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Seasonal chemical composition, *in vitro* fermentation and *in sacco* dry matter degradation of four indigenous multipurpose tree species in Nigeria

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ABSTRACT

A study was carried out to estimate the nutritive value of four indigenous multi-purpose tree (MPT) species (*Enterolobium cyclocarpum*, *Treculia africana*, *Gliricidia sepium* and *Millettia griffoniana*) by the evaluation of their seasonal chemical composition, *in vitro* fermentation and *in sacco* dry matter (DM) degradation. The main objective of the study was to assess the potential of these indigenous MPT in supplementing the feed of ruminant animals during the dry season when grasses are scarce and their quality generally fall short of animal requirements. Leaf samples were randomly collected from the trees for estimation of DM, crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDFom), acid detergent fibre (ADFom), lignin (sa), *in vitro* fermentation and *in sacco* DM degradation. Samples were collected three times to represent seasonal variations as follows: November: early dry; February: mid-dry and April: late dry seasons.

Abbreviations: ADFom, acid detergent fibre expressed exclusive residual ash; CP, crude protein; DM, dry matter; ED, effective degradability; EE, ether extract; GV, gas volume; ME, metabolizable energy; MPT, multi-purpose trees; NDFom, neutral detergent fibre expressed exclusive residual ash; NFC, non-fibre carbohydrates; OMD, organic matter digestibility; PD, potential degradability; SCFA, short-chain fatty acids; WAD, West African dwarf.

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All samples had high CP (160–199 g/kg DM) and moderate fibre concentrations (NDFom, 380–580 g/kg DM; ADFom, 290–400 g/kg DM and lignin (sa), 75–107 g/kg DM). *T. africana* recorded the highest (180–199 g/kg DM) ($P<0.001$) CP content throughout the seasons. The values obtained for the *in vitro* fermentation characteristics and *in sacco* DM degradation of these indigenous MPT indicated the presence of potentially degradable nutrients in the MPT. Data from this study showed that *E. cyclocarpum*, *T. africana*, *G. sepium* and *M. griffoniana* have potentials that could be harnessed as feed supplements for ruminant animal production in Nigeria during the dry season.

1. Introduction

Ruminant animal production systems in Nigeria are generally characterized by limitations posed by non-availability of year-round feed resources due to prolonged annual dry season. Many grasses, such as *Panicum maximum*, *Pennisetum purpureum*, *Andropogon gayanus*, *A. tectorum*, *Cynodon nlemfuensis* and *C. dactylon*, have played prominent roles in forage research and livestock production in Nigeria. Most of these grasses usually occur as components of the natural vegetation that constitute the cheapest grazing resource to ruminant animals (Mohammed-Saleem, 1994). The intake of animals on the natural vegetation is fairly high during the growing season as the plants produce fresh and lush leaves and stem that could be grazed and utilized accompanied by reasonable body weight gains and general performance. As the plants mature, all their quality indices depreciate rapidly aggravated by the approaching dry season. Animal intake, digestibility and other quality variables also progressively decrease to the extent that, depending on the severity of the dry season, considerable proportion of the weight earlier gained is lost and the general animal performance negatively affected (Tarawali et al., 1999).

As part of global efforts to improve animal nutrition during this critical period of the year, attention is being shifted to the evaluation of indigenous multi-purpose tree (MPT) species. Apart from being sources of high quality feed resource during the dry season by production of higher dry matter and ability to retain or produce green leaf during this period of low soil moisture, MPT also provide other benefits such as shade, fuel wood, green manure and improved land use systems (Cobbina et al., 1990). A lot of these MPT species can also fix atmospheric nitrogen, and in this way, improve soil fertility. These indigenous MPT are well distributed throughout Nigeria and adapted to the hot tropical climate (Anele et al., 2008). They thrive very well in soils that are low in pH and nutrient level and will thus improve land use through the fixation of atmospheric nitrogen. These indigenous MPT species are easily established, have exhibited rapid regrowth after been lopped and ability to remain productive under repeated cutting at frequent intervals. The current utilization level of these indigenous MPT is still low compared with their potentials.

Browse trees are important in ruminant feeding systems. They have been reported to be more nutritious than most grasses and herbaceous legumes and conserve their nutrients into the dry season when feed resources are depleted (FAO, 1997). The leaves from these MPT are lopped and fed to the animals during the dry season. Thus, they form a readily available source of valuable feed supplements for herds of resource-poor farmers. This study intends to contribute towards addressing shortages in quantity and quality of forages in the tropics especially Nigeria through the assessment of the nutritive potentials of four indigenous MPT, namely *Enterolobium cyclocarpum*, *Treculia africana*, *Gliricidia sepium* and *Millettia griffoniana*.

2. Materials and methods

2.1. Experimental site

The experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. The site lies within the derived savanna (formerly a rainforest) agro-ecological zone of southwestern Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Temperatures are fairly uniform with daytime values of 28–30 °C during the rainy season and 30–34 °C during the dry season with the lowest night temperature of around 24 °C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to the dry season (55–84%). The temperature of the soil ranges from 24.5 to 31.0 °C (*Source*: Agromet Dept., UNAAB).

Four indigenous MPT, namely *E. cyclocarpum*, *T. africana*, *G. sepium* and *M. griffoniana*, were established in June 2004 and biomass production determined the year after.

2.2. Experimental design

A 4 (MPT) × 3 (season) factorial design with three replicates was used to examine the effect of season on the chemical composition, *in vitro* fermentation and *in sacco* dry matter (DM) degradation of the MPT. Each of the MPT constituted a treatment as follows: *E. cyclocarpum*, *T. africana*, *G. sepium* and *M. griffoniana.* The experimental area was divided into three equal parts and each part sub-divided into four plots each measuring 40 m × 10 m with spacing of 3 m between the plots. The treatments were randomly assigned to plots with each MPTS planted in three different plots which constituted the replicates. Each plot had five rows of plants, spaced two meters apart, a total of twenty stands per species per row and hundred stands per plot. One thousand and two hundred seedlings of the MPT were used in this study, with each MPT contributing 300 seedlings.

2.3. Sample collection

The biomass production of each MPT was determined by cutting their hedgerows back to 50 cm above ground level in June 2005. Total harvests from each MPT were sorted out into foliage (leaves + fine stem < 6 mm diameter) and stem (>6 mm diameter). Foliage samples were collected three times to represent seasonal variations as follows: November: early dry (2006); February: mid-dry (2007); April: late dry (2007) seasons. Three 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 implies that nine plants per plot (replicate) per MPT were sampled and bulked separately according to the three different plots (replicates) and sub-sampled for analysis. Approximately 0.2 kg of foliage was taken from each plant.

2.4. Chemical analysis

The foliage samples were sub-sampled and weighed fresh on the field, then oven-dried to constant weight at 65 °C. The dried foliage samples were divided into two portions. The first portion was hammer-milled through a 1 mm sieve and used to analyze crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDFom), acid detergent fibre (ADFom), lignin (sa) and gas production. Crude protein (ID 984.13), ash (ID 942.05) and EE (ID 963.15) were analysed according to the standard methods of AOAC (1990). The NDFom and ADFom were determined according to Van Soest et al. (1991), the NDFom was determined without α-amylase and sodium sulphite. Both NDFom and ADFom were expressed without residual ash. Lignin (sa) was determined by solubilisation of cellulose with sulphuric acid on the ADF residue (Van Soest et al., 1991). Hemicellulose was calculated as NDFom-ADFom. Non-fibre carbohydrates (NFC) were calculated as NFC = 1000 − CP − ash − EE − NDFom.

The second portion of the foliage samples was ground through a 2.5 mm sieve and used for the *in sacco* degradation studies.

2.5. In vitro gas production

In vitro gas production was determined according to Menke and Steingass (1988). Rumen fluids were collected prior to feeding from three rumen fistulated West African Dwarf (WAD) rams (27 ± 4 kg) fed a mixed diet of fresh *P. purpureum* (1 kg/d) and concentrates (200 g/d) (2:1, DM) to fulfill maintenance requirements. The concentrate feed consisted of (as fed basis, g/kg) 400 maize grain, 100 wheat bran, 100 palm kernel cake, 200 groundnut cake, 50 soybean meal, 100 dried brewers grain, 10 common salt, 37.5 oyster shell and 2.5 fish meal. Feeds were offered in two equal meals at 07:00 and 19:00 h. Rumen fluid was strained through two layers of gauze into a prewarmed, insulated bottle. All laboratory handling of rumen fluid was carried out under a continuous flow of CO_2. Samples (200 mg) of the air-dry leaves were accurately weighed into 100-ml glass syringes fitted with plungers. *In vitro* incubation of the samples was conducted in triplicate. Syringes were filled with 30 ml of medium consisting of 10 ml of rumen fluid and 20 ml of buffer solution as described by Menke and Steingass (1988). Three blanks containing 30 ml of medium only were included. The syringes were placed in a rotor inside the incubator (39 °C) with about one rotation per min. The gas production was recorded after 6, 12, 24, 48, 72, and 96 h of incubation.

2.6. In sacco dry matter degradation

In sacco DM degradation was determined according to Ørskov et al. (1980). 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 the three WAD rams. This resulted in each ram serving as a replicate. All bags were inserted at the same time, just before the morning feeding. The animals were fed fresh *P. maximum* and concentrates (2:1, as fed basis) throughout the experimental period. They also had free choice access to clean water and salt licks. Feeds were offered in two equal meals at 07:00 and 19:00 h. Immediately after withdrawal, bags were dipped into cold water and then washed gently under slow running tap water for 30 min. Finally, they were dried at 65 °C for 48 h in a forced air oven, desiccated for 30 min and then weighed. To determine washing loss, two 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.

2.7. Calculations and statistical analysis

The data obtained from *in vitro* gas production was fitted to the non-linear equation (Larbi et al., 1996):

$$V(\text{ml}/0.2\,\text{g DM}) = \text{GV}(1 - \text{e}^{-ct})$$

where V is the potential gas production, GV is the volume of gas and cg is the fractional rate of gas production.

Organic matter digestibility (OMD) was estimated as

$\text{OMD} = 14.88 + 0.889\,\text{GV} + 0.45\,\text{CP} + 0.651\,\text{ash}$ (Menke and Steingass, 1988).

Short-chain fatty acids (SCFA) were estimated as

$\text{SCFA} = 0.0239\,\text{GV} - 0.0601$ (Getachew et al., 2000).

Metabolizable energy (ME) was calculated as

$\text{ME} = 2.20 + 0.136\,\text{GV} + 0.057\,\text{CP} + 0.029\,\text{CP}^2$ (Menke and Steingass, 1988).

Total gas volume (GV) is expressed as ml/0.2 g DM, CP and ash as g/kg DM, ME as MJ/kg DM and SCFA as μmol/g DM.

Data obtained from DM degradation was fitted into the exponential equation (McDonald, 1981):

$$Y = a + b(1 - e^{-ct})$$

where Y is the DM degradation at time t, a is the rapidly degradable (or soluble) fraction, b is the slowly degradable (or insoluble but degradable) fraction, c is the rate of degradation, and t is the time. $(a+b)$ = potential extent of degradation. ED is the effective degradability, calculated as $a + [(b \times c)/(c + k)]$, where $k = 0.020$/h (AFRC, 1993).

The data were subjected to analysis of variance using the general linear models (GLM) procedure of SAS (2002) in a 3×4 factorial arrangement with three replicates. The model used was:

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

where Y_{ijk} is the observation, μ is the population mean, t_i is the MPT species effect ($i = 1$–4), s_j is the season effect ($j = 1$–3), $(ts)_{ij}$ is the interaction between MPT species and season and ε_{ijk} is the residual error. The model considered main effects (i.e., MPT species, season) and their interaction. Means were compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Probability values less than 0.001 are expressed as 'P<0.001' rather than the actual value.

3. Results

3.1. Chemical composition

Species×season interactions were observed for the DM, EE, ash, NDFom, ADFom and hemicellulose concentrations of the MPT with P value of 0.001 except for ADFom (0.0014). *T. africana* had the highest DM, EE and ash contents during the late dry season, whereas *M. griffoniana* had the greatest NDFom and hemicellulose values during the early dry season and *E. cyclocarpum* had the highest ADFom concentrations during the late dry season (Table 1). The DM contents of all the MPTS increased with time while the reverse was the case with CP which declined with time with the exception of *T. africana* which had a slight increase during the late dry season. There was no interaction in the CP, lignin and NFC concentrations of the MPTS. There were differences (P<0.001) in the chemical composition of the MPT. Across species, ADFom and lignin (sa) contents ranged from 306 to 373 g/kg DM and 80 to 91 g/kg DM respectively.

3.2. In vitro fermentation

Interactions between season and species were observed for *cg* (P<0.001), OMD (P<0.001), SCFA (P=0.0034), ME (P<0.001) and GV (P<0.0140) (Table 2). *T. africana* had the highest OMD and ME values in early and late dry seasons, while *M. griffoniana* had similar OMD and ME values in the late dry season. The cg increased with time for *E. cyclocarpum* and *G. sepium*, appeared to have a quadratic effect with *M. griffoniana*, and declined with *T. africana.* Species affected (P<0.001) the rate of gas production (*cg*), OMD and ME of the MPT. There was a slight difference (P=0.0284) between the SCFA content of *T. africana* and *M. griffoniana*. The highest values for cg, SCFA and GV were all observed during the late dry season while OMD and ME were highest during early dry season.

3.3. In sacco dry matter degradation

In contrast to the *in vitro* data, *M. griffoniana* had the highest effective degradability throughout the dry season. Interactions between species and season (P<0.001) occurred for PD, ED and the *a* and *b* fractions. There was no interaction between species and season on the rate of degradation of the MPT (Table 3).

Table 1
Interaction and main effects of species and season on the composition (g/kg DM, unless stated) of the multi-purpose trees.

Interaction	DM[a] (g/kg)	CP[b]	EE[c]	Ash	NDFom[d]	ADFom[e]	Lignin (sa)	Hemicellulose	NFC[f] (%)
Early dry season									
E. cyclocarpum	353d	181	60.0c	66.0c	500bc	340bc	87.0	160cd	193
G. sepium	330de	167	70.0bc	33.0d	500bc	340bc	91.0	160cd	230
M. griffoniana	334de	185	85.0ab	23.0d	580a	300cd	85.0	280a	127
T. africana	385bc	199	63.0bc	103b	420cd	310cd	75.0	110f	215
Means	351	183	69.5	56.3	500	323	84.5	178	191
Mid-dry season									
E. cyclocarpum	369cd	175	42.0d	63.0c	520b	380ab	91.0	140de	200
G. sepium	372cd	164	69.0bc	28.0d	480bc	310cd	95.0	170c	259
M. griffoniana	368cd	180	72.0bc	31.0d	550ab	340bc	81.0	210b	167
T. africana	396bc	180	78.0b	98.0b	390d	290d	78.0	100f	254
Means	376	175	65.3	55.0	485	330	86.3	155	220
Late dry season									
E. cyclocarpum	385bc	169	40.0d	67.0c	570ab	400a	103	170c	154
G. sepium	384bc	160	100a	35.0d	460c	340bc	107	120e	245
M. griffoniana	404b	172	90.0ab	33.0d	540ab	380ab	97.0	160cd	165
T. africana	453a	182	100a	136a	380d	320cd	87.0	60.0g	202
Means	407	171	82.5	67.8	488	360	98.5	128	192
SEM[g]	5.21	3.80	3.17	3.02	10.2	9.75	1.63	4.01	14.2
Main effect									
E. cyclocarpum	369b	175b	47.3b	65.3b	530b	373a	93.7b	157b	182b
G. sepium	362b	163c	79.7a	32.0c	480c	330b	97.7a	150b	245a
M. griffoniana	368b	179ab	82.3a	29.0c	556a	340b	87.7c	216a	154b
T. africana	411a	187a	80.3a	112a	396d	306c	80.0d	90.0c	225a
SEM[h]	3.01	2.19	1.83	1.75	5.89	5.63	0.94	2.32	8.19
P value (main effect)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
P value (interaction)	0.0007	0.4343	0.0001	0.0001	0.0001	0.0014	0.1457	0.0001	0.1874

Means with different letters along columns are significantly different.

[a] Dry matter.
[b] Crude protein.
[c] Ether extract.
[d] Neutral detergent fibre expressed exclusive residual ash.
[e] Acid detergent fibre expressed exclusive residual ash.
[f] Non-fibre carbohydrates.
[g] Standard error of means (interaction).
[h] Standard error of means (main effect).

Table 2
Interaction and main effects of species and season on the *in vitro* gas production of the leaves of the multi-purpose trees.

Interaction	*cg*[a] (h^{-1})	OMD[b]	SCFA[c] (μmol/g DM)	ME[d] (MJ/kg DM)	GV[e] (ml/0.2 g DM)
Early dry season					
E. cyclocarpum	0.007f	0.651c	0.95ab	9.95bc	42.7abcd
G. sepium	0.034d	0.619d	0.94ab	9.67c	42.0abcde
M. griffoniana	0.044bc	0.595de	0.87bc	9.56c	39.0cdef
T. africana	0.051a	0.726a	1.01a	10.6a	45.0ab
Means	0.034	0.648	0.94	9.95	42.2
Mid-dry season					
E. cyclocarpum	0.021e	0.609d	0.86bc	9.29c	38.3cdef
G. sepium	0.038cd	0.603d	0.91abc	9.45c	40.7abcde
M. griffoniana	0.039c	0.574e	0.81bc	9.13c	36.7ef
T. africana	0.042c	0.649c	0.90abc	9.61c	40.0bcdef
Means	0.035	0.609	0.87	9.37	38.9
Late dry season					
E. cyclocarpum	0.052a	0.647c	0.96ab	9.79bc	42.7abcd
G. sepium	0.044bc	0.618d	0.95ab	9.58c	42.0abcde
M. griffoniana	0.050ab	0.658c	1.04a	10.3ab	46.0a
T. africana	0.039c	0.690b	0.99a	10.2abc	44.0abc
Means	0.046	0.653	0.99	9.97	43.7
SEM[f]	0.001	0.06	0.02	0.12	1.16
Main effect					
E. cyclocarpum	0.027c	0.636b	0.92	9.68b	41.2
G. sepium	0.039b	0.613c	0.93	9.57b	41.6
M. griffoniana	0.044a	0.609c	0.90b	9.66b	40.3
T. africana	0.044a	0.688a	0.96a	10.1a	43.0
SEM[g]	0.001	0.09	0.01	0.07	0.67
P value (main effect)	0.0001	0.0001	0.0284	0.0001	0.0964
P value (interaction)	0.0001	0.0001	0.0034	0.0003	0.0140

Means with different letters along columns are significantly different.
[a] Rate of fermentation.
[b] Organic matter digestibility.
[c] Short-chain fatty acids.
[d] Metabolizable energy.
[e] Gas volume.
[f] Standard error of means (interaction).
[g] Standard error of means (main effect).

The effect of species on the rapidly degradable fraction (*a*), slowly degradable fraction (*b*), PD and ED were all significant. The rate of degradation only differed between *M. griffoniana* and *T. africana* (*P*=0.0091).

4. Discussion

4.1. Chemical composition

The DM concentration recorded for the MPT in this study was within the ranges reported under similar conditions in southwestern Nigeria (Arigbede, 1998; Anele et al., 2008) and elsewhere (FACT Net, 2000; Ly et al., 2001). The higher DM contents of the MPT observed during the late dry season may be a result of reduced photosynthetic activity probably due to the lower moisture levels experienced during the late dry season relative to early and mid dry seasons. All the MPT contained sufficient DM to support a reasonable amount of DM intake. Earlier studies

Table 3
Interaction and main effects of species and season on the dry matter degradation of the multi-purpose trees.

	a[a]	b[b]	c[c] (h^{-1})	PD[d]	ED[e]
Early dry season					
E. cyclocarpum	0.206d	0.156e	0.023	0.362g	0.288e
G. sepium	0.298a	0.095f	0.033	0.393f	0.356bc
M. griffoniana	0.260b	0.293b	0.046	0.553b	0.461a
T. africana	0.214cd	0.216cd	0.020	0.430e	0.319de
Means	0.245	0.190	0.031	0.435	0.356
Mid-dry season					
E. cyclocarpum	0.236c	0.168e	0.020	0.404f	0.318de
G. sepium	0.260b	0.157e	0.018	0.417ef	0.332cd
M. griffoniana	0.254bc	0.221c	0.021	0.475d	0.365b
T. africana	0.207d	0.279b	0.012	0.486d	0.308de
Means	0.239	0.206	0.018	0.446	0.331
Late dry season					
E. cyclocarpum	0.247bc	0.158e	0.015	0.405f	0.312de
G. sepium	0.284a	0.228c	0.006	0.512c	0.335bcd
M. griffoniana	0.297a	0.198d	0.038	0.495cd	0.365b
T. africana	0.234c	0.439a	0.005	0.673a	0.318de
Means	0.266	0.256	0.016	0.521	0.333
SEM[f]	0.05	0.08	0.008	0.08	0.06
Main effect					
E. cyclocarpum	0.229c	0.161c	0.019	0.390d	0.306c
G. sepium	0.281a	0.160c	0.019	0.441c	0.341b
M. griffoniana	0.270b	0.237b	0.035a	0.508b	0.397a
T. africana	0.218d	0.311a	0.012b	0.529a	0.315c
SEM[g]	0.08	0.12	0.004	0.12	0.09
P value (main effect)	0.0001	0.0001	0.0091	0.0001	0.0001
P value (interaction)	0.0001	0.0001	0.4633	0.0001	0.0001

Means with different letters along columns are significantly different.
[a] Rapidly degradable fraction.
[b] Slowly degradable fraction.
[c] Rate of degradation.
[d] Potential degradability.
[e] Effective degradability.
[f] Standard error of means (interaction).
[g] Standard error of means (main effect).

have reported a restriction in DM intake where DM content is low (Pasha et al., 1994; Van Soest, 1994).

The range of CP concentrations (160–199 g/kg DM) of the MPT is in agreement with other reports (Ly et al., 2001; Murro et al., 2003). A higher CP content during the early dry season compared with the other two seasons as a result of higher moisture content and nitrogen uptake being more rapid than dry matter accumulation agrees with Bamualim et al. (1980) and Larbi et al. (1997), who reported that seasonal variations occur between plant species and between seasons with higher values reported for seasons with higher moisture levels. The higher CP content of the MPT in the early dry season was due to the continuous flush (regrowth) of leaves during this period. The lower CP contents during the mid and late dry seasons may be largely due to moisture stress experienced by the trees during this period and build up of lignocellulosic fibre structures of the plants, diluting the nitrogen.

The little decline in the CP content of the MPT between early and late dry season showed that the MPT are capable of retaining this important nutrient further into the dry season than herbs and grasses. The lowest value of CP (160 g/kg DM) for *G. sepium* during the late dry season is well above

the range of 70–80 g/kg DM suggested as critical limit below which intake of forages by ruminants and rumen microbial activity would be adversely affected (Van Soest, 1994). Reduction in the CP content of the MPT during the late dry season versus other seasons is consistent with other studies, as was the observation that the minimum CP content of MPT in the dry season was more than twice that of grasses in the wet season (Evitayani et al., 2004). This makes the trees more reliable than herbaceous legumes and grasses for providing high quality protein supplement for dry season livestock production.

The range of values for the ADFom and lignin (sa) contents of the MPT indicated that they were not diverse in terms of their cell wall contents. The values for fibre fractions (NDFom, ADFom, lignin (sa) and hemicellulose) fell within the range that can be handled by the ruminant animals without adverse effects on DM and nutrient intakes. The NDFom and ADFom of the MPT observed in this study, in the range of 380–580 g/kg DM and 290–400 g/kg DM, respectively, are higher than those reported for *E. cyclocarpum* and *G. sepium* (Ondiek et al., 1999; Aregheore and Perera, 2004) but consistent with other reports (Mota et al., 2005; Juma et al., 2006). Arigbede et al. (2008) reported higher value for *T. africana* compared with figures in this study. The range of NDFom contents in our samples is below the range of 600–650 g/kg DM suggested as the limit above which intake of tropical feeds by ruminant would be limited (Van Soest et al., 1991). Moderate fibre levels facilitate colonization of ingesta by rumen microorganism which in turn might induce higher fermentation rates, hence improving digestibility, intake and animal performance (Klopfenstein et al., 2001). The MPT had moderate levels of lignin and hemicellulose. The digestion of hemicellulose depends on microbial enzymes because of its complex structure. Hemicellulose is associated intimately with lignin, which exerts a strong negative influence on fibre digestion (Van Soest, 1994). The range of NFC contents of the MPT indicated that they can be easily degraded or fermented as NFC is a crude 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).

4.2. *In vitro* fermentation

Results obtained for the fermentation of the MPT in this study were similar to those reported by others (Brenda et al., 1997; Ly et al., 1997; Juma et al., 2006; Anele et al., 2008; Arigbede et al., 2008). Brenda et al. (1997) reported a lower value of 30.5 ml/0.2 g DM for *G. sepium*. The extent of *in vitro* fermentation of *T. africana* suggests that it is of higher nutritional value than the other MPT. The OMD and SCFA in *T. africana* were higher than those in the other MPT, possibly because *T. africana* contains more fermentable carbohydrate which is a vital substrate for growth of ruminal microorganisms (Van Soest, 1994). Also, lower fibre fractions (NDFom, 396 g/kg DM; ADFom, 306 g/kg DM; lignin 80 g/kg DM and hemicellulose, 90 g/kg DM) in *T. africana* versus other MPT may have resulted in the higher values for OMD and SCFA (Van Soest, 1994).

The variation of the ME values among the MPT was less than 1 MJ/kg DM. The estimation of the ME values is valuable for purposes of ration formulation and to set economic value of feeds for other purposes (Getachew et al., 2002). One major advantage of the gas measurement technique is that it focuses on the appearance of fermentation products (soluble but non-fermentable substrates do not contribute to gas production). The other *in vitro* methods are based on gravimetric measurements which follow disappearance of the substrate (components which may or may not necessarily contribute to fermentation) (Getachew et al., 1998). Gas production is a reflection of the generation of SCFA and microbial mass (Getachew et al., 1998). The values of 0.027–0.044 for the fractional rate of gas production of the MPT under investigation show that they are highly digestible as the rate at which a feed or its chemical constituents are digested in the rumen is as important as the extent of digestion.

4.3. *In sacco* dry matter degradation

In agreement with our results, Larbi et al. (1998) and Perera et al. (1996) reported significant differences in DM degradation characteristics. The overall DM degradability values in this study were higher than the range of 0.29–0.335 and 0.095–0.334 reported by Perera et al. (1996) and Larbi et al. (1998). There has not been any report on the DM degradation of *M. griffoniana* and *T. africana*,

hence no comparison with any previous finding can be made. The observed differences in the DM degradation characteristics of the MPT may be due to the differences in chemical composition. The seasonal variation in the chemical composition and degradation characteristics of the MPT suggest that the feed value of MPT could be improved through management strategies such as harvest season and frequency of defoliation. The ranking of the MPTS using the *in sacco* technique is different from the *in vitro* because secondary metabolites like tannins are known to exact more influence *in vitro*.

Degradation constants as measured by the *in sacco* nylon bag technique are related to digestible DM intake of these MPT. Thus, the inter-species differences in DM degradation observed could result in different intakes of the MPT when fed as sole diet.

5. Conclusions

Differences in chemical composition, *in vitro* fermentation and DM degradation characteristics reported in this study have practical implications for MPT-based livestock system in the tropics. Multipurpose tree species with improved chemical composition and greater potential extent of degradation than their herbaceous counterpart could be fitted into smallholder resource-poor animal husbandry systems. They could be used in live fences, feed gardens, fodder banks, improved fallow and alley farms as sources of home grown supplements for low quality crop residues, especially in the dry season.

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