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Effect of Partial Replacement of Concentrates with Barhar (*Artocarpus lakocha*) Leaves on Growth Performance of Kids Fed a Mixed Jungle Grass-based Diet

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ABSTRACT : A feeding trial was conducted to study the replacement value of concentrates with *Barhar* (*Artocarpus lakocha*) leaves on growth performance of kids fed a mixed jungle grass-based diet. Fifteen Sikkim local kids, about 4 months of age and body weight ranging from 5.8 to 9.2 kg, were randomly distributed into three groups of five. Kids were stall fed *ad lib* with mixed jungle grass collected from the nearby forest and native scrubland. The kids in group I received supplementary concentrate (Maize 35%, mustard cake 32%, rice bran 30%, mineral mixture 2% and common salt 1%) at approximately 2% of BW. For groups II and III, 25 and 50% of the concentrate was replaced with *Barhar* (*Artocarpus lakocha*) leaves, respectively. Total dry matter intake (DMI) was not significantly different among groups. Digestibility of CP decreased (p<0.05) and that of NDF increased (p<0.01) with increasing level of *Barhar* leaves in the diet. Digestibility of ADF (p<0.01), hemi cellulose (p<0.05) and cellulose (p<0.01) was higher in groups II and III than in group I. Ruminal pH and TVFA concentration were not significantly different among groups. Rumen ammonia-N concentration decreased (p<0.01) with increased level of *Barhar* leaves in the diet. Similarly, plasma urea nitrogen and blood glucose levels were reduced (p<0.05) with increasing level of *Barhar* leaves in the diet. Replacement of concentrate with *Barhar* resulted in reduced Hb and lower serum iron concentration. Levels of other serum metabolites including minerals were not altered by the replacement. Average daily gain (ADG) was 53.3, 54.4 and 41.8 g/d in groups I, II and III, respectively. ADG was not adversely affected when the level of replacement was restricted to 25%. However, at 50% of replacement ADG was significantly lower than the control (p<0.05). Thus, it was concluded that *Barhar* leaves might replace 25% of the supplemental concentrate for growing Sikkim local kids fed on a mixed jungle grass-based diet. (**Key Words :** *Artocarpus lakocha*, *Barhar* Leaves, Concentrate Replacement, Goat, Growth, Jungle Grass)

INTRODUCTION

Most of the goats in mid-altitude regions of the Himalaya are raised by poor and landless farmers. They cut and carry vegetation from the backyard, farm boundaries, community land and nearby forest land. Such vegetation comprises many different kinds of plant species and leaf blades and is grossly termed as "mixed jungle grass". As forest grazing is not desirable in this fragile ecosystem of the state, mixed jungle grass plays a pivotal role in raising goats. Earlier, Balaraman and Gupta (1990) suggested that mixed jungle grass could support only maintenance of goats. It is therefore desirable to increase intake and digestion of nutrients and thereby growth performance of kids through supplementation. Supplementation with concentrate increased production performance of sheep (Karim et al., 2001) and goats (Das and Ghosh, 2000; Das and Ghosh, 2001a) reared under grazing on native pasture. However, considering the cost and availability of concentrates, it will be wise to use it most judiciously and to replace it with locally available feed ingredients like tree fodders. However, there are only few reports concerning direct replacement of concentrates with tree fodders. These studies indicate that responses to supplementation vary with the nature of the basal diet (Mui et al., 2002), degradation characteristic of the forage (Bates et al., 1988), level of replacement and interaction between nutrients of the feed ingredients (Brown and Pitman, 1991).

Barhar (*Artocarpus heterophyllus*) is one of the most popularly grown trees in the Himalayan mid-altitude region. The tree is grown as a component of traditional Silvi-

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pasture system (Singh et al., 1996) in the Himalayan region. The crown volume of a fully-grown tree may go up to 246 sqm, with biomass yields of 102 kg DM/tree. The trees are lopped and fed to livestock during the winter period when the scarcity of fodder is very acute. *Barhar* leaves are very highly palatable and contain 8% digestible CP and 59% TDN (Das and De, 2001), and like jack fruit leaves have the potential to partially replace concentrates (Das and Ghosh, 2007). This experiment was conducted to study the effect of partial replacement of concentrates with *Barhar* leaves on growth performance of kids fed a mixed jungle grass-based diet.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the ICAR Research Complex for the North Eastern Hill Region, Sikkim Centre, Tadong, situated in the East District of Sikkim State in the Northeast region of India, at an elevation of 1,325 msl. The general topography of the site is hilly. The climate of the area is sub-tropical humid with distinct seasonal variation. During the trial period (November to February) the site recorded 212.4 mm of rainfall and the average temperature ranged from 7.2 to 22.9°C.

Animals and design of experiment

Fifteen male Sikkim local kids, about 4 months of age and body weight ranging from 5.8 to 9.2 kg, were selected. Before onset of the experiment, the animals were washed with 2 ml of delta methrin (Butox, Inter Vet India Ltd, Bombay) diluted in 1 litre. They were also drenched with Albomar (Analgon, Wockhardt Veterinary Pvt. Ltd., Bombay) at 7.5 mg/kg BW. The animals were randomly distributed into one of the 3 dietary treatments.

Herbal composition of mixed jungle grass

For determination of the herbal composition of mixed jungle grass, 5 plots of 4 sqm each were randomly selected during the digestion trial. All the vegetation was removed at ground level and weighed. A sample (1 kg) was separated into the different components. Mixed jungle grass of Sikkim is comprised of various species of grasses, shrubs and weeds. The components of the mixed jungle grass were identified by local names and then correlated with the literature for their respective botanical name. During the experimental period most of the herbage components were at a late stage of maturity. The predominant pasture species were *Setaria palmifolia* (25.1%), *Pennisetum purpureum* (21.3%), *Thysaenolena maxima* (11.4%), *Penicum maxima* (5.2%), *Ageritum conyzoides* (9.1%), *Euopotaruim odoratum* (8.9%), *Desmodium intortum* (13.05) and *Crystellina parasitica* (3.0%). The rest (4.1%) of the mixed jungle grass was comprised of leaf blades and stems from unidentified species.

Feeding management and dietary treatments

The kids were housed in a well-ventilated shed with arrangements for individual feeding and faeces collection. A concentrate mixture (maize 35, rice bran 30, mustard cake 32, common salt 1, mineral mixture 2 kg) was offered at 7.00 am. Immediately after consumption of the concentrate, mixed jungle grass was offered and made available to the kids for the rest of the day. Animals in group I received concentrate at 2% of their body weight; 25 and 50% of the concentrate was replaced with an equal amount (DM basis) of *Barhar* leaves in groups II and III, respectively. After lopping, *Barhar* leaves were separated from branches and offered to the animals at 2.00 pm. Clean and fresh drinking water was freely available to the kids.

Estimation of intake and digestibility, collection of blood and rumen fluid

During the mid-phase of the trial (days 50-56), the animals were transferred to metabolism cages. After an adaptation period of 7 days, a digestion trial of 5 days was conducted. Blood was collected from the jugular vein with a hypodermic needle 2 h prior to feeding on days 30, 60 and 89 of the study. Blood glucose was analyzed on the same day. Another sample of blood was used to harvest plasma using heparin as anticoagulant. Rumen liquor was collected from each kid using a stomach tube at 0, 2, 4, 6 and 8 h after feeding on day 31, 61 and 90 of the study.

In sacco-degradation characteristics

For rumen degradation studies, fortnightly samples of *Barhar* leaves, pasture herbage and concentrates were collected up to 56 days of the trial and pooled. Samples were ground (2 mm sieve) and about 3 g of samples were put into nylon bags (60 m×12 cm, 41 μm pore size) and incubated inside the rumen of three ruminally-fistulated steers fed a diet of maize fodder and concentrate mixture. Samples of mixed jungle grass and *Barhar* leaves were incubated for 6, 12, 24, 48, 72 and 96 h; concentrate mixture was incubated for 3, 6, 9, 12, 18 and 24 h. On removal of the bags after each incubation period, the bags were rinsed under tap water until the wash water was clean and then the bags were oven dried at 60°C for 48 h for determination of DM. Residues remaining in the bags were analyzed for N (AOAC, 1984).

Chemical analysis

Estimation of tannins in mixed jungle grass and Barhar leaves : Condensed and other fractions of tannins in jungle grasses and *Barhar* leaves were estimated as per the method described by Makkar (2003). Leaf samples (200 mg) were extracted with ultrasonicator (Cell Disrupter Ultrasonic Probe, Model 1000L) at 4°C in a 10 ml aqueous acetone solution (acetone/water: 7/3 v/v). After centrifugation (3,000×g at 4°C for 20 min), the supernatants (total phenolics extract) were analyzed for phenolic components (total phenolics, non-tannin phenolics, total tannin phenolics and condensed tannins) as described by Makkar (2003).

Contents of total phenolics was analyzed using Folin–Ciocalteu reagent (Sisco Research Laboratories Pvt., Ltd, Mumbai, India) based on tannic acid standard (Qualigens fine chemicals, GlaxoSmithKline Pharmaceuticals Ltd., Mumbai, India). Total phenolics consist of simple phenolic compounds or non-tannin phenolics and pure tannins or total tannin phenolics. Polyvinyl polypyrrolidone (PVPP, Sigma-Aldrich) has the property to bind tannins but not the simple phenolics. Distilled (triple glass) water (2 ml) and total phenolics extract (2 ml) were added to the test tube containing 200 mg PVPP, vortexed twice and filtered through Whatman No. 1 filter paper. The filtrate was used to estimate non-tannin phenolics, which was subtracted from total phenolics to obtain total tannins. The concentration of total phenolics and total tannins were expressed as tannic acid equivalent.

Condensed tannin : Three ml n-butanol-HCl (95:5 v/v) and 0.1 ml ferric ammonium sulphate (1%) were added to the test tube containing 0.5 ml phenolics extract. The test tube was closed with a glass marble and heated in a boiling water bath for 60 min. The absorbance of the red anthocyanidin products (i.e. condensed tannin) was measured at 550 nm and condensed tannin was expressed as leucocyanidin equivalent.

Proximate principles and cell wall components : Forage and fecal samples were analyzed for DM, CP, ash and acid insoluble ash (AOAC, 1984), NDF, ADF and acid detergent lignin (ADL) (Van Soest et al., 1991). Samples incubated in nylon bags and their residues were analyzed for DM and N. Frozen fecal samples were analyzed for DM, N and NDF. Hemicellulose was calculated as the difference between NDF and ADF. Similarly, cellulose was calculated as the difference between ADF and ADL.

Rumen and blood metabolites : Ammonia-N in rumen liquor was estimated by the micro-diffusion technique of Conway as cited by Raghuramulu et al. (1983). TVFA concentration in rumen fluid was measured by Markham's distillation (Barnett and Reid, 1957). A digital pH meter was used to measure pH of rumen fluid. Serum samples were analyzed for glucose (Folin and Wu, 1920), total protein (Lowry et al., 1951), albumin (Doumas et al., 1971) and urea (Rahamatullah and Boyde, 1980); hemoglobin in whole blood was estimated as described by Dacie and Lewis (1968).

Estimation of minerals in feed and serum samples : Estimation of Ca and P in feed samples was done by the methods of Talapatra (1940) and AOAC (1984), respectively. Serum Ca and P were determined using a diagnostics kit (Span Diagnostics Ltd., Sachin, India). Concentrations of Fe, Zn and Cu in feed and serum samples were determined using an atomic absorption spectrophotometer (Model No: AAS 4141, ECIL, Hyderabad, India).

Calculation and statistics

To characterize the rumen degradability of feeds, their rumen degradation values were fitted to the equation:

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

Where Y is the degradation at time t and a, b, c are parameters describing rapidly and slowly degradable fractions and rate of degradation, respectively (Orskov and McDonald, 1979). Data obtained were analyzed statistically following the procedure for a randomized block design, and treatment means were separated using students "t" test (Snedecor and Cochran, 1967).

RESULTS

Chemical composition of feeds and fodders

Chemical composition of feeds and fodder and their degradation characteristics are presented in Table 1. Proportion of N bound to NDF was greater in *Barhar* leaves in comparison to pasture and concentrate. Rate and extent of degradation of DM and N was much greater in concentrate in comparison to pasture and *Barhar* leaves. Rapidly soluble and potentially degradable fraction of both DM and N was greater in pasture in comparison to *Barhar* leaves. Mixed jungle grass contained much higher condensed tannins than most of the cultivated grasses/grass based diets. Total condensed tannin of *Barhar* leaves, however, was 9 times higher than that of mixed jungle grass. Both mixed jungle grass and *Barhar* leaves were characterized by high Ca and low P level. Concentration of Zn and Cu was within normal range for both the feed ingredients; however, they were characterized by higher Fe content.

Chemical composition of components of mixed jungle grass

The mixed jungle grass comprised 4 grass species (*Setaria palmifolia*, *Panicum maximum*, *Thysanolaena maxima*, and *Pennisetum polystachyon*), 1 legume

Table 1. Chemical composition of feeds and fodders used for the digestion trial

Parameter	Mixed jungle grass[1]	Barhar[2]	Concentrates[3]
DM (g/kg)	215.1	338.8	894.2
(g/kg DM)			
Organic matter	883.2	894.5	904.2
Crude protein	68.7	123.9	160.45
NDF	678.9	321.6	123.6
ADF	424.5	252.0	52.4
Hemicellulose	254.4	69.6	71.2
Cellulose	289.5	136.1	26.2
Nitrogen	10.99	20.6	31.8
NDF-nitrogen (%)	44.98	48.45	7.71
Concentration of minerals			
Ca (g/kg)	13.7	15.2	4.0
P (g/kg)	3.5	3.9	12.4
Cu (mg/kg)	8.6	9.5	10.2
Fe (mg/kg)	5.9	577	312
Zn (mg/kg)	56	43	65
Mn (mg/kg)	44	62	70
Concentration of phenolics (g/kg DM)			
Total phenolics	44	204	nd
Non-tannin phenolics	18	11	nd
Tannin phenolics	26	193	nd
Condensed tannins	18	158	nd
Degradation characteristics (%)			
DM			
a	28.33+0.55	25.15+0.79	43.08+0.99
b	35.06+0.73	32.11+2.62	51.29+0.50
c (%/h)	3.74+0.14	3.48+0.04	8.95+0.05
Nitrogen			
a	36.65+0.94	29.65+1.44	47.43+1.36
b	42.56+1.36	36.70+1.11	49.59+0.33
c (%/h)	5.03+0.14	4.69+0.29	11.06+0.20

a = Rapidly degradable fraction, b = Slowly degradable fraction, c = Rate of degradation.
[1] Late stage of maturity. [2] Mature leaves.
[3] Maize 35%, mustard cake 32%, rice bran 30%, mineral mixture 2% and common salt 1%.

(*Desmodium intortum*), 1 member of compositae (*Eupotarium odoratum*), 1 member from *Asteracecae* (*Ageritum conyzoides*) and 1 fern (*Crystellina parasiticus*). *Desmodium intortum* contained the most N and least NDF, followed by *Setaria palmifolia* (Table 2). *Setaria palmifolia* contained the least amount of condensed tannins. *Ageritum conyzoides* and *Eupotarim oduratum* were the most unique component of the mixed jungle grass. There is no previous report concerning their nutritional or anti-nutritional value. Nevertheless, they contained higher amounts of condensed

Table 2. Chemical composition of pasture herbage

			Chemical composition (g/kg DM)					
			OM	N	NDF	ADF	Hemicellulose	Cellulose
Setaria palmifolia	252	243	893	11.9	654.5	297.3	357.2	252.5
Pennisetum polystachyon	213	292	906	11.5	742.5	432.2	310.3	364.8
Thysanolaena maxima	114	328	882	6.7	782.5	462.9	319.6	342.8
Panicum maxima	52	268	912	9.3	741.9	392.5	349.4	332.7
Ageritum conyzoides	91	312	864	10.9	664.5	582.5	82.0	504.5
Euopotaruim odoratum	89		876	18.4	692.3	612.6	79.7	432.5
Desmodium intortum	130	287	902	34.4	582.3	504.5	77.8	362.5
Crystellina parasitica	30	179	842	13.4	496.7	372.6	124.1	301.2
Others	41							

Table 3. Phenolics concentration of different components of mixed jungle grass

	Phenolics (g/kg DM)			
	Total phenolics	Non-tannin phenolics	Tannin phenolics	Condensed tannins
Setaria palmifolia	10	7	3	2
Pennisetum polystachyon	42	18	24	11
Thysanolaena maxima	29	14	15	13
Panicum maxima	29	9	20	12
Ageritum conyzoides	85	14	70	56
Euopotaruim odoratum	67	15	52	34
Desmodium intortum	125	21	104	87
Crystellina parasitica	37	8	29	19

tannins and, with *Desmodim intortum*, contributed to the higher condensed tannins content of mixed jungle grass (Table 3).

Feed consumption, nutrient intake and diet digestibility

Feed and nutrient intake are presented in Table 4. Intake of DM, OM, NDF, ADF, hemicellulose and cellulose was not significantly different among the groups. Replacing concentrates with *Barhar* leaves resulted in a small, but significant decrease ($p<0.05$) in CP intake. Overall tract digestibility of DM and OM was not significantly different among the groups (Table 4). However, increasing *Barhar* leaves in the diet resulted in an increase ($p<0.01$) in digestibility of NDF, ADF ($p<0.05$), hemicelluloses ($p<0.05$) and cellulose ($p<0.01$), whereas digestibility of N decreased ($p<0.01$).

Rumen fermentation, blood metabolites and diet digestibility

Ruminal pH and TVFA concentration were not

Table 4. Effect of partial replacement of concentrate mixture with *Barhar* on feed consumption, nutrient intake and digestibility in Sikkim local kids fed a mixed jungle grass-based diet

Parameter	Dietary treatments[1]			SEM
	I	II	III	
Feed consumption (g/d)				
Mixed jungle grass	421.00	406.00	414.00	0.74
Concentrate**	178.84[a]	134.13[b]	89.42[c]	0.81
Artocarpus lakocha	-	50.82	92.13	0.82
Total	599.84	589.95	595.54	0.73
As % of body weight				
Nutrient intake (g/d)				
OM	533.52	525.18	528.89	19.15
CP*	58.34[a]	56.21[ab]	54.21[b]	0.21
NDF	329.38	333.11	347.51	0.61
ADF	211.10	215.36	226.70	8.51
Hemicellulose	118.27	117.75	120.81	4.66
Cellulose	152.49	153.40	158.41	5.65
Digestibility of nutrients (%)				
DM	63.38	66.17	64.30	0.24
OM	64.38	67.44	65.30	1.93
CP**	71.57[a]	65.48[b]	59.60[c]	0.24
NDF*	48.66[a]	53.25[b]	53.30[b]	0.24
ADF*	47.22[a]	52.08[b]	51.29[b]	1.43
Hemicellulose*	51.21[a]	55.65[b]	56.96[b]	1.47
Cellulose**	49.83[a]	56.75[b]	55.00[b]	1.13

[a,b,c] Means in the same line with different letters differ significantly, * $p<0.05$, ** $p<0.01$.

SEM = Standard error of the mean.

[1] All the kids were fed mixed jungle grass *ad libitum.* Kids of Group I received concentrate at 2% of BW; however, 25 and 50% of the concentrate was replaced with equal amount (DM basis) of Barhar leaves in groups II and III, respectively.

Table 5. Effect of partial replacement of concentrates with *Barhar* leaves on feed consumption, nutrient utilization, rumen fermentation pattern and certain blood metabolites in Sikkim local goats fed a mixed jungle grass-based diet

	Dietary treatments[1]			SEM
	I	II	III	
Rumen fermentation pattern				
pH	6.85	6.91	6.89	0.044
NH_3**	198.6[c]	155.6[b]	115.4[a]	0.788
VFA	112	107.8	106	0.293
Blood metabolites				
Hb (g/dl)**	14.08[a]	13.06[a]	11.22[b]	0.59
Glucose**	61.80[c]	57.40[b]	50.00[a]	0.30
BUN*	20[b]	14[a]	12[a]	0.256
Protein	6.68	6.86	6.84	0.062
Albumin	3.42	3.36	3.58	0.061
Globulin	3.18	3.50	3.16	0.074

[a,b,c] Values bearing different superscript in a row differ significantly, * p<0.05 ** p<0.01.
SEM = Standard error of the mean. [1] For detail see Table 4.

significantly different among the groups however, rumen ammonia-N concentration decreased (p<0.01) with increased level of *Barhar* leaves in the diet. Blood urea N and blood glucose levels were lower (p<0.05) in groups fed *Barhar* leaves (Table 5).

Intake and serum profile of certain minerals

Intake and serum profile of selected minerals are presented in Table 6. Intake of P decreased (p<0.05) as the level of *Barhar* leaves increased in the diet. Intakes of other minerals were not significantly different among the groups. Replacement of 50% of the concentrates with *Barhar* leaves resulted in decreased blood hemoglobin (p<0.01) and serum Fe (p<0.05) concentration.

Table 6. Effect of partial replacement of concentrates with *Barhar* leaves on intake and serum mineral profile of Sikkim local goats fed a mixed jungle grass-based diet

	Dietary treatments[1]			SEM
	I	II	III	
Intake				
Ca (g/dl)	6.48	6.87	7.44	0.27
P (g/dl)**	3.70[a]	3.28[b]	2.92[c]	0.067
Fe (μg/L)	305.03	311.52	326.14	11.51
Zn (μg/L)	35.36	33.79	33.11	0.87
Cu (μg/L)	5.44	5.34	5.35	0.17
Serum profile				
Ca (g/dl)	10.38	10.68	10.80	0.45
P (g/dl)	4.82	4.84	4.84	0.16
Fe (μg/L)*	1,520[a]	1,428[ab]	1,310[b]	42.23
Cu (μg/L)	1,216	1,206	1,150	16.04
Zn (μg/L)	590	578	568	15.55

[a,b,c] Values bearing different superscript in a row differ significantly, * p<0.05, ** p<0.01.
SEM = Standard error of the mean. [1] For detail see Table 4.

Growth performance

Replacing 25% of concentrate with *Barhar* leaves showed no effect on ADG. However, replacing 50% of the concentrate resulted in reduction (p<0.05) in ADG (Table 7). Replacing 50% of the concentrates with *Barhar* leaves resulted in increased (p<0.05) fecal excretion and decreased (p<0.05) N balance.

DISCUSSION

Herbal and chemical composition of feeds and fodder

Herbal composition of the mixed jungle grass during the

Table 7. Effect of partial replacement of concentrates with *Artocapus lakocha* leaves on N balance and growth performance of Sikkim local goats fed a mixed jungle grass-based diet

	Dietary treatments[1]			SEM
	I	II	III	
N balance (g/d)				
N intake*	9.32[b]	8.99[ab]	8.73[a]	0.085
NF*	2.64[a]	2.76[ab]	3.00[b]	0.064
NU	3.09	2.88	3.10	0.097
NB*	3.59[b]	3.35[b]	2.62[a]	0.093
Growth performance				
Initial Wt (kg)	7.00	7.40	7.90	0.139
Final Wt	11.80	11.78	11.76	0.146
Wt change*	4.80[a]	4.38[a]	3.76[b]	0.100
ADG*	53.33[a]	50.44[ab]	41.78[b]	0.343

NF = Nitrogen excreted through faeces; NU = Nitrogen excreted through urine; NB = Nitrogen balance.
[a,b,c] Values bearing different superscript in a row differ significantly * p<0.05 ** p<0.01.
SEM = Standard error of the mean. [1] For detail see Table 4.

trial period was quite different from that observed during the monsoon at the same location (Balaraman and Gupta, 1990). However, the herbal composition of mixed jungle grass reported from the same location during winter (Das, 2005) was more or less similar to that observed during the present investigation. CP content of mixed jungle grass during winter (present experiment) was lower and NDF content was higher than the values reported earlier during the monsoon from the same location (Balaraman and Gupta, 1990). Thus, it is evident that herbal and chemical composition of mixed jungle grass varies according to the season. Similar change in nutrient composition was also reported in arid pasture (Shinde et al., 1998). The change in nutrient composition could be correlated with stage of maturity. During the monsoon, most of the pasture components were in pre-flowering/full bloom stage, during which the nutrient concentration is maximum.

Among the different components of mixed jungle grass, *Setaria palmifolia* was characterized by higher CP, lower NDF and very low content of tannins. These attributes make it a suitable component for a native silvi-pasture system (Rai et al., 1988). Another notable component of mixed jungle grass was *Thysanolaena maxima*, the broom grass. Usually this multipurpose herb is grown in the terrace risers for conservation of soil, flowers are used as commercial broom and, after harvesting of broom, the leaves are fed to livestock and the left-over sticks are either used as fuel or for thatching. The broom grass is often grown wild in the scrub and forest land. Two of the most striking components of mixed jungle grass were *Ageritum conyziodes* and *Eupotarium odoratum*. There is no previous report regarding their nutritional/anti-nutritional value. Nevertheless they were characterized by a high content of tannins and, along with *Desmodium intortum*, probably contributed to the high tannin content of mixed jungle grass. It seems that C3 plants accumulate more condensed tannins than C-4 plants (Capinera et al., 2005).

The chemical composition of *Barhar* was similar to earlier reports on the same species (Das and De, 2001; Khanal and Subba, 2001). The leaves contained much higher tannins and condensed tannins than other tree fodder of the region (Khanal and Subba, 2001). Another notable feature of the leaves was the very low content of P. The P content of *Barhar* was 3 times lower than that of the concentrate mixture. Thus, extensive replacement of concentrates with *Barhar* leaves may impair P metabolism and animal performance.

Rate and extent of degradation of *Barhar* leaves was similar to pasture but lower than concentrates. This is contrary to leguminous tree fodders, which are very highly degradable (Bonsi et al., 1995). Such difference could be due to more NDF and ADF, and also due to more proportion of ADF-N and NDF-N in *Barhar* leaves. About 48 and 41% of N of *Barhar* leaves was bound to NDF and ADF, respectively. ADF-bound N is unavailable for degradation as observed in the case of *Artocarpus heterophyllus* (Das and Ghosh, 2007).

Nutrient intake, rumen fermentation pattern, blood metabolites and diet digestibility

As the goats consumed the entire amount of *Barhar* leaves offered to them, replacing concentrates with *Barhar* leaves did not affect the total DMI. Similarly, replacing concentrates with *Gliricidia* leaves showed no affect on total DMI in growing and lactating goats (Richards et al., 1994a, b). However, replacing concentrate with *Sesbania* leaves reduced DMI in lactating cows (Khalili and Varvikko, 1992). This difference in response could be attributed largely to the reluctance of animals to eat all the leaves and also due to wilting of *Sesbania* leaves, which resulted in dry hard stems which were most probably unpleasant to eat. *A. lakocha*, leaves were, however, highly palatable and the animals consumed the entire amount offered to them (Das and De, 2001). Replacing concentrates with tree fodder like *Artocapus heterophyllus* resulted in increased pasture intake (Das and Ghosh, 2007). Failure to observe any such positive response in the present experiment could be explained on the basis of a very high level of intake in the control group. It is to be noted that in this experiment, DMI as a proportion of BW was higher than 6.00% in all the groups. However, DMI in goats fed solely on Jack fruit leaves was only 4.11% (Das and Ghosh, 2001b), whereas it was 4.61% of BW in goats fed solely on *Barhar* leaves (Das and De, 2001). It was amazing to note that a diet comprising of components like *Ageritum conyzoides, Eupotarium odoratum* and *Crystellina parasitica* (all of which contained high level of condensed tannins and their nutritional/anti-nutritional attributes require further elaborate study) was relished to such an extent by the goats. Opportunistic feeding behavior of goats and their preference for a greater variety of feeds (Sharma et al., 1998) over a large quantity of one type of feed might have resulted in increased DMI in goats fed on a jungle grass-based diet. Overall DMI up to 6.71% of BW has been recorded in Black Bengal goats fed on a Jack fruit leaves-based diet supplemented with concentrates (Kibria et al., 1994). Mackenzie (1970) has indicated that, in terms of DM consumption, records up to 15% of BW have been observed in goats compared to only 2.5-3.0% in the case of cattle and sheep.

Rumen pH was not significantly different among the groups. The pH was above the cellulolytic threshold of 6.2 (Mould and Orskov, 1983) in all groups. Rumen NH_3-N concentration decreased ($p<0.01$) with increasing level of replacement. This was in accordance with lower degradability of N from *Barhar leaves*. Similar observations were made when the concentrate mixture was replaced with tree fodders like *Sesbania* (Khalili and Varvikko, 1992) and *Gliricidia* (Richards et al., 1994a). However, the NH_3-N level was above or about 100 mg/L in all the groups, which has been recommended as the minimum acceptable level for optimization of digestion of a forage-based diet (Leng, 1990; Das and Singh, 1999). In this experiment, feed consumption and overall tract digestibility was similar in all the groups, resulting in similar DOM intake. This effect was also reflected in similar TVFA concentration in all the groups. Replacement of concentrates with jack fruit leaves in previous studies produced similar responses (Das and Ghosh, 2007).

Blood urea concentration was a reflection of the rumen NH_3-N level. This could be due to a decrease in protein degradability. Similar responses have been observed when concentrates were replaced with jack fruit leaves (Das and Ghosh, 2007). Replacing concentrate with *Barhar* leaves resulted in a decreased blood glucose level. This could be due to the increased acetate and decreased propionate observed with increasing *Barhar* leaves in the diet. Replacement of concentrates with tree leaves resulted in a higher proportion of fibre in the diet. In a diet containing more fibre, acetate production increases at the expense of propionate owing to low carbon flow through electron accepting channels such as the glycolytic acid-propionate production pathway (Van Houlert, 1983). Replacing a concentrate mixture with jack fruit leaves, produced a similar response in earlier studies (Das and Ghosh, 2007).

In spite of the slower rate and extent of degradation of *Barhar* leaves in comparison to concentrate, digestibility of DM and OM was similar in all groups. However, digestibility of NDF increased and that of CP decreased with increased level of *Barhar* leaves in the diet. Similar observations have been reported when concentrate mixture was replaced with *Sesbania* in lactating cows (Khalili and Varvikko, 1992), *Gliricidia* in growing goats (Richards et al., 1994a) or *Artocarpus heterophyllus* in kids (Das and Ghosh, 2007). Increased fibre digestibility in the group fed *Barhar* leaves could be due to supply of degradable cellulose by *Barhar* leaves which is essential to seed fibrolytic bacteria (Silva and Orskov, 1988). The concentrate-fed group, although provided with readily degradable nitrogen, contained very negligible amounts of degradable cellulose and hemicelluloses. Replacing concentrates with *Barhar* leaves is expected to decrease the passage rate and increase mean retention time due to their bulkiness (Bonsi et al., 1994). Higher levels of concentrate in the control diet might have increased the rate of passage of particulate matter from the reticulo-rumen, which is inversely correlated to digestibility (Aitchison et al., 1985). It is logical to assume that replacing concentrates with *Barhar* leaves would result in decreased level of starch in the rumen. Consequently, the adverse effect of starch on fibre digestion was lower when concentrate was replaced with *Barhar* leaves. As a result, fibre digestion was higher in groups fed *Barhar* leaves.

Intake and serum profile of some minerals

Mixed jungle grass and *Barhar* leaves had a higher Ca content, more than 1% on DM basis, which made these feed ingredients suitable for early lactation and growth. The P content of both mixed jungle grass and *Barhar* leaves was relatively low, but within the normal requirement range (Khanal and Subba, 2001). As the concentration of Ca was higher and P was lower in mixed jungle grass, the cereal byproduct-based concentrate mixture which was rich in P and low in Ca was a perfect supplement for the mixed jungle grass-based diet. Replacing concentrates with tree leaves, however, may upset this balance and may cause some problems with Ca, P and Vitamin D metabolism (Khanal and Subba, 2001). Replacing 50% of the concentrate with *Barhar* leaves resulted in a 22% reduction of P intake. Considering the large variation in P content between concentrates and *Barhar* leaves, the extent of reduction in P intake was small, because consumption of *Barhar* leaves never exceeded 20% of dietary DM. Such difference in intake of P was, however, not reflected in serum P level. At a marginal level of lower intake, input of P to the blood pool is maintained by an increased bone resorption and P mobilization from soft tissues. As all the animals were growing in the present experiments, mobilization of P from bone and soft tissue is least likely. Rather, the efficiency of absorption might have increased in the low intake group due to active demand for P as observed by Vitti et al. (2000). Further, P intake was much higher than the recommended value of 0.91 g/d for a 20 kg goat growing at 50 g/d (AFRC, Kessler, 1991). Hence, replacement of concentrates with *Barhar* leaves is not likely to hamper production performance of goats through interference in P metabolism.

Both mixed jungle grass and *Barhar* leaves contained Zn and Cu above the normal requirement range (Khanal and Subba, 2001). It is notable that both feed ingredients contained Fe above its normal range. High levels of Fe could mostly be attributed to the acidic soils of Sikkim since such soils may elevate Fe levels in plants (McDowell, 1997). In spite of higher Fe intake, replacing concentrates with *Barhar* leaves resulted in decreased blood hemoglobin and serum Fe concentration. Priolo et al. (2000) reported that even a small amount of condensed tannin may depress blood Hb concentration. Tannins are known to chelate Fe and thus reduce absorption (Gillooly et al., 1983). The lower hemoglobin concentrations of animals fed a higher level of *Barhar* leaves are probably a direct result of this effect. There are conflicting results on the effect of tannins on availability of Cu and Zn (Jansman et al., 1993; Vaquero et al., 1994). In this experiment, irrespective of dietary level of *Barhar* leaves and condensed tannins, serum Cu and Zn levels were similar in all the groups.

Nitrogen utilization and growth performance

CP digestibility decreased with increased level of *Barhar* leaves in the diet. Similarly, decreased N utilization has been reported when a concentrate mixture was replaced with tree fodders like *Sesbania* (Khalili and Varvikko, 1992) or *Gliricidia* leaves (Richards et al., 1994a). This could be due to slower rate and extent of degradation of N from *Barhar* leaves as most of its N is bound to the fibre fraction as already discussed. Greater faecal N production in goats fed *Artocarpus lakocha* leaves suggests impairment of N utilization in the small intestine. Traditionally, impairment of N utilization in tree fodder-based diets has been attributed to the presence of tannins and other phenolics (Bakshi and Wadhawa, 2004). In this experiment, the total tannin content was 15.8% of DM, which is much higher than reported in other tree fodders of the region (Khanal and Subba, 2001). Replacing concentrate with *Barhar* leaves resulted in a linear increase in the condensed tannin content of the diet. Even though goats are more tolerant to tannin content than sheep and other ruminants (Narjisse et al., 1995), impairment of N utilization was observed in the present experiment when concentration of condensed tannins was 3.70%. In fact, even a small amount of dietary condensed tannin may adversely affect the performance of animals (Priole et al., 2000).

In this experiment, replacing 50% of concentrates with *Barhar* leaves resulted in reduced ADG. Reduced protein intake or amino acid absorption in the small intestine most likely limited performance rather than energy. Blood glucose level in group III was lower than in other groups, which indicates that propionate level was lower in that group. It would be logical to assume that supply of glucogenic amino acids for protein synthesis was lower in group III due to lower availability of propionate. However, these adverse effects on protein intake and utilization were not evident when the replacement was restricted to 25%. Protein intake and utilization were similar in groups I and II. It seems that *Barhar* leaves can replace 25% of the concentrates.

CONCLUSION

Although there was large variation in CP content of concentrate and *Barhar* leaves, CP consumption was similar in groups I and II, and there was only a small decrease in CP consumption in group III in comparison to the control. On the contrary, there was large variation in CP digestibility among the groups. The CP digestibility decreased by 9 and 17% in groups II and III, respectively. It was evident that most of the adverse effects of replacing 50% of the concentrates with *Barhar* (*Artocapus lakocha*) leaves were due to impairment of utilization of protein rather than its intake.

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