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ORIGINAL ARTICLE

Effects of species and season on chemical composition and ruminal crude protein and organic matter degradability of some multi-purpose tree species by West African dwarf rams

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Summary

Seasonal chemical composition and ruminal organic matter (OM) and crude protein (CP) degradabilities were determined in four tropical multi-purpose tree species (MPTS) namely; *Pterocarpus santalinoides, Grewia pubescens, Enterolobium cyclocarpum* and *Leucaena leucocephala.* Three West African dwarf (WAD) rams fitted with permanent rumen cannula were used for the degradability trials. Foliage samples were collected four times to represent seasonal variations as follows: January – mid dry; April – late dry; July – mid rainy and October – late rainy seasons. Leaf samples were randomly collected from the trees for estimation of dry matter (DM) and chemical composition. Ruminal in sacco OM and CP degradabilities were estimated from residues in nylon bags. All samples had high CP (161–259 g/kg DM) and moderate fibre concentrations [neutral detergent fibre (without residual ash], 300–501 g/kg DM; acid detergent fibre (without residual ash), 225–409 g/kg DM and acid detergent lignin, 87–179 g/kg DM across seasons. Interaction effects of species and season on chemical composition were highly significant (p = 0.001) except for trypsin inhibitor (p = 0.614). The MPTS recorded more than 60% OM and CP degradability at 24 h, which implied that they were all highly degradable in the rumen. Their incorporation into ruminant feeding systems as dry season forage supplements is therefore recommended.

Introduction

In Sub-Saharan Africa, the dry season is always a critical period when most feed resources especially grasses and herbaceous forages dry out. Multi-purpose tree species (MPTS) foliage has been recognized as reliable substitute either as sole or protein supplements which can be utilized to prevent decline in the productivity of animals during this period (Kanani et al., 2006). Foliage, twigs, pods and fruits of MPTS have been used as cheap and affordable supplements for ruminant animals in herds of resource poor farmers in several regions of the World. The foliage of MPTS has been used to supplement straws to alleviate crude protein (CP) deficiency in fibrous feeds, reduce rumen acidosis and other health-related problems, and improve intake and productivity of animals (Owens et al., 1998; Salem et al., 2006).

Despite these benefits, adoption of MPTS into farming systems by resource-poor farmers was generally poor. This is due to several reasons among which were slow establishment and high labour requirements to lop the tree foliage especially in cut and carry systems as well as poor adaptation to the prevailing soil and climatic conditions (AFNETA, 1996). To encourage the adoption of MPTS by farmers, evaluation of different species peculiar to different geographical areas is necessary. Also, the levels of various secondary metabolites present in each species as well as their effects on availability of other nutrients and nutritional quality of the plants should be well documented.

Although many investigations have been carried out on the nutritive potentials of MPTS in several African countries (Ahmed and El-Hag, 2004; Ben Salem et al., 2005; Gasmi-Boubaker et al., 2005; Salem et al., 2006; Tefera et al., 2008), there are still several species yet to be covered in these countries. A detailed study and documentation of the nutritive potentials of different MPTS for different countries and geographical locations is therefore necessary to expand the array of tree species with forage value available for use as protein supplements by farmers during periods of feed scarcity.

Pterocarpus santalinoides, a leguminous tree, is native to tropical Africa and tolerates acidic soils. It was one of the MPTS that recorded high dry matter (DM) yield and dry season green leave retention in alley cropping trials (Gutteridge, 1990; Topps, 1992). *Grewia pubescens*, though a non-leguminous tree belonging to the family Tiliaceae, is native to tropical Africa and also well tolerant of acid soils. It remains green longer in the dry season and coppices vigorously with good weed control. Its leaves are used for forage and its ash is a vegetable salt source (Le Houerou, 1980) while its bark is good for cordage which is used for making fishing net and whip in several parts of Africa (ICRAF, 1994). *Enterolobium cyclocarpum*, though originated from tropical America, is a leguminous tree that has been well adapted to soil and climatic conditions of Africa. It has potential for high forage yield with edible fruit and seeds which could be used for livestock feeding (Blair et al., 1989). *Leucaena leucocephala*, which was included in this trial as the control, is also leguminous and exotic and has received much research attention for over three decades. It has high potentials as ruminant feed in the tropics and sub-tropics (Kanani et al., 2006) because of its high level of protein and evergreen nature of its foliage. This study was conducted to further explore the nutritive potentials of these MPTS in comparison with *L. leucocephala* through the determination of their seasonal chemical composition, secondary metabolites and in-sacco organic matter (OM) and CP degradability.

Materials and methods

Experimental site

This study was carried out at the livestock farm of the International Livestock Research Institute (ILRI). The site is located at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (7°20′N; 3°54′E). Ibadan lies in the derived savanna agro-ecological zone and has a bimodal rainfall pattern which typically peaks around June and September with a break of approximately 2–3 weeks in August. Temperatures are fairly uniform with daytime values of 30–34 °C during the late dry season while the lowest night temperature of around 24 °C are recorded during the harmattan period (between December and February).

Experimental design

The experiment was arranged in a 4 × 4 factorial design with four MPTS and four seasons. The four MPTS were *P. santalinoides, G. pubescens, E. cyclocarpum* and *L. leucocephala* and the seasons were mid rainy, late rainy, mid dry and late dry seasons. These species were selected because of their records of high nutrient content and dry matter yield with good dry season leave retention and adaptation to the acidic soils and climatic conditions of humid tropics.

Hedgerow establishment and management

The land was cleared of existing vegetation in April 2000 followed by ploughing 4 days later and allowed to rest for 2 weeks before harrowing. The experimental area measuring about 4000 m^2 was mapped out after harrowing. It was divided into three blocks (replicates) and each block sub-divided into four plots each measuring 16 m × 10 m. The layout was according to the alley farming model of 4-m alleys and 6 m between plots. The intra row spacing was 0.25 m. This close spacing was used because the focus was biomass yield per unit area rather than per tree. Each plot had five rows of trees, 4 m apart making a total of 40 stands per row and 200 stands per MPTS.

The seeds for the study were obtained from the International Center for Research in Agroforestry (ICRAF) station at IITA, Ibadan. They were established in the nursery in March, 2000. Nursery nylon bags were purchased, filled with loamy soil and arranged in blocks of 20 m by 20 m under the nursery shed made of bamboo poles and palm fronds. Two seeds were sown into each bag and watered daily until rainfall became frequent in June. The seedlings were transplanted into the field in August, 2000 and all the tree seedlings that died within the first 8 weeks after transplanting were replaced with spare plants from the nursery. The plots were maintained weed free by manual clearing with hoes.

Sample collection

Sampling commenced in July 2001 when approximately 0.2 kg leaf samples per plant stand (leaves + fine stem <6 mm diameter) were randomly collected from the MPTS for the determination of the chemical composition and estimation of *in situ* ruminal degradation. Samples were collected four times to represent seasonal variations as follows: July, 2001 – mid rainy; October, 2001 – late rainy; January, 2002 – mid dry; April, 2002 – late dry seasons. Sampling was carried out during the first and last week of each month. Six plants per row from the three middle rows were tagged for sampling to prevent border effects and ensure that the same plants were repeatedly sampled. This implied that 18 plants per plot or 72 stands per MPTS were sampled, dried in an oven at 60 °C for 72 h and kept frozen (–4 °C) until required for analysis. This was repeated again between July, 2002 and April, 2003 and samples for the two years were later pooled together for analysis.

In sacco degradation

Ruminal in sacco degradation was determined according to Ørskov et al. (1980). Prior to milling, samples were oven-dried at 60 °C for 96 h to determine the residual dry matter (DM). Dried forage samples milled to pass through a 2.5-mm sieve screen were weighed (5 g/bag) into 9 cm × 18 cm nylon bags (pore size 40 μm, Polymon; Swiss Silk Bolting Cloth Mfg., Zurich, Switzerland). Duplicate sample bags were incubated for 6, 12, 24, 48, 72 and 96 h in the rumen of three West African dwarf rams (approximately 35 kg live weight). This resulted in each ram serving as a replicate. All bags were inserted at the same time, just before morning feeding. The animals were fed a standard diet of grass hay and concentrates (2:1) throughout the experimental period. Feeds were offered in two equal meals at 07:00 and 19:00 hours. The rams also had free access to clean water and salt licks. Immediately after withdrawal, the bags were kept on ice cubes to stop the fermentation process and then washed gently under running tap water for 30 min. Finally, they were dried at 60 °C for 48 h in a forced air oven, desiccated for 30 min and then weighed. To determine washing loss (0-h disappearance), three additional bags containing 5 g of each test feed were soaked in a water bath at 39 °C for 1 h and thereafter underwent the same washing and drying procedures as the incubated bags.

Degradabilities (Y) of OM and CP were calculated using the equation of Ørskov and McDonald (1979):

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

where a is the soluble fraction,

b is the insoluble but fermentable fraction,

c is the degradation rate constant of the 'b' fraction, t is the degradation time 6, 12, 24, 36, 48, 72 and 96 h and L is the lag phase.

The nonlinear parameters a, b, c and L were estimated using GraphPad Prism (2009). The effective degradability (ED) of OM and CP was calculated using the following equation (McDonald, 1981):

$$\text{ED} = a + (bc/(c + k)) \times e^{-kL},$$

where k is the estimated rate of outflow from the rumen and a, b, c and L are the same parameters as described above. The ED of OM and CP was estimated as ED2, ED5 and ED8 assuming rumen outflow rates of 2%, 5% and 8% per hour, which is representative for low, medium and high feeding levels (ARC, 1980). The in sacco ruminally undegraded fraction was estimated by subtracting a and b fractions from 100.

Chemical analyses

The foliage samples and residues after in sacco incubation were milled through a 1-mm sieve and analysed for CP, neutral detergent fibre (not assayed with a heat-stable amylase and expressed exclusive residual ash, NDFom) and acid detergent fibre (expressed exclusive residual ash, ADFom). Lignin was determined on ADF residues by solubilization of cellulose with sulphuric acid. Crude protein (ID 984.13) was analysed according to the standard methods of AOAC (1997). The NDFom was determined according to Van Soest et al. (1991) while ADFom was determined according to AOAC (1997; method 973.18). The NDFom was determined without sodium sulphite. Hemicellulose was calculated as NDFom – ADFom and cellulose as ADFom - Lignin. Non-fibre carbohydrates (NFC, g/kg DM) were calculated as NFC = 1000 – CP – ash – EE – NDFom, with all concentrations expressed as g/kg DM. Tannin content was determined by the Folin–Denis method as outlined by Hoff and Singleton (1977), trypsin inhibitor was determined according to the method of Kakade et al. (1974) using benzyl-DL-arginine-P-nitroanilide as substrate while the phytic acid content was determined with the method of Wheeler and Ferrell (1971).

Statistical analyses

The data were subjected to analysis of variance using the general linear model (GLM) procedure of SAS (2002) in a 4 x 4 factorial arrangement with three field replicates. The model used was:

$$Y_{ijk} = \mu + t_i + s_j + (ts)_{ij} + \varepsilon_{ijk}$$

Where: Y_{ijk} is observation, μ is population mean, t_i is treatment effect (i = 1 to 4), s_j is season effect (j = 1 to 4), $(ts)_{ij}$ is interaction between treatment and season, and ε_{ijk} is residual error.

Results

Chemical composition

The MPTS showed higher DM content from 366 g/kg DM in *P. santalinoides* to 440 g/kg DM in *G. pubescens* during the mid dry season than in other seasons (p = 0.001; Table 1). They also recorded CP content of more than 100 g/kg DM with highest values ranging between 213 g/kg DM in *G. pubescens* to 259 g/kg DM in, *E. cyclocarpum* during the mid rainy season except *L. leucocephala* that recorded 224 g/kg DM during the mid rainy season and higher value of 226 g/kg DM during the late rainy season. Low contents of secondary metabolites were observed in all the MPTS across seasons with a range of 13.5–33.5, 0.8–11.5 and 3.0–17.4 g/kg DM for tannins, trypsin inhibitors and phytic acid respectively. Interaction effects between species and season were observed for DM, CP and secondary metabolite contents of the MPTS except for trypsin inhibitor (p = 0.614).

There were significant differences (p = 0.001) in the fibre components of the MPTS across seasons (Table 2). The NDFom values ranged from 300 g/kg DM in *G. pubescens* during the mid dry season to 501 g/kg DM in *P. santalinoides* during the late dry season. The ADFom content ranged from 225 to 409 g/kg DM in *L. leucocephala* during the late rainy and late dry seasons respectively. The lignin, cellulose, hemicellulose and NFC contents followed similar trend across seasons. Highly significant season × species interaction (p = 0.001) was observed for all the fibre components.

Table 1 Effects of species and season on dry matter, crude protein and secondary metabolites contents (g/kg DM) of multi-purpose tree species (MPTS)

	DM (g/kg)	CP	Tannin	Trypsin inhibitor	Phytic acid
Mid rainy season					
E. cyclocarpum	299	259	17.8	2.3	7.2
G. pubescens	277	213	20.4	5.6	13.0
L. leucocephala	267	224	31.2	6.8	12.7
P. santalinoides	306	217	24.8	2.9	13.7
Late rainy season					
E. cyclocarpum	369	243	21.8	0.8	4.5
G. pubescens	347	180	25.6	3.1	10.2
L. leucocephala	289	226	33.5	4.9	17.4
P. santalinoides	333	208	26.9	3.2	7.5
Mid dry season					
E. cyclocarpum	439	199	15.4	3.7	4.8
G. pubescens	440	168	16.2	10.7	13.3
L. leucocephala	394	212	24.5	11.5	7.2
P. santalinoides	366	189	23.4	8.5	7.2
Late dry season					
E. cyclocarpum	320	177	13.5	5.6	3.0
G. pubescens	310	161	15.3	11.3	6.3
L. leucocephala	298	211	24.0	11.0	6.2
P. santalinoides	327	185	23.4	11.3	8.4
SEM	7.22	7.67	1.78	0.65	1.00
Effect (p-level)					
MPTS	0.001	0.001	0.001	0.001	0.001
Season	0.001	0.001	0.001	0.001	0.001
MPTS x Season	0.001	0.005	0.003	0.614	0.001

DM, dry matter; CP, crude protein; SEM, standard error of means (interaction).

Ruminal degradation characteristics

Table 3 shows the nonlinear parameter estimates and effective degradability values of OM of the MPTS. Season × species interactions were observed for all the parameters estimated with the exception of lag time. The soluble fraction (*a*) ranged from 17.9% in *P. santalinoides* during the late rainy season to 33.0% for *G. pubescens* during the mid rainy season. The insoluble but degradable fraction (*b*) was 26.1% in *L. leucocephala* during the late rainy season and 45.2% in *G. pubescens* during the mid rainy season. The degradation rate constants (*c*) varied widely between MPTS with similar rates for both *E. cyclocarpum* and *G. pubescens.* A lag phase occurred before the degradation of the b fraction and effective degradability values of OM at the different passage rates were consistently higher in *E. cyclocarpum* and *G. pubescens*.

Season × species interactions were observed for the soluble fraction (*a*), degradation rate (*c*) and effective degradability of the CP of the MPTS

Table 2 Effects of species and season on the fibre and non-fibre carbohydrate contents (g/kg DM) of the multi-purpose trees

	NDFom	ADFom	Lignin	Hemi	Cellulose	NFC
Mid rainy season						
E. cyclocarpum	403	318	87	85	231	252
G. pubescens	416	319	98	97	221	280
L. leucocephala	416	283	119	133	163	268
P. santalinoides	466	383	114	83	269	228
Late rainy season						
E. cyclocarpum	401	227	101	174	126	262
G. pubescens	383	280	99	103	181	329
L. leucocephala	424	225	140	199	85	232
P. santalinoides	415	300	134	115	166	277
Mid dry season						
E. cyclocarpum	312	237	102	75	134	361
G. pubescens	300	230	114	70	116	437
L. leucocephala	461	293	150	168	143	203
P. santalinoides	466	408	160	58	248	267
Late dry season						
E. cyclocarpum	455	368	124	87	244	258
G. pubescens	392	327	136	65	191	328
L. leucocephala	485	409	155	76	254	184
P. santalinoides	501	395	179	106	216	228
SEM	8.1	8.3	3.8	13.9	10.7	10.3
Effect (p-level)						
MPTS	0.001	0.001	0.001	0.001	0.001	0.001
Season	0.001	0.001	0.001	0.001	0.001	0.001
MPTS x Season	0.001	0.001	0.001	0.001	0.001	0.001

NDFom, neutral detergent fibre expressed exclusive residual ash; ADFom, acid detergent fibre expressed exclusive residual ash; Hemi, hemicellulose; NFC, non-fibre carbohydrates; SEM, standard error of means (interaction).

(Table 4). The soluble fraction varied from 23.5% in *L. leucocephala* during the late rainy season to 48.3% in *E. cyclocarpum* during the mid rainy season. The MPTS were degraded at different rates and a lag phase occurred prior to the beginning of degradation of the *b* fraction. The result showed that more than 50% CP were degraded in most of the MPTS at 24 h while undegraded fraction ranged from 17.5% to 47.6%. Effective degradability values of CP at the three assumed passage rates of 2%, 5% and 8% followed similar trend observed in the OM with *E. cyclocarpum* and *G. pubescens* consistently recording higher values than other MPTS.

Discussion

Chemical composition

The chemical composition of the MPTS showed substantial variation across species and seasons. The DM content was higher during the dry than rainy seasons and was within the ranges reported for browse trees under similar conditions in southwestern Nigeria (Asiegbu and Anugwa, 1988; Anele et al., 2008) and elsewhere (Topps, 1992; Ly et al., 2001). Greater DM content observed during the dry season might be as a result of reduced photosynthetic activity due probably to the lower moisture levels in the soil during this period relative to the rainy season. Contrary to this, greater CP content recorded during the rainy season might be due to re-growth of new flush of leaves during this period and their lower CP content during the dry season may be largely due to the moisture stress experienced by the trees during this period. The little decline in the CP content between the rainy and dry season showed that the MPTS used in this study are capable of retaining this important nutrient further into the dry season than their herbaceous counterparts and grasses. The lowest CP content of *G. pubescens* across seasons is probably because it is a non-leguminous species. Its CP content is however, above the threshold of 60 g/kg DM required by the microbes in the rumen to support metabolic functions of their host (Van Soest, 1994). The CP content across seasons for all MPTS investigated was adequate to support meat and milk production of ruminant animals (Lamers and Khamzina, 2010). They may therefore serve as ready source of year-round cheap protein supplements for

Table 3 Effects of species and season on the nonlinear parameter estimates and effective degradability values of organic matter

	a (%)	*b* (%)	*c* (%/h)	Lag (h)	Undegraded (%)	ED (2%)	ED (5%)	ED (8%)
Mid rainy season								
E. cyclocarpum	27.3	33.0	0.032	5.03	39.2	45.7	37.3	33.6
G. pubescens	33.0	45.2	0.034	4.93	21.7	58.9	47.3	42.1
L. leucocephala	22.5	30.7	0.044	4.94	46.8	41.5	33.6	29.7
P. santalinoides	21.3	31.4	0.038	5.06	47.2	39.9	31.9	28.1
Late rainy season								
E. cyclocarpum	28.3	37.3	0.030	5.33	34.3	48.4	39.1	35.0
G. pubescens	31.1	39.9	0.034	4.69	28.8	54.1	44.1	39.4
L. leucocephala	21.6	26.1	0.049	4.92	52.2	37.9	31.3	27.0
P. santalinoides	17.9	34.9	0.034	5.06	47.2	37.7	28.9	24.9
Mid dry season								
E. cyclocarpum	26.5	34.0	0.037	5.19	39.5	46.3	37.6	33.6
G. pubescens	29.7	40.0	0.042	5.13	30.3	54.0	43.6	38.7
L. leucocephala	19.9	33.3	0.031	5.53	46.7	38.1	29.6	25.9
P. santalinoides	19.0	33.8	0.033	5.06	47.1	38.0	29.4	25.6
Late dry season								
E. cyclocarpum	25.9	34.9	0.031	5.11	39.2	44.9	36.1	32.3
G. pubescens	31.5	44.7	0.033	5.07	23.7	56.6	45.2	40.2
L. leucocephala	21.9	34.5	0.037	5.43	43.6	41.7	33.0	29.0
P. santalinoides	22.1	29.3	0.049	5.23	48.5	40.9	33.3	29.5
SEM	0.60	1.40	0.0037	0.23	1.57	1.03	0.92	0.85
Effect (p-level)								
MPTS	0.001	0.001	0.026	0.459	0.001	0.001	0.001	0.001
Season	0.001	0.636	0.916	0.325	0.116	0.006	0.003	0.002
MPTS x Season	0.002	0.001	0.006	0.798	0.001	0.015	0.019	0.014

Undegraded (%) = 100 − (a + b); ED (2%, 5% and 8%), effective degradability at 2%, 5% and 8% assumed passage rates; SEM, standard error of means (interaction).

herds of resource-poor farmers in Sub-Saharan Africa and thereby help to improve the quality of feed and at the same time reduce the cost of production.

On the average, the level of secondary metabolites in the MPTS as shown by the contents of tannins, trypsin inhibitors and phytic acid contents is considered low and will not have any negative effect on digestion (Mueller-Harvey, 2006). Apart from poultry and horses which have been reported to develop symptoms of toxicity when fed tannic acid at levels of about 20 mg/g DM of diet (Chang and Fuller, 1964), most reports from literature confirmed that ruminant animals are able to handle browse plants with tannin content below 100 mg/g DM (Gasmi-Boubaker et al., 2005) although, the tolerance level may vary between animal species (Onwuka, 1992). Apart from seeds, trypsin inhibitors and phytic acid have not been reported at levels that could pose nutritional dangers to ruminant animals in most tropical browse species, thus, their analysis before feeding may become optional for farmers in Sub-Saharan Africa.

Contrary to expectation, greater NDFom and ADFom values were observed in mid rainy season than in mid dry season. Although, there is no clear explanation for this, one can only speculate on the probable cause. Despite greater NDFom content of *P. santalinoides* and *L. leucocephala*, all the MPTS in this study had NDFom values below 650 g/kg DM suggested as the limit above which intake of tropical feeds by ruminant animals would be limited (Van Soest, 1994). The range of NFC content showed that the trees under evaluation can be easily degraded or fermented because NFC is an estimate of the carbohydrate pool that differ in digestibility from NDFom. It has also been reported that NFC has a positive relationship with ammonia nitrogen (NH_3-N) utilization in the rumen (Tylutki et al., 2008). As nitrogen utilization by rumen microflora is related to the amount of fermentable energy, the adequate NFC contents especially in *G. pubescens* could enable efficient microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Cabrita et al., 2006).

In sacco OM and CP degradation

The high washing loss (0 h disappearance) of MPTS evaluated in this study is an indication of the

Table 4 Effects of species and season on the nonlinear parameter estimates and effective degradability values of crude protein

	a (%)	*b* (%)	*c* (%/h)	Lag (h)	Undegraded (%)	ED (2%)	ED (5%)	ED (8%)
Mid rainy season								
E. cyclocarpum	48.3	32.7	0.025	5.67	18.9	64.3	56.5	53.3
G. pubescens	35.0	44.6	0.041	5.15	20.3	61.9	50.5	44.9
L. leucocephala	25.7	29.9	0.045	4.91	44.4	43.7	36.1	32.5
P. santalinoides	33.0	19.3	0.069	4.52	47.6	46.4	41.0	39.0
Late rainy season								
E. cyclocarpum	44.5	38.0	0.027	5.56	17.5	63.9	54.6	50.7
G. pubescens	32.5	41.5	0.047	5.03	25.9	58.9	48.2	42.9
L. leucocephala	23.5	31.1	0.045	4.96	45.3	42.6	34.6	30.8
P. santalinoides	39.1	25.9	0.033	5.19	34.9	53.6	47.02	44.0
Mid dry season								
E. cyclocarpum	44.2	33.2	0.032	5.27	22.6	62.7	54.3	50.6
G. pubescens	33.9	44.7	0.031	5.19	21.3	58.5	47.1	42.2
L. leucocephala	26.2	27.6	0.039	4.99	46.2	42.6	35.6	32.2
P. santalinoides	31.2	25.6	0.038	5.19	43.2	46.1	39.5	36.5
Late dry season								
E. cyclocarpum	43.5	34.5	0.041	5.09	21.9	64.6	55.7	51.4
G. pubescens	40.8	40.1	0.045	4.99	19.1	65.7	55.5	50.3
L. leucocephala	26.1	29.6	0.046	5.05	44.3	44.3	36.7	33.0
P. santalinoides	31.8	30.1	0.031	5.27	38.0	47.3	40.1	36.9
SEM	1.69	3.01	0.0065	0.21	1.72	1.13	1.26	1.39
Effect (p-level)								
MPTS	0.001	0.001	0.043	0.043	0.001	0.001	0.001	0.001
Season	0.459	0.666	0.197	0.839	0.101	0.005	0.022	0.067
MPTS x Season	0.003	0.435	0.012	0.232	0.001	0.001	0.001	0.002

Undegraded (%) = 100 − (a + b); ED (2%, 5% and 8%), effective degradability at 2%, 5% and 8% assumed passage rates; SEM, standard error of means (interaction).

presence of soluble or ruminally degradable nutrients that may be rapidly utilized in the rumen. The MPTS recorded more than 60% OM and CP degradabilities at 24 h which implied that they were extensively degraded in the rumen. Variation in protein degradability is directly related to the proportion of structural and non-structural protein and carbohydrate fractions which in turn affects their solubility and bioavailability (Whetton et al., 1997). Extensive ruminal degradation of CP results into ammonia production above the level that can be utilized for microbial protein synthesis or reabsorbed into the rumen and converted into urea then excreted in urine. This constitutes a loss to the nitrogen economy of the animal and consequently puts a limit on animal production (Buxton, 1996). The CP degradability as observed in this study was not affected by the presence of secondary metabolites probably due to their low levels. Several studies have documented effects of secondary metabolites especially tannins (Ammar et al., 2004; Gasmi-Boubaker et al., 2005) on CP degradability and they concluded that tannins at levels reported in this study could not affect nutrient degradability and might even be beneficial to the animal.

The observed differences in OM and CP degradation characteristics of the MPTS may be partly due to the differences in their chemical composition which is influenced by the species, season or age of the trees. The range of values for the soluble '*a*', potentially degradable fractions '*b*', the rate '*c*' and extent of OM and CP degradation in this study agreed with earlier reports (Perera et al., 1996; Larbi et al., 1998; El Hassan et al., 2000) which also confirmed significant differences in OM and CP degradation characteristics of several tropical browse trees. Degradation constants as measured by the in sacco nylon bag technique are strongly related to digestible DM intake (Kibon and Ørskov, 1993). Thus, inter-species variations in OM and CP degradabilities could result in differential intakes of the MPTS when given as sole diets to animals.

MPTS in ruminant feeding systems in south-western Nigeria

Differences in chemical composition and in OM and CP degradation characteristics have practical implications for MPTS-based agroforestry technologies in the lowland tropics and ruminant feeding systems in south-western Nigeria. Because of their high CP content and potential extent of OM and CP degradation, they can be a source of rapidly degradable nutrients for microbial protein synthesis in the rumen. The portion that is not degraded in the rumen, e.g. the ruminally undegraded CP could be retained within the body and contribute to the amino acids pool available for synthesis of milk (Lamers and Khamzina, 2010). Majority of resource poor farmers in south-western Nigeria keep their stock under semi-intensive system. They allow them to roam about and graze on natural pastures during the day and feed them with small amounts of farm wastes and low quality roughages as well as providing sleeping shelter for them at night. This is because feed from conventional sources are very expensive especially during dry seasons, leading to high cost of feeding which cannot be afforded by the farmers. Taking cognizance of the high CP content of the MPTS evaluated in this trial, they could be used as cheap CP supplements to farm wastes to reduce the cost of feeding, enhance utilization of low quality roughages and may help improving the performance of ruminant livestock in tropical countries (Patra, 2010). Since the nutrients are retained for most part of the year, the MPTS will be more readily available than most conventional supplements and more nutritious than the natural pastures that would have been depleted in quantity and quality during dry seasons.

As illustrated in Table 5, stock of resource poor farmers depend mainly on grazing, thus it can be assumed that 80% of DM intake of ruminants is from grazing with supplements making up the remaining 20%. The type of supplement will depend on the crop cultivated by the farmer. This commonly ranges from cassava or yam peels to cowpea or melon husks and straw as well as other stubbles. Incorporation of MPTS foliage could increase the CP content to above 10% of DM, even at low levels of supplementation. With depleted grazing resources in the dry season, the grazing period could be drastically reduced and level of foliage intake increased to 50%. This practice will increase the CP content of diet to 14% or above during the dry season and at the same time reduce the cost of feeding and amount of energy normally expended on trekking in search for grazing resources.

Table 5 Influence of MPTS supplementation on current ruminant feeding regime in south-western Nigeria

	Resulting CP content of diet (% DM)	
	Rainy	Dry
80% Grazing (CP content 8% DM in rainy and 4% DM in dry season)	6.4	3.2
+ 20% cassava peels (CP content 5% DM) or	7.4	4.2
+ 20% yam peels (CP content 4% DM) or	7.2	4.1
+ 20% cowpea / melon husk (CP content 12% DM) or	8.8	5.6
+ 20% MPTS (CP content 20% DM in rainy and 16% DM in dry season)	10.4	6.4
50% MPTS + 50% cowpea or melon husk	–	14

Nutrients levels were obtained from tropical feeds composition table (Aduku, 1993).
MPTS, multi-purpose tree species; CP, crude protein, DM, dry matter.

Excess foliage produced during rainy season could be sun-dried and stored till dry season to be fed as dried herbage or milled and fed as leaf meal or along with other farm wastes as total mixed rations. Alternatively, the foliage could be ensiled, especially during periods of high humidity when sun-drying may not be feasible. The MPTS could also be used in live fences, feed gardens, fodder banks, intensive feed garden, improved fallow and alley farms (Paterson et al., 1996) as sources of home grown supplements for low quality crop residues, and household wastes. Since all MPTS contain secondary metabolites, their level of inclusion in animal rations should be kept low, perhaps at about 16% (Patra, 2010) for greater efficiency of nutrient utilization from low quality roughage base diets.

Conclusions

The MPTS evaluated in this study recorded high levels of CP and NFC, moderate fibre levels and low contents of secondary metabolites. In sacco degradability trial showed presence of both ruminally degradable and undegradable dietary nutrients. Cognizance of the advantage of ruminally degradable nutrients to rumen microbes and undegradable dietary nutrients to the host ruminant animal, intensification of screening trials on indigenous MPTS to identify those that are rich in both proportions is hereby advocated. *Pterocarpus santalinoides* and *G. pubescens* demonstrated ability to retain most of their nutrients in the rumen and release such in the lower gut. Further research should therefore be intensified on these two species to identify the best seasonal management strategies and frequency of defoliation that will guarantee optimum yield of foliage at the best quality and quantity. *In vivo* studies to determine the optimum level of supplementation in total mixed rations are also necessary.

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