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

Research Article

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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*); T_1 (100% Moringa foliage); T_2 (75% Moringa foliage+25% napier grass); T_3 (50% Moringa foliage+50% napier grass); T_4 (25% Moringa foliage+75% napier grass) and T_5 (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 deficient 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 randomely 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 m^2 (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:

T_1= 100% Moringa foliage
T_2 = 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 faces 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 NH_3-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 Sànchez *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 Sànchez *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 T_1 diet than T_2, T_3 and T_4 or T_5 diet.

However, there were no significant (P>0.05) differences in intake of T_2, T_3, T_4 and T_5 diets. Dry matter intake (DMI) as percent live weight and DMI ($g^{-1}W^{0.75}$) 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 T_2 and T_3 diets, and between the T_3 and T_4 diets. The lowest CP intake was observed in the T_5 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 (T_1) 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 T_1 diet than in T_2, T_3, T_4 and T_5 diets. However, there were no significant (P>0.05) differences among the diets T_2, T_3 and T_4. The lowest FCR was observed in the T_5 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 T_1 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	$6.70^b±0.43$	$7.41^b±0.80$	$8.23^b±0.89$	$8.56^b±0.89$	$22.06^a±1.84$	*

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 T_1 diet compared to the other experimental diets. However, there were no significant (P>0.05) differences among the T_2, T_3 and T_4 mixture diets. The CP digestibility was significantly (P<0.05) lower in the T_5 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 T_1 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 T_1 and T_2 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^{-1}$$animal^{-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 T_3, T_4 and T_5 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 T_4 diet to T_1 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 T_5 (control) diet.

Nitrogen retention values were significantly (P<0.05) higher in T_1 than T_2, T_3, T_4 and T_5 diets while there were no significant (P>0.05) differences among the two diets combination T_3 and T_4. 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 T_5 diet than in the T_2, T_3, T_4 and T_5 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 NH_3-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. NH_3-N in rumen liquor gradually increased (P<0.05) with increasing levels of Moringa foliage in the diets.

The optimum concentration of rumen NH_3-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 T_5, T_4 and T_3 diets compared to T_1 and T_2 diets after feeding. However, there was not significant (P>0.05) difference in protozoa number between the T_3 and T_4 diets.

It has been reported that unsaturated C_{18} fatty acids are toxic to rumen ciliate protozoa (Newbold and Chaberlain, 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.

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