Nutritive Evaluation of Some Browse Tree Legume Foliages Native to Semi-arid Areas in Western Tanzania*

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ABSTRACT : Browse tree legume leaves from *Acacia spp (A. nilotica, A. tortilis, A. polyacantha*), *Dichrostachys sp, Flagea villosa, Piliostigma thonningii, Harrisonia sp* were evaluated for nutritive potential (chemical compositions and degradability characteristics) compared *to Gliricidia sepium*. Effect of tannins anti-nutritive activity on digestibility was also assessed by polyethylene glycol (PEG) tannin bioassay. Crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) differed ($p<0.05$) between legume foliages. Mean CP, ash, NDF, ADF and ADL for fodder species tested were 158, 92, 385, 145, and 100 g/kg DM, respectively. CP ranged from 115 (*P. thonningii*) to 205 g/kg DM (*G. sepium*). *Acacia spp* had moderate CP values (g/kg DM) of 144 (*A. nilotica*), to high CP in *A. tortilis* (188) and *A. polyacantha* (194) comparable to *G. sepium*. The forages had relatively lower fiber compositions. *A. nilotica* had ($p<0.05$) lowest NDF, ADF and ADL (182, 68 and 44) compared to *P. thonningii* (619, 196 and 130) g/kg DM, respectively. Except *G. sepium*, all fodder species had detectable high phenolic and tannin contents greater than 5% DM, an upper beneficial level in animal feeding and nutrition. Mean total phenolics (TP), total tannins (TT) and condensed tannins (CT) (or proanthocyanidins) for fodder species tested were 139, 113 and 43 mg/g DM, respectively. *F. villosa* had ($p<0.05$) lowest TP and TT of 65 and 56 mg/g DM, respectively, compared to *A. nilotica* (237 and 236 mg/g DM, respectively). The CT varied ($p<0.05$) from 6 (*F. villosa*) to 74 mg/g DM (*Dichrostachys sp*). *In vitro* organic matter (OM) degradability (OMD) differed ($p<0.05$) between fodder species. *G. sepium* had ($p<0.05$) high degradability potential compared to *A. polyacantha* that had ($p<0.05$) the lowest OMD values. Forage degradability ranked: *G. sepium>A. nilotica>P. thonningi>F. villosa>Dichrostachys* sp>*A. tortilis>A. polyacantha*. Addition of PEG resulted to ($p<0.05$) improvement in *in vitro* OM digestibility (IVD). Increase in IVD was mainly due to binding action of PEG on tannins; and represents potential nutritive values previously depressed by tannins anti-nutritive activity. Browse fodder has potential as sources of ruminal nitrogen especially for ruminants consuming low quality roughages due to high protein, lower fiber compositions and high potential digestibility. However, utilization of browse supplements in ruminants is hampered by high phenolic and tannin contents. Deactivation of tannin anti-nutritive activity, possibly by feeding tanniniferous browse with other readily available nitrogen sources to dilute tannin anti-nutritive activity could improve utilization of browse fodder supplements. Further studies are needed to assess browse fodder palatability and intake, and their effect on growth performance in ruminants. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 10 : 1429-1437)***

Key Words : Anti-nutritive Factors, Tree Legumes, Legume Fodder, Nutritive Value, Tannin Bioassay

INTRODUCTION

Ruminant production in Tanzania depends on communal rangelands. Livestock production is constrained by fodder scarcity during the dry seasons. In semi-arid parts of western Tanzania, cattle graze on poor quality forages with low crude protein (CP) (30-40 g/kg DM) (Kakengi et al., 2001) and high fiber contents (Rubanza, 1999). The forages are of low digestibility and poor utilization efficiency to meet animal requirements for maintenance and production (Leng, 1990). The CP is too low to meet minimum nitrogen requirement of 8% DM necessary for optimal rumen microorganisms function (Hungate, 1966; Annison and Bryden, 1998). Supplementation with protein and energy rich feeds could alleviate ruminant nutrition and production in this part of the tropics. Conventional protein and energy supplements (fish meals, cereals and oil-seed cake based concentrates) are expensive and unaffordable by most traditional livestock keepers (Shem et al., 1998).

Browse fodder represents a good source of cheap and locally available protein supplement to ruminants. Several reports have been documented on utilization of browse legume fodder (Gutteridge and Shelton, 1994) for livestock feeding. However, utilization of legume browse fodders is

* Part of the data were presented to the 10th International Congress of the Asian-Australian Association of Animal Production Societies (AAAP), 23-27 September 2002, Ashok Hotel, New Delhi, India.

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Received September 5, 2002; Accepted April 21, 2003

limited by presence of phenolics and tannin's anti-nutritive factors (ANFs) (Mangan, 1988; Kumar and D'Mello, 1995). Tannins (hydrolyzable and condensed) refer to naturally occurring high molecular weight soluble polyphenolic compounds that bind to, and form complex with proteins, carbohydrates, minerals, and other dietary nutrients during feed digestion (Mangan, 1988); rendering them unavailable to the animal. Tannin levels greater than 5% DM cause deleterious adverse effects on feed utilization by animal through lowered nutritive value (reduced intake, palatability, protein and dry matter digestibility); inhibition of digestive enzymes; complex formation with rumen microorganisms, and toxic effects to the animal body (Mangan, 1988; Makkar et al., 1995). Findings from previous studies (Reed, 1986; Shayo and Udén, 1999; Abdulrazak et al., 2000a,b; Fadel Elseed et al., 2002) indicate presence of tannins in some selected browse legume species native to East Africa. Results from the latter studies indicate high variability in phenolic and tannin content in forages due to species differences, plant's stage of growth, part and proportion of sampled vegetations, as well as differences due to climatic effects (Makkar and Becker, 1998). However, no comprehensive study has been conducted on nutritive evaluation of browse, and hence a complete lack of information on nutritive value of browse fodder species in most areas of Tanzania. A study was therefore conducted to determine nutritive value of selected browse species in terms of essential chemical compositions (feed protein and fibers); phenolics and tannin's ANFs, feed degradability potential, and to assess adverse effects of tannins on *in vitro* digestibility and nutrients availability.

MATERIALS AND METHODS

Study area

The study was conducted in semi-arid parts of western Tanzania in Shinyanga Region (2-5^{o}S; 31-35^{o}E) south of Lake Victoria. The region is characterized by small hills separated by clay loam soils with vertic properties and tremendous variation from hilltop to valley bottom; and gentle slopes with short grasses, scattered trees, dominated mainly by Acacia spp and other shrub vegetations (Otsyina et al., 1994). Shinyanga region receives 600 to 800 mm per annum unimodal rains between November and May. Minimum and maximum temperatures range from 18.1°C to 36.5°C, respectively (Otsyina et al., 1997).

Browse forage sample collection

Browse legume foliage (leaves and twigs) samples were randomly harvested (hand plucked) from 8 to 10 trees in every four sub-plots (70 m×70 m) in four agroforestry based traditional fodder banks in five administrative districts in Shinyanga region during the late rainy season (April to May in 2000). Three *Acacia spp* (*A. nilotica, A. tortilis, A. polyacantha*); *Dichrostachys sp, Flagea villosa, Piliostigma thonningii, Harrisonia sp* and *G. sepium* leaves and soft twigs were sampled for nutritive value study.

Forage sample preparation

Harvested samples were wilted under shed, then dried at 50°C in a forced air oven for 48 h to constant weight; and ground to pass through a 2 mm sieve, thoroughly mixed and sub-sampled into four representative bulk samples for each legume fodder species for further analysis. Forage samples for phenolic and tannin analyses, *in vitro* degradability and tannin bioassay were ground to pass through a 1 mm-sieve.

Chemical analyses

Chemical compositions [DM, ash and CP (N×6.25) (Kjeldahl technique)] were estimated (AOAC, 1990). Fiber fractions: neutral detergent fiber (NDF); acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined using detergent solutions (Van Soest et al., 1991).

Phenolic and tannin assays

Approximately 200 mg DM fine ground sample was extracted in 10 ml of aqueous acetone (7:3 v/v) in a water bath maintained at 39±0.5°C at 130 cycles per second for 90 minutes (Makkar, 2000). Total extractable phenolics (TP) were assayed by Folin- Ciocalteu's reagent (Sigma®, Germany) based on known concentrations of tannic acid standard (Sigma®, Germany) as described by Jolkumen–Tiito (1985). Total extractable tannins (TT) were estimated gravimetrically by quantification of amount of phenolics remaining from total phenolics after binding tannins with polyvinyl polypyrrolidone (PVPP) (Sigma®, Germany) as described by Makkar et al. (1993). Total extractable condensed tannins (CT) or total proanthocyanidins were assayed by n-butanol- HCl- Fe^{3+} (Porter et al., 1986). Concentrations of TP and TT were expressed as tannic acid equivalent, while CTs were expressed as proanthocyanidins equivalents.

Animals and management

Rumen fluid for *in vitro* gas production, digestibility and tannin bioassay was obtained from three healthy mature Japanese corriedale female sheep fitted with permanent rumen cannulae (50 mm o.d.). The fistulated animals were kept on a standard hay ration of 800 g timothy hay and 200 g concentrates (2-parts wheat bran and 1-part rolled barley) divided into two equal meals fed at 8.00 h and 16.00 h daily. The animals were supplemented with minerals to meet body requirements according to ARC (1990); and had free access to water throughout the experimental duration.

Table 1. Chemical compositions (g/kg DM); total phenolics (TP), total tannins (TT) and total condensed tannins (CT) (mg/g DM) in selected browse legume tree leaves native to Tanzania

Forage species	CP	Ash	NDF	ADF	ADL	TP †	TT†	CT‡
A. polyacantha	194^{ad}	121^{ad}	416^{a}	136^{a}	107^{a}	98^{a}	95^{a}	46^{a}
A. tortilis	188^{ad}	82^{b}	361^{ac}	150^{b}	101^{a}	127^{b}	121^{b}	51^{b}
A. nilotica	144^{b}	70^{bc}	182^{b}	68^{c}	44^{b}	237^{c}	236^{c}	47^{ab}
Dichrostachys sp.	141^{b}	96^{ab}	380^{a}	146^{b}	123^{c}	184^{d}	100^{a}	74^{c}
F. villosa	130^{b}	75^{bc}	305^{c}	167^{b}	63^{b}	65^{e}	56^{d}	6^{d}
P. thonningii	115^{c}	52^{c}	619^{d}	196^{d}	130^{c}	128^{b}	57^{d}	46^{a}
Harrisonia sp.	150^{b}	126^{d}	494^{e}	183^{d}	127^{c}	136^{b}	125^{b}	33^{e}
G. sepium	205^{d}	115^{d}	324^{c}	114^{e}	105^{a}	n.a	n.a	n.a
Mean	158	92	385	145	100	139	113	43

$^{a, b, c, d, e}$ Means with different superscripts along the same column are significantly ($p<0.05$) different, † Total phenolics and tannins expressed as tannic acid equivalents, ‡ Condensed tannins expressed as proanthocyanidins equivalents, n.a=Respective phenolics and tannins not detected.

In vitro gas production

Rumen fluid for both degradability and tannin bioassay studies was sampled early in the morning before feeding, harnessed and flushed with CO_2 throughout to maintain an anaerobic condition. In both total gas production and tannin bioassay experiments, test feed samples were incubated in buffered rumen fluid mixture as described by Makkar (2000).

Forage degradability characteristics were estimated by *in vitro* gas production technique (Menke and Steingass, 1988). Test feed samples were incubated *in vitro* with buffered rumen fluid for 96 h. Gas production was recorded at 0; 3; 6; 12; 36; 48; 72 to 96 h incubation intervals, when the experiment was terminated. Each test feed sample was incubated in triplicate. Three blank samples were incubated together with test feed samples in each run.

Degradability characteristics were obtained by fitting corrected gas volumes into degradability curve (Ørskov and McDonald, 1979), to estimate both rate and extent of dry matter degradability (DMD) based on the mathematical model: $G=A+B(1-e^{-ct})$. Where G is the potential gas production, and represents potential organic matter (OM) degradable at time, t; A, is the immediately soluble OM fraction; B is the slowly degradable OM fraction with time; and c describes the rate at which B is degraded. Degradability characteristics' constants were computed using the 'Neway' computer program (E. R. ∅rskov, Macaulay Institute, Aberdeen).

Tannin bioassay

Adverse effects of phenolics and tannins on feed digestibility were assessed by incubation of 500 mg test feed with or without 1 g (PEG of polyethylene glycol) (molecular weight, MWT 4000) (Makkar et al., 1995; Makkar, 2000) in a similar procedure described earlier for gas production except for the incubation intervals. Gas productions during incubations were recorded at 0, 2, 4, 6, 8, 10, 12, 16 and 24 h intervals. Feed *in vitro* organic matter digestibility (IVD) (%), and metabolizable energy (ME) (MJ/kg DM) were estimated from equations (Menke and Steingass, 1988; Makkar and Becker, 1996):

IVD (%)=14.88+0.889Gv+0.45CP; and
ME (MJ/kg DM)=2.20+0.136Gv+0.057CP

Where Gv is the 24 h gas production, with and without PEG; CP is the crude protein content (% DM) in the browse foliages.

Statistical analysis

Results on chemical compositions; degradability characteristics and *in vitro* organic matter digestibility (IVD) estimates were subjected to analysis of variance (ANOVA) using the General Linear Model Procedure (GLM) (SAS/ Statview, 1999). All analyses were conducted based on statistical model: $Y_{ij}=\mu_{ij} + S_i + s_e$. Where, Y_{ij} is the general observation on chemical composition and degradability parameters, μ_{ij} is the general mean common to each parameter under investigation; S_i is the i^{th} browse forage species effect on the observable parameters, and s_e is the standard error term. Means on the estimated parameters were compared by the least significant difference (LSD) test.

RESULTS

Chemical compositions

Results on chemical compositions are presented in Table 1. Mean compositions for CP, ash, NDF, ADF and ADL were 158, 92, 385, 145 and 100 g/kg DM, respectively. *A. tortilis* and *A. polyacantha* had relatively high CP contents (188 and 194 g/kg DM, respectively), and were not significantly ($p>0.05$) different from G. sepium that had the highest CP content (205 g/kg DM). Other browse forages had moderate (141 to 150) or low (115 to 130) g/kg DM CP contents (Table 1). The forages had relatively high ash contents ranging from 52 to 126 g/kg DM in *P. thonningii* and *Harrisonia sp*, respectively. Except *P. thonningii*, all browse forage species had low fiber fractions denoted by lower NDF values (less than 500 g/kg DM) (Table 1). *A. nilotica* had significantly ($p<0.05$) the lowest fiber fractions

Table 2. Cumulative *in vitro* rumen gas production potential (mls/200 mg DM) in selected browse leaves from western Tanzania

Forage species	*In vitro* incubation time intervals (h)						
	3	6	12	24	48	72	96
A. polyacantha	6.1^{ab}	8.8^{ab}	13.3^{a}	17.8^{a}	19.7^{a}	22.3^{a}	23.9^{a}
A. tortilis	4.1^{a}	7.3^{a}	14.8^{a}	23.0^{b}	28.7^{b}	31.3^{b}	31.5^{b}
A. nilotica	7.9^{bc}	12.9^{bd}	20.3^{b}	27.2^{c}	33.3^{c}	36.1^{c}	37.3^{cd}
Dichrostachys sp.	7.1^{b}	10.8^{b}	16.9^{ab}	23.5^{b}	28.3^{b}	30.4^{b}	31.6^{b}
F. villosa	7.5^{b}	10.9^{ab}	16.1^{a}	23.6^{bd}	35.4^{c}	35.4^{cd}	36.0^{c}
P. thonningii	10.8^{cd}	16.1^{c}	20.2^{c}	26.1^{cd}	34.0^{c}	35.7^{c}	36.8^{d}
Harrisonia sp	14.4^{d}	21.3^{d}	25.6^{d}	29.8^{e}	33.7^{c}	36.9^{d}	37.9^{d}
G. sepium.	13.3^{d}	19.0^{cd}	26.7^{d}	31.8^{e}	36.4^{cd}	38.5^{d}	38.7^{de}
Mean	8.9	13.4	13.4	25.4	31.2	33.3	34.2

$^{a-e}$ Means with same superscripts along the same column are not significantly (p>0.05) different.

Table 3. Organic matter degradability characteristics: A; B; (A+B) (%) and OM degradation rate constant (c) (% fraction/h)

Forage species	OM degradability characteristics			
	A	B	(A+B)	c
A. polyacantha	3.65^{a}	19.28^{a}	22.94^{a}	5.2^{ab}
A. tortilis	-1.41^{b}	33.16^{be}	31.75^{b}	5.5^{a}
A. nilotica	3.41^{a}	33.32^{bc}	36.73^{cd}	5.4^{a}
Dichrostachys sp	3.09^{a}	28.15^{cd}	31.23^{b}	5.3^{ab}
F. villosa	2.96^{ab}	34.54^{b}	37.50^{cd}	4.2^{b}
P. thonningii	8.20^{c}	28.97^{cd}	37.17^{cd}	4.3^{b}
Harrisonia sp	12.29^{cd}	24.63^{d}	36.93^{c}	5.7^{a}
G. sepium	8.04^{c}	30.16^{ce}	38.19^{d}	7.2^{c}
Mean	5.0	29.5	34.0	5.4

$^{a-d}$ Means with same superscripts along the same column are not significantly (p>0.05) different.

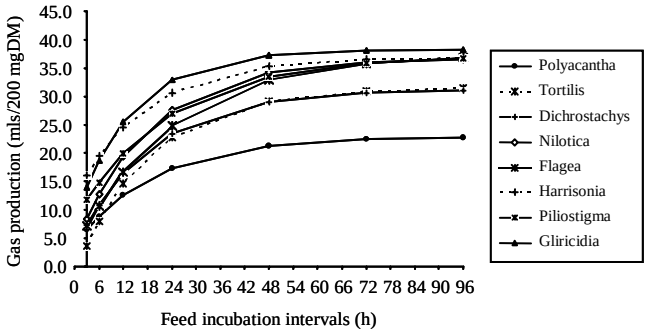

Figure 1. In vitro rumen gas production characteristics in selected legume forages.

(182, 68 and 44 g/kg DM) compared to *P. thonningii* that had the highest fiber compositions (619, 196, and 130 g/kg DM) for NDF, ADF and ADL, respectively. Similarly, other *Acacia spp* and *Dichrostachys sp* had relatively lower NDF values (Table 1).

Phenolics and tannins

Browse foliages had relatively high phenolics and tannins ANFs with mean compositions of 139, 113 and 43 mg/g DM, for TP, TT and CT, respectively. *Acacia spp*, *Dichrostachys sp*, *Harrisonia sp* and *P. thonningii* foliages had detectable phenolics and tannins almost greater than 100 mg/g DM (Table 1). *A. nilotica* had (p<0.05) highest contents of 237 and 236 mg/g DM for TP and TT, respectively. Dichrostachys sp had the highest CT (74 mg/g DM). Neither phenolics nor tannins were detectable in *G. sepium*.

Forage degradability

Table 2 presents forages *in vitro* gas production potential. Gas production potential varied significantly (p<0.05) between legume forage species. Gas production was lower in *A. polyacantha, Dichrostachys sp*; high in *G. sepium* and intermediate in the rest of other species (Table 2). Results in Table 3 shows variable gas productions and different degradability potential between the browse forages studied. Immediately soluble OM fraction, A; slowly degradable OM fraction, B; potential degradability, (A+B); and feed degradation rate constant of B (c) differed (p<0.05) between browse species (Table 3), and increased with incubation period (Figure 1). Degradability characteristics (on percentage basis) ranged from -1.41 (*A. tortilis*) to 12.29 (*Harrisonia sp*), 19.28 (*A. polyacantha*) to 34.54 (*F. villosa*), 22.94 to 31.18 (*G. sepium*) and from 4.2 (*F. villosa*) to 7.2 (*G. sepium*) for the A, B, (A+B) and c values, respectively. All *Acacia spp* and *Dichrostachys sp* had relatively lower degradability values compared to *P. thonningii* and *Harrisonia sp* that had higher degradability values almost comparable to *G. sepium* (Table 3). With exception of *A. polyacantha* that had the lowest B fraction, other *Acacia spp* had high degradability potential though with higher proportion of slowly degradable feed fraction B than *G. sepium. A. polyacantha, A. tortilis* and *Dichrostachys sp* had significantly (p<0.05) lower potential degradability compared to other forages whose (A+B) values were either similar to or greater than those of *G. sepium. G. sepium* had (p<0.05) high degradation rate constant compared to the rest of the forages (Table 3). Forage degradability trend is indicated in Figure 1. Forage degradability potential could be categorized into low (*A. polyacantha*); intermediate (*Dichrostachys sp* and *A. tortilis*); moderate to high (*F. villosa, P. thonningii* and *A. nilotica*), and high degradability in *G. sepium* (Figure 1).

Table 4. Correlation coefficient (r) between fiber compositions (NDF, ADF and ADL) with gas production and OMD characteristics [A, B, (A+B) and c]

Gas production at different incubations	NDF	ADF	ADL	TP	TT	CT
6 h	0.233	0.111	0.224	0.003	-0.027	-0.451
12 h	-0.056	-0.09	-0.016	0.174	0.214	-0.564
24 h	-0.197	-0.144	-0.147	0.192	0.251	-0.50
48 h	-0.088	0.107	-0.131	0.036	0.039	-0.192
72 h	-0.189	-0.099	-0.131	0.127	0.15	-0.27
96 h	-0.198	-0.112	-0.279	0.174	0.191	-0.329
OM degradability characteristics						
A	0.434	0.121	0.353	-0.066	-0.183	-0.145
B	-0.522	-0.184	-0.556	0.16	0.24	-0.063
(A+B)	-0.182	-0.092	-0.289	0.131	0.122	-0.204
c	-0.314	-0.115	-0.084	0.123	0.281	-0.48

Table 5. Effect of Polyethylene (PEG) treatment on *in vitro* gas production (mls/500 mg DM) at 16 h and 24 h incubations

Forage species	No PEG	+PEG	Increase	% Increase
Effect of PEG on gas production response at 16 h				
A. polyacantha	26.0	32.5	6.5	25.0
A. tortilis	22.0	29.5	7.5	32.1
A. nilotica	21.5	29.0	7.5	39.2
Dichrostachys sp.	27.0	35.5	8.5	31.2
F. villosa	12.5	18.0	5.4	43.3
P. thonningii	28.9	34.1	5.2	18.1
Harrisonia sp.	28.1	30.2	2.1	7.3
G. sepium	40.0	42.1	2.1	5.1
Effect of PEG on gas production response at 24				
A. polyacantha	28.0	36.0	8.0	28.7
A. tortilis	26.5	38.0	11.5	43.0
A. nilotica	27.0	38.5	11.5	46.6
Dichrostachys sp.	31.0	42.5	11.5	37.1
F. villosa	16.2	24.3	8.1	50.3
P. thonningii	30.0	38.1	8.1	26.8
Harrisonia sp.	32.3	36.4	4.3	13.2
G. sepium	48.1	50.5	2.4	5.0

[a, b] Mean with same superscripts along the same row between No PEG and PEG are not significant (p>0.05) different.

Table 6. Effect of PEG treatment on IVD (%) and metabolizable energy (ME) (MJ/kg DM) at 24 h

Forage species	No PEG	+PEG	Increase	% Increase
Effect of PEG treatment on IV response (%)				
A. polyacantha	48.5	55.6	7.1	14.7
A. tortilis	46.9	57.1	10.2	21.7
A. nilotica	45.4	55.6	10.2	23.4
Dichrostachys sp.	48.8	59.0	10.2	21.0
F. villosa	35.1	42.4	7.2	20.6
P. thonningii	46.7	53.9	7.2	15.3
Harrisonia sp.	50.2	54.0	3.8	7.5
G. sepium	66.0	69.0	2.1	3.2
Effect of PEG treatment on ME response (MJ/kg DM)				
A. polyacantha	7.11	8.20	1.09	15.32
A. tortilis	6.88	8.44	1.56	22.62
A. nilotica	6.69	8.26	1.56	24.34
Dichrostachys sp.	7.22	8.78	1.56	21.66
F. villosa	5.14	6.25	1.11	20.51
P. thonningii	6.94	8.03	1.10	15.79
Harrisonia sp.	7.43	8.01	0.58	7.78
G. sepium	9.90	10.23	0.33	3.29

[a, b] Mean with same superscripts along the same row between No PEG and PEG are not significant (p>0.05) different.

Correlations between *in vitro* degradability parameters with chemical compositions are indicated in Table 4. Gas production, NDF, ADF and ADL contents were negatively correlated with gas production potential post 6 h incubations, slowly degradable OM fraction B, potential degradability (A+B) and OM degradation rate constant (c) (Table 4). Total phenolics and tannins were low and positive correlated with gas production (post 6 h incubations) and potential OM degradability (A+B) (Table 4). On the other hand, condensed tannins were negatively correlated with gas production at all incubations periods and with all degradability characteristics. Negative correlation between condensed tannins and degradability characteristics suggests a negative role of tannins on fodder digestibility potential.

Effect of PEG on *in vitro* digestibility

Effect of PEG treatment on *in vitro* gas production is presented in Table 5. Addition of PEG resulted into a significant ($p<0.05$) increase in gas production. The response in gas production due to PEG varied significantly ($p<0.05$) between the different browse species (Table 5). Effect of PEG treatment on IVD and ME contents are indicated in Table 6. Addition of PEG resulted to significant ($p<0.05$) increase on IVD and ME (Table 6). Responses of IVD and ME on PEG treatment increased with tannin concentrations in browse forages. *Acacia spp*, *Dichrostachys sp* and *F. villosa* foliages had ($p<0.05$) higher response on *in vitro* gas production (Table 5), IVD and ME values (Table 6) due to PEG treatment. Addition of PEG had no ($p>0.05$) effect on neither digestibility in *G. sepium* nor on blank samples, suggesting negative role of tannins on feed digestibility.

DISCUSSIONS

High CP and lower fiber compositions indicate browse legume fodder potential as N supplements to ruminants fed on low quality roughage. Incorporation of browse fodder supplements into the basal diets would overcome animal nitrogen requirements, and could enhance utilization of these feed resources. Utilization of low quality forages, for example standing hay is constrained by low nitrogen (protein). Following high CP values (Table 1) in browse foliage fodder, and assuming that this nitrogen will be available to the animal, supplements from browse could provide deficient nitrogen for improved feed digestibility and possible utilization of released nutrients. Differences in CP contents between the different browse species could be mainly due to variations in factors controlling protein accumulation in forages during the growth process. Results from this study compares well with those documented elsewhere (Le Houérou, 1980; Topps, 1992; Abdulrazak et al., 2000a,b; Fadel Elseed et al., 2002). The latter authors reported values ranging from 100 to 250, 35 to 60, 154 to 511, 114 to 396 and 51 to 206 for CP, ash, NDF, ADF and ADL, respectively. However, some variations in chemical compositions between the current findings and some literature values could be due to stage of foliages' growth at vegetative sampling and the proportion of foliage sampled (twigs, leaves, or soft stems). Variations could also be due to site or location and climatic influences on forages growth and plants nutrients accumulation.

Phenolics and tannins compositions

All browse forages except *Gliricidia sepium* had high phenolics and tannins contents greater than 50 mg/g DM, reported to be the upper beneficial level in animal feeding and nutrition (Mangan, 1988). Therefore, to a large extent, high phenolics and tannins compositions in browse fodder could lower feed digestibility and associated feed utilization by ruminant animals. Higher levels of tannins depress feed nutritive values through lowered feed digestibility and nutrient availability and utilization (Makkar et al., 1995; Makkar and Becker, 1996). *Gliricidia sepium* had no detectable polyphenolics, accounting for its higher nutritive values especially when fed in wilted or dry forms (Norton, 1994). With exception of *F. villosa* that had the lowest proanthocyanidins (Table 1), the rest of browse species had high phenolic and tannin contents which are known to have adverse nutritional effects in ruminants by lowering feed nutritive values. Reed (1986); Shayo and Udén (1999) and Abdulrazak et al. (2000a,b) also reported high phenolics and tannins compositions in some browse legumes in East African browse legumes. High polyphenolics compounds were similarly reported in semi-arid and arid regions of Sudan (Fadel Elseed et al., 2002). High phenolic and tannin contents in tropical legumes are reported to be mainly a property of plant genotypic factors controlling physiological synthesis and accumulation of ANFs. Other factors associated with high rates of polyphenolics secondary plant metabolite synthesis include high environmental temperatures; drought stress, plant defensive mechanisms against pests, pathogens and predators (Mangan, 1988)

Results from this study show that phenolic and tannin contents in the Acacia species compared well to *Acacia spp* native to East Africa (Reed, 1986) and Abdulrazak et al. (2000a,b). However, there might have been some variations largely due to the different assays used, and due to the nature of variability in polyphenolics between forage samples and the standards used (Makkar and Becker, 1993). Differences might also have likely been due to the stage of plant growth, season of sampling as well as proportion of foliages sampled. Phenolic and tannin's ANFs are reported to vary with stage of growth (Woodward and Reed, 1989) and site (Makkar and Becker, 1998).

Forage degradability characteristics

Differences in feed degradability are largely attributed to phenolic and tannin's ANFs as well as fiber type and proportion in forages. Tannins depress forage digestibility by binding feed nutrients rendering them unavailable for digestion (Makkar and Becker, 1996; Makkar et al., 1995; Getachew et al., 2000). Variability in degradability potential could partly be explained by plant genotypic differences in tannin compositions and specific tannin activity on digestibility. Makkar and Becker (1993) denoted a variable nature of tannins between and within plant species as related to type of phenolic group; conformity and reaction mechanisms that could lead to differential effect of tannins on degradability between legume fodder species. Variability in feed degradability could also be due to forage' fiber compositions. Fiber proportion and type determine both extent and rate of feed degradation (Fonseca et al., 1998). Some of the browse forages used in this study (for example *P. thonningii*) had high ADF and ADL contents that might account for variations in their degradability. Extent and rate of feed degradation also depends on fiber composition and extent of fiber lignification in forages (Van Soest, 1994). Role of fiber fractions on degradability is further indicated by the observed negative correlation between NDF, ADF and ADL on gas production and degradability characteristics *in vitro* (Table 4). Low positive correlation between total phenolics and tannins on gas production (post 6 h) and OM degradability characteristics (B; A+B and c) (Table 4) could be explained by relatively less adverse effects of total phenolics and tannins on digestibility compared to condensed tannins. Negative role of tannins (especially total condensed tannins or proanthocyanidins)

on digestibility is further supported by negative correlation between total condensed tannins with gas production (r= -0.192 to -0.564), and degradability parameters (r=-0.063 and -0.48), respectively (Table 4). Tolera et al. (1997); Fadel Elseed et al. (2002) similarly reported negative correlation between proanthocyanidins with both gas production and degradability characteristics in some browse legume species. Contrary, Khazaal et al. (1994) found a positive correlation between condensed tannins and degradability estimates, a reason that could be attributed to different nature and tannin activity between the standard (tannic acid) and those in forage species under investigation (Makkar and Becker, 1993). Degradability potential ranked in a declining order of *G. sepium>F. villosa>P. thonningii> Harrisonia sp>A. nilotica>A. tortilis>Dichrostachys sp>A. polyacantha*. Degradability trend could be attributed to the adverse effects of phenolics and tannins on forage degradability.

Effect of PEG on *in vitro* digestibility

Observed improved gas production, IVD and ME values represent PEG binding tannins, and deactivation of tannin activity. PEG has high affinity for tannins (Makkar et al., 1995; Makkar and Becker, 1996). Improved *in vitro* OM digestibility and ME values due to addition of PEG on *in vitro* fermentation system indicates potential nutritive value in browse foliages previously depressed by tannin anti-nutritive activity. Makkar et al. (1995); Makkar and Becker (1996); Getachew et al. (2000) similarly noted improved digestibility in legume foliages due to PEG treatment. For example, Makkar et al. (1995) reported improved *in vitro* OM digestibility from 25.3 to 39.5%, and from 25.3 to 42.5% in Dichrostachys cinerea incubated with PEG MWT 4000 and 6000, respectively. In the current work, *Dichrostachys sp* leaves had relatively higher IVD values at 24 h corresponding to 48.8 and 59.0%, without and with PEG 4000, respectively, (Table 3), compared to the findings by the latter authors. Similarly, Makkar and Becker (1996) reported 47.3; 17 and 24% increase in gas production, *in vitro* OM digestibility and ME values, respectively, in *Acacia saligna* leaves due to PEG 6000 treatment. Positive response in increase in gas production, *in vitro* OM digestibility and ME clearly indicate the adverse effects of tannins on nutritive value in tanniniferous browse foliages. *In vitro* tannin bioassay is a simulation model on the possible effect of tannins on digestibility in vivo in relation to tannin anti-nutritive activity. Phenolic and tannin contents in these feeds had adverse effects on potential nutritive values, and indicate what would be negative effects on in vivo digestibility. Therefore, reduction of phenolics and tannins possibly by locally affordable processing techniques, for example sun drying, could optimize utilization of these legume feed resource as protein supplements to low quality roughages by possibly lowering tannin anti-nutritive activity. Alternatively, utilization of tanniniferous browse fodder could be optimized through feeding a mixture of supplements with readily available nitrogen to dilute the tannin anti-nutritive activity.

CONCLUSIONS

Browse legume forages native to western Tanzania have potential nutritive values indicated by high crude protein and low fiber compositions. The forages had detectable phenolics and tannins greater than 5% DM, an upper beneficial level in ruminant feeding and nutrition, therefore would depress potential nutritive values in browse fodder. High tannin compositions in these forages depressed both forage OM degradability and digestibility *in vitro*. Tannins lowered nutritive potential in these browse forages by depressing digestibility, hence would limit utilization of protein supplements from browse legume forages. Addition of PEG improved significantly ($p<0.05$) digestibility by binding tannins. PEG reversed effects of tannins on digestibility by deactivation of the negative activity of tannins on feed digestibility, and possibly released previously bound feed nutrients. *In vitro* tannin bioassay demonstrates on what would be positive benefits of reduction of tannin levels in browse. Therefore, utilization of browse fodder as protein supplements could be optimized subject to manipulation (reduction) of adverse activity of phenolics and tannins on feed digestibility. Further studies are recommended on affordable and appropriate techniques to reduce levels of phenolics and tannins in browse legume foliages; and browse feed nutritive potential through palatability and intake feeding studies as well as animal performance (growth) trials.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Japanese Ministry of Higher Education, Science, Sports and Culture (Monbusho) for scholarship award to the first author. ICRAF/Tanzania Agroforestry Project is acknowledged for various supports to the first author.

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