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Chemical composition, in sacco degradation and in vitro gas production of some Ghanaian browse plants

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Abstract

The nutritive value of leaves from four Ghanaian fodder trees, that is, *Spondias mombin*, *Antiaris toxicaria*, *Baphia nitida* and *Ficus exasperata* and three shrubs, that is, *Thespesia populnea*, *Grewia carpinifolia* and *Griffornia simplicifolea*, were evaluated by chemical, in sacco and in vitro methods. Introduced *Gliricidia sepium* leaves were included as control feed. Chemical analysis indicated that all samples were high in N (2.84%–4.08%) and low in neutral detergent fibre (NDF) (36.0%–60.6%). With the exception of *S. mombin* leaves, which had 10.5% total extractable phenolic and 8.6% extractable tannin content, all other tested feeds were low in extractable phenolics (0.56%–3.18%), extractable tannins (0.11%–2.52%) and condensed tannins (<1.21%). Dry matter (DM) and protein degradation after 48 h incubation in sacco ranged from 60.0%–87.5% and 73.1%–93.4%, respectively. *B. nitida* showed the lowest degradability values (45.7% and 52.5%, respectively). A similar trend was observed from the in vitro gas production data. Use of polyethylene glycol 4000 (phenolic binding agent) indicated that inhibitory effect of phenolics on rumen microbial fermentation was minimal. Data from this study have shown that such Ghanaian browse plants have potential to be used as feed supplements. © 1998 Elsevier Science B.V.

Keywords: Browse plants; in sacco degradation; in vitro gas production; Nutritive value

1. Introduction

Non-indigenous multipurpose trees (*Gliricidia*, *Leucaena* and *Acacia* sp.) have been introduced into Ghana and other African countries as a protein feed bank and agroforestry

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packages with the objective of providing good quality fodder trees and shrubs to improve ruminant production. Such introductions were carried out disregarding the indigenous browse plants being used by the farmers over the years. Regardless of the introduction of these 'improved' species, small holding farmers have continued using the native species.

Le Houerou (1980) reported that domesticated livestock and game graze about 75% of trees and shrubs in Africa. Rittner and Reed (1992) studied 72 indigenous fodder trees and shrubs from semi-arid (Niger), sub-humid (Nigeria) and humid/sub-humid (Benin) zones of west Africa. The study showed wide variation in chemical composition, crude protein (CP) and neutral detergent fibre (NDF) degradabilities. CP degradability was negatively correlated with soluble phenolics ($p<0.01$, $R=-0.34$) and pro-anthocyanidins ($p<0.001$, $R=-0.47$) whilst NDF degradability was negatively correlated with soluble pro-anthocyanidins ($p<0.001$, $R=-0.40$) and lignin ($p<0.001$, $R=-0.59$). It was concluded that most west African browse plants had the potential to be used as protein supplements due to their high nitrogen content. A similar study by Menke et al. (1992) on 40 tanniferous west African browse plants indicated a negative effect of polyphenolics on protein degradation and efficiency of microbial protein synthesis. Chemical analysis showed that only 20 had less than 5% total phenolics, 2% total tannin and 1% insoluble condensed tannins (Menke et al., 1992).

Currently, agronomic and palatability characteristics of *Leucaena*, *Gliricidia* and *Acacia* sp. limit a more effective utilisation of such plants as fodder trees. This suggests the need to screen native browse plants so as to identify promising species for further use in farming systems. In Ghana, there is limited information on the nutritive value of tree shrubs and forbs fed to ruminant livestock. The aim of the current study was to assess the chemical composition and nutritive value of four fodder tree leaves, namely, *Spondias mombin* (Atoa), *Antiaris toxicaria* (Kyenkyen), *Baphia nitida* (Odwene), *Ficus exasperata* (Onyankyeren) and three shrub leaves, namely *Thespesia populnea* (Ayeduru), *Grewia carpinifolia* (Ntanta) and *Griffornia simplicifolea* (Kagya). These leaves, widely used by small holding farmers, were identified during a diagnostic survey under a National Agricultural Research Project on limitations to small ruminant livestock production in the central region of Ghana with *Gliricidia sepium* leaves being used as a control substrate (Adam et al., 1996).

2. Materials and methods

Approximately 5 kg of leaf samples from browse trees (*Spondias mombin*, *Antiaris toxicaria*, *Baphia nitida* and *Ficus exasperata*) and shrubs (*Thespesia populnea*, *Grewia carpinifolia* and *Griffornia simplicifolea*) were collected at the end of the rainy season in the Teaching and Research Farm, University of Cape Coast, Cape Coast, Ghana, which is located in a coastal Savannah ecological zone. Samples from each plant species were collected from at least 10 individual trees or shrubs and pooled for further analysis.

The leaves were oven-dried at 50°C for 48 h and stored in sealed plastic bags. Samples were milled through a 2.5 mm screen for in sacco analysis and a 1.0 mm screen for in vitro gas production and chemical analysis.

2.1. In sacco DM and protein degradability analysis

The dry matter (DM) and CP in sacco degradation analysis was carried out according to the procedure described by Mehrez and Ørskov (1977). 4 g samples were weighed into nylon bags and incubated in three rumen-fistulated sheep for 8, 16, 24, 48, 72 and 96 h. The sheep were fed twice daily on a 67% hay and 33% grass cube diet. On removal the nylon bags were thoroughly washed for 20 min in a washing machine in cold water and dried at 60°C for 48 h. Washing losses were measured by soaking nylon bags containing samples at 39°C for 1 h prior to washing. The dried washed residues for each incubation time were pooled and further ground, using a 1 mm screen, for nitrogen determination. The DM and CP in sacco degradation data were fitted to the exponential equation: $P = a + b(1 - e^{-c \cdot t})$ (Ørskov and McDonald, 1979).

2.2. In vitro gas production analysis

Gas production was completed as described by Menke and Steingass (1988). 200 mg dried browse leaf samples alone were incubated in duplicate with 30 ml rumen liquor–artificial saliva mixture (1:2) in calibrated glass syringes at 39°C. A second assay was carried out with 200 mg browse samples incubated with 200 mg polyethylene glycol (PEG 4000) as described by Makkar et al. (1995). Readings were recorded after 3, 6, 12, 24, 48, 72 and 96 h of incubation and cumulative gas production data fitted into an exponential equation as described in previous section (Ørskov and McDonald, 1979).

2.3. Chemical analysis

DM, ash and ether extract analyses were completed as described by AOAC (1984). NDF and acid detergent lignin (ADL) were determined according to the method of Goering and van Soest (1970). Total nitrogen from original browse samples, NDF residues and in sacco undegraded residues were analysed by an automated method (Davidson et al., 1970). It involved the conversion of nitrogen in the sample to gas by oxidative combustion at 1000°C and measuring N concentration by thermal conductivity. Total phenolic content (TP) was determined in the supernatant, which was extracted with 70% acetone solution (Mueller-Harvey and Dhanoa, 1991). Total extractable phenolic content (TEPH) was determined by the Folin–Ciocalteau method (Julkunen-Tiito, 1985) using tannic acid as a standard. Total extractable tannins (TETA) were determined by the Watterson and Butler (1983) procedure and extractable condensed tannins (TCTA) by the vannilin–HCl assay (Broadhurst and Jones, 1978).

2.4. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using general linear model. Chemical analysis, in sacco degradability and in vitro gas production data for the indigenous browse leaves were also analysed by linear regression.

3. Results

Chemical composition of browse plant leaves is shown in Table 1. Generally, there were wide variations between chemical components of the browse species, with *B. nitida* showing the lowest ash content (5.23%). Nitrogen content was high in all samples (>2.84%). There was a significant positive correlation between NDF–N and NDF content ($p<0.001$, $R=0.925$) and between NDF and ADL content ($p<0.05$, $R=0.794$). The data also showed that a high proportion of the protein fraction (21% in *T. populnea* to 48% in *G. carpinifolea*) was bound to NDF.

Low levels of phenolic compounds were observed in all species except *S. mombin*, which had 10.5% TEPH and 8.6% TETA.

In sacco degradability data are shown in Table 2. The 48 h DM degradation (DMD) of *T. populnea*, *A. toxicaria* and *F. exasperata* was significantly higher than that of *G. sepium*. Variation between 48 h DMD values for *G. sepium* and *S. mombin* was small, as was the difference between *G. carpinifolia* and *G. Simplicifolea*, with *G. sepium* having the highest soluble fraction (34%). The fermentable fraction (b value) of the browse plants, except *B. nitida* and *G. simplicifolea*, were significantly higher ($p<0.05$) than that of *G. sepium*. The highest degradation rate constants (c values) were obtained from *T. populnea*, *F. exasperata* and *G. simplicifolea* ($p<0.05$). There was significant negative correlation between NDF content and 48 h DMD ($p<0.001$, $R=-0.715$) or potential degradability (DMPD, $a+b$ values) ($p<0.001$, $R=-0.927$).

Protein degradability (PD) after 48 h incubation, protein potential degradability (PPD) and protein degradation rate constant (c value) of *A. toxicaria*, *T. populnea* and *F. exasperata* leaves were significantly ($p<0.05$) higher than that of introduced *G. sepium*. *S. mombin* and *G. simplicifolea* which were superior to *G. carpinifolia* and *B. nitida* at 48 h PD. In sacco 48 h DMD was positively correlated with 48 h protein degradability ($p<0.001$, $R=0.924$, Fig. 1).

Table 1
Chemical composition of leaf samples from some Ghanaian browse plants

Leaf sample	Ash	N	NDF	NDF–N	ADL	TEPH	TETA	TCTA	EE
	% on DM basis[a]								
G. sepium – ctl[b]	6.98	3.99	41.5	1.08	9.20	1.00	0.22	0.10	2.49
S. mombin	7.83	3.28	36.9	0.99	7.15	10.5	8.60	0.66	3.42
T. populnea	15.0	3.34	36.0	0.72	6.80	2.25	1.97	0.89	3.74
A. toxicaria	13.6	2.84	39.9	1.13	6.30	0.89	0.56	0.33	2.92
B. nitida	5.29	4.15	60.6	1.89	13.7	1.21	0.55	0.21	2.97
F. exasperata	16.6	4.09	43.8	1.43	4.20	0.56	0.11	nd[c]	1.89
G. carpinifolia	9.24	3.92	54.1	1.89	8.80	2.56	1.78	0.89	2.11
G. simplicifolea	8.42	3.26	54.6	1.48	14.5	3.18	2.52	1.21	3.0[d]
SED[4]	0.034	0.27	0.53	0.021	0.16	0.041	0.024	0.010	0.085

[a]N: nitrogen, NDF: neutral detergent fibre, NDF–N: neutral detergent fibre nitrogen, ADL: acid detergent lignin, TEPH: total extractable phenolics, TETA: total extractable tannins, TCTA: total condensed tannins and EE: ether extract.
[b]ctl: control feed.
[c]nd: not detected.
[d]SED: standard error of the difference.

Table 2
In sacco degradability data of leaf samples from some Ghanaian browse plants

Leaf samples	Total degradability		Equation parameters			
	24h	48h	*a*	*b*	*a*+*b*	*c* rate
Dry matter degradability						
G. sepium-ctl[a]	63.8	70.9	34.0	40.7	74.8	0.0597
S. mombin	56.9	70.8	32.5	43.7	76.2	0.0433
T. populnea	81.4	87.5	25.0	63.4	88.4	0.1180
A. toxicaria	62.3	77.5	14.3	68.0	82.0	0.0640
B. nitida	42.3	45.7	25.3	25.3	50.6	0.0513
F. exasperata	71.8	83.4	21.3	62.4	83.7	0.1043
G. carpinifolia	46.96	60.1	14.6	49.4	63.9	0.0563
G. simplicifolea	59.9	62.5	23.4	39.4	63.1	0.1250
SED[b]	2.05	1.31	0.298	1.10	1.17	0.017
LSD[c] (p<0.05)	4.36	2.79	0.609	2.322	2.49	0.036
Protein degradability						
G. sepium- ctl[a]	58.9	72.2	25.0	56.9	81.9	0.0457
S. mombin	54.0	75.0	23.7	59.2	82.9	0.0417
T. populnea	83.9	93.4	26.5	66.0	94.9	0.0967
A. toxicaria	66.8	87.0	9.50	83.2	92.7	0.0603
B. nitida	48.4	52.5	30.2	40.3	70.5	0.0217
F. exasperata	76.3	89.9	29.1	64.2	93.3	0.0797
G. carpinifolia	60.2	73.1	16.5	63.4	79.0	0.0567
G. simplicifolea	72.1	82.9	20.1	63.5	83.6	0.1023
SED	2.07	1.12	0.909	2.17	1.79	0.0085
LSD (p<0.05)	4.40	2.37	1.93	4.60	3.79	0.0180

[a]ctl: control feed.
[b]SED: standard error of the difference.
[c]LSD: least significant difference.

The cumulative gas production is shown in Table 3. Both the potential and 24 h gas production from *F. exasperata* were significantly (p<0.05) higher than that of *G. sepium*, which in turn was similar to *T. populnea* and *A. toxicaria*. The in vitro gas production data of the remaining samples were lower than that of *G. sepium*.

There was a positive correlation between 24 h DMD and 24 h gas production data (p<0.05, R=0.697, Fig. 2) as well as 24 h PD data and 24 h gas production data (p<0.05, R=0.677).

Increases in gas production, expressed as percent increase when samples were incubated without or with PEG 4000 was minimal. It ranged from 2.88% for *F. exasperata* to 13.88% for *S. mombin* after 24 h incubation, with no significant (p<0.05) differences amongst browse leaves.

4. Discussion

The observed variation in chemical composition of browse leaves in this study is similar to that previously reported in other West African browse plants (Rittner and Reed,

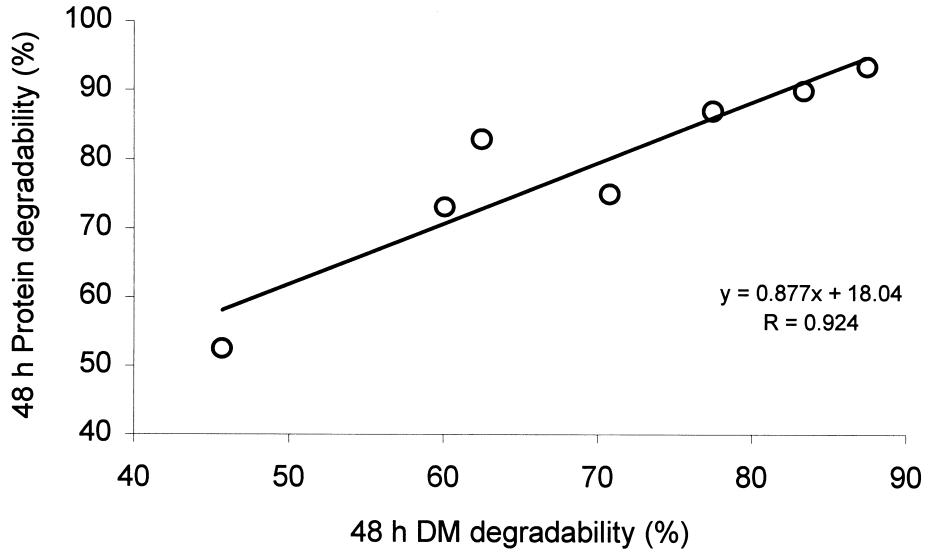

Fig. 1. Correlation between 48 h DM in sacco degradability and 48 h protein degradability data from Ghanaian browse plants.

1992). Nitrogen, NDF and phenolic content data suggest that browses analysed in the current study have the potential to be used as feed supplements. Composition of such plants is similar to that of known tropical leguminous forages, for example, *S. sesban*, *C. cajan* and *G. sepium* (Dzowela et al., 1995a; Whetton et al., 1997).

The presence of condensed tannins in *G. sepium* leaf samples in this current study is consistent with an earlier report (Dzowela et al., 1995b) and chemical analysis of

Table 3
In vitro gas production data of browse leaves from some Ghanaian browse plants

Species	Total gas production			Constant
	24 h	48 h	*a*+*b* ml	*c* rate
G. sepium- ctl	31.8	38.4	40.4	0.0654
S. mombin	18.9	24.4	29.3	0.0361
T. populnea	28.6	33.5	36.1	0.0584
A. toxicaria	30.7	37.6	41.0	0.0533
B. nitida	20.1	26.1	30.8	0.0397
F. exasperata	35.2	41.5	44.5	0.0622
G. carpinifolia	22.0	29.3	33.3	0.0428
G. simplicifolea	20.5	24.2	26.5	0.0589
SED[b]	1.59	1.75	2.09	0.0026
LSD[c] (p<0.05)	3.66	3.05	4.82	0.0061

[a]ctl: control feed.
[b]SED: standard error of the difference.
[c]LSD: least significant difference.

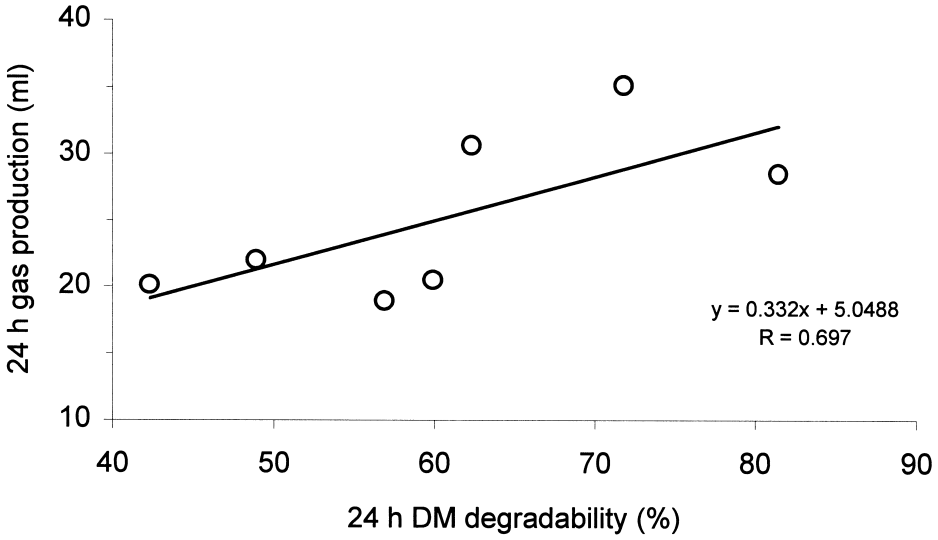

Fig. 2. Correlation between 24 h DM in sacco degradability and 24 h in vitro gas production data from Ghanaian browse plants.

12-week-old *G. sepium* leaves showed low levels of soluble phenolics (2.3% on DM basis). In other studies, Dzowela et al. (1995a) and Whetton et al. (1997) did not detect condensed tannins in *G. sepium* leaves.

The 48 h in sacco DM and protein degradability of *G. sepium* leaves used in this study were lower than those reported by Dzowela et al. (1995a) on 12-week-old samples (79.6% and 86.7%, respectively). *T. populnea* and *F. exasperata* in sacco protein degradability data were similar to those reported for 12-week-old *S. sesban* and *C. cajan* leaves (Dzowela et al., 1995a). Variation in protein degradability is believed to be related to the proportion of structural and non-structural protein and carbohydrate fractions, which in turn affects their solubility and bio-availability (Whetton et al., 1997).

The positive and significant ($p<0.05$) correlation between in sacco degradability and in vitro gas production data suggests that either method could be used to estimate nutritive value of such feeds. Previous experiments have shown a positive relationship between in sacco degradability and both voluntary intake and in vivo digestibility (Ørskov et al., 1988; Blümmel and Ørskov, 1993; Kibon and Ørskov, 1993) as well as 24 h in vitro gas production and metabolisable energy for ruminants from various forages (Menke and Steingass, 1988). Khazaal et al. (1994) reported that in sacco method should be used with caution when estimating the nutritive value of high phenolic feeds. The potential negative effect of phenolic compounds on rumen microbial fermentation is unlikely to be detected by in sacco method. In this respect in vitro methods are more reliable in detecting inhibitory compounds in feeds. The in vitro gas production technique is a closed system with limited supply of rumen liquor where if there is any anti-nutritive compound, it is likely to affect the activity of rumen microbes. On the contrary, the in sacco method is associated with a dilution effect, which results from an open system with a wider rumen environment and copious supply of rumen fluid to nylon bag contents.

The browse species evaluated in the present study can be classified as low tanniferous plants with high protein content. The in sacco degradability data suggest that leaves from Ghanaian indigenous browse plants are of high nutritive value. Additionally, in vitro gas production data indicated absence of inhibitory compounds in such feeds. In order to optimise their use as feed supplements it is crucial that further in vivo studies are carried out so that optimal level of inclusion in the diet and feeding conditions are properly defined. Agronomic studies may also be required so that biomass production and seasonal effect on nutritive value are better understood.

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