Effect of Replacing Wheat Bran with Air Dried *Moringa stenopetala* Pod on Nutrient Intake, Digestibility and Growth Performances of Yearling Sheep

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Abstract

A study was conducted to assess the effect of a partial substitution of wheat bran with air-dried Moringa stenopetala pod meal (MSPM) on nutrient intake, digestibility, growth performance and nitrogen utilization. Twenty-four yearling sheep with initial average body weight of 14.1±0.78 kg were divided into four groups of six animals and randomly allocated to dietary treatments. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) by partially substituting the wheat bran in the control diet The feeding experiment was conducted for 70 days followed by 10 days of digestibility trial. The dry matter (DM) intakes of sheep fed T1 and T2 was higher (p<0.05) than that of T3. Sheep reared in T4 diet had higher (p<0.001) crude protein (CP) intake than those fed with the other treatment diets. The neutral detergent fiber (NDF) intake of sheep fed with T4 diet was higher (p<0.05) than those of the control diet (T1) but did not vary with those fed T2 and T3 diets. The DM and organic matter digestibility was higher (p<0.05) in sheep fed with T4 diet than those of T3. The CP digestibility for T3 and T4 diets was higher (p<0.05) than those fed T1 and T2 diets. The NDF digestibility was higher (p<0.05) for sheep fed with T2 and T4 diets than those of T1. The average daily gain was higher (p<0.05) in sheep reared on T1 and T2 diets than those fed T4 diet. The average daily fain did not differ (p>0.05) among T1, T2 and T3 diets. Feed conversion ratio (FCR, g DM/g weight gain) was higher (p<0.05) in sheep fed with T4 than those of T1 and T2 diets. The FCR was similar (p>0.05) between T1, T2 and T3 diets. Nitrogen retention was higher (p<0.05) in sheep fed with T1 and T3 diets than the other treatment diets. Sheep reared in T2 diet had better nitrogen retention compared with T4 diet. In conclusion, M. stenopetala pod can substitute wheat bran (up to 15%) without affecting the voluntary feed intake and growth performances of yearling sheep.

***Key words**: body weight; digestibility; feed intake; Moringa pod; nitrogen retention*

Introduction

Livestock production is an integral part of Ethiopian agricultural system under heterogeneous agro-ecologies. The sub-sector contributes about 12-16% to the total GDP and 30-35% of total agricultural GDP, and 60-70% livelihoods of the Ethiopia population. Ethiopia's sheep population is about 29.0 million, out of which 22.8 % heads of sheep are under small farmers or landless livestock farmers (CSA, 2015). Sheep production contributes to subsistence and cash income generation for smallholder farmers. Sheep contribute substantially to food (meat supply), hides, wool and manure production. They serve as part of the crop failure risk coping portfolio, and investment as well as many other cultural functions (Markos, 2006).

Sheep production is a function of nutrition, health, genetics, climate and management among which nutrition plays an important role. Inadequate nutrition is the major constraint, for the low productivity of sheep. Sheep production relies on crop residues and natural pasture, which are usually deficient in nitrogen and limit animal performance. Thus, supplementation of low-quality roughages with conventional by-products is required for reasonable levels of animal performance. Farmers traditionally use conventional supplements like noug seed cakes, wheat bran and maize grains to improve the nutritive value of fibrous basal feeds. However, the use of such supplements is usually limited under smallholder livestock production systems due to their limited supply and high cost. Thus, evaluation of potentially useful unconventional feed resources is important in order to increase the resource base for livestock production. In this regard, parts of multipurpose trees have been considered as alternative feed sources during the dry season. Substitution of conventional ingredients by multipurpose tree parts such as leaves as suitable feeds for livestock has been reported (Aberra et al., 2011; 2013; Etana et al., 2011). One of such feed is *Moringa stenopetala*.

Moringa stenopetala is widely cultivated in southern Ethiopia and the leaf parts have been used for human consumption while pods are not; rather they are dried on the tree and became unpalatable to animals by the time they dropped from the tree to the ground (personal observations). Different studies have been shown the importance of *M. stenopetala* leaves in the diets of poultry (Aberra et al., 2011, 2013), sheep (Feleke et al., 2011) and goats (Kholif et al., 2015). However, the leaves of Moringa are also used for human consumption as well as for making tea and medicinal drugs for commercial purposes. Thus, it has been increasingly commercialized and become expensive in the recent times making difficult for smallholder farmers to use it for livestock feeding.

On the other hand, *M. stenopetala* pods are mainly available during most parts of the year and could be used as a good source of feed mainly during the dry season as a protein and energy supplement to low-quality roughages. Recent studies have indicated that the pod part of *M. stenopetala* contained crude protein ranging from 15.4 to 18.5%, which is comparable to that of wheat bran that has been commonly used as livestock feed in Ethiopia (Aberra et al., 2012). It has been further reported that the pods contained reasonable amounts of essential amino acids particularly those limiting amino acids such as lysine, methionine and cystein (Aberra et al., 2012). The same authors also reported that the pod contains 6.8 MJ/kg DM of Metabolizable energy.

However, the potential of the Moringa tree pod for future development and its role as suitable livestock feed resource in general and that of sheep in particular has not yet been investigated. Moreover, wheat bran is costly and thus most smallholder farmers cannot afford it. This study was thus initiated to study the effect of substituting wheat bran with air-dried *Moringa stenopetala* pods on nutrient intake, feed digestibility and growth performances of local sheep fed a basal diet of natural grass hay.

Materials and Methods

Experimental site

The experiment was carried out at Animal Farm of School of Animal and Range Sciences, Hawassa University (Ethiopia), which lies geographically between 7° 5′ N latitude and 38° 29′ E longitude at an elevation of 1700 m above sea level. The average annual rainfall ranges from 800 mm to 1100. The mean minimum and maximum temperatures in the area are 13.5 °C and 27.6 °C, respectively.

Preparation of experimental rations

The fresh green pods bearing seeds of *M. stenopetala* were harvested from available trees regardless of tree age. The green pods were collected at their early maturity and had deep green color when they were collected. The green pods were then chopped by using mortar and pestle (local material) and spread on a plastic sheet for drying in an area protected from direct sun light to prevent loss of vitamins and other volatile nutrients. Regular turning of the feed ingredient was done to facilitate drying and prevent growth of molds. The dried-pods were then ground using locally available materials to produce the *M. stenopetala* pod meal (hereafter referred to as MSPM). A concentrate mix was prepared with the following feed ingredients: wheat bran, maize, noug seed cake, salt and mineral lick. The ground pod was then packed in bags of 100 kg and stored until used. Before the commencement of the trial, the milled pods were mixed with the concentrate mix to prepare the experimental diets. Natural grass hay was bought from a private farm and hand chopped into the size of 3 to 5 cm and offered separately.

Experimental design and treatment diets

Twenty-four yearling local male sheep with initial average body weight of 14.1±0.78 kg were purchased and allowed to be adapted to the experimental environment for three weeks. At the end of the adaptation period, all sheep were ear tagged and blocked according to their body weights and then randomly assigned to the individual pens, which were fitted with individual feeders and watering troughs. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) by partially substituting the wheat bran in the control diet (Table 1). The feeding experiment was conducted for 70 days followed by 10 days of digestibility trial.

Management of experimental animals

About year old (age determined by dentition) male sheep were purchased from local market and transported to the experimental site. Upon arrival, the sheep were adapted to the environment for 3 weeks before the commencement of the actual experiment. During the adaptation period, the sheep were sprayed with acaricide (stalidon) and drenched with antihelminthics (Albendazole 300 mg) according to the dosage recommended by the manufacturers.

Table 1. The design of experimental diets with substitution levels of wheat bran by air-dried *Moringa stenopetala* pod

Feed ingredients	T1	T2	T3	T4
Grass hay	*Ad-libitum*	*Ad-libitum*	*Ad-libitum*	*Ad-libitum*
Wheat bran	62	46.5	34	15.5
Maize	16	16	16	16
Noug cake	20	20	20	20
Air-dried *M. stenopetala* pod	0	15.5	28	46.5
Salt	1	1	1	1
Mineral lick	1	1	1	1
Total	100	100	100	100

All the experimental sheep had *ad libitum* access to natural grass hay and clean water. The supply of natural grass was measured and adjustment was made when the refusal was less than 10% of the feed offered. Pens were cleaned on weekly basis while watering and feeding troughs were cleaned on daily basis.

Data collection procedures

Feed intake and body weight change: The sheep were weighed (prior to being offered any feed) for two consecutive days and the body weight was averaged, which was then considered as initial body weight for individual animals. Three hundred grams of the supplements as fed basis) per sheep and provided twice a day in equal portions at 8:00 a.m and 5:00 p.m. Feed intake was then determined by difference between amounts of feed offered and refused. To monitor body weight change, body weights were recorded every 14 days early in the morning before feed was offered. At the end of the experiment, all sheep were weighed individually for two consecutive days in the morning before feeding, and the average was taken as final body weight. Total body weight gain was then calculated by subtracting the initial body weight from the final. Feed conversion ratio (FCR) was calculated as a ratio of feed intake to weight gain.

Apparent digestibility trial and nitrogen balance: At the end of the growth trial, all sheep were transferred to metabolic cages. They were adapted to the cages, faecal collection bags and urine collection harnesses for three days followed by data collection for 7 days. The feeding regime was the same as in the preceding growth experiment. Details of faeces and urine sampling were according to Ajebu (2010). Faeces from each sheep were collected in faecal bags attached to the sheep every morning before feed offered and weighed. Then, 10% of the daily faecal output for the 7-day collection period was taken and bulked and stored at -20 0C. The daily total urine output of each sheep was collected in bottles containing 100 ml of 10% hydrochloric acid. Ten percent of the samples collected each day was taken and stored at -20 ^{0}C. At the end of the experiment, samples of faeces and urine were kept at room temperature and allowed to thaw for 24 h. After having the results of the chemical analysis, apparent digestibility, and N retention was determined using the following formula:

$$\text{Apparent digestibility} = \frac{\text{nutrient consumed} - \text{nutrient excreted in faeces}}{\text{Nutrient consumed}} \times 100$$

N-retention = N in feed consumed – (N excreted in faeces + N excreted in urine)

Chemical analysis

Dry matter (DM) content of the feed was determined by drying the samples at 105°C overnight. Faecal samples for chemical analysis were oven dried at 60°C for 48 h and milled using cross-beater mill (Thomas Wiley, Philadelphia, PA, USA) to pass through 1-mm sieve and stored in plastic bags for later chemical analysis. Ash was determined by combusting the samples at 550°C for 5 h. The organic matter (OM) content was computed as 100 - ash. Total nitrogen content of the feed, faeces and urine samples was determined using micro-Kjeldahl method. The crude protein (CP) was then calculated as nitrogen × 6.25. The acid detergent fibre (ADF) and neutral detergent fibre (NDF) contents were analyzed using the method of Van Soest et al. (1991) in an ANKOM® 200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA). All samples were analyzed in duplicates at Animal Nutrition Laboratory of Animal and Range Sciences, Hawassa University.

Statistical analysis

Data on nutrient intakes, nutrient digestibility, body weight, and nitrogen retention were subjected to one-way ANOVA using the GLM procedures of SAS (SAS, 2012, ver. 9.4) by fitting treatment diet as a single fixed factor. Mean comparisons were conducted using Tukey's Studentized Range Test and values were considered significant at $p<0.05$. The following linear model summarizes the statistics used to analyze the data:

$Y_{ij} = \mu + A_i + D_j/A_i + e_{ij}$

where: Y_{ij} = individual values of the dependent variables (feed intake, body weight, etc.); μ = overall mean of the response variable; A_i = the fixed effect of the i^{th} treatment diet (i = 1, 2, 3 and 4) on the dependant variables; Dj/Ai = the effect of the j^{th} animals (j =1, 2, 3, 4, 5, 6) within i^{th} treatment diets; e_{ij} = random variation in the response of individual animals.

Results

Chemical composition of feed ingredients and treatment diets

The chemical composition of the feeds used in this study (Table 2) shows that natural grass hay had low CP but high NDF and ADF contents. The MSPM had higher CP and lower NDF and ADF contents than wheat bran. The CP content was similar across the treatment diets. The DM content was similar for most feed ingredients.

Table 2. Chemical composition of feed ingredients used in the experimental diets (g/kg DM)

Feed ingredients	DM (g/kg feed)	CP	NDF	ADF	Ash
Maize (white)	961	86.4	241	205	35.2
Noug seed cake	961	303	345	215	116
Wheat bran	972	146	425	253	96.2
Air-dried Moringa pod	973	160	323	215	55.5
Natural grass hay	944	28.5	661	337	96.2

Dry matter and nutrient intake

The DM intake was significantly higher in sheep fed with T1 and T2 diets than those of T3 (Table 3). Sheep fed with T2 diet had also higher OM intake than those of T3. On the other hand, sheep reared in T4 diet had higher ($p<0.001$) CP intake than those fed on the other treatment diets. The lowest CP intake was observed in sheep fed with the T2 diet being significantly different from the rest of the treatments. The NDF intake in sheep fed with T4 diet did not vary from those fed T2 and T3 diets but was higher ($p<0.05$) than those reared in the control diet. On the contrary, the ADF intake was lowest in sheep fed with the T4 diet and differed ($p<0.01$) from the other treatments.

Table 3. Dry matter and nutrients intake (g/d) of sheep fed with air-dried *Moringa stenopetala* pod by partial substitution wheat bran

Intake	Treatments				SEM	P-value
	T1	T2	T3	T4		
Dry matter	566^{a}	575^{a}	522^{b}	552^{ab}	10.6	0.011
Organic matter	496^{ab}	525^{a}	487^{b}	515^{ab}	9.38	0.04
Crude protein	54.7^{b}	51.4^{c}	54.4^{b}	57.1^{a}	0.44	<0.001
Neutral detergent fiber	190^{b}	206^{ab}	207^{ab}	216^{a}	6.62	0.05
Acid detergent fiber	133^{a}	132^{a}	135^{a}	103^{b}	4.68	0.002

[a,b] Row means between treatment diets with different superscript letters are significantly different at $p<0.05$. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) as a partial substitute to wheat bran. SEM = standard error of mean

Apparent digestibility

The DM and OM digestibility coefficients were higher ($p<0.05$) in sheep fed with T4 diet than those of T3 (Table 4). No significant differences were observed in DM and OM digestibility coefficients between T1, T2 and T3. The CP digestibility coefficient was similar for sheep fed with T3 and T4 diets but was higher (P<0.05) than those of T1 and T2. The NDF digestibility coefficient was higher (p<0.05) for sheep fed with T2 and T4 diets than those of T1. No significant differences were observed in ADF digestibility among sheep fed with different levels of treatments diets.

Table 4. Apparent digestibility coefficients of sheep fed with different levels of air-dried Moringa *stenopetala* pod as partial replacement of wheat bran

Digestibility	Treatments				SEM	P-value
	T1	T2	T3	T4		
Dry matter	76.1^{ab}	73.6^{ab}	72.3^{b}	81.2^{a}	1.91	0.019
Organic matter	77.5^{ab}	76.3^{ab}	75.6^{b}	82.3^{a}	1.67	0.025
Crude protein	78.8^{b}	74.2^{b}	86.6^{a}	84.8^{a}	0.87	<0.001
Neutral detergent fiber	51.0^{b}	63.7^{a}	59.4^{ab}	65.7^{a}	2.52	0.025
Acid detergent fiber	61.8	66.6	59.5	62.7	2.37	0.286

^{a,b} Row means between treatment diets with different superscript letters are significant at p<0.05. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) as a partial substitute to wheat bran
SEM = standard error of mean.

Body weight and feed conversion ratio

The average body weight gain was significantly (p<0.05) higher in sheep fed with T1 and T2 diets than those of T4 (Table 5). Average daily body weight gain of sheep fed with T1, T2 and T3 diets did not vary significantly. Feed conversion ratio was higher (p<0.05) for those sheep fed with T4 diet than those of T1 and T2 diets. No significant difference was noted in feed conversion values between T1, T2 and T3 diets.

Table 5. Body weight, weight gain and feed conversion ratio of sheep fed with air-dried *Moringa stenopetala* pod as a partial replacement of wheat bran

Parameters	Treatments				SEM	P
	T1	T2	T3	T4		
Initial weight (kg)	13.1	13.3	13.0	13.1	0.384	0.918
Final weight (kg)	17.9	18.1	17.4	16.8	0.374	0.087
Total weight gain (kg)	4.80^{a}	4.79^{a}	3.97^{ab}	3.67^{b}	0.269	0.013
Average daily gain (g)	60.0^{a}	59.9^{a}	49.7^{ab}	45.9^{b}	3.365	0.013
Daily DM intake (g)	566^{a}	575^{a}	522^{b}	552^{ab}	10.63	0.011
FCR (g DM/g gain)	9.53^{b}	9.71^{b}	10.8^{ab}	12.3^{a}	0.648	0.023

^{a,b} Row means between treatment diets with different superscript letters are significant at p<0.05. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) as a partial substitute to wheat bran.
SEM = standard error of mean; FCR = feed conversion ratio

Nitrogen utilization

The nitrogen utilization values of sheep fed with diets containing different levels of *Moringa stenopetala* pod are presented in Table 6. The highest nitrogen intake was noted in those sheep fed with T1 and T3 diets which differed significantly (P<0.05) from those fed with other treatment diets. The amount of fecal nitrogen excreted in sheep fed with T2 diet was higher (P<0.05) than those fed T3 and T4 diets. Sheep fed with T1 and T3 diets had similar fecal nitrogen loss but were significantly higher than those of T4. Urinary nitrogen values were similar among those sheep fed with T3 and T4 diets but were higher (P<0.05) than those of T1 and T2 diets which showed similar values in these parameters. Nitrogen retention values in sheep fed with T1 and T3 diets were higher (p<0.05) than the other treatment diets. Similarly, sheep fed with T2 diet had better nitrogen retention than those of T4.

Table 6. Nitrogen utilization of sheep fed with different levels of *Moringa stenopetala* pod meal as a partial substitution of wheat bran

Parameters	Treatment				SEM	P-value
	T1	T2	T3	T4		
N intake (g/head/d)	8.75^{a}	8.21^{b}	8.70^{a}	4.13^{c}	0.059	<0.001
N excretion (g/head/d)						
Faeces	1.85^{ab}	2.13^{a}	1.79^{b}	0.38^{c}	0.083	<0.001
Urine	0.80^{b}	0.91^{b}	1.09^{a}	1.13^{a}	0.039	<0.001
N retained (g/head/d)	6.11^{a}	5.18^{b}	5.83^{a}	2.63^{c}	0.109	<0.001

[a,b,c] Row means between treatment diets with different superscript letters are significant at p<0.05. The treatment diets contained the control diet (T1) without MSPM, and diets containing MSPM at the level of 15.5% (T2), 28% (T3) and 46.5% (T4) as a partial substitute to wheat bran; SEM = standard error of the mean

Discussion

Chemical composition

The present findings have proved that natural grass hay that is commonly used as basal roughage cannot support the maintenance requirement of animals due to the high fiber and low crude protein content. Moreover, the CP content below the minimum microbial requirement (70 g CP/kg DM) cannot support microbial activity and the maintenance requirement of animals (McDonald et al., 2002). The CP content of the natural grass hay in this study (2.85%) is lower than those reported by Aberra et al. (2016) and Berhanu et al. (2014). These variations might be due to differences in location, soil type, post harvest handling, leaf to stem ratio and maturity stage of the forage itself at the harvest.

The CP content of *M. stenopetala* pods in the current study was slightly higher than those reported by Aberra et al. (2012) for mid elevation (154 g/kg DM) but was lower than the value reported for low elevation (184 g/kg DM). Etana and Adugna (2013) reported 191 g/kg DM CP that is higher than the result in the current study. These variations could be associated with the elevation where the samples were collected, soil type as well as the stage of maturity of the plant material.

The NDF and ADF values for *M. stenopetala* pod in the current study were lower than those reported by Aberra et al. (2012) and Etana and Adugna (2013). According to Van Soest (1991) the critical ranges of NDF supply to ruminants are 600–650 g/kg DM above which feed intake will be affected. Multipurpose tree parts like *M. stenopetala* pod maintain the initial high level of crude protein for long periods before the protein content drops below the maintenance requirement of animals, with advance in plant maturity (Etana and Adugna, 2013).

Dry matter and nutrient intakes

The chemical composition of feed ingredients supports the variation in feed intake of treatment diets. The *M. stenopetala* pod meal maintained the increased intake of basal and total feed DM at increased levels of inclusion, which may suggest that air-dried pods did not reduce the general intakes of animals. Zemmelink and t'Mannetje (2002) reported that increasing the level of feed offers resulted in higher DM and nutrient intakes by reducing the feed refusal, which may suggest the palpability of the offered feed material. In contrast, Koech et al. (2010) reported increased levels of basal feed refusals at higher levels of supplementation of *Prosopis juliflora* seedpod meal to goats, which might be due to the substitution effect on basal feed DM at increased levels of supplementation (Umunna et al., 1995). Moreover, the negative effect of condensed tannins and soluble phenolics contained in *Prosopis juliflora* pods (Aberra et al., 2017) might have imposed limitations on CP intake, by forming protein-tannins complex and rendering it indigestible.

Increasing levels of MSPM substitution for wheat bran did not have undesirable effect on basal feed DM intake. This suggests that the less likelihood of fast degrading supplements to substitute the basal feed DM, which was in good agreement with the observation of Nsahlai et al. (1998) and Patra (2009). The CP intake was also increased similar to the trends of DM intake, which is in good agreement with the reports of Tegene et al. (2000).

Apparent digestibility of nutrients

The digestibility of feed nutrients influences the speed with which the feed passes through the digestive system. Generally, feedstuffs with higher digestibility will be processed more rapidly, allowing animals to eat more and have higher production. The nutrient composition of the basal feed and supplement consumed together affects digestibility (McDonald et al., 2002). In the current study, sheep fed with high levels of substitution of wheat bran (46.5%) with air-dried pods of *M. stenopetala* had higher DM and OM digestibility coefficients than at 28% level of substitution. The variations in DM and CP digestibility coefficients might be due to the supplementation level (only partial replacement of the control diet). However, the nutrients supplied by the different combination of supplements used in this study were sufficient to make more or less similar effect on the digestibility of DM and nutrients.

The higher CP digestibility of sheep fed with T4 diet compared with that of T1 and T2 could be due to high CP intake of T4 supplied by Moringa pods. The results are consistent with the findings of Feleke et al. (2011), Dougnon et al., (2012) and Khalel et al. (2014) who reported positive effects of *M. stenopetala* and *M. olifera* leaves on the performance of sheep, rabbits, and lactating cows, respectively. The present results are also in good agreement with those reported by Newton et al. (2010), Mendieta-Araica et al. (2011) and Nouman et al. (2014) who suggested that *Moringa* tree parts are rich in most nutrients and thus it can serve as useful source of supplementation to low quality diets so as to increase the nutrients digestibility.

The current results further showed that there is a higher NDF digestibility coefficient as the level of *M. stenopetala* pod meal increased and the results are consistent with Etana and Adugna (2013) and Aberra et al. (2013) who reported higher fermentation characteristics of pods of *M. stenopetala* suggesting improved digestibility and availability of nutrients to ruminant animals. Moreover, Makkar and Becker (1996) reported that about 95% of *Moringa* CP was found to be available either in the rumen or in the post rumen. Kleinschmit et al. (2007) reported the bypass protein that resists degradation in the rumen, which then passes to the lower tract for digestion, is necessary for maximizing production of ruminant animals. It could be thus speculated that an increase in CP content of treatments (as the inclusion level of *M. stenopetala* pod increased) might be beneficial due to the action of fermenting microorganisms in the synthesis of some amino acids. Therefore, increased CP digestibility and CP intake could be the result of improved quality of protein, which is the result of amino acid profiles, physical and chemical characteristics and microbial proliferation initiated by *M. stenopetala* pod inclusion in the diet.

Body weight and feed conversion ratio

In the current study, sheep fed with all treatment diets had a positive weight gain, which indicates the nutritive value of the *M. stenopetala* pod as a potential source of protein and energy. The average daily body weight gains in the current study were higher than those reported by Lemma (1993) for lambs fed with *Leucaena* by substituting Noug seed cake but were lower than those of Feleke et al. (2011) for sheep supplemented with *M. stenopetala* leaves.

The weight gains of the sheep reared in T1, T2 and T3 diets was similar (with increasing levels of *M. stenopetala* pod), which might be associated with higher digestibility coefficients of CP. This observation is consistent with the findings of Nouman et al. (2014) and Adegun and Aye (2013) on West African Dwarf Rams fed *Moringa oleifera* and cotton seed cake.

Animals that convert at a high rate (lower FCR, g DMI / g gain) are more preferred to those with lower ratio as they optimize performance and are economically valuable in environments that have low quality and quantity of feed resources. Feed conversion ratio (g DMI/ g gain) in the current study has increased as the level of *M. stenopetala* pod meal increased. However, the FCR in those sheep fed with T1, T2, and T3 diets had similar values and did not vary significantly from each other. This might be due to the contribution of *M. stenopetala* pod fermentation quality brought into the rumen in the form of available cellulose and hemicelluloses which stimulate fiber digestion and hence nutrient released for growth (Etana and Adugna, 2013).

Nitrogen utilization

All the treatment groups fed with *M. stenopetala* pods have shown a positive nitrogen balance, which suggests that the supply of energy and nitrogen were higher than the maintenance requirement. The results are consistent with the findings of Ajebu (2010), Mendieta-Aracia et al. (2011) and Nouman et al. (2014) who reported improved growth performance as a result of better nitrogen balance in sheep fed with basal diet of wheat straw supplemented with local agricultural by-products and *Moringa* leaves. On the other hand, contradictory results were reported in sheep fed *with Prosopis juliflora* pods and *Cenchrus* grass (Chaturvedi and Sahoo, 2013). In the current study, the urine nitrogen increased with increased levels of *M. stenopetala* pod substitution, which is consistent with the reports of Clark et al. (1992). The positive balance shows the nitrogen (N) availability for microbial protein synthesis and that the captured N from the treatment diets. Moreover, the amount of N excreted with the faeces decreased as the level of pods increased suggesting efficient utilization of the protein in pods. However, the amount of nitrogen retained did not show a consistent trend among treatment diets and was higher only in sheep fed with T3 and T1 diets, which differed with those of T2 and T3. Nitrogen retention for a specific ration might be affected by factors such as increasing presence of fermentable energy, available fermentable energy, and variation in rumen undegradeble nitrogen (Holzer et al., 1986). Moreover optimizing factors for nitrogen retention enhances utilization of ammonia in the rumen and reduces the effect of free fats in protein synthesis (Hagemeister et al., 1981).

Conclusion

The findings of the present study indicated that *M. stenopetala* pod could substitute wheat bran by serving as protein and energy sources without affecting the voluntary feed intake and growth performances of local sheep. *M. stenopetala* pod can thus partially replace wheat bran in the concentrate mixture up to 15% in sheep feeding for improved performances. Smallholder farmers in Moringa growing regions can substitute conventional concentrate supplements by *M. stenopetala* pod due to its year round availability and easy access.

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