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

A. Das*, D. De and S. Katole1

ICAR Research Complex for NEH Region, Sikkim Centre, Tadong-737 102, Sikkim, India

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-
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 (Analogon, 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%), *Penicium maxima* (5.2%), *Ageritum conyzaoides* (9.1%), *Euapotarium odoratum* (8.9%), *Desmodium intortum* (13.05) and *Crystallina 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
(Desmodium intortum), 1 member of compositae (Eupotarium odoratum), 1 member from Asteraceae (Ageritum conyzoides) and 1 fern (Crystellina parasitica). 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 Eupotarium odoratum 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 1. Chemical composition of feeds and fodders used for the digestion trial

| Parameter                  | Mixed jungle grass | Barhar | Concentrates |
|----------------------------|--------------------|--------|--------------|
| 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%.

Table 2. Chemical composition of pasture herbage

|                     | OM  | N   | NDF | ADF | Hemicellulose | Cellulose |
|---------------------|-----|-----|-----|-----|---------------|-----------|
| Setaria palmifolia  | 252 | 243 | 893 | 11.9| 654.5         | 297.3     |
| Pennisetum polystachyon | 213 | 292 | 906 | 11.5| 742.5         | 432.2     |
| Thysanolaena maxima  | 114 | 328 | 882 | 6.7 | 782.5         | 462.9     |
| Panicum maxima       | 52  | 268 | 912 | 9.3 | 741.9         | 392.5     |
| Ageritum conyzoides  | 91  | 312 | 864 | 10.9| 664.5         | 582.5     |
| Eupotarium odoratum  | 89  | 876 | 18.4| 692.3| 612.6         | 79.7      |
| Desmodium intortum   | 130 | 287 | 902 | 34.4| 582.3         | 504.5     |
| Crystellina parasitica | 30  | 179 | 842 | 13.4| 496.7         | 372.6     |
| Others               | 41  |     |     |     |               |           |
tannins and, with *Desmodium 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 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                |
| *Euopaturn odoratum*        | 67              | 15                   | 52               | 34                |
| *Desmodium intortum*        | 125             | 21                   | 104              | 87                |
| *Crystellina parasitica*    | 37              | 8                    | 29               | 19                |

---

**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 | SEM  |
|----------------------------|--------------------|------|
| Feed consumption (g/d)     |                    |      |
| Mixed jungle grass         | 421.00             | 0.74 |
| Concentrate**              | 178.84a            |      |
| *Artocarpus lakocha*       | -                  |      |
| Total                      | 599.84             | 0.73 |
| As % of body weight        |                    |      |
| Nutrient intake (g/d)      |                    |      |
| OM                         | 533.52             |      |
| CP*                        | 58.34a             |      |
| NDF                        | 329.38             |      |
| ADF                        | 211.10             |      |
| Hemicellulose              | 118.27             |      |
| Cellulose                  | 152.49             |      |
| Digestibility of nutrients (%) |                |      |
| DM                         | 63.38              |      |
| OM                         | 64.38              |      |
| CP**                       | 71.57a             |      |
| NDF*                       | 48.66a             |      |
| ADF*                       | 47.22a             |      |
| Hemicellulose*             | 51.21a             |      |
| Cellulose**                | 49.83a             |      |

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.
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.

### 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 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 | I | II | III | SEM |
|--------------------|---|----|-----|-----|
| Rumen fermentation pattern |   |    |     |     |
| pH                 | 6.85 | 6.91 | 6.89 | 0.044 |
| NH₃**              | 198.6⁰ | 155.6⁰ | 115.4⁰ | 0.788 |
| VFA                | 112 | 107.8 | 106 | 0.293 |
| Blood metabolites  |   |    |     |     |
| Hb (g/dl)**        | 14.08⁰ | 13.06⁰ | 11.22⁰ | 0.59  |
| Glucose**          | 61.80⁰ | 57.40⁰ | 50.00⁰ | 0.30  |
| BUN*               | 20⁰ | 14⁰ | 12⁰ | 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 |

** 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.

#### 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 | I | II | III | SEM |
|--------------------|---|----|-----|-----|
| Intake             |   |    |     |     |
| Ca (g/dl)          | 6.48 | 6.87 | 7.44 | 0.27 |
| P (g/dl)**         | 3.70⁰ | 3.28⁰ | 2.92⁰ | 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)*         | 1,520⁰ | 1,428⁰ | 1,310⁰ | 42.23 |
| Cu (μg/L)          | 1,216 | 1,206 | 1,150 | 16.04 |
| Zn (μg/L)          | 590 | 578 | 568 | 15.55 |

** 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.

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

| Dietary treatments | I | II | III | SEM |
|--------------------|---|----|-----|-----|
| N balance (g/d)    |   |    |     |     |
| N intake*          | 9.32⁰ | 8.99⁰ | 8.73⁰ | 0.085 |
| NF*                | 2.64⁰ | 2.76⁰ | 3.00⁰ | 0.064 |
| NU                 | 3.09 | 2.88 | 3.10 | 0.097 |
| NB*                | 3.59⁰ | 3.35⁰ | 2.62⁰ | 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*         | 4.80⁰ | 4.38⁰ | 3.76⁰ | 0.100 |
| ADG*               | 53.33⁰ | 50.44⁰ | 41.78⁰ | 0.343 |

** 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 (Capineria 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 Varvikkko, 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 Artocarpus 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 NH3-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 increase the rate of passage 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 Varvikkio, 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 from 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 (Artocarpus lakocha) leaves were due to impairment of utilization of protein rather than its intake.

**REFERENCES**

AFRC. 1998. Agricultural and Food Research Council. The Nutrition of Goats. CAB International, Wallingford, UK.

Aitchison, E. M., M. Gill and D. F. Osbourn. 1985. The effect of supplementation with maize starch and level of intake of perennial ryegrass hay on the removal of digesta from the rumen of sheep. Br. J. Nutr. 56:463-476.

Anonymous. 1994. Basic statistics of Tripura, directorate of statistics, government of Tripura, Agartala, Tripura, India, p. 19.

AOAC. 1984. Official methods of analysis, 14th edn. Association of Official Analytical Chemists, Washington, DC.

Bakshi, M. P. S. and M. Wadhwa. 2004. Evaluation of forest tree leaves of semi-hilly arid region as livestock feed. Asian-Aust. J. Anim. Sci. 17:777-783.

Balaraman, N. and H. K. Gupta. 1990. Nutritive value of mixed jungle grass for goats in Sikkim. Indian J. Anim. Nutr. 7:63-66.

Barnett, A. J. and R. L. Reid. 1957. Studies on the production of volatile fatty acids from grass by rumen liquor in artificial rumen. I. The volatile fatty acid production from fresh grass. J. Agric. Sci. 49:171-179.

Bates, D. B., G. A. Morantes and G. E. Moore. 1988. Nitrogen utilization of lambs fed limopgrass supplemented with molasses-urea or legume-protein supplements. Nutr. Rep. Int. 38:487-499.

Bonsi, M. L. K., P. O. Osuji and A. K. Tuan. 1995. Effect of supplementing teff straw with different levels of leucaena or sesbania leaves on the degradability of teff straw, sesbania, leucaena, tagasaste and vernonia and on certain rumen and blood metabolites in Ethiopian Menz sheep. Anim. Feed. Sci. Technol. 52:101-129.

Bonsi, M. L. K., P. O. Osuji, V. I. Nasihai and A. K. Tuan. 1994. Graded levels of Sesbania sesban and Leucaena leucocephala as supplement to teff straw given to Ethiopian Menz sheep. Anim. Prod. 59:235-244.

Brown, W. F. and W. D. Pitman. 1991. Concentration and degradation of fibre fraction in selected tropical grasses and legumes. Trop. Grasal. 25:305-311.

Capinera, J. L., A. R. Renaud and N. E. Roehrig. 2005. Chemical basis for host selection by Hernileuca oliviae. J. Chem. Ecol. 9:1425-1437.

Dacie, J. V. and S. M. Lewis. 1968. Practical hematology. J and A Churchill, UK p. 37-39.

Das, A. and G. P. Singh. 1999. Eating behaviour, VFA production passage rate and nutrient digestibilities in cattle fed on wheat straw supplemented with different levels of berseem. Asian-Aust. J. Anim. Sci. 12:1040-1048.

Das, A. and S. K. Ghosh. 2000. Effect of concentrate supplementation on growth performance of kids grazing in
Das, A. and S. K. Ghosh. 2001a. Effect of concentrate supplementation on growth performance of grazing kids. Indian J. Anim. Nutr. 17:179-183.

Das, A. and S. K. Ghosh. 2001b. Nutritive value of jackfruit tree leaves for goats. Indian J. Anim. Nutr. 18:185-186.

Das, A. 2005. Effect of nevaro (Ficus hookeri) leaves supplementation of mixed jungle grass on intake and digestion in Sikkim local goats. Anim. Nutr. Feed Technol. 5:83-89.

Das, A. and S. K. Ghosh. 2007. Effect of partial replacement of concentrates with jackfruit (Artocarpus heterophyllus) leaves on growth performance of kids grazing on native pasture of Tripura, India. Small Rumin. Res. 67:36-44.

Doumas, B., W. Watson and H. Biggs. 1971. Albumin standards and measurement of serum albumin with bromocresol green. Clin. Chem. Acta. 31:87-92.

Folin, O. and H. Wu. 1920. A simplified and improved method for the determination of sugar. J. Biol. Chem. 41:367-374.

Gillooly, M., T. H. Bothwell, J. D. Torrance, A. P. MacPahil, D. P. Derman and W. R. Bezvoda. 1983. The effect of organic acids, phytates and polyphenolics on the absorption of iron from vegetables. Br. J. Nutr. 49:331-342.

Jansman, A. J. M., J. G. M. Houdijk and M. W. A. Verstegen. 1993. Effects of condensed tannins in faba beans on the availability of minerals in pigs. In: Bioavailability'93. Nutritional, Chemical, and Food Processing Implications of Nutrient Availability (Ed. G Schlemmer). Fed. Eur. Chem. Soc. 2:48-52.

Karim, S. A., A. Santra and V. K. Sharma. 2001. Growth performance of weaner lambs maintained on varying levels of dietary protein and energy in the pre-weaning phase. Asian- Aust. J. Anim. Sci. 14:1394-1399.

Kessler, J. 1991. Mineral nutrition of goats. In: Goat Nutrition (Ed. P. Morand-Fehr). pp. 105-119. Pudoc, Wageningen, The Netherlands.

Khalili, H. and T. Varvikko. 1992. Effect of replacing concentrate mixture by wilted sesbania forage on diet digestibility, rumen fermentation and milk production in Friesian-Zebu crossbred cows fed low quality native hay. Anim. Feed Sci. Technol. 36: 275-285.

Khanal, R. C. and D. B. Subba. 2001. Nutritional evaluation of some major fodder trees cultivated in the hills of Nepal. Anim. Feed Sci. Technol. 92:17-32.

Kibria, S. S., T. N. Nahar and M. M. Mia. 1994. Tree leaves as alternative feed responses for black Bengal kids under stall fed conditions. Small Rumin. Res. 13:217-222.

Leng, R. A. 1990. Factors affecting the utilization of poor quality forages by ruminants particularly under tropical condition. Nut. Res. Rev. 3:277-303.

Lowry, O. H., A. Walker, D. Brown and R. J. Randall. 1951. Protein measurement by Folin-Phenol reagent. J. Biol. Chem. 143:265.

McDowell, L. R. 1997. Minerals for grazing ruminants in tropical regions. University of Florida. Institute for Food and Agricultural Sciences, USA.

Makkar, H. P. S. 2003. Effect and fate of tannins in ruminant animals, adaption to tannins and strategies to overcome detrimental effects of feeding tannin-rich foods. Small Rumin. Res. 49:249-256.

Mackenzie, D. 1970. Goat husbandry, 3rd edn. Faber & Faber Ltd, London, UK, pp. 141-179.

Mould, F. L. and E. R. Orskov. 1983. Manipulation of rumen fluid pH and its influence on cellulolysis, in sacco dry matter degradation and the rumen microflora of sheep offered hay or concentrates. Anim. Feed Sci. Technol. 10:1-14.

Mui, L. I., I. T. Nguyen, P. Uden and B. Van Dinh. 2002. The foliage of Flemingia (Flemingia macrophylla) or Jackfruit (Artocarpus heterophyllus) as a substitute for a rice bran - soya bean concentrate in the diet of lactating goats. Asian-Aust. J. Anim. Sci. 15:45-54.

Narjisse, N., M. A. Elbousali and J. D. Olsr. 1995. Effect of oak tannins (Quercus ilex) on digestion and nitrogen balance in sheep and goat. Small Rumin. Res. 18:201-206.

Orskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. Cambridge 92:499-503.

Priolo, A., G. C. Waghorn, M. Lanza, L. Biondi and P. Pennisi. 2000. Polyethylene glycol as a means for reducing the impact of condensed tannins in carob pulp: effects on lamb growth performance and meat quality. J. Anim. Sci. 78:810-816.

Raghuramu, N., K. M. Nair and S. Kalyansundaram. 1983. A manual of laboratory techniques. National Institute of Nutrition, Hyderabad, India, pp. 68-69.

Rai, R. N., K. Venugopal, K. A. Singh and R. D. Singh. 1988. Studies on compatibility of grasses under natural forest otutis (Alnus nepalnensis) and chilowane (Schima wallchii). Indian J. Hill Farming 1A(1):71-72.

Rahamullah, M. and J. R. C. Boyde. 1980. An improvement in determination of urea using diacetyl monoxyme method with or without deproteinization. Clin. Chem. Acta. 107:3-9.

Richards, D. E., W. F. Brown, G. Ruegssegger and D. B. Bates. 1994a. Replacement values of tree legumes for concentrates 1. Replacement values of Gliricidia sepium leaves for growing goats. Anim. Feed Sci. Technol. 46:37-51.

Richards, D. E., W. F. Brown, G. Ruegssegger and D. B. Bates. 1994b. Replacement value of tree legumes for concentrates in forage based diets II. Replacement value of Leucaena leucocephala and Gliricidia sepium for lactating goats. Anim. Feed Sci. Technol. 46:55-65.

Sharma, K., A. L. Saini, N. Singh and J. L. Ogra. 1998. Seasonal variation in grazing behaviour and forage nutrient utilization by goats on a semi arid reconstituted silvipasture. Small Rumin. Res. 27:47-54.

Shinde, A. K., S. A. Karim, S. K. Sankhyan and R. Bhatta. 1998. Seasonal changes in biomass growth and quality and its influence on cellulolysis, in sacco dry matter degradation and the rumen microflora of sheep offered hay or concentrates. Anim. Feed Sci. Technol. 30:29-35.

Silanikove, N., N. Gilboa and Z. Perevolotsky. 1996. Goat fed artocarpus foliage as a substitute for a rice bran - soya bean concentrate in the diet of lactating goats. Small Rumin. Res. 19:289-298.

Singh, K. A., B. P. S. Yadav and S. N. Goswami. 1996. Forage resource management for sustained livestock productivity in Himalayan agro-ecosystem. Research Bulletin No. 39, ICAR,
Research Complex for NEH Region, Barapani, 793 103, Meghalaya, India. pp. 42-60.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods, 6th edn. Oxford and IBH Publishing Co., Calcutta, India. pp. 299-320.

Talapatra, S. K., S. N. Ray and K. C. Sen. 1940. The analysis of mineral constituents in biological material. Part I. Estimation of phosphorus, chlorine, calcium, magnesium, sodium and potassium in foot stuffs. Indian J. Vet. Sci. Anim. Husbandry 10:243-246.

Van-Houlert, M. F. J. 1983. The production and metabolism of volatile fatty acids by ruminants fed roughages - a review. Anim. Feed Sci. Technol. 43:189-225.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Method of dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3582-3597.

Vaquero, M. P., M. Veldhuizen, W. van Dokkum, C. J. A. van den Hamer and G. Schaafsma. 1994. Copper availability from breakfasts containing tea. Influence of the addition of milk. J. Sci. Food Agric. 64:475-481.

Vitti, D. M., E. Kebreab, J. B. Lopes, A. L. Abdalla, F. F. De Carvalho, K. T. De Resende, L. A. Crompton and J. France. 2000. A kinetic model of phosphorus metabolism in growing goats. J. Anim. Sci. 78:2706-2712.