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NUTRITIONAL EVALUATION OF FODDER TREE LEAVES OF NORTHERN GRASSLANDS OF PAKISTAN

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Abstract

The Intent of this experiment was to figure out the nutritive value of fodder tree leaves of Chagharzai vlley in Bunair district, North Western Frontier Province (NWFP), Pakistan. Leaves of 12 fodder trees (*Grewia oppsitifolia, Morus alba, Betula celtis, Celtus australis, Diospyros lotus, Aesculus indica, Celtis caucasica, Robinia pseudoacacia, Olea ferruginea, Melia azedarach, Ailanthus chinensis and Quercus incana)* were selected and analyzed for dry matter (DM), organic matter (OM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemi-cellulose and lignin contents. The mean percentage values for DM, OM, ash, CP, NDF, ADF, hemi-cellulose and lignin were 27.65±1.64, 26.87±1.37, 5.72±0.43, 14.29±1.00, 55.50±1.82, 28.83±1.63, 26.67±1.09 and 6.02±0.54, respectively. In fodder tree leaves the highest potential intake rate (PIR) was observed for *Grewia oppsitifolia* (72.80±16.35 g/4 minute) and the lowest for *Quercus incana* (18.24±2.38 g/4 minute). The relative preference (RP) was the highest for *Betula celtis* (84.25±1.50%) and the lowest for *Quercus incana* (2.08±0.24%). The mean *In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of fodder tree leaves were 54.16±2.06% and 7.24±0.30 MJ/kg DM, respectively.The chemical and structural composition, IVDMD, RP and PIR values indicate that fodder tree leaves can be fed to livestock with some supplementation for different levels of production and types of livestock.

Introduction

Grazing management is an important component of land management system in non-cultivated lands of hilly areas. Livestock grazing in rangelands is the most effective lands use in rangeland system (Jones & Martin, 1994). According to recent statistics rangelands support 30 million herds of livestock, which contribute about 400 million US to Pakistan's annual export earnings (Anon., 2006). Good pastures are being converted into croplands leaving increasingly poorer lands for livestock production (Pratt *et al.*, 1997), without thinking about the conservation of soil. Previously there was no appreciation of the value of fodder tree leaves and their ability to hold the soil against destructive erosion (Heath *et al*., 1985). In the northern areas of Pakistan, livestock shares about 55% to the gross provincial income of the agriculture sector. Mostly the hilly terrain (73%) of the province has little land for crop agriculture, hence, dependence on livestock is relatively high, particularly for rural subsistence (Anon., 1998). To fulfil the maintenance requirements of livestock, there is a need of 13.5 and 110.3 million tons of crude protein (CP) and total digestible nutrients (TDN), respectively (Anon., 2006). As, present feed resources provide 40% CP and 75% TDN to the livestock (Younas & Yaqoob, 2005). In the present senario the acute deficieny of nutrients leads to under nourishment, low productivity and predisposes the livestock to parasitism, epidemics and breeding problems. The misuse of rangelands has deteroiorated the rangeland ecosystem. The more palatable fodder trees species are becoming extinct and are replaced by less palatable speceis (Humphreys, 1984). An indicator to range deterioration, in NWFP is the decline in range dependent sheep and goat population by 10.43% and 39.23%, in 1986 and 1996, respectively (Anon., 1996).

Fodder tree leaves are an alternative source of livestock feeding in scarcity period, specially in prolonged winter. The fodder tree leaves are harvested from protected hillside rangelands and are stored as hay. Fodder tree leaves from ranges and uneven areas are also harvestesd several times during summer and are fed to livestock. Rangeland grasses are, although the main way of procuring feed, yet fodder trees play an important role in livestock raising. As there is little information regarding the nutritive value of locally available fodder tree leaves so the study was conducted to establish the nutritive value of the fodder tree species of northern grasslands of Pakistan.

Materials and Methods

Study site: The experiment was conducted in the valley of Chagharzai in Bunair district lying in the North Trans-Himalayan moist zone occupying Malakand Division, North Western Frontier Province, Pakistan to determine the nutritive value of leaves from locally available fodder tree species. The study area is located within 34.42 to 34.66° latitude and 72.62 to 72.78° longitude, having a humid subtropical to temperate environment. The surface area is approximately 209 sq km, with north and south parts divided by a mountain ridge known as “Sar Qala”. The average precipitation varies from 600-1000 mm annually. The forage is harvested at a mature stage during early autumn and fed as hay to the wintering livestock. The steeper hill slopes near the residences are generally used for free grazing by settled livestock throughout the year.

Identification and sampling of fodder tree species : To achieve this aspect, a questionnaire was prepared and the farmers of various social groups at three elevations i.e., upper, middle and lower elevations were interviewed. They were asked about the names of trees in local language (Pashtu), their season of use, location, elevations and aspects of their availability, species of animal fed and trends in their frequency. Ninety farmers (30 x 3, at each elevation) were interviewed in 9 villages (3 x 3, villages at each elevation). Based on the information generated by the farmers through the questionnaire, the samples of different fodder tree species were collected and their specimens were sent to Pakistan Forest Institute, Peshawar, Pakistan for botanical identification. Twelve commonly available fodder tree species were harvested and air dried and stored in polyethylene bags for further analysis.

Nutritional value of fodder tree species

Chemical analysis: The air-dried fodder tree leaves samples were further dried in a hot air oven at 60°C and were analyzed for dry matter (DM), organic matter (OM), ash and nitrogen (Anon., 1990). Samples of fodder tree leaves were also analyzed for neutral detergent fiber, (NDF) acid detergent fiber (ADF) hemi-cellulose and lignin (Van Soest & Robertson, 1990).

Palatability of fodder tree leaves: Four mature local sheep of average body weight 40 kg were procured from the local market and they were drenched for internal parasites. The sheeps were adapted for five weeks to the dry leaves, trained in the experimental procedure by offering the test samples to them alone or in pairs daily. During preliminary periods animal were fed a diet consisting of 80% mixed dry leaves and 20% concentrate mixture. This diet had 10% crude protein (CP) and 8.37 MJ/kg metabolizable energy (ME). The mineral mixture was also added in the diet to meet the sheep requirement (Anon., 1985). The potential intake rate (PIR) for different tree leaves was determined through the procedure adopted by Rehman (1995). Each tree leaves species was offered to sheep for a set of comparisons consisting of 4 consecutive periods of one minute duration each at 10 minutes interval. Sheep were offered tree leaves in plastic containers ensuring that part of forage was left over after one minute of intake. Relative preference (RP) was also evaluated in 95 days through the procedure used by Rehman (1995). The preference ranking of fodder tree leaves within each group was determined by offering fodder of tree leaves in pairs, initially with the forage having highest PIR and then with other forages, until all possible combination within a group was studied and similarly all fodder trees were studied. Like PIR, RP test also consisted of a set of four consecutive period of one-minute duration each at 10 minutes interval. There was one-hour gap before a new set of comparisons was started with a maximum of 4 sets in a day. The containers of both forages in a pair were reversed for each successive comparison to avoid left or right hand bias. The preference for particular forage was determined by the standard procedure developed by Bell (1959) for two choice tests, as the intake of fodder tree leaves expressed as a percentage of the combined intake of both test and standard forage.

$$\text{Relative preference (RP) \%} = \frac{\text{Amount of test forage eaten}}{\text{Amount of test + standard forage eaten}} \text{ X100}$$

***In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) MJ/kg DM:** For the IVDMD determination, oven dried ground samples were incubated at 37±1°C for 48 hours between pH 6.7-7.0 in an all glass system using 45 ml of inoculums. The inoculums comprised of 36 ml of McDougal's artificial saliva and 9.0 ml of strained fresh rumen liquor from leaves fed sheep. After incubation and centrifugation the residue was then treated for 48 hours with pepsin in weak acid (pH 2.0). The final residue was composed of undigested plant cell wall and bacterial debris and yield values were supposed to be comparable to *In vivo* apparent digestibility (Tilley & Terry, 1963). The IVDMD was used for calculating the metabolizable energy (ME) of fodder tree species by the following equation (Anon., 1984).

ME (MJ/kg DM)= 0.15 IVDMD%
IVDMD% = 0.98 IVDMD% - 4.8

The average values for chemical composition, structural constituents, IVDMD and ME were integrated to develop a matrix of correlation (Steel *et al.*, 1997).

Results and Discussion

Identification of fodder tree species and their use pattern: The fodder tree species included *Grewia oppsitifolia, Morus alba, Betula celtis, Celtus australis, Diospyros lotus, Aesculus indica, Celtis caucasica, Robinia pseudoacacia, Olea ferruginea, Melia* *azedarach, Ailanthus chinensis* and *Quercus incana* (Ahmad *et al.*, 2008). The trees of *Aesculus indica* and *Betula celtis* were only at higher elevations while *Olea ferruginea* trees were mainly available at lower elevation. *Grewia oppsitifolia* and *Melia azedarach* were mainly at lower and middle elevations, while the remaining fodder trees were at all elevations. *Grewia oppsitifolia* was the main fodder tree used during winter scarcity particularly at lower and middle elevations for all types of lactating animals, whereas, *Olea ferruginea* was particularly used for sheep and goat during winter at lower and middle elevation. *Quercus incana* was found at all elevations, but only used at higher elevation and occassionally at middle elevations. *Quercus incana* leaves were also fed to sheep and goat at lower elevations and all non lactating animals were fed at upper elevation during winter scarcity. The use pattern of leaves of fodder trees can not be described, as most of them were harvested combinely and stored as hay or freely browsed. However, for the purpose of discussion in their use pattern, these can be grouped on the basis of range type they occupy. It was observed that *Celtus australis* tree leaves were mainly used during summer scarcity and fed to lactating herds at almost all elevations.

Informations regarding identification and use pattern of fodder tree leaves in particular to the area under study are scanty. Most of the tree leaves acted as a feed source provided they were free from any ant-nutritional factor (Chakraborti *et al*., 1988). Tree were preffered when fed as protein supplement to ruminants under low protein forage diet (Long, 1997). In NWFP, *Grewia oppsitifolia* and *Celtus australis* tree leaves were commonly available for livestock feeding (Perveen, 1998). In Malakand Division, *Grewia oppositifolia*, tree leaves significantly contributed during winter scarcity period particulary in the narrow and humid temperate-subtropical valleys. At upper elevations of arid temperate zone *Quercus incana* tree leaves contributed significantly to winter scarcity feeding, whereas, *Celtus australis* tree leaves were commonly used during summer scacity period (Leede & Inam-ur-Rahim, 1997).

The results of present study were in line with the findings of Sajjad (1991) who reported that in certain part of Indian sub-continent, leaves of fodder trees are lopped regularly for feeding to ruminants. The results of the present study supported the findings of Perveen (1998) who reported that in NWFP, *Grewia oppsitifolia* and *Celtus australis* tree leaves were commonly available for livestock feeding. Leede & Inam-ur-Rahim (1997) also reported that *Celtus australis* leaves were used for feeding livestock in these regions during summer scarcity period.

Chemical and structural constituents: The chemical constituents of fodder tree leaves are presented in Table 1. The DM contents of fodder tree leaves varied from 18.2% (*Betula celtis)* to 37.4% (*Quercus incana)* and the mean was 27.65±1.64%. The OM contents in these fodder tree leaves varied from 20.50% (*Melia azedarach)* to 36.1% (*Quercus incana*) and the mean was 26.87±1.37%. The ash contents of fodder tree leaves varied from 3.5% (*Quercus incana)* to 8.1% (*Aesculus indica*) and the mean was 5.72±0.43%. The CP contents of fodder tree leaves varied from 10.1% (*Celtis caucasica*) to 19.9% (*Grewia oppsitifolia)* and the mean was 14.29±1.00%. Distel *et al*., (2005) reported that CP contents in different forage species declined with time. Similar findings were reported by Verma *et al.*, (1982) who reported a decline in CP contents of tree leaves from 6.9 to 28.8% on DM basis in mature leaves of fodder trees.

Table 1. Chemical and structural constituents of fodder tree leaves of Northern grasslands of Pakistan.

S. No	Fodder tree name	DM %	OM %	Ash %	CP %	NDF %	ADF %	Hemi-cellulose %	Lignin %
1.	*Grewia oppsitifolia*	27.3	25.3	7.4	19.9	57	30	27	3.6
2.	*Morus alba*	26.5	25.0	5.5	14.8	56	24	32	3.8
3.	*Betula celtis*	18.2	26.1	7.5	19.7	47	28	19	5.2
4.	*Celtus australis*	23.7	22.5	4.9	10.7	44	22	22	4.7
5.	*Diospyros lotus*	29.4	27.3	7.3	14.2	54	29	25	6.7
6.	*Aesculus indica*	28.6	26.3	8.1	18.7	58	26	32	5.9
7.	*Celtis caucasica*	32.2	30.5	5.3	10.1	61	34	27	7.4
8.	*Robinia pseudoacacia*	23.7	22.5	4.9	11.9	51	22	29	6.9
9.	*Olea ferruginea*	36.4	34.8	4.5	11.6	63	39	24	8.8
10.	*Melia azedarach*	21.7	20.5	5.3	12.8	55	28	27	4.6
11.	*Ailanthus chinensis*	26.7	25.5	4.4	15.2	54	26	28	5.2
12.	*Quercus incana*	37.4	36.1	3.5	11.9	66	38	28	9.4
Mean ± SE		27.65 ±1.64	26.87 ±1.37	5.72 ±0.43	14.29 ±1.00	55.5 ±1.82	28.83 ±1.63	26.67 ±1.09	6.02 ±0.54

DM = Dry matter, OM = Organic matter, CP= Crude protein, NDF = Neutral detergent fiber ADF = Acid detergent fiber

The structural constituents of fodder tree leaves are presented in Table 1. The NDF contents in fodder tree leaves varied between 44% (*Celtus australis*) to 66% (*Quercus incana*) and the mean was 55.5±1.82%. The ADF contents in these fodder tree leaves varied from 22% (*Celtus australis*) to 39% (*Olea ferruginea)* and the mean was 28.83±1.63%. The hemi-cellulose percentage of fodder tree leaves varied between 19% (*Betula celtis*) to 32% (*Morus alba; Aesculus indica*) and the mean was 26.67±1.09%. The lignin contents of fodder tree leaves varied between 3.6% (*Grewia oppositifolia)* to 9.4% (*Quercus incana*) and the mean was 6.02±0.54%.

The NDF, ADF and lignin contents were lower in vegetative leaves than mature leaves, indicating relatively smaller stem proportion in the anatomy of vegetative leaves. All the structural constituents (NDF, ADF, hemi-cellulose and lignin) increased in mature leaves. According to Cherney *et al*., (1993) and Hameed *et al*., (2008), the tropical grasses generally showed an increase in structural constituents with increasing maturity. Bourquin *et al*., (1994) reported 72.4% NDF and 43.8% ADF in the orchard grass on DM basis. Sanderson *et al*., (1989) observed a difference of 3l.4 to 66.8% in NDF contents of alfalfa in two different years. In stem of alfalfa, the NDF concentration ranged from 21 to 68%. According to Cherney *et al*., (1990) NDF and ADF tended to be lower in inflorescence than in other morphological components. They also reported higher ADF in stem than in blade and sheath of leaves.

The findings of this study were in line with those of Cherney *et al*., (1993) who also reported an increase in all fiber constituents with increasing maturity. They reported that lignin was proportionately higher in stem than other parts of the plants. Brown *et al.*, (1984) reported that the soil fertility also influenced grass lignin concentration.

Table 2. Potential intake rate (PIR) and relative preference (RP) of fodder tree leaves of Northern grasslands of Pakistan.

S. No	Fodder tree name	PIR (g/4 minute) ± SE*	RP (%) ± SE**
1.	*Grewia oppsitifolia*	72.80±16.35[a]	77.10±2.05[b]
2.	*Morus alba*	72.32±11.40[a]	75.95±1.70[b]
3.	*Betula celtis*	70.85±12.17[a]	84.25±1.50[a]
4.	*Celtus australis*	69.79±7.66[a]	69.35±0.48[c]
5.	*Diospyros lotus*	68.378±15.62[a]	65.53±2.23[c]
6.	*Aesculus indica*	67.87±15.12[a]	38.70±0.65[ef]
7.	*Celtis caucasica*	67.63±20.89[a]	33.22±0.75[g]
8.	*Robinia pseudoacacia*	40.31±8.61[b]	45.03±1.98[d]
9.	*Olea ferruginea*	38.78±10.73[b]	35.42±2.69[fg]
10.	*Melia azedarach*	36.29±2.63[b]	21.02±1.43[h]
11.	*Ailanthus chinensis*	37.00±3.42[b]	12.13±1.51[i]
12.	*Quercus incana*	18.24±2.38[c]	2.08±0.24[j]

*Each figure represent mean (± standard error of the mean) of 4 samples.

*Figures having different letters are significant (p<O.05) within the same forage grass.

**Each figure represent mean (± standard error of the mean) of 48 comparisons.

Figures having different letters are significant (p<0.05) within the group.

Palatability of fodder tree leaves: Palatability refers to the relish with which feed is consumed as stimulated by the sensory impulses (Heath *et al.*, 1985).The potential intake rate (PIR) and relative preference (RP) are considered the main indicators for palatability (Rehman, 1995). The PIR and RP of 12 fodder tree leaves are presented in Table 2. The average PIR (grams consumed during 4 minutes per sheep) was the highest for *Grewia oppositifolia* (72.80±16.35 g/4 minute) followed by *Morus alba* (72.32±11.40 g/4 minute), *Betula celtis* (70.85±12.17g/4 minute) and *Celtus australis* (69.79±7.66 g/4 minute). The lowest PIR value was for *Quercus incana* (18.24±2.38 g/4 minute). The RP was the highest for *Betula celtis* (84.25±1.5%) followed by *Grewia oppositifolia* (77.10±2.05%), *Morus alba* (75.95±1.70%) and *Celtus australis* (69.35±0.48%). The lowest RP was observed for *Quercus incana* (2.08±0.24%). The fodder tree leaves having higher PIR values showed relatively higher RP. The lower RP noted in free rangeland grasses and marginal land grasses might be due to the presence of an essential oil (piperitone) that made these forages less palatable. This essential oil is responsible for the peculiar smell and taste of the grass (Rehman, 1995) and might decrease its relative preference despite of its higher PIR. The higher PIR and RP noted in fodder tree leaves might be due to lower concentration of essential oil (piperitone) commonly present in free rangeland and marginal land grasses which makes the vegetative parts less palatable for livsestock. The PIR was more strongly affected by the degree of tenderness and stage of growth while the RP seemed to be more affected by the intrinsic chemical factors, hence when the grass was offered in pair with other forages having no such repellent essential oil, the other forage showed higher RP value despite of their lower PIR.

Correlation of palatability with chemical constituents, structural constituents and IVDMD is presented in Table 4. The RP and PIR were positively correlated (r=0.85) with each other across all fodder tree leaves studied. These results supported the findings of Rehman (1995) who suggested PIR as a useful indicator of preference. The results of present study revealed that although the PIR and RP were correlated with each other, their major determinant affects both the parameters differently. The PIR was influenced by the degree of tenderness, while RP was influenced by chemical factors. The present study suggests that more precise prediction equations can be developed if concentrations of sugars and chemical factors were integrated. Kenney & Black (1984) reported that when effects of taste and odor are removed, sheep preferred diet having faster intake rates. The IVDMD showed negative correlation with both RP (*r*= -0.06) and PIR (*r*= -0.07) across all the fodder tree leaves (*r*= -0.06, -0.07). The CP contents had negetive correlation with RP (*r*= -0.05) and with PIR (*r*= -0.06). These results did not support the findings of Provenza *et al*., (1996) who reported that lambs preferred food having higher CP contents. The NDF, ADF, hemi-cellulose and lignin showed negative correlation with both RP and PIR (Table 4). The results of present study were in agreement with Rehman (1995) who reported that NDF and lignin had negative correlation with both RP and PIR across all the forage species. The rapid accumulation of cell wall contents, fast lignification of cell wall and rapid reduction in CP levels may allow the unpalatable grass to avoid grazing since an early stage of re-growth. Fibrousness reduced intake rate because of the associated reduction in bite size to properly sever forage and the associated increase in chewing time necessary to adequately process the forage (Laca *et al*., 2001). Lignin and CP contents interfered with the digestion of structural carbohydrates, the former by acting as a physical barrier to rumen microbial enzymes (Moore & Jung, 2001) and the later by limiting rumen microbial growth (Orskov, 1982). The factors affecting palatability need more investigation (Pratt *et al*.,1997).

***In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME):** The mean IVDMD and derived ME values for all fodder tree leaves are presented in Table 3. The IVDMD value for fodder tree leaves ranged from 42.4% (*Quercus incana)* to 63.2% (*Ailanthus chinensis)* and the mean was 54.16 ± 2.06%. The derived ME value had a range from 5.52 MJ/kg DM (*Quercus incana*) to 8.58 MJ/kg DM *(Ailanthus chinensis)* with a mean of 7.24±0.30 MJ/kg DM. The 1VDMD was positively correlated with CP (*r*= +0.7), NDF (*r*= +0.03) and hemi-cellulose (*r*= +0.121) but IVDMD was negatively correlated with ADF (*r*= -0.41) and lignin (*r*= -0.37) in fodder tree leaves. The IVDMD was higher in vegetative leaves than mature leraves. The IVDMD decreased with increasing maturity of the plants and similar findings were reported by Skerman & Riveros (1990) who found a fall of 0.1 to 0.2% DM digestibilities per day with maturity of pasture grasses. Buxton (1989) reported that the proportion of stem in a grass approaching maturity was the main morphological factor determining the digestibility. Gabrielsen *et al*., (1990) and Van Soest (1965) reported that NDF, ADF and lignin concentration increased with maturity while IVDMD and CP declined. Revell *et al*., (1994) reported a positive correlation between CP and digestibility, whereas, Cherney *et al*., (1990) observed negative correlation of IVDMD with NDF, ADF and lignin. The results of our study were in line with those of Van Soest (1978) who reported poor relationship of NDF with digestibility. Lichtenberg & Hemken (1985) also reported that per unit increase in lignin often resulted in a three to four unit decrease in DM digestibility. It had been reported that cell wall component NDF, ADF and lignin were negatively correlated with IVDMD in tree leaves (Mowatt *et al.*, 1969, Kundu & Sharma,1988; Perveen, 1998). The chemical and structural composition, IVDMD, RP and PIR values of fodder tree leaves suggest that these can be fed to livestock with some supplementation for different levels of production.

Table 3. Digestibility and metabolizable energy of fodder tree leaves of Northern grasslands of Pakistan.

S. No	Fodder tree name	IVDMD %	ME MJ/kg DM
1.	*Grewia oppsitifolia*	62.2	8.41
2.	*Morus alba*	52.3	6.95
3.	*Betula celtis*	54.4	7.28
4.	*Celtus australis*	49.3	6.53
5.	*Diospyros lotus*	57.5	7.74
6.	*Aesculus indica*	60.6	8.20
7.	*Celtis caucasica*	46.3	6.07
8.	*Robinia pseudoacacia*	52.7	7.03
9.	*Olea ferruginea*	46.4	6.11
10.	*Melia azedarach*	62.6	8.50
11.	*Ailanthus chinensis*	63.2	8.58
12.	*Quercus incana*	42.4	5.52
Mean ± SE		54.16±2.06	7.24± 0.30

IVDMD = *In vitro* dry matter digestibility, ME = Metabolizable energy

Table 4. Correlation matrix among relative preference, potential intake rate, digestibility, crude protein and structural constituents of fodder tree leaves of Northern grasslands of Pakistan.

.	PIR	IVDMD	CP	NDF	ADF	Hemi-cellulose	Lignin
RP %	+0.85	-0.06	-0.05	-0.58	-0.38	-0.34	-0.27
PIR	-	-0.07	-0.06	-0.45	-0.32	-0.22	-0.30
IVDMD	-	-	+0.7	+0.03	-0.41	+0.12	-0.37

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