Nutritional Evaluation of Some Tropical Crop Residues: *In Vitro* Organic Matter, Neutral Detergent Fibre, True Dry Matter Digestibility and Metabolizable Energy Using the Hohenheim Gas Test

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ABSTRACT : The Hohenheim *in vitro* gas test was used to assess the nutritional value of some crop residues of known *in vivo* digestibility. The crop residues are groundnut shells (GNS) corn cobs (CC); cassava peels (CaP); unripe and ripe plantain peels (UPP, RPP) and citrus pulp/peels (CPP). Compared to other crop residues, crude protein (CP) content of CC was low. Except for CaP and CPP that had low neutral detergent fibre (NDF) and acid detergent fibre (ADF), other residues contained a high amount of cell wall constituents. Net gas production was significantly different among the crop residues ($p<0.05$). Gas production was highest in CPP followed by CaP. CC, UPP and RPP have the same volume of net gas production, while the least net gas production was in GNS. True dry matter (TDM) digestibility was significantly different ($p<0.05$) among the residues. GNS was the least in TDM digestibility. CaP, UPP and RPP had similar TDM digestibility values, while the highest TDM digestibility was obtained in CPP. OM digestibility was different among the residues ($p<0.05$). CaP and CPP had the same ME value while CC, UPP and RPP had close ME values and GNS the least in ME ($p<0.05$). The potential extent (b) and rate (c) of gas production were statistical different among the residues ($p<0.05$). The Hohenheim gas test gave high *in vitro* organic matter (OM) digestibility for CC, CaP, UPP and RPP and CPP. Fermentable carbohydrates and probably available nitrogen in the crop residues influenced net gas production. The results showed that crop residues besides, providing bulk are also a source of energy and fermentable products which could be used in ruminant livestock production in the tropics. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 5 : 747-751)*

Key Words : Chemical Analyses, Hohenheim Gas Test, NDF, OMD Digestibilities, Metabolizable Energy, Crop Residues

INTRODUCTION

Most countries in the tropics do not yet have enough feed resources to sustain high levels of livestock production, therefore development of rations based on readily available resources is imperative. Crop residues are easily available at low cost and have great potential if properly harnessed. They are a key element in tropical ruminant nutrition (de Haan, 1991) and can meet the nutritional requirements of livestock for growth, reproduction and maintenance during adverse climatic conditions. The role played by crop residues in tropical livestock nutrition has been stressed by several researchers (Diarra and Bosma, 1987; Aregheore and Chimwano, 1991; Aregheore, 1996, 1997a). Crop residues are low quality roughage that are low in protein, minerals and vitamins.

Chemical composition of crop residues can give an idea of their nutritive value (Oyenuga 1968; Gohl, 1981; Abate, et al 1984; Aregheore, 1993, 1994a). However, the chemical components of crop residues are not always directly related to the response of an animal because it is also a function of the ability of the animal to derive useful nutrients from the ration. Besides digestibility, the voluntary intake of a roughage is another essential factor in quality assessment (Minson, 1990). The digestible nutrient content is determined by *in vivo* experiments or estimated using *in vitro* procedures, which are cheaper and more convenient. There is scant literature report using a combination of chemical constituents and gas released on incubation of feeds in an *in vitro* medium containing rumen microbes (Menke and Steingass, 1988) to assess the nutritional quality of tropical crop residues. The objective of this study was to use the Hohenheim gas test to assess the nutritional value - *in vitro* organic matter, neutral detergent fibre and true dry matter digestibilities and metabolizable energy of some tropical crop residues.

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MATERIALS AND METHODS

Crop residues analyzed

The crop residues were from groundnut shells (GNS), corn cobs (CC), cassava peels (CaP), unripe and ripe plantain peels (UPP, RPP) and citrus pulp/peels (CPP). These residues were obtained from Delta State, Nigeria. Previously, six different digestion trials had been conducted with West African Dwarf (WAD) goats and the WAD sheep separately or with a combination of both species (Aregheore, 1994b, 1996, 1997a, 1997b). The goats and sheep weighed on average (SD) 12.96±0.28 and 14.05±0.18 kg, respectively. In all the trials urea (46 % N) was used as a N source (Aregheore, 1994b, 1996, 1997a, 1997b).

Voluntary feed intake was expressed as g/kg live weight (LW) per day (d) and varied between 58.0~62.0 g/kg LW per d in goats and 70.0~83.0 g/kg LW per d in sheep. In all trials no refusals were observed because the residues were used in complete mash rations.

Proximate analysis

Proximate components were analyzed according to AOAC (1980). Fibre analyses [neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined by the procedures of Van Soest et al. (1991).

Nutritional evaluation using *in vitro* gas method

Rumen liquor and particulate matter (approximately 60:40) were collected from a cannulated dairy cow (kept exclusively on a medium quality diet) before the morning feeding into prewarmed CO_2 filled thermos flasks and then streamed through a cheese cloth. The samples (200 mg) were weighed into 100 ml calibrated syringes. *In vitro* incubation was conducted according to the procedures of Menke and Steingass, (1988) using 30 ml buffered rumen inoculum. Three syringes containing 30 ml inoculum only served as blanks. Another three syringes with 200 mg of hay reference standard were also carried out. Incubations were stopped after 24 h incubation and gas volume (Gv) was noted. The organic matter digestibility (OMD, %) and metabolizable energy (ME, MJ kg^{-1} DM) were calculated using the following equations: OMD=14.88+0.889*Gv+0.45*CP, and ME=2.20+0.136*Gv+0.057* CP. The Gv is in ml and CP in percent in DM. These equations were derived from digestion experiments (n=400) on sheep and have been tested with 300 other digestion experiments including 15 respiration trials. The residual standard deviation was 4.2% for both equations (Menke and Steingass, 1988).

True dry matter digestibility

For determination of true dry matter digestibility 500 mg of samples were incubated in a buffered medium containing rumen liquor (40 ml). True dry matter digestibility was determined after 24 h of incubation by treating the syringe contents with neutral detergent solution to obtain NDF (Van Soest and Robertson, 1985: Blummel et al. 1997). Truly digested substrate was the difference in weights between the sample taken for incubation and the NDF residues following 24 h fermentation. This procedure for determination of *in vitro* true digestibility is essentially according to Van Soest and Robertson (1985);

$$\% \text{ True dry matter digestibility} = \frac{\text{(Truly digested substrate (DM))}}{\text{(Weight of sample DM taken for incubation)}} \times 100$$

Rate and potential extent of gas production

The samples (200 mg) were incubated in triplicate in graduated syringes containing 30 ml of the *in vitro* medium containing rumen liquor (Menke et al 1979). At 2, 4, 6, 8, 10, 12, 24, 30, 36, 48, 54, 60, 72 and 96 h, gas values were recorded. The potential extent (b) and rate (c) of gas production were determined using a one pool exponential model, $y=b\ (1-e^{-ct})$, where 'y' is the gas produced at time 't'.

Statistical analysis

Data obtained were analyzed by ANOVA and significant differences between means were compared by using Duncan's multiple range test with the aid of SAS/STAT program (Statistical Analysis Systems Institute Inc., 1988).

RESULTS AND DISCUSSION

Chemical composition of the crop residues is presented in table 1. Compared to the other residues that had similar crude protein (CP) value, CP was low in CC. Except for CaP and CPP that had low neutral

Table 1. Chemical composition of crop residues

Nutrients	GNS	CC	CaP	UPP	RPP	CPP
Dry matter (%)	92.3	94.5	94.3	92.6	90.1	88.5
Proximate composition (% in DM)						
Crude protein	6.3	3.4	7.2	7.9	7.7	6.0
Ash	2.8	4.2	14.2	12.3	13.9	7.7
Neutral detergent fibre	63.7	76.1	32.0	60.0	62.6	37.8
Acid detergent fibre	43.6	49.9	21.0	47.9	46.4	25.9
Acid detergent lignin	9.6	15.9	7.2	16.9	24.0	6.7
Hemicellulose	20.1	26.2	11.0	12.1	16.3	11.9
Cellulose	34.0	23.7	13.8	31.0	22.4	19.2

Abbreviations are GNS: Groundnut shell, CC: Corn cobs, CaP: Cassava peels, UPP: Unripe plantain peels, RPP: Ripe plantain peels, CPP: Citrus peels/pulp.

Table 2. Net gas produced, mg substrate truly digested/ml gas produced, true dry matter, neutral detergent fibre (NDF %) and organic matter (OM) digestibilities and metabolizable energy (ME, MJ/kg of DM)

Parameters	GNS	CC	CaP	UPP	RPP	CPP
Net gas produced (ml/24 h)	9.1 ± 1.2^a	43.9 ± 2.1^b	78.9 ± 1.9^c	44.7 ± 4.5^b	45.4 ± 1.6^b	90.7 ± 2.1^d
mg substrate truly digested/ml gas produced	3.5 ± 0.1	3.3 ± 0.1	3.9 ± 0.7	4.5 ± 0.0	3.6 ± 0.1	4.9 ± 0.3
True dry matter digestibility (%)	20.0 ± 0.5^a	52.2 ± 1.9^b	78.9 ± 1.5^c	73.8 ± 0.7^c	77.9 ± 3.1^c	87.4 ± 1.1^d
NDF digestibility (%)	10.7 ± 0.6^a	37.7 ± 2.6^b	63.0 ± 2.7^{cd}	59.6 ± 1.1^c	68.3 ± 4.4^d	69.8 ± 0.9^d
OM digestibility (%)	25.8 ± 1.0^a	55.5 ± 1.9^b	88.3 ± 1.6^c	58.1 ± 4.0^b	58.7 ± 1.4^b	98.4 ± 2.1^c
ME (MJ/kg of DM)	3.8 ± 0.2^a	8.4 ± 0.3^b	13.3 ± 0.9^c	8.7 ± 1.6^b	8.8 ± 0.2^b	14.9 ± 0.3^c

[a,b,c,d] Means within each row with different superscript, differ significantly $p<0.05$.

Abbreviations are GNS: Groundnut shell, CC: Corn cobs, CaP: Cassava peels, UPP: Unripe plantain peels, RPP: Ripe plantain peels, CPP: Citrus peels/pulp.

detergent fibre and acid detergent fibre, the other residues were high in cell wall constituents. The actual nutrient content of the residues may differ from tabular values given because of the wide variation that may occur between plant varieties, processing methods and handling of the residues after processing (Aregheore, 1993, 1996; Arosemena et al; 1995; DePeters et al; 1997). The proximate chemical composition values obtained are within the values reported for tropical crop residues (Oyenuga, 1968; Gohl, 1981).

Net gas production, mg substrate truly digested/ml gas produced, true dry matter (TDM), NDF and organic matter (OM) digestibilities and metabolizable energy (ME, MJ/kg of DM) are presented in table 2. Significant differences were obtained among the residues in net gas production ($p<0.05$). Groundnut shell had low net gas production. Corn cobs, UPP and RPP had the same volume of gas production. Gas production was highest in CPP followed by CaP. Gas production reflects more on the content of digestible energy rather than on protein and fat (Abate, 1980; Krishna and Gunther, 1987). The high gas production observed in CPP and CaP may be due to their high digestibility as reflected by true dry matter (TDM) digestibilities. The high OM digestibility of CPP and CaP as estimated by Hohenheim gas test may be due to the low cell wall. Generally, the differences observed in net gas production reflect the contents of fermentable carbohydrates and also probably available nitrogen in the crop residues. While fermentable carbohydrates increase gas production, degradable N compounds have been reported to decrease gas production to some extent because of the binding of carbon dioxide to ammonia (Menke and Steingass, 1988; Krishnamoorthy et al, 1995).

In contrast with mg substrate truly digested/ml gas produced, true dry matter (TDM) digestibility was significantly different ($p<0.05$) among the residues (table 2). The values of mg substrate truly digested/ml gas produced are within the range reported by Blümmel et al (1997). Groundnut shell was lowest in true dry matter digestibility. Cassava peels, UPP and RPP had similar and intermediate true dry matter digestibility (TDM) values, while the highest TDM digestibility was obtained for CPP. Corn cobs digestibility was higher than that of GNS but lower than the values of the other residues. Cassava peel, RPP and CPP had similar NDF digestibility, but higher ($p<0.05$) than values in GNS, CC and UPP. Although RPP showed higher TDM and NDF digestibilities than UPP, the OM digestibilities and ME contents were almost the same between the above two. The difference could be that the starch present in ripe plantain peels got converted into sugars and this resulted in loss in energy content (Oyenuga, 1968). The low NDF values in CaP and CPP showed that they contain more soluble materials which ruminants can benefit from. In the present *in vitro* report, CaP and CPP were fermented faster than other residues due to the presence of more soluble materials. In *in vivo* trials using goats and sheep, growth rate and nutrient digestibility were better in rations formulated with CaP peels and CPP compared to crop residues such as groundnut shells, corn cobs, sunflower heads and cocoa pod husk (Aregheore, 1994b; 1996).

Organic matter digestibility was lowest in GNS and highest in CPP ($p<0.05$). The crop residues have varying effective NDF and OM digestibilities and total gas production. Variation in gas production and OM digestibility has been reported for agro-industrial by-products (Krishna and Gunther, 1987). Cassava peels and CPP had similar ME values and these were higher ($p<0.05$) than those for CC, UPP and RPP. Groundnut shell was significantly the least in ME ($p<0.05$).

The potential extent (b) and rate (c) of gas production (table 3) were statistically different ($p<0.05$) among the residues. They followed the pattern of OM digestibility (table 2). A comparison of gas production and concomitant *in vitro* OM and NDF digestibilities demonstrated that gas production reflects substrate fermentation. The conversion rate of true fermented organic matter into gas varied with type of crop residue. Economic factors and problems of feed unavailability usually necessitate the formulation of rations based on crop residues. Although, in *in vivo* trial, goats and sheep performed better with rations formulated from CaP and CPP (Aregheore, 1994b, 1996) compared to other residues such as corn cob and groundnut shell, the high gas production observed shows that care has to be exercised in feeding them to animals at high levels to avoid accumulation of gases and fermentation products which could lead to displaced abomasum and acidosis.

Table 3. The rate (c) and the potential extent (b) of gas production of the crop residues gas production

Crop residues	Rate **c** (ml/h^{-1})	Potential **b** (ml)
Groundnut shell	0.1259 ± 0.0212^a	10.8 ± 0.8^a
Corn cobs	0.0566 ± 0.0067^b	59.5 ± 2.1^b
Cassava peels	0.0584 ± 0.0016^b	94.1 ± 2.3^c
Unripe plantain peels	0.0529 ± 0.0019^b	61.0 ± 3.2^b
Ripe plantain peels	0.0765 ± 0.0031^c	56.4 ± 2.07^b
Citrus peels/pulp	0.0719 ± 0.0037^c	104.8 ± 1.3^c

[a,b,c] Means within column with different superscript differ at $p<0.05$.

In conclusion, the Hohenheim gas test gave higher *in vitro* OM digestibility for CC, CaP, UPP, RPP and CPP compared to published *in vivo* data (Aregheore, 1997b). It was demonstrated further that crop residues besides, providing bulk (very essential for rumen function) in the ration, serve as a source of energy and fermentable products in ruminant nutrition.

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