Iranian Journal of Applied Animal Science

Potential Nutritive Value of Selected Leguminous Browse Forage Species from Nigeria Using *in vitro* Gas Production Technique

Research Article

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Received on: 31 Dec 2016
Revised on: 16 Mar 2017
Accepted on: 30 Apr 2017
Online Published on: Dec 2017

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ABSTRACT

The chemical composition and *in vitro* gas production of some leguminous browse species were evaluated. Crude protein (CP) content was highest (P<0.05) in *Pterocarpus erinaceus*. Neutral detergent fibre, acid detergent fibre and total condensed tannins (TCT) were highest (P<0.05) in *Erythrina senegalensis*. Acid detergent lignin was greatest in *Parkia biglobosa* and lowest in *Acacia seyal*. *In vitro* organic matter degradability (IVOMD) was lowest and highest in *Desmodium relatinum* (11.87%) and *Fadhebia albida* (74.29%), respectively. *Pterocarpus erinaceus* had the highest volume of gas production (GP; 29.33 mg/200 g DM) while *Parkia biglobosa* had the least GP (2.00 mL/200 mg DM) at 96 h. The GP from the immediately soluble fraction (*a*) and volume of gas produced (mL) at time *t* (*Y*) were highest in *Pterocarpus erinaceus* and *Erythrina senegalensis*. Gas production from the insoluble but degradable fraction (*b*) and potential GP (*a*+*b*) were greatest in *Dicrostachys cinerea*. Rate of GP (*c*) varied among the browses without a definite pattern. The CP of browses was positively significantly correlated with incubation period at all hours and fermentation characteristics (*a*, *c* and *Y*). Neutral detergent fibre (NDF) was positively correlated with incubation periods and *a*, *a* + *b* and *c*. Acid detergent fibre (ADF) was negatively correlated with incubation hours but was positively related to gas fermentation characteristics. Acid detergent lignin (ADL) and IVOMD were weakly correlated with incubation hours but had a strong relationships with some gas fermentation characteristics. Total condensed tannins (TCT) showed a positive correlation with incubation period at 6, 12, 24 and 96 h but their relationship with fermentation characteristics was positive and weak. Phenolic content was positive and strongly correlated with incubation period at 3, 6 12 and 24 h, *a*, *c* and *Y*. Based on their relatively high CP, moderate fibre levels and low condensed tannins contents, it can be concluded that the browse legume forages have nutritive potential as fodders for ruminants in tropical environment.

KEY WORDS browses, degradability, fodder, gas production, *in vitro*.

INTRODUCTION

Leguminous tree foliage is potential source of protein and minerals and could be employed as supplements to non-legumes to increase the level of production of livestock. The protein content in fodder legumes consist of both soluble and insoluble compounds and as such is used both as an important source of nitrogen for increased rumen microbial activity and by-pass protein for supplying amino acids to the lower gut of the host animal (Leng, 1997). In addition, fodder legumes are also important source of minerals but poor source of manganese, zinc and phosphorus. Supplementation of fodder legumes in the feed of ruminant animals up to about 35% does not seem to have any effect on the intake of fibrous feed materials. As such the intake of DM is often increased by the amount of green fodder given to the animal. However, the presence of tannins in both legumes and non-legumes limits utilization of both species as they can reduce the feed intake, nutrient digestibility and protein availability (Silanikove *et al*. 2001). Nevertheless, some tanniniferous feeds have beneficial effects in ruminant diets by improving nitrogen utilization efficiency and amino acid absorption. Condensed tannins also have biological effects on the control of gastro-intestinal parasites; possible direct effects could be mediated through CT-nematode interactions, which reduce nematode viability (Nguyen *et al*. 2005).

A management strategy to reduce negative effects of tannins in fodder trees could be to feed mixtures of low and high tannin content species, which could create positive effects on *in vitro* GP, rumen degradation and digestibility of diets (Castro-Gonzáles and Alayon-Gamboa, 2008). A better understanding of the effects of low and high tannin foliage mixtures on nutrient digestibility and methane mitigation properties would improve management of such resources (Naseri *et al*. 2017). This knowledge would be of considerable importance to Nigeria for the efficient utilization of tree forage, and research must be established to develop feeding strategies to overcome undesirable effects when using tanniniferous foliage. This study evaluated the nutritive value legume with low tannin on *in vitro* GP and fermentation characteristics.

MATERIALS AND METHODS

Experimental location and forage samples

All the forages were harvested from Gwoza Local Government Area, Borno State, Nigeria. The area is located at 11.05˚ North and 30.05˚ East and at an elevation of about 364 m above sea level in the north eastern part of Nigeria. The ambient temperature ranges between 30 ˚C and 42 ˚C being the hottest period (March to June) while it is cold between November and February with temperatures ranging from 19-25 ˚C (Ijere and Daura, 2000). Twelve indigenous browse plants (leaves) commonly consumed by ruminant animals were sampled and used in this study. The species were: *Acacia nilotica*, *Acacia senegalensis*, *Acacia seyal*, *Bauhenia nufescens*. *Daniellia oliveri*, *Desmodium relutinum*, *Dicrostachys cinerea*, *Erythrina senegalensis*, *Fadhebia albida*, *Parkia biglobosa*, *Pterocarpus erinaceus* and *Tamarindus indica*. The browses were harvested from at least 10 trees per species selected at random in four locations within the study area at the end of the rainy season. The harvested samples were pooled for each individual tree species and oven dried at 105 ˚C for 24 h to a constant weight and ground to pass through a 1.0 mm sieve. The dried samples were sub-sampled to obtain three samples for each tree species and analysed for their composition.

***In vitro* gas production study**

Rumen fluid was obtained from 3 West African dwarf female goats through suction tube before morning feed. The goats were fed with concentrate feed (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 and and 40% Guinea grass; *Panicum maximum*).

Incubation was as reported by some studies using 120 mL calibrated syringes in three batch incubation at 39 ˚C. Into 200 mg sample (n=12) in the syringe was introduced 30 mL inoculums containing cheese cloth strained rumen liquor and buffer ($NaHCO_3$+$3Na_2HPO_4$+KCl+NaCl+$MgSO_4.7H_2O$+$CaCl_2.2H_2$) (1:4, v/v) under continuous flushing with CO_2. The gas production was measured at 3, 6, 12, 24, 48, 72 and 96 h. The net gas volumes data was then fitted in the equation (Menke and Steingass, 1988):

$$Y= a + b(1-e^{-c\,t})$$

Where:

Y: volume of gas produced (mL) at time t.

a: gas production from the immediately soluble fraction (mL).

b: gas production from the insoluble but degradable fraction (mL).

a + *b*: potential gas production (mL).

c: constant of gas production (fraction/h).

t: gas production intervals i.e. 3, 6, 12, 24, 36, 48, 72, 84 and 96 hours.

Organic matter digestibility (OMD) was estimated as OMD= 14.88 + 0.889 GV + 0.45 CP + 0.651 XA (Menke and Steingass, 1988).

Chemical analysis

Browse species were analysed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ash according to AOAC (2005). Crude protein was calculated as N × 6.25. The leaves samples were analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and cellulose according to Van Soest *et al*. (1991). Total condensed tannins (CTs) analysis were according to Polshettiwar *et al*. (2007).

Statistical analysis

Data obtained were subjected to analysis of variance in a completely randomized design using SAS (1996). Where significant differences occurred, the means were separated using the Duncan multiple range test of the same statistical package.

RESULTS AND DISCUSSION

Chemical composition

The chemical composition of the browse forage leaves is presented in Table 1. The examined plant leaves had high CP values ranging from 111.60 in *Acacia senegalensis* to 172.4 g kg^{-1} DM in *Pterocarpus erinaceus*. The highest NDF content of 532.8 g kg^{-1} DM was recorded in *Erythrina senegalensis* while *Acacia nilotica* had the lowest value of 336.40 g kg^{-1} DM. The ADF level in the experimental leaves ranged from 231.4 g kg^{-1} DM in *Bauhenia nufescens* to 431.6 g kg^{-1} DM in *Erythrina senegalensis*. *Acacia seyal* had the least lignin content of 92.0 g kg^{-1} DM while *Parkia biglobosa* had the highest value of 131.60 g kg^{-1} DM. Total condensed tannins varied from 0.09 mg/g DM in *Acacia senegalensis* to 0.62 mg/g DM in *Erythrina senegalensis*. A range of 0.32 mg/g DM in *Fadhebia albida* to 0.46 mg/g in *Bauhenia nufescens* was obtained for phenolics. The *in vitro* organic matter degradability (IVOMD) was generally low, except for *Acacia seyal* (71.25%) and *Fadhebia albida* (74.29%) which had high values. The family and local names of the browse forage samples studied is presented in Table 2.

In vitro gas production

The *in vitro* cumulative GP of the browse fodders is presented in Table 2. The forages significantly ($P<0.05$) differed in the GP; *Pterocarpus erinaceus* had the highest GP (29.33 mL/200 mg DM) throughout the incubation periods from 3 to 96 h while *Parkia biglobosa* produced the least gas volume of 2.00 ml/200 mg DM at 48, 72 and 96 h of incubation.

Fermentation characteristics of semi-arid browse forages

The GP from the immediately soluble fraction (*a*) as shown in Table 3 is generally low for all the browse forages, with values ranging from 2.67 in *Acacia senegalensis* to 6.00 mg/200 g DM in *Erythrina senegalensis* and *Pterocarpus erinaceus*. The value for GP for insoluble but degradable fraction (*b*) was highest in *Dicrostachys cinerea* (17.00 mL) and least in *Acacia seyal* and *Fadhebia albida* (7.00 mL). The potential gas production (*a*+*b*) was generally low for all the browse forages with the highest value (21.00 mL) in *Dicrostachys cinerea* and the least value (10.00 mL) in *Fadhebia albida*.

The rate of GP (*c*) ranged from 0.97 in *Acacia senegalensis* to 0.46 in *Desmodium relutinum*. The GP production (*Y*) at time‘t’ ranged between 6.00 in *Fadhebia albida* and 13.67 mL/200 mg DM in *Erythrina senegalensis* and *Pterocarpus erinaceus.*

Correlation coefficient

Correlation coefficient (r) between chemical composition and *in vitro* GP and fermentation characteristics is presented in Table 4. The CP content of the browse forages showed positive correlations with incubation period at all hr, and with *a*, *c* and *Y* while it was not correlated with other gas production kinetics. ADF is negatively correlated at all incubation periods and positively correlated with fermentation characteristics. ADL and IVOMD are weakly correlated with incubation period and positively correlated with fermentation characteristics. NDF was negatively significantly correlated with all the incubation periods except at 3 and 96 h. Whereas NDF was positively significantly correlated with *b*, *t* and Y, a weak but positive relationship existed between these parameters and NDF. ADL was negatively significantly correlated with incubation period at 3 and 6 h but the relationship between it and the rest of the incubation periods was weak and negative. Except for *a* + *b* and *t* which showed a weak positive relationship with ADF, ADF was positively significantly correlated with *a*, *b*, *c* and Y. ADL was weakly positively related to all incubation periods and Y, but it was significantly positively correlated with fermentation characteristics. There was a positive significant relationship between IVOMD and incubation period at 6 h, *a*, *c* and Y but its relationship with other parameters were positive and weak. Total condensed tannins showed a positive significant correlation with incubation period at 6, 12, 24 and 96 h. while its relationship with incubation period at 3, 48 and 72 h and all fermentation characteristics was positive but non-significant. Phenolic content was positively and significantly correlated with incubation period at 3, 6, 12, and 24 h, *a*, *c* and Y while its relationship with rest of the parameters was positive and non-significant.

Leguminous forages have been used as feed for livestock in many regions of the world, mainly because of their high protein contents throughout the year (Debela *et al.* 2011). In this study, the crude protein (CP) content of the browse forages compares favourably with values reported by Kumara Mahipala *et al.* (2009) who studied the nutritive value of browse in natural population. The high CP content of browse species is well documented and is one of the main distinctive characteristic of browse compared to most grasses.

Generally, the CP content in the browse forages was observed to be above the minimum level required (7%) for microbial activities in the rumen (Norton, 1998). The species in the leguminosae family have a higher protein content compared to other species, although species in the Capparidaceae family have on average 25% more protein than legumes (Le Houerou, 1980).

Table 1 Chemical composition of browse species

Browse forages	Chemical composition						
	CP	NDF	ADF	ADL	TCT	PHE	IVOMD
Acacia nilotica	112.00^{d}	336.40^{i}	237.00^{g}	112.6^{c}	0.12^{f}	0.33	32.71^{g}
Acacia senegalensis	111.60^{d}	493.22^{c}	321.44^{c}	93.2^{g}	0.09^{g}	0.35	38.14^{e}
Acacia seyal	112.60^{d}	482.40^{d}	396.10^{b}	92.0^{h}	0.11^{f}	0.32	71.25^{b}
Bauhenia nufescens	114.90^{d}	493.10^{c}	231.40^{g}	93.7^{g}	0.45^{b}	0.46	32.31^{g}
Daniellia oliveri	132.10^{b}	442.20^{e}	341.60^{c}	112.8^{c}	0.34^{c}	0.38	41.76^{d}
Desmodium relutinum	112.30^{d}	521.60^{b}	412.00^{a}	92.3^{d}	0.23^{e}	0.41	11.87^{i}
Dicrostachys cinerea	114.60^{d}	482.60^{d}	385.40^{b}	112.0^{c}	0.33^{c}	0.39	35.79^{f}
Erythrina senegalensis	121.30^{c}	532.80^{a}	431.60^{a}	94.3^{f}	0.62^{a}	0.37	35.80^{f}
Fadhebia albida	121.40^{c}	387.10^{h}	256.40^{f}	96.3^{e}	0.29^{d}	0.32	74.29^{a}
Parkia biglobosa	108.30^{d}	396.30^{g}	332.40^{c}	131.6^{a}	0.14^{f}	0.43	17.96^{h}
Pterocarpus erinaceus	172.40^{a}	482.10^{d}	234.80^{g}	129.9^{b}	0.43^{b}	0.33	53.27^{c}
Tamaridus indica	132.00^{b}	421.10^{f}	318.40^{c}	97.0^{d}	0.33^{c}	0.42	39.13^{e}
SEM	2.23	1.06	2.24	0.67	0.05	0.19	0.76

CP: crude protein (g kg^{-1} DM); NDF: neutral detergent fibre (g kg^{-1} DM); ADF: acid detergent fibre (g kg^{-1} DM); ADL: acid detergent lignin (g kg^{-1} DM); TCT: total condensed tannin (mg/g DM); PHE: phenolics (mg/g DM) and IVOMD: *in vitro* organic matter degradability (%).
DM: dry matter.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 2 *In vitro* gas production of selected semi-arid browses (mL/200 mg DM)

Browse forages	Incubation period (h)						
	3	6	12	24	48	72	96
Acacia nilotica	0.33	1.00^{bc}	2.00^{de}	3.00^{h}	4.21^{f}	6.57^{d}	8.72^{ef}
Acacia senegalensis	0.33	0.66^{d}	1.37^{def}	2.66^{i}	3.33^{g}	4.66^{def}	5.66^{i}
Acacia seyal	0.26	3.00^{b}	4.00^{c}	5.67^{e}	8.00^{d}	9.21^{c}	10.33^{e}
Bauhenia nufescens	1.00	1.33^{bc}	2.66^{d}	4.33^{f}	5.00^{e}	5.00^{de}	5.00^{i}
Daniellia oliveri	0.33	1.33^{bc}	2.67^{d}	3.67^{g}	4.67^{f}	6.76^{d}	8.27^{g}
Desmodium relutinum	0.33	2.33^{b}	6.00^{b}	11.00^{b}	13.33^{b}	15.33^{b}	17.63^{b}
Dicrostachys cinerea	0.33	0.67^{d}	1.33^{def}	3.33^{g}	4.00^{f}	6.13^{d}	7.66^{gh}
Erythrina senegalensis	0.33	0.67^{d}	1.33^{def}	3.00^{h}	4.00^{f}	5.33^{de}	6.33^{ghi}
Fadhebia albida	0.66	2.33^{b}	4.00^{c}	6.67^{d}	8.33^{d}	10.66^{c}	12.66^{d}
Parkia biglobosa	0.11	0.33^{d}	1.67^{def}	2.00^{i}	2.00^{h}	2.00^{g}	2.00^{j}
Pterocarpus erinaceus	3.33	5.00^{a}	9.00^{a}	17.00^{a}	25.66^{a}	29.33^{a}	29.33^{a}
Tamaridus indica	2.00	3.66^{b}	5.66^{b}	7.66^{c}	11.33^{c}	14.00^{b}	14.00^{c}
SEM	0.87	0.96	0.78	0.20	1.20	1.31	1.27

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Le Houerou (1980) also noted that all browse species are able at all their phenological stages to meet the energy requirements of livestock at maintenance level and often well above, and thus West African browses are considered to be excellent fodder, with very few exceptions. The NDF, ADF and ADL contents were similar to the values reported by Njidda *et al*. (2011).

The higher values might be attributed to oven-drying process which the browse forages were subjected to. This finding is similar to the report of Parissi *et al*. (2005) who reported that the NDF and ADL contents of browse species increase as a result of oven drying and increased formation of insoluble condensed tannin-protein polymers. Heat treatment has also been found to cause polymerization of sugar residues with amino acids resulting in a 'Maillard' complex with physical and chemical properties similar to lignin (i.e., artifact lignin) (Van Soest, 1994).

The chemical composition and digestibility of forages are influenced by plant species, plant morphological fractions, environmental factors and stage of maturity (Papachristou and Papanaastasis, 1994).

The decrease in IVOMD of these browse samples may also be attributed to oven-drying through solubility of protein-tannin complexes with the negative effect of depressing forage digestibility (Buritt *et al*. 1988; Parssi *et al*. 2005). Generally, the browse species were high in CP, NDF, ADF and ADL contents while they were low in TCT, PHE and IVOMD. Njidda (2011) in a study of 37 browse plant species in the semi-arid area of northern Nigeria found that leguminous browse species typically contained high CP, NDF, ADF and ADL contents. Utilization of CP in leguminous forages may be negatively affected by the contents of CTs, alkaloids and saponins (Kumar and D'Mello, 1995).

Table 3 *In vitro* fermentation characteristics of some leguminous browse forages

Browse forages	*a*	*b*	a+*b*	*c*	*t*	*Y*
Acacia nilotica	5.00^{b}	10.00^{e}	15.00^{d}	0.073^{ab}	16.00^{a}	11.67^{b}
Acacia senegalensis	2.67^{e}	8.00^{g}	10.67^{i}	0.097^{a}	10.00^{c}	7.00^{bc}
Acacia seyal	4.00^{bc}	7.00^{h}	11.00^{g}	0.048^{abcd}	12.00^{b}	7.00^{dcf}
Bauhinia nufescens	3.67^{d}	13.00^{c}	16.67^{c}	0.063^{abc}	6.00^{f}	7.67^{de}
Daniellia oliveri	3.00^{de}	11.67^{d}	14.67^{e}	0.068^{abc}	7.00^{e}	7.33^{de}
Desmodium relutinum	3.67^{d}	13.00^{c}	16.67^{c}	0.046^{abcd}	9.00^{d}	8.00^{cd}
Dicrostachys cinerea	4.00^{bc}	17.00^{a}	21.00^{a}	0.054^{abcd}	6.00^{b}	8.67^{cd}
Erythrina senegalensis	6.00^{a}	14.00^{b}	20.00^{b}	0.088^{a}	9.00^{d}	13.67^{a}
Fadhebia albida	3.00^{de}	7.00^{h}	10.00^{h}	0.048^{abcd}	12.00^{b}	6.00^{defg}
Parkia biglobosa	4.00^{bc}	11.67^{d}	15.67^{d}	0.063^{abc}	10.00^{c}	9.00^{c}
Pterocarpus erinaceus	6.00^{a}	14.00^{b}	20.00^{b}	0.088^{a}	9.00^{d}	13.67^{a}
Tamarindus indica	4.67^{b}	9.00^{f}	13.67^{f}	0.073^{ab}	10.00^{c}	9.00^{bc}
SEM	0.98	0.57	0.02	0.009	0.03	1.21

a: gas production from the immediately soluble fraction (mL); *b*: gas production from the insoluble but degradable fraction (mL); *a* + *b*: potential gas production (mL); *c*: constant of gas production (fraction/h) and *t*: gas production intervals.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Correlation coefficient (r) between chemical composition and *in vitro* gas production and *in vitro* fermentation characteristics

Incubation period (h)	CP	NDF	ADF	ADL	IVOMD	TCT	PHE
3	0.897^{***}	-0.054	-0.493^{*}	-0.307	0.307	0.226	0.833^{***}
6	0.802^{***}	-0.066^{*}	-0.258^{*}	-0.411	0.052^{*}	0.678^{**}	0.833^{***}
12	0.749^{***}	-0.113^{*}	-0.244	-0.139	0.139	0.665^{**}	0.626^{**}
24	0.773^{***}	-0.225^{*}	-0.218	-0.170	0.170	0.503^{*}	0.543^{*}
48	0.831^{***}	-0.193^{*}	-0.251	-0.223	0.223	0.481	0.447
72	0.844^{***}	-0.153^{*}	-0.251	-0.223	0.223	0.491	0.354
96	0.808^{***}	-0.137	-0.223	-0.189	0.189	0.503^{*}	0.412
***In vitro* FCs**^{2}							
a	0.864^{***}	0.789^{***}	0.999^{***}	0.318^{*}	0.867^{***}	0.095	0.693^{**}
b	0.348	0.228	0.517^{*}	0.224^{*}	0.082	0.059	0.171
a + *b*	0.385	0.877^{***}	0.041	0.182^{*}	0.136	0.027	0.312
c	0.566^{*}	0.601^{**}	0.547^{*}	0.589^{*}	0.725^{***}	0.455	0.683^{**}
t	0.060	0.256	0.445	0.466^{*}	0.409	0.064	0.036
y	0.985^{***}	0.001	0.883^{***}	0.172	0.545^{*}	0.105	0.659^{**}

CP: crude protein (g kg^{-1} DM); NDF: neutral detergent fibre (g kg^{-1} DM); ADF: acid detergent fibre (g kg^{-1} DM); ADL: acid detergent lignin (g kg^{-1} DM); IVOMD: *in vitro* organic matter degradability (%); TCT: total condensed tannin (mg/g DM) and PHE: phenolics (mg/g DM).
a: gas production from the immediately soluble fraction (mL); *b*: gas production from the insoluble but degradable fraction (mL); *a* + *b*: potential gas production (mL); *c*: constant of gas production (fraction/h) and *t*: gas production intervals.
DM: dry matter.
*** (P<0.001); ** (P<0.01) and * (P<0.05).

Contents of alkaloids and saponins were not determined in this study but the concentrations of CTs in all the browse species were low implying that the browse species may reduce ruminal microbial degradation of the CP and increase the supply of by-pass proteins.

Gas production

High CP and relatively high non-structural carbohydrate content of the forages (though not determine in this study) may have resulted in substrate yielding more microbial biomass production and polysaccharides storage in the cell and hence causing less gas production (Osuga *et al.* 2006).

The low GP of the studied forages could be due to amount of lignin, extent of lignification and other anti-nutritive substances and their related biological activities. It may as well be due to low organic matter (OM) degradability and hence availability.

Cell wall contents ADF were negatively correlated with gas production at all incubation times and estimated parameters. This may tend to reduce the microbial growth and enzyme activity (McSweeny *et al*. 2001) or intestinal bacterial activity (Salem *et al*. 2004). Getachew *et al*. (2000) and Salem *et al.* (2007) reported a decrease in rate and extent of GP of some shrubs due to their high contents of lignin and tannins through increasing the adverse environmental conditions as incubation time progressed. McAllister *et al.* (1994) also observe that higher NDF and lignifications and / or higher ADF/NDF proportion and free-CT contents can reduce attachment of ruminal microbes to feed particles, as well as inhibit microbial growth and enzyme activity (McSweeny *et al.* 2001) or intestinal bacterial activity (Salem *et al.* 2004) by free-condensed tannins and hence lead to lower gas production. Since GP on incubation of feeds in buffered rumen fluid is associated with feed fermentation, and carbohydrate fractions, the low GP of the browse forages seems to suggest low feeding value of these feeds. On incubation of feedstuff with buffered rumen fluid *in vitro*, the carbohydrates are fermented to short chain fatty acids (SCFA), gases, mainly CO_2 and CH_4, and microbial cells. Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate (Wolin, 1960; Steingass and Menke, 1986; Njidda, 2010) and substantial changes in carbohydrate fractions were reflected by total gas produced (Deaville and Givens, 2001). Gas production from protein fermentation is relatively small as compared to carbohydrate fermentation while contribution of fat to gas production is negligible (Wolin, 1960). However, some other prospective and novel plant genera with desirable agronomic and nutritive profiles, such as *Acacia*, (Dynes and Schlink, 2002), had potent inhibitory effects on gas production and volatile fatty acids (VFA). Other researchers have reported similar findings with plants that are known to contain plant secondary compound (PSC) that can affect rumen microbes when examined *in vitro* (Soliva *et al*. 2008; Tefera *et al*. 2008). While legumes are reported to contain tannins that can reduce fermentation parameters (Carulla *et al*. 2005; Tefera *et al*. 2008), for others, such as the genus *Leptadenia*, the effect may be related to different classes of bioactive PSC (Ghisalberti, 1994). The lower volume of gas recorded may also attributed to the presence of high concentrations of CP that results in more Mailard polymerization, since Maillard products do not degrade rapidly, gas production would be depressed. Intense heating during the process of oven-drying of leguminous plants may reduce their feed value (Merkel *et al*. 2000).

Differences in feed degradability are largely attributed to phenolic compounds and tannins as well as fibre type and proportion in forages. All the *in vitro* fermentation characteristic parameters showed significant differences among browse forages. The extent of GP (a+b) was higher for *Dicrostachys cinerea* than the other browse forages species.

Khazaal *et al*. (1995) indicated that the intake of a feed is mostly explained by the rate of gas production (c) which affects the rate of passage of the feed through the rumen, whereas the potential gas production (a+b) is associated with the degradability of the feed. Thus, the values of the studied fermentation characteristic parameters suggest that nutrient availability for rumen microbes in animals grazing such vegetative specie will be affected since higher values of such parameters (c and a+b of feed) indicate a better nutrient availability for rumen microorganism. This could be possible due to the high level of NDF and lignin in the browse which may hinder rumen microbe from degrading the feed material. Also the higher fibre content may affect the feed intake. These factors might have contributed to the lower values observed for the fermentation characteristics of the browse forages. The gas production (a) from quickly soluble fraction is in agreement with those reported by Kamalak *et al.* (2005) whereas gas production (b) from slowly fermentable fraction and potential gas production (a+b), and gas production rate (c) was lower than those reported that by Filya *et al.* (2002) and Kamalak *et al.* (2005). This might be due to differences in rumen fluid content and chemical composition of the browse forage used.

Significant positive correlation between gas production (post 3 h), and total phenolics, tannins and fermentation characteristics (a, b, a+b, c, t and Y) respectively could be explained by relatively less adverse effect of total phenolics and tannins on digestibility. 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. The relatively lower rate and extent of GP from browse forages leaves could also be attributed to compositional differences of the browse forages, especially CP, fibre nature and concentration of polyphenolics and may be other anti-nutritional components (Salem *et al*. 2007).

Chemical composition and *in vitro* fermentation and digestibility are largely affected by plant species, plant morphological fraction, environmental factors, and stage of maturity. These factors influence the amount of substrate OM that is fermented and the short chain fatty acids (SCFAs) produced upon fermentation. This is because gas production results from fermentation of the feed OM and CO_2 produced from the buffering of the SCFAs by the bicarbonate buffer.

Correlation between chemical constituents and gas production at 96 hrs of the browse forages shows that there were both positive and negative relationships between the volume of gas produced and their chemical constituents. This is consistent with the reports of Getachew *et al*. (2003) and Arigbede *et al.* (2006). This could be as a result of the feed constituents, such as NDF and ADF, which contribute more gas if they are degradable as shown by their positive effect on gas production. The positive correlation between CP and gas production of the browse forage leaves is consistent with the reports.

The high CP content may partly be the reason why degraded material was not associated with gas production, as protein is not extensively fermented and ammonia produced from its fermentation reduces estimated gas volumes produced. The positive relationship (0.749 to 0.897) indicates that the CP content of the browse forages had a contributory effect on the gas production. This may be due to the significantly higher CP content of the browse forage. In agreement with the negative correlation recorded between NDF and *in vitro* gas production of the browse forages (Arigbede *et al*. 2006; Cerillo and Juarez, 2004; Getachew *et al*. 2004) all reported negative relationship between NDF and gas production in various tropical tree species. The extent of the negative effect of the NDF on gas production was higher for *Pterocarpus erinceus* than the other browse forages. This indicates that the effect of NDF on gas production becomes more important if the level of NDF is high. The negative correlation between the ADF of the browse is similar to the report of Cerillo and Juarez, (2004) which recorded a negative highly significant correlation between ADF and *in vitro* gas production. Correlations between IVOMD and gas production and kinetics parameters were less significant in the legume forage studied except for soluble fraction *a* and rate constant of gas production *c* which were strongly and positively correlated. Njidda, (2011) report a strong and positive correlation (*r*=0.992); (*n*=37) between gas production and IVOMD. The low correlation observed in this study is an indication of the strong influence OMD has on gas production and this attest for the low gas produce from the browse forages. The significant positive correlation between TCT and gas production and fermentation parameters indicates that the effect of CT is more strongly reflected in the reduction of gas production. The relationship between phenolics and gas production and fermentation parameters was positive and tends to be strong at 3 h, 6 h and 12 h incubation periods and with a, c and y. Njidda (2011) reported that tropical browses with less than approximately 45 and g kg of total phenol and tannin respectively are not likely to produce significant adverse effects on ruminant livestock.

CONCLUSION

Though the gas production and fermentation characteristics were generally low for all the browse forages, their high CP, moderate fibre levels, low condensed tannins and all year round availability underscore their nutritive potential as fodders for ruminants. They may, therefore, be used either as a sole fodder or supplementary fodder to low nutritive roughages, particularly grasses that are unavailable during the critical the dry season.

ACKNOWLEDGEMENT

The authors would like to thank Professor O.J. Babayemi for assisting us with his laboratory.

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