Original Research

Chemical Composition, Tannins and *In Situ* Degradation Characteristics of Selected Tree Leaves

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Abstract

Eight tree leaves were evaluated for chemical composition, tannin content, ME and in situ degradation of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF). Chemical composition revealed that CP was more in Moringa oleifera. Dillenia was had more NDF and ADF and Acacia auriculiformis with Acid detergent lignin (ADL). The metabolisable energy (ME) was higher in Melia dubia and lower in Dillenia. Phenolics fractions were present in all tree leaves and condensed tannins (CT) ranged from 0.02 to 15.26%. Moringa oleifera, Melia dubia and Sesbania grandiflora had more effective and potential degradability. The soluble protein losses were more in Sesbania grandiflora. The undegradable CP at 96h was more in Acacia auriculiformis (54.13 per cent). The rumen degradable nitrogen (RDN) (g) and RDN g/kg DOMR (degradable organic matter in rumen) values were highest for Moringa oleifera (24.19 and 36.62) and lowest for Dillenia sp. (4.39 and 15.13). CP was positively correlated and NDF, ADF, ADL and tannin fractions were negatively correlated with potential degradability (Y), effective degradability (P), RDN and RDN/Kg of DOMR. It can concluded that on the basis of chemical composition, tannin, ME and in situ degradability, potentiality of tree leaves for usage as feed supplements can be known.

Key words: Chemical Composition, *In Situ*, ME, Ruminants, Tannins, Tree Leaves

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Introduction

The tree fodders are an integral part of diet in ruminants and these have been traditionally used by farmers in many countries. Tree fodders are frequently used as a buffer to overcome feed gaps and these are readily available source of valuable nitrogen, energy, minerals and vitamins (Devendra, 1992). Its inclusion needs concern about presence of secondary metabolites (tannins, saponin) and fibre (NDF, ADF and associated lignin) which interferes with preference, intake and digestibility. It is known that fibre degradation determine rumen fill and intake (Van Soest, 1994). Ruminants prefer rapidly degradable forage source (Chenost *et al.,* 2001). Due to wider variation in fibre and tannin content of tree leaves the screening is required with respect to degradability (El Hassan *et al.,* 2000). Current feed evaluation systems focus on dynamic aspects of ruminal degradation of DM, OM, CP, NDF and ADF (NRC, 2001). Assessment of preference of tree fodder can be done by employing *In situ* degradation techniques, which would be complimentary to traditional chemical measurements (Carlos *et al*., 2005).

The *In situ* technique is a widely adopted reference technique to characterize the dynamics of degradation of feedstuffs as well as nutrients in the rumen (Orskov and McDonald, 1979). Our aim of this study was to evaluate the chemical composition, tannins, ME and *in situ* degradability of eight selected tree leaves of this region and the data generated was used to evaluate the potentiality as a supplementary role in ruminants.

Materials and Methods

Description of the Study Area

The study was conducted to evaluate the nutritional value of eight selected tree leaves found in Karnataka, India. This study was carried out at the Department of Animal Nutrition, Veterinary College, Bengaluru, Karnataka Veterinary Animal and Fisheries Sciences University (KVAFSU).

Collection of Tree Leaves and Processing

Tree leaves of *Sesbania grandiflora* (Agase, *Kan.*), *Melia dubia* (Hebbevu, *Kan.*), *Dillenia sp.* (Kaadu kanigalu, *Kan.*), *Artocarpus heterophyllus* (Halasu, Kan), *Commiphora caudata* (Konda Maavu, *Kan.*), *Moringa oleifera* (Nugge, Kan.), *Leucaena leucocephala* (Subabul) and *Acacia auriculiformis* (Acacia) were chosen. The tree leaves were hand plucked, oven dried at 55^{0}C for 48h and grounded to pass through size of 1mm sieve for further analysis (*Kan.* regional language, Kannada).

Chemical Composition

These tree leaves were analyzed for proximate composition (AOAC, 2005), forage fibre fractions (Van Soest *et al.*, 1991), total phenolics (TP), non-tannin phenols (NTP), total tannins (TTP), condensed tannins (CT) and hydrolysable tannins (HT) (Makkar, 2003).

Metabolisable Energy

The selected tree leaves were subjected to rumen *in vitro* incubation and gas production (RIVIGP) for estimating metabolisable energy (ME, MJ/Kg). A lactating dairy cow producing 3 kg of milk per day, fitted with a flexible rumen canula of large diameter (Bar Diamond, Inc. USA), receiving a basal diet consisting of Finger millet straw (FMS) and CFM (Maize 60%, WB 35%, mineral mixture 2%, urea 2%, salt 1%) was used as the donor cow for rumen fluid. For RIVIGP test, rumen fluid was collected before offering CFM. Air equilibrated feed samples (200 ± 10 mg) of tree leaves were incubated in 100 ml calibrated glass syringes in triplicate with 30 ml mixed rumen suspension with three blank incubations and standards

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(Menke and Steingass, 1988). Cumulative gas production was recorded after 24 hours of incubation to estimate the ME. The ME was estimated based on equation of Menke and Steingass (1988).

$$ME (MJ/Kg) = 2.2 + 0.1357 GP + 0.0057 CP + 0.0002859 EE^2$$

Where,

GP = Corrected Net Gas production at 24h, ml/200 mg. DM; CP = Crude protein, g/kg. DM; EE = Ether extract g/kg. DM.

Tannin Fractions

Total phenols (TP) were estimated by the Folin–Ciocalteu reaction (Makkar, 2003). For the condensed tannin (CT) fraction, the extract was treated with butanol–HCl in the presence of ferric ammonium sulphate, and CT (% of DM) expressed as leucocyanidin equivalent is calculated by the formula, (*A*550 nm × 78.26 × Dilution factor) / (% of DM), where *A*550 nm is absorbance at 550 nm assuming that the effective *E*1%, 1 cm, 550 nm of leucocyanidin is 460 (Porter *et al.*, 1986). The phenolic content of the supernatant after precipitating with polyvinylpolypyrrolidone (PVPP; 100 mg) was measured by the Folin-Ciocalteau reaction and this was regarded as the non-tannin phenol (NTP). Total tannin phenols (TTP) were calculated as the difference of TP and NTP. Hydrolysable tannins (HT) were calculated as the difference between TTP and CT.

***In situ* Degradability**

The *in situ* procedure used for incubation of tree leaves in the rumen was similar to that described by Singh *et al*. (1995). Dacron bags of size 15 x 8.5 cm with a round base and pore size of 50 to 55 µm were used. Pore size was measured under 100x magnification using Olympus B×51 microscope fitted with a photomicrography camera with ProgRes C3 software. About 5 g of the dried sample (1 mm particle size) was weighed into the bag and closed with a plastic tie. The bags were anchored to a weight (450g) and suspended in the rumen of lactating dairy cow producing 3 kg of milk per day, receiving a basal diet consisting of Finger millet straw (FMS) and CFM (maize 60 per cent, wheat bran 35 per cent, mineral mixture 2 per cent, urea 2 per cent and salt 1 per cent). Bags in triplicates were introduced in the rumen in reverse sequence and the incubation times were 0.1, 1, 3, 6, 12, 24, 48, 72 and 96 hours. After the incubation all the bags were removed at once, washed in a cold water in 2 cycles of 5 minutes each using a commercial washing machine and then dried at 60°C for 48 hours. The amount of residual DM, OM, NDF, ADF and CP in the incubated samples were analysed as per AOAC (2005).

The soluble or rapidly degradable fraction (a), insoluble but potentially degradable fraction (b), residual component at 96 h of incubation (c), the rate of degradation (k_d, $h^{-1}=0.693/t_{1/2}$), potential degradability [$Y=a+b(1-e^{-kd*t})$], effective degradability [$P= a+b(Kd/Kd+Kp)$], Kp is the rate of passage, taken as 0.056/h] and rumen undegradable component ($=100-P$) profile of tree leaves in terms of DM, OM, NDF, ADF and

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CP were obtained after fitting data to the exponential model of nonlinear regression as per Orskov and McDonald (1979).

Statistical Analysis

In situ degradation profiles of tree leaves were obtained after fitting data to the exponential equation of Orskov and McDonald (1979), using the GraphPad Prism 5.01 (2007). Pearson correlation analysis was used to assess the relationship of chemical composition, tannins and ME with *In situ* degradation of DM, OM, CP, NDF and ADF.

Results and Discussion

Chemical Composition and ME

The chemical composition and ME content of tree leaves are presented in Table 1. The CP ranged from 7.89 (*Dillenia sp.*) to 19.69% (*Moringa oleifera*) and an average CP of 15.65%. The fibre components are most varied, the NDF ranged from 24.96 (*Moringa oleifera*) to 54.32% (*Dillenia sp.*); ADF from 13.03 (*Moringa oleifera*) to 47.09% (*Dillenia sp.*); ADL from 3.62.

Table 1: Chemical composition[1] (per cent DMB) of tree leaves

Tree Leaves	DM	OM	CP	NDF	ADF	ADL	ME (MJ/kg)
Sesbania grandiflora	20.31	90.9	17.9	45.81	33.93	3.62	8.48
Melia dubia	34.12	90.24	15.67	32.04	21.51	8.25	9.6
Dillenia sp	31.49	90.54	7.89	54.32	41.7	15.25	4.9
Moringa oleifera	30.9	89.56	19.69	24.96	13.03	4.57	8.28
Artocarpus heterophyllus	37.45	89.24	12.83	50.01	30.45	9.14	7.16
Commiphora caudata	28.74	87.97	17.03	38.27	31.96	15.3	7.96
Acacia auriculiformis	34.91	93.95	16.19	51.26	47.09	21.98	5.03
Leucaena leucocephala	34	90.74	17.98	36.02	22.66	8.07	8.08
Mean	31.49	90.39	15.65	41.59	30.29	10.77	7.44
SEM	1.86	0.72	2.03	3.21	3.01	2.2	0.59

Mean of two replicates, Variations in duplicate measurements were within ±3% of the mean.

ME (MJ/Kg) = 2.2 + 0.1357 GP + 0.0057 CP + 0.0002859 EE^2 (Menke and Steingass, 1988) (*Sesbania grandiflora*) to 21.98% (*Acacia auriculiformis*). The ME (MJ/Kg) was higher in *Melia dubia* (9.6) and lower in *Dillenia sp* (4.90) indicating these tree leaves were good source of energy. The previous studies on CP content of tree forages showed that it varied from 10 to 24 per cent (Singh *et al.*, 2005; Carlos *et al.*, 2005 and Camacho *et al.*, 2010), 11.5 to 25.6 per cent (Raja Kishore and Parthasarathy, 2009; Dzowela *et al.*, 1995 and Anele *et al.*, 2009), 7.9 to 38.6 per cent (Jayanegara *et al.*, 2011) and 10 to 16 per cent (Reddy and Elanchezhian, 2008; Patra, 2009; Pal *et al.*, 2015), 21 to 26 per cent (Melaku *et al.*, 2003). In present study, CP varied from 7.89 to 19.69 per cent. Similarly, the NDF, ADF and ADL content of analysed tree leaves were in the similar range as reported by Singh *et al.* (2005), Raja Kishore and Parthasarathy (2009) and Girma *et al.* (2015). The lignin content was more in *Dillenia sp.*, *Acacia auriculiformis* and *Commiphora Caudata* which may be due to more matured leaves than others.

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In the present study, there were considerable variations in chemical compositions between the tree leaves. This was due to differences in genotype, environment, stage of maturity and harvesting (Larbi *et al.*, 1998; Singh *et al.*, 2005; Arhab *et al.*, 2009; Elghandour *et al.*, 2014, Ramachandran *et al.*, 2015 and Camacho *et al.* 2010). The multipurpose tree leaves contained moderate levels of CP, minerals and vitamins that are deficient in many low-quality roughages and It was found that CP level above the threshold level (11-12%) that is required for moderate level of ruminant production (ARC, 1984). In the present study, the level of ME was closely related to OM, CP, fibre and tannins as in previous observations (Makkar *et al.*, 1995; Singh *et al.*, 2005; Salem *et al.*, 2005).

Tannin Fractions

Polyphenolic fractions (on DM basis) of the eight tree leaves is presented in the Table 2. The TP content of tree leaves was high in *Artocarpus heterophyllus* (17.35%) and low in *Sesbania grandiflora* (1.77%).

Table 2: Polyphenolic contents (%) of tree leaves on dry matter basis

	Total Phenol (TP) [1]	**Non Tannin Phenol (ntp)[2]**	**Total Tannin Phenol (ttp)[3]**	**Condensed Tannin (CT)[4]**	**Hydrolysable Tannin (HT)[5]**
Sesbania grandiflora	1.77	1	0.77	0.02	0.75
Melia dubia	1.89	1.11	0.77	0.19	0.58
Dillenia sp	11.67	5.7	5.97	1.25	4.72
Moringa oleifera	1.83	1.44	0.4	0.19	0.2
Artocarpus heterophyllus	17.35	1.88	15.47	15.26	0.21
Commiphora Caudata	4.98	3.35	1.63	1.25	0.38
Acacia auriculiformis	9.04	4.95	4.09	2.37	1.72
Leucaena leucocephala	4.76	2.68	2.07	1.99	0.09
SEM	1.99	0.63	1.79	1.8	0.55

All values were mean of triplicates

1. *TP by Folin–Ciocalteu reaction (Makkar, 2003)*
2. *NTP by Folin–Ciocalteu reaction using PVPP (Makkar, 2003)*
3. *TTP by Difference between TP and NTP*
4. *CT expressed as leucocyanidin equivalent*
5. *HT calculated by difference between TTP and CT.*

The NTP was rich in *Dillenia sp.* (5.7%) and low in *Sesbania grandiflora* (1.00%). TTP content was more in *Artocarpus heterophyllus* (15.47%) low in *Moringa oleifera* (0.40%). The potent source of CT and HT was *Artocarpus heterophyllus* (15.26%) and *Dillenia sp.* (4.72%) respectively. This suggests that tannin content varies among these tree leaves so the preference and quality. The literature on polyphenolic content of tree leaves depicts that the concentration remarkably varies from source to source. Because, polyphenolic content estimated by Singh *et al.* (2005), Dey *et al.* (2008); Pal *et al.* (2015) and Singh *et al.* (2015); were lower than present values. Whereas, similar range of values was observed by Reddy and Elanchezhian (2008); Chander Datt *et al.* (2008); Jayanegara *et al.* (2011) and Baruah *et al.* (2018).

Tannin composition in plants depends on type of plant, photosynthetic capacity, soil fertility, environmental conditions, maturity of the leaves, processing and the analytical method employed in analysis (Makkar,

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2003). In general the intake of CT below 5 per cent improves the utilization of feed by ruminants, mainly because of a reduction in ruminal protein degradation and, as a consequence, a greater availability of (mainly essential) amino acids for absorption in the small intestine (Min *et al*., 2003). Values of CT's exceeding 5 per cent on DMB could inhibit microbial activity, depress dry matter digestibility (Kumar and Vaithiyanathan, 1990) and reduce voluntary intake (Waghorn *et al*., *1990*).

In situ Degradability

In situ degradability of tree leaves for DM, OM, CP, NDF and ADF are shown in Table 3 to 7.

Table 3: *In situ* rumen degradability of DM (per cent) of tree leaves

Variables	*Sesbania grandiflora*	*Melia dubia*	*Dillenia sp.*	*Moringa oleifera*	*Artocarpus heterophyllus*	*Commiphora caudata*	*Acacia auriculiformis*	*Leucaena leucocephala*
a	38.65	46.3	34.61	49.56	32.1	13.96	29.89	48.34
b	32.41	35.88	25.96	42.77	51.26	64.52	15.97	31.84
c	29.3	18.27	39.44	3.43	18.37	20.07	55.08	21.17
k_d (h^{-1})	10.03	12.73	0.00005	7.49	4.27	7.68	3.13	4.67
Y	71.06	82.18	60.57	92.33	83.36	78.48	45.86	80.18
P	59.45	71.22	34.61	74.03	54.27	51.26	35.62	62.86
Rumen undegradable DM[1]	40.55	28.78	65.39	25.97	45.73	48.74	64.38	37.14

a = soluble or rapidly degradable fraction; b = insoluble but potentially degradable fraction; c=residual dry matter at 96 h of incubation; $k_d=0.693/t_{1/2}$*, degradation rate* (h^{-1})*; [a, b and* k_d *are based on nonlinear regression using the exponential model]; Y, potential degradability at time t,* $Y=a+b\ (l-e^{-kd*t})$*; P, effective degradability , P = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h] ;* [1]*= (100 – P)*

Along with this RDN and RDN per Kg of DOMR was also calculated using 'P' value of CP and the kd (h^{-1}), Y(%) and P (%) values of DM of tree leaves were ranged from 5×10^{-7} (*Dillenia sp*) to 0.127 (*Melia dubia*); 45.86 (*Acacia auriculiformis*) to 92.33 (*Moringa oleifera*); and 34.61(*Dillenia sp.*) to 74.03(*Moringa oleifera*) respectively. The kd (h^{-1}), Y(%) and P (%) values of OM of tree leaves were ranged from 6×10^{-5} (*Dillenia sp*) to 0.103 (*Melia dubia*); 44.54 (*Acacia auriculiformis*) to 91.95 (*Moringa oleifera*); and 32.06 (*Dillenia sp.*) to 73.77 (*Moringa oleifera*) respectively. The a(%), b(%), c (%), kd (h^{-1}), Y(%) and P (%) values of CP degradability of tree leaves were ranged from 10.87 (*Commiphora caudata*) to 55.69 (*Sesbania grandiflora*); 15.65 (*Acacia auriculiformis*) to 66.34 (*Artocarpus heterophyllus*); 3.43 (*Moringa oleifera*) to 54.13 (*Acacia auriculiformis*); 5×10^{-6} (*Dillenia sp*) to 0.105 (*Sesbania grandiflora*); 46.28 (*Acacia auriculiformis*) to 98.11 (*Moringa oleifera*); and 30.63 (*Acacia auriculiformis*) to 78.93 (*Sesbania grandiflora*) respectively. The RDN (g/Kg) ranged from 5.34 (*Dillenia sp*) to 30.65 (*Sesbania grandiflora*) and the RDN as fraction of the degradable organic matter in the rumen (RDN/Kg DOMR) is ranged from 18.47 (*Dillenia sp*) to 58.59 (*Sesbania grandiflora*). The kd (h^{-1}), Y(%) and P (%) values of NDF degradability of tree leaves were ranged from 0.0002 (*Dillenia sp*) to 0.136 (*Melia*

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dubia); 28.33 (*Acacia auriculiformis*) to 72.24 (*Artocarpus heterophyllus*); and 4.15 (*Acacia auriculiformis*) to 46.33 (*Moringa oleifera*) respectively. The kd (h^{-1}), Y (%) and P (%) values of ADF degradability of tree leaves were ranged from 0.001 (*Dillenia sp.* and *Acacia auriculiformis*) to 0.123 (*Melia dubia*); 27.66 (*Acacia auriculiformis*) to 64.17 (*Artocarpus heterophyllus*); and 1.67 (*Dillenia sp.*) to 36.25 (*Moringa oleifera*) respectively.

Table 4: *In situ* rumen degradability of OM (per cent) of tree leaves

Variables	*Sesbania grandiflora*	*Melia dubia*	*Dillenia sp.*	*Moringa oleifera*	*Artocarpus heterophyllus*	*Commiphora caudata*	*Acacia auriculiformis*	*Leucaena leucocephala*
a	36.09	45.33	31.78	49.69	31.42	12.04	27.89	47.59
b	32.87	35.49	27.41	42.26	52.38	65.52	16.65	32.09
c	31.27	19.85	41.28	8.37	17.92	21.03	55.83	21.74
k_d (h^{-1})	10.21	10.34	0.006	7.42	4.42	7.61	3.1	4.4
Y	68.96	80.82	59.19	91.95	83.8	77.56	44.54	79.68
P	57.32	68.35	32.06	73.77	54.51	49.79	33.82	61.71
Rumen undegradable OM[1]	42.68	31.65	67.94	26.23	45.49	50.21	66.18	38.29

a = soluble or rapidly degradable fraction; b = insoluble but potentially degradable fraction; c=residual organic matter at 96 h of incubation; k_d=0.693/$t_{1/2}$, degradation rate (h^{-1}); [a, b and k_d are based on nonlinear regression using the exponential model]; Y, potential degradability at time t, Y=a+b (l-e^{-kd*t}); P, effective degradability , P = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h] ; [1]= (100 – P)

In situ degradability varied between the tree leaves. *Moringa oleifera*, *Melia dubia* and *Sesbania grandiflora* are having the highest effective degradability.

Table 5: *In situ* rumen degradability of protein (per cent) of tree leaves

Variables	*Sesbania grandiflora*	*Melia dubia*	*Dillenia sp.*	*Moringa oleifera*	*Artocarpus heterophyllus*	*Commiphora caudata*	*Acacia auriculiformis*	*Leucaena leucocephala*
a	55.69	47.06	34.79	46.41	26.37	10.87	30.63	34.54
b	35.64	47.41	25.75	51.7	66.34	60.38	15.65	47.53
c	9.26	6.78	39.64	3.43	9.65	29.16	54.13	18.58
k_d (h^{-1})	10.5	10.28	0.00005	7.98	4.91	5.74	0.0004	5.51
Y	91.33	94.47	60.54	98.11	92.71	71.25	46.28	82.07
P	78.93	77.75	34.79	76.79	57.35	41.43	30.63	58.12
Rumen undegradable CP[1]	21.07	22.25	65.21	23.21	42.65	58.57	69.37	41.88
RDN	22.61	19.49	4.39	24.19	11.77	11.29	7.93	16.72
RDN/Kg DOMR	43.39	31.6	15.13	36.62	24.2	25.77	24.97	29.86

a = soluble or rapidly degradable fraction; b = insoluble but potentially degradable fraction; c=residual CP at 96 h of incubation; k_d=0.693/$t_{1/2}$, degradation rate (h^{-1}); [a, b and k_d are based on nonlinear regression using the exponential model]; Y, potential degradability at time t, Y=a+b (l-e^{-kd*t}); P, effective degradability , P = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h] ; [1]= (100 – P); RDN, Rumen degradable nitrogen (g/Kg DM); RDN/Kg DOMR, Rumen degradable nitrogen per Kg Degradable organic matter in rumen.

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Table 6: *In situ* rumen degradability of NDF (per cent) of tree leaves

Variables	*Sesbania grandiflora*	*Melia dubia*	*Dillenia sp.*	*Moringa oleifera*	*Artocarpus heterophyllus*	*Commiphora caudata*	*Acacia auriculiformis*	*Leucaena leucocephala*
a	9.58	5.27	14.32	25.31	1.55	1.16	0.54	5.09
b	30.92	46.35	25.37	46.73	70.69	58.77	27.79	52.24
c	59.28	45.8	61.59	27.07	29.56	39.83	84.63	46.15
k_d (h^{-1})	7.39	13.56	0.016	4.58	4.13	4.27	0.84	3.72
Y	40.5	51.61	39.69	72.04	72.24	59.93	28.33	57.33
P	27.17	38.06	14.39	46.33	31.54	26.58	4.15	25.95
Rumen undegradable NDF[1]	72.83	61.94	85.61	53.67	68.46	73.42	95.85	74.05

a = soluble or rapidly degradable fraction; b = insoluble but potentially degradable fraction; c=residual NDF at 96 h of incubation; [1]effective degradability, k_d=0.693/$t_{1/2}$, degradation rate (h^{-1}); [a, b and k_d are based on nonlinear regression using the exponential model]; Y, potential degradability at time t, Y=a+b (l-e^{-kd*t}); P, effective degradability , P = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h] ; [1] = (100 – P)

Table 7: *In situ* rumen degradability of ADF (per cent) of tree leaves

Variables	*Sesbania grandiflora*	*Melia dubia*	*Dillenia sp.*	*Moringa oleifera*	*Artocarpus heterophyllus*	*Commiphora caudata*	*Acacia auriculiformis*	*Leucaena leucocephala*
a	9.55	2.17	0.86	15.35	4.03	0.36	5.55	-1.81
b	30.5	37.41	34.47	45.54	60.15	58.08	22.11	51.6
c	60.42	57.8	64.31	35.24	38.8	43.25	73.65	54.72
k_d (h^{-1})	7.22	12.3	0.14	4.75	2.96	3.98	0.14	3.13
Y	40.05	39.58	35.32	60.89	64.17	58.44	27.66	49.79
P	26.73	27.88	1.67	36.25	24.84	24.51	6.1	16.69
Rumen undegradable ADF[1]	73.27	72.12	98.33	63.75	75.16	75.49	93.9	83.31

a = soluble or rapidly degradable fraction; b = insoluble but potentially degradable fraction; c=residual ADF at 96 h of incubation; k_d=0.693/$t_{1/2}$, degradation rate (h^{-1}); [a, b and k_d are based on nonlinear regression using the exponential model]; Y, potential degradability at time t, Y=a+b (l-e^{-kd*t}); P, effective degradability , P = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h] ; [1]=(100 – P)

Soluble protein losses were particularly high for *Sesbania grandiflora*. The undegradable residual fraction of CP is more in *Acacia auriculiformis* (54.13) and *Dillenia sp.* (39.64). The RDN (g) and RDN g/kg DOMR values were highest for *Moringa oleifera* (24.19 and 36.62) and *Sesbania grandiflora* (22.61 and 43.39) and lowest for *Dillenia sp.* (4.39 and 15.13) and *Acacia auriculiformis* (7.93 and 24.97), where N might be associated with fibre and lignin. Similar degradability of tree leaves was observed in past. Ondiek *et al.* (2010) found that 'P' ranged was from 36.5 to 97.7 and k_d from 0.05 to 24.5. Apori *et al.* (1998) found 'P' value for DM and CP in the range from 50.6 to 88.4 and 70.5 to 94.6 respectively. Similary, Melaku *et al.* (2003) found the P and Y value from 78.1 to 96.2 and 51.4 to 86.0 per cent respectively. Prakash *et al.* (2006) found potential degradability of protein ranged from 40 to 72.9 per cent and the effective protein degradability was 26.4 to 44.1 per cent. The undegradable protein (UDP) contents of different fodders varied from 55.9 to 73.6 g per 100 g of protein. The faster degradation of DM could be advantageous, which may probably release greater rumen metabolites, enhance rumen microbial functions and proliferations

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(Bonsi *et al.*, 1995). Slow rate and lower extent of cell wall degradation were implicated to constrain the feeding value of forages. The tree leaves containing more CP, degradation process was higher may be due to more microbial activity. Such variation in degradability is also observed in the present finding. The tree leaves with higher degradability can be assessed as having higher nutritive value compared to others. Ruminal degradation of different components is generally influenced by many factors like type of forage species (El Hassan *et al.*, 2000), cultivars (Elizalde *et al.*, 1999), season of harvesting (Camacho *et al.*, 2010), stage of maturity (Dzowela *et al.*, 1995), chemical composition (Valk *et al.*, 1996), tannins (Waghorn, 2008) parts of the forage, particle size, preservation method and animal factors (Camacho *et al.*, 2010).

The tree leaves would be good protein supplements, if they were degraded adequately and were non-toxic. El hassan *et al.* (2000) found RDN ranged from 12.2 to 29.8 and RDN/Kg DOMR 24.9 to 50.3 in tree leaves. In present findings also similar trend, The CP, RDN and RDN per DOMR are very important indices of nutritional quality of feeds, since these tree leaves are intended to be used as protein supplements for low-quality fodders. The normal range of RDN/Kg DOMR is from 14 to 60 (ARC, 1984) in ruminants.

Correlation Analysis

Pearson correlation analysis was used to assess the relationship of chemical composition, tannins and ME with *in situ* degradation of DM, OM, CP, NDF and ADF (Table 8).

Table 8: Correlation coefficients (*r*) of *In situ* degradability with chemical composition, ME and polyphenolics

	CP	NDF	ADF	ADL	ME	TP	TTP	CT
Y, Dry matter	0.391	-0.753*	-0.926*	-0.776*	0.786*	-0.286	-0.051	0.145
P, Dry matter	0.653	-0.878*	-0.946*	-0.836*	0.918*	-0.615	-0.369	-0.141
Y, Organic matter	0.38	-0.742*	-0.921*	-0.760*	0.766*	-0.252	-0.018	0.179
P, Organic matter	0.659	-0.873*	-0.953*	-0.837*	0.903*	-0.576	-0.325	-0.091
Souble protein	0.225	-0.248	-0.314	-0.643	0.353	-0.5	-0.379	-0.372
Y, Crude Protein	0.389	-0.622	-0.841*	-0.937*	0.839*	-0.332	-0.042	0.148
P, Crude Protein	0.52	-0.643	-0.765*	-0.928*	0.852*	-0.576	-0.31	-0.132
RDN	0.762*	-0.760*	-0.781*	-0.859*	0.838*	-0.733*	-0.5	-0.289
RDN/Kg DOMR	0.804*	-0.547	-0.512	-0.730*	0.721*	-0.729*	-0.525	-0.323
Y, Neutral Detergent Fibre	0.253	-0.566	-0.772*	-0.542	0.512	0.058	0.257	0.436
P, Neutral Detergent Fibre	0.435	-0.802*	-0.935*	-0.820*	0.820*	-0.414	-0.168	0.016
Y, Acid Detergent Fibre	0.272	-0.449	-0.636	-0.466	0.435	0.108	0.289	0.469
P, Acid Detergent Fibre	0.659	-0.756*	-0.810*	-0.757*	0.856*	-0.486	-0.222	0.021

** P<0.05;CP, crude protein; NDF, neutral detergent fiber; ADF, Acid detergent fiber; ADL, acid detergent lignin; TP, total phenolic; TTP, Total tannins phenols; CT, condensed tannins; Y is fraction degradation nutrients at time t,* $Y=a+b\ (l-e^{-kd*t})$*; P (effective degradability of nutrient) = a+b(Kd/Kd+Kp) [Kp is the rate of passage, taken as 0.056/h]. Rumen degradable nitrogen (g/Kg DM); RDN/Kg DOMR, Rumen degradable nitrogen per Kg Degradable organic matter in rumen*

CP is positively correlated with Y (*r*=0.38), P (*r*=0.52), RDN (*r*=0.76, P<0.05), and RDN/KgDOMR (*r*=0.80, P<0.05). ME was positively correlated with *In situ* degradability of nutrients. Soluble protein is

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positively correlated with CP and ME but negatively correlated with fibre and tannins indicating association of protein of tree leaves with fibre and tannins. The NDF, ADF and ADL are negatively correlated with Y, P, RDN and RDN/Kg of DOMR. TP, TTP and CT negatively correlated with most of *In situ* parameters but are insignificant. As *In situ* method is evaluating rumen degradability of tree leaves, the potential of the feed to supply energy and N, a strong relationship is always been expected.

The phenolics/tannins (Dzowela *et al.*, 1995; Melaku *et al.*, 2003), NDF (Carlos *et al.*, 2005; Ramana *et al.*, 2000; Melaku *et al.*, 2003; Trujillo *et al.*, 2010); and ADF (Melaku *et al.*, 2003), ADL (Melaku *et al.*, 2003), had negative effects on *In situ* degradability parameters. The tree leaves with low content of NDF, ADF, ADL, NDF-N and condensed tannins produced higher degradability (Bonsi *et al.*, 1995; Dzowela *et al.*, 1995). The tree leaves with more fibre and lignin may result in inadequate nutrient supply for rumen microbial proliferation. Therefore, supplementation of such tree leaves may result in reduced performance of animal.

Conclusion

The tree leaves with high CP, RDN, RDN/DOMR, 'Y' and 'P' value and lower Fibre, lignin and tannin makes them potential candidates for use as protein supplements. Based on this *Moringa oleifera*, *Melia dubia* and *Sesbania grandiflora regarded as best*. Although these'P' value of *Leucaena leucocephala* was slightly lower which may be due to presence of CT but ME, CP, RDN and RDN/DOMR values suggest that they are also potential supplement of nutrients. *Artocarpus heterophyllus* contains high content of CT which lead to lower 'a' and 'P' value and more of undegradable protein (42.65%) and in *Commiphora caudata* due to CT and ADL, the 'a' and 'P' value were lesser so these two are moderate potential in their feeding value. Whereas, *Dillenia* and *Acacia auriculiformis* with least 'Y', 'P' CP, RDN and ME among these tree leaves so these can be suggested as poor in supplementary feeding value.

The *In situ* rumen degradability measurements appear to be suitable for assessing the potential nutritive value of tree leaves especially for those which are unaware or underutilized. It can be concluded that the chemical composition, tannin and ME and *in situ* degradability could be used to evaluate nutritive potentiality of tree leaves for ruminants.

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