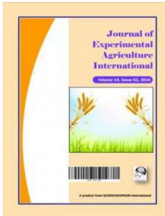

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Effect of Replacement of Conventional Concentrate in a Rice Straw Diet by Moringa Foliage on Lamb Production Performances

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Authors' contributions

This work was carried out in collaboration between all authors. Author NS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MRHR conducted the field research trail and managed the literature searches. Authors SMJH and SA managed the research inputs. Authors ME and MAIT supported with research facilities and funding. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this study was to examine the effect of replacement of conventional concentrate mixture with *Moringa oleifera* on growth performance and carcass characteristics in growing lamb.
Study Design: The design of the experiment was a completely randomized design (CRD) with five treatments and each treatment consisted of six lambs of 3 to 6 months old.
Place and Duration of Study: This study was conducted at the Sheep Farm of Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh, between July 2015 and June 2016.
Methodology: Thirty growing lambs aged about 4.5 months (9.73 ± 1.52 kg) were randomly allotted to five treatments with varying moringa (M) and concentrates (C): 100M, 75M:25C, 50M:50C and 75C:25M and 100C. Rice straw was provided at 30 percent of the total ration.
Results: Average daily gain (ADG) and Feed conversion ratio (FCR) were not significantly (P>0.05) different among treatments. Similarly, no significant differences were observed in slaughter weight,

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warm carcass weights and dressing percentage. The percentages of lean, and lean:fat ratio were significantly higher (P<0.01) for 100M and 75M:25C diet than 50M:50C, 25M:75C and 100M diets. Conversely, carcass fat percentage of warm carcass was significantly (P<0.001) increased with increasing level of concentrate in the diet.

Conclusion: It is recommended that replacing moringa foliage at 75 and100% with conventional concentrate could be used as a cheap protein supplement in rice straw based diets for lamb production.

Keywords: Moringa oleifera; replacement; concentrate; growth; carcass characteristics; lamb.

1. INTRODUCTION

In developing countries, feeding of ruminant animal depend on crop residues or agro-industrial by-product, poor quality hay and natural pasture. However, crop residues, hay and natural pasture are characterized by high fiber content and low protein, energy, mineral and vitamin contents which cannot meet even the maintenance requirements of animals. As a result, the digestibility and intake of these feeds are low which results in poor performances. Supplementing concentrates to low-quality roughages is known to improve intake and digestibility of roughages [1]. Conventional feed ingredients such as cereals, cereal by-product, oil cakes and soybean meal supplementation to low-quality feeds is exorbitant by smallholder farmers in addition to scarcity and its use as human food and other non-ruminant and poultry feed [1] united with a deficit of animal protein intake especially in developing countries [2]. Therefore, there is a need to look for concentrate sources that farmers could get from their own farm with minimum cost. One potential way for increasing the availability of feeds for smallholder farmers could be through the use of fodder trees.

One of such fodder trees is Shajna (*Moringa oleifera*) whose leaves and soft branches are an important fodder and serves as valuable source of feed for farm animals [3,4,5,6]. *Moringa oleifera* is a relatively drought-resistant plant, which can thrive in a harsh environment in tropical region of the world [7]. *Moringa oleifera* Lamarck, a small non-leguminous multipurpose tree native to the sub-Himalayan tract of India, Pakistan, Bangladesh and Afganistan [8], grows fast and rich in protein containing negligible amounts of anti-nutritive compounds [9,10,11]. The dry and fresh leaves or leaves with woody stem could be used as a feed supplement to ruminant livestock [5,12,13]. Moringa has a potential to produce high biomass ranging from 13.3 to 40.00 DM t ha –1y–1 [6,12,14]. Yield of DM could be affected by cutting interval, plant density, cutting height, age of plant and soil topography. The fresh Moringa leaves are accessible during the most part of the year and could be a good source of feed mainly during the dry season as a protein and energy supplement for ruminant livestock [15,16]. Dried *Moringa oleifera* leaves or leaves with succulent branch can be stored for longer periods without deterioration in nutritive value [5]. In that case, Moringa leaves with branches can be harvested during the periods of high yields and afterward used for feeding during the dry season when the quality and quantity of feed is scarce.

Moring leaf or Moring foliage is an excellent source of protein ranging from 21.0-26.0% [6,14]. The replacement of conventional ingredients by dried tree leaves will make the concentrate feed cheaper than the commercial concentrates [17]. Moringa leaf meal having 18.26% CP is a potentially completely substitute for conventional concentrate for feeding growing goats [18]. Moringa can be fed along with low quality roughages to improve their utilization and to increase growth rates [3,4,18,19]. However, information on feeding value of dried Moringa leaves in relation to sheep performance is scanty especially as a substitute to conventional concentrate supplement. Therefore, the objective of the study was to assess the effect of substitution of conventional concentrate mixture with dried Moring leaves with twigs on feed intake, digestibility, nitrogen utilization, weight gain and carcass characteristics in sheep.

2. MATERIALS AND METHODS

2.1 Location

This study was conducted at the Sheep Farm of Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh.

2.2 Experimental Animals

A total of thirty growing male sheep selected from the herd at the Sheep Farm of BLRI were used in this study. They were 3-6 months of age and had an average body weight of 9.73 ± 1.52 kg (mean ± standard error). All sheep were treated with antihelminthes (Endex, Novartis, India limited) before the commencement of the experiment to ensure the sheep were free of intestinal worm. The sheep were kept in individual pens measuring 1.25 m^2 (1.25 m × 1.0 m) and provided individual feeders and water buckets. The lambs were allowed 14 days of adjustment period during which they were gradually introduced to the experimental diets.

2.3 Experimental Diet

Fresh Moringa foliages were collected from farmers on contact basis from Savar area near to experimental site. The foliages were harvested from available trees regardless of tree age and transported into farm. The collected moringa foliage consisted of leaves and twigs. The hard woody rachis was removed from the foliage to allow the intake of biomass having leaf to stem ratio of 2:1. The whole foliage was chopped into size of 1.0 to 1.5 inch and sun dried on thick plastic sheets for three days, then bagged and stored until further use. Rice straw was collected from central feed store of BLRI. Rice straw was chopped by scythe into the size of 2 to 2.5 inch for ease of feeding. Subsequently chopping rice straw was mixed with 2.5% molasses prior to feed to animals.

The conventional concentrate ingredients (broken maize, soybean meal, wheat bran, vitamin mineral premix, DCP and salt) were procured from a local feed mill, and the dietary mixtures were prepared weekly for feeding the sheep. The composition of conventional concentrate mixture, moringa foliage and straw are given in Table 1. All diets were considered to be iso-caloric and iso-nitrogenous (Table 2) and formulated to meet the nutritional requirements of the growing lamb adjusted according to their live weight [20]. The total feed was offered at 4.0% live weight on dry matter basis of each animal. Rice straw was offered to each animal thirty percent of total diet with 15% extra for adlibitum feeding. Moringa foliage was substituted at 0.0, 17.5, 35.0, 52.5, and 70.0% with conventional concentrate mixture in remaining diet. The stipulated amount of rice straw, concentrate mixture and dry moringa foliage for each lamb were weighed once a day. They are divided in to two parts. One part was offered at 08:00, another part was given at 15:00. In case of concentrate and moringa foliage combination diets (52.5M: 17.5C, 35.0M: 35.0C and 17.5M: 52.5C), concentrate was offered prior to moringa foliage. The straw was offered after concentrate and moringa foliage feeding in separate feeder.

Table 1. Ingredient (%) of concentrate and chemical composition of concentrate mixture, moringa foliage and paddy straw (%DM)

Ingredients	Concentrate mixture	Roughage	
		Moringa foliage	Straw
Broken maize	42.0	-	-
Soybean meal	38.0	-	-
Wheat bran	17.0	-	-
Vitamin mineral premix	1.0	1.0	-
Dicalcium phosphate (DCP)	1.0	1.0	-
Salt	1.0	1.0	-
Moringa foliage	-	97.0	-
Paddy straw	-	-	97.5
Molasses	-	-	2.5
Total	100.0		
Chemical Composition, % DM			
Dry matter	88.03	80.17	81.58
Crude protein	22.77	23.11	4.01
Organic matter	93.57	88.65	86.79
Ash	6.43	11.35	13.21
Ether extract	4.48	4.26	2.35
Acid detergent Fiber	11.56	32.72	68.35
Neutral detergent fiber	28.76	45.15	91.32
Metabolizable Energy (MJ/kgDM)	11.31	11.36	5.26

Table 2. Chemical composition of five experimental diet mixtures (% in DM)

Chemical composition	Experimental diet				
	100M1	75M:25C2	50M:50C3	25M:75C4	100C5
DM	80.59	81.97	83.34	84.72	90.00
CP	13.95	14.22	14.48	14.74	15.00
ADF	35.09	32.28	29.47	26.66	23.85
NDF	47.68	45.78	43.87	41.97	34.85
OM	77.09	88.30	88.94	89.59	90.23
Ash	9.60	9.00	8.40	7.80	7.20
EE	2.97	3.15	3.15	3.24	3.34
ME(MJ/kgDM)	9.51	9.53	9.55	9.57	9.17

M= Moringa foliage; C=Concentrate; DM= Dry Matter; CP = Crude Protein; ADF= Acid Detergent Fiber;NDF= Neutral detergent fiber;OM=Organic Matter; EE= Ether extract; ME= Metabolizable Energy (MJ/kg DM); Ca= Calcium; P= phosphorus. 1= (straw-30%: moringa foliage -70%: concentrate-0%); 2= (straw-30%: moringa foliage -52.5%: concentrate-17.5%); 3= (straw-30%: moringa foliage -35%: concentrate-35%); 4= (straw-30%: moringa foliage -17.5%: concentrate-52.5%); 5=(straw-30%: moringa foliage -0%: concentrate-70%).Chemcal composition is inclusive 30% straw for all diets

The ADF and NDF content of the five experimental diets was 35.09, 32.28, 29.47, 26.66 and 23.80%; and 47.68, 45.78, 43.87, 41.97 and 34.85%, respectively for T1, T2, T3, T4 & T5 diet.

2.4 Experimental Procedure and Design

A total of thirty 3 to 6 months old male sheep were allocated into five groups with six animals per treatment. The design of the experiment was a completely randomized design (CRD) with five treatments and each treatment consisted of six lambs. The five experimental treatments were:

100M= 30% rice straw + 70 % moringa foliage + 0.0% concentrate mixture
75M:25C= 30% rice straw+ 52.5% moringa foliage + 17.5% concentrate mixture
50M:50C = 30% rice straw+ 35.0 % moringa foliage + 35.0 % concentrate mixture
25M:75C = 30% rice straw+ 17.5% moringa foliage + 52.5 % concentrate mixture
100C= 30% rice straw + 70 % concentrate mixture + 0.0% moringa

Feed was offered twice daily at 4.0% BW on dry matter basis. The feed was given twice daily at 08:00 and 15:00 h. The feeders and water buckets were cleaned daily before fresh feed and water were offered. Feed intake for each day during the collection period was determined by subtracting the mass of rice straw moringa foliage and concentrate refusals from the offered rice straw, moringa foliage and concentrate. The sheep were allowed 14 days of adaptation to experimental diet and pens. Quantities of feeds offered and refused were measured daily during the 91 days of experimental period to compute feed intake.

2.5 Live Weight Recording

Before morning feeding, all animals were weighed at the commencement of the experiment and subsequently every week. 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. The feed conversion ratio (FCR) was calculated as a proportion of live weight gain to feed intake of whole experimental period. Feed cost per kg gain was calculated as a ratio of cost of total feed consumed to total weight gain. The duration of the feeding trial was 91 days including 14 days adaptation period and 10 days collection period.

2.6 Digestibility and Nitrogen Balance Studies

These were carried out immediately after the growth trial; four lambs from each of the dietary group were randomly selected for determining digestibility of the feeds and nutrients using the total collection method during the last ten days of the trial. Metabolic trays were placed under individual pens for the collection of feces and urine separately. The animals were continued to feed the experimental diets. They were allowed 3 days to adjust with the additional management system prior to start of the total collection of urine and feces for 7 days. The feces of each of the animals were collected, weighed, and sampled (10%), and kept in a freezer (-20℃) for further analysis. The total urine of each of the animal was weighed, sampled (10%), and kept in plastic containers containing 100 ml 6N H_2SO_4 to prevent ammonia loss. The containers were kept in a freezer. The samples of feed and refusals of the total collection period were mixed thoroughly, and a composite sample for each animal was taken for analysis of the chemical components. Dry matter and crude protein was determined using the fresh sample and the other chemical components (ether extract, ash, neutral detergent fiber, acid detergent fiber and fatty acid profiles) were analyzed using dried and milled sample.

2.7 Slaughter Procedure and Carcass Sampling

At the end of the growth and digestibility trial, four sheep were randomly selected from each of the treatments for slaughtering. All the twenty animals selected were fasted for twenty four hours and slaughtered according to the 'Halal' method. The fasted live weights of the animals were recorded before slaughtering, and individual hot carcass weights were recorded immediately after evisceration. Non-carcass components (skin, head, feet, lung, heart, liver, spleen, kidneys, kidney fat, and gastro-intestinal tract fat) were removed and weighed individually. The stomach (rumen, reticulum, omasum and abomasum) and post-ruminal tract (small intestine, large intestine and caecum) were removed and weighed separately. The digesta content of the stomach and post-ruminal tract were removed, and the empty tract was washed and weighed. Dressing percentage was calculated as hot carcass weight relative to fasted body weight. The carcasses were divided into equal halves along the midline using a carcass saw. The left half was used for the determination of chemical composition, while the right half was assigned for determining carcass composition (lean, bone and fat) and carcass cut. The sample was taken from Longissimus dorsi (LD) area for proximate analysis.

2.8 Carcass Cuts

The right side of each carcass was weighed and then separated into eight primal cuts according to AUS-MEAT specifications: neck, shoulder, rack, loin, foreshank, flank, leg champ and leg. The cuts were weighed and expressed as percentage of the total hot carcass. Each cut was dissected in to components of lean, bone and fat.

2.9 Chemical Analysis

Samples of concentrates, moringa forage and straw, feed refusal and faces in each animal during the collection period were taken separately and thoroughly mixed together. Faecal samples for chemical analysis were dried at 65℃ for 48 hours. All dried mixed samples (Feed and refusal) were ground through 1 mm sieve. Sub-sample was taken for subsequent chemical analysis. Dry matter content of the samples was determined by drying the samples at 105℃ overnight. The N content of feed, faeces and urine was determined using a Kjeldahl method [21] while ether extract (EE) was determined in petroleum ether using a Soxtec Auto Analyzer (Tecator) [21]. The ash content was determined by ashing the samples in a muffle furnace at 550℃ for 5 h and the Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the method of Van Soest et al. [22]. ME (Metabolizable energy) (MJ kg DM) was calculated according to the following formula [23]:

ME in straw = 0.36XGE (Gross Energy)
ME in high quality pasture or concentrate= 0.66XGE

2.10 Statistical Analysis

The collected data on feed intake, digestibility, nitrogen utilization, weight gain and carcass characteristics were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of the Statistical Analysis System (SAS) computer package (2001). Significant differences among means were separated using the Duncan's multiple Range Test (DMRT) at 5% level. The model used for the data analysis was $Y_{ij} = \mu + \alpha_i + e_{ij}$; wherr Y_{ij}= is the response variable (feed intake, digestibility, nitrogen utilization, weight gain and carcass characteristics); μ is overall mean; α_i is the treatment effect; e_{ij} is random error.

3. RESULTS AND DISCUSSION

3.1 Chemical Composition of the Experimental Diet

The nutritional composition of the experimental feed is depicted in Table 1. The paddy straw used in the basal diet had low CP and high fiber. The ME value (MJ kg–1 DM) of the concentrate mixture, moringa foliage and paddy straw were

11.31, 11.36 and 5.26, respectively. The nutrient compositions of the five experimental diets are presented in Table 2. The five diets containing 13.95% to 15.0% CP and 9.17 to 9.57 ME (MJ kg–1DM) were considered to be iso-nitrogenous and iso-caloric. The CP content of paddy straw used in the experiment was low (5.52%), and a feed having CP of this level fails to support the minimum microbial requirement (70–80 g CP kg–1 DM) for the efficient functioning of the rumen microbial activities. Thus, the supplementation of protein rich feed to a straw diet was essential at least for supporting the maintenance requirements of CP of the experimental lambs [24]. The CP content of moringa foliage, including leaves, soft rachis and stems used in this study was comparable to 21.35% and 22.20% reported by Sànchez and Asaolu [7,25]. But the values were lower than the values 32.0%, 27.7% and 27.4% CP of *Moringa oleifera* leaves [26,27,28].

The NDF content of the moringa foliage in the study was similar to the values reported by Kakengi et al. [29]. The ADF content of moringa foliage of the present study was similar to the findings of Sarwatt et al. [28] and Ndemanisho et al. [30]. However, both the ADF and NDF contents were higher than the values reported by Sànchez et al. [6]. These variations may be due to the differences in the stage of maturity and fraction of plant parts. A higher crude protein content in the moringa foliage (MF) may have qualified the moringa foliage (MF) as a palatable feed for goats [31] which was stated that moringa leaves are beneficial for animal health and may increase growth performances [4,11,19,32]. Moringa foliage contains several bioactive compounds such as, carotenoids, vitamins, minerals, amino acids, sterol, glycosides, alkaloids, flavonoids or phenols and they have strong antioxidant properties [8,33,34]. This suggests that moringa foliage could be used as a feed for improving growth performances and carcass characteristics of goat or sheep as well as their health status.

3.2 Feed Intake

The effect of replacement of moringa foliage with conventional concentrate on the intake of Bengal goats fed a basal diet of paddy straw is presented in (Table 3). Total DM, CP and OM intake of lamb were significantly (P<0.05) higher in T5 compare to T4, T3, T2 & TI. The ADF and NDF intake of lambs fed T1 and T2 diet was significantly (P<0.05) higher than that of the lamb fed T4 and T5 diets while there was no significance (P>0.05) difference with T3 diet, and intake was reduced significantly (P<0.05) with the decreasing of MF level in the diet. The ranges of dry matter intake (DMI) as percent of live weight and DM intake of metabolic body weight of lambs were from 3.96 to 4.11% and 85.02 to 89.84 g–W0.75 kg.

The intake of DM, CP or OM of experimental animal was the highest in T5 treatment and decreased when replace concentrate with moringa foliage which was not followed any trend with concentrate replacement (Table 3). The feed intake is a measure of appreciation, selection or extent of consumption of a diet by an animal [35]. The amount of feed intake of an animal is calculated in a certain period of time, usually expressed in a day [36]. The daily DMI of the experimental lambs indicate that the diets used in the present study were well accepted to the animals.

The CP intake trend was followed the total DMI. Positive correlations have between crude protein intake and dry matter intake [37]. The ADF and NDF intake increased with the increasing level of moringa foliage due to having higher fiber in moringa foliage. All the experimental lambs had an adequate amount of total DMI (g d–1 animal–1) and it ranged from 818.12 to 939.0 g d–1 animal–1. The total DM intake as percentage of live weights ranged from 3.96 to 4.11 (Table 3) and a similar level of intake of dry matter was recommended by NRC [20]. Expressing DMI on unit metabolic weight (g /kg0.75) basis showed that it ranged from 85.02 to 89.84 g/ kg0.75 in different diets which was similar to findings of Gebregiorgis et al. [19]. Conversely, these values were higher than those reported by Asaolu et al. [38,39].

3.3 Nutrient Utilization

The digestibility of DM, CP and OM was statistically similar (P>0.05) among the treatment diets (Table 4). The ADF digestibility was significantly higher (P<0.05) in lambs on T1 and T2 treatment than that of T3, T4 and T5 diets while there was no significant (P>0.05) among T2 and T3 and T3 and T4 diet. However ADF digestibility increased positively with increasing moringa foliage in the diet. The NDF digestibility of lambs on T1, T2, T3 & T4 treatment was significantly (P<0.05) higher than that of lambs on T5 treatment (Table 4).

Table 3. Effect of replacement moringa foliage with conventional concentrate on intake of Bengal sheep fed straw based diet

Variables	Treatments					Sign.
	T1 (100M)	T2 (75M:25C)	T3 (50M:50C)	T4 (25M:75C)	T5 (100C)	
TDMI (g/d)	818.12±12.3[b]	836.27±14.26[b]	826.0±25.0[b]	823.30±40.0[b]	939.0±27.9[a]	*
DMI (% LW)	4.0±0.11	3.96±0.03	4.09±0.04	3.99±0.07	4 .11±0.04	NS
DM (g/$W^{0.75}$kg)	85.02±1.87	86.05±0.43	86.70±1.01	86.54±0.73	89. 84±0.98	NS
CPI (g/d)	125.07±2.75[b]	124.30±3.16[b]	127.88±3.7[b]	126.3±6.88[b]	138.20±4.93[a]	*
ADFI (g/d)	341.20±7.30[a]	327.32±5.35[a]	291.21±10.59[ab]	253.72±12.82[b]	252.98±9.19[b]	*
NDFI(g/d)	424.9±9.99[a]	412.80±7.52[a]	382.28±5.71[ab]	335.78±10.03[b]	329.22±7.33[b]	*
OMI (g/d)	714.24±16.81[b]	723.48±12.82[b]	742.88±22.38[b]	748.20±36.18[b]	854.90±31.92[a]	*

**Means within rows with different superscripts are significantly different at 5% level.*
TDMI= Total Dry Matter Intake; DMI= Dry Matter Intake; %LW= % Live Weight; DM= Dry Matter; CPI= Crude Protein Intake; ADFI= Acid Detergent Fibre Intake; NDFI= Neutral Detergent Fibre Intake; OMI= Organic Matter Intake

The DM, CP and OM digestibility of the experimental diets having a constant level of paddy straw was not significant (P>0.05). This indicates that the supplementary feed irrespective of their combination of MF or moringa-concentrate diets had also a similar level of digestibility of the nutrients (DM, CP and OM). The digestibility of DM, CP and OM of 30% paddy straw and 70% MF was 75.30%, 81.20% and 78.74%, respectively, and that of 30% paddy straw and 70% conventional concentrate was 76.49%, 79.20% and 78.63%, respectively. These results suggest that digestibility value of moringa foliage diet was similar to that of the conventional concentrate. However, the ADF and NDF digestibility was found to be the highest in the T1 diet and decrease with the increase of conventional concentrate level in the diet, it differed significantly (P<0.05) with that of the T5 diet. The ADF and NDF digestibility is positively correlated with ADF and NDF intake in the study. The digestibility of CP in 70% supplementary feed of 100% MF based on 30% paddy straw was almost similar (83.87%) to the finding of Asaolu et al. [38] while higher CP digestibility (89.35) was obtained in 100% sole moringa in West African Dwarf goats [39]. Fadiyimu et al. [40] obtained 84.96% CP digestibility when fed 100% fresh moringa leaf to growing sheep. The present values of DM and OM digestibility were comparable with the ranges of 73 to 74% for DM and 76 to 77% for OM as reported by Mendieta-Araica et al. [11]. Moreover, DM digestibility ranging from 70 to 75%, when moringa leaf meal was replaced with cotton seed cake as the protein source in concentrates for growing sheep [27].

The nitrogen balance of the lambs is shown in Table 5. The intake of nitrogen, excretion of faecal or urinary nitrogen, or the nitrogen retention of the lambs fed different diets was significantly (P<0.05) higher in animals on T1 treatment compared to other treatments while nitrogen balance was not significant (P>0.05) difference among the treatments.

The diets were iso-nitrogenous, the digestibility of DM; digestibility or retention of nitrogen or CP did not vary significantly. A positive nitrogen retention in the lamb of different diets showed that their protein requirements for maintenance and growth were sufficiently met by the diets. Thus, MF may effectively replace CP of a conventional concentrate supplemented to a straw diet. High nitrogen retention could be due to the presence of higher levels of crude protein in the experimental diets [41].

Table 4. Effect of replacement moringa foliage with conventional concentrate on digestibility of Bengal sheep fed straw based diet

Digestibility (%)	Treatments					Sign.
	100M	75M:25C	50M:50C	25M:75C	100C	
DM	75.30±0.54	76.57±1.57	77.74±1.49	79.98±2.38	76.49±1.98	NS
CP	81.21±0.49	81.74±1.02	81.28±1.28	79.28±1.06	79.20±2.48	NS
ADF	83.98±0.69^{a}	79.48±1.87^{ab}	77.78±0.97^{bc}	72.64±1.26^{c}	64.64±3.06^{d}	*
NDF	77.89±1.40^{a}	77.51±1.58^{a}	77.58±1.17^{a}	74.41±2.08^{a}	68.51±2.38^{b}	*
OM	78.74±0.68	78.91±1.37	80.07±0.65	79.55±1.30	78.63±1.73	NS

^{a,b,c} Means within a raw with different superscripts are significantly different at P<0.05. DM= Dry matter, CP= Crude protein, ADF= Acid detergent fiber, NDF= Neutral detergent fiber and OM= Organic matter ; 1= (straw-30%: moringa foliage -70%: concentrate-0%); 2= (straw-30%: moringa foliage -52.5%: concentrate-17.5%); 3= (straw-30%: moringa foliage -35%: concentrate-35%); 4= (straw-30%: moringa foliage -17.5%: concentrate-52.5%); 5=(straw-30%: moringa foliage -0%: concentrate-70%)

Table 5. Effect of replacement moringa foliage with conventional concentrate on nitrogen balance (g) of Bengal sheep fed straw based diet

Variables	Treatments					Sign.
	100M	75M:25C	50M:50C	25M:75C	100C	
N-intake	20.01±0.88^{b}	19.90±0.51^{b}	20.46±0.60^{b}	20.21±1.10^{b}	22.11±0.79^{a}	*
FN-out go	3.80±0.27^{b}	4.51±0.28^{b}	4.56±0.33^{b}	4.84±0.42^{b}	5.92±0.52^{a}	*
UN-out go	4.50±0.18^{b}	4.26±0.28^{b}	4.3±0.33^{b}	4.28±0.42^{b}	5.37±0.52^{a}	*
Total N out go	8.30±0.38^{b}	8.77±0.35^{b}	8.86±0.36^{b}	9.12±0.43^{b}	11.28±0.80^{a}	*
N-balance	10.15±0.31	10.48±0.60	11.52±0.49	10.97±0.87	11.46±0.78	NS

**Means within rows with different superscripts are significantly different at 5% level*

The study showed that the efficiency of protein utilization of moringa foliage on a paddy straw based diet was comparable to the conventional concentrate mixture. The nitrogen retention value (10.15 g animal–1 d–1) in the 100M diet of the study was higher than that was reported by Asaolu et al. [39]. The positive nitrogen retention indicates that replacing a conventional concentrate with moringa foliage may avoid competition for the latter by the ruminant and the monogastric animals.

3.4 Growth Performances

The body weight and daily gains of the sheep fed with the five dietary treatments are presented in Table 6. The mean initial and final live weights of the lambs among the diets were not significantly different (P>0.05). The average daily gains of goats was not affected significantly (P>0.05) with substitution of moringa foliage. No definite trend was found in live weight gain or FCR in response to graded level of moringa foliage in diets (Table 6). The average daily gain (ADG) of animals fed T5 were higher (P>0.05) than those fed T4,T3, T2 & T1 diet.

The growth performance of the lamb fed five different diets containing a variable level of MF did not significantly (P>0.05) affect. The experimental diets containing 30% paddy straw as a basal feed and 70% supplementary feed of 100% MF and 0% mixed concentrate (T1), 75% MF and 25% mixed concentrate (T2), 50% MF and 50% mixed concentrate (T3), 25% MF and 75% mixed concentrate (T4) or 100% mixed concentrate (T5) resulted in a non-significant variation in daily live weight gain (118.17, 124.3, 129.83, 129.83 and 134.33 g, respectively). It may be stated that moringa foliage may replace a mixed conventional concentrate feed without affecting daily live gain or FCR of the Bengal lamb fed a paddy straw diet. The lamb fed MF or moringa-concentrate diets had apparently no health problems.

3.5 Carcass Composition

The carcass characteristics and primal cut percent of warm carcass of the experimental lambs fed with different replacement levels of moringa foliage are presented in Table 7. Slaughter weight and hot carcass weights did not differ significantly (P>0.05) among the treatments. Similarly, there were no variations (P>0.05) in dressing percentage of the carcasses. The range of values of dressing percentage of the Bengal lambs in the current study was from 51.27 to 53.41%. The warm carcass weight and dressing percentage depend on the final live weight at slaughter [42] and were consequently affected by treatments. A variable level of concentrates and moringa foliage in the diets used in the present study did not affect the hot carcass weights or dressing percentage. The increasing level of MF in the diet significantly decreased (P<0.01) the percentage waste fat or the ether extract of different muscle tissues, and increased lean to fat ratio (P<0.05) of the carcass (Table 7, Table 8 & Table 9). The percentages of lean of the hot carcass were significantly higher (P<0.01) in the lamb fed T2 and T1 diet compared to that of the other groups of animals while the percentage of lean was recorded in the lambs of T5 diet. Similarly, lean: fat and carcass: fat percentage of carcass weight was significantly (P<0.05) increased with increasing moringa foliage in the diet.

Table 6. Effect of replacement moringa foliage with conventional concentrate on live weight change of Bengal sheep fed straw based diet

Variables	Treatments					Sign
	100M (T_1)	75M:25C (T_2)	50M:50C (T_3)	25M:75C (T_4)	100C (T_5)	
ILW (kg)	9.87±0.50	10.23±0.23	10.45±0.70	10.53±0.70	10.87±0.60	NS
FLW (kg)	20.53±0.70	21.42±1.06	21.78±0.96	22.02±0.91	22.80±0.93	NS
TLWG (kg)	10.67±0.35	11.18±0.58	11.33±0.73	11.48±0.73	11.93±0.42	NS
ADG (g/d)	118.17±3.82	124.33±5.14	129.83±6.07	129.50±0.50	134.33±3.79	NS
TFI (kg)	55.69±2.48	55.22±2.12	57.04±3.34	57.20±3.05	59.89±4.04	NS
FCR	5.22±0.15	4.93±0.18	5.07±0.30	5.0±0.32	5.0±0.20	NS

**Means within rows with different superscripts are significantly different at 5% level. ILW= Initial live weight; FLW= Final live weight gain; TLWG= total live weight gain; ADG= average daily gain; TFI= total feed intake; FCR= feed conversion ratio*

Conversely, the carcass fat percentage of the warm carcass was linearly (r^2=0.92) increased with increasing concentrate feed in the diet T5, T4 and T3 diet than those fed T1 and T2 diet. The differences in bone and lean to bone ratio of the animals fed different diets were not significant (P>0.05). The presence of polyphenols in moringa foliage may have limited fat deposition in the body. It has been reported that *Moringa oleifera* leaf extract contain anti-hyperlipidemic mechanisms by inhibiting cholesterol esterase activity [43]. There is a positive correlation between of phenolic compound, flavonoids, and condensed tannin in the moringa leaf extract and the ability to inhibit α-glucosidase and α- amylase activities [44,45,46]. Tea polyphenols reduced fat deposition and acted as an anti-lipogenosis in a high fat diet fed to rats [47,48]. The proportion of lean and fat of the carcass ranged from 65.82% to 71.22% and 8.04% to 14.09% in the present study. Similarly, range of lean and fat of lamb carcass was reported by Cadavez [49] and Gavani et al. [50]. On the contrary, the increasing proportion of concentrate or energy intake increased fat deposition [31,51,52,53,54].

The percentage of primal cut of warm carcass is presented in Table 7. No significant differences were observed in primal cuts neck, shoulder, rack, loin, fore shank, leg chump and leg except the flank. Flank was significantly (P<0.05) higher in T5 and T4 dietary treatment than T1 and T2 dietary treatments. In general, different combinations of moringa foliage and concentrate dietary supplementation had no specific trend on the different primal cuts except flank.

The percent of edible and non-edible part of slaughter weights are summarized in Table 8. The dietary treatments did not significantly (P>0.05) influence the percentage of slaughter weights, and as well as edible parts such as head, four shank and plunk while empty gastro-intestinal tract and waste fat

Table 7. Effect of replacement moringa foliage with conventional concentrate on carcass composition and primal cut of Bengal lamb fed straw based diet

Variables	Treatments					Sign.
	100M (T_1)	75M:25C (T_2)	50M:50C (T_3)	25M:75C (T_4)	100C (T_5)	
SLW (kg)	20.93±0.52	21.13±0.31	20.50±0.61	20.38±1.0 2	21.15±0.43	NS
WCW (kg)	10.73±0.26	10.87±0.15	10.61±0.18	10.66±0.5 4	11.30±0.20	NS
Dressing (%)	51.27±0.58	51.43±0.56	51.84±0.91	52.34±0.49	53.41±0.40	NS
Lean (% of WC)	70.88±0.94^a	71.22±0.94^a	68.62±1.07^b	68.26±0.61^b	65.82±0.20^c	*
Bone (% of WC)	21.07±0.30	20.45±0.42	20.42±0.28	20.41±0.08	20.10±0 .09	NS
Fat(% of WC)	8.04±1.03^c	8.32±0.73^c	11.11±0.87^b	11.34±0.58^b	14.09± 0.23^a	
Lean: bone	3.37±0.06	3.49±0.11	3.36±0.09	3.35±0.04	3.28±0.01	NS
Lean: fat	9.40±1.57^a	8.82±1.02^{ab}	6.41±0.63^{bc}	6.07±0.38^{bc}	4.68±0.09^c	*
Carcass: fat	13.18±2.0^a	12.34±1.24^{ab}	9.31±0.77^{bc}	8.89±0.47^{bc}	7.11±0.12^c	*
Primal cut (% carcass weight)						
Neck	5.50±0.29	5.33±0.26	5.13±0.49	5.68±0.45	6.26±0 .23	NS
Shoulder	29.36±0.47	29.18±0.74	29.36±0.42	29.31±0. 95	29.07±0.25	NS
Rack	10.06±0.009	10.12±0.17	10.07±0.00	10.07± 0.0	10.33±0.24	NS
Loin	12.38±0.50	12.60±0.36	12.90±0.36	12.27±0.57	12 .39±0.26	NS
Fore shank	4.48±0.15	4.28±0.08	4.29±0.22	4.19±0.38	4.11±0.23	NS
Flank	6.18± 0.29^b	6.40±0.16^b	6.74±0.33^{ab}	7.32±0.14^a	7.34±0.07^a	*
Leg chump	26.67±0.36	26.09±0.36	26.42±0.80	25.91±1. 0	25.07±0.22	NS
Leg	5.39±0.28	5.54±0.27	5.36±0.23	5.27±0.02	5.45±0 .07	NS

^{a,b,c} *Means within a raw with different superscripts are significantly different at P<0.05.*
T_1= (straw-30%:moringa foliage -70%: concentrate-0%);
T_2= (straw-30%: moringa foliage 52.5%: concentrate-17.5%);
T_3= (straw-30%: moringa foliage -35%: concentrate-35%);
T_4= (straw-30%: moringa foliage-17.5%: concentrate-52.5%);
T_5= (straw-30%: moringa foliage -0%: concentrate-70%);
SLW= slaughter weight; WCW= warm carcass weight

Table 8. Effect of replacement moringa foliage with conventional concentrate on edible and non-edible part of non-carcass part of Bengal sheep fed straw based diet

Variables	Treatments					Sign.
	100M (T_1)	75M:25C (T_2)	50M:50C (T_3)	25M:75C (T_4)	100C (T_5)	
Edible part (% of slaughter weight)						
Head	7.26±0.20	7.26±0.28	7.26±0.16	7.13±0.30	7.49±0 .18	NS
Fore shank	2.19±0.04	2.40±0.08	2.23±0.09	2.32±0.09	2.35±0.11	NS
Plunk	4.51± 0.21	4.83±0.11	4.38±0.15	4.75±0.16	4.83±0.17	NS
Empty GI tract	5.88±0.33^{b}	6.36±0.37^{ab}	6.43±0.15^{ab}	6.86±0.41^{ab}	7.24±0.24^{a}	*
Waste fat	2.41±0.17^{d}	3.12±0.05^{cd}	3.76±0.30^{bc}	4.34±0.05^{b}	5.67±0.36^{a}	*
Total edible part	22.06±0.70^{c}	24.85±0.61^{b}	23.56±0.26^{b}	24.51±0.16^{b}	27.07±0.83^{a}	*
Non-edible part (% slaughter weight)						
Skin	10.82±0.15	11.15±0.36	12.09±0.47	11.99±0.37	12 .08±1.03	NS
Blood	4.10±0.04	4.10±0.06	4.50±0.20	4.56±0.12	4.30±0.24	NS
Panis+gall bladder	0.53±0.05	0.55±0.06	0.55±0.06	0.55±0.04	0.55±0.04	N S
Rumen digesta	13.70± 0.63^{ab}	13.97±0.46^{a}	12.31±0.30^{bc}	11.45±0.56^{c}	11.55±0.33^{c}	*
Total non-edible part	29.15±0.54	29.76±0.73	29.46±0.91	28.56±0.52	28.51± 1.04	NS

^{a,b,c} Means within a raw with different superscripts are significantly different at 5% level; T_1= (straw-30%: moringa foliage -70%: concentrate-0%); T_2= (straw-30%: moringa foliage -52.5%: concentrate-17.5%); T_3= (straw-30%: moringa foliage -35%: concentrate-35%); T_4= (straw-30%: moringa foliage -17.5%: concentrate-52.5%); T_5=(straw-30%: moringa foliage -0%: concentrate-70%); Plunk (Heart+kidney+lung+spleen+liver); GI= Gastro-intestinal tract

Table 9. Effect of dietary levels of moringa foliage on proximate composition in longissimus dorsi of Bengal sheep (Mean±SE; n=4)

Variables	Treatments					P-Value
	100M (T_1)	75M:25C (T_2)	50M:50C (T_3)	25M:75C (T_4)	100C (T_5)	
Moisture	74.92±0.19	75.34±0.85	74.34±0.65	73.85±0.47	73.38±0.68	1.69
Crude protein	20.62±0.46	19.45±0.50	19.93±0.54	19.61±0.25	19.62±0.46	1.05
Ether extract	1.72±0.20a	2.29±0.16b	2.45 ±0.23b	2.67±0.07b	3.88±0.18a	7.02
Ash	5.45±0.13a	5.30±0.20a	4.31 ± 0.15b	4.65± 0.16b	4.48±0.19b	9.12

^{a,b,c} Means within a raw with different superscripts are significantly different at 5% level; T1= (straw-30%: moringa foliage -70%: concentrate-0%); T2= (straw-30%: moringa foliage -52.5%: concentrate-17.5%); T3= (straw-30%: moringa foliage -35%: concentrate-35%); T4= (straw-30%:moringa foliage-17.5%:concentrate-52.5%); T5=(straw-30%: moringa foliage -0%: concentrate-70%)

was significantly (P<0.05) decreased with increasing moringa foliage in the diet (Table 8). On the hand, non edible parts such as skin, blood and (penis + gall bladder) was not significantly (P>0.05) different among the dietary treatments. However, the rumen digesta was increased (P>0.05) with the increasing levels of moringa foliage. However, breed, age, maturity stage, carcass weight or birth weight influence the distribution of fat depositions by the growing lamb [55].

4. CONCLUSION

The results of the current study show that intake, nutrients utilization and growth rate of lambs fed on the dried Moringa foliage diet was comparable to conventional concentrate diet. It can be used efficiently as an alternate for conventional concentrate or commercial concentrate in the diet of growing lambs. Moreover the cost of kg–1 weight gain is reduced with increasing moringa foliage in the diet. It is recommended that replacing moringa foliage at 75 and100% with conventional concentrate could be used as a cheap protein supplement in rice straw based diets for lamb production. The result of the study show that lambs fed Moringa foliage supplemented diets achieved a favorable growth performance and more desirable leaner carcass with higher proportion of meat and lower weight of subcutaneous fat to promote carcass characteristics after 91 days feeding trial. It can be used efficiently as an alternate for conventional concentrate or commercial concentrate in the diet of growing lambs.

ETHICAL APPROVAL

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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