NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 52 Number 2, August 2021 Pg. 390-399
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng

ANTI-NUTRITIVE FACTORS, MINERAL PROFILE, *IN VITRO* GAS PRODUCTION AND FERMENTATION CHARACTERISTICS OF TEN BROWSE FORAGE LEAVES

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Abstract
The nutritive values of leaves from ten (10) different browse plants were analyzed using the *in vitro* gas production. Crude protein (CP) contents in the browses plants ranged from 114.90 to 173.90g kg^{-1} dry matter (DM). Ranges of 30.60 to 51.60g kg-1 DM were recorded for EE values for the eight browse plants. The NDF, ADF and ADL were 412.10 to 688.10, 211.60 to 265.60, and 88.30 to 140.30g kg^{-1} DM respectively. The values reported for anti-nutritive factors ranged from 0.08 to 0.39 for TCT, 0.31 to 0.71 for phenolics, 1.08 to 2.99 for Saponin, 4.58 to 8.00 for Oxalate, and 2.22 to 7.33 for phytate. The values reported for minerals showed significant differences ($p<0.05$) for all the macro minerals; this followed a similar pattern for the trace minerals except for cobalt and nickel. The *in vitro* gas production was highest (28.33ml / 200g DM) and lowest (3.66ml / 200g DM). The fermentation characteristics a, b, a+b, c, t, Y were highest at 3.67, 25.00, 28.33, 0.057, 18.00, and 11.33 respectively. All the gas production parameters differed significantly ($P<0.05$). Based on chemical composition and *in vitro* gas production, results show that the leaves of the browse forages have nutritive value and therefore, may serve as potential supplements for ruminants in Nigeria.

Keywords: *In vitro*, browse, semi-arid, anti-nutritive, forage

Introduction

Forage and grain-based diets have similar energy contents, yet productivity of ruminants fed grains is often twice that from good quality forages. The principal difference between grains and forage is the presence of lignified cell walls that account for 300-500g kg^{-1} forage DM. Cell walls are the dominant feed fraction for grazing ruminants. They comprise mainly cellulose and hemicellulose, and in legumes pectin, all of which are rapidly and extensively degraded by rumen micro flora when lignin is not present. The use of *in vitro* gas production method to estimate digestion of feeds is based on measured relationship between the *in vivo* digestibility of feeds and chemical composition (Menke and Steingass, 1988); *in vitro* gas methods primarily measure digestion of soluble and insoluble carbohydrates (Menke and Steingass, *ibid*). The amount of gas produced from a feed on incubation reflects production of volatile fatty acids (VFA), which are major sources of energy for ruminants. Gas arises directly from microbial degradation of feeds and indirectly from buffering of acids generated as a result of fermentation. The aim of this research was therefore, to evaluate the nutritive value of some selected browse forage leaves available as livestock feeds.

Materials and Methods

Description of site and the browse forage species

All forages were harvested from Gwoza Local Government Area of Borno State. The area is located on Longitude 11.05^0 North and Latitude 30.05^0 East and at an elevation of about 364m above sea level in the North-East 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 between 19 – 25°C (Njidda *et al.*, 2008). Ten browse forages commonly found in the Semi-arid and derived Savannah zones were used in this experiment. The samples were sundried, milled and sub samples taken for analysis. The species include: *Adansonia digitata, Anageisus celecarpus, Analgeosus leocarpus, Batryospermum*

paradoxum, Buahinea nufescens, Ceiba pentendra, Celtis integuifolis, Khaya senegalensis, Kigalia africana, and *Poupartia sirrea.* The browse forages were harvested from at least 10 trees per specie selected at random in four locations within the study area at the end of rainy season (October to November).

Sample Preparation

About 500g of the harvested browse samples were pooled weekly from each plant and oven dried at 105°C for 24hours, cooled and weighed. The weight difference between the initial and dry weights were taken 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 milled to pass through 1mm screen sieve, labeled and stored in sealed polythene bags for degradability and *in vitro* studies. The other portion was milled to pass through 1mm screen sieve, labeled and also stored for proximate composition and anti-nutritional factor determination.

Chemical Analysis

Triplicate samples of the thirty seven samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), Oxalate, Fluoroacetate and ash according to AOAC (2002) procedures. The dry matter content of the samples was determined as earlier described. Exactly 1g of each sample was used for the determination of ash by complete combustion in a furnace at 550o^{0}C for 4hours. The fibre fractions were determined according to the method of Van Soest *et al.* (1991).

Mineral analysis

The mineral contents of the browse leaves used in this experiment were analysed using the Standard Method of AOAC (2002). Calcium, magnesium, iron, copper, zinc selenium, nikel and manganese were analyzed using the atomic absorption spectrophotometery (Zohary, 1973). Phosphorus was determined according to the vanadomolybdophosphoric acid method (Shio, 1996) using a spectrophotometer (Jenway 6100, UK), while the flame photometer was used to estimate sodium and potassium contents.

Anti-Nutritional Factor Assessment in the Samples

Some anti-nutritional constituents that were determined in the browses include; Phytate estimated as phytic acid using the method prescribed by Maga (1982), while hydrogen cyanide (HCN) was determined by the Knowels and Watkins distillation method as described by Pearson (1976). Saponins and total condensed tannin were determined as reported by Babayemi *et al*. (2004a) and (Polshettiwar *et al*., 2007). Finally, Phenolics were determined using Folin Ciocalteu method as described by Makkar (2000).

***In-vitro* gas production study**

Management of the Animals

Rumen fluid was obtained from three West African Dwarf goats using a suction tube before morning feeding. The goats were fed 60% concentrate (which contains 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 40% Guinea grass (*Panicum maximum*).

Incubation of samples

The incubation procedure was as reported by Menke and Steingass (1988). The 120ml calibrated syringes fitted with silicon tube at the mouth were used, while the incubation was in three batches. The incubation temperature was maintained at 39 ± 1ºC. The buffer (containing 9.8g $NaHCO_3$ + 2.77g Na_2 HPO_4 + 0.57g KCl + 0.47g NaCl + 0.12g $MgSO_4.7H_2O$ + 0.16g 1 litre $CaCl_2.2H_2O$) (1:4, v/v) was used and kept in the incubator for warming. About 200mg of the feed sample (substrate) was measured and introduced into the syringe after removing the plunger. The plunger was replaced by pushing the substrate upward the syringe. The rumen liquor was strained through a four layer cheese cloth. Rumen liquor and buffer were mixed together (1:4, v/v) as inoculums, all under continuous flushing with streams of CO_2. Using 120ml capacity syringe, 30ml of inoculums was dispensed into the substrate through the silicon tube. The plunger was pushed upwards by pushing the inoculums to the tip of the syringe, thereafter, the silicon was tightened with a metal clip. The gas production was measured from the calibrated syringe at 3, 6, 12, 24, 48, 72 and 96 hours and expressed thus.

$$G=a+b\,(1-e^{-ct})$$

Where; G = is the gas production (ml) at time t, a = is the gas production from the immediately soluble fraction (ml), b = is the gas production from the insoluble but degradable fraction (ml), a + b = is the potential gas production (ml), and c = is the rate constant of gas production (fraction/h).

Statistical analysis

Data obtained were subjected to analysis of variance; where significant differences occurred, the means were separated using Duncan multiple range F-test using the software; SAS (2004) options.

Results and Discussion

Proximate composition

The chemical composition of the browse forage leaves determined in this study is presented in Table 1. Generally, the examined plant leaves had high significant ($p<0.05$) crude protein content with values ranging from a low value of 114.90g kg^{-1} DM in *Bauhinea nufescecens* to 160.00g kg^{-1} DM in *Adansonia digitata.* The significant ($p<0.05$) range for ether extract in the browse was 30.30g kg^{-1} DM in *Khaya senegalensis* to 51.60g kg^{-1} DM in *Poupartia sirrea.* Values obtained

for organic matter content of the browse forage ranged from 742.60% in *Poupartia sirrea* to 868.70g kg^{-1} DM in *Khaya senegalensis.* The highest significant ($p<0.05$) neutral detergent fibre content of 595.90g kg^{-1} DM was recorded in *Celtis integuifolis*, while *Adansonia digitata* had the lowest value of 412.10g kg^{-1} DM. The acid detergent fibre levels in the experimental leaves ranged from 211.60g kg^{-1} DM in *Khaya senegalensis* to 265.60g kg^{-1} DM in *Batryospermum paradoxum*. The least lignin content of 88.30g kg^{-1} DM in the browse forages was recorded in *Anageisus celecarpus*, while *Poupartia sirrea* had the highest value of 140.30g kg^{-1}DM.

Anti-nutritional factor levels of semi-arid browse forage

The result of the anti-nutritional constituents in the browse forage leaves is shown in Figure 1. Total condensed tannin varied from 0.08mg/g DM in *Kigalia africana* to 0.39mg/g DM in *Celtis integuifolis*. A range of 0.31mg/g DM in *Analgeousus leocarpus,* and *Poupartia sirrea* to 0.71 mg/g in *Ceiba pentendra* was obtained for phenolic. Saponin content of the experimental leaves ranged from 1.08mg/g DM in *Poupartia sirrea* to 2.99mg/g DM in *Ceiba pentendra.* Oxalate in the browses used ranged from 4.58mg/g DM in *Ceitis integuifolis* to 8.00mg/g DM in *Batryospermum paradoxum*. The highest value of 7.33mg/g DM was obtained in *Kigalia Africana*, while *Ceiba pentendra* had the lowest value of 2.22mg/g DM for Phytic acid in the browses studied.

Macro mineral concentration of semi-arid browse forage

The result of the macro mineral concentration is shown in Table 2. Leaves from *Analgeosus leocarpus* had the highest calcium amongst the browses with 13.20g kg^{-1} DM which dropped to 7.60g kg^{-1} DM in *Buahenia nufescens.* Phosphorus had the highest recorded level of macro mineral (271.80g kg^{-1} DM) in *Ceiba pentendra*, while *Kigalia africana* with 102.50g kg^{-1} DM had the lowest level. The magnesium level was highest with a value of 10.40g kg^{-1} DM in *Celtis integuifolis* and lowest with a value of 1.70g kg^{-1} DM in *Kigalia africana.* The sodium concentration in the browse forage was generally low with levels less than 1.50g kg^{-1} DM for the browse forage leaves. Potassium concentration in *Poupartia sirrea* was significantly ($p<0.05$) higher (120.00g kg^{-1} DM) than all the browses studied, while *Bauhinea nufescence* had the lowest value (6.30g kg^{-1} DM) amongst the browse forage.

Trace mineral concentration of semi-arid browse forage

Results in Table 3 show the composition of micro minerals estimated in the browse forage used in this experiment. The iron content of the browse forage ranged between 1.216mg/g DM in *Ceiba pentendra* to 16.24mg/g DM in *Kigalia africana*. Significant differences ($p<0.05$) were observed among browse forage for zinc with *Adansonia digitata* having the highest, while *Poupartia sirrea* had the lowest value of 1.064mg/g DM. The cobalt and Nickel content of the browse forage leaves was generally low for all the browse forage leaves (below 0.012 and 0.032mg g^{-1} DM) and showed no significant differences among browse forage leaves. Among the browse forage leaves, *Kigalia africana* had the highest value of 2.923mg/g DM, while *Poupartia sirrea* had the lowest concentration of 0.234mg g^{-1} DM.

In vitro gas production

The *in vitro* cumulative gas production after 96hrs, potential gas production (asymptotics gas production; fraction b), and rate of gas production (fraction c) of the browse forage leaves are presented in Figure 2. The forage significantly ($P<0.05$) differed in the gas production and fermentation characteristics. *Adansonia digitata* produced the highest gas production (28.33ml/200mg DM) throughout the incubation period from 3 to 96hrs, while *Analgeousus leocarpus* produced the least gas volume of 3.66ml/200mg DM at 96hrs.

Fermentation characteristics of semi-arid browse forage

The gas production from the immediately soluble fraction 'a' as shown in Table 4 was generally low for all the browse forages with values ranging from 1.33 in *Analgeosus leocarpus* and *Buahenia nufescens* to 3.67 in *Anageisus celecarpus.* The fermentation of the insoluble but degradable fraction 'b' is shown in Table 4. The value for 'b' was highest in *Adansonia* (28.33ml) and least in *Analgeosus leocarpus* (2.67ml). The potential gas production 'a+b' was observed to be low for all the browse forage with the highest value (28.33ml) in *Adansonia digitata* and the least value (4.00ml) in *Analgeosus leocarpus*. The gas production 'Y' at time't' ranged between 3.50 in *Analgeosus leocarpus* and 11.33 in *Adansonia digitata.*

The Crude protein (CP) content of *Adansonia digitata* was found to be highly significant ($p<0.05$) than the other species. The CP of the browse species ranged from 114.90 to 160.00g kg^{-1} DM which is above the 7% CP requirement for ruminants and could provide ammonia required for optimum microbial activity in the rumen (Norton, 2003). The values also fall within the range reported by Njidda *et al.* (2010) and Njidda *et al.* (2013c). The high CP content of browse species is one of the main distinctive characteristic of browse forage compared to most grasses. The NDF, ADF and ADL values of the experimental diets were higher than earlier reports on the tropical forage species (Njidda 2008, Njidda *et al.* 2012a; Njidda *et al.* 2012b and Njidda *et al.* 2016). Differences in composition may be due to variation in age, environmental and soil conditions and climatic factors. Although the NDF was slightly higher than the recommended value of 20–35% for effective ruminal degradation (Norton 1994; Bakshi and Wadhwa 2004; Njidda *et al.* 2013b), but lower than 60% value at which feed intake is depressed (Meissner *et al*., 1991). This species also had a high lignin content ranging from 88.30 to 140.30g kg^{-1} DM. Lignin is a component of the cell wall and deposited as part of the cell wall-thickening process (Boudet, 1998) and it is in generally

higher in browse (Njidda 2010; Njidda *et al.* 2012b and Njidda *et al.* 2016) than in herbaceous plants (Boudet, 1998). Positive correlations were reported between contents of lignin and soluble or insoluble proanthocyanidins (Rittner and Reed, 1992; Njidda 2011). The total condensed tannins (TCT) ranged from 0.08mg/g to 0.39mg/g DM. The level is lower than the range of 60 to100g Kg DM that is considered to depress feed intake and growth (Barry and Duncan, 1984) and Njidda (2011) (*n*=37). 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).

The values for the phenolic content were within the range reported by Njidda (2011) (*n*=37). Phenolic compounds are the largest single group of 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).

Feedstuffs containing saponin had been shown to be defaunating agents (Teferedegne, 2000) and capable of reducing methane production (Babayemi *et al.* 2004b). Cheeke (1971) reported that saponin 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 effect when ingested (Belmar *et al*., 1999). The values (1.08 to 99mg g^{-1} DM) reported in this present study is low compared to values reported by other authors.

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 (Le Houerou, 1980; Akinsoyinu and Onwuka, 1988). The phytin levels reported in this study ranged from 2.22 to 7.33mg g^{-1} DM for northeastern browse forage, which is lower than 13.80 to 25.20mg/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.

Mineral composition

More than 90% of 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). Variations in the levels of Ca from this present study could be partly explained by the mature forage species, species composition, and variations in soil characteristics due to location of the different browse forage. The browse forage had higher levels of P than values obtained from other parts of the world. Aganga and Mesho (2008) reported lower values of P for browse forage in Botswana and Shamat *et al*. (2009) for browses in 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^{-1} 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. Norton (1994), Njidda *et al*. (2011) and Njidda and Olatunji (2012) reported that browses are generally high in phosphorus. All the browse samples had sufficient Mg level as reported in Khan *et al*. (2007). Based on Minson (1990) recommendation (2.0g kg^{-1} DM), Mg in the diets of ruminants, the browse plants had higher levels of Mg. Shamat *et al*. (2009) reported that Mg was not limiting in tropical forage, although Jumba *et al*. (1996) reported exceptionally low Mg concentrations in Kenya. Sodium level is adequate compared to normal levels (0.36 to 0.37% DM) reported in Shamat *et al*. (2009) for other browse forage of other regions. The level reported in this study was 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 (Aregheore, 2002). 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). However, it has been suggested that high producing ruminants may require K level above 10mg kg^{-1}, under stress, particularly heat stress (Khan *et al.*, 2005). Potassium concentrations similar to levels found 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 (100- 700mg kg^{-1} DM) reported for tropical grasses and legumes (McDowell, 1992). These species had higher levels of Fe than tabulated requirements for dairy and beef cattle (50mg kg^{-1} DM) (Khan *et al*., 2009). Although its availability could vary because 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 above the requirements for ruminants during winter as earlier reported in Reuter and Robinson (1997). It has been suggested that 30mg/kg Zn is a critical dietary level, although it has been recommended that concentrations of 12-20mg kg^{-1} DM 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 1.26mg 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 – 0.7mg kg^{-1} DM), (ARC, 1980) and sheep and goats (0.11mg kg^{-1} DM) (ARC, *ibid*). The browses had moderate levels of Mn that were comparable to the contents of Mn in pastures and established legumes (14 – 148mg/kg DM) (Minson, 1990). There was a high Mn concentration in the forage during the dry season possibly because of low rates of Mn translocation and accumulation of Mn in older tissues (Khan *et al*., 2009). All the plant species had higher levels of Mn than the normal dietary requirements of 20 – 40mg kg^{-1} DM (NRC, 2001), although, its supply could be lowered by its low absorbability efficiency from forage. However, Mn may interfere with the metabolism of other minerals and may result in low reproductive rates of cattle (McDowell *et al*., 1984). Selenium is a very important trace mineral. The level of selenium in the studied browses ranged from 0.012 to 0.410mg 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 9000mg/Kg can be found in selenium accumulator plants (Johnson and Larson 1999). Consumption of these plants leads to rapid death. Chronic toxicity can occur at 5mg g^{-1} DM (Brooks, 1998). The level of nickel ranged from 0.006 to 0.042mg g^{-1} DM with a low overall mean of 0.025mg g^{-1} DM for the browses. Nickel concentration ranged widely from 0.08 to 0.35mg g^{-1} DM with a low overall mean of 0.18mg g^{-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).

Gas production on incubation of feeds in buffered rumen fluid is associated with feed fermentation and carbohydrate fractions; the low gas production from *Analgeosus leocarpus* and other browse forage characterized with low gas production could be related to low feeding value of these feeds. These browse forage contain more than 40% of its dry matter in the form of cellulose and hemicelluloses, but its degradability is very low. One of the main reasons for this low degradability is the presence of lignin which protects carbohydrates from attack by rumen microbes. 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 (Steingass and Menke, 1986) 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). 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* (Tefera *et al.*, 2008). Legumes are reported to contain tannins that can reduce fermentation parameters (Tefera *et al.* 2008) for others, such as the genus *Leptadenia*; the effect may be related to different classes of bioactive PSC (Ghisalberti, 1994).mKinetics of gas production obtained from the exponential model is presented in Table 4. Both rate constants b and c showed significant differences among browse forages. Similarly, the extent (a + b) of gas volumes was higher for *Adansonia digitata* than for trees. 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 higher values obtained for the (c) and (a + b) parameters in the browse forage, may indicate a better nutrient availability for rumen micro-organisms in animals grazing such vegetative species in semi-arid areas.

Conclusion

The ten browse species evaluated in the current study had high CP content which may be found to be of good protein supplements to poor quality roughages, especially during the dry season in the semi-arid region of Nigeria. The macro and micro minerals are high and can meet the requirement of ruminant animals. Although, the gas production from the ten browse plants despite the high CP content is low. The low degradation may be attributed to the high lignification of the browse plants.

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Table 1: Chemical composition of the browse forages (g kg^{-1} DM)

Browse Forage	CP	EE	OM	NDF	ADF	ADL
Adansonia digitata	160.00^{a}	30.60^{e}	809.70^{d}	412.10^{i}	219.70^{g}	116.30^{d}
Anageisus celecarpus	149.10^{d}	31.60^{d}	838.00^{d}	542.80^{e}	231.30^{f}	88.30^{i}
Analgeosus leocarpus	150.70^{d}	51.60^{a}	848.30^{c}	542.10^{e}	241.80^{e}	130.00^{b}
Batryospermum paradoxum	145.90^{c}	50.00^{a}	859.00^{b}	572.30^{d}	265.60^{a}	112.60^{e}
Buahinea nufescens	114.90^{h}	47.30^{b}	812.70^{f}	493.10^{g}	231.40^{f}	93.70^{h}
Ceiba pentendra	173.90^{a}	31.60^{d}	828.00^{e}	514.60^{f}	244.80^{d}	112.40^{e}
Celtis integuifolis	153.60^{c}	31.00^{d}	794.60^{g}	595.90^{b}	246.00^{c}	105.60^{f}
Khaya senegalensis	139.60^{e}	30.30^{e}	868.70^{a}	486.20^{h}	211.60^{h}	121.00^{c}
Kigalia Africana	134.02^{f}	34.60^{c}	766.70^{h}	688.10^{a}	255.20^{b}	97.00^{g}
Poupartia sirrea	132.20^{g}	51.60^{a}	742.60^{i}	591.20^{c}	230.30^{f}	140.30^{a}
SEM	**1.25**	**1.35**	**2.64**	**3.25**	**2.07**	**1.86**

CP=crude protein; EE=ether extract; OM=Organic matter; NDF=neutral detergent fibre; ADF=acid detergent fibre; ADL=acid detergent fibre

Table 2: Macro minerals concerntration of semi-arid browses of Nigeria (g kg^{-1} DM)

Browse Forage	Ca	P	Mg	Na	K
Adansonia digitata	9.60^{d}	212.50^{d}	5.60^{c}	0.90^{b}	19.30^{f}
Anageisus celecarpus	10.80^{c}	203.70^{e}	5.30^{c}	0.50^{f}	14.80^{h}
Analgeosus leocarpus	13.20^{b}	203.30^{e}	3.10^{d}	0.60^{e}	18.50^{g}
Batryospermum paradoxum	12.00^{b}	110.70^{g}	3.10^{d}	1.10^{a}	30.00^{c}
Buahinea nufescens	7.60^{e}	211.70^{d}	6.00^{b}	0.60^{e}	6.30^{i}
Ceiba pentendra	10.40^{c}	271.80^{a}	2.50^{e}	0.70^{d}	27.50^{d}
Celtis integuifolis	19.30^{a}	112.80^{f}	10.40^{a}	0.80^{c}	25.00^{e}
Khaya senegalensis	7.80^{e}	265.70^{b}	2.50^{e}	1.10^{a}	11.50^{i}
Kigalia Africana	9.00^{d}	102.50^{h}	1.70^{f}	0.90^{b}	40.00^{b}
Poupartia sirrea	10.10^{c}	256.70^{c}	5.60^{c}	1.20^{a}	120.00^{a}
SEM	**0.06**	**1.94**	**0.05**	**0.04**	**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 3: Trace minerals concentration of semi-arid browses of Nigeria (mg/g DM)

Browse Forage	Fe	Zn	Co	Mn	Se	Ni
Adansonia digitata	4.840^{b}	7.110^{a}	0.007	0.507^{d}	0.145	0.026
Anageisus celecarpus	4.702^{b}	1.664^{e}	0.004	0.319^{f}	0.085	0.011
Analgeosus leocarpus	3.087^{c}	2.403^{d}	0.012	1.082^{c}	0.153	0.015
Batryospermum paradoxum	1.982^{e}	1.632^{e}	0.006	0.388^{f}	0.168	0.006
Buahinea nufescens	3.688^{c}	1.623^{e}	0.009	2.675^{b}	0.180	0.032
Ceiba pentendra	1.216^{f}	1.220^{e}	0.003	0.410^{e}	0.114	0.007
Celtis integuifolis	3.126^{c}	2.500^{d}	0.006	0.457^{e}	0.130	0.027
Khaya senegalensis	2.973^{d}	5.725^{b}	0.005	0.512^{d}	0.157	0.009
Kigalia Africana	16.24^{a}	4.240^{c}	0.012	2.923^{a}	0.062	0.023
Poupartia sirrea	1.618^{c}	1.064^{f}	0.007	0.234^{g}	0.149	0.085
SEM	**0.55**	**0.26**	**0.0006^{NS}**	**0.14**	**0.09^{NS}**	**0.008^{NS}**

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

Table 4: *In vitro* fermentation characteristics of semi-arid browse forages

Browse Forages	a	b	a+b	c	t	Y
Adansonia digitata	3.33	25.00	28.33	0.032	12.00	11.33
Anageisus celecarpus	3.67	4.33	8.00	0.046	14.00	5.00
Analgeosus leocarpus	1.33	2.67	4.00	0.053	16.50	3.50
Batryospermum paradoxum	1.00	4.67	5.67	0.057	11.00	3.00
Buahenia nufescens	1.33	11.00	12.33	0.046	18.00	6.67
Ceiba pentendra	2.00	6.33	8.33	0.050	14.00	4.67
Celtis integuifolis	2.33	7.00	9.33	0.034	10.00	4.33
Khaya senegalensis	2.33	4.00	6.33	0.042	16.00	4.00
Kigalia Africana	2.67	6.00	8.67	0.028	13.00	4.00
Poupartia sirrea	3.00	19.67	22.67	0.035	10.00	8.33
SEM	**1.21**	**2.67**	**2.12**	**0.019**	**1.37**	**1.21**

a,b,c,d=mean values along the same column with different superscripts are significantly different (P<0.05); SEM=Standard error of means

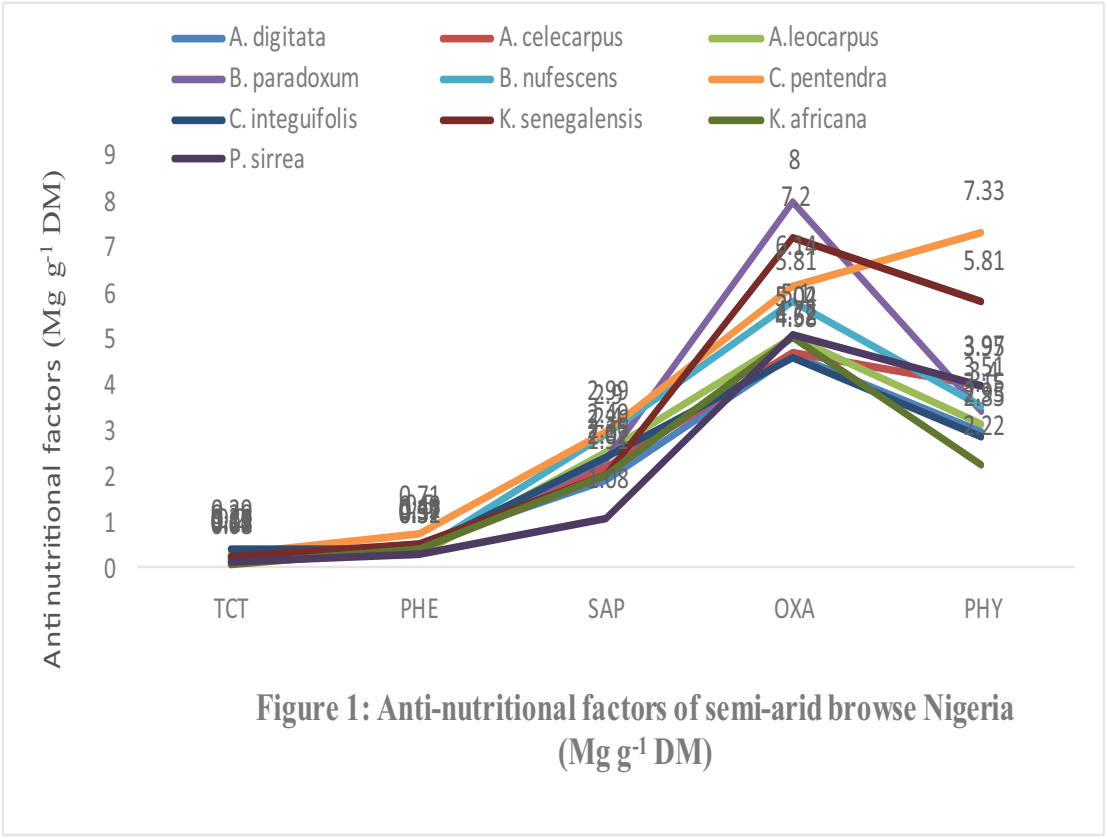

Figure 1: Anti-nutritional factors of semi-arid browse Nigeria (Mg g^{-1} DM)

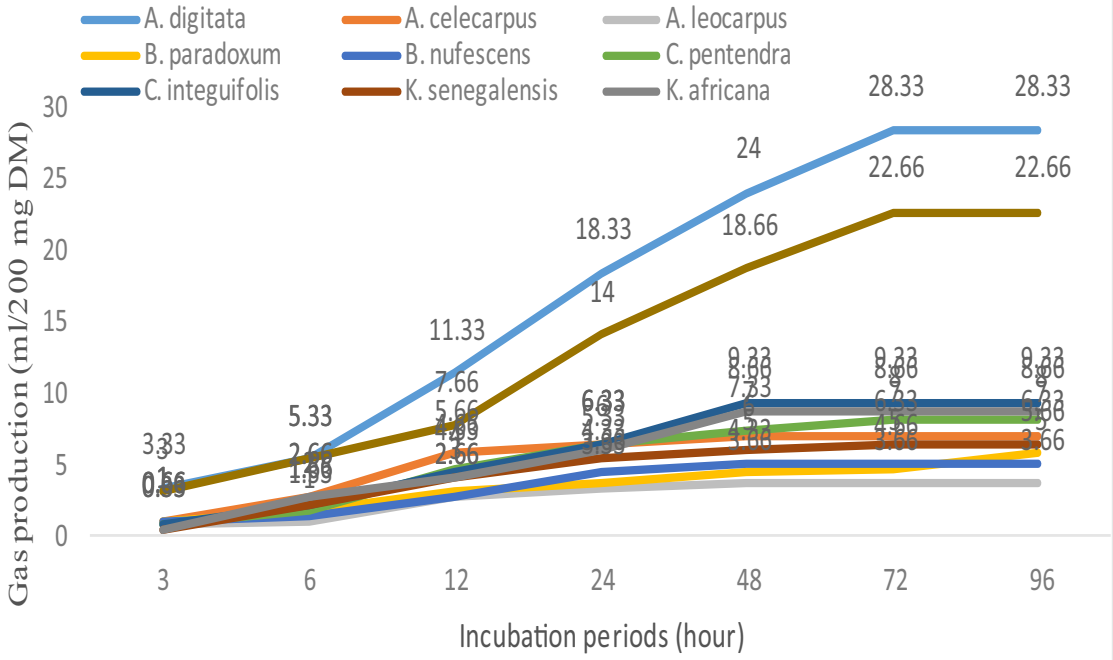

Figure 2: ***In vitro*** **gas production of semi-arid browse forages**