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RESEARCH ARTICLE

In Situ Crude Protein Degradation and Mineral Composition of Browse Forages of Semi Arid Nigeria

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ABSTRACT

An experiment was conducted to determine the crude protein degradation kinetics of browse forages of semi arid of Nigeria. Crude protein (CP) contents were higher (P<0.05) in all the browse forages. Higher numerical values of neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin and cellulose were recorded. The result showed significant differences (P<0.05) for all the ant-nutritive factors and no significant difference (P>0.05) among the browse forages. Crude protein (CP) degradability after 24, 48, 72 and 96 h of ruminal incubation were higher (P<0.05) in all the browses. Higher values (P<0.05) in CP bag losses at zero time ('a' fraction) were high for the browses. The insoluble but fermentable CP ('b' fractions) were low (P<0.05) among browse forages. Numerically lower values of CP 'c' fraction were found in browses whereas CP potential degradability were higher (P<0.05) in all the experimental leaves. High (P<0.05) contents of CP in the browse forages, the potential degradability was high in all the browse forages. Thus, these results may be related to both the better feeding value of forage consumed by the animals and better performance of livestock in these areas. The soluble fraction 'a', rate of degradation 'c' and effective degradability 'ED' were generally low for all the browse forages while the insoluble but degradable fraction 'b' and potential degradability a+b were high for all the browse forages. Base on these findings, it can be concluded that the browse forages are of good nutritive value and can be use as supplement.

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INTRODUCTION

Grazing ruminants are exposed to quantitative and qualitative changes in the nutritive value of forages during different periods (Buxton and Fales, 1994). Forage composition and ruminal DM and CP degradation are affected by forage species and maturity (Balde *et al.* 1993; Coblentz *et al.* 1998). The effects of forage species and maturity on digestion and animal performance have been well characterized in processed forages (Nelson and Satter, 1990).

Most laboratory techniques used in food evaluation are still judged according to their ability to predict the nutritive value of foodstuffs. The *in situ* dry matter (DM) degradability of forage consumed by livestock has been used in this way to determine whether degradation characteristics of individual vegetative species could be used to predict its nutritive value (Shem *et al*., 1995).

Knowledge on mineral composition of browse forages would form base-line data on mineral status of available feed resources for enhanced nutrition of grazing ruminants in semi arid areas of north eastern Nigeria. Content of minerals of indigenous browse fodder species such as *Acacia, Ficus* and *ziziphus* sp. that grow naturally in the semi arid areas has been established (Njidda, 2011). A study was therefore conducted to assess the *in situ* protein degradation and mineral nutritive potential of selected ficus species available for ruminants feeding in Gwoza local Government area of Borno state, north eastern Nigeria.

MATERIALS AND METHODS

Description of site and samples

All forages were harvested from Gwoza local government area (11.05^0 N, 30.05^0 E, 364 m above sea level) of Borno State, North Eastern part of Nigeria. The ambient temperature ranges between 30 and 42 ^{0}C during the hottest period (March to June) and decreases to 19-25^{0}C between November and February (Alaku and

Moruppa, 1988). Ten browse forage species commonly found in the semi-arid and derived savannah zones were used in this experiment; the species were *Khaya senegalensis, Kigalia africana, Leptadenia lancifolia, Maerua angolensis, Olea hochstteteri, Poupartia sirrea, Prosopis africana, Pterocarpus earinceus, Sterculia setigera,* and *Tamarindus indica,*. The browse forages were harvested from at least 10 trees per species selected at random in four locations within the study area at the end of rainy season. The samples were sun-dried, milled and sub- sampled for analysis.

Sample preparation

About 500 g of the harvested and pooled samples from each plant were oven dried at 105^0C for 24 h, cooled and weighed. The weight difference between the initial weights and dried weights was taken as the moisture content of the leaves and then converted to percentage. Percent dry matter content was then obtained as the difference between 100 and percent moisture content (AOAC, 2002). The dried weekly samples were then bulked according to plant species and each shared into two portions. One portion was sun dried and milled to pass through 2 mm sieve, labelled and stored in sealed polythene bags for degradability and *in vitro* studies. The other portion (also milled to pass through 1 mm sieve) was labelled and as well stored for proximate analysis.

Chemical analysis

The samples were analyzed in triplicate for dry matter (DM) and crude protein (CP), according to AOAC (2002) procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were determined as described in Van Soest *et al*. (1991). Hemicellulose was estimated as NDF-ADF and cellulose as ADF-lignin. anti-nutritional constituents that were determined in the browses include Phytate estimated as phytic acid using the method prescribed by Maga (1982), while saponins and total condensed tannin were determined as reported by (Babayemi *et al*., 2004) and (Polshettiwar *et al*., 2007). Finally, phenolics were determined using Folin Ciocalteu metho as described by Makkar (2000).

Management and feeding of animals

Three ruminally cannulated bulls were used for this experiment. They were housed in individual pens with concrete floors bedded with wood shavings. The beddings were changed weekly. In these pens, they were offered corn bran, cowpea husk and salt lick as supplements daily. The animals also had free access to fresh clean water daily. The diet given to the animals were to allow the rumen microbial population meet their requirement for essential nutrients as well as provide optimum rumen environment for degradability. The area around the opening of the cannulae was cleaned regularly with warm water and detergent to prevent infection by pathogens.

Incubation of samples

The effects of ten browse species on the rate of nutrient disappearance were determined by the use of nylon bag technique. The browse plants were grounded to pass through 1.0 mm screen sieve and the bags measure 140 mm x 20 mm when laid flat. They were numbered for easy identification. The feed samples were oven-dried and grounded using a laboratory grinder for dry feeds and then kept in glass cylinders. The samples were then put in the oven overnight (24 h) at 70^oC prior to weighing into the bags. A piece of marble was included in each bag containing 5g of feed sample to prevent the bag from floating in the rumen. The weight of each bag and its content was then recorded. Ten bags containing the sample were incubated at the same time in each animal. A bag was removed from each of the three animals at 3, 6, 12, 24, 48, 72 and 96 h for observation on nutrient disappearance. The experiment was carried out in two periods so that each of the fistulated bulls will have 10 bags/sample. The bags were tied using a nylon twine and carefully inserted into the rumen. After each incubation period, the bags were carefully removed and rinsed with tap water until the water was clean and clear. The washing procedure took 30 min and then oven-dried. The bags were allowed to air-calibrate to room temperature for about three hours in a desiccator before weighing to determine bag plus marble plus feed sample residue weight for dry matter determination. The difference between the initial and final weights of each sample was regarded as degraded material and thereafter expressed as a percentage of the initial weight.

Washing and Drying of withdrawn sample bags

After incubation, all the bags were withdrawn from the rumen at the same time and immediately placed under running cold tap water until the rinse water became clear. This was done to wash off ingested feed particles adhering to the bags as well as stop further fermentative processes. The bags with the sample residues were then oven dried at 65^0C for 48 h and the weight of the bags plus residues measured and recorded. The zero-hour washing losses that is, losses due to non-incubation, were determined by soaking 5 g of each of the samples in triplicates in warm water (37^0C) for 1 h which was followed by washing and drying of the bags as done with the incubated sample residues.

Chemical analysis of residues from incubated samples

Dry matter losses was computed as the difference between the determined dry matter content of the pre-incubated samples and the determined dry matter content of the incubated residues. To determine the organic matter content of the residues, sub-samples (500 mg) were placed in crucibles and burnt for 2 h at 500°C. The ash was weighed and the value was subtracted from the values for dry matter. The balance sample residues were then re-milled to pass through a 1.00 mm screen sieve for other chemical analyses. Nitrogen was analyzed according to standard AOAC (2002) procedure. Crude protein was calculated by multiplying the percent nitrogen content by the factor 6.25.

$$\text{CP disappearance (\%)} = \frac{\text{Initial CP - final CP}}{\text{Initial CP}} \times 100$$

Digestion characteristic of CP was obtained by fitting data to the equation according to Ørskov and McDonal (1979) $P=a + b (1-e^{-ct})$, Where:

P = Potential degradability after time 't'

a = Water Soluble Fraction (zero hour)

b = Insoluble but degradable fraction after time 't'

c = Rate of degradation of slowly degradable fraction b
t = Incubation length i.e. 3, 6, 12, 24, 36, 48, 72, 84 and 96 h
e = exponential

Statistical Analysis

Data obtained from the computer analysis for degradation characteristic for the different incubated plant species at the different hours were subjected to analysis of variance (Gomez and Gomez, 1984) using the completely randomized design. Significant means were separated by Duncan multiple range test of SAS (1988).

RESULTS

Chemical Composition of the Browse Forages of Semi-arid climatic zone

The chemical composition of the browse forage leaves determined in this study is presented in Table 1. Dry matter content ranged from 838.30 g kg^{-1} DM in *Poupartia sirrea* to 976.30 g kg^{-1} in *Khaya senegalensis* on DM basis. Generally, the examined plant leaves had high crude protein values, ranging from 132.20 g kg^{-1} DM in *Poupartia sirrea* to 174.30 g kg^{-1} DM in *Maerua angolensis.* Ash content of the browse forages range from 107.60 g kg^{-1} DM in *Khaya senegalensis* to 174.60 g kg^{-1} DM in *Kigalia africana*. Values obtained for organic matter content of the browse forages ranged from 801.30 g kg^{-1} DM in *Olea hochstteteri* to 868.70 g kg^{-1} DM in *Khaya senegalensis*. The highest neutral detergent fibre content of 688.10 g kg^{-1} DM was recorded in *Kigalia Africana,* while *leptadenia lancifolia* had the lowest value of 433.10 g kg^{-1} DM. The acid detergent fibre levels in the experimental leaves ranged from 206.80 g kg^{-1} DM in *Olea hochstteteri* to 255.20 g kg^{-1} DM in *Kigalia aficana*. The least lignin content of 86.40 g kg^{-1} DM in the browse forages was recorded in *Prosopis africana* while *Maerua angolensis* had the highest value of 144.70 g kg^{-1} DM. Acid detergent insoluble ash content in the experimental leaves ranged from 412.30 g kg^{-1} DM in *Khaya senegalensis* to 521.90 g kg^{-1} DM in *Pterocarpus erinceus*. Cellulose levels in the browse forages were within the range of 131.20 g kg^{-1} DM in *Leptadenia lancifolia* to 182.50 g kg^{-1} DM in *Khaya senegalensis* while hemicellulose content of the browse leaves ranged from 189.20 g kg^{-1} DM in *Leptadenia lancifolia* to 432.90 g kg^{-1} DM in *Kigalia africana.*

Anti-nutritional factor levels of semi-arid browse forages

The result of the anti-nutritional factors in the browse forage leaves is shown in Table 2. Total condensed tannin varied from 0.08 mg/g DM in *Kigalia africana* to 0.41 mg/g DM in *Maerua angolensis*. A range of 0.31 mg/g DM in *Poupartia sirrea* to 0.61 mg/g in *Ptericarpus erinceus* was obtained for phenolic. Saponin content of the experimental leaves range from 1.08 mg/ g DM in *Poupartia sirrea* to 2.89 mg/g DM in *Sterculia setigera.* Oxalate in the browses used ranged from 4.59 mg/g DM in *Maerua angolensis* to 8.14 mg/g DM in *Olea hochstteteri*. The highest value of 6.08 mg/g DM was obtained in *Sterculia setigera* while *Olea hochstteteri* had the lowest value of 2.02 mg/g DM for Phytic acid in the browses studied.

Macro mineral concentration of semi-arid browse forages

The result of the macro mineral concentration is shown in Table 3. Leaves from *Olea hochstteteri* had the highest calcium amongst the browses with 12.50 g kg^{-1} DM which dropped to 7.80 g kg^{-1} DM in *Khaya senegalensis* and *Sterculia setigera.* Phosphorus had the highest recorded level of macro mineral (445.50 g kg^{-1} DM) in *Sterculia setigera* while *Kigalia africana* with 102.50 g kg^{-1} DM had the lowest level. The magnesium level was highest with a value of 7.20 g kg^{-1} DM in *Maerua angolensis* and lowest with a value of 1.70 g kg^{-1} DM *Kigalia africana.* The sodium concentrations in the browse forages were generally low. *Poupartia sirrea* had the highest value 1.20 g kg^{-1} DM while *Olea hochstteteri* had the lowest 0.40 g kg^{-1} DM. Potassium concentration in *Poupartia sirrea* was significantly higher than all the browses studied while *Khaya senegalensis* had the lowest value amongst the browse forages.

Trace mineral concentration of semi-arid browse forages

Table 4 presented the composition of micro minerals estimated in the browse forages used in this experiment. The iron content of the browse forages ranged between 1.618 mg/g DM in *Poupartia sirrea* to 16.24 mg/g DM in *Kigalia africana*. Significant difference were observed among browse forages for zinc with *Pterocarpus erinceus* having the highest while *Poupartia sirrea* having the lowest value of 1.064 mg/g DM. Among the browse forages, manganese showed significant difference ($P<0.05$) with *Pterocarpus erinceus* having the highest

Table 1: Chemical Composition of the Browse Forages of Semi-arid region of Nigeria (g kg^{-1} DM)

Browse Forages	DM	CP	Ash	OM	NDF	ADF	ADL	ADIash	Cellu.	Hemi Cell
Khaya senegalensis	976.30^{a}	139.60^{f}	107.60^{i}	868.70^{a}	486.20^{f}	211.60^{f}	121.00^{e}	412.30^{e}	182.50^{b}	274.60^{f}
Kigalia Africana	946.30^{c}	134.02^{g}	179.60^{a}	766.70^{g}	688.10^{a}	255.20^{a}	97.00^{f}	501.50^{d}	187.20^{a}	432.90^{a}
Leptadenia lancifolia	958.30^{b}	163.30^{c}	176.00^{b}	782.30^{ef}	433.10^{g}	243.90^{b}	152.80^{a}	498.90^{ef}	131.20^{h}	189.20^{c}
Maerua angolensis	922.60^{d}	174.30^{a}	154.30^{c}	767.60^{g}	586.70^{c}	228.90^{e}	144.70^{b}	513.30^{c}	164.00^{d}	357.80^{c}
Olea hochstteteri	941.30^{c}	138.70^{e}	142.00^{e}	801.30^{e}	438.40^{g}	206.80^{g}	96.70^{f}	526.30^{a}	171.30^{c}	231.60^{h}
Poupartia sirrea	838.30^{e}	132.20^{f}	109.00^{i}	742.60^{h}	591.20^{b}	230.30^{e}	140.30^{c}	482.30^{f}	143.00^{f}	360.90^{b}
Prosopis Africana	934.00^{c}	150.20^{d}	117.30^{g}	816.60^{d}	559.10^{e}	227.60^{e}	86.40^{h}	488.70^{g}	142.40^{f}	331.50^{e}
Pterocarpus erinceus	953.60^{b}	172.40^{b}	111.00^{h}	842.70^{b}	482.10^{g}	234.80^{c}	129.90^{d}	521.90^{b}	134.90^{g}	247.30^{g}
Sterculia setigera	943.60^{c}	151.10^{d}	151.00^{d}	792.70^{e}	587.40^{c}	229.10^{e}	92.60^{g}	468.10^{g}	157.70^{e}	358.30^{c}
Tamarindus indica	943.70^{c}	146.60^{e}	121.00^{f}	822.60^{c}	565.90^{d}	232.00^{d}	87.80^{h}	485.50^{e}	172.10^{c}	333.90^{d}
SEM	2.43	1.25	1.62	2.64	2.96	1.33	1.59	1.36	2.27	1.97

a,b,c,d=mean values along the same column with different superscripts are significantly different ($P<0.05$); DM=Dry matter; CP=Crude Protein; OM=Organic Matter; NDF=Neutral detergent fibre; ADF=Acid detergent fibre; Acid detergent lignin; ADIash=Acid detergent insoluble ash; Cell.=Cellulose and Hemi cellulose; SEM=Standard error of means.

Table 2: Anti-nutritional factors of browse forages of semi arid zone of Nigeria (mg g^{-1} DM)

Browse Forages	TCT	PHE	SAP	OXA	PHY
Khaya senegalensis	0.21^{e}	0.48^{c}	2.02^{e}	7.20^{b}	5.81^{b}
Kigalia Africana	0.08^{h}	0.37^{e}	2.02^{e}	5.02^{d}	2.22^{f}
Leptadenia lancifolia	0.15^{f}	0.45^{d}	2.16^{d}	6.22^{c}	4.51^{c}
Maerua angolensis	0.41^{a}	0.32^{f}	2.78^{b}	4.59^{e}	2.82^{de}
Olea hochstteteri	0.12^{g}	0.24^{g}	2.05^{e}	8.14^{a}	2.02^{f}
Poupartia sirrea	0.14^{f}	0.31^{f}	1.08^{f}	5.10^{d}	3.97^{d}
Prosopis Africana	0.15^{f}	0.36^{e}	1.48^{f}	6.61^{c}	4.59^{c}
Pterocarpus erinceus	0.23^{d}	0.61^{a}	2.69^{c}	4.84^{e}	4.09^{c}
Sterculia setigera	0.34^{b}	0.48^{c}	2.89^{a}	7.90^{b}	6.08^{a}
Tamarindus indica	0.28^{c}	0.57^{b}	2.12^{d}	5.94^{c}	3.04^{d}
SEM	0.02	0.02	0.08	0.23	0.20

a,b,c,d=mean values along the same column with different superscripts are significantly different (P<0.05); TCT=Total condenced tannin; PHE=Phenolics; SAP=Saponin; OXA= Oxalate; PHY=Phytate; SEM=Standard error of means.

Table 3: Macro minerals concerntration of semi-arid browses of Nigeria (g kg^{-1} DM)

Browse Forages	Ca	P	Mg	Na	K
Khaya senegalensis	7.80^{def}	265.70^{d}	2.50^{e}	1.10^{a}	11.50^{h}
Kigalia Africana	9.00^{bc}	102.50^{i}	1.70^{e}	0.90^{ab}	40.00^{d}
Leptadenia lancifolia	10.60^{b}	305.20^{c}	4.00^{c}	0.60^{e}	16.80^{g}
Maerua angolensis	12.40^{a}	112.50^{h}	7.20^{a}	0.90^{ab}	32.50^{e}
Olea hochstteteri	12.50^{b}	203.30^{g}	5.80^{b}	0.40^{f}	16.00^{g}
Poupartia sirrea	10.10^{b}	256.70^{f}	5.60^{b}	1.20^{a}	120.00^{a}
Prosopis Africana	9.70^{bc}	350.00^{b}	4.50^{c}	1.00^{ab}	110.00^{b}
Pterocarpus erinceus	8.30^{de}	262.00^{e}	5.00^{b}	0.70^{abcd}	12.00^{h}
Sterculia setigera	7.80^{def}	442.50^{a}	4.50^{c}	0.90^{ab}	62.50^{c}
Tamarindus indica	11.50^{a}	260.90^{e}	3.20^{cd}	0.80^{abc}	18.30^{f}
SEM	0.06	1.94	0.05	.04	0.44

a,b,c,d=mean values along the same column with different superscripts are significantly different (P<0.05); Ca=Calcium; P=Phosphorus; Mg=Magnesium; Na=Sodium; K=Potassium; SEM= Standard error of means.

Table 4: Trace minerals concentration of semi-arid browses of Nigeria (mg g^{-1} DM)

Browse Forages	Fe	Zn	Co	Mn	Se	Ni
Khaya senegalensis	2.973^{d}	5.725^{a}	0.005	0.512^{d}	0.157	0.009
Kigalia Africana	16.24^{a}	4.240^{ab}	0.012	2.923^{b}	0.062	0.023
Leptadenia lancifolia	3.897^{c}	1.813^{d}	0.005	0.342^{e}	0.109	0.021
Maerua angolensis	2.311^{de}	1.801^{d}	0.006	0.845^{c}	0.099	0.017
Olea hochstteteri	2.196^{de}	1.406^{d}	0.006	0.136^{f}	0.165	0.021
Poupartia sirrea	1.618^{aef}	1.064^{d}	0.007	0.234^{f}	0.149	0.085
Prosopis Africana	6.220^{b}	3.998^{abc}	0.007	0.765^{d}	0.125	0.017
Pterocarpus erinceus	15.420^{a}	6.528^{a}	0.011	3.823^{a}	0.012	0.024
Sterculia setigera	$1.957d^{ef}$	1.497^{d}	0.005	0.354^{e}	0.129	0.004
Tamarindus indica	5.974^{b}	4.191^{ab}	0.007	0.757^{d}	0.108	0.023
SEM	0.55	0.26	0.0006	0.14	0.09	0.008

a,b,c,d=mean values along the same column with different superscripts are significantly different (P<0.05); Fe=Iron; Zn=Zinc; Co=Cobalt; Mn=Manganese; Se=Selinium; Ni= Nickel; SEM=Standrd error of means.

value of 3.823 mg/ g DM while *Olea hochstteteri* had the lowest concentration of 0.136 mg/g DM. The concentration of cobalt, selenium and nickel were generally low and showed no significant differences among browse forages.

Crude Protein (CP) disappearance

The crude protein disappearance of the browse forages is shown in Table 5. A close rate of disappearance of CP from the incubation of leaves was observed in all the browses. These values differed significantly (P<0.05) in the 0-96 h incubation periods. With a range of 40 to 65 % disappearance value at 0 hr the CP contents of these leaves are considered highly degraded. Generally CP disappearance at 96 h was high for all browse forages with all values above 80%. The mean 96 h incubation value for CP disappearance was calculated to be 86.11%. The pattern in the differences between crude protein disappearances from the browse leaves was similar for all the incubation periods.

Crude Protein Degradation Characteristic (CP)

Significant differences (P<0.05) were observed in the CP degradation characteristics in the browse forage leaves except for the degradation rate constant as shown in Table 6**.** Crude protein in all the browse leaves investigated was highly soluble. The solubility of CP was higher in *Maerua angolensis* with a value of 62.39% and least soluble in *Olea hochstteteri* with 46.79%. As a result of the high solubility of CP in the browse leaves, reported values for the insoluble but degradable fraction 'b' appeared to be low. It ranged from 26.78% in *Maerua angolensis* to 37.34% in *Olea hochstteteri.* The potential degradation 'a+b' of CP in the browse leaves was generally high with a range between 82.27 % in *Khaya senegalensis* and 91.42 % in *leptadenia lancifolia*. Estimate for the rate of degradation of CP in the leaves per hour in this experiment was lowest in *leptadenia lancifolia* (0.014/h) and highest in *Prosopis africana* (0.078/ h). The results of this study recorded effective degradability of CP at an outflow rate of 0.12 to be higher 67.30 in *Maerua angolensis* and lowest in *Poupartia sirrea* 57.60%.

DISCUSSION

The crude protein (CP) content of the browse forages studied was generally higher in all the browse forages and is above the 7% CP requirement for ruminants that should provide ammonia required by rumen microorganism to support optimum microbial growth. Norton (2003) justifies the use of browse forages in small quantities in order to supplement poor quality pastures and crop residues. The high CP content of browse species is well documented and is one of the main distinctive characteristic of browse compared to most grasses. Norton (1998) reported a range of CP contents from 12 to 30% for tropical tree legumes, and Le Houerou (1980) gave a mean of 12.5% in West African browse species with about 17% for leguminous species. Generally, the CP content in browse has been shown to be above the minimum level required (7%) for microbial activities in the rumen (Norton, 1998).

The values of fibre fraction in the present study fall within the range reported by Njidda *et al*. (2008). NDF and ADF contents in the browse forages studied were generally higher compare to the values reported by Njidda (2010) and this can limit feed intake (Meissner *et al.,* 1991). This species also had high lignin content. Lignin is a component of the cell wall, and deposited as part of the cell wall-thickening process (Boudet, 1998). Lignin is in general higher in browse than in herbaceous plants. The content varies according to species, age and the plant parts. Positive correlations were reported between contents of lignin and soluble or insoluble proantho-

Table 5: Crude Protein Disappearance of semi-arid browses (% DM)

Browse forages	0	3	6	12	24	48	72	96
Khaya senegalensis	50.23^{d}	47.99^{c}	62.46^{c}	69.77^{ab}	72.49^{bcd}	75.57^{bcd}	83.23^{cd}	84.81^{bcd}
Kigalia Africana	49.99^{d}	45.97^{d}	60.75^{de}	67.76^{abcd}	71.34^{bcde}	75.67^{bcd}	83.50^{cd}	85.07^{bc}
Leptadenia lancifolia	60.34^{b}	58.29^{a}	61.97^{d}	67.29^{abcd}	73.32^{bc}	80.64^{b}	86.65^{b}	87.63^{a}
Maerua angolensis	62.39^{a}	60.29^{a}	65.00^{b}	69.36^{ab}	80.72^{a}	81.21^{a}	87.89^{a}	88.52^{a}
Olea hochstteteri	46.79^{def}	43.69^{f}	56.09^{f}	70.22a	75.41^{b}	77.57^{bc}	84.64^{c}	86.37^{b}
Poupartia sirrea	48.94^{de}	45.23^{d}	53.70^{g}	68.30^{abc}	74.73^{b}	76.09^{bcd}	82.14^{cd}	84.03^{bcd}
Prosopis Africana	48.01^{de}	46.00^{e}	62.64^{c}	70.03^{a}	78.56^{a}	79.02^{b}	84.28^{c}	85.81^{b}
Pterocarpus erinceus	55.72^{c}	52.66^{b}	70.06^{a}	69.77^{ab}	79.81^{a}	81.38^{a}	86.31^{b}	87.70^{a}
Sterculia setigera	47.98^{def}	45.92^{d}	65.78^{b}	65.18^{e}	76.10^{b}	78.55^{bc}	83.91^{cd}	85.70^{bc}
Tamarindus indica	49.89^{d}	47.88^{e}	57.43^{f}	60.84^{f}	74.62^{b}	77.21^{bc}	84.10^{c}	85.47^{bc}
SEM	1.31	1.97	0.86	1.17	2.09	0.78	1.11	1.05

a, b, c, means in the same column with different superscript differ significantly (P<0.05); SEM=Standard error means; NS=Not Significant

Table 6: Degradation characteristics and Effective degradability of CP of semi arid browse forages incubated in the rumen of bulls

Browse Forages	a	b	a+b	c	Lag T	ED
Khaya senegalensis	50.23^{d}	32.04^{abc}	82.27cde	0.060	0.80^{bc}	60.00^{d}
Kigalia Africana	49.99^{ef}	33.44^{ab}	83.43^{cd}	0.048	1.10^{b}	58.50^{de}
Leptadenia lancifolia	60.34^{b}	31.08^{abcd}	91.42^{a}	0.024	2.70^{a}	64.10^{c}
Maerua angolensis	62.39^{a}	26.78^{e}	89.17^{b}	0.036	2.40^{a}	67.10^{a}
Olea hochstteteri	46.79^{h}	37.34^{a}	84.13^{cd}	0.065	1.40^{b}	57.80^{def}
Poupartia sirrea	48.94^{ef}	33.43^{ab}	82.37^{cde}	0.059	2.00^{a}	57.60^{def}
Prosopis Africana	48.01^{ef}	35.79^{a}	83.80^{cd}	0.078	1.10^{b}	60.50^{d}
Pterocarpus erinceus	55.72^{c}	30.42^{abcd}	86.14^{c}	0.062	1.00^{b}	65.00^{b}
Sterculia setigera	47.98^{g}	35.71^{a}	83.69^{cd}	0.064	0.70^{bc}	59.50^{d}
Tamarindus indica	49.89^{e}	35.74^{a}	85.63^{c}	0.040	1.50^{b}	57.90^{def}
SEM	0.56	0.80	0.56	0.031	0.85	0.88

a, b, c, means in the same column with different superscript differ significantly (P<0.05); SEM=Standard error means; NS=Not Significant.

cyanidins (Rittner and Reed, 1992). Reed (1986) also found a negative correlation between the content of NDF and soluble phenolics, while the correlation with insoluble proanthocyanidins was positive. The browse forages had moderate to high content of fibre. This is a positive attribute of the browse forages since the voluntary DM intake and digestibility are dependent on the cell wall constituents (fibre), especially the NDF and lignin (Bakshi and Wadhwa, 2004).

Cellulose is closely associated with lignin thus the observed relatively high lignin content in the examined plant leaves may have resulted in the high cellulose levels in this study. In other words, the concentration of cellulose provides an insight as to the level to which the forage has been lignified. The high level of lignin in the studied leaves could be adduced to their maturation. This is likely so because according to Wilson (1982) environmental factors, particularly temperature, significantly influence the content and digestibility of cell wall in forage through faster tissue maturation.

The cell wall content hemicellulose was observed to be fairly high. With a mean value of 303.20 g kg^{-1} DM in the investigated plants, they appeared quite high compared to reported levels in the common browse forages. These hemicelluloses levels in the plants may be acceptable levels although rumen microbes are incapable of adequately degrading this fibre component of plants. Going by the observations of Roger *et al.* (1996) who noted that sun drying affected the chemical composition of tree legumes, the high hemicellulose content of the leaves in this study may have probably been due to the drying of samples of the plants before they were analyzed.

Tannins are phenolic plant secondary compounds and are widely distributed through the plant kingdom, especially legumes and browses which affect animal performance in many countries (Min *et al*., 2003). The level of CT is lower than the range of 60 to100 g Kg^{-1} DM considered depressing feed intake and growth (Barry and Duncan, 1984) but within the range 0.41 to 0.81 mg g^{-1} DM reported by Njidda *et al*. (2008) for semi arid browse forages. Feeding tannin containing plant can decrease ruminal protein degradation, promote microbial crude protein (CP) synthesis (Cardozo *et al.,* 2004), and prevent excessive ruminal gas formation which can lead to bloat (Wina *et al.,* 2004). However, in ruminants, dietary condensed tannins of 2 to 3% have been shown to have beneficial effects because they reduce the protein degradation in the rumen by the formation of a protein-tannin complex (Barry, 1987) and increasing absorption of amino acids in the small intestine (Barry and McNabb, 1999). On this basis, they have been proposed as feed additives to improve digestive utilization of dietary protein (Schwab, 1995). While moderate concentrations of CT (2-4.5% DM) can exert beneficial effects on protein metabolism in ruminants, high dietary CT concentrations (>5.5% DM) can depress voluntary feed intake, digestive efficiency and animal productivity. However, effects are not the same for all CT as they depend upon its chemical structure (Min *et al.,* 2003). The values for phenolic compounds in this study were lower compared to that reported by Osuga *et al.* (2006). Phenolic compounds are the largest single group of secondary plant compounds (SPCs), and total phenolics in plants can reach up to 40% of the dry matter (Reed 1986; Tanner *et al*., 1990). In grasses, the major phenolic is lignin that is bound to all plant cell walls, and is a significant limiting factor in their digestion in the rumen (Minson, 1990). Lignin is also a limiting factor in the digestion of legumes, but is bound largely to the vascular tissue (Wilson 1993), with often high concentrations of other free and bound phenolic

compounds (phenolic acids, coumarins and flavonoids) in floral, leaf and seed tissues (McLeod, 1974).

Oxalate content in this present study was low. It has been reported that 20g/ kg oxalate can be lethal to chicken (Acamovic *et al*., 2004). Oxalate has been shown to deplete the calcium reserve, but these browse species were found to contain reasonable amount of calcium, magnesium and phosphorus. Ca and carbon are also released from the hydrolysis of Ca Oxalate some of which will be either absorbed or excreted by the ruminant animals. With Ca absorption rate of ruminants put at 31% (Haenlein, 1987) and P at 4% absorption (Iqbal *et al.,* 2005) reasonable amount of the Ca and P intakes will be lost via faeces and urine to the soil. Such voided minerals/nutrients are thereby recycled for further use to support plants which are ploughed back into the soil. When so much N is returned to the soil, this reduces the use of inorganic N fertilizer and lends weight to the use of organic manure in farming. However, given the time to adapt, the microorganisms in the rumen can metabolise moderate amounts of oxalate.

Saponins are group of compounds containing α-glycone moiety linked to carbohydrates. Many plant species consumed by livestock contain saponins. Feedstuffs containing saponin have been shown to be defaunating agents (Teferedegne, 2000) and capable of reducing methane production (Hu *et al.,* 2005). Cheeke (1971) reported that saponins have effect on erythrocyte haemolysis, reduction of blood and liver cholesterol, depression of growth rate, bloat (ruminant), inhibition of smooth muscle activity, enzyme inhibition and reduction in nutrient absorption. Saponins have been reported to alter cell wall permeability and therefore to produce some toxic effects when ingested (Belmar *et al*., 1999). The anti-nutritional effects of saponins have been mainly studied using alfalfa saponins. Sharma and Chandra (1969) observed that 4-7 weeks of *ad libitum* feeding of *albizia* gave rise to toxic manifestation in sheep. Symptoms include listlessness, anorexia, weight loss and gastro-enteritis. The toxicity of saponins can be reduced by repeatedly soaking the feed in water. The level recorded in this present study may not pose any problem the animals.

Phytic acid is a phosphoric acid derivative of myo-inositol. It constitutes an important component of forage plants with the ability to chelate essential minerals including calcium, magnesium, iron, zinc and molybdenum (Iqbal *et al*., 2005). The resulting chelates resist breakdown in the digestive tract and become unavailable thus inducing dietary deficiency of these elements (NRC, 2001; Iqbal *et al*., 2005). Most of the phosphorus in plants is organically bound to phytic acid (Maga, 1982). In this regard, Deka and Sarkar (1990) reported that 40-50% and 28% respectively of the total phosphorus are present as phytate-phosphorus, which is unavailable for utilization by animals. However, Iqbal *et al.* (2005) noted that a phytic acid degrading enzyme phytase appears to be present in the gastrointestinal tract. This is possibly why phytic acid bound phosphorus can be utilized to some extent by ruminants (McDonald *et al.,* 1988). The phytin levels reported in this study is lower than 13.80 to 25.20 mg/g DM reported by Okoli *et al.* (2003) for the southeastern browses in Nigeria. These levels are unlikely to have any adverse effects on ruminants.

The Ca content of browse was adequate, all the browse forages had higher Ca than the recommended requirements (g/kg^{-1} DM diet) for growing cattle (2.6-10.8), pregnant cows (2.1-3.5) and lactating cows (2.9-5.3), (Shamat *et al*., 2009). Reuter and Robinson (1997) suggested Ca requirement for maintenance of growing and lactating sheep to be 1.2-2.6 g/kg. Forage Ca concentrations in the range of 2-6 g/kg, with higher requirements for lactation have been variously recommended for cattle and sheep (Khan *et al.,* 2006). However, Sykes and Field (1972) suggest that levels of 2.5 g/kg are adequate in most circumstances. The majority of browses examined had lower P level than established tropical pasture (2.7 g/kg DM) (Minson, 1990). The browse forages had higher levels of P compared to values obtained from other parts of the world. Aganga and Mesho (2008) reported lower values of P for browse forages of Botswana and Shamat *et al.* (2009) for browses of Sudan. The variation in the content of observed P could be due to the available soil P and soil pH, browse growth stage and proportions of leaf and stem fractions harvested for mineral analyses and sampling season. Browse and forage plants had higher concentrations of P than the normal requirements of P (g/kg DM diet) of growing cattle (1.1-4.8), pregnant heifers and cows (0.9-2.0) and lactating cows (2.0-30), suggesting nutritional adequacy for livestock. Njidda *et al.* (2010) and Norton (1994) reported that browses are generally high in phosphorus. All the browse samples analyzed had sufficient Mg level in agreement with the report of Khan *et al.* (2007). Based on Minson (1990) recommendation (2.0 g/kg DM), Mg in the diets of ruminants the browse plants examined had higher levels of Mg. Shamat *et al*. (2009) reported that Mg in tropical forage was not considered to be limiting, although Jumba *et al*. (1996) reported exceptionally low Mg concentrations in Kenya. Na level is adequate compared to normal levels (0.36 to 0.37% DM) reported by Shamat *et al*. (2009) for other browse forages of other regions. The level reported in this study is below the Na requirements (0.8-1.2% DM) for cattle. There seem to be a general agreement that Na is deficient in most tropical grasses, in agreement with Areghoere (2002) that many tropical regions have reported low forage sodium concentrations. Sodium deficiency can be corrected by providing common salt *ad libitum* which can also satisfy the requirement for chloride (McDowell, 1985). The need for Na is particularly pronounced in hot weather to compensate for losses due to respiration and perspiration. Potassium is reported to be extremely mobile in plants and is translocated from the oldest to the fastest growing tissues (Gomide *et al*., 1969). Losses of potassium as the plant mature was attributed to translocation of potassium to the root system and then to the soil (Blue and Tergas, 1969). However, it has been suggested that high producing ruminants may require K level above 10 g/kg, under stress particularly heat stress (Khan *et al.,* 2005). Similar K concentrations observed in this study have been reported by Ogebe *et al.* (1995) in Nigeria.

The plant species had high concentrations of Fe that were comparable to high levels of Fe (100- 700 mg/ kg DM) for tropical grasses and legumes (McDowell, 1992). These species had higher levels of Fe than tabulated requirements of Fe for dairy and beef cattle (50 mg/kg

DM) (Khan *et al*., 2009). Although its availability could vary due to the fact that Fe is absorbed according to the need, and thus its absorption would depend on dietary factors, age of the animal and body Fe status. Forage Zn concentration was also found above the requirements of ruminants during winter as earlier reported by Reuter and Robinson (1997). It has been suggested that 30 mg/ kg Zn is a critical dietary level, although it has been recommended that concentrations of 12-20 mg/kg are adequate for growing ruminants (Anon., 1980). Almost similar results were reported by Tiffany *et al.* (2001) in North Florida. Cobalt is a serious mineral limitation to livestock because even when grazing is abundant deficiency will lead to chronic starvation or wasting which is often indistinguishable from energy and protein mal-nutrition (McDowell *et al*., 1984). The concentration of Co observed in this study was comparable to that in most tropical grasses (<0.01 to 1.26 mg kg^{-1} DM) as reported by Minson (1990). The browse forages had higher levels of Co than the dietary recommended levels for cattle (0.06-0.7 mg kg^{-1} DM), (ARC, 1980), sheep and goats (0.11 mg kg-1 DM) (ARC. 1980). The browses had moderate levels of Mn that were comparable to the contents of Mn of pastures and established legumes (14-148 mg/kg DM) (Minson, 1990). High forage concentration of Mn in dry season was detected and attributed to low rates of Mn translocation and accumulation of Mn in order tissue (Khan *et al*., 2009). All plant species had higher levels of Mn than the normal dietary requirements of 20-40 mg kg^{-1} DM (NRC, 2001), although, its supply could be lowered by its low absorbability efficiency, from forage. However Mn concentrations may interfere with the metabolism of other minerals and has been observed to result in low reproductive rates of cattle (McDowell *et al*., 1984). Selenium is a very important trace mineral. The result of selenium in the studied browse ranged from 0.012 to 0.410 mg g^{-1} DM. Reproductive problems, retained placenta, white muscle disease and an inadequate immune system (leading to mastitis and metritis) may result when selenium is deficient in livestock rations. Selenium levels of 100 to over 9000 mg Kg^{-1} can be found in selenium accumulator plants (Johnson and Larson, 1999). Consumption of these plants leads to rapid death. Chronic toxicity can occur at 5 mg kg^{-1} (Brooks, 1998). The result of nickel concentration ranged from 0.006 to 0.042 mg g^{-1} DM with a low overall mean of 0.025 mg g^{-1} for the browses. Nickel concentration ranged widely from 0.08 to 0.35 mg kg^{-1} DM with a low overall mean of 0.18 mg kg^{-1} DM. The concentration is not influence by dietary nickel intake in animals. The values recorded for Ni were above toxic levels suggested for typical plants (Tokalioglu and Kartal, 2005).

Crude protein in the browse leaves was found to be highly soluble. A mean value of 78.29% of the potential degradability value of the plants during 48hr incubation buttresses this fact. The generally observed low differences between 48hrs and 96hrs disappearance values in all the investigated leaves indicates that most of the crude protein in these leaves had been degraded at earlier incubation times. According to Apori *et al.* (2000) high protein degradability is an indication that the amino acids in these plants may not be relevant to the ruminant, as most of the protein would have been converted to microbial proteins in the rumen.

Establishing optimum feeding systems involves reliable rumen degradability estimates for protein in their feeds to adequately assess their protein nutrition (Repetto *et al* 2003). Accordingly protein nutrition evaluation as suggested by the reports of ARC (I984) and NRC (1985) requires knowledge of the ability of feedstuffs to provide both microbial proteins and undegraded intake proteins. Ruminal ammonia, an important factor in microbial protein synthesis, has the tendency to be lacking in the rumen with low dietary crude protein (Mackie and White, 1990). Russell *et al*. (1983) reported the presence of both rumen degradable and undegradable intake protein to be beneficial in ruminant feeding. Why the degradable portion is needed to supply rumen microbes with protein for their growth the undegradable intake protein is used for tissue synthesis by the animal.

The high value observed for the immediately soluble crude protein fraction ‘a’ in the leaves used in this experiment indicated a solubility of this nutrient in the .leaves. Although the crude protein content in the leaves was relatively high, however, the high crude protein soluble fraction values may have resulted from the problem of microbial contamination *in situ* (Michelet-Doman and Ould-Bah, 1992). According to Vanzant *et al.* (1996) the problem of microbial contamination, could emanate from the influence of the number of' bags simultaneously rinsed within a bucket or from contamination by the ruminal fluid within the buckets. Besides, milled feed particle size has been shown to affect soluble crude protein fraction (Freer and Dove, 1984; Mass *et al.* 2001; Gonzalez and Andres, 2003). Nevertheless, Wallace and Gotta (1988) are of the view that in high soluble protein fractions may stimulate proteolysis bacteria in the rumen. Consequent upon the observed high crude protein 'a' fractions in the leaves, the value obtained for the slowly degradable fraction ‘b’ was low. The degradation rate of crude protein in, the leaves of this study were generally low compared with the values reported for selected multipurpose trees and shrub leaves in wet season but however relatively similar to their dry season levels (Larbi *et al* 1998). According, to Preston and Leng (1987) the extent to which protein escapes from the rumen is partly a function of its rate of degradation in the rumen. Limitation in the rate of crude protein degradation is to some extent related to dietary forage quality. Ganev *et al*. (1979) and Zhao *et al*. (1993) have shown the ratio of forage to concentrate to influence *in situ* protein degradation. Vanzant *et al* (1996) demonstrated this influence to be due to forage type and quality. Low ruminal ammonia levels have been associated with depressed bacteria growth hence limits potential for *in situ* protein degradation (NRC, 1985). Dixon (1999) and Olsen *et al.* (1999) are of the opinion that feeding greater concentrations of rumen degradable protein may increase their digestion of fibre and organic matter *in situ.* Potentially degradable 'a+b' crude protein portion was generally high in all the browse leaves tested. This could have been due to the low insoluble but degradable fraction, which suggests high effective degradability of these leaves. Potential degradability values in the leaves reported in this study were comparable

to those reported for tropical grass and legume forages (Mgheni *et al.*, 1996) as well as wet and dry season values of some multipurpose fodder trees and shrubs of West Africa (Larbi *et al*, 1996). However compared to values found in feed legume seeds (Gonzalez and Andres, 2003) they were lower. Of notable interest in this study were the very high but statistically insignificant values for lag time in the crude protein degradation pattern for the leaves investigated. Newman *et al*. (2002), believe long lag times influence the degree to which the slowly degraded fraction 'b' is broken down in the rumen as well as the extend of nitrogen deficiency or sufficiency. Nocek and Grant (1987) associated long lag times with factors such as oven drying and microbial contamination of the forages. Brown *et al*. (1991) have showed that with low supply of nitrogen to the rumen and long lag phase for crude protein degradation, high concentrations of insoluble but degradable crude protein, will mostly pass to the lower digestive tract before being degraded. Thus, this is unavailable for microbial growth and forage digestion in the rumen. A possible explanation for this may have been the high fibre content in the leaves. The effective degradability of crude protein in the tree shrub leaves studied at an outflow rate of 0.12% was quite high and mostly above 60%. This presupposes that these leaves could serve as a high-protein value source for ruminants. High effective degradability crude protein values can arise from high value of soluble fraction and rate of passage of feed through the rumen (Gonzalez and Andres, 2003; Dolezal and Trinacty, 2003). The site of digestion has an influence on the effective degradability of crude protein, Jančík *et al.* (2010) observed a close but negative relationship between effective degradability of crude protein and that digested in the intestines. From this they inferred that the reduction in effective degradability of crude protein always enhances the protein value of feed consequent upon an increase in the crude protein digested in the intestine. Effective crude protein degradability values, reported for the leaves in these experiments at a similar outflow rate, were higher than the majority of values reported by Mgheni *et al.* (1996) for tropical grasses and legumes. As well, the mean effective degradability of the leaves studied was higher than the average of 64% reported in. grasses and Lucerne (Kowalski *et al.*, 1995).

Conclusion

The browse species evaluated in the current study had high CP content which would make them good protein supplements to poor quality roughages, especially during the dry season in the semi arid region of Nigeria. The anti-nutritive factors were generally low for all the browses. The browse forages studied had a greater CP degradation. Therefore, forages with high CP content provide more dietary protein to the small intestine.

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