Evaluation of Forest Tree Leaves of Semi-hilly Arid Region as Livestock Feed

M. P. S. Bakshi* and M. Wadhwa
792, Punjab Mata Nagar, Pakhowal Road, Ludhiana-141002, India

ABSTRACT : Samples of 13 species of forest tree leaves fed to livestock in the semi-hilly arid zone of Punjab State in India were collected at 30 d interval for 12 months, in order to assess their nutritional worth for livestock. The ground samples were pooled for 4 different seasons viz. dry hot, hot humid, fall and winter. The chemical composition irrespective of the season revealed that CP content varied between 8.9 (*Carrisa*) to 22.0% (*Leucaena*). Globulin was the major protein fraction in most of the leaves. The lowest concentration of cell wall constituents was observed in *Morus alba* and *Grewea*. The leaves in general became fiberous and lignified during winter and fall as compared to summer season. The leaves of *Grewea, Morus alba, Leucaena, Carrisa* and *Acacia* were rich in Ca, P and most of the trace elements. The total phenolics ranged between 1.88% (*Azardirachta*) to 15.82% (*Acacia*). The leaves of *Acacia* had the highest concentration of hydrolysable tannins (14.6%) whereas that of *Carrisa* had that of condensed tannins (5.9%). The condensed tannins (more than 3%) were negatively correlated to the digestibility of dry matter (DM), neutral detergent fiber (NDF) and crude protein (CP). The digestion kinetic parameters for DM, NDF and CP revealed that leaves of *Morus alba, Zizyphus* and *Ehretia* had highest insoluble but potentially degradable fraction. The minimum rumen fill values also revealed that leaves of *Grewea, Azardirachta, Morus, Ehretia* and *Leucaena* had great potential for voluntary DM intake. The leaves of *Ougeinia, Malha, Dodenia* and *Carrisa* had significantly higher rumen fill value indicating poor potential for voluntary DM intake. Season did not have any significant impact on digestion kinetic parameters except that most of the leaves had low potentially degradable fraction, which was degraded at slow rate during winter. It was concluded that the leaves of *Morus, Ehretia, Grewea* and *Leucaena* had great potential as livestock feed, while feeding of *Ougeinia, Malha* and *Dodonea* leaves should be avoided. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 6 : 777-783)***

Key Words : Forest Tree Leaves, Protein Fractions, Tannins, Mineral Profile, *In-sacco* Degradability

INTRODUCTION

The current status of feed and fodder, in India, is very bleak, as the availability of different nutrients viz. DM, TDN and DCP is 497, 249 and 20 million tons (MT) as against the ones required 624, 322 and 30 MT (on adult unit basis), resulting in a deficit of 127, 73 and 10 MT, respectively. To cover the above deficit 26, 280 and 44 MT of concentrates, forages/grasses and dry roughages, respectively, are required over and above the quantity available at present to feed 373 million heads of livestock. The area under fodder production cannot be increased due to ever exploding human population and urbanization. To sustain the animal production under these conditions seems rather impossible, until and unless we exploit the non-conventional feed resources or lesser-known seed bearing plants capable of growing in waste/poorly irrigated land.

In Punjab state, about 81 per cent of the farmers in semi-hilly arid zone belong to marginal, small and semi-middle class, who have less than 4.0 ha of land, indicating the inability of these farmers to feed their animals the required quantity, what to talk of quality feed. The livestock of this area are mostly dependent upon the tree leaves and grasses available in forest (300-350 MT/yr). The nutritional evaluation, of commonly fed tree leaves needs attention, so as to guide the farmers to feed particular tree leaves in a particular season is the objective of the present study.

* Corresponding Author: M. P. S. Bakshi. Tel: +91-161-2560370, E-mail: bakshimps@yahoo.com
[1] Department of Animal Nutrition, Punjab Agricultural University, Ludhiana-141004, India.
Received August 7, 2003; Accepted January 13, 2004

MATERIALS AND METHODS

Samples of forest tree leaves (thirteen species) commonly fed to livestock in the semi-hilly arid zone of Punjab State were collected at 30 day interval for 12 months and dried in a forced air oven at 60°C for 48 h. The ground samples were pooled according to season viz. dry hot (April to June), hot humid (July to September), fall (October to December) and winter (January to March).

The chemical composition of tree leaves was estimated as proximate components (AOAC, 1990), cellulose (Crampton and Maynard, 1938) and other cell wall constituents (Robertson and VanSoest, 1981). The defatted samples were fractionated into four protein fractions based on solubility in different solvents (Monteiro et al., 1982). The protein content of these fractions was estimated by Lowry's (1951) method. The anti-nutritional factors viz. tannins (Makkar et al., 1993) and oxalates (Abaza et al., 1968) were also determined. The trace elements were estimated by Atomic Absorption Spectrophotometer, while calcium by AOAC (1990) and phosphorus was determined by colorimetric method (Jackson, 1987).

In sacco studies

Three male rumen fistulated buffaloes (live weight

Table 1. Chemical composition of tree leaves irrespective of season (% DM basis)

Local name	Botanical name	OM	CP	EE	NDF	ADF	Cellulose	Hemicellulose	ADL
Kikar	*Acacia nelotica*	94.24^{gh}	12.23^{b}	1.98^{a}	50.75^{a}	29.71^{a}	16.68^{a}	21.04^{g}	10.88^{b}
Tun	*Toona ciliata*	89.60^{ab}	12.75^{b}	3.68^{c}	58.88^{de}	41.93^{cd}	22.98^{bc}	16.94^{ef}	13.23^{cd}
Tut	*Morus alba*	88.96^{a}	15.08^{def}	4.66^{d}	50.00^{a}	39.25^{bcd}	23.34^{bc}	10.75^{abc}	11.80^{bc}
Garuna	*Carrisa spinarum*	92.80^{ef}	8.88^{a}	3.76^{cd}	57.72^{cde}	49.86^{e}	23.57^{bc}	7.87^{a}	17.32^{ef}
Chamroar	*Ehretia leavis*	90.22^{bc}	13.56^{bcd}	3.66^{c}	55.98^{bcde}	41.28^{cd}	24.61^{cd}	14.70^{cde}	9.86^{ab}
Tahli	*Dalbergea sisso*	91.86^{de}	14.45^{cde}	1.99^{a}	54.48^{abcd}	39.86^{bcd}	23.39^{bc}	14.62^{cde}	10.36^{ab}
Chanjhan	*Ougeinia oojeineusis*	92.01^{def}	12.01^{b}	2.09^{a}	70.59^{g}	55.34^{e}	27.99^{d}	15.24^{def}	21.75^{h}
Subabul	*Leucaena leucocephala*	90.79^{bcd}	22.05^{g}	3.67^{c}	56.42^{bcde}	37.21^{bc}	19.60^{ab}	19.22^{fg}	10.42^{ab}
Beri	*Zizyphus mairatiana*	93.22^{fg}	16.53^{f}	1.91^{a}	59.78^{ef}	43.75^{d}	20.46^{abc}	16.02^{def}	17.95^{fg}
Nim	*Azardirachta indica*	90.96^{cd}	15.02^{def}	1.74^{a}	53.71^{abc}	41.18^{cd}	19.53^{ab}	12.53^{bcd}	15.28^{de}
Malha	NA	94.57^{h}	13.36^{bc}	2.11^{a}	70.20^{g}	53.80^{e}	27.92^{d}	16.41^{def}	20.49^{h}
Mahender	*Dodonea viscose*	94.93^{h}	10.24^{a}	3.10^{bc}	64.30^{f}	53.97^{e}	23.94^{cd}	10.33^{ab}	19.74^{gh}
Biul	*Grewea optiva*	90.91^{cd}	15.93^{ef}	2.54^{ab}	52.52^{ab}	34.40^{ab}	23.85^{cd}	18.12^{efg}	8.57^{a}
Pooled SE		0.44	0.56	0.32	1.67	1.94	1.47	1.41	0.78

Different superscripts in a column differ significantly ($p<0.05$).

Table 2. Seasonal variation in the chemical composition of tree leaves (%)

Constituent	Dry hot	Hot humid	Fall	Winter	Pooled SE
OM	91.63	91.76	92.24	92.08	0.24
CP	14.10^{ab}	14.21^{ab}	14.35^{b}	13.36^{a}	0.31
EE	3.07^{b}	3.24^{b}	2.81^{b}	2.22^{a}	0.18
NDF	56.50^{a}	57.33^{a}	57.66^{a}	60.92^{b}	0.93
ADF	42.06	44.03	42.63	44.06	1.08
Cellulose	23.16	23.53	21.48	23.48	0.82
Hemicellulose	14.44^{a}	13.30^{a}	15.03^{ab}	16.86^{b}	0.78
ADL	13.65^{a}	15.33^{b}	14.58^{ab}	14.31^{ab}	0.43

Different superscripts in a row differ significantly ($p<0.05$).

387±25 kg) were used for *in sacco* degradability studies. Animals were maintained on 1.5 kg concentrate mixture (maize 15, wheat 15, mustard cake 20, groundnut cake 10, rice bran 10, deoiled rice polish 27, mineral mixture 2, salt 1 part each), 5 kg wheat straw and 2 kg green fodder so as to meet their nutrient requirements (NRC, 1989). Animals were adapted for 20 days on this diet before starting the *in sacco* evaluation.

The *in sacco* degradability was assessed by parachute nylon bag (8×15 cm; 50±10 μ pore size) technique (Mehrez and Orskov, 1977). The bags containing 3 mg ground test sample in triplicate were incubated in the rumen of three rumen fistulated male buffaloes. The bags were taken out at 0, 3, 6, 9, 12, 24, 36, 48, 60 and 72 h after incubation in the rumen. The bags were washed under running tap water till the rinsing water became colourless. The bags after squeezing gently were dried at 55°C for 48 h. The disappearance of DM was calculated from the amount incubated and left in the bag at each incubation period. The residue was also analysed for N and NDF for determining their rate and extent of digestion in the rumen.

The different parameters, characterizing extent and rate of ruminal degradation i.e. 'a' rapidly soluble fraction, 'b' insoluble but degradable fraction and 'c' degradation rate of potentially degradable fraction 'b', were calculated according to Orskov et al. (1988). The effective degradability was estimated according to McDonald (1981) at an outflow rate of 5% per hour. The rumen fill values were calculated by using the equation of VanEys (1982). The data were analysed by following factorial and completely randomised design (Snedecor and Cochran, 1968).

RESULTS AND DISCUSSION

Chemical composition

The proximate constituents of different tree leaves irrespective of seasons (Table 1) indicated that leaves of *Dodonea* had the highest ($p<0.05$) and that of *Morus alba* had the lowest ($p<0.05$) organic matter (OM) content. The OM content of *Malha* and *Acacia* was comparable to that of *Dodonea*. The CP content in tree leaves varied between 8.9 to 22.0%. The leaves of *Leucaena* had the highest ($p<0.05$) CP followed by that in *Zizyphus*, which was comparable with that of *Grewea*, *Morus* and *Azardirachta*. The ether extract was highest ($p<0.05$) in leaves of *Morus alba* comparable with that of *Carrisa* followed by that of *Toona*, *Leucaena* and *Ehretia* and the lowest concentration was observed in leaves of *Azardirachta* and *Zizyphus*.

The cell wall analysis, based on detergent extraction, is a good indicator for predicting nutritional worth of fibrous feed resources. Because, voluntary dry matter intake and dry matter digestibility are dependent on cell wall constituents, especially NDF and lignin. The leaves of *Ougeinea, Malha* and *Dodonea* were highly fibrous and lignified (highest NDF, ADF and ADL contents). The lowest NDF and ADF contents were observed in the leaves of *Morus alba*. *Acacia* and *Grewea* had NDF and ADF content equivalent to that of *Morus alba*. The leaves of *Grewea* had the lowest lignin content followed by that of *Ehretia* and *Acacia* leaves. The variation in the proximate and cell wall constituents observed in the present study from reported values (Singh, 1999; Sharma et al., 2000) could be due to differences in species of tree leaves selected or time and stage of collection of tree leaves.

Different seasons showed significant effect on the chemical composition of tree leaves (Table 2). The leaves, in general, became more fibrous and lignified during winter and fall as compared to summer season. The reason is shorter days and cooler temperatures, which signal leaf senescence (in which concentration of enzyme that promote the breakdown of cells increase). The veins that carry fluids into and out of leaf gradually closes off as a layer of cells (abscission layer) formed at the base of each leaf petiole where it is attached to the twig. These clogged veins trap sugars in the leaf and promote production of anthocyanins, the secondary metabolites. However, severe but significant effect was observed in case of EE content and this could be due to presence of more pigments like chlorophyll and carotenoids during summer season. Seasons showed no significant effect on the OM content.

The water-soluble sugars in tree leaves ranged between 2.7 to 7.1% (Table 3). The highest amount of water-soluble sugars was observed in the leaves of *Dalbergea* followed by that in *Morus alba*. Most of the carbohydrates are synthesized in the leaf in the presence of sunlight and these sugars get trapped in the leaves during winter season and are converted into anthocyanins and tannins.

The highest amount of true protein was observed in *Acacia nilotica* followed by that in *Carrisa* species. In almost all the tree leaves, the major protein fraction was salt soluble i.e. globulin, except for *Acacia nilotica* and *Dodonea viscosa*, where alcohol soluble fraction, prolamin predominated. The water-soluble fraction albumin ranged between 6.5 to 29.0%. The glutelin fraction ranged between 10 to 26% of total proteins (Table 3).

Table 3. Relative proportion of different protein fractions in tree leaves

Local name	Botanical name	Water soluble sugars (% DMB)	Albumin	Globulin	Prolamin	Glutelin
Kikar	*Acacia nelotica*	3.62	13.37	18.46	51.15	17.02
Tun	*Toona ciliata*	4.90	7.32	42.02	39.99	10.67
Tut	*Morus alba*	6.03	16.21	41.73	21.71	20.35
Garuna	*Carrisa spinarum*	4.66	12.64	30.88	30.11	26.38
Chamroar	*Ehretia leavis*	4.02	28.67	46.15	13.28	11.90
Tahli	*Dalbergea sisso*	7.13	10.95	46.71	25.53	16.81
Chanjhan	*Ougeinia oojeineusis*	3.60	10.09	40.81	26.94	22.15
Subabul	*Leucaena leucocephala*	3.71	8.04	65.14	15.45	11.37
Beri	*Zizyphus mairatiana*	2.71	6.53	41.08	30.32	22.01
Nim	*Azardirachta indica*	5.31	14.25	50.72	21.24	13.79
Malha	NA	4.52	8.79	36.10	33.31	21.80
Mahender	*Dodonea viscose*	5.23	10.10	25.50	47.38	17.03
Biul	*Grewea optiva*	3.97	15.71	48.96	14.29	21.03

Table 4. Anti nutritional factors in tree leaves (% DWB)

Local name	Botanical name	TP	CT	HT	CT%TT	HT%TT	Water soluble oxalates
Kikar	*Acacia nelotica*	15.82	1.23	14.60	7.80	92.30	0.79
Tun	*Toona ciliata*	4.69	1.34	3.35	28.60	71.40	0.51
Tut	*Morus alba*	2.99	0.05	2.94	1.67	98.33	0.39
Garuna	*Carrisa spinarum*	6.75	5.93	0.82	87.80	12.20	0.90
Chamroar	*Ehretia leavies*	3.95	0.10	3.85	2.50	97.50	0.84
Tahli	*Dalbergea sisso*	2.25	0.06	2.19	2.67	97.33	0.56
Chanjhan	*Ougeinia oojeineusis*	4.44	3.46	0.98	77.90	22.10	0.39
Subabul	*Leucaena leucocephala*	5.19	1.12	4.07	21.60	78.40	0.45
Beri	*Zizyphus mairatiana*	4.91	3.23	6.68	65.80	34.20	0.84
Nim	*Azardirachta indica*	1.88	0.49	1.33	26.06	73.94	1.18
Malha	NA	4.15	3.04	1.11	73.25	26.75	0.90
Mahender	*Dodonea viscosa*	5.82	3.82	2.00	65.60	34.40	0.62
Biul	*Grewea optiva*	2.50	0.17	2.33	6.8	93.2	0.56

TP: total phenols, CT: condensed tannins, HT: hydrolysable tannins.

The total phenolics in tree leaves (Table 4), ranged between 1.88% (*Azardirachta*) to 16% (*Acacia nilotica).* Except *Morus, Dalbergea*, *Azardirachta* and *Grewea,* all had more than 3% total phenols. The levels of hydrolysable tannins were observed to be highest in *Acacia* followed by that in *Zizyphus,* which constituted 92 and 34% of total tannins, respectively. Leaves of *Carrisa* had the maximum amount of condensed tannins (5.9%) amongst the selected tree leaves and constituted 88% of total tannins. The leaves of *Ougeinia*, *Zizyphus*, *Dodonea* and Malha, had condensed tannins more than 3% on dry weight basis. Although the leaves of *Morus*, *Dalbergea,* and that of *Grewea* had low levels of hydrolysable tannins but they constituted 98, 97 and 93% of total tannins, respectively. When the level of condensed tannins exceeded 3%, the digestibility of DM, NDF and CP was affected. They were negatively correlated (r=-0.67, -0.71 and -0.61 for DMD, NDFD and CPD, respectively) with the levels of condensed tannins, confirming previous reports (Kumar and Vaithiyanathan, 1990; Waghorn et al., 1990; Rittner and Reed, 1992) on toxicity of CT. However, levels of hydrolysable tannins showed positive, although low, correlation with these parameters. The analysis of tree leaves revealed the presence of water- soluble oxalates in the range of 0.4-1.2%. The highest level was observed in the leaves of *Azardirachta* and lowest in the leaves of *Morus*. The high concentration of oxalates reduces the availability of calcium by forming precipitates of calcium oxalates. The level of soluble oxalates in tree leaves was much below the toxic level of 4% (Lal et al., 1966). The higher concentration may cause alkalosis and impair calcium assimilation (Gupta et al., 1970).

The mineral profile of tree leaves revealed that *Grewea* leaves had the highest concentration of calcium followed by leaves of *Toona ciliata* and *Morus alba*. *Dodonea viscosa* had the lowest Ca (1.05%) content, which was comparable to that of *Malha* (Table 5). The level is quite higher than the recommended level in the diet (0.19-0.82%, NRC, 1989) and could be useful for high yielding animals during early stages of lactation. Calcium is closely associated with phosphorus metabolism. Tree leaves of *Morus alba* had the highest concentration of phosphorus followed by that in *Malha*, *Grewea optiva* and *Leucaena*. The minimum requirement of P in the diet of ruminants varies from 0.12 to 0.24%. Leaving aside the leaves of *Grewea* and *Leucaena,* the others, if fed as complete feed, may not be able to meet the P requirements of ruminants. The tree leaves were observed to be very rich in magnesium, which ranged from 22 ppm in *Acacia nilotica*, *Malha* and *Dodonea viscosa* to 72 ppm in *Ehretia leavis*. The trace element composition revealed that leaves of *Grewea* had the highest concentration of Zn and Co, while leaves of *Carrisa spiriarum* had that of Fe and minimum Mn in A*zardirachta indica*. The leaves of *Acacia nilotica* and *Zizyphus* were observed to be richest in Cu. The leaves of *Morus alba* appeared to be good source of Fe and Co.

Digestion kinetic parameters

Dry matter : The digestion kinetics of dry matter irrespective of season (Table 6) revealed that soluble fraction (a) ranged from 17.3 to 44.11%. The leaves of *Grewea* had the highest (44%) level of rapidly soluble fraction followed by that in *Leucaena* (38.66%). The insoluble but potentially degradable dry matter ranged from 24.71 to 50.18%, and that of *Morus*, *Zizyphus* and *Ehretia* was close to 50%. The rate constant, at which potentially degradable dry matter is degraded, ranged between 4.3 to 9.0% per hr. The potentially degradable fraction, of *Morus, Zizyphus* and *Ehretia,* was degraded at almost same rate i.e. 5.1 to 5.8% per h, resulting in almost same value for 48 h degradability in *Morus* and *Ehretia*, but the difference in *Zizyphus* was due to lesser amount of soluble fraction (22%) compared to 27-29% in *Ehretia* and *Morus*. These tree leaves along with *Leucaena* showed the highest 48 h degradability. The minimum rumen fill values revealed that leaves of *Grewea*, *Azardirachta*, *Morus*, *Ehretia* and

Table 5. Mineral profile (ppm) of tree leaves

Local name	Botanical name	Ca*	P*	Mg	Zn	Fe	Mn	Cu	Co
Kikar	*Acacia nelotica*	1.96^{c}	0.09^{bc}	22.04^{a}	0.185^{b}	0.057^{a}	0.139^{c}	0.089^{gh}	0.046^{ab}
Tun	*Toona ciliata*	3.20^{hi}	0.06^{ab}	50.90^{e}	0.235^{d}	0.057^{a}	0.101^{a}	0.072^{ab}	0.097^{ab}
Tut	*Morus alba*	3.00^{ghi}	0.18^{d}	39.01^{cd}	0.185^{b}	0.061^{ab}	0.153^{e}	0.073^{ab}	0.098^{ab}
Garuna	*Carrisa spinarum*	1.92^{c}	0.07^{ab}	40.88^{d}	0.176^{b}	0.065^{b}	0.273^{i}	0.076^{cd}	0.086^{ab}
Chamroar	*Ehretia leavis*	2.28^{d}	0.06^{ab}	71.60^{h}	0.182^{b}	0.060^{ab}	0.154^{e}	0.087^{g}	0.105^{ab}
Tahli	*Dalbergea sisso*	2.73^{efg}	0.05^{a}	48.58^{e}	0.165^{a}	0.059^{a}	0.202^{g}	0.072^{b}	0.082^{ab}
Chanjhan	*Ougeinia oojeineusis*	2.70^{ef}	0.06^{ab}	31.30^{b}	0.156^{a}	0.058^{a}	0.112^{b}	0.078^{e}	0.042^{ab}
Subabul	*Leucaena leucocephala*	2.62^{e}	0.11^{c}	37.19^{c}	0.165^{a}	0.057^{a}	0.148^{d}	0.074^{ab}	0.027^{a}
Beri	*Zizyphus mairatiana*	2.15^{cd}	0.07^{ab}	29.29^{b}	0.180^{b}	0.057^{a}	0.153^{e}	0.090^{h}	0.027^{a}
Nim	*Azardirachta indica*	2.92^{fgh}	0.06^{ab}	67.31^{g}	0.181^{b}	0.059^{a}	0.156^{e}	0.068^{a}	0.039^{ab}
Malha	NA	1.40^{b}	0.12^{c}	21.72^{a}	0.180^{b}	0.057^{a}	0.174^{f}	0.084^{f}	0.121^{b}
Mahender	*Dodonea viscose*	1.05^{a}	0.09^{bc}	22.26^{a}	0.201^{c}	0.057^{a}	0.174^{f}	0.074^{bc}	0.082^{ab}
Biul	*Grewea optiva*	3.28^{i}	0.11^{c}	61.37^{f}	0.435^{e}	0.059^{a}	0.244^{h}	0.078^{de}	0.564^{c}
Pooled SE		0.09	0.01	1.15	0.003	0.002	0.001	0.004	0.03

* Per cent DM basis: different superscripts in a column differ significantly ($p<0.05$).

Table 6. Degradation pattern of DM of tree leaves (%), irrespective of season

Local name	Botanical name	48 h degradability	Rapidly soluble fraction (a)	Potentially degradable fraction (b)	Degradation rate (c)	UDF	Effective degradability (Ed)	Rumen fill	Predicted DM intake (kg/d)
Kikar	*Acacia nelotica*	68.71^{def}	30.69^{cd}	43.03^{cde}	0.056^{abc}	26.28	59.86^{bc}	20.16^{bc}	6.96^{cd}
Tun	*Toona ciliata*	69.92^{def}	34.21^{cd}	37.44^{bcd}	0.065^{abc}	28.35	61.20^{bc}	19.54^{bc}	7.18^{cde}
Tut	*Morus alba*	73.47^{f}	28.87^{bc}	50.18^{e}	0.057^{abc}	20.95	63.60^{c}	18.43^{abc}	7.41^{def}
Garuna	*Carrisa spinarum*	64.64^{d}	27.90^{bc}	39.55^{bcd}	0.061^{abc}	32.55	55.78^{b}	21.12^{c}	6.71^{cd}
Chamroar	*Ehretia leavis*	71.67^{ef}	27.12^{bc}	48.66^{e}	0.058^{abc}	24.22	61.00^{bc}	19.12^{abc}	7.21^{cde}
Tahli	*Dalbergea sisso*	65.92^{de}	32.16^{cd}	35.53^{bc}	0.066^{bc}	32.31	57.70^{bc}	20.78^{c}	6.56^{cd}
Chanjhan	*Ougeinia oojeineusis*	47.70^{a}	26.19^{bc}	24.71^{a}	0.043^{a}	49.10	42.11^{a}	27.63^{d}	4.73^{a}
Subabul	*Leucaena leucocephala*	71.70^{ef}	38.66^{de}	35.59^{bc}	0.059^{abc}	25.75	63.48^{c}	19.50^{bc}	7.11^{cd}
Beri	*Zizyphus mairatiana*	63.36^{cd}	21.72^{ab}	49.14^{e}	0.051^{abc}	29.14	54.57^{b}	21.42^{c}	6.30^{bc}
Nim	*Azardirachta indica*	73.41^{f}	28.41^{bc}	45.91^{de}	0.090^{d}	25.68	64.24^{c}	17.28^{ab}	8.38^{f}
Malha	NA	53.40^{ab}	17.30^{a}	40.04^{bcd}	0.046^{abc}	42.66	43.19^{a}	25.73^{d}	5.44^{ab}
Mahender	*Dodonea viscose*	57.25^{bc}	26.59^{bc}	32.41^{ab}	0.044^{ab}	41.00	47.31^{a}	25.52^{d}	5.40^{ab}
Biul	*Grewea optiva*	80.79^{g}	44.11^{e}	38.09^{bcd}	0.070^{cd}	17.80	71.99^{d}	16.19^{a}	8.16^{ef}
Pooled SE		2.43	2.86	2.96	0.008		2.32	1.13	0.36

Different superscripts in a column differ significantly ($p<0.05$).

Table 7. Effect of season on the degradation of DM

Parameters	Dry hot	Hot humid	Fall	Winter	Pooled SE
48 h deg.%	65.24	67.88	67.12	64.96	1.35
a, %	24.97^{a}	27.66^{a}	33.13^{b}	32.38^{b}	1.58
b, %	43.55^{b}	43.12^{b}	37.29^{a}	36.12^{a}	1.64
c, /h	0.061	0.063	0.056	0.056	0.004
Ed, %	55.30	58.22	58.88	57.15	1.29
RF, kg	21.24	20.15	20.91	21.52	0.63
PDMI, kg/d	6.79^{ab}	7.02^{b}	6.72^{ab}	6.42^{a}	0.37

Different superscripts in a row differ significantly ($p<0.05$).

Leucaena had great potential, as voluntary dry matter intake of these leaves will be sufficient to support maintenance. The leaves of *Ougeinia, Malha* and *Dodonea* had very high rumen fill values, which predicted the poor voluntary dry matter intake in these leaves.

The digestion kinetic parameters for DM showed little variations due to change of season (Table 7) except that the leaves in general had significantly higher rapidly soluble fraction and low potentially degradable fraction, which degraded at a slower rate, during winter. The leaves being highly lignified during this period results in high rumen fill value and low potential for voluntary DM intake.

Neutral detergent fiber : The digestion kinetic parameters, for NDF, indicated that leaves of *Zizyphus* and *Morus* (Table 8) had almost the same and the highest potentially degradable fraction amongst the tree leaves selected. But, the rate of degradation of insoluble but potentially degradable fraction of *Morus* was higher than that of *Zizyphus* leaves. The high fiber and/or lignin content in *Ougeinia, Malha*, *Dodonea* and *Carrisa* leaves resulted in low potentially degradable fraction that was degraded at a slow rate. The effective degradability values were significantly ($p<0.05$) lower in these leaves than that of *Grewea*, *Ehretia*, *Toona, Morus* and L*eucaena* leaves. The higher undegradable fractions in *Dodonea, Ougeinia, Malha* and *Carrisa* leaves were responsible for significantly higher ($p<0.05$) rumen fill values, resulting in poor potential for voluntary NDF intake in these tree leaves. The lowest rumen fill values were observed in the leaves of *Grewea* followed by *Azardirachta*, *Ehretia*, *Morus* and *Toona*. The predicted NDF intake followed the trend opposite to that of rumen fill.

With change in the season, there is a change in the availability of potentially degradable fraction and it was low in winter and reverse trend was observed for soluble fraction, which was low during July to September (Table 9). The effective NDF degradability was not affected by the season.

Crude protein : The digestion kinetics of tree leaves, for crude protein, irrespective of seasons (Table 10) showed a lag phase (negative rapidly soluble fraction) in the leaves of *Acacia,* which could be due to high concentration of hydrolysable tannins that might have delayed microbial colonization. The leaves of *Acacia* had the highest potential

Table 8. Degradation pattern of NDF (%) of tree leaves, irrespective of season

Local name	Botanical name	48 h degradability	Rapidly soluble fraction (a)	Potentially degradable fraction (b)	Degradation rate/hr (c)	UDF	Effective degradability (Ed)	Rumen fill (kg)
Kikar	*Acacia nelotica*	50.70[bc]	8.82[bc]	49.50[c]	0.051[abc]	41.68	41.17[defg]	24.88[bc]
Tun	*Toona ciliata*	58.38[cd]	13.34[cd]	47.38[bc]	0.071[c]	39.28	48.09[g]	22.36[ab]
Tut	*Morus alba*	57.11[cd]	-0.02[ab]	64.28[d]	0.061[abc]	35.74	45.07[efg]	22.34[ab]
Garuna	*Carrisa spinarum*	47.12[ab]	7.88[bc]	42.18[abc]	0.065[abc]	49.94	37.80[bcde]	25.82[cd]
Chamroar	*Ehretia leavis*	60.06[de]	11.95[bcd]	51.94[cd]	0.059[abc]	36.11	48.36[g]	22.31[ab]
Tahli	*Dalbergea sisso*	50.04[bc]	4.21[abc]	49.32[c]	0.065[abc]	46.47	39.31[edef]	25.41[bc]
Chanjhan	*Ougeinia oojeineusis*	38.62[a]	13.41[cd]	29.55[a]	0.044[ab]	57.04	32.51[abc]	29.40[e]
Subabul	*Leucaena leucocephala*	58.51[cd]	11.67[bcd]	51.38[cd]	0.058[abc]	36.45	47.29[fg]	22.69[abc]
Beri	*Zizyphus mairatiana*	50.56[bc]	-6.62[a]	64.84[d]	0.051[abc]	41.78	36.85[abcd]	24.80[bc]
Nim	*Azardirachta indica*	57.77[cd]	7.32[bc]	51.58[cd]	0.070[c]	41.10	45.03[defg]	22.01[ab]
Malha	NA	41.52[ab]	4.10[abc]	41.42[abc]	0.045[ab]	54.48	30.42[ab]	28.97[de]
Mahender	*Dodonea viscose*	40.62[a]	7.22[bc]	34.94[ab]	0.041[a]	57.84	29.19[a]	29.55[e]
Biul	*Grewea optiva*	68.43[e]	23.66[d]	46.45[bc]	0.068[bc]	29.89	57.29[h]	19.87[a]
Pooled SE		3.21	4.48	4.95	0.009		2.86	1.19

Different superscripts in a column differ significantly ($p<0.05$).

Table 9. Effect of season on the degradation of NDF

Parameters	Dry hot	Hot humid	Fall	Winter	Pooled SE
48 h deg., %	49.56	54.23	52.80	52.46	1.78
a., %	6.05[ab]	3.27[a]	10.74[b]	12.84[b]	2.49
b., %	47.58[ab]	54.93[b]	45.82[a]	43.90[a]	2.74
C, /h	0.052[a]	0.067[b]	0.055[ab]	0.055[ab]	0.005
Ed., %	38.15	42.66	42.21	42.64	1.59
RF, kg	25.42[b]	23.48[a]	24.76[ab]	24.84[ab]	0.66

Different superscripts in a row differ significantly ($p<0.05$).

Table 10. Degradation pattern of CP (%) of tree leaves, irrespective of season

Local name	Botanical name	48 h degradability	Rapidly soluble fraction (a)	Potentially degradable fraction (b)	Degradation rate/hr (c)	UDP	Effective degradability (Ed)
Kikar	*Acacia nelotica*	73.82[bcd]	-1.29[a]	79.39[f]	0.080[c]	21.9	57.98[b]
Tun	*Toona ciliata*	82.80[efg]	28.61[bc]	56.09[cde]	0.074[c]	15.3	70.59[defg]
Tut	*Morus alba*	89.81[g]	31.48[bc]	60.88[de]	0.073[c]	7.64	77.03[g]
Garuna	*Carrisa spinarum*	75.35[cde]	19.04[b]	60.52[de]	0.064[c]	20.44	62.10[bc]
Chamroar	*Ehretia leavis*	81.50[defg]	33.23[bc]	52.05[cde]	0.53[c]	14.72	68.64[cdef]
Tahli	*Dalbergea sisso*	78.48[cdef]	29.92[bc]	49.93[cd]	0.083[e]	20.15	68.16[cdef]
Chanjhan	*Ougeinia oojeineusis*	45.90[a]	22.71[b]	26.86[b]	0.038[c]	50.43	39.64[a]
Subabul	*Leucaena leucocephala*	84.41[fg]	42.04[c]	45.55[c]	0.066[c]	12.41	74.56[efg]
Beri	*Zizyphus mairatiana*	75.55[cde]	25.48[b]	55.39[cde]	0.55[c]	19.13	63.51[bcd]
Nim	*Azardirachta indica*	87.66[g]	22.32[b]	65.74[ef]	0.104[c]	11.94	75.37[fg]
Malha	NA	70.94[bc]	31.79[bc]	42.84[c]	0.043[c]	25.37	58.34[b]
Mahender	*Dodonea viscose*	65.32[b]	65.72[d]	1.34[a]	-0.86[b]	32.94	67.11[cde]
Biul	*Grewea optiva*	89.97[g]	90.72[e]	0.08[a]	-2.01[a]	9.20	90.80[h]
Pooled SE		3.00	5.11	5.05	0.12		2.78

Different superscripts in a column differ significantly ($p<0.05$).

degradable fraction amongst the selected leaves. The potentially degradable fraction in the leaves of *Morus, Carrisa* and *Azardirachta* was more than 60%. On the contrary, leaves of *Dodonea* (66%) and *Grewea* (91%) had significantly higher rapidly soluble fraction as compared to other leaves. The leaves of *Grewea* had the highest effective protein degradability, indicating it to be a poor source of bypass protein.

Seasons did not have any consistent effect on the digestion kinetics of crude protein (Table 11). The rapidly soluble fraction, 48 h and effective degradability of CP were significantly higher during winter season. Reverse trend was observed in case of potentially degradable fraction.

The results conclusively revealed that leaves of *Morus, Ehretia, Grewea* and *Leucaena* had great potential as livestock feed, especially during summer season, whereas leaves of *Ougeinia, Malha* and *Dodonea* showed poor nutritional worth and should not be fed to the ruminants.

Table 11. Effect of season on the degradation of CP

Parameters	Dry hot	Hot humid	Fall	Winter	Pooled SE
48 h deg., %	76.15	74.53	79.03	78.43	1.66
a, %	28.12[a]	32.45[ab]	35.83[ab]	39.52[b]	2.86
b, %	51.34[b]	45.73[ab]	45.22[ab]	41.28[a]	2.80
c, /h	-0.083[b]	-0.271[a]	-0.146[ab]	-0.154[ab]	-0.064
Ed, %	65.92[ab]	64.32[a]	69.66[b]	68.96[b]	1.54

Different superscripts in a row differ significantly ($p<0.05$).

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