Chemical composition and *in sacco* ruminal degradation of tropical trees rich in condensed tannins

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ABSTRACT: The study was aimed at determining the chemical composition, *in sacco* ruminal dry matter and organic matter degradability of leaves and fruits of tropical condensed tannin rich multipurpose tree species (MPTS). The MPTS studied were *Ekebergia capenesis, Ficus sycomorus, Maesa lanceolata,* and *Rhus glutinosa*. Chemical composition of dry matter (DM), crude protein (CP), crude ash (CA), ether extract (EE), crude fibre (CF), neutral detergent fibre (NDF), non-fibre carbohydrates (NFC), and condensed tannin (CT) was determined. *In sacco* rumen degradability was measured using three rumen fistulated Holstein Friesian-Boran cross steers at 0, 6, 12, 24, 48, 72, and 96 h. The DM and organic matter (OM) degradability data were fitted to the equation $Y = a + b(1 - e^{-ct})$. The values for each chemical constituent ranged 5.43–11.49% (CA), 7.97–17.06% (CP), 1.57–31% (EE), 12.20–27.5% (CF), 5.84–39.30% (NFC), and 7.2–16.72% (CT). *Ekebergia capensis* leaves had the greatest values for slowly degradable fraction (*b*), effective degradability (*ED*), and rate of degradation (*c*) in DM ($P < 0.001$) whereas *E. capensis* fruit had significantly the greatest soluble fraction (*a*), potential degradability (*b*), and effective degradability (*ED*) values as compared to the *a*, *PD*, and *ED* values in the fruits of other plants($P < 0.001$). Yet in OM degradation kinetics, the greatest and least values of potential degradability (PD) were recorded for *F. sycomorus* (89.89%) and *E. capensis* (55.90%) leaves ($P < 0.001$). Similar to the rapidly soluble fraction *a*, *ED* was found to be the greatest in fruits as compared to leaves of the plants ($P < 0.001$). Generally variation of plant parts led to significant differences in chemical composition, DM, and OM degradability and the degradable parameters. The leaves and fruits recorded more than 60% DM and OM degradability at 24 h, which implied that they were all greatly degradable in the rumen.

Keywords: dry matter and organic matter degradability; fruit; leaf; multipurpose trees; tannins

Inadequate feed supply is a major constraint of livestock production in Sub-Saharan African countries (Arigbede et al., 2011). This obviously adds to the poor performance of ruminant livestock. Improvement of the performance of ruminants in Sub-Saharan Africa (Kaitho et al., 1998; Mekonnen et al., 2006, 2009; Mekoya et al., 2008) calls for using the methods of extending the availability and quality of local feedstuffs. One potential way for increasing the quality and availability of livestock feeds is the use of various multipurpose trees and shrubs (MPTS) (Ngodigha and Anyanwu, 2009). Leaves 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 (Yisehak et al., 2009, 2012). Currently small-holder farmers of Sub-Saharan African countries in general (Aremu and Onadeko, 2008) and Ethiopia in particular (Yisehak and Belay, 2011; Yisehak et al., 2012) are increasingly relying on various potential MPTS that can provide a green feed throughout the year which may be particularly useful as feed supplements to the typical low-quality diets. A variety of MPTS is

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growing in Omo-Gibe basins of Ethiopia (OGBE) (Yisehak et al., 2010), mainly due to the suitability of the environment and the need to use them as fire wood, local construction material, mulch, and shade for cash crops like coffee and spices. They replenish soil fertility, serve for human and veterinary medicine, and also serve as environmental conservation. Among MPTS growing in the OGBE, *Ekebergia capensis, Ficus sycomorus, Maesa lanceolata*, and *Rhus glutinosa* are widely abundant and greatly preferred by farmers. They are evergreen throughout the year, yield a good biomass, and can serve a multiple purpose.

Foliages of multipurpose trees and shrubs are generally richer in protein and minerals (Alonso-Diaz et al., 2010) and thus have the potential to be an inexpensive, locally produced protein supplement that plays an important role in the nutrition of grazing animals. Unfortunately, they contain nutrient activating factor such as condensed tannins (CT) that varies widely and unpredictably (Babayemi et al., 2004). Great levels of CTs in edible parts of plants restrict the nutrient utilization and decrease voluntary food intake, nutrient digestibility, and nitrogen (N) retention (Silanikove et al., 1996; Makkar, 2003). The CT concentration in plants is influenced by plant species (Ozturk et al., 2006), stage of growth, and may vary with plant part (leaf, stem, inflorescence, seed), season of growth, and other specific environmental factors such as temperature, rainfall, cutting, and defoliation by grazing herbivores including insects (Makkar and Singh, 1991).

Since the rumen is the primary site of digestion of forages, it is important to monitor their degradation kinetics. This can be achieved by using *in sacco* technique which is quicker and cheaper than the whole animal studies. The *in sacco* nylon bag technique, when feed samples in nylon bags are suspended in the rumen, is widely used to estimate the rate and extent of degradation and digestion of feed in the rumen (Orskov and McDonald, 1979). Important characteristics of digestion in the rumen with regard to forages are: effective degradability, rate of digestion, and the amount of digestible fibre (Larbi et al., 1997). Rumen degradation is thus regarded as a major descriptor of forage quality (Orskov and McDonald, 1979). Thus, it is useful in ranking trees and shrubs in terms of nutritive value (Larbi et al., 1998) and for comparing the digestive capabilities of forages.

No information is available on the combined effects of the factors (species and plant parts) on chemical composition and *in sacco* ruminal degradation characteristics of condensed tannin-rich MPTS. Therefore, the present research was initiated to investigate the effect of browse species and plant parts on the chemical composition and *in sacco* ruminal degradation characteristics of dry matter and organic matter.

MATERIAL AND METHODS

Study area

The chemical composition study including condensed tannin components was carried out in animal nutrition laboratory of Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) campus which is located at Jimma, a city in south-western Ethiopia, situated at 7°40'N and 36°50'E latitude and longitude, respectively (http://en.wikipedia.org/wiki/Jimma). The *in sacco* rumen degradation study was carried out in Holeta Agricultural Research Center (HARC) animal nutrition laboratory. HARC is located in the West Shewa zone of the Oromia National Regional State, Ethiopia. It has a latitude and longitude of 9°3'0''N and 38°30'0''E, respectively. The centre is located at an average altitude of 2391 m a.s.l. (http://en.wikipedia.org/wiki/Holeta_Genet).

Browse species

The browse species were selected based on their abundance in the area, preference, and accessibility to browsing livestock as well as additional usage other than livestock feed (Yisehak et al., 2010). The browse species included in the study were *Ekebergia capensis, Ficus sycomorus, Maesa lanceolata,* and *Rhus glutinosa*, which are non legume trees. These species are commonly consumed by ruminants and equines. They are available to animals throughout the year.

Sampling, drying, and storage of plant materials

Plant parts/morphological fractions of the condensed tannin-rich browse species were collected from Jimma zone, south-western Ethiopia. Fresh leaves and fruits were harvested from *Ekebergia*

capensis, Ficus sycomorus, Maesa lanceolata, and *Rhus glutinosa*, then placed into plastic bags, and transported to JUCAVM, animal nutrition laboratory. Leaves and fruits of three individual plants per species were sampled from various MPTS populations at the same locality with similar climatic and soil characteristics and analyzed individually to allow quantification of the inter-species variation and to perform statistical analyses in a factorial procedure. Plant samples were replicated in order to obtain sufficient number of statistical units (Robinson et al., 2006). After arrival to laboratory in 35 min, the plant parts were placed in new yellow paper bags, measured (fresh weight), and placed in an oven at 55°C for 72 h (checked for a constant dry weight). The dried samples were grinded to pass through a 1-mm sieve of a Wiley mill for chemical analysis and 2-mm sieve for rumen *in sacco* degradation measurement and placed in air-tight plastic sample containers and stored in the nutrition laboratory at room temperature until analysis.

Chemical analysis

Browse species were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), and ash according to AOAC (2005), whereas neutral detergent fibre (NDF) was determined by the method of Van Soest et al. (1991). Hemicellulose was calculated as NDF – ADF and cellulose as ADF – lignin. Non-fibre carbohydrates (NFC, g/kg DM) were calculated as NFC = 1000 – (CP + ash + EE + NDF), with all concentrations expressed as g/kg DM. Chemical extraction of foliages for CT analysis was done following the procedures of FAO (2000). CT was measured by the butanol-HCl-Fe method and the results were expressed as leucocyanidin equivalent (Porter et al., 1986).

In sacco degradability measurements

Ruminal *in sacco* degradation of DM and OM was determined according to Orskov and McDonald (1979). Dried forage samples (AOAC, 2005) milled to pass through a 2-mm sieve screen were weighted (3 g/bag) into 4.5 × 18 cm nylon bags (pore size 40 μm). The bags were manually pushed deep into the liquid phase of the ventral sac of the rumen and incubated for 6, 12, 24, 48, 72, and 96 h in the rumen of three male Boran × Holstein-Friesian steers at the age of 9.4 years, fed twice daily with pasture hay (60%) and concentrate mixture (40%) and having free access to water and mineral/vitamin licks. The natural pasture hay exhibited 4.8% CP, 65.6% NDF, 43.8% ADF, 53.4% organic matter digestibility (OMD), 8.51 ME (MJ/kg), and 4.6 and 1.7 g/kg DM of Ca and P, respectively. On the other hand, chemical composition and OMD of the concentrate mixture was 24% CP, 48% NDF, 20.3% ADF, 73.6% OMD, and 12.3 and 7.9 g/kg of Ca and P, respectively. The ration was assumed to meet all nutrient and energy requirements of the animals. Two bags were incubated for each sample in each bull for each incubation time. Upon removal from the rumen, bags were washed in running tap water while rubbing gently between thumb and fingers until the water became clear. Zero time disappearances (washing losses) were obtained by washing unincubated bags in a similar fashion. Bags were dried in an oven at 60°C for 48 h and weighed to determine the dry weight of the incubation residues.

In the experiment, the animals were allocated to a maintenance ration composed of natural pasture hay offered *ad libtum* as a basal ration and 2 kg of a concentrate diet formulated from wheat bran, noug seed cake, and salt in the ratio of 55 : 43 : 2. The animals were housed in individual pens and provided water *ad libitum*.

Dry matter disappearance (DMD) was estimated as follows (Osuji et al., 1993):

$$DMD = \frac{((BW + S_1) - (BW + RW))}{(S_1 \times DM)} \times 100$$

where:
BW = bag weight
RW = residue weight
S_1 = sample weight
DM = dry matter concentration of the original sample

Degradability (Y) of DM was calculated using the equation of Orskov and McDonald (1979):

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

where:
a = soluble fraction
b = insoluble but potentially degradable fraction
c = degradation rate constant of the b fraction
t = degradation time (0, 6, 12, 24, 48, 72, and 96 h)
e = base for natural logarithm

The nonlinear parameters *a*, *b*, and *c* were estimated using non-linear procedures of SAS (Statistical Analysis System, Version 9.3, 2010).

Potential degradability (*PD*) was determined by the equation:

$$PD = a + b$$

Effective degradabilities (*ED*) for DM and OM were estimated according to ARC (1980):

$$ED = a + bc/k + c$$

where:
a = soluble fraction
b = insoluble but potentially degradable fraction
c = degradation rate constant of the *b* fraction
k = rumen outflow rate (assumed to be 0.03/h)

Statistical analysis

A Two-Way Analysis of Variance was performed according to 4 × 2 factorial arrangements with two fixed factors being plant species (S; 4 levels) and plant parts (P; 2 levels) using General Linear Models Procedure of SAS (Statistical Analysis System, Version 9.3, 2010). Duncan's multiple range test procedure was used for mean separation. Mean differences were considered significant at $P \leq 0.05$. The linear model used was:

$$Y_{ij} = \mu + S_i + P_j + (SP)_{ij} + \varepsilon_{ij}$$

where:
Y_{ij} = response variable
μ = population mean
S_i = i^{th} plant species effect (i = 1–4)
P_j = j^{th} effect of plant parts (j = 1–2)
$(SP)_{ij}$ = interaction effect between *S* and *P*
ε_{ij} = residual error

The DM and OM disappearances and the degradation characteristics such *a*, *b*, *c*, *PD*, *ED* were estimated for each plant species and plant parts using nonlinear regression procedures of SAS. Spearman's correlation analysis was used to establish the relationship between some chemical composition parameters and *in sacco* ruminal DM and OM disappearances.

RESULTS AND DISCUSSION

Chemical composition of plant species and forage parts

The Least Squares Means for the chemical compositions of forage parts (leaves and fruits) of the

Table 1. Least Squares Means for chemical compositions of plant species

Plant species	Plant part	Chemical composition, mean (%)							
		DM	CA	CP	EE	NDF	CF	NFC	CT
E. capensis	leaf	96.84^{a}	7.91^{c}	9.76^{d}	5.06^{a}	37.96^{c}	19.10^{ab}	39.30^{a}	8.00
F. sycomorus		92.66^{c}	11.49^{a}	12.42^{c}	1.57^{b}	61.01^{a}	15.40b^{c}	13.51^{bc}	8.49
M. lanceolata		95.10^{b}	7.15^{d}	17.06^{a}	5.17^{a}	61.33^{a}	21.45^{a}	8.71^{c}	13.65
R. glutinosa		96.86^{a}	9.29^{b}	16.04^{b}	4.70^{a}	49.31^{b}	12.20^{c}	20.66^{b}	16.72
	SE	0.06	0.17	0.27	0.16	2.46	1.49	2.41	1.66
	P	***	***	***	***	***	**	**	ns
E. capensis	fruit	94.11^{c}	5.43^{d}	11.07	31.00^{a}	35.90^{d}	20.25	17.28^{a}	7.27
F. sycomorus		95.56^{b}	9.70^{a}	10.81	5.97^{c}	66.71^{b}	27.5	9.07^{bc}	8.17
M. lanceolata		96.5^{a}	7.45^{b}	7.97	8.20^{b}	62.00^{c}	22.20	14.38^{b}	7.20
R. glutinosa		92.43^{d}	5.57^{c}	11.21	5.33^{d}	68.9^{a}	22.30	5.84^{c}	8.59
	SE	0.30	0.30	2.04	0.18	1.26	2.41	2.39	0.86
	P	***	***	ns	***	***	ns	*	ns

DM = dry matter, CA = crude ash, CP = crude protein, EE = ether extract, NDF = neutral detergent fibre, CF = crude fibre, NFC = non-fibre carbohydrates, CT = condensed tannin

$^{a–d}$means with different letters within the column are significantly different ($P < 0.05$)

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ns = non-significant ($P > 0.05$)

studied plant species separately compared for the each plant species are given in Table 1. The crude ash (CA) concentration obtained in the present study for the plants' leaves fell within the range of 7.15–11.49% in *M. lanceolata* and *F. sycomorus*, respectively. A significant difference was observed for CA values in the leaves of the plant species ($P < 0.001$). The CP concentrations varied among the species leaves and ranged from 9.76% in *E. capensis* to 17.06% in *M. lanceolata* ($P < 0.001$). The greatest concentration of ether extract (EE) was recorded in the leaves of *M. lanceolata* (5.17%), *R. glutinosa* (4.71%), and *E. capensis* (5.06%) while the least EE concentration was obtained in *F. sycomorus* leaf (1.57%) ($P < 0.001$). The neutral detergent fibre (NDF) concentration in leaves made 37.96% in *E. capensis*, 61.33% in *M. lanceolata,* and 61.01% in *F. sycomorus* ($P < 0.001$). On the other hand, the greatest and least concentrations of non-fibre carbohydrates (NFC) were estimated for *E. capenis* (39.30%), *F. sycomorus* (13.51%), and *M. lanceolata* (8.71%), respectively ($P < 0.001$). Likewise, significant variations in a majority of chemical composition parameters ($P < 0.001$) were detected also in the fruits of the tree species. The chemical concentrations ranged 7.97–12.10% (CP), 5.97–31% (EE), 35.90–68.90% (NDF), 5.84–17.28% (NFE), and 7.20–10.17% (CT).

The Least Squares Means differences for the chemical composition parameters compared between leaves and fruits are presented in Table 2. The greatest CA content was determined in the leaves of *F. sycomorus* whereas the least total cash values were recorded for fruits of *E. capensis* (5.43%) and *R. glutinosa* (5.57%) ($P < 0.001$). Similarly, greater CP concentrations were recorded in leaves as compared to fruits ($P < 0.001$). By far the greatest EE concentration was determined for fruits of *E. capensis* as compared to the rest of plant parts; EE concentration in the fruits tended to be greater except for the *R. glutinosa* fruit ($P < 0.001$). Fruits exhibited also greater NDF concentration than the leaves ($P < 0.001$). Unlike the concentration of EE, CF, and NDF of the fruits, the nitrogen free carbohydrate concentration was found to be the greatest for leaves of *E. capensis* ($P < 0.001$). Furthermore, CT, of leaves and fruits was comparable and attained the level that affects utilization of feedstuffs by livestock species. The greatest ash concentration was obtained in the leaves of *F. sycomorus* as compared to ash values of leaves and fruits of the studied plant species ($P < 0.001$). CP values in leaves were relatively greater than in fruits ($P < 0.001$).

The greater NDF concentration in fruits compared to leaves could be attributed to the lack of including amylase, an enzyme that catalyzes the breakdown of starch into sugars enzyme digests starch during NDF analysis. Starch concentration decreases in the leaves during fruit development

Table 2. Comparison of Least Squares Means for chemical compositions of leaves and fruits of the plant species

Plant species	Plant part	Chemical composition, mean (%)							
		DM	CA	CP	EE	NDF	CF	NFC	CT
E. capensis	leaf	96.84^{a}	7.91^{d}	9.76^{d}	5.06^{de}	37.96^{d}	19.10^{bc}	39.30^{a}	8.00^{b}
F. sycomorus		92.66^{d}	11.49^{a}	12.42^{bc}	1.57^{f}	61.01^{b}	15.40^{cd}	13.51^{bc}	8.49^{b}
M. lanceolata		95.10^{b}	7.15^{e}	17.06^{a}	5.17^{de}	61.33^{b}	21.45^{bc}	8.71^{cd}	13.65^{a}
R. glutinosa		96.86^{a}	9.29^{c}	16.04^{ab}	4.70^{e}	49.31^{c}	12.20^{d}	20.66^{b}	16.72^{a}
E. capensis	fruit	94.11^{c}	5.43^{f}	11.07^{c}	31.00^{a}	35.9^{d}	20.25^{bc}	17.28^{b}	7.27^{b}
F. sycomorus		95.56^{b}	9.70^{b}	10.81^{c}	5.97^{c}	66.71^{ab}	27.5^{a}	9.07^{cd}	8.17^{b}
M. lanceolata		96.5^{a}	7.45^{e}	7.97^{c}	8.20^{b}	62.00^{b}	22.20^{ab}	14.38^{bc}	7.20^{b}
R. glutinosa		92.43^{d}	5.57^{f}	11.21^{c}	5.33^{d}	68.9^{a}	22.30^{ab}	5.84^{d}	8.59^{b}
	SE	0.31	0.35	0.72	1.57	2.29	1.00	1.92	0.55
	P	**	**	**	**	**	**	**	*

DM = dry matter, CA = crude ash, CP = crude protein, EE = ether extract, NDF = neutral detergent fibre, CF = crude fibre, NFC = non-fibre carbohydrates, CT = condensed tannin

$^{a–f}$means with different letters within the column are significantly different ($P < 0.05$)

*$P < 0.05$, **$P < 0.001$

(Gerhard and Peter, 1997; Proietti et al., 2000). In the present study, the crude ash (CA) concentration of the leaves and fruits, the mineral level in the feed, and large amount of silica ranged approximately 5–12%. CA concentrations of browse trees ranged 8–12% (Bogdan, 1977). Carlos et al. (2005) also found 7.9–12.6% CA for leaves of some tree fodders.

In general, all the tree leaves and fruits had a great CP concentration (more than 7%) which indicates their great nutritive value in terms of CP, since the browses are intended to be used as protein supplements for low quality tropical pastures and crop by-products. Norton (1994) reported that feeds with less than 6% CP levels are unlikely to provide the minimum ammonia levels required for maximum microbial growth in the rumen. Therefore, all browse species evaluated in this study would be good protein supplements provided that they were adequately degraded and non-toxic to the rumen microbes and host animal. The preference of differences in the CP concentration across the plants is inconsistent with the reports of Mekoya et al., 2008; Mekonnen et al., 2009; Ngodigha and Anyanwu, 2009 and Arigbede et al., 2011. In the present study, the CP concentration of the browse species was greater than the minimum level of 7–8% CP in DM required for optimum rumen function and feed intake in ruminant livestock (Norton, 1994; Van Soest, 1994; McDonald et al., 2002).

The CP values obtained from the leaves and fruits of non-leguminous trees in the present study were, however, lower than those reported for some leguminous browse species in south-west Nigeria (Larbi et al., 1998) and lower than the CP values obtained for *Acacia* species (Abdulrazak et al., 2000).These variations could be due to plant variety, agro climatic conditions, or even maturity stages at harvesting (Makkar and Becker, 1998; Bamikole et al., 2004). The chemical composition of tree leaves varies with the maturity of leaves and also with localities (Bamikole et al., 2004). Thus, the leaves of plant species analyzed here provide a good nutrient source for ruminant animal feed. The level of CP was, however, comparable with the reported CP of browsed species in tropical West Africa (Le-Houerou, 1980).

The all browse species in this study had CP level within the acceptable range (7–14%) for production and reproduction performance of ruminants (NRC, 1981). The results of the present study also agree with Getachew et al. (2000) in that the browse forages are a better protein supplement than poor quality roughages such as hay, straws, and stovers whose CP concentration is lower than 7% (Skerman and Riveros,1990). Voluntary feed intake rapidly falls if CP concentration of forage is below 6.2% (Nasrullah et al., 2003). It is well reported that feeds containing less than 7% CP cannot provide the minimum ammonia levels

Table 3. The Least Squares Means of *in sacco* ruminal dry matter disappearance of the plant species

Plant species	Plant part	Incubation time (h), mean (%)						
		0	6	12	24	48	72	96
E. capensis	leaf	29.43^{a}	32.12^{a}	59.47^{a}	73.11^{a}	82.49^{a}	81.79^{a}	83.38^{a}
F. sycomorus		6.32^{d}	15.82^{b}	26.09^{c}	22.53^{b}	61.07^{b}	59.52^{b}	69.89^{c}
M. lanceolata		23.69^{b}	32.60^{a}	35.59^{b}	64.99^{a}	65.72^{b}	81.46^{a}	77.53^{b}
R. glutinosa		19.28^{c}	16.87^{b}	17.99^{c}	23.72^{b}	38.20^{c}	47.07^{c}	47.64^{d}
	SE	0.68	1.88	3.13	3.87	4.71	2.79	1.47
	P	*	*	*	*	*	*	*
E. capensis	fruit	39.28^{a}	43.34^{a}	60.01^{a}	62.02^{a}	78.95^{a}	75.94^{a}	84.85^{a}
F. sycomorus		20.81^{b}	23.29^{b}	34.20^{b}	43.17^{b}	58.90^{b}	62.34^{b}	69.89^{b}
M. lanceolata		10.32^{d}	15.14^{c}	19.03^{c}	28.64^{c}	40.11^{c}	54.04^{c}	46.08^{c}
R. glutinosa		17.60^{c}	17.91b^{c}	20.30^{c}	22.16^{c}	26.46^{d}	34.16^{d}	21.65^{d}
	SE	0.45	2.12	1.49	3.37	2.44	2.79	1.57
	P	*	*	*	*	*	*	*

$^{a–d}$ means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

required by rumen microorganisms to support optimum activity, the leaves and fruits of the present study can be potential supplement for low CP feeds except for their CT concentration. Further, rumen fermentation is affected if the CP level in diet is less than 10% (Alam and Djajanigra, 1994), however, CP level in these trees is higher except for *M. lanceolata* fruit. Differences in CP concentrations between leaves of different trees are probably due to differences in protein accumulation in them during growth. Even though the CP concentrations of the plant parts attained the minimum protein level for optimum rumen function, their CP concentration was relatively lower than that of protein supplementary legume browses such as *Leucaena leucocephala* (27.2%), *Sesbania sesban* (27.6%) (Thandei et al., 2001; Mupangwa et al., 2003; Giang et al., 2004), and *Albizia gummifera* (29.6%) (Yisehak et al., 2010).

The NDF concentration of the plants, except for *E.capenesis* leaf (47.72%), *M.lanceolata* fruit (56.67%), and *R.glutinosa* leaf (49.50%) was over 60%. Optimum NDF concentration of a ration should range 27–30% (Jolly and Wallace, 2007). The threshold level of NDF in tropical plants beyond which feed intake of ruminants is affected is 60% (Meissner et al., 1991) suggesting that some of the diets included in this study marginally have above 60% NDF in DM. Tree forages with a low NDF concentrations (20–35%) are usually of great digestibility (Norton, 1994; Bakshi and Wadhwa, 2007). This can induce even greater fermentation rate, therefore, improving its digestibility (Van Soest, 1994). The results of the present study were inconsistent with Schmidek et al. (2000) and Cheema et al. (2011) who reported 26.2 to 39.3% NDF for multipurpose trees and shrub species. The NDF results of the present study were also comparable with the NDF values reported for some browse species in Nigeria (Larbi et al., 1998) and shrub species from a mountain area in northern Spain (Frutos et al., 2000) with just little variations. Great concentrations of cell wall are typical of tropical forages (Van Soest, 1982) which have serious implication on the digestibility of forages.

The EE concentration in leaves of the plants except *F. sycomorus* (1.57% on average) exceeded 5%. The EE concentration (average < 5% in DM) is an indication of low energy level for the animal. Odedire and Babayemi (2008) reported that feedstuffs containing more than 5% EE had greater energy concentrations than those attaining less than 5%. Therefore the present study could achieve the above requirement. However, the EE concentration of *E. capenesis* fruits was above the acceptable range for the animals (28.10% on average). The greater value of ether extracts in some of the tested samples is an indication of greater energy level for the animal (Babayemi and Bamikole, 2006; Odedire and Babayemi, 2008) and this is a major form of energy storage in plants which is being utilized by the animals for body maintenance and production. The crude fat concentrations of all the tree fruits and leaves evaluated were greater than the levels reported in pasture grass (0.6–1.3%) and fodder maize (4.4%) (Schlink and Burt, 1993).

The CT concentration in all the plants was above 5% that is why these plants can be considered as CT rich plants. Condensed tannin concentrations greater than 5% adversely affect forage intake and digestibility (Perevolotsky et al., 1993; Silanikove et al., 1996). However, some reports from literature confirmed that ruminant animals are able to handle browse plants with tannin content below 100 g/kg DM (Gasmi-Boubaker et al., 2005) although the tolerance level may vary between animal species (Onwuka, 1992). Condensed tannins have ability to bind and inhibit the digestive enzyme activities (Kumar and Singh, 1984) and affect the microbial and enzyme activities (Makkar et al., 1989), whereas lower concentration of CT can improve nutrition for ruminants by reducing protein degradation in the rumen and increasing the flow of amino acids to the intestine (McNabb et al., 1996). Concentration of CT in the ration lower than 4% is beneficial by promoting bypass protein and bloat suppression in ruminant animals (Aganga and Tshwenyane, 2003). Compared with tropical, mature grasses, browse appears to be richer in protein and minerals (Le Houerou, 1980; Devendra, 1995). In most situations, it can be used as a supplement to enhance the intake and utilization of other fibrous crop residues like cereal straws and hays, and thus meet the maintenance and variable levels of production requirements.

In sacco ruminal dry matter disappearances

Interspecies variation for DM disappearances from leaves and fruits of condensed tannin-rich trees for different incubation hours are presented in Table 3. The greatest DM disappearance at 0-hour incubation was recorded in leaves of *E. capensis*

(29.43%) whereas the DM disappearance value was the least for *F. sycomorus* leaves (6.32%) ($P < 0.001$). Six hours post incubation, the greatest DM disappearances were recorded for the leaves of *E. capensis* (32.12%) and *M. lanceolata* (32.60%) where as the least DM disappearances were determined *F. sycomorus* (15.82%) and *R. glutinosa* (16.87%) leaves ($P < 0.001$). Yet at a 6-hour incubation, the *E. capensis* fruits had the greatest DM disappearances as compared to the rest of the plants ($P < 0.001$). Across all the incubation hours, the leaves of *E. capensis* had the greatest DM disappearances; comparably, *M. lanceolata* leaves had also the greatest DM disappearances at 6, 24, and 72 h incubation in contrast to the rest of the plants ($P < 0.001$). In comparison, the greatest DM disappearance value was only recorded for *E. capensis* fruit ($P < 0.001$).

The Least Squares Means differences for the DM disappearance as compared between leaves and fruits are given in Table 4. At 0-hour incubation both the greatest and least DM disappearance or bag wash loss were recorded in *E. capensis* fruit (39.28%) and *F. sycomorus* leaves (6.32%), respectively ($P < 0.001$). *E. capensis* leaves and fruits acquire the greatest share in DM disappearances in almost all incubation hours as compared to DM disappearances in edible parts of the rest plants ($P < 0.001$).

The greatest DM disappearance at 0-hour incubation was recorded in leaves of *E. capensis* (29.43%) whereas it was the least for *F. sycomorus* leaves (6.32%) ($P < 0.001$). This might be attributed to processing or distribution in particle size of the ground materials. The reports of Welch (1986), Singh et al. (1989), and Khan et al. (2009) confirmed that DM disappearance at 0-hour is mainly due to mechanical action rather than microbial fermentation. Six hours post incubation, the greatest DM disappearances were recorded for the leaves of *E. capensis* (32.12%) and *M. lanceolata* (32.60%) and the least DM disappearances were determined for *F. sycomorus* (15.82%) and *R. glutinosa* (16.87%) leaves ($P < 0.001$). Yet at 6 hour incubation, the *E. capensis* fruits had the greatest DM disappearances as compared to the rest of the plants ($P < 0.001$). Across all the incubation hours, the leaves of *E. capensis* had the greatest DM disappearances; comparably, *M. lanceolata* leaves had also the greatest DM disappearances at 6, 24, and 72 h incubation in contrast to the rest of the plants ($P < 0.001$). In comparison, the greatest DM disappearance value was only recorded for *E. capensis* fruit ($P < 0.001$). In general, species variation was significant for DM disappearances across the incubation hours. A possible reason of this effect might be differences in chemical composition of the plant parts used for rumen microbes. Arigbede et al. (2011) reported similar findings that an effect of species variation is significant for variations in DM disappearances of different multipurpose tree species.

It has also been reported that NFC has a positive relationship with ammonia nitrogen (NH_3-N)

Table 4. Least Squares Means for *in sacco* ruminal dry matter disappearances compared for leaves and fruits of the plant species

Plant species	Plant part	Incubation time (h), mean (%)						
		0	6	12	24	48	72	96
E. capensis	leaf	29.43^{b}	32.12^{b}	59.47^{a}	73.11^{a}	82.49^{a}	81.79^{a}	83.38^{a}
F. sycomorus		6.32^{g}	15.82^{d}	26.09^{c}	22.53^{d}	61.07^{b}	59.52^{b}	69.89^{c}
M. lanceolata		23.69^{c}	32.60^{b}	35.59^{b}	64.99^{ab}	65.72^{b}	81.46^{a}	77.53^{b}
R. glutinosa		19.28^{de}	16.87^{d}	17.99^{d}	23.72^{d}	38.20^{c}	47.07^{c}	47.64^{d}
E. capensis	fruit	39.28^{a}	43.34^{a}	60.01^{a}	62.02^{b}	78.95^{a}	75.94^{a}	84.85^{a}
F. sycomorus		20.81^{d}	23.29^{c}	34.20^{b}	43.17^{c}	58.90^{b}	62.34^{b}	69.89^{c}
M. lanceolata		10.32^{f}	15.14^{d}	19.03^{d}	28.64^{d}	40.11^{c}	54.15^{bc}	46.08^{d}
R. glutinosa		17.60^{e}	17.91b^{cd}	20.30^{cd}	22.16^{d}	26.46^{d}	34.16^{d}	21.65^{e}
	SE	2.04	1.55	2.47	3.14	2.99	2.51	3.06
	P	*	*	*	*	*	*	*

$^{a-g}$means in a column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

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 concentrations especially in *E. capensis* could enable efficient microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with great concentration of rumen degradable CP (Cabrita et al., 2006). DM disappearance values were the greatest at terminal incubation hours across plant species. Many authors (Orskov et al., 1988; Kabuga and Darko, 1993; Tesema et al., 2003; Lanyasunya et al., 2006; Vranic et al., 2009, and Lebopa et al., 2011) confirmed the increasing trends of that ruminal degradation of DM as advances in incubation hours. The other possible reason could be condensed tannin concentration of the feed materials. Although the condensed tannin concentration of the leaves and fruits attained the level that affects nutrient utilization, CT concentration in leaves and fruits of *E. capensis* was one of the least CT values among the plant parts. Condensed tannins are complex polyphenolic compounds with an ability to precipitate proteins and to form complexes with carbohydrates thereby reducing the digestibility (Kumar and Vaithiyanathan, 1990; Mezzomo et al., 1991; Makkar, 2003; Ferreira, 2004).

Except in fruits and leafs of *E. capensis* and leaves of *M. lanceolata,* the DM disappearance of the plants is lower than the values recorded for most of the legume and non-legume multipurpose trees reported by Ramana et al. (2000). This difference might be associated with the differences in plant species. The greater NDF and CT concentrations in the plant species might also be attributed to lower DM disappearances.

The other possible reason might be associated with the NFC concentration, the major energy source for rumen microbes, which were found to be superior in the leaves and fruits of *E. capensis*. The range of NFC concentration showed that the trees under evaluation can be easily degraded or fermented because NFC is an estimate of the carbohydrate pool that differs from CF and NDF in digestibility.

In sacco dry matter degradability characteristics

The *in sacco* DM degradability characteristics of leaves and fruits of the studied plants are presented in Table 5. The greatest and least soluble fraction (*b*) of leaves was recorded in *M. lanceolata* (14.55%) and *E. capensis* (–16.20%), respectively ($P < 0.001$). This could be related to the loss of finer particles from the bags in this treatment, rather than a greater solubility. Yet in the fruit, the greatest value of soluble fraction (35.51%) was obtained for *E. capensis*. However, the Least Squares Means obtained for slowly degradable fraction (*b*) in the leaves of *E. capensis* were superior (98.37%) while in *R. glutinosa* leaves we recorded the least value ($P < 0.001$). In general, *E. capensis* leaves had the greatest values for slowly degradable fraction, effective degradability, and rate of degradation (*c*) as compared to values recorded for other plants ($P < 0.001$). Unlike in leaves, *E. capensis* fruit had significantly the greatest soluble fraction (*a*), potential degradability (*b*), and effective degradability (*ED*) values as compared to *a, PD,* and *ED* values in the fruits of other plants ($P < 0.001$).

Table 5. *In sacco* dry matter degradability characteristics for the leaves and fruits of the plant species

Plant species	Degradability parameters (leaf)					Degradability parameters (fruit)				
	a	*b*	*PD*	*ED*	*c*	*a*	*b*	*PD*	*ED*	*c*
E. capenesis	-16.2^{d}	98.37^{a}	82.17^{b}	61.83^{a}	0.12^{a}	35.51^{a}	47.11^{b}	82.62^{a}	63.18^{a}	0.04^{b}
F. sycomorus	7.37^{c}	77.82^{b}	85.19^{a}	35.78^{c}	0.02^{c}	15.49^{b}	56.15^{a}	71.64^{b}	43.28^{b}	0.03^{c}
M. lanceolata	14.55^{a}	64.91^{c}	79.47^{c}	53.76^{b}	0.05^{b}	5.78^{d}	46.59^{c}	52.36^{c}	29.22^{c}	0.03^{c}
R. glutinosa	11.23^{b}	52.76^{d}	63.99^{d}	27.86^{d}	0.01^{d}	13.92^{c}	13.69^{d}	27.61^{d}	22.57^{d}	0.05^{a}
SE	0.17	0.03	0.12	0.05	0.001	0.007	0.01	0.01	0.01	0.004
P	*	*	*	*	*	*	*	*	*	*

a = soluble fraction, *b* = slowly degradable fraction, *c* = rate of degradation, *PD* = potential degradability, *ED* = effective degradability

$^{a–d}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

Table 6. Comparison of Least Squares Means for *in sacco* ruminal dry matter degradability characteristics of leaves and fruits of the plant species

Plant species	Plant part	Degradability parameters				
		a	*b*	*PD*	*ED*	*c*
E. capenesis	leaf	–16.2^{h}	98.37^{a}	82.17^{c}	61.83^{b}	0.12^{a}
F. sycomorus	leaf	7.37^{f}	77.82^{b}	85.19^{a}	35.78^{e}	0.02^{e}
M. lanceolata	leaf	14.5^{c}	64.91^{c}	79.47^{d}	53.76^{c}	0.05^{b}
R. glutinosa	leaf	11.23^{e}	52.76^{e}	63.99^{f}	27.86^{g}	0.01^{f}
E. capenesis	fruit	35.51^{a}	47.11^{f}	82.62^{b}	63.18^{a}	0.04^{c}
F. sycomorus	fruit	15.49^{b}	56.15^{d}	71.64^{e}	43.28^{d}	0.03^{d}
M. lanceolata	fruit	5.78^{g}	46.59^{g}	52.36^{g}	29.22^{f}	0.03^{d}
R. glutinosa	fruit	13.92^{d}	13.69^{h}	27.61^{h}	22.57^{h}	0.05^{b}
SE		2.63	4.69	3.99	3.11	0.006
P		*	*	*	*	*

a = soluble fraction, *b* = slowly degradable fraction (%/h), *c* = rate of degradation, *PD* = potential degradability, *ED* = effective degradability

$^{a–h}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

The *in sacco* DM degaradability characteristics of fruits and leaves of various multipurpose tree species (MPTS) compared and the results were presented in Table 6. Although the species variation was significant for degardability parameters, the effect of plant parts was significant, too ($P < 0.001$). Based on *ED* values in this study, MPTS could be assigned to great (> 450 g/kg DM), medium (400–450 g/kg DM), and low (< 400 g/kg DM) quality groups. *E. capensis* (leaf and fruit) and *M. lanceolata* (fruit) belonged to great quality group, *F. sycomorus* fruit to medium quality group, while both *R. glutinosa* leaf and fruit and *M. lanceolata* fruit belonged to low quality group. The greatest (0.12%/h) and least (0.01%/h) values of degradation rate were recorded for leaves of *E. capensis* and *R. glutinosa* as compared to the *c* values in fruits of the plant species, respectively ($P < 0.001$).

The *in sacco* DM degradability characteristics of leaves and fruits of the studied plants are presented in Table 5. The greatest and least soluble fraction (*b*) of leaves was recorded in *M. lanceolata* (14.55%) and *E. capensis* (–6.20%), respectively ($P < 0.001$). This could be related with the loss of finer particles from the bags in this treatment, rather than with greater solubility. Yet in the fruit, the greatest value of soluble fraction (35.51%) was obtained for *E. capensis*. Except in fruits of *M. lanceolata* (14.55%) and *F. sycomorus* (15.49%), the values of soluble fraction *a* in the present study were lower than the *a* values estimated for 20 multipurpose trees and shrub species (both legumes and non legumes) studied in Nigeria by Ngodigha and Anyanwu (2009). The possible reason could be linked to variation in plant species. However, the Least Squares Means obtained for slowly degradable fraction *b* in the leaves of *E. capensis* were found to be superior (98.37%) whereas the least value was recorded for *R. glutinosa* leaves ($P < 0.001$). This could be associated with the concentration of CTs; the greatest CT concentration in *R. glutinosa* leaves had the least DM disappearance of the potentially degradable fraction. The CTs depress DM degradability (Gonzalez et al., 2002; Gupta et al., 2011). In general, *E. capensis* leaves had the greatest values for slowly degradable fraction, effective degradability and rate of degradation *c* as compared to values recorded for other plants ($P < 0.001$). Unlike in leaves, *E. capensis* fruit had significantly the greatest soluble fraction *a*, potential degradability *b*, and effective degradability (*ED*) values as compared to *a, PD,* and *ED* values in the fruits of other plants ($P < 0.001$). This might be due to greater concentration of NFC as well as EE concentration in *E. capensis* leaves and fruits. Higher level of soluble fraction is known to result in a more efficient fermentation in the rumen (Beever et al., 1978). The differences in soluble fraction could be attributed to the proportion of soluble carbohydrates to structural carbohydrates

(Ngodigha and Anyanwu, 2009). According to Van Soest (1982), the soluble carbohydrates ferment faster than structural carbohydrates.

In sacco ruminal organic matter disappearances

The 0-hour disappearance of OM was the greatest for leaves and fruits of *E. capensis* as compared to the rest of plants ($P < 0.001$) (Table 7). Similarly, at 6 h incubation the greatest OM disappearance was recorded for leaves and fruits of *E. capensis*, as well as leaves of *M. lanceolata.* Throughout the incubation hours the leaves and fruits of *E. capensis* had the greatest OM disappearance values followed by leaves of *M. lanceolata* as compared to OM disappearance values of plant parts in the rest of plant species ($P < 0.001$).

The great washing loss (0 h disappearance) of MPTS evaluated in this study is an indication of the presence of soluble or ruminally degradable nutrients that may be rapidly utilized in the rumen. The MPTS recorded more than 60% OM degradability at 24 h which implied that they were extensively degraded in the rumen. As compared to 0-hour OM disappearances of leaves and fruits, the greatest value (39.28%) was recorded in the *E. capensis* fruit ($P < 0.001$) (Table 8). Even though, throughout the incubation hours other than zero, the OM disappearance values were one of the highest values among plants and their edible fractions, statistically significant variation was not recorded between leaves and fruits of *E. capensis* ($P > 0.001$).

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). The least OM degradability values for leaves and fruits (< 60%) of the plant species except for *E. capensis*, as well as for *M. lanceolata* leaves might be associated with the presence of secondary metabolites. Several studies have documented effects of secondary metabolites, especially condensed tannins (Reed, 1995; Ammar et al., 2004; Gasmi-Boubaker et al., 2005), on OM degradability; however, it can be concluded that condensed tannins at levels reported in this study could not affect OM degradability in *E. capensis* leaves and fruits and leaves of *M. lanceolata,* even if CT concentration would reach the values that complicate feed digestion. Although changes in the condensed tannin concentration of individual species may affect rumen nitrogen and OM degradability (Barry and Forss, 1983), to compare the effect of condensed tannin concentration on such parameters between species is perhaps not valid as there is no existing accurate method for estimation of "active" condensed tannins. The other possible reason might be associated with

Table 7. Least Squares Means for *in sacco* ruminal organic matter disappearance of leaves and fruit of tannin-rich trees

Plant species	Plant part	Incubation time (h), mean (%)						
		0	6	12	24	48	72	96
E. capensis	leaf	29.43^{a}	37.55^{a}	61.05^{a}	73.28^{a}	82.48^{a}	81.79^{a}	83.38^{a}
F. sycomorus		6.32^{d}	22.63^{c}	26.45^{c}	23.57^{b}	62.64^{b}	61.05^{b}	69.89^{c}
M. lanceolata		23.70^{b}	31.21^{ab}	36.05^{b}	65.91^{a}	72.30^{ab}	81.69^{a}	77.60^{b}
R. glutinosa		19.28^{c}	17.44^{c}	20.63^{c}	26.26^{b}	42.02^{c}	47.27^{c}	48.98^{d}
	SE	0.68	3.49	3.03	3.54	3.46	2.36	1.43
	P	*	*	*	*	*	*	*
E. capensis	fruit	39.28^{a}	43.34^{a}	60.68^{a}	64.81^{a}	81.34^{a}	80.29^{a}	84.99^{a}
F. sycomorus		20.81^{b}	21.27^{b}	34.96^{b}	45.43^{b}	53.40^{b}	64.88^{b}	69.36^{b}
M. lanceolata		10.32^{d}	14.85^{b}	19.03^{c}	29.73^{c}	47.86^{b}	54.61^{c}	45.63^{c}
R. glutinosa		17.60^{c}	17.91^{b}	20.30^{c}	24.39^{c}	27.73^{c}	38.25^{d}	31.09^{d}
	SE	0.45	2.44	1.60	2.91	2.31	1.73	3.50
	P	*	*	*	*	*	*	*

$^{a–d}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

Table 8. Comparison of Least Squares Means of leaves and fruits of the tannin-rich plants for *in sacco* organic matter disappearances

Plant species	Plant part	Incubation time (h), mean (%)						
		0	6	12	24	48	72	96
E. capensis	leaf	29.43^{b}	37.55^{ab}	61.05^{a}	73.28^{a}	82.48^{a}	81.79^{a}	83.38^{a}
F. sycomorus		6.32^{g}	22.63^{cd}	26.45^{c}	23.57^{c}	62.64^{c}	61.05^{b}	69.89^{b}
M. lanceolata		23.69^{c}	31.21^{bc}	36.05^{b}	65.91^{a}	72.30^{b}	81.69^{a}	77.60^{a}
R. glutinosa		19.28^{de}	17.44^{d}	20.63^{c}	26.26^{c}	42.02^{e}	47.27^{d}	48.98^{c}
E. capensis	fruit	39.28^{a}	43.34^{a}	60.68^{a}	64.81^{a}	81.34^{a}	80.29^{a}	84.99^{a}
F. sycomorus		20.81^{d}	21.27^{d}	34.96^{b}	45.43^{b}	53.40^{d}	64.88^{b}	69.36^{b}
M. lanceolata		10.32^{f}	14.85^{b}	19.03^{c}	29.73^{c}	47.86^{de}	54.61^{c}	45.63^{c}
R. glutinosa		17.60^{e}	17.91^{d}	20.30^{c}	24.39^{c}	27.73^{f}	38.25^{e}	31.09^{d}
	SE	2.04	1.73	2.49	3.06	2.83	2. 37	2.82
	P	*	*	*	*	*	*	*

$^{a–g}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

greater NDF concentrations. Ruminant livestock requires fibre for normal rumen function but fibre also limits feed intake and digestibility (Albrecht and Broderick, 1990).

In sacco organic matter degradability

Table 9 shows the nonlinear parameter estimates and effective degradability values of OM of the leaves and fruits of the studied plants. On the other hand, the greatest and least *a* value was recorded for fruits of *R. glutinosa* (31.84%) and *E. capensis* (14.22%) ($P < 0.001$). The insoluble but degradable fraction *b* was 83.35% in *R. glutinosa* and 45.21% in *E.capensis* leaves ($P < 0.001$); in contrast, the greatest and least values of *PD* were recorded for *F. sycomorus* (89.89%) and *E. capensis* (55.90%), respectively ($P < 0.001$). Similarly, the greatest and least *ED* was obtained in *R. glutinosa* (63.97%) and *E. capensis* leaves ($P < 0.001$). The degradation rate constants *c* varied widely between MPTS with similar rates for *E. capensis* and *F. sycomorus*. The washing losses and soluble or rapidly degradable OM fraction at 0-hour were the greatest for *R. glutinosa* fruit and the least (–1.02%) for its leaves ($P < 0.001$)(Table 10). This might be associated with differences in the solubility of leaves and fruits of

Table 9. *In sacco* organic matter degradability characteristics of leaves and fruits of selected browses species

Plant species	Degradability parameters (leaf)					Degradability parameters (fruit)				
	a	*b*	*PD*	*ED*	*c*	*a*	*b*	*PD*	*ED*	*c*
E. capenesis	10.69^{b}	45.21^{d}	55.90^{d}	29.61^{d}	0.02^{c}	14.22^{c}	21.38^{d}	35.60^{d}	24.58^{d}	0.03^{c}
F. sycomorus	12.63^{a}	77.27^{b}	89.89^{a}	38.11^{c}	0.02^{c}	15.26^{b}	56.40^{a}	71.66^{b}	42.84^{b}	0.03^{c}
M. lanceolata	8.11^{c}	71.98^{c}	80.09^{c}	54.55^{b}	0.05^{b}	2.06^{d}	50.28^{c}	52.34^{c}	30.59^{c}	0.04^{b}
R. glutinosa	–1.02^{d}	83.35^{a}	82.33^{b}	63.97^{a}	0.11^{a}	31.84^{a}	52.02^{b}	83.86^{a}	64.65^{a}	0.05^{a}
SE	0.02	0.009	0.08	0.04	0.002	0.01	0.06	0.05	0.007	0.001
P	*	*	*	*	*		*	*	*	*

a = soluble fraction, *b* = slowly degradable fraction, *c* = rate of degradation, *PD* = potential degradability, *ED* = effective degradability

$^{a–d}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

Table 10. Comparison of Least Squares Means for *in sacco* ruminal degradability characteristics of organic matter of leaves and fruits of the plant species

Plant species	Plant part	Degradability parameters				
		a	*b*	*PD*	*ED*	*c*
E. capenesis	leaf	10.69^{e}	45.21^{g}	55.90^{f}	29.61^{g}	0.02^{e}
F. sycomorus		12.63^{d}	77.27^{b}	89.89^{a}	38.11^{e}	0.02^{e}
M. lanceolata		8.11^{f}	71.98^{c}	80.09^{d}	54.55^{c}	0.05^{b}
R. glutinosa		–1.02^{h}	83.35^{a}	82.33^{c}	63.97^{b}	0.11^{a}
E. capenesis	fruit	14.22^{c}	21.38^{h}	35.60^{h}	24.58^{h}	0.03^{d}
F. sycomorus		15.26^{b}	56.40^{d}	71.66^{e}	42.84^{d}	0.03^{d}
M. lanceolata		2.06^{g}	50.28^{f}	52.34^{g}	30.59^{f}	0.04^{c}
R. glutinosa		31.84^{a}	52.02^{e}	83.86^{b}	64.65^{a}	0.05^{b}
SE		2.03	4.04	3.82	3.15	0.006
P		*	*	*	*	*

a = soluble fraction, *b* = slowly degradable fraction, *c* = rate of degradation, *PD* = potential degradability, *ED* = effective degradability

$^{a–h}$means within the same column with different superscripts are significantly different ($P < 0.05$)

*$P < 0.001$

the same plant. Yet, in leaves and fruits, the value recorded for the insoluble but potentially fermentable OM fraction that degrades with time was the greatest in *R. glutinosa* (83.35%) leaves and least in *E. capensis* fruit (45.21%) ($P < 0.001$). Conversely, among the plant species, the greatest (89.89%) and least (35.60%) *PD* was determined for *F. sycomorus* leaves and *E. capensis* fruit ($P < 0.001$). Similarly to the rapidly soluble fraction *a*, *ED* was found to be greater in fruits than in leaves of the plants ($P < 0.001$). In general, it was observed that variation of plant parts led to significant differences in OM degradability characteristics of the plant species.

The observed differences in OM degradation characteristics of the studied plant species may be partly due to the differences in their chemical composition which is influenced by the species, foliage parts of the trees. The range of values for the readily soluble fraction *a*, potentially degradable fraction *b*, the rate *c*, and extent of OM degradation in this study agreed with the reports of Larbi et al., 1998, El- hassan et al., 2000, and Hervas et al., 2000 who also confirmed significant differences in OM 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 Orskov, 1993). Thus, interspecies variations in OM degradability could result in different intakes of the plants when given as sole diets to animals. The values of *a* for leaves of the plants are lower than presented in previous reports for various MPTS in Nigeria (Ngodigha and Anyanwu, 2009; Arigbede et al., 2011), and for 12 species in Kenya (Ondiek et al., 2010). These differences might be attributed to differences in plant species location and concentrations of secondary plant components, especially condensed tannin; greater CT concentration has been obtained in the present study.

CONCLUSION

The chemical composition of the MPTS has wide-ranging variation both in plant species and edible plant parts. The present study shows that all the MPTS studied can serve as potential protein banks to supplement grasses or crop residues in dry seasons. However, the nutrient activating factor (condensed tannin) in the edible parts of the studied plants was greater than the threshold value that affects nutrient utilization and bioavailability in grazing livestock species. Yet, higher levels of CT in some species may be a major constraint to their utilization by the livestock. The leaves and fruits of *E. capensis* are superior in DM and OM disappearances of the other plant species. The least DM and OM were detected both in leaves

and fruit of *R. glutinosa* plant at the end of 96 h incubation. In general, the DM and OM disappearances of plant parts were negatively correlated to concentrations of condensed tannins. Among the plant species, the greatest (89.89%) and the least (35.60%) *PD* was determined for *F. sycomorus* leaves and *E.capensis* fruit ($P < 0.001$). Similarly to the rapidly soluble fraction *a*, *ED* was found to be greater in fruits than in leaves of the plants ($P < 0.001$). In general, it was observed that variation of plant parts led to significant differences in OM degradability characteristics of the plant species.

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