitude of 1,066 m above sea level with average annual rainfall and temperature of 700 mm and 24°C respectively.

The browse forages were harvested during the wet season (April/May). They were then oven dried at 50°C for 48 h to constant weight and were ground to pass through a 2.0 mm sieve for the laboratory analysis. However, for the analysis of phenolics and *in vitro* gas production experiments, the forages were further ground to pass through a 1.0 mm sieve.

Chemical analysis

Dry matter (DM), organic matter (OM) and crude protein (CP) contents were measured according to the official methods of the Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to the methods of Van Soest et al. (1991).

Phenolic compounds

The extraction of phenolics was done using 70% aqueous acetone. Total extractable phenolics (TEPH) were determined using Folin Ciocalteu as described by Makkar (2000). The concentration of TEPH was calculated using the regression equation of tannic acid standard. Total extractable tannins (TET) were estimated indirectly after being absorbed to insoluble polyvinyl pyrrolidine (PVP). The concentration of TET was calculated by subtracting the TEPH remaining after PVP treatment from the TEPH. For both the TEPH and TET, the absorbance was measured using a spectrophotometer (Quantification-2 program pack, Shimadzu Corporation, Kyoto, Japan).

***In vitro* gas production study**

Animals and rumen fluid extraction : Rumen liquor for *in vitro* degradability (*in vitro* gas production and tannin bioassays) was obtained from three mature healthy Japanese Corriedale sheep fitted with permanent rumen fistula. The animals were fed on standard diet of 800 g DM timothy hay and 200 g DM concentrate twice daily at 0900 and 1600 h. The animals had free access to water and mineral lick throughout the experiment period. The rumen liquor was withdrawn prior to morning feeding, mixed, strained through various layers of cheesecloth and kept at 39°C under a CO_2 atmosphere.

***In vitro* gas production**

Samples were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedure of Menke and Steingass (1988). About 200 mg of sample (milled through 1.0 mm sieve) were weighed into 100 ml calibrated glass syringes in duplicate. Vaseline oil was applied to the pistons to ease movement and to prevent escape of gas. The syringes were pre-warmed at 39°C before addition of 30±1 ml of rumen liquor-buffer mixture (ratio 1:2) into each syringe. Blanks with buffered rumen fluid without feed sample were also included in duplicate. All the syringes were incubated in a water bath maintained at 39±0.1°C. The syringes were gently shaken every hour during the first 8 hours of incubation and readings were recorded after 3, 6, 12, 24, 48, 72 and 96 h of incubation. The degradability characteristics were estimated by fitting the mean gas volumes in the exponential equation $p=a+b(1-e^{-ct})$ (Ørskov and McDonald, 1979) using 'Neway' computer program (Chen X. B., Rowett Research Institute, Aberdeen), where p is the gas production (ml/g OM) at time t, a is the gas production (ml/g OM) from immediately soluble OM fraction, b is the gas production (ml/g OM) from the slowly but potentially degradable fraction and c is the gas production (ml/g OM) rate constant from b.

Effect of Polyethylene glycol (PEG) addition on digestibility

Incubation was carried out using the method of Menke and Steingass (1988) as modified by Makkar et al. (1995). Makkar et al. (1995) increased the sample size from 200 mg to 500 mg and consequently increased the amount of buffer two-fold. The incubation volume was also increased from 30 ml to 40 ml of the rumen-buffer mixture. About 500 mg DM of the feed samples were incubated with or without 1.0 g Polyethylene glycol (PEG) (MW 6000).

The syringes were pre-warmed at 39°C for 1 h before addition of 40±0.5 ml rumen liquor-buffer mixture into the syringes and incubated in water bath maintained at 39±0.1°C. Blanks were also included in the incubation. The syringes were gently shaken every hour during the first 4 h and thereafter, every 2 h up to 8 h of incubation. The gas production readings (ml) were recorded after 2, 4, 6, 8, 12, 16 and 24 h of incubation.

Feed organic matter digestibility (OMD) (%) and metabolizable energy (ME) (MJ/kg DM) were estimated from equation of Menke and Steingass (1988) and Makkar and Becker (1996) based on 24 h gas production (Gv, ml) and crude protein content (CP, % DM):

Table 1. Chemical composition of the browse species

Species	DM	OM	CP	NDF	ADF	ADL	TEPH	TET
	g/kg	g/kg of DM						
Bauhinia alba	905	939	154	522	380	134	88	58
B. variegata	895	945	206	498	343	101	90	56
Bridelia micrantha	903	934	149	549	403	151	66	42
C. calothyrsus	890	925	268	386	193	44	223	152
Carisa edulis	903	933	152	440	283	133	136	77
Cratylia argentea	906	868	155	479	301	119	67	44
Gliricidia sepium	889	911	265	476	301	108	19	3
Lantana camara	889	887	263	411	312	113	49	22
Maerua angolensis	941	824	253	239	144	60	9	3
Sesbania micrantha	888	919	253	403	239	85	58	16
Sesbania sesban	889	901	267	325	184	46	23	6
SEM	3.2	7.6	11.3	18.9	17.2	7.6	12.7	9.2
LSD (p<0.05)	3.9	3.8	12.4	8.6	4.7	6.6	12.2	14.1

SEM: standard error of the means. LSD: least significant difference.
OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre.
ADL: acid detergent lignin; TEPH: total extractable phenolics; TET: total extractable tannins.

OMD (%) = 14.88+0.889 Gv+0.45 CP
ME (MJ/kg DM) = 2.20+0.136 Gv+0.057 CP.

Statistical analysis

Analysis of variance (ANOVA) was carried out on chemical composition, phenolics, *in vitro* gas production, degradability characteristics and digestibility estimates data using the General Linear Model (GML) procedure (SAS/StatView, 1999). The *in vitro* gas production data was analysed by two factorial design (species and time). Significance between means was tested using the least significance difference (LSD).

RESULTS AND DISCUSSION

The chemical composition and the phenolics content of the browse species are presented in Table 1. *Maerua angolensis* had the highest ash content, at 176 g/kg DM while *Bauhinia variegata* had the lowest ash content, at 55 g/kg DM. The CP contents varied among the species, ranging from 268 g/kg DM (*Calliandra calothyrsus*) to 149 g/kg DM (*Bridelia micrantha*). The concentrations of fibre varied significantly ($p<0.05$) among the species. The NDF, ADF and ADL were highest ($p<0.05$) in *Bridelia micrantha* and lowest ($p<0.05$) in *Maerua angolensis* except *Sesbania sesban*, which had lowest ADL. The TEPH concentrations ranged between 223 mg/g DM to 9 mg/g DM. The TET concentration ranged from 152 mg/g DM to 3 mg/g DM. *Calliandra calothyrsus* had the highest TEPH and TET concentration, which was significantly ($p<0.05$) different from all the other browse species.

The chemical composition did not vary much from values published in the literature for the browse species (Teguia et al., 1999; El hassan et al., 2000). The browses had high CP content, which would indicate their high nutritive value, since the browses are intended to be used as protein supplements for low quality tropical pastures and crop by-products, which are low in protein. Norton (1994) reported that feeds with less than 6% CP levels are unlikely to provide the minimum ammonia levels required for maximum microbial growth in the rumen. Therefore, all the browse species evaluated in this study would be good protein supplements if they were adequately degraded and were non-toxic to the rumen microbes and host animal.

The NDF content of the browse species was low to moderate. This indicates the browses have high cell contents, which is related with high digestibility. The fibre of browses has also been shown to be digestible (El hassan et al., 2000). Hence, digestibility of the fibre may not be a problem.

High phenolics and tannins in browse species have been shown to be the major drawback in their use as protein supplements. This is because the tannins depress feed intake, impair feed digestibility and are toxic to rumen microbes (Mangan, 1988). The high tannin content of *C. calothyrsus* has also been reported (Salawu et al., 1997). The other species had low to moderate content of the phenolics and tannins, which would indicate high nutritive value.

Table 2 summarises the cumulative gas production (ml/g OM) and the fermentation characteristics of the tested feeds. There were significant ($p<0.05$) variations among the browse species. The highest gas production values at 24 h of incubation were obtained with *Sesbania sesban*, *Sesbania micrantha*, *Gliricidia sepium* and *Lantana camara*. At 96 hour, *Sesbania micrantha*, *Sesbania sesban*, *Maerua angolensis*, *Lantana camara*, and *Gliricidia sepium* had higher gas production in that order. *Calliandra calothyrsus* produced signicantly ($p<0.05$) the least gas volumes in all the hours. For all the browse species except *Calliandra calothyrsus* and *Sesbania sesban*, there was no significant

Table 2. Cumulative *in vitro* gas production (ml gas/g OM) and degradation characteristics (a, b, a+b and c) of the browse species

Species	Incubation interval (h)									Degradability characteristics			
	3	6	12	24	48	72	96	SEM	LSD	a	b	a+b	c
Bauhinia alba	26.0	44.7	69.2	95.2	103.9	121.2	127.0	9.9	8.0	11.7	110.1	121.7	5.7[e]
B. variegata	26.3	33.6	61.4	87.7	117.0	143.3	152.0	13.1	10.4	15.0	146.8	161.8	2.7[g]
Bridelia micrantha	20.2	39.0	52.0	78.1	89.6	107.0	107.0	8.8	14.7	11.5	95.6	107.1	4.7[f]
C. calothyrsus	10.2	10.2	17.5	40.8	72.8	90.2	99.0	9.9	6.2	-0.9	126.5	125.6	1.7[h]
Carisa edulis	24.5	30.3	51.9	60.6	77.9	98.0	109.6	8.4	18.7	22.2	103.1	125.3	1.9[h]
Cratylia argentea	27.7	43.1	75.5	103.2	123.3	137.1	137.1	11.5	5.3	7.8	128.8	136.6	5.7[e]
Gliricidia sepium	40.6	73.7	123.4	147.5	162.5	174.5	176.0	13.5	6.8	-2.3	173.1	170.8	9.8[a]
Lantana camara	47.8	72.5	117.3	145.0	166.6	179.0	179.0	13.5	8.8	17.2	159.4	176.6	7.4[c]
Maerua angolensis	18.5	24.6	69.3	112.4	149.3	170.9	180.1	17.3	10.8	-6.9	189.0	182.2	4.0[f]
Sesbania micrantha	51.5	98.5	133.3	163.6	187.8	209.0	215.1	15.6	16.7	30.2	177.1	207.3	6.5[d]
Sesbania sesban	45.3	78.6	137.5	167.8	185.9	204.0	210.1	16.3	4.7	3.0	198.3	201.2	8.3[b]
SEM	2.8	5.7	8.2	8.8	8.8	8.7	8.6			2.4	7.5	7.3	0.5
LSD ($p<0.05$)	7.1	9.8	8.3	9.5	12.6	11.5	12.2			6.9	15.5	18.9	0.7

SEM: Standard error of the means; LSD: Least significant difference.

a, b, c constants in the equation $p = a+b\,(1-e^{-ct})$ (Orskov and McDonald, 1979).

Table 3. Effect of PEG addition on gas production (ml gas/g OM)

Species	Gas production response at different incubation intervals (h)							
	16 h				24 h			
	-PEG	+PEG	Increase	%	-PEG	+PEG	Increase	%
Bauhinia alba	93.4	120.0	26.6	28.5	109.8	132.8	23.1	21.0
B. variegata	82.3	137.5	55.1	66.9	107.1	158.6	51.6	48.1
Bridelia micrantha	76.7	114.6	38.0	49.5	90.8	124.1	33.3	36.6
C. calothyrsus	58.9	127.5	68.7	116.7	78.1	145.6	67.5	86.5
Carisa edulis	63.5	155.5	91.9	144.7	68.2	169.6	101.4	148.6
Cratylia argentea	137.1	150.4	13.3	9.7	163.7	168.2	4.5	2.8
Gliricidia sepium	161.1	162.9	1.8	1.1	183.1	184.9	1.9	1.0
Lantana camara	149.1	149.2	0.1	0.1	168.0	168.3	0.3	0.2
Maerua angolensis	121.1	122.0	0.9	0.8	149.1	151.2	2.1	1.4
Sesbania micrantha	162.6	162.8	0.2	0.1	179.7	180.5	0.8	0.4
Sesbania sesban	171.6	173.2	1.6	0.9	184.0	185.6	1.6	0.9
SEM	8.9	4.2			9.3	4.3		
LSD ($p<0.05$)	6.6	6.3			6.8	5.8		

SEM: standard error of the means; LSD: least significant difference.

($p<0.05$) increase in gas volume after 72 h of incubation. The potential gas production (a+b) was significantly ($p<0.05$) highest in *Sesbaina micrantha* and lowest in *Bridelia micrantha* while the rate constant (c) was highest in *Gliricidia sepium* and lowest in *Calliandra calothyrsus*.

Gas production basically results from fermentation of carbohydrates to short chain fatty acids (SCFA)-mainly acetate, propionate and butyrate (Blümmel and Ørskov, 1993) and from the buffering of the SCFA (CO_2 released from the bicarbonate buffer). Hence, the extent of gas production reflects the efficiency and/or extent of degradability of the feed OM. Besides SCFA and gas (mainly CO_2 and CH_4) the feed OM is also fermented to microbial biomass (microbial protein) (Getachew et al., 1998). *In vitro* fermentation of protein produces ammonium carbonate and the ammonia. The ammonia produced from protein breakdown may be directly used by bacteria for protein synthesis. Hence, low amount of gas is recorded from protein synthesis (González et al., 1998).

In vitro gas production (ml/g OM) was significantly ($p<0.05$) higher in *Sesbania micrantha, Sesbania sesban, Maerua angolensis, Lantana camara* and *Gliricidia sepium*. This would indicate high rate and extent of fermentation of the feed OM of these species. This could be due to their high CP content (253-267 g/kg DM) and comparatively low fibre and tannin content. Variations in gas production among the species could also be due to the nature and proportion of the forage fibre such as proportion of pectin in the cell walls (Marinas et al., 2003). Most of the fermentation of the OM of forages was achieved up to 48 hours of incubation, indicating rapid degradation by the rumen microbes (Marinas et al., 2003). The decrease in degradability of some of the species could be explained by their tannin contents. For instance, the poor performance of *Calliandra calothyrsus* could be related to its high content of soluble phenolics especially tannins (Salawu et al., 1997; Teguia et al., 1999). The tannin activity differences among the plant species is also known to affect the degradability of

Table 4. Effect of PEG addition on estimated *in vitro* OMD (%) and ME (MJ/kg DM)

Species	OMD and ME response at different incubation intervals (h)							
	24 h response in OMD, %				24 h response in ME, MJ/kg DM			
	-PEG	+PEG	Increase	%	-PEG	+PEG	Increase	%
Bauhinia alba	40.1	44.0	3.86	9.6	5.9	6.5	0.59	10.0
B. variegata	42.1	50.8	8.67	20.6	6.1	7.5	1.33	21.6
Bridelia micrantha	36.7	42.2	5.52	15.1	5.4	6.2	0.85	15.8
C. calothyrsus	39.8	50.9	11.11	27.9	5.7	7.4	1.70	29.9
Carisa edulis	33.0	49.9	16.81	50.9	4.8	7.4	2.57	53.6
Cratylia argentea	47.1	47.8	0.69	1.5	6.9	7.1	0.11	1.5
Gliricidia sepium	56.5	56.8	0.30	0.5	8.2	8.2	0.05	0.6
Lantana camara	53.2	53.3	0.08	0.1	7.8	7.8	0.01	0.1
Maerua angolensis	48.1	48.4	0.31	0.7	6.9	7.0	0.05	0.7
Sesbania micrantha	55.6	55.8	0.17	0.3	8.1	8.2	0.03	0.3
Sesbania sesban	56.4	56.6	0.26	0.5	8.2	8.3	0.04	0.5
SEM	1.8	1.0			0.3	0.1		
LSD ($p<0.05$)	1.1	1.1			0.2	0.2		

SEM: Standard error of the means. LSD: Least significant difference.

Table 5. Correlation coefficient (r) of the relationship between the concentration of NDF, ADF, ADL, TEPH, TET and gas production parameters, OMD and ME

Incubation hour	NDF	ADF	ADL	TEPH	TET
12	-0.210	-0.140	-0.140	-0.737	-0.800
24	-0.296	-0.205	-0.217	-0.794	-0.838
48	-0.435	-0.349	-0.363	-0.762	-0.805
72	-0.458	-0.370	-0.389	-0.753	-0.801
96	-0.508	-0.423	-0.437	-0.723	-0.777
Degradability characteristics					
a	0.374	0.397	0.432	0.126	0.009
b	-0.705	-0.658	-0.691	-0.604	-0.628
a+b	-0.606	-0.551	-0.574	-0.583	-0.647
c	-0.004	0.049	0.009	-0.728	-0.735
OMD	-0.408	-0.385	-0.439	-0.656	-0.684
ME	-0.389	-0.364	-0.415	-0.671	-0.698

the browse species (Makkar and Becker, 1998). *Bridelia micrantha* had the lowest potential gas production (a+b), probably due to its high NDF, ADF and ADL contents.

Data on effect of PEG addition on gas production, OMD and ME estimates are presented in Table 3 and 4. At 24 h of incubation, the increase in gas production ranged from 0.2% (*Lantana camara*) to 148.6% (*Carisa edulis*). The OMD increase ranged from 0.1% (*Lantana camara*) to 50.9% (*Carisa edulis*) while the range for ME was 0.1% (*Lantana camara*) to 53.6% (*Carisa edulis*). *Carisa edulis* and *Calliandra calothyrsus* had relatively the highest response to PEG addition on gas production, OMD and ME estimates.

The gas method has been used to assess the actions of anti-nutritive factors on rumen fermentation of browse species (Nsahlai et al., 1994; Makkar et al., 1995; Getachew et al., 2002). PEG binds to the tannins forming inert PEG-tannin complexes, which results in increase in gas production. The higher the biological activity of the tannins on rumen microbes, the higher the increase in gas production in the presence of PEG (Makkar and Becker, 1998). The increase in gas production due to incubation with PEG could be due to increase in SCFA production and/or changes in molar proportions of the acids (Blümmel and Ørskov, 1993). This suggests that removal of adverse effects of tannins by PEG increases the digestibility and energy content of the browse feeds (Makkar et al., 1995). In the current study, *Carisa edulis* and *Calliandra calothyrsus* had the highest ($p<0.05$) response to PEG addition. This could be because of the high tannin content of the two species. However, the tannin in *Carisa edulis* seems of high activity owing to their smaller concentration than *Calliandra calothyrsus* but high response in gas production. Getachew et al. (2002) concluded that tropical browses with less than 45 and 20 g/kg DM of total phenols and tannin respectively are unlikely to produce significant adverse effects on ruminant livestock. The same trend was observed in this study. The species, which had low tannin content, had minimal response to PEG addition on gas production, OMD and ME.

Table 5 presents the correlations between fibre fractions and phenolic compounds with *in vitro* gas production parameters, OMD and ME. The NDF, ADF and ADL were negatively correlated with the gas production parameters and the OMD and ME. The TEPH and TET concentration were strongly and negatively correlated with the gas production parameters and the OMD and ME ranging from r=-0.583 (a+b) to r=-0.838 (24 h incubation) except a, which was positively correlated. These findings were consistent with the findings of other studies reported in the literature (Abdulrazak et al., 2000; Fadel Elseed et al., 2002; Rubanza et al., 2003b). While Rubanza et al. (2003b) and Abdulrazak et al. (2000) found a negative but poor relationship between the TET content and the digestibility of the browses, our results found a strong negative correlation. This could be attributed to the different nature and activity of the tannins among the browse species (Abdulrazak et al., 2000). The negative correlation between the tannins content and the degradability characteristics indicates the adverse effects of the tannins on the use of such browse species as animal feeds.

CONCLUSION AND IMPLICATIONS

It is concluded that the browse species used in this study could be good protein supplements to low quality basal diets. However, the high phenolics content and activity in some of the browse species could limit their nutritive value. Use of tannin binding agents such as PEG would increase their nutritive value. Further studies to evaluate more browse species especially the locally available species are recommended. Animal feeding experiments are also necessary to ascertain the nutritive value of the promising species in terms of palatability, intake, digestion and effect on production performance of the animals.

ACKNOWLEDGEMENT

The authors thank ICRAF-Maseno staff for collection of forage samples.

REFERENCES

Abdulrazak, S. A., E. A. Orden, T. Ichinohe and T. Fujihara. 2000. Chemical composition, phenolic concentration and *in vitro* gas production characteristics of selected Acacia fruits and leaves. Asian-Aust. J. Anim. Sci. 13:935-940.

Abdulrazak, S. A., J. Nyangaga and T. Fujihara. 2001. Relative palatability to sheep of some browse species, their *in sacco* degradability and *in vitro* gas production characteristics. Asian-Aust. J. Anim. Sci. 14:1580-1584.

AOAC (Association of Official Analytical Chemists). 1990. Official methods of analysis, 15th Edn. Association of Official Analytical Chemists, Washington DC, USA.

Blümmel, M. and E. R. Orskov. 1993. Comparison of gas production and nylon bag degradability of roughages in predicting feed intake in cattle. Anim. Feed Sci. Tech. 40:109-119.

El hassan, S. M., A. Lahlou Kassi, C. J. Newbold and R. J. Wallace. 2000. Chemical composition and degradation characteristics of foliage of some African multipurpose trees. Anim. Feed Sci. Tech. 86:27-37.

Fadel Elseed, A. M. A., A. E. Amin, Khadiga, A. Abdel Ati, J. Sekine, M. Hishinuma and K. Hamana. 2002. Nutritive evaluation of some fodder tree species during the dry season in central Sudan. Asian-Aust. J. Anim. Sci. 15:844-850.

Getachew, G., H. P. S. Makkar and K. Becker. 2002. Tropical browses: contents of phenolic compounds, *in vitro* gas production and stoichiometric relationship between short chain fatty acid and *in vitro* gas production. J. Agric. Sci. 139:341-352.

Getachew, G., M. Blümmel, H. P. S. Makkar and K. Becker. 1998. *In vitro* gas measuring techniques for assessment of nutritional quality of feeds: a review. Anim. Feed Sci. Tech. 72:261-281.

González Ronquillo, M., M. Fondevila, A. Barrios Urdaneta and Y. Newman. 1998. *In vitro* gas production from buffel grass (*Cenchrus ciliaris* L.) fermentation in relation to the cutting interval, level of nitrogen fertilisation and season of growth. Anim. Feed Sci. Tech. 72:19-32.

Kibon, A. and E. R. Orskov. 1993. The use of degradation characteristics of browse plants to predict intake and digestibility by goats. Anim. Prod. 57:247-251.

Makkar, H. P. S. 2000. Quantification of tannins in tree foliage. A laboratory manual for the FAO/IAEA co-ordinated research project on 'Use of Nuclear and Related Techniques to Develop Simple Tannin Assays for Predicting and Improving the Safety and Efficiency of Feeding Ruminants on Tanniniferous Tree foliage'. FAO/IAEA working document IAEA, VIENA (Austria), p. 14.

Makkar, H. P. S. and K. Becker. 1996. A bioassay for polyphenols (tannins). Polyphenols communications 96, July 15-18, Bordenaux (France).

Makkar, H. P. S. and K. Becker. 1998. Do tannins in leaves of trees and shrubs from African and Himalayan regions differ in level and activity? Agrofor. Sys. 40:59-68.

Makkar, H. P. S., M. Blümmel and K. Becker. 1995. Formation of complexes between polyvinyl pyrrolidones or polyethylene glycols and tannins and their implication in gas production and true digestibility in *in vitro* techniques. Br. J. Nutr. 73:897-913.

Mangan, J. 1988. Nutritional effects of tannins in animal feeds. Nutr. Res. Rev. 1:209-231.

Marinás, A., R. Garcia-González and M. Fondevila. 2003. The nutritive value of five pasture species occurring in the summer grazing ranges of the Pyrenees. Anim. Sci. 76:461-469.

McSweeney, C. S., B. Palmer, R. Bunch and D. O. Krause. 1999. *In vitro* quality assessment of tannin-containing tropical shrub legumes: protein and fibre digestion. Anim. Feed Sci. Tech. 82:227-241.

Menke, K. H. and H. Steingass. 1988. Estimation of the energetic feed value obtained from chemical analysis and *in vitro* gas production using rumen fluid. Anim. Res. Develop. 28:7-55.

Nair, P. V., A. K. Verma, R. S. Dass and U. R. Mehra. 2002. Growth and nutrient utilization in Buffalo calves fed on urea-ammoniated wheat straw and hydrochloric acid plus urea treated wheat straw. Asian-Aust. J. Anim. Sci. 15:682-686.

Norton, B. W. 1994. The nutritive value of tree legumes. In: (Ed. R. C. Gutteridge and H. M. Shelton), Forage Tree Legumes in Tropical Agriculture, CAB international, pp. 177-191.

Nsahlai, I. V., D. E. K. Siaw and P. O. Osuji. 1994. The relationship between gas production and chemical composition of 23 browses of the genus *Sesbania*. J. Agric. Food Sci. 65:13-20.

Orskov, E. R. and I. McDonald. 1979. The estimation of protein degradation in the rumen from incubation measurements weighted according to the rate of passage. J. Agri. Sci. 92:499-503.

Rubanza, C. D. K., M. N. Shem, R. Otsyina, N. Nishino, T. Ichinohe and T. Fujihara. 2003a. Content of phenolics and tannins in leaves and pods of some *Acacia* and *Dichrostachys* species and effects on *in vitro* digestibility. J. Anim. Feed Sci. 12:645-663.

Rubanza, C. D. K., M. N. Shem, R. Otsyina, T. Ichinohe and T. Fujihara. 2003b. Nutritive evaluation of some browse tree legume foliages native to semi-arid areas in western Tanzania. Asian-Aust. J. Anim. Sci. 16:1429-1437.

Salawu, M. B., T. Acamovic, C. S. Stewart and B. Maasdorp. 1997. Assessment of nutritive value of *Calliandra calothyrsus*: its chemical composition and influence of tannins, pipecolic acid and polyethylene glycol on *in vitro* organic matter digestibility. Anim. Feed Sci. Tech. 69:207-217.

SAS/Statview. 1999. Using Statview. Statistical Analysis System (SAS) Inc. 3rd Ed.

Teguia, A., E. R. Orskov and D. J. Kyle. 1999. A note on ruminal *in situ* degradability and *in vitro* gas production of some West African grass species and multipurpose legume tree leaves. J. Anim. Feed Sci. 8:415-424.

Tolera, A., K. Khazaal and E. R. Orskov. 1997. Nutritive evaluation of some browse species. Anim. Feed Sci. Tech. 67:181-195.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods of fiber, neutral detergent fiber and non-starch carbohydrates in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Viengsavanh, P. and L. Inger. 2002. Performance of growing goats fed *Panicum maximum* and leaves of *Gliricidia sepium*. Asian-Aust. J. Anim. Sci. 15:1585-1590.