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Rumen Degradability of Dry Matter and Crude Protein in Tree Leaves and Crop Residues of Humid Nigeria

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Abstract: Degradability characteristics of dry matter (DM) and crude protein (CP) in four tree leaves and four crop residues were evaluated in this study using the nylon bag technique with three cannulated rams. The results revealed significant variations between the leaves and residues in terms of DM and CP degradability characteristics. The potential degradability of DM ranged from 65.94 to 96.69% in the leaves and 51.28 to 73.77% in the residues whereas DM disappearance after 48 hrs of incubation was from 43.27 to 73.50% and 34.03 to 54.27% respectively. Effective degradability (ED) of DM decreased with increase in outflow rates ranging from a low of 35.88% (k=0.05) to 72.67% (k=0.02) in the leaves and 26.59% (k=0.05) to 54.60% (k=0.02) in the residues. Potentially the degradability of CP in the leaves was between 22.41 and 57.38% and 22.87 and 57.19% in the residues. The least ED (k=0.05) of CP was 14.11% while the highest was 48.01% (k=0.02) in the leaves whereas the residues had a range between 13.20% (k=0.05) and 46.70% (k=0.02). Crude protein disappearance post-incubation for 48 hrs ranged between 17.63 and 53.81% and 14.34 and 53.07% in the leaves and residues respectively. The findings of this study showed that the DM compared with CP in the leaves and residues was more degradable in the rumen with the leaves better in this same regard. The information thus provided by this study could be useful in the planning of ruminant diets particularly in the dry season of the tropics.

Key words: Rumen degradation, effective degradability, dry matter, crude protein, tree leaves, crop residues

Introduction

The poor nutritional status, especially in terms of quality, of the feed resources available to ruminants in the tropics is mostly adducible to the low plane of nutrition (Doma *et al.*, 1999) and the low productivity (Otchere *et al.*, 1987) of these animals. The humid and sub-humid climatic zones of West Africa are habitats for a wide variety of indigenous multipurpose tree species that are important components of the agro-forestry systems of these areas (Oji and Kalio, 2004), and produce large amounts of biomass (Kaitho *et al.*, 1997). The ability of these tree foliages to remain green and maintain a relatively high crude protein content during the dry season (D'Mello, 1992) make them potential sources of protein and energy supplements (Reed *et al.*, 1990). Tchinda *et al.* (1993) reported native pastures and crop residues to be the most widely available low-cost feeds for ruminants in the tropics. Occasionally however, supplementary feeding is provided by way of food processing byproducts such as cassava peels and cereals milling byproducts (Okojie, 1999). In the dry season and post-harvest periods, characteristic of tropical environments, these feed resources become the main sources of energy for use by ruminants when poor quality forages prevail (Ahn *et al.*, 1989; Kibon and Ørskov, 1993). This is important in view of the fact that rural dwellers in the humid tropics, who mostly rear one type of small ruminant or the other (ILCA, 1979), as an adjunct to arable and tree-crop production (Upton, 1988) hardly have the means to purchase completely mixed diets for their animals (Tuah *et al.*, 1993) nor can they afford to invest in the establishment of improved pastures and feed concentrate supplements supplies (Smith *et al.*, 1991). Aganga and Tshwenyane (2003) reported the use of leaves and twigs of trees as supplements to a wide range of forages and agricultural byproducts in the diets of many ruminants in Botswana. Nonetheless, despite the abundance of a variety of these tree fodders and large quantities of post-harvest crop residues in these climatic zones, little information is available on the usefulness of most of these materials as feed for ruminants, particularly in terms of their degradability in the rumen. The use of the *in situ* Dacron bags feed evaluation method developed by Ørskov and McDonald (1979) is an important tool in the measurement of the quality of ruminant feeds by ruminant nutritionists. Apart from providing a reliable means of predicting the digestibility of feedstuffs in the rumen (Arieli *et al.*, 1998), Dhanoa *et al.* (2000) are of the opinion that compared to the end-point quality measurement techniques such as digestibility; the *in situ* method further provides information on their degradation kinetics. The objective of this study therefore was to evaluate the degradation characteristics and effective degradability of the dry matter and crude protein contents of selected tree leaves and crop residues as a

Table 1: Chemical composition of the studied tree leaves and crop residues

Leaves/residues	DM (%)	CP (%DM)	EE (%DM)	Ash (%DM)
Ficus exasperata	94.47	12.25	0.58	2.09
Spondias monbin	96.20	9.56	0.81	2.67
Tectonia grandis	96.68	11.06	0.66	1.60
Terminalia catappa	94.53	8.75	0.81	3.72
Groundnut husk	96.65	10.63	0.63	1.61
Pineapple peels	95.32	12.69	1.59	2.09
Plantain peels	96.12	11.25	0.63	1.88
Rice offal	96.13	11.56	0.59	1.80

way of providing some information regarding their use in the strategic supplementation of ruminant diets in the humid tropics, especially in the dry season.

Materials and Methods

Leaves from four naturally growing tropical tree species and four residues from crops within and around Ambrose Alli University campus, Ekpoma (Lat. 6.46N; Long. 6.04E), and situated in the humid climatic zone of Nigeria, were used for nutrient compositional and *in situ* degradability evaluations. The tree species included *Ficus exasperata* Vahl, (Sandpaper tree), *Spondias monbin* L., (Hog plum), *Tectonia grandis* L.f., (Teak) and *Terminalia catappa* L., (Indian almond) while the crop residues included groundnut husk, pineapple peels, plantain peels and rice offal observed to be readily available wastes from crop harvests in the study area.

Analytical procedures as outlined by AOAC (2000) were used to determine the chemical components in the studied materials. DM was determined by oven drying the samples at 105°C for 24 hours and then shared into two portions. One portion was milled to pass through 2.5mm mesh sieve while the other half was milled to pass through 1mm mesh sieve and stored in sealed polythene bags for DM and crude protein (CP) degradation evaluations and chemical composition respectively. Ash was estimated by igniting the samples in a muffle furnace at 500°C for 12 hours. Nitrogen (N) in the samples was measured using the Kjeldahl's procedure with the crude protein (CP) calculated as N x 6.25. Measurements were taken for only the DM and CP contents in the residues obtained after incubation. The chemical composition of the incubated tree leaves and crop residues are thus presented in Table 1.

The level of DM was observed to be quite close in the analyzed residues and tree leaves averaging 95.76%. Hindrichsen *et al.* (2001) reported similar values for some multipurpose trees. Crude protein values were comparable to reported values for grass forages and byproducts but not to the browses in the studies by Smith *et al.* (1991) and Mgheni *et al.* (1996). However, the CP values were observed to be low when compared with 25% in *Gliricidia sepium* and 25.3% in *Leucaena leucocephala* (Little *et al.*, 1989). These variations in the CP values as observed in this present study may have resulted from varying stages of maturity amongst the leaves or the processing methods of the byproducts.

To determine the *in situ* degradation characteristics of the DM and CP contents in the four tree leaf species and four crop residues, three West African Dwarf (WAD) sheep (rams), weighing on the average 38kg, each fitted with rumen cannulae of 45mm internal diameter, were used. The animals were allowed to graze freely on *Panicum maximum* (Guinea grass) between 0800 and 1500 hrs and offered corn bran as well as free access to multi-nutrient blocks and fresh clean water daily.

Approximately 3g of the sampled materials were weighed into labeled nylon bags measuring 7x12cm and with pore size 40µm thus, giving a sample weight to surface area ratio of about 18 mg/cm^2 (Ørskov, 1982). These bags were then introduced into the rumen of each sheep thereby ensuring 3 replicates per sample. The test time periods were for 0, 24, 48, 72 and 96 hrs. Bags corresponding to the longest incubation time were inserted first and followed by the other bags in sequentially decreasing time (Ørskov, 1982; Osuji *et al.*, 1993: Newman *et al.*, 2002). This was to ensure that all the bags were withdrawn at about the same time.

On withdrawal of the bags from the rumen they were washed under running tap water until the rinse water was clear and the bag-attached microbe contamination assumed to have reduced to the barest minimum. At the end of rinse, the bags were then dried at 65°C for 48 hrs to constant weight to determine rumen residue DM content. To determine the washing loss at zero hour, that is, loss due to non-incubation, for both the DM and CP components, samples of the test materials were soaked in warm water (approx. 37°C) for 1 hour followed by washing and drying as done with the residues from incubation. Dry matter and CP losses were computed as the difference in weight between the pre-incubated and post-incubation samples and expressed as percent.

The weight data gathered were subsequently analyzed using the NEWAY computer program for estimating degradability constants, by fitting them into the non-linear equation $P = a+b\ (1-e^{-ct})$ of McDonald (1981) where P is the potential degradation of the nutrient components under investigation after time 't', 'a' the water soluble fraction, 'b' the insoluble but rumen degradable fraction and 'c' the rate of degradation of the

Table 2: Degradation characteristics and disappearance of DM in the tree leaves

	Ficus exasperata	*Spondias monbin*	*Tectonia grandis*	*Terminalia catappa*	SEM
Degradation characteristics					
Leaves					
a[1]%	56.11[a]	49.40[b]	29.27[c]	26.88[d]	-
b[2]%	29.65[c]	47.29[a]	36.67[b]	46.71[a]	1.65
c[3]/hr	0.025[a]	0.012[c]	0.018[b]	0.012[c]	0.001
a+b[4]%	85.76[b]	96.69[a]	65.94[d]	73.59[c]	1.65
Effective degradability (%)					
k=0.02	72.67[a]	66.81[b]	46.43[c]	44.33[d]	0.08
k=0.03	69.67[a]	62.63[b]	42.82[c]	40.17[d]	0.22
k=0.04	67.60[a]	60.07[b]	40.47[c]	37.62[d]	0.20
k=0.05	66.07[a]	58.34[b]	38.82[c]	35.88[d]	0.25
Disappearance (%)					
24hrs	63.30[a]	56.02[b]	35.19[c]	33.52[d]	0.48
48hrs	73.50[a]	65.82[b]	45.73[c]	43.27[d]	0.51
72hrs	76.06[a]	73.25[b]	52.63[c]	50.63[d]	0.45
96hrs	82.10[a]	78.88[b]	57.18[c]	56.20[d]	0.42

a,b,c,d means along same rows bearing different superscripts are significantly different (P < 0.05).
1,2,3,4 constants in the equation P=a+b (1-e-ct) where “P” is level of degradation at time “t”; “a”, readily soluble fraction; “b”, insoluble fraction but degradable in rumen; “c”, rate of degradation of “b” per hour; “a+b”, potentially degradable fraction.
ED (k=0.02; 0.03; 0.04; 0.05) - effective degradability calculated with outflow rates of 2, 3, 4 & 5%. SEM - standard error of mean.

rumen degradable fraction ‘b’. Effective degradability (ED) of the examined nutrient components were calculated using the outflow rates of 0.02, 0.03, 0.04 and 0.05/hr, according to Ørskov *et al.* (1980) model: ED = a+[bc/(c+k)] where ED is effective degradability and ‘a’, ‘b’ and ‘c’ are the constants as described earlier in the non-linear equation above and ‘k’ the rumen fractional outflow rate.

Data obtained for the DM and CP degradation characteristics; effective degradability and disappearance from the incubated bags were then subjected to analysis of variance (ANOVA) in a completely randomized design using the SAS program General Linear Model procedure (SAS, 1990). Significant means were compared using the Duncan’s multiple range tests.

Results and Discussion

The degradation of DM in the test leaves differed significantly (P < 0.05) both in their characteristics, disappearance rates and effective degradability in the different incubation times as shown in Table 2 and 3.

The immediately soluble fraction ‘a’ ranged from 26.88% in *T. catappa* to 56.11% in *F. exasperata*. The insoluble but rumen degradable fraction ‘b’ was least in *F. exasperata* (29.65%). This is a reflection of the fact that its DM component was most readily soluble. With a similar slowest rate of degradation ‘c’ per hour of the rumen degradable fraction in *S. monbin* and *T. catappa*, these leaves appear to be potential sources of energy for use by microorganisms in the rumen. *Spondias monbin* was observed to contain the highest amount of potentially degradable DM with 96.69%.

Effective degradability (ED) of DM calculated at 2, 3, 4 and 5% outflow rates from the rumen showed *F. exasperata* consistently had significantly highest values while the least value was recorded in *T. catappa*. Effective DM degradability decreased with increase in outflow rates in this study. Mupangwa *et al.* (1997) observed ED of DM to decrease as the outflow rate increased. The ED values calculated as a proportion of their DM contents in Table 1, using values for 5% outflow rate, showed *F. exasperata* and *S. monbin* had over 60% of their DM contents effectively degraded whereas similar proportions of the other leaves were barely up to 40%.

The disappearance of the DM contents in the leaves by the end of 48 hrs of incubation, generally considered to be equivalent to digestibility (Ehargava and Ørskov, 1987) and being the mean retention time of fibrous feeds in ruminants (Kimambo and Muya, 1991), revealed that *T. grandis* and *T. grandis* had less than 50% DM loss compared to the over 65% value obtained for *F. exasperata* and *S. monbin*. However, beyond 72 hrs incubation, all the leaves had DM disappearance values above 50%. The difference between values for the DM contents in Table 1 and the disappearance values after 96 hrs of incubation (Table 2) showed a range of 12.37% - 39.50% in *F. exasperata* and *T. grandis* respectively. This information provides an insight into the level of rumen undegradable DM post incubation for 96 hrs.

The relatively high soluble DM values in these tree leaves, especially in *F. exasperata* and *S. monbin*,

Table 3: Degradation characteristics and disappearance of DM in the crop residues

	Groundnut husk	Pineapple peels	Plantain peels	Rice offal	SEM
Degradation characteristics					
Residues					
a^1%	16.39^d	33.88^b	37.31^a	23.49^c	-
b^2%	34.89^{ab}	34.40^{ab}	36.46^a	33.38^b	1.09
c^3/hr	0.021^{ab}	0.019^{ab}	0.018^b	0.023^a	0.002
$a+b^4$%	51.28^d	68.28^b	73.77^a	56.87^c	1.09
Effective degradability (%)					
k=0.02	34.12^d	50.73^b	54.60^a	41.18^c	0.32
k=0.03	30.62^d	47.34^b	51.02^a	37.82^c	0.36
k=0.04	28.27^d	44.75^b	48.83^a	35.53^c	0.48
k=0.05	26.59^d	43.29^b	47.01^a	33.88^c	0.13
Disappearance (%)					
24hrs	23.55^d	40.07^b	43.63^a	29.77^c	0.27
48hrs	34.03^d	50.42^b	54.27^a	41.07^c	0.44
72hrs	41.54^d	56.96^b	61.12^a	47.63^c	0.58
96hrs	44.85^d	61.10^b	65.53^a	51.46^c	0.19

a,b,c,d means along same rows bearing different superscripts are significantly different (P < 0.05).
1,2,3,4 constants in the equation P=a+b(1-e-ct) where "P" is level of degradation at time "t"; "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a+b", potentially degradable fraction.
ED (k=0.02; 0.03; 0.04; 0.05) - effective degradability calculated with outflow rates of 2, 3, 4 & 5%. SEM - standard error of mean.

reveals the potential of their being good sources of more nutrients for microbial growth (Djouvinov and Todorov, 1994) as Clark *et al.* (1992) and Gomes *et al.* (1994) reported a strong positive relationship between DM intake and microbial growth. The high potentially degradable DM fraction in the leaves studied is of interest for the fact that this parameter measures the proportion that is fermentable if this component does not bypass the rumen. However, this did not translate into high ED in the leaves of *T. grandis* and *T. grandis* in this experiment. This may have resulted from high cell wall contents (Van Soest, 1988), although this was not determined in this study. The findings of this investigation showed DM disappearance values for the leaves after 48 hrs of incubation to be satisfactory since they were above the prescribed 40-50% (Preston, 1986) to warrant further considerations as ruminant feed resources.

Degradation characteristics of the DM in the crop residues showed equally significant (P < 0.05) variations as seen in Table 3.

Potentially degradable DM fraction 'a+b' in the residues was measured highest in plantain peels with the value 73.77% while groundnut husk recorded the least value of 51.28%. The rate per hour of DM degradation did not vary (P > 0.05) between groundnut husk and pineapple peels. The slowest rate of 0.018/hr was recorded in plantain peels. All the residues studied had less than 50% ED values except for plantain peels when it was calculated at 2 and 3% outflow rates. This a confirmation of the generally low quality ascribed to crop residues. Only pineapple and plantain peels had DM disappearance values above 50% after 48 hrs of incubation. However, by the end incubation for 96 hrs, over 50% of the DM contents in the residues had disappeared from the rumen with the exception of that in groundnut husk.

Tropical roughages have been reported to be of low feeding value (Kimambo *et al.*, 1994). According to Preston (1986) the rate of degradation is an important parameter in the assessment of the fermentation of crop residues in the rumen. The low ED (k=0.05) of the DM content of the crop residues in this study, despite high potentially degradable values, is most likely a result of the low rate degradation observed suggesting therefore that they could have high fill values hence low intake and animal productivity (Mgheni *et al.* 2001). Measurements for DM disappearance from the residues after 48 hrs of incubation were satisfactory (Preston, 1986). However, when viewed against the potentially degradable fraction, the disappearance levels of the DM in the residues appeared virtually complete by 96 hrs of incubation. Nevertheless, Dhanoa (1988) had suggested that with low degradable feeds, incubation should be for longer time periods. This is to ensure that the potentially degradable fraction is reasonably characterized.

Estimates for the CP degradation characteristics and disappearance from incubation bags in the tree leaves studied are as shown in Table 4. Variations in all the parameters measured were significantly (P < 0.05) different.

The readily soluble CP fraction 'a' was significantly more in *F. exasperata* with a value of 25.88% as compared to the least value of 10.97% in *T. catappa*. *Ficus exasperata*

Table 4: Degradation characteristics and disappearance of CP in the tree leaves

	Ficus exasperata	*Spondias monbin*	*Tectonia grandis*	*Terminalia catappa*	SEM
Degradation characteristics					
Leaves					
a[1]%	25.88[a]	17.16[b]	16.88[b]	10.97[c]	-
b[2]%	31.50[a]	21.56[b]	29.72[a]	11.44[c]	1.12
c[3]/hr	0.047[a]	0.009[c]	0.012[c]	0.019[b]	0.002
a+b[4]%	57.38[a]	38.72[c]	46.60[b]	22.41[d]	1.12
Effective degradability (%)					
k=0.02	48.01[a]	23.66[c]	28.20[b]	16.53[d]	0.16
k=0.03	45.16[a]	22.00[c]	25.53[b]	15.39[d]	0.18
k=0.04	42.95[a]	21.02[c]	23.88[b]	14.64[d]	0.20
k=0.05	41.19[a]	20.37[c]	22.75[b]	14.11[d]	0.20
Disappearance (%)					
24hrs	46.50[a]	20.06[c]	22.31[b]	14.90[d]	0.24
48hrs	53.81[a]	23.53[c]	28.50[b]	17.63[d]	0.14
72hrs	56.34[a]	26.25[c]	33.00[b]	19.08[d]	0.12
96hrs	56.70[a]	28.32[c]	36.37[b]	20.53[d]	0.11

a,b,c,d means along same rows bearing different superscripts are significantly different ($P < 0.05$).

1,2,3,4 constants in the equation $P=a+b(1-e^{-ct})$ where "P" is level of degradation at time "t"; "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a+b", potentially degradable fraction.

ED (k=0.02; 0.03; 0.04; 0.05) - effective degradability calculated with outflow rates of 2, 3, 4 & 5%. SEM - standard error of mean.

as well had the highest estimate for the insoluble but rumen degradable fraction 'b' although this was not statistically different from the value recorded for *T. grandis*. The rate of degradation 'c' of CP in the leaves was fastest in *F. exasperata* (0.047/hr) while the estimated degradation rate did not differ between *S. monbin* and *T. grandis*. Potentially degradable CP was higher in the leaves of *F. exasperata* and *T. grandis* than in those of *S. monbin* and *T. catappa*. Effective CP degradability as was also observed with DM, decreased with increase in outflow rates. Similar observations relating to foregoing have been reported for dry matter and protein in tropical grass and legume forages (Mgheni *et al.*, 1996) and for plant and animal derived protein sources (Kamalak *et al.*, 2005). The ED of CP in *T. catappa* was least in the entire outflow rates used for calculation. Effective degradability of CP in the leaves, calculated as a proportion of the potentially degradable fraction, appeared mostly well degraded except for *T. grandis* that had less than 50%. The disappearance of the CP in all the leaves from the bags increased with increasing incubation time. At 48 hrs incubation time, the mean estimates for CP disappearance from the leaves of *F. exasperata* was significantly higher than that of the others, a trend maintained up till 96 hrs incubation time. The varied ($P < 0.05$) estimates for the degradation characteristics, effective degradability and disappearance of CP in the investigated residues are presented in Table 5.

The CP in rice offal was most readily soluble with a mean value of 26.16%. The peels from pineapple and plantain did not differ significantly in their insoluble but rumen degradable CP content. A significantly different rate of CP degradation, ranging from 0.011/hr (Plantain peels) to 0.039/hr (Rice offal) was observed in this study. Plantain peels had the least estimates for the potentially degradable CP fraction of 22.87%, which rose to a highest value of 57.19% in rice offal. As a proportion of the potentially degradable fraction the ED (k=0.05) of CP in the residues gave values of 57% and above. Crude protein loss from the residues, as in the foliages increased with incubation time. It was observed that there was a consistent significantly varied pattern in the of CP loss from the residues in the following decreasing order: Rice offal > Groundnut husk > Pineapple peels > Plantain peels.

The seemingly better degradation of rice offal may affect the availability of CP from this residue for use by rumen microbes. This view is supported by the findings of Salter *et al.* (1979) of the need to match the release of ammonia-N from dietary protein with the release of useable energy for feed resources to be of benefit to ruminant animals.

Conclusion: Our data in this experiment showed that the DM and CP contents of the tree leaves and crop residues evaluated on the basis of their rumen fermentation kinetics, presented significant variations between the feed resources under study in the two groups. Although there were noticeable differences within the groups, the tree leaves showed better nutritional quality in terms of their disappearance, rumen and effective degradability than the crop residues. This is an indication that these leaves could be considered

Table 5: Degradation characteristics and disappearance of CP in the crop residues

	Groundnut husk	Pineapple peels	Plantain peels	Rice offal	SEM
Degradation characteristics					
Residues					
a[1]%	17.72[b]	14.06[c]	11.25[d]	26.16[a]	-
b[2]%	20.81[b]	12.56[c]	11.62[c]	31.03[a]	1.10
c[3]/hr	0.022[c]	0.031[b]	0.011[d]	0.039[a]	0.004
a+b[4]%	38.53[b]	26.62[c]	22.87[d]	57.19[a]	1.10
Effective degradability (%)					
k=0.02	28.50[b]	21.60[c]	15.09[d]	46.70[a]	0.34
k=0.03	26.41[b]	20.35[c]	14.15[d]	43.73[a]	0.37
k=0.04	25.00[b]	19.46[c]	13.58[d]	41.52[a]	0.38
k=0.05	23.97[b]	18.79[c]	13.20[d]	39.80[a]	0.37
Disappearance (%)Residues					
24hrs	21.94[b]	21.38[c]	11.90[d]	46.41[a]	0.22
48hrs	28.50[b]	24.10[c]	14.34[d]	53.07[a]	0.20
72hrs	32.44[b]	25.40[c]	16.22[d]	55.60[a]	0.22
96hrs	34.78[b]	25.97[c]	17.53[d]	56.62[a]	0.21

a,b,c,d means along same rows bearing different superscripts are significantly different (P < 0.05).
1,2,3,4 constants in the equation P=a+b(1-e-ct) where "P" is level of degradation at time "t"; "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a+b", potentially degradable fraction.
ED (k=0.02; 0.03; 0.04; 0.05) - effective degradability calculated with outflow rates of 2, 3, 4 & 5%. SEM - standard error of mean.

potential sources of roughages in this climatic zone particularly in the dry season when regular feed resources are lean and low in quality. The leaves of *F. exasperata* and the residues from rice were outstanding in terms of the different parameters measured in either of the groupings. It is our belief that the results of the DM and CP degradation kinetics in this study could be useful information when considering supplementation strategies for ruminant diets especially in the topics.

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