

Evaluation of Moringa Foliage (*Moringa oleifera*) as Goat Feed

Research Article

N. Sultana^{1,2*}, A.R. Alimon¹, K.S. Huque², M. Baba³ and J. Hossain²

¹ Department of Animal Science, Faculty of Agriculture, University Putra Malaysia, Serdang 43400, Selangor, Malaysia

² Livestock Research Institute, Savar, Dhaka-1341, Bangladesh

³ Department of Crop Science, Faculty of Agriculture, University Putra Malaysia, Serdang 43400, Selangor, Malaysia

Received on: 26 Sep 2014

Revised on: 15 Jan 2015

Accepted on: 31 Jan 2015

Online Published on: Dec 2015

*Correspondence E-mail: info@blri.gov.bd

© 2010 Copyright by Islamic Azad University, Rasht Branch, Rasht, Iran

Online version is available on: www.ijas.ir

ABSTRACT

Thirty five growing male goats (6.98±0.86 kg BW) were divided into five equal groups with seven animals in each group. The five dietary treatments were consisted of varying proportions of Moringa foliage (*Moringa oleifera*) and napier grass (*Pennisetum purpurium*); T₁ (100% Moringa foliage); T₂ (75% Moringa foliage+25% napier grass); T₃ (50% Moringa foliage+50% napier grass); T₄ (25% Moringa foliage+75% napier grass) and T₅ (100% napier grass) (control). The experiment was arranged in complete randomized design to evaluate the feed intake, nutrient digestibility and live weight gains of Bengal goats fed napier grass mixed with different levels of Moringa foliage. The dry matter (DM), crude protein (CP) and ash contents of the diets increased as the proportion of Moringa foliage increased and the reverse was seen for organic matter (OM) and acid detergent fiber (ADF) content. The DM intake was significantly (P<0.01) higher in sole Moringa diet than napier-Moringa foliage mixture and sole napier diet. Crude protein intake increased with higher inclusion level of Moringa foliage in the diet. The DM and OM digestibility of goats was significantly (P<0.01) higher in sole Moringa foliage diet than in other experimental diets. The CP digestibility was increased linearly with increasing level of Moringa foliage in the diet. Nitrogen retention was significantly (P<0.01) higher in sole Moringa and Moringa-napier mixture diets than in the sole napier grass diet. The mean daily average live weight gain followed a similar trend as the nitrogen retention which revealed that the nitrogen retention of all treatment groups was above the maintenance level of the animals. It is concluded that Moringa foliage can be replaced in goat diet up to 75% in napier grass based diet.

KEY WORDS goat feed, Moringa foliage, napier grass.

INTRODUCTION

In many developing countries, ruminant production is largely limited by unavailability and high cost of quality feeds. Low quality feeds are considered to be the major constraints hampering productivity of farm animals. The availability of feed is particularly decreased in the dry season when natural pastures are mature and highly fibrous (Oni *et al.* 2010) and with low nutritive value due to low crude protein content (Moyo *et al.* 2012a). Generally, farmers feed their animals with crop residues and low-quality hay that are low in nitrogen, high in lignocellulose and de-

ficient in vitamins and minerals, which leads to low digestibility and reduced voluntary intake, poor growth, delayed sexual maturity, poor reproductive performance, poor meat quality and low milk yield (Gebregiorgis *et al.* 2012). Many researchers have worked on fodder trees, shrubs and browses and confirmed the potential of these plants for ruminant nutrition in the tropics (Dzowela *et al.* 1997; McDonald *et al.* 1998; Benninson and Paterson, 2003). Their use as supplements has been shown to improve intake of poor quality roughages, increase growth rates and improve reproduction efficiency in ruminants (Karachi and Zengo, 1997; Alayon *et al.* 1998; Orden *et al.* 2000).

Moringa oleifera Lamarck, is a small tree native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afganistan (Sreelatha and Padma, 2009). Moringa is a non-leguminous multipurpose tree and is one of the fastest growing trees in the world, with leaves high in crude protein and contains negligible amounts of anti-nutritive compounds (Ogbe and Affiku, 2011; Aye and Adegun, 2013). It has been reported that Moringa leaves contain good quality protein with high digestibility (Makkar, 2012). Additionally, the leaves are rich in carotenoids, vitamin C and other antioxidants (Yang *et al.* 2006). The leaves of *Moringa oleifera* (MO) leaves are gradually gaining importance in the West African sub-region and Nicaragua as protein supplements to address the observed crude protein shortages of natural pastures and crop residues (Sánchez *et al.* 2006a; Sánchez *et al.* 2006b; Asaolu *et al.* 2009a; Asaolu *et al.* 2009b; Asaolu *et al.* 2010; Mendieta-Araica *et al.* 2011). Hence, the objective of the present study was to evaluate the effect of supplementation with different levels of *Moringa oleifera* foliage (MOF) on feed intake, nutrient utilization and live weight gain of Bengal goats fed a basal diet of napier grass.

MATERIALS AND METHODS

This study was conducted at the Goat Farm of Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh. The station is located at 23°42'0"N, 90°22'30"E at an altitude of 4 meters above the sea level. Thirty five Bengal male goats (4 to 5 months old; 6.98±0.86 kg BW) were randomly selected from the herd at the Goat Farm of BLRI in 2013. All goats were treated with antihelminthes (Endex, Novartis, India) before the commencement of the experiment. The goats were kept in individual pens measuring 1.25 m² (1.25 m×1.0 m) and equipped with feeders and water buckets. The goats were allowed a 10 day adjustment period during which they were gradually introduced to the experimental diets. Napier grass and Moringa foliage were collected from the fodder plot and the Moringa plot respectively. Moringa foliage consisted of leaf, petiole, stem and soft rachis. The hard woody rachis was removed from the foliage to ensure suitable intake. Napier and Moringa foliage were harvested in the afternoon to supply the next morning. Napier and whole Moringa foliage was chopped with a chaff cutter into 2 to 3 cm pieces after harvesting. The napier grass and Moringa forage were mixed thoroughly and offered as a sole diet to the goats. The mixed feed in each treatment was mixed with 2.5, 1.0 and 0.5% molasses, di-calcium phosphate (DCP) and salt respectively, prior to feeding. The required amount feed for individual animals was weighed and divided into two equal portions and offered two times a day at 8.30 and 15.00.

The pens and water buckets were cleaned every day before offering the feed. All animals were provided with plenty of water.

The feeding trial was carried out for 56 days with a 10 day adjustment period. Thirty five goats were selected, weighed and divided into five different groups with seven goats per diet per treatment. A completely randomized design (CRD) was used with seven animals in each treatment. The dietary treatments were as follows:

- T₁= 100% Moringa foliage
- T₂= 75% Moringa foliage + 25% napier grass
- T₃= 50% Moringa foliage + 50% napier grass
- T₄= 25% Moringa foliage + 75% napier grass
- T₅= 100% napier grass (control)

Data collection was carried out for 56 days. Offered feed and refusal of individual animals were recorded once in a week for dry matter analysis to estimate voluntary feed intake. Dry matter analysis was carried out on the same day. Experimental animals were weighed at the commencement of the experiment and subsequently at weekly intervals before offering the morning feed. The average daily live weight gain was calculated by regression of body weight of each animal on number of days of feeding during experimental period.

Last week of the experiment, total faeces and urine samples were collected from each animal daily and weighed. During the collection period, samples of feed and refusals were collected, composited by animals, ground (1-mm screen) and kept for further analysis (AOAC, 2000). Digestibility trial was continued for 7 days. The daily faeces and urine voided was recorded and a 10% alichot of fecal and urine was preserved for further analysis.

At the end of the digestibility trial, three goats were randomly selected from each treatment to collect rumen liquor. Approximately, 20 mL rumen liquor was collected from each goat using rumen stomach tube at 0 and 4 h after offering feed to determine pH, ammonia-N and to enumerate total protozoa in the rumen fluid.

A 5 mL portion of each rumen sample was squeezed through one layer of cheesecloth and the ruminal fluid was used for measurement of pH and for protozoal counts. A 5 ml portion of the ruminal fluid was squeezed through four layers of cheesecloth, mixed with 0.3 mL 6.0 M HCl and frozen (-20 °C) for the analysis of ammonia-N. The pH of all samples was measured immediately using a digital pH meter (Mettler Toledo, AG 8603, Switzerland). The NH₃-N concentration of rumen liquor was determined by direct distillation and titration using an automatic N analyzer (AOAC, 2000). Total protozoal count in the rumen fluid was determined as described by (Dehority, 1984). Triplicate

feed, refusal and faeces samples were subjected to proximate analysis following the standard methods of AOAC (2000). Acid detergent fiber (ADF) was determined according to the method of Van Soest *et al.* (1991).

Statistical analysis

The data were subjected to ANOVA using the general linear model procedure in SAS (2007). The differences in the means were compared by least significant differences (LSD) at 5% level ($P < 0.05$).

RESULTS AND DISCUSSION

Nutrient composition of feed ingredient

The nutrient composition of Moringa foliage, napier grass is presented in Table 1. The DM, CP and ash contents were higher in Moringa foliage than napier grass, while the OM and ADF contents were higher in the napier grass than in Moringa foliage.

Table 1 Nutrient composition of Moringa foliage and napier grass (% of DM)

Nutrients	Feed	
	Moringa foliage	Napier grass
DM	25.46	22.24
CP	18.23	10.43
ADF	36.48	47.08
OM	88.42	91.61
Ash	11.58	8.39
ME (MJ/kg DM)	9.60	8.20

DM: dry matter; CP: crude protein; ADF: acid detergent fiber; OM: organic matter and ME: metabolizable energy.

The DM, CP and ash contents of the Moringa foliage are in agreement with the findings of Asaolu *et al.* (2009a) and Asaolu *et al.* (2009b). The OM content of the Moringa foliage in the present study was similar with the findings of Aregheore (2002) (885.0 g kg⁻¹ DM), lower than the values reported by Fadiyimu *et al.* (2010) (924.6 g kg⁻¹ DM) and Manh *et al.* (2005) (917.1 g kg⁻¹ DM), but higher than the values reported by Ndemanisho *et al.* (2007) (869.0 g kg⁻¹ DM). The ADF content of Moringa foliage was similar to the findings by Kakengi *et al.* (2005), but the value in the present study was higher than that reported by Manh *et al.* (2005) and Sánchez *et al.* (2006a). The CP content of Moringa foliage in the present study was similar with the findings by Aregheore (2002), Kakengi *et al.* (2005) and Sánchez *et al.* (2006b) ranging from 193.0 to 217.0 g kg⁻¹ DM, but were lower than the values reported by Manh *et al.* (2005) (259.5 g kg⁻¹ DM).

The CP content of napier grass (10.43%) was above the recommended range of 70-80 g kg⁻¹ DM required for optimum rumen function, which can support maintenance and certain level of production in ruminant animals that utilize any kind of feed (Whitman, 1980; Van Soest, 1994).

Nutrient intake and growth performance

Mean nutrient intake, average growth and feed conversion ratio (FCR) of the different dietary treatments to the experimental goats are presented in Table 2. The DM intake was significantly ($P < 0.05$) higher in the T₁ diet than T₂, T₃ and T₄ or T₅ diet.

However, there were no significant ($P > 0.05$) differences in intake of T₂, T₃, T₄ and T₅ diets. Dry matter intake (DMI) as percent live weight and DMI (g⁻¹W^{0.75}) of the experimental goats were followed the same trend as for total dry matter intake. DMI as percent body weight of goats ranged from 3.39 to 3.97; which fell within recommended dry matter intake levels for small ruminants (NRC, 1985). The results are in agreement with that of Asaolu *et al.* (2009a), Kahindi *et al.* (2007) and Manaye *et al.* (2009) for Moringa foliage, *Sesbania sesban* and *Pithecellobium dulce* respectively.

Conversely, Fadiyimu *et al.* (2010) observed that increasing supplementation of Moringa foliage with guinea grass decreased DM intake. In the present study, it was observed that the basal diet intake was depressed with increasing Moringa foliage supplementation.

The CP intake of goats was significantly ($P < 0.05$) higher in the sole Moringa foliage diet compared to the other experimental diets. However, there were no significant ($P > 0.05$) differences between the T₂ and T₃ diets, and between the T₃ and T₄ diets. The lowest CP intake was observed in the T₅ diet. In general, the CP intake increased linearly ($r = 0.97$) as the proportion of Moringa foliage in the diet increased.

This was due to the higher CP content of Moringa foliage compared to the napier grass. CP intake was seemingly a reflection of DM intake and CP content of the supplements. Moreover, there was a positive correlation between crude protein intake and dry matter intake (Mtenga and Shoo, 1990).

The OM intake of goats was significantly ($P < 0.05$) higher in the sole Moringa foliage (T₁) diet than the other experimental diets.

The initial live weight of experimental goats was not significantly ($P < 0.05$) different among the experimental treatments. The final live weight of experimental goats has progressively increased with the increasing level of Moringa foliage supplementation in the diet. Consequently, daily average live weight gain was significantly ($P < 0.05$) higher in goats on the T₁ diet than in T₂, T₃, T₄ and T₅ diets. However, there were no significant ($P > 0.05$) differences among the diets T₂, T₃ and T₄. The lowest FCR was observed in the T₅ diet while FCR increased linearly ($r = 0.98$) with the addition of Moringa foliage to the napier grass. The highest (61.74 g d⁻¹) growth was obtained with the T₁ diet (Table 2).

Table 2 Nutrient intake and average body weight gain of Black Bengal goats fed napier grass mixed with different level of Moringa foliage

Variables	Treatments					Sig.
	T ₁	T ₂	T ₃	T ₄	T ₅	
DM intake (g/d)	410.46 ^a ±17.74	312.28 ^b ±20.16	296.52 ^b ±17.43	287.39 ^b ±18.99	281.20 ^b ±6.59	*
DMI (%LW)	3.97 ^a ±0.12	3.39 ^b ±0.18	3.48 ^b ±0.17	3.42 ^b ±0.15	3.49 ^b ±0.06	*
DM (g/W ^{0.75})	71.19 ^a ±2.23	58.85 ^b ±2.38	59.69 ^b ±0.17	58.04 ^b ±2.38	59.69 ^b ±1.26	*
CPI (g/d)	74.83 ^a ±3.50	55.24 ^b ±2.74	43.74 ^{bc} ±1.79	39.88 ^c ±2.71	25.82 ^d ±3.22	*
ADFI (g/d)	136.40±10.43	125.11±7.41	122.88±9.11	121.78±7.00	119.13±7.40	NS
OMI (g/d)	360.17 ^a ±15.82	281.76 ^b ±11.59	265.42 ^b ±11.23	258.01 ^b ±18.67	255.12 ^b ±10.66	*
Initial BW (kg)	7.14±0.21	7.60±0.78	7.28±0.67	7.33±0.59	7.14±0.19	NS
Final BW (kg)	10.64 ^a ±0.33	9.66 ^{ab} ±0.78	8.97 ^{ab} ±0.72	8.91 ^{ab} ±0.71	8.00 ^b ±0.28	*
ADG (g/d)	61.74 ^a ±3.59	34.16 ^b ±4.09	30.00 ^b ±2.51	28.24 ^b ±2.27	16.00 ^c ±2.07	*
FCR	6.70 ^b ±0.43	7.41 ^b ±0.80	8.23 ^b ±0.89	8.56 ^b ±0.89	22.06 ^d ±1.84	*

BW: body weight; DM: dry matter; DMI: dry matter intake; CPI: crude protein intake; ADFI: acid detergent fiber intake; OMI: organic matter intake; ADG: average daily gain and FCR: feed conversion ratio.

The means within the same row with at least one common letter, do not have significant difference ($P>0.05$).

NS: non significant.

Moyo *et al.* (2012a) found that the daily average LWG was 103.3 g d⁻¹ in sole *Moringa oleifera* leaf meal (MOL) with 200 g wheat bran per day as energy source. This finding was higher than the findings of the present study due to supplementation of concentrate. However, the present results on the daily average LWG were higher than the findings by Asaolu *et al.* (2012) (20.83 g d⁻¹ animal⁻¹) who fed Cassava peels based diets supplemented with *Moringa oleifera* foliage. The observed differences in the different studies are attributed to variations in voluntary dry matter intake, efficiency of feed utilization, type of basal diets and the physiological state of the animals. The FCR results from the present study indicate that increased supplementation with Moringa foliage increased efficient utilization of feed and was attributed to the influence of better nutrient density and quality of nutrients available for utilization. All the experimental goat showed growth performance during the experimental period, which indicates that all the experimental diets had nutrient content above the minimum level for maintenance requirement of goats. In addition, there were no health implications when Moringa foliage was used to replace the napier grass over the experimental period.

Digestibility

The percent digestibility of dry matter (DM), crude protein (CP), organic matter (OM) and acid detergent fiber (ADF) are presented in Table 3. The DM and OM digestibility in goats was significantly ($P<0.05$) higher with the T₁ diet compared to the other experimental diets. However, there were no significant ($P>0.05$) differences among the T₂, T₃ and T₄ mixture diets. The CP digestibility was significantly ($P<0.05$) lower in the T₅ than in other experimental diets. The CP digestibility decreased with increasing in the levels of napier in the diet. Crude protein digestibility increased linearly ($r=0.9$) with increasing supplementation

with Moringa foliage while the highest (83.90%) crude protein digestibility was recorded with the sole Moringa foliage diet. Similar results were observed by Fadiyimu *et al.* (2010) who obtained 84.96% CP digestibility in sheep on sole Moringa foliage diet. The ADF digestibility was significantly ($P<0.05$) higher in the T₁ diet than in other experimental diets.

ADF digestibility increased linearly ($r=0.99$) with increasing levels of Moringa foliage. This indicates that increasing the level of Moringa foliage increased the activities of fibrolytic bacteria in the rumen due to the availability of essential nutrients in balanced proportions for improved microbial growth and multiplication, resulting in efficient fiber utilization. It has been reported that DM digestibility was above 70%, which place them in category of high quality feeds (Meissner *et al.* 2000). Manaye *et al.* (2009) also reported that supplementation of *Sesbania sesban* with napier improved DM, OM, CP and neutral detergent fiber (NDF) digestibility in sheep, leading to higher animal performance. The results of the present study clearly indicate that Moringa foliage played a positive role in improving rumen function and digestibility compared to the napier grass based diet.

Nitrogen balance

Nitrogen utilization in goats fed with graded levels of *Moringa oleifera* foliage (MOF) and napier grass are presented in Table 4. The mean nitrogen intake of goats was significantly ($P<0.05$) higher with increase in the inclusion levels of Moringa foliage from 25 to 100% of diet. The nitrogen intake values obtained in the study were comparable to the values reported by Asaolu *et al.* (2010) and Fadiyimu *et al.* (2010) for west African dwarf goats on Moringa supplemented based diet. Faecal nitrogen excretion was significantly ($P<0.05$) higher in the T₁ and T₂ groups compared to the other treatment groups.

Table 3 Nutrient digestibility (%) of diets with different levels of Moringa foliage and napier grass mixture for goats

Variables	Treatments					P-value
	T ₁	T ₂	T ₃	T ₄	T ₅	
DM	77.75 ^a ±1.34	73.14 ^{ab} ±4.15	71.97 ^{ab} ±3.07	71.43 ^{ab} ±3.07	68.58 ^b ±2.25	*
CP	83.90 ^a ±0.63	78.67 ^{ab} ±2.68	78.63 ^{ab} ±2.35	76.04 ^b ±2.81	63.43 ^c ±3.25	*
ADF	76.02 ^a ±1.42	74.35 ^{ab} ±1.05	71.78 ^{abc} ±2.03	69.25 ^{bc} ±2.61	66.86 ^c ±2.53	*
OM	78.32 ^a ±1.83	73.26 ^{ab} ±4.03	76.08 ^{ab} ±2.81	74.44 ^{ab} ±2.76	70.31 ^b ±2.07	*

DM: dry matter; CP: crude protein; ADF: acid detergent fiber and OM: organic matter.

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 4 Nitrogen balance (g d⁻¹animal⁻¹) in goats fed different levels Moringa foliage and napier grass

Variables	Treatments					P-value
	T ₁	T ₂	T ₃	T ₄	T ₅	
N-intake	11.97 ^a ±0.80	8.84 ^b ±0.89	7.0 ^{bc} ±0.88	6.38 ^c ±0.77	4.13 ^d ±0.32	*
Faecal-N	1.90 ^a ±0.08	1.78 ^a ±0.11	1.50 ^b ±0.08	1.40 ^b ±0.08	1.45 ^b ±0.03	*
Urinary-N	2.50 ^a ±0.16	1.95 ^b ±0.11	1.78 ^b ±0.17	1.32 ^c ±0.08	1.12 ^c ±0.09	*
N-digestibility	10.07 ^a ±0.74	7.06 ^b ±0.85	5.50 ^b ±0.87	4.98 ^b ±0.82	2.70 ^c ±0.33	*
Total N-out go	4.40 ^a ±0.02	3.71 ^b ±0.2	3.28 ^b ±0.16	2.72 ^c ±0.14	2.57 ^c ±0.10	*
N-retention	7.53 ^a ±0.80	5.11 ^b ±0.81	3.7 ^{bc} ±0.90	3.7 ^{bc} ±0.83	1.56 ^c ±0.3	*

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

There were no significant (P>0.05) differences among the T₃, T₄ and T₅ treatment groups. This is attributed to the higher intake of nitrogen from the experimental diets (Patra, 2009). On the other hand, Asaolu *et al.* (2010) and Fadiyimu *et al.* (2010) observed that faecal nitrogen was not affected by nitrogen intake. Similarly, the urinary nitrogen excretion of the goats was increase with increasing level of Moringa foliage in diets.

According to Brooker *et al.* (1995), when feed is high in soluble plant protein, it produces large amounts of ammonia-N in excess of the requirements of rumen microorganisms, and surplus ammonia is converted to urea by the animals and excreted in the urine. This implies that more rumen ammonia was produced with Moringa supplemented diets, which increased urinary nitrogen from the T₄ diet to T₁ diet. Total N output followed the same pattern as urinary excretion. Nitrogen digestibility was directly correlated with the levels of Moringa foliage inclusion, and hence the value of N digestibility recorded for the supplemented diets were significantly higher (P<0.05) than the T₅ (control) diet.

Nitrogen retention values were significantly (P<0.05) higher in T₁ than T₂, T₃, T₄ and T₅ diets while there were no significant (P>0.05) differences among the two diets combination T₃ and T₄. Similar results were observed by Patra (2009), Fadiyimu *et al.* (2010) and Asaolu *et al.* (2010). All the diets showed positive N balance, which indicates that the protein requirements for maintenance in the experimental animals were satisfactorily met by the dietary treatments.

Rumen environment

Mean values for pH, ammonia and protozoa numbers in rumen fluid before and after feeding with the different dietary treatments are presented in Table 5. The pH values were significantly (P<0.05) higher in the T₅ diet than in the T₂, T₃, T₄ and T₅ diets both before and after feeding. The ranges in pH values were from 6.62 to 6.79 and 6.67 to 6.83 before and after feeding, respectively. Rumen pH values were in the normal range for roughage diets (Ørskov and Ryle, 1990) and decreased with increasing Moringa foliage both before and after feeding.

Table 5 Rumen environment in goats fed different levels of Moringa foliage and napier grass

Variables	Treatments					P-value
	T ₁	T ₂	T ₃	T ₄	T ₅	
pH						
0 h	6.62 ^b ±0.08	6.66 ^b ±0.03	6.66 ^{ab} ±0.03	6.76 ^{ab} ±0.02	6.79 ^a ±0.03	*
4 h	6.67 ^c ±0.02	6.72 ^{bc} ±0.03	6.72 ^{bc} ±0.02	6.78 ^{ab} ±0.04	6.83 ^a ±0.03	*
Ammonia (mg/L)						
0 h	254.00 ^a ±5.51	234.00 ^{ab} ±7.23	217.33 ^{bc} ±7.17	204.00 ^c ±5.69	146.33 ^d ±8.19	*
4 h	297.67 ^a ±10.84	230.33 ^b ±6.96	223.67 ^b ±8.95	169.66 ^c ±5.46	136.67 ^d ±12.35	*
Protozoa (10 ⁴ /mL)						
0 h	4.70±0.53	4.83±0.26	5.17±0.13	4.06±0.17	4.70±0.70	NS
4 h	4.17 ^c ±0.32	4.50 ^{bc} ±0.10	4.9 ^{ab} ±0.12	5.00 ^{ab} ±0.10	5.30 ^a ±0.10	*

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

NS: non significant.

The range in NH₃-N in the rumen fluid was from 146.33 to 254.00 and 136.67 to 297.67 mg/L before and after feeding, respectively. NH₃-N in rumen liquor gradually increased (P<0.05) with increasing levels of Moringa foliage in the diets.

The optimum concentration of rumen NH₃-N for efficient digestion has been estimated at 150 to 200 mg/L (Krebs and Leng, 1984; Preston, 1986). The protozoa number was not significantly (P>0.05) different among the dietary treatments before feeding, while the number of protozoa was significantly (P<0.05) higher in the T₅, T₄ and T₃ diets compared to T₁ and T₂ diets after feeding. However, there was not significant (P>0.05) difference in protozoa number between the T₃ and T₄ diets.

It has been reported that unsaturated C₁₈ fatty acids are toxic to rumen ciliate protozoa (Newbold and Chaberalain, 1988). Moringa leaves are rich in unsaturated C₁₈ fatty acids (Sánchez-Machado *et al.* 2010; Moyo *et al.* 2011) and hence could be responsible for the reduced protozoa numbers in the supplemented groups.

CONCLUSION

Moringa inclusion at all levels increased nutrient intake, improved digestibility and nitrogen utilization with the highest values being observed with the sole Moringa foliage diet. Average body weight gain also increased with increasing levels of Moringa foliage. The highest performances in terms of feed intake, nutrient digestion, nitrogen utilization and bodyweight gain was obtained from the sole Moringa supplemented goat. It can be concluded that Moringa foliage could be replaced satisfactorily with up to 100% inclusion level.

ACKNOWLEDGEMENT

The authors would like to thank the Director General of Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh for permission to conduct the experiment at the BLRI Goat Farm, at Savar, Dhaka, Bangladesh.

REFERENCES

- Alayon J.A., Ramirez-Aviles L. and Ku-Vera J.C. (1998). Intake, rumen digestion, digestibility and microbial nitrogen supply in sheep fed *Cynodon nlemfuensis* supplemented with *Gliricidia sepium*. *Agrofor. Syst.* **41**, 115-126.
- AOAC. (2000). Official Methods of Analysis. 17th ed. Association of Official Analytical Chemists, Arlington, VA.
- Aregheore E. (2002). Intake and digestibility of *Moringa oleifera* batiki grass mixture by growing goats. *Small Rumin. Res.* **46**, 23-28.
- Asaolu V.O., Odeyinka S.M., Akinbamijo O.O. and Sodeinde F.G. (2009a). Feed intake, nutrient digestibility and nitrogen utilization of graded levels of Moringa and Bamboo leaves by West African Dwarf Goats. *Bull. Anim. Health Prod. African.* **57**, 361-368.
- Asaolu V.O., Odeyinka S.M., Akinbamijo O.O., Babayemi O.J. and Hoffmann E. (2009b). Preliminary evaluation of *Moringa oleifera* and *Oxytenanthera abyssinica* (bamboo) leaves as feed supplements for ruminants. *Bull. Anim. Health Prod. African.* **57**, 349-360.
- Asaolu V.O., Odeyinka S.M., Akinbamijoand O.O. and Sodeinde F.G. (2010). Effect of Moringa and bamboo leaves on groundnut hay utilization by West African Dwarf goats. *Livest. Res. Rural Dev.* Available at: <http://www.lrrd.org/lrrd22/1/asao22012.htm>.
- Asaolu V., Binuomote R., Akinlade J., Aderinola O. and Oyelami O. (2012). Intake and growth performance of west african dwarf goats fed *Moringa oleifera*, *Gliricidia sepium* and *Leucaena leucocephala* dried leaves as supplements to Cassava Peels. *J. Biol. Agric. Health Care.* **2**, 76-88.
- Aye P.A. and Adegum M.K. (2013). Chemical Composition and some functional properties of Moringa, Leucaena and Gliricidia leaf meals. *Agric. Biol. J. N. Am.* **4**, 71-77.
- Benninson J.J. and Paterson R.T. (2003). Use of Trees by Livestock: *Gliricidia*. Natural Resource Institute, Chatham, UK.
- Brooker J.D., Lum D.K., Miller S., Skene I. and O' Donovan L. (1995). Rumen microorganisms as providers of high quality protein. *Livest. Res. for Rural Dev.* Available at: <http://www.lrrd.org/lrrd6/3/1.htm>.
- Dehority B.A. (1984). Evaluation of subsampling and fixation procedures used for counting rumen protozoa. *Appl. Environ. Microbiol.* **48**, 182-185.
- Dzowela H.B., Hove L., Maasdop B.V. and Mafongoya P.L. (1997). Recent work on the establishment, production and utilization of multipurpose trees as a feed resource in Zimbabwe. *Anim. Feed Sci. Technol.* **69**, 1-15.
- Fadiyimu A.A., Alokun J.A. and Fajemisin A.N. (2010). Digestibility, nitrogen balance and haematological profile of West African dwarf sheep fed dietary levels of *Moringa oleifera* as supplement to *Panicum maximum*. *J. Am. Sci.* **6**, 634-643.
- Gebregiorgis F., Negesse T. and Nurfeta A. (2012). Feed intake and utilization in sheep fed graded levels of dried Moringa (*Moringa stenopetala*) leaf as a supplement to Rhodes grass hay. *Trop. Anim. Health Prod.* **44**, 511-517.
- Kahindi R.K., Abdulrazak S.A. and Muinga R.W. (2007). Effect of supplementing Napier grass (*Pennisetum purpureum*) with Madras thorn (*Pithecellobium dulce*) on intake, digestibility and live weight gains of growing goats. *Small Rumin. Res.* **69**, 83-87.
- Kakengi A.M.V., Shem M.N., Sarwatt S.V. and Fujihara T. (2005). Can Moringa oleifera Be Used as a Protein Supplement for Ruminants? *Asian-Australas J. Anim. Sci.* **18**, 42-47.
- Karachi M. and Zengo M. (1997). Legume forages from pigeon pea, Leucaena and Sesbania as supplements to natural pastures for goat production in western Tanzania. *Agrofor. Syst.* **39**, 13-21.

- Krebs G. and Leng R.A. (1984). The effect of supplementation with molasses/urea blocks on ruminal digestion. *Anim. Prod. Australian*. **15**, 704.
- Makkar H.P.S. (2012). Feed and Fodder challenges for Asia and the Pacific. In Asian Livestock challenges, opportunities and response. Pp. 82-97 in Proc. Int. Pol. Forum. Bangkok, Thailand.
- Manaye T., Tolera A. and Zewdu T. (2009). Feed intake, digestibility and body weight gain of sheep fed Napier grass mixed with different level of *Sesbania Sesban*. *Livest. Sci.* **122**, 24-29.
- Manh L.H., Dung N.N.X. and Xuan V.T. (2005). Introduction and evaluation of *Moringa oleifera* for biomass production and as feed for goats in the Mekong Delta. *Livest. Res. Rural Dev.* Available at: <http://www.lrrd.org/lrrd17/9/manh17104.htm>.
- McDonald M.W., Maslin B.R., Thompson L.A.J. and Hamilton-Brown S. (1998). Edible Wattle Seeds of Southern Australia: A Review of Species Used in Semi-Arid Regions. CSIRO Publishing, Australia.
- Meissner H.H., Zacharias P.J.K. and Reagain P.J. (2000). Forage quality (feed value). Pp. 66-88 in Pasture Management in South Africa. N.M. Tainton, Ed. University of Natal Press, Pietermaritzburg, KwaZulu-Natal.
- Mendieta-Aracia B., Spörndly R., Sánchez R.N. and Spörndly E. (2011). *Moringa (Moringa oleifera)* leaf meal as a source of protein in locally produced concentrates for dairy cows fed low protein diets in tropical areas. *Livest. Sci.* **137**, 10-17.
- Moyo B., Masika P.J., Hugo A. and Muchenje V. (2011). Nutritional characterization of *Moringa (Moringa oleifera)* leaves. *African J. Biotechnol.* **10**, 12925-12933.
- Moyo B., Patrick J.M. and Muchenje V. (2012a). Effect of supplementing crossbred Xhosa lop-eared goat catrates with *Moringa oleifera* leaves on growth performance, carcass and non-carcass characteristics. *Trop. Anim. Health Prod.* **44**, 801-809.
- Mtenga L.A. and Shoo R. (1990). Growth rate, feed intake and feed utilization of Small East African goats supplemented with *Leucaena leucocephala*. *Small Rumin. Res.* **3**, 9-18.
- Ndemanisho E.E., Kimoro B.N., Mtengeti E.J. and Muhikambe V.R.M. (2007). *In vivo* digestibility and performance of growing goats fed maize stover supplemented with browse leaf meals and cotton seed cake based concentrates. *Livest. Res. Rural Dev.* Available at: <http://www.lrrd.org/lrrd19/8/ndem19105.htm>.
- Newbold C.J. and Chaberlain D.G. (1988). Lipids as rumen de-faunating agents. *Proc. Nutr. Soc.* **47**, 154.
- NRC. (1985). Ruminant Nitrogen Usage. National Academy Press, Washington, DC, USA.
- Ogbe A.O. and Affiku J.P. (2011). Proximate study, mineral and ant-nutrient composition of *Moringa oleifera* leaves harvested from Lafia, Nigeria: potential benefits in poultry nutrition and health. *J. Microb. Biotechnol. Food Sci.* **1**, 296-308.
- Oni A., Arigbede O.M., Oni O.O., Onwuka C.F.I., Anele U.Y., Oduguwa B.O. and Yusuf K.O. (2010). Effect of feeding levels (*Manihot esculenta*) based concentrates with *Panicum maximum* basal on the performance of growing west African dwarf goats. *Livest. Sci.* **129**, 24-30.
- Orden E.A., Abdulrazak S.A., Cruz E.M., Orden M.E., Ichinohe T. and Fujihara T. (2000). *Leucaena leucocephala* and *Gliricidia sepium* supplementation in sheep fed with ammonia treated rice straw: effect on intake, digestibility, microbial protein yield and live-weight changes. *Asian-Australas J. Anim. Sci.* **13**, 1659-1666.
- Ørskov E.R. and Ryle M. (1990). Energy Nutrition in Ruminants. Elsevier Science Publishers Ltd., Essex, UK.
- Patra A.K. (2009). A meta-analysis on effects of supplementing low quality roughages with foliages from browses and tree fodders on intake and growth performance in sheep. *Livest. Sci.* **121**, 239-249.
- Preston T.R. (1986). Better Utilization of Crop Residues and by-Products in Animal Feeding. Research Guidelines 2. A practical manual for research worker. FAO Animal Production and Health Paper. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy.
- Sánchez R.N., Ledin S. and Ledin I. (2006a). Biomass production and chemical composition of *Moringa oleifera* under different regimes in Nicaragua. *Agrofor. Syst.* **66**, 231-242.
- Sánchez R.N., Spörndly E. and Ledin I. (2006b). Effect of feeding different levels of foliage of *Moringa oleifera* to creole dairy cows on intake, digestibility, milk production and composition. *Livest. Sci.* **101**, 24-31.
- Sánchez-Machado D.I., Nunez-Gastelum J.A., Reyes-Moreno C., Ramirez-Wong B. and Lopez-Cervantes J. (2010). Nutritional quality of edible parts of *Moringa oleifera*. *Food Anal. Meth.* **3**, 175-180.
- SAS Institute. (2007). SAS[®]/STAT Software, Release 9.2. SAS Institute, Inc., Cary, NC, USA.
- Sreelatha S. and Padma P.R. (2009). Antioxidant activity and total phenolic content of *Moringa oleifera* leaves in two stages of maturity. *Plant Foods Hum. Nutr.* **64**, 303-311.
- Van Soest P.J., Robertson J.B. and Lewis B.A. (1991). Methods for dietary fiber, neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **74**, 3583-3597.
- Van Soest P.J. (1994). Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca, New York.
- Whitman P.C. (1980). Tropical Pasture Science. Oxford University Press, New York.
- Yang R.Y., Chang L.C., Hsu J.C., Weng B.B.C., Palada M.C., Chadha M.I. and Levasseur V. (2006). Nutritional and functional properties of *Moringa* leaves from germplasm to plant, to food, to health. Pp. 1-8 in Proc. *Moringa* and other high nutritious plant resources: strategies, standards and markets for better impact on nutrition in Africa. Accra, Ghana.