



**ASSESSMENT OF CHEMICAL COMPOSITION AND *IN VITRO*
DEGRADATION PROFILE OF SOME GUINEA SAVANNAH BROWSE
PLANTS OF NIGERIA**

[EVALUACIÓN DE LA COMPOSICIÓN QUÍMICA Y DEGRADACIÓN *IN VITRO* DE ALGUNAS PLANTAS ARBUSTIVAS DE LA SABANA DE GUINEA DE NIGERIA]

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SUMMARY

The study was conducted to estimate the nutritive value of six indigenous browse fodders (*Etanda africana*, *Piliostigma thonningii*, *Detarium microcarpum*, *Daniellia oliveri*, *Pterocarpus erinaceus*, and *Azelia africana*) by the evaluation of chemical composition, anti-nutritional factors and *in vitro* gas characteristics. All samples (g/100g DM) had high CP (12.6–24.7), moderate fibre concentrations (NDF, 34.7–54.6; ADF, 19.7–35.2 and lignin, 7.36–12). There were significant differences ($P < 0.05$) in NDF, ash, ether extract, hemicellulose, cellulose and mineral concentrations among the browse fodders. Except for condensed tannins which were similar among the browse fodders, other anti-nutritional factors were different ($P < 0.05$). The relative feed values of the selected legume browses ranged from 114.43 in *E. africana* to 202.94 in *A. africana*. Gas volume (ml/200mg DM), methane (ml/200mg DM), methane/total gas volume (v:v), metabolisable energy (MJ/kg DM), organic matter digestibility (%), short chain fatty acids (μmol) and *in vitro* dry matter degradability (%) ranged from 19-34, 8.66-11.33, 0.29-0.46, 4.53-6.48, 35.73-49.06, 0.15-0.43 and 46-67 respectively. Results show that the browse species have good nutrient profile, low and safe levels of anti-nutritional factors and relatively high degradability which qualify them as suitable feed supplements to low quality basal diets for ruminants.

Key words: browse fodder; chemical composition; relative feed value; anti-nutritional factors; *in vitro* gas degradability profile.

RESUMEN

Se estimó el valor nutritivo de seis plantas arbustivas indígenas (*Etanda africana*, *Piliostigma thonningii*, *Detarium microcarpum*, *Daniellia oliveri*, *Pterocarpus erinaceus* y *Azelia africana*) mediante la evaluación de su composición química, factores antinutricionales y características de la producción de gas *in vitro*. Todas las plantas tuvieron (g/100 MS) un alto contenido de PC (12.6-24.7), contenido moderado de fibra (FDN, 34.7-54.6; FDA, 19.7-35.2 y lignina, 7.36-12.0). Se encontró diferencias ($P < 0.05$) entre especies en los contenidos de FDN, cenizas, extracto etéreo, hemicelulosa, celulosa y minerales. Excepto por el contenido de taninos que fue similar entre especies, los factores anti nutricionales fueron diferentes ($P < 0.05$) el valor relativo varió de 114.43 para *E. africana* hasta 202.94 para *A. africana*. El volumen de gas (ml/200mg MS), metano (ml/200 mg MS), metano/total gas (v/v), energía metabolizable (MJ/kg MS), digestibilidad de la materia orgánica (%), ácidos grasos de cadena corta (μmol) y digestibilidad *in vitro* de la MS (%) fluctuó de 19-34, 8.66-11.33, 0.29-0.46, 4.53-6.48, 35.73-49.06, 0.15-0.43 y 46-67 respectivamente. Los resultados mostraron que las especies tienen un buen perfil de nutrientes, niveles bajos y seguros de factores anti nutricionales y degradabilidad relativamente alta lo que los hace adecuados como suplementos para rumiantes con dietas basales de baja calidad.

Palabras clave: follaje de arbustos; composición química, valor relativo; factores antinutricionales; perfil producción de gas *in vitro*; degradabilidad.

INTRODUCTION

The relevance of evaluating the nutritional value of indigenous shrubs, trees and browse plants is evident (Topps, 1992; Nherera *et al.*, 1999; Cerillo and Juarez, 2004) as their foliage can make important contributions to the protein and energy consumption of ruminant animals. This is particularly important during the critical dry season when forage availability and quality are severely limited and affected.

The nutritive value of a ruminant feed is determined by the concentration of its chemical components, as well as the rate and extent of digestion. *In vivo* determination of nutritive value most accurately reflects feed nutritive value. However, *in vivo* techniques are strenuous; it is difficult to assess large number of samples. Also, determining the digestibility of feeds *in vivo* is laborious, expensive; requiring large quantities of feed, and is largely unsuitable for single feedstuff thereby making it unsuitable for routine feed evaluation (Getachew *et al.*, 2004). There are a number of *in vitro* techniques available to evaluate the nutritive value of feeds at relatively low cost.

The leaves of the evergreen tree and shrub are used as emergency food by ruminants in the Guinea savanna region of northern Nigeria where it is customary to feed non-conventional feedstuffs such as browse species (Olafadehan, 2011). However, there is little information on their nutritive values. Chemical composition, in combination with *in vitro* digestibility and ME content can be considered useful indicators for preliminary evaluation of the potential nutritive value of previously uninvestigated shrub and tree leaves (Ammar *et al.*, 2005).

The rational use of fodder and browse requires accurate information about the nutritive value of these alternative feed resources. Along with the information on the nutrient content, the presence of anti-nutritional compounds is of special interest for this sort of feedstuff, as high concentrations of tannins are found in many browse trees (Dube *et al.*, 2001). These compounds can impair the digestive utilization of the feed ingested by the animal and even induce toxicity when consumed above the threshold level. There is therefore the need for continuous screening of non-conventional browse plants to identify those with good potentials as livestock fodder which can serve as alternatives to those species that have already been evaluated.

Current chemical analytical techniques do not reflect the biological effects of tannin therefore the use of *in vitro* techniques has been proposed to supplement the chemical analysis (Nsahlai *et al.*, 1994). The gas production technique has proved to be efficient in

determining the nutritive value of feeds containing anti-nutritive factors (Siaw *et al.*, 1993). The objective of this study was to investigate the nutritive value of foliage from selected tropical browse species based on chemical analysis, quantification of anti-nutritional factors and *in vitro* gas production technique.

MATERIALS AND METHODS

Experimental site

This study was carried out at the Federal College of Wildlife Management, New Bussa, Niger State. It is located between latitudes 7° 80' and 10° 00'N and longitudes 4° 30' and 4° 33' E and has mean annual temperature of about 34°C with relative humidity of about 60%.

Collection of forages and processing

Fresh leaves from the branches of six selected browse plant species (*Etanda africana*, *Piliostigma thonningii*, *Daniellia oliveri*, *Detarium microcarpum*, *Pterocarpus erinaceus* and *Azelia africana*) were harvested from several stands in the rangeland of the Federal College of Wildlife Management New Bussa, Niger state, Nigeria and its environment between April and May 2013. Samples from fresh foliage of the selected browse plants were oven-dried to constant weight at 60°C for 72 hours to determined dry matter. Dried sample were milled to pass through 1mm screen for subsequent laboratory analysis after stored in air tight container.

Chemical analysis

Samples of green forages were analyzed according to the standard methods of AOAC (2002) for dry matter (DM), crude protein (CP), ether extract (EE) and ash. Neutral detergent fibre (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined as described by Van Soest *et al.* (1991). Hemicellulose and cellulose were estimated as the difference between NDF and ADF and ADF and ADL, respectively. Non-fiber carbohydrates were estimated as 100–CP–NDF–EE–ash (Sniffen *et al.*, 1992). Condensed tannins were determined according to the procedures of Makkar (2005), saponins by Babayemi *et al.* (2004), phytate as phytic acid using the method of Maga (1982) and oxalate was determined by the method of (AOAC, 2002). Calcium, magnesium, potassium and phosphorus were analysed using atomic absorption spectrophotometer.

***In vitro* gas production study**

The *in vitro* gas production was determined according to Menke and Steingass (1988). Three Red Sokoto goats fed a mixed diet of *Panicum maximum* (60% DM) and concentrates (40% DM) were used. The concentrate feed consisted of 40% corn, 10% wheat offal, 10% palm kernel cake, 20% groundnut cake, 5% soybean meal, 10% dried brewers' grain, 1% common salt, 3.75% oyster shell and 0.25% fish meal. Feeds were offered in two equal meals at 07:00 and 18:00 h, respectively, to the goats. The animals had free access to water and mineral licks. Rumen fluid was collected from the goats with the use of suction tube prior to morning feeding. The collected rumen liquor was strained through four layers of cheese cloth and kept at 39°C. All laboratory handling of rumen fluid was carried out under a continuous flow of carbon IV oxide. Samples (200 mg) of the oven dry and milled leaves were accurately weighed into 100 ml glass syringes fitted with plungers. *In vitro* incubation of the samples was conducted in triplicates. Syringes were filled with 30 ml of medium consisting of 10 ml of rumen fluid and 20 ml of buffer solution (g/liter of 1.985 (Na₂)HPO₄ + 1.302 KH₂PO₄ + 0.105 MgCl₂.6H₂O + 1.407 NH₂HCO₃ + 5.418 NaHCO₃ + 0.390 Cystine HCl + 0.100 NaOH) and three blank samples containing 30 ml of medium (inoculums and buffer) only were incubated at the same time. The syringes were placed in a rotor inside the incubator (39°C) with about one rotation per min. The gas production was recorded at 3, 6, 9, 12, 18, 24, 36 and 48 h. At post incubation period, 4 ml of (10M) Sodium hydroxide (NaOH) was dispensed into the each incubated sample. Sodium hydroxide was added to absorb carbon-dioxide that was produced during the process of fermentation and the remaining volume of gas was recorded as methane according to the report of Fievez *et al.* (2005). The average of the volume of gas produced from the blanks was deducted from the volume of gas produced from sample.

***In vitro* dry matter degradability (IVDMD)**

After 24h digestion, the samples were transferred into test tubes and centrifuge for 1hour in order to obtain the residues which were then filtered using Whatman No 4 filter paper by gravity and the residues placed in crucible for drying at 65°C for 24h. The dry residues were weighed and digestibility calculated using the equation as follows:

$$\text{IVDMD (\%)} = \frac{\text{Initial DM} - \text{DM residue-Blank}}{\text{Initial DM Input}} * 100$$

Statistical analysis and calculations

Data were subjected to one way of ANOVA in completely randomized design using version 9.1 of SAS software (SAS Institute, 2003). Significance difference between individual means was separated by Duncan's procedure of the same software. Mean differences were considered significant at $P < 0.05$.

Relative feed value (RFV) of the legume tree leaves was calculated from the estimates of dry matter digestibility (DMD) and dry matter intake (DMI) according to Rohweder *et al.* (1978). Following are the equations used:

$$\begin{aligned} \text{DMD (\%)} &= 88.9 - (0.779 - \text{ADF \%}) \\ \text{DMI (as \% of body weight)} &= 120/\text{NDF \%} \\ \text{RFV} &= (\text{DMD\%} \times \text{DMI \%})/1.29 \end{aligned}$$

Forage quality was determined using the standard assigned by Hay Market Task Force of American Forage and Grassland Council (Table 1). Metabolisable energy (ME, MJ/Kg DM) and organic matter digestibility (OMD%) of the incubated samples were estimated at 48 hr post gas collection with equation according to Menke and Steingass (1988), while short chain fatty acid (SCFA, μmol) at 24 h post gas collection was computed using linear equation by Makkar (2005).

$$\text{ME} = 2.20 + 0.136\text{GV} + 0.057\text{CP} + 0.0029\text{CF}$$

$$\text{OMD} = 14.88 + 0.889 \text{GV} + 0.45 \text{CP} + 0.651 \text{ash}$$

(Menke and Steingass, 1988)

$$\text{SCFA}(\mu\text{mol}) = 0.0222\text{GV (at 24 hr)} - 0.00425$$

(Makkar, 2005)

where: Total gas volume (GV) is expressed as (ml/0.2 g DM) CP and ash as g/kg DM. CP and CF are crude protein and crude fibre of the incubated samples respectively.

RESULTS

Chemical composition and fibre fraction

There were differences ($P < 0.05$) in the chemical composition of the browse fodders except for the DM and OM (Table 2). Crude protein (CP) contents were highest ($P < 0.05$) in *A. africana* (24.64 g/100 g DM) and least in *D. microcarpum* (12.64 g/100 g DM). Ash and ether extract contents varied ($P < 0.05$) from 4.40 in *D. microcarpum* to 8.99 g/100g DM in *P. thonningii* and 37.45 in *D. oliveri* to 63.8 g/100 g DM in *A. africana*, respectively. Non-fibre carbohydrate values were highest ($P < 0.05$) in *D. microcarpum* (31.22 g/100 g DM). There were variations ($P < 0.05$) in the NDF, ADF, cellulose and hemicellulose

contents of the browse species. Acid detergent lignin was highest ($P < 0.05$) in *P. erinaceus* (12.00 g/100 g DM).

Macro mineral concentration

Ca concentration was different ($P < 0.05$) among the browse fodders, the value ranged between 9.0 g/kg DM in *D. oliveri* to 5.9 g/kg in *E. africana*. Highest ($P < 0.05$) P concentration was observed in *P. erinaceus* (6.7 g/kg DM), while *D. microcarpum* (2.8 g/kg DM) had the least ($P < 0.05$) concentration. K concentrations were higher ($P < 0.05$) in *D. oliveri* (9.6 g/kg DM) while Mg concentration was highest in and *P. erinaceus*, (5.8 g/kg DM) relative to other browse fodders (Table 3).

Anti-nutritional factors concentration

Plant phytochemical components (saponins, phytate and oxalate) in the browse species forages were

different ($P < 0.05$) except for the tannin concentration levels (Table 4).

Relative feed value (RFV)

Estimated DMD and DMI of the browse fodders ranged ($P < 0.05$) from 61.50% in *D. microcarpum* to 73.53% in *A. africana* and 2.23% in *P. thonningii* to 3.55% in *A. africana*, respectively (Table 5). *A. africana* had the best RFV value (202.94%), while *E. africana* had the least RFV (114.43%). The grade of the legume browses ranged from 4 to prime in the following order: *D. microcarpum* (4), *E. africana* (3), *P. thonningii* (2), *D. oliveri* (2), *P. erinaceus* (1) and *A. africana* (prime), respectively, according to the standard assigned by Hay Market Task Force of American Forage and Grassland Council.

Table 1. Legume, grass and legume-grass mixture quality standards

Quality standard ^a	CP	ADF (DM %)	NDF (DM %)	RFV ^b
Prime	>19	<31	<40	>151
1	17- 19	31-40	40-46	151-125
2	14 - 16	36-40	47-53	124-104
3	11 - 15	41-42	54-60	102.87
4	8 - 10	43-45	61-65	86.75
5	<8	>45	>	<

^aStandard assigned by Hay Market Task Force of American Forage and Grassland Council;

^bRelative Feed Value (RFV) – Reference hay of 100 RFV contains 41% ADF and NDF and 53% NDF

Table 2. Chemical composition and fibre fraction (g/100 g DM) of the selected browse foliages

Browse species	DM	OM	CP	Ash	EE	NFC	NDF	ADF	ADL	HC	CEL
<i>E. africana</i>	91.66	86.39	20.33 ^b	5.27 ^{bc}	4.37 ^b	15.47 ^c	54.56 ^a	33.76 ^a	7.73 ^b	20.79 ^b	26.03 ^a
<i>P. thonningii</i>	91.83	82.84	14.23 ^c	8.99 ^a	3.89 ^b	18.03 ^d	53.86 ^a	27.11 ^b	8.98 ^b	26.75 ^a	18.15 ^b
<i>D. microcarpum</i>	89.52	85.11	12.64 ^{cd}	4.40 ^c	5.18 ^{ab}	31.22 ^a	46.53 ^{ab}	23.65 ^b	7.36 ^b	22.87 ^b	16.31 ^b
<i>D. oliveri</i>	91.83	84.04	14.00 ^c	7.79 ^{ab}	3.75 ^b	27.08 ^b	49.80 ^{ab}	26.27 ^b	9.36 ^b	23.62 ^b	16.91 ^b
<i>P. erinaceus</i>	92.97	85.39	18.42 ^b	7.63 ^{ab}	4.73 ^b	20.00 ^d	45.79 ^{ab}	35.15 ^a	12.00 ^a	15.38 ^c	23.15 ^{bc}
<i>A. africana</i>	90.79	83.57	24.69 ^a	7.22 ^{ab}	6.38 ^a	23.78 ^c	34.36 ^b	19.73 ^c	8.07 ^b	14.63 ^c	11.66 ^c
Mean	91.43	84.56	17.49	6.83	4.72	22.59	48.28	27.61	8.91	20.67	18.49
SEM	1.24	1.25	0.69	0.69	0.73	1.39	1.75	1.71	0.98	1.93	1.60

^{abc} means within the same column with different superscripts are significantly different ($P < 0.05$).

DM = dry matter, OM, organic matter; CP = crude protein, EE = ether extract, NFC, Non-fiber carbohydrates; NDF, neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, HC = hemicellulose, CEL = cellulose,

Table 3: Macro mineral composition (g/100 g DM) of the selected browse foliages

Browse species	Calcium	Phosphorus	Ca:P	Magnesium	Potassium
<i>Etanda africana</i>	5.9 ^c	4.4 ^b	1.3 ^d	3.8 ^c	8.3 ^b
<i>Piliostigma thonningii</i>	8.2 ^{ab}	3.7 ^b	2.2 ^b	3.9 ^c	8.1 ^b
<i>Detarium microcarpum</i>	7.5 ^b	2.8 ^c	2.7 ^a	3.2 ^{cd}	7.2 ^b
<i>Daniellia oliveri</i>	9.0 ^a	4.4 ^b	2.0 ^b	2.5 ^d	9.6 ^a
<i>Pterocarpus erinaceus</i>	6.0 ^c	6.7 ^a	0.9 ^d	5.8 ^a	8.3 ^b
<i>Afzelia africana</i>	7.7 ^b	4.1 ^b	1.9 ^{bc}	5.0 ^b	8.3 ^b
Mean	7.4	4.5	1.6	4.0	8.3
SEM	1.5	1.2	0.5	0.01	0.15
Recommended requirement range ^b					
Minimum	1.9	1.2	1:1	0.1	5
Maximum	8.2	4.8	2:1	2.5	10

Means within the same column with different superscripts are significantly different ($P < 0.05$).

^b Recommended range of mineral elements (for all classes of ruminants) as suggested by the National Research Council and summarized by McDowell (1997).

Table 4: Anti-nutritional concentration (g/kg DM) of the selected browse foliages

Browse species	Tannin	Saponin	Phytate	Oxalate
<i>Etanda africana</i>	0.60	2.08 ^a	3.79 ^{ab}	0.43 ^{ab}
<i>Piliostigma thonningii</i>	0.34	0.57 ^b	4.81 ^{ab}	1.26 ^{ab}
<i>Detarium microcarpum</i>	0.81	1.06 ^{ab}	7.82 ^a	1.58 ^{ab}
<i>Daniellia oliveri</i>	0.50	0.38 ^b	6.42 ^{ab}	1.48 ^{ab}
<i>Pterocarpus erinaceus</i>	0.40	2.02 ^a	5.38 ^{ab}	0.26 ^b
<i>Afzelia africana</i>	0.90	0.59 ^b	0.92 ^b	1.79 ^a
Mean	0.59	1.12	3.89	1.13
SEM	0.41	0.54	1.01	0.49

Means within the same column with different superscripts are significantly different ($P < 0.05$).

Table 5: Dry matter digestibility, dry matter intake and relative feed value of selected browses

Browses	DMD (%)	DMI (% BW)	RFV	Quality standard
<i>Etanda africana</i>	61.52 ^c	2.35 ^b	114.43 ^c	3
<i>Piliostigma thonningii</i>	67.78 ^b	2.23 ^b	117.14 ^c	2
<i>Detarium microcarpum</i>	61.50 ^c	2.44 ^b	116.76 ^c	4
<i>Daniellia oliveri</i>	68.43 ^b	2.48 ^b	132.69 ^{bc}	2
<i>Pterocarpus erinaceus</i>	70.47 ^{ab}	2.64 ^{ab}	145.60 ^b	1
<i>Afzelia africana</i>	73.53 ^a	3.55 ^a	202.94 ^a	Prime
Mean	67.21	2.62	143.26	-
SEM	1.73	0.31	19.99	-

Means within the same column with different letters are significantly different ($p < 0.05$).

DMD = dry matter digestibility (%), DMI = dry matter intake (% of body weight), RFV = relative feed value

***In vitro* gas production**

In vitro degradation profile of the different foliages is presented in Table 6. The final net gas volumes at 48 h after incubation and CH₄ production were significantly different ($P < 0.05$) among the browse fodders. Ratio of methane/total gas volume (v: v)

produced which indicates the methanogenic property of the browses was least ($P < 0.05$) in *A. africana*. The estimated ME (MJ/kg DM), OMD% and SCFA (μmol) were higher ($P < 0.05$) in *A. africana* compared to other browse fodders. Figure 1 shows the *in vitro* gas production pattern of the browses.

Table 6: *In vitro* gas production (ml/200 mg DM), Metabolizable energy (ME MJ/kg DM), Organic matter (OMD %), Short chain fatty acids (SCFA μ mol), Methane (CH₄ ml/200g DM) production of the browse species

Browse species	NGV (48 h)	CH ₄	CH ₄ /total gas (v:v)	ME	OMD	SCFA	IVDMD
<i>Etanda Africana</i>	19.00 ^c	8.66 ^b	0.46 ^a	5.43 ^b	40.49 ^b	0.29 ^c	46 ^b
<i>Piliostigma thonningii</i>	26.00 ^b	9.33 ^{ab}	0.36 ^b	5.28 ^b	41.36 ^b	0.32 ^b	63 ^a
<i>Detarium microcarpum</i>	21.00 ^c	9.33 ^{ab}	0.44 ^{ab}	4.81 ^c	32.11 ^d	0.15 ^d	59 ^a
<i>Daniellia oliveri</i>	20.70 ^c	8.70 ^b	0.42 ^{ab}	4.53 ^c	35.73 ^c	0.19 ^d	63 ^a
<i>Pterocarpus erinaceus</i>	34.00 ^a	11.33 ^a	0.38 ^b	5.28 ^b	45.32 ^b	0.32 ^b	66 ^a
<i>Afzelia Africana</i>	33.50 ^a	11.00 ^a	0.29 ^c	6.48 ^a	49.06 ^a	0.43 ^a	67 ^a
SEM	1.06	0.44	0.03	0.15	1.07	0.02	2.0

Means in the same column with different superscripts are significantly different ($P < 0.05$)

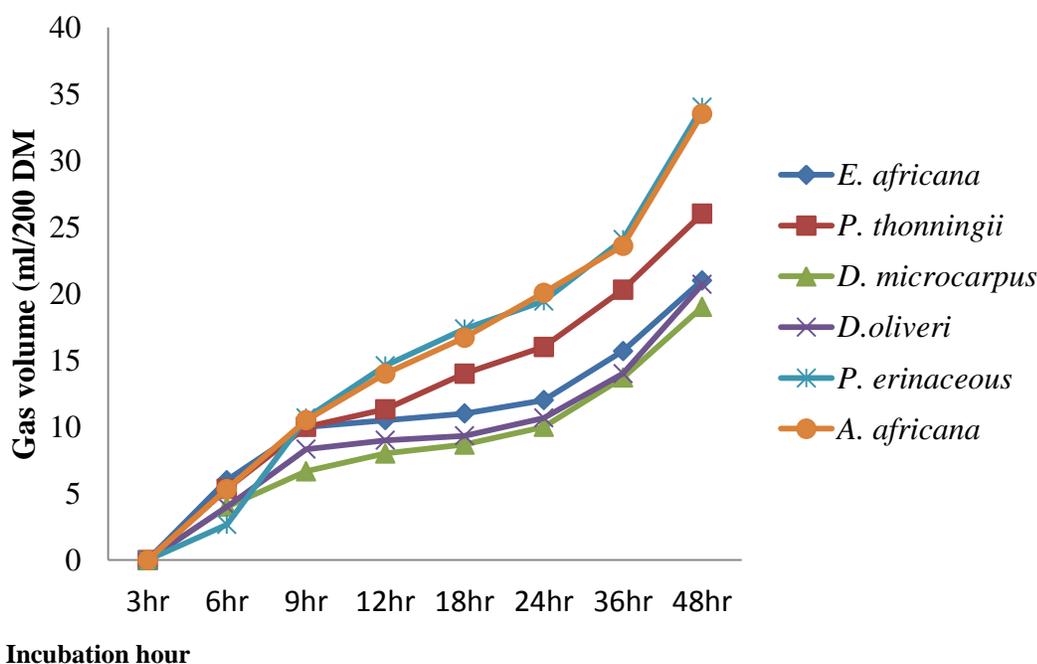


Figure 1: *In vitro* gas production characteristics

DISCUSSION

The range of the CP content of the browse fodders is in agreement with previous reports (Osuga *et al.*, 2006; Bouazza *et al.*, 2012). The lowest value of CP (12.64 g/100 g DM) for *D. microcarpum* is well above the range of 7.0–8.0 g/100 g DM suggested as critical limit below which intake of forages by ruminants and rumen microbial activity would be adversely affected (Van Soest, 1994). The CP content of the browse fodders is an indication of their nutritional quality since CP content is a very important index of nutritional quality of a feed. This justifies their use as supplements to poor quality natural pastures and crop residues. The NFC contents

of the browse species should be adequate to stimulate NH₃-N utilization in the rumen (Tylutki *et al.*, 2008). The optimal concentration of NFC is important in ruminant diets to avoid acidosis and other metabolic problems. Diets with excess NFC can cause ruminal upsets and health problems (Nocek, 1997). The fibre fraction contents of the plant species were generally moderate and within the limits established by NRC (1978) for ruminant animals for ensuring proper digestion and rumination. The mean NDF and ADF values of 48.28 and 27.61 g/100 g DM were low to moderate when compared with low quality roughages, which ruminants can effectively degrade (Arigbede and Tarawali, 1997). The low to moderate fibre contents of the browse fodders suggests their

high nutritive value since fibre plays a significant role in voluntary intake and digestibility. The range of cellulose concentration shows that the fodders have the potentials to support intestinal movement, proper rumen function and promote dietary efficiency. Humphreys (1991) opined that the higher the hemicellulose fraction, the higher is the feed value.

Most of the foliages contained high Mg relative to requirements (Table 3). Therefore, deficiencies of these elements seem unlikely in ruminants maintained solely on these foliages. Ca concentration compares favourably with other Nigerian browse species (Yusuf *et al.*, 2013) and within the recommended range (McDowell, 1997) except for *D. oliveri* which was higher. Phosphorus in the plant foliages was comparable to values reported by Topps (1992) for several browse plants and was within the required range for ruminants (McDowell, 1997) except for *P. erinaceus*. The Ca:P ratio compared to those recommended for ruminants (McDowell, 1997, Ahn *et al.*, 1989), which may not create problem with vitamin D metabolism (ARC, 1984). Ca and P are very important for growing ruminants and too much P compared to Ca can lead to urinary calculi. The content of K was within the required range for ruminants (McDowell, 1997). All the foliages contained high Mg relative to requirements. It appears that the deficiencies of the studied macrominerals seem unlikely in ruminants maintained solely on these foliages. Most of the minerals except P are present in more than adequate levels when compared with NRC recommendation for ruminant animals (NRC, 1978).

The levels of CTs recorded in this study are much below the range of 60 to 100 g/kg DM, considered to depress feed intake and growth (Mbomi *et al.*, 2011). Therefore, the browse species contained CTs at levels beneficial to ruminants because CTs at low level produce mild or low protein binding effect (Olafadehan, 2013). Similarly, CT-containing forage minimizes methane emission by ruminants (methane mitigation), in addition to other benefits, when not included at a high proportion of the diet (Bodas *et al.*, 2012; Cieslak *et al.*, 2012). Saponin levels in all the samples were lower than the tolerable level of 15-20 g/kg DM reported for goats (Onwuka, 1983), which suggests the levels reported herein are not likely to affect nutritional potentials of the browses to ruminants. Feedstuffs containing saponin have been shown to act as defaunating agents (Teferedegne, 2000) and capable of reducing methane production. Both the phytate and oxalate concentrations are lower than the values reported by Fadiyimu *et al.* (2011). The low level of phytate in the forages indicates the potential of the browse fodders to make minerals available to the ruminants since phytates bind

minerals like Ca, Mg Fe and Zn, interfere with their metabolism and cause muscular weakness and paralysis. Oxalates have been implicated for decreased availability of Ca during digestion (Norton, 1994). However, the low content of oxalate in the experimental fodder may not interfere with Ca utilization.

The mean estimated DMD and DMI compared favourably with mean values of 65.07% and 3.47%, respectively, reported by Hanlin *et al.* (2011) for several tropical legumes in China. However, the overall RFV is lower than mean value (181.00), while the quality standard followed the same trend as reported by the same authors. All the selected six legume browses except *D. microcarpum* may be regarded as having high relative nutritive value for ruminants in Nigeria based on this ranking.

Although, gases produced during rumen fermentation process are waste products and of no nutritive value to the ruminant, gas production tests are used routinely in feed research because gas volumes are related to both the extent and rate of substrate degradation (Blummel *et al.*, 1997). The cumulative volume of the gas production by the browse fodders increased with increasing hour of the *in vitro* incubation (Fig. 1). The significant differences among the browse foliages for their *in vitro* gas production and fermentation characteristics are in agreement with previous studies on tropical browses in Kenya (Abdulrazak *et al.*, 2000; Osuga *et al.*, 2006) and Nigeria (Isah *et al.*, 2012). In the current study, all the browse foliages generally had moderate gas production potential. The *in vitro* gas production pattern of the forages shown in Fig. 1 indicates that more degradation of DM was still possible beyond 48 h. Many factors such as the nature and level of fibre, the presence of secondary metabolites and potency of the rumen liquor for incubation have been reported (Babayemi *et al.*, 2004) to determine the amount of gas to be produced during fermentation. In the current study, it appears the secondary metabolites more than fibre content influence *in vitro* gas production and hence degradability. Higher gas production and the extent of *in vitro* fermentation of *P. erinaceus* and *A. africana* suggests that these substrates are of higher nutritional value than the other browse species, in agreement with Isah *et al.* (2012). The low gas production of *E. africana* could be attributed to its high amount of saponin (Table 6). Saponin is known to deter the activities of bacteria in the rumen (Babayemi *et al.*, 2004). Although, high methane implies an energy loss to the animal, forage with a higher degradability will lead to more intensive fermentation in the rumen (Rinne *et al.*, 1997) and thereby increase in CH₄ production. This possibly explained why *P. erinaceus* and *A. africana* had the higher CH₄ production compared with other browse

fodders. However, when ranking plants according to their methanogenic property, the proportion of methane-to-total gas ratios is more relevant than absolute methane formation: a low value for this proportion indicates a low methanogenic potential of the digestible part of the feed, i.e. fewer methane production per unit net gas volume production (Moss *et al.*, 2000). In the light of this, *A. africana*, with the least (0.29 ml/200 mg DM) CH₄ production value (on the basis of methane-to-total gas volume ratio), was the most promising fodder regarding a low methanogenic potential, while *E. africana* with the highest CH₄ production on the basis of methane-to-total gas volume ratio may contribute most to the green house effect if fed solely to ruminant animals. A mutual relationship exists between total gas production and ME, OMD and SCFA. The estimation of the ME values is imperative for purposes of ration formulation and to set economic value of feeds for other purposes. The values of the ME agree with that of Isah *et al.* (2012), but higher than (3.28 - 3.83 MJ/kg) value recorded by Getachew *et al.* (2002). The highest ME of *A. africana* coupled with its highest CP suggests that such fodder may enhance microbial protein synthesis as it may promote better synchronization of fermentable energy and degradable N in the rumen (Olafadehan, 2014). The browse foliages generally had relatively high IVOMD, but comparable to the values reported for some tropical browse species (Anele *et al.*, 2008). This relatively high IVOMD is an indication of the high nutritive value of the browse foliages when used in ruminant feeding. Lower fibre fractions in *A. africana* relative to other browse fodders may have resulted in the higher values for IVOMD and SCFA (Van Soest, 1994). The IVDMD values obtained in the present study except for *E. africana* were found to be slightly higher than IVDMD values reported by Mokonnen *et al.* (2009) for multipurpose fodder tree and shrub species in central highlands of Ethiopia. Low level of tannins and moderate levels of NDF and ADF may be responsible for generally high IVDMD in fodders (Njidda, 2014) since, tannins in the NDF and ADF fractions are tightly bound to the cell wall and cell protein and seem to be involved in decreasing digestibility (Reed *et al.*, 1990). In reality, when IVDMD falls below 550 g/kg there is physical limitation on the rate of eating and the rate of digestion and passage through the gastrointestinal tract is restricted while live weight loss becomes inevitable (SCA, 1990). Based on this, the generally high IVDMD demonstrates the high nutritive potential of the browses when used in livestock feeding.

CONCLUSION

Results show that all the selected browses are rich in crude protein as well as macro minerals, have moderate fibre level and low concentrations of anti-nutritional factors. The generally high *in vitro* degradability and estimated dry matter digestibility suggest their nutritive potential as alternative low cost sources of good protein supplements to poor quality roughages for ruminant feeding especially during the dry season. The browse species are thus promising fodders that can be used for sustainable ruminant production in the tropics. Further research should, however, be conducted to establish their fodder value in *in vivo* trials.

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