Effect of Different Proportions of Fig (*Ficus sur*) Fruits and Oats (*Avena sativa*) Grain Supplementation on Feed Intake, Digestibility, Nitrogen Retention and Live Weight Change of Hararghe Highland Sheep Fed Natural Pasture Hay Based Diets

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Abstract

Energy and protein supplements are very scarce feed resources in Ethiopia. The present study was carried out to investigate the effect of inclusion of graded levels of dried and ground Ficus sur fruits (FSF) in the ration on feed intake, digestibility, growth performance and nitrogen (N) balance of Hararghe highland lambs. The experiment was laid out in a randomized complete block design (RCBD). A total of 30 yearling intact male lambs with similar body condition were grouped into six blocks based on their initial body weight and animals from each block were assigned to five treatment diets giving a replication of six animals per treatment. The dietary treatments used in the experiments were ad libitum natural pasture hay (control); 100% FSF and 0% oat grain (OG), which was represented as [100FSF]; 67%FSF:33%OG [67FSF]; 33%FSF:67%OG [33FSF]; 0%FSF:100% OG [0FSF]. Noug seed cake (NSC) was given to all animals to provide at least the maintenance requirement for protein at isonitrogenous level. The lambs fed the control diet achieved the least (p<0.0001) nutrient intake from the basal, concentrate and the total diet compared to those fed diets supplemented with FSF and OG. Lambs fed 100FSF consumed the highest (p<0.0001) amount of nutrients than the other treatment groups. The group fed 100FSF also achieved the highest apparent nutrient digestibility, average daily gain and N retention than the other groups. This implies that FSF is a better energy supplement than OG in the diets of growing lambs.

Keywords: *Digestibility, Feed intake, Fig fruits, Oat grain, Live weight change, Nitrogen balance, Sheep*

Introduction

Sheep are one of the very valuable livestock species reared in different agro-ecologies and production systems all over the world (Assen and Aklilu, 2012). They are particularly very important for the livelihood of the poor and economically disadvantaged members of the community. They are suitable for smallholder farmers as they serve as a means of survival, source of cash income and asset for the poor and the landless, and as a source of food and nutrition security.

Despite their relevance, sheep production in most sub-Saharan African countries is constrained mainly by feed shortage (Tessema et al., 2013). The natural pasture and crop residues, which serve as the main source of feed for livestock in Ethiopia, are characterized by low nutrient content, low digestibility and low voluntary intake resulting in poor animal performance (Adugna et al., 2012). Thus, in order to improve the nutritive value of the predominant feed resources to enhance productivity of livestock, including sheep, supplementation with energy and protein source diets is imperative (Dutta et al., 2009). Under smallholder farm conditions, different green herbages such as leguminous trees and herbaceous legumes grown on farm can be used as protein supplements (Getnet et al., 2008) whereas energy source concentrate supplements are very scarce in these production systems. Most of the energy rich supplements are costly cereal grains that are used as staple food by most farmers in the tropics. Other sources are agro-industrial by products that rural households cannot easily access due to inadequacy, localized availability and very high cost associated with their purchase and transport.

Therefore, searching for alternative and locally available energy supplements with minimal competition with human beings would be important to support the sector. *Ficus sur* fruit (FSF) could be hypothesized to be one of such locally available alternative energy supplements in rural areas. The genus *Ficus* comprises about 750 species, with about 100 species in Africa, 500 species in tropical Asia and Australia, and 150 species in tropical America (Lumbile and Mogotsi, 2008). One of the species found in Ethiopia is *Ficus sur* (Cv. Forssk.), which is commonly known as fig. It is widely distributed in different parts of the country and has been used as feed for many years by livestock (personal observation). During dry seasons of severe feed shortage, the ripen fruits drop from the trees by wind and all classes of livestock freely access with no restriction. During this time, these fruits become important natural concentrate supplements for livestock and many lambs and kids grow fast and reach market weight in short period of time (personal observation).

In spite of its nutritional merits and availability, this feed resource has not yet been studied. Thus, the objective of this study was to compare the effect of inclusion of graded levels of dried and ground FSF with levels of ground OG in the ration on feed intake, digestibility, nitrogen balance and live weight change of lambs.

Materials and Methods

Experimental site

The study was conducted at Haramaya University sheep farm, located at 9^{o} 26’N latitude and 42^{o}3’E longitude in eastern Ethiopia. The altitude of the area is about 1980 meters above sea level and the mean annual rainfall is about 910 mm with a range of 560-1260 mm. The mean maximum and minimum temperatures are 23.4^{o}C and 8.25^{o}C, respectively (summary report from Haramaya University Meteorological Station, 2012).

Animals, treatments and experimental design

A total of 35 yearling intact male Hararghe highland sheep with similar body condition were purchased from Kulubi open market. The animals were transported to Haramaya University and quarantined for 3-weeks during which they were sprayed with accaricides against external parasites, treated with *ivermectin* injection against internal parasites and *Penistrep* against Pneumonia disease. During this adaptation period, animals were fed natural pasture hay and noug seed cake (NSC) supplement which is the same size with the actual level of NSC in the experiment.

The different dietary treatments used in the experiments were natural pasture hay offered *ad libitum* at 20% refusal rate plus noug seed cake (NSC) supplement (control). The other four treatments received *ad libitum* natural pasture hay supplemented with different proportions of *Ficus sur* fruits (FSF) and oats gain (OG) in addition to NSC, and the treatments include 100% FSF and 0%OG [100FSF]; 67%FSF & 33%OG [67FSF]; 33%FSF & 67%OG [33FSF]; and 0%FSF & 100% OG [0FSF]. The amount of noug seed cake (NSC), as protein supplement, varied based on the nitrogen content of energy diets, FSF and OG, to keep all the treatments at isonitronegous level. This was to fulfill at least the maintenance requirement for protein of the control treatment (McDonalds et al, 2010).

At the end of the quarantine period, 30 animals that were healthy and in good condition were selected and ear-tagged. The experiment was laid out in a randomized complete block design (RCBD). The animals were grouped into 6 blocks based on their initial body weight and animals from each block were assigned to five treatment diets randomly giving a replication of six animals per treatment. The animals were then assigned to individual pens furnished with feeder and water trough in the experimental house. Both hay and concentrate diets were offered using separate containers in two equal meals at 08:00 and 16:00 hours.

Experimental feeds, feeding management and body weight measurement

Naturally ripen and dry FSF were collected as they drop on the ground from fig trees in Horro district, western Ethiopia, packed in clean sacks and taken to Haramaya University sheep farm. The fruits were further sun dried to ensure ease of grinding in conventional grain mill. The OG was purchased from Sheno town of North Shewa zone of Oromia National Regional State, ground in a similar mill, using the same speck size as FSF. These two feeds were used as energy supplements after being mixed in different proportions as shown in Table 1.

Prior to commencement of data collection, the animals were adapted to the experimental diets for two weeks. Clean tap water was provided in a bucket and changed whenever contaminated with feces or feed material. The hay basal diet and concentrate supplement were offered in separate feed troughs. The amount of feed offered and refused was measured and recorded every day. The basal diet offer was adjusted at interval of 3 days for *ad libitum* intake at 20% refusal rate. The live weight of the animals was recorded every fortnight before morning feeding using a balance that has sensitivity of 10 g and maximum weighing capacity of 100 kg. The total weight gain was calculated as the difference between the final and initial weights of the animals. The daily average weight gain of the animals was calculated by dividing the total weight gain (g) by the number of feeding days.

Natural pasture hay was offered *ad libitum* whereas noug seed cake was given to make the diets of all animals isonitrogenous. Control= ad libitum natural pasture hay supplemented with noug cake; 100FSF = 100% FSF with 0% oats grain; 67FSF= 67% FSF with 33% oats grain; 33FSF= 33% FSF with 67% oats grain; 0FSF= 0% FSF with 100% oats grain

Table 1. Ingredient proportion and chemical composition of experimental diets (DM basis)*

	Dietary proportions (DM basis)				
Ingredients (g)	Control	100FSF	67FSF	33FSF	0FSF
Ficus sur fruits	0	300	201	99	0
Oats grain	0	0	99	201	300
Noug seed cake	225	210	190	170	150
Nutrient composition of diets (%)					
Dry matter	91.8	91.4	91.4	91.4	91.4
Ash	9.3	8.1	7.3	6.9	5.6
Crude protein	15.4	15.4	15.4	15.4	15.4
Neutral detergent fiber	58.3	33.7	35.2	36.8	38.6
Acid detergent fiber	41.1	22.6	23.1	23.7	24.3
Hemicelluloses	17.1	11.1	12.0	13.1	14.3
Cellulose	33.6	17.2	17.7	18.3	18.8
Acid detergent lignin	7.6	5.4	5.4	5.5	5.5
ME calculated (MJ/kg DM)	8.6	10.4	10.2	9.9	9.6

FSF= *Ficus sur* fruits; ME= metabolizable energy; *

Digestibility and nitrogen balance experiment

The digestibility and nitrogen balance experiments were conducted following the completion of the growth experiment. To determine the nutrient digestibility, total fecal collection method was employed using the same lambs used in the growth experiment. The fecal samples were collected using feces collection bags made of canvas (inner plastic sheet) fitted to each animal. Animals were adapted to carrying of fecal collection bags for three days followed by seven consecutive days of fecal collection. Every morning, the feces voided by each animal was emptied into plastic bucket, weighed and recorded for each animal, thoroughly mixed and about 20% was sampled each day to make seven days of composite samples. The feces samples were kept frozen at −20oC in deep freezer pending chemical analysis. The frozen feces were thawed, thoroughly mixed, sub-sampled and half of the samples were oven dried at 105^{o}C for 24 hours for DM determination. The rest of the samples were dried at 65^{o}C to constant weight in a forced draft oven and ground to pass through1mm sieve size for chemical analysis. Feed intake during the digestibility period was recorded following similar procedure as described for growth experiment. A sample of feed offer was collected every day, bulked, and sub-sampled at the end of the trial for later chemical analysis. Likewise, refusals by each animal was collected, weighed and pooled per treatment, thoroughly mixed and sub-sampled for chemical analysis per treatment. Apparent dry matter digestibility was calculated as:

$$\text{Apparent Digestibility (\%)} = \frac{\text{Nutrients intake} - \text{Nutrients voided in feces}}{\text{Nutrient intake}} * 100$$

The amount of urine excreted by individual animal, kept in metabolic cage, was collected into plastic bottles. About 10ml of (10%) H_2SO_4 was added to each urine collection bottle daily to trap the N that may escape as NH_3 from the urine. After recording the volume of urine excreted by each animal using a graduated cylinder, about 20% of the urine excreted daily per animal was sampled and stored in deep freeze at -20^{o}C, and pooled for the collection period for N analysis. Nitrogen retention was calculated as the difference between N consumed and N excreted in the feces and urine.

Chemical analysis of feeds, feces and urine

The chemical analysis of the experimental feeds, feces and urine were performed at Haramaya University Animal Nutrition laboratory. The chemical analysis for each sample was run in duplicates. The DM and ash contents of the feed and feces samples were determined following the procedure of AOAC (1995). The NDF, ADF, and ADL were determined according to Van Soest and Robertson (1985). Hemicelluloses and cellulose were calculated as NDF-ADF and ADF - (ADL+ADF ash), respectively.

The ME (MJ/kg) of the diets was estimated according to the procedure described by Moran (2005) as ME = 0.16DDM%-0.8. The N content of the samples was determined by the micro-Kjeldahl method and CP was calculated as N X 6.25.

Statistical Analysis

Data were analyzed using the General Linear Model (GLM) procedure of the statistical analysis system (SAS, 2008). When the ANOVA declared difference among the dietary treatments, Tukey test was used to separate means. The model used in the analysis was: $Yijk=\mu + \tau i + \beta j + \varepsilon ijk$ where, μ=overall mean of the population; τi= the i^{th} ($1\text{-}5^{th}$) dietary treatment effect; βj= the j^{th} ($1\text{-}6^{th}$) block effect and εijk=random error associated with yij.

Results

Nutrient composition of experimental diets

There were no differences in the DM and CP contents of the experimental diets (Table 1).The Ash content was numerically higher in the control diet and tended to decrease with decreasing level of FSF in the diet. The fiber (NDF, ADF, cellulose, hemicelluloses and lignin) contents were higher in the control than in the supplemented diets and tended to increase with decreasing level of FSF in the diet. On the other hand, the calculated ME content was lower in the control than in the supplemented diets and tended to decrease with decreasing level of FSF in the diet.

Voluntary feed intake

Basal diet DM intake was higher (P<0.05) in groups supplemented with different proportions of FSF and OG than the control group (Table 2). Basal diet DM intake was higher (P<0.05) in groups supplemented with different proportions of FSF and OG than the control group (Table 2). On the other hand, the concentrate DM intake was higher (P<0.05) in sheep fed 100FSF than in those fed 33FSF, 0FSF and the control diets. The total DM and OM intakes were significantly higher (P<0.05) in animals fed 100FSF than in those fed 33FSF, 0FSF and control diets. The NDF intake was also higher (P<0.05) in animals fed the 100FSF diet than the other treatments. Animals fed the control diet had the lowest intake of DM, OM and NDF. In general, DM, OM and NDF intake showed an increasing trend, at least in magnitude, with increasing level of FSF in the diet. However, no significant differences were detected in the CP intake among the different dietary treatments.

Table 2. Voluntary nutrient intake of sheep fed natural pasture hay supplemented with graded levels of FSF

	Treatments						
Intake (g/day)	Control	100FSF	67FSF	33FSF	0FSF	SEM	P-level
Dry matter							
Basal hay	316.3^{b}	356.5^{a}	349.6^{a}	345.3^{a}	331.0^{a}	2.98	0.001
Noug seed cake	168.8^{d}	250.1^{a}	237.1^{ab}	223.7^{bc}	211.4^{c}	3.37	0.001
Total	480.0^{d}	601.6^{a}	580.7^{ab}	564.0^{b}	537.4^{c}	5.08	0.001
Organic matter	475.0^{d}	596.6^{a}	575.7^{ab}	559.0^{b}	532.4^{c}	5.08	0.001
Neutral detergent fiber	304.6^{d}	374.7^{a}	364.4^{b}	357.8^{b}	349.7^{c}	1.74	0.001
Crude protein	71.3	71.3	70.7	71.0	70.6	0.24	0.062

^{abc}Means with different superscript in the same row are significantly different. FSF=*Ficus sur* fruits; Control = fed natural pasture hay *ad libitum*; 100FSF = supplemented with 100% FSF and 0% oats grain (OG); 67FSF = supplemented with 67% FSF and 33% OG; 33FSF = supplemented with 33% FSF and 67% OG; 0FSF = supplemented with 0% FSF and 100% OG

Apparent digestibility

Apparent nutrient digestibility of the experimental diets is shown in Table 3.

Table 3. Nutrient digestibility of experimental diets in sheep fed natural pasture hay supplemented with different proportions of FSF

	Treatments						
Digestibility (%)	Control	100FSF	67FSF	33FSF	0FSF	SEM	P-level
Dry matter	59.0^{c}	69.9^{a}	68.7^{a}	67.4^{ab}	65.5^{b}	0.64	0.001
Organic matter	62.0^{c}	73.0^{a}	71.8^{a}	70.4^{ab}	68.5^{b}	0.64	0.001
Neutral detergent fiber	57.2^{d}	64.7^{a}	62.7^{b}	60.5^{c}	59.8^{c}	0.37	0.001
Crude protein	63.0	63.1	63.0	62.9	62.9	0.24	0.062

^{abcd}Means with different superscript in the same row are significantly different. FSF=*Ficus sur* fruits; SEM= standard error of the mean; Control treatment = fed natural pasture hay *ad libitum*; 100FSF = supplemented with 100% FSF and 0% oats grain (OG); 67FSF = supplemented with 67% FSF and 33% OG; 33FSF = supplemented

The 100FSF and 67FSF diets had significantly higher (P<0.05) DM digestibility (DMD) and OM digestibility (OMD) values than the 0FSF diet, which in turn had higher (P<0.05) DMD and OMD values compared to the control diet. The NDF digestibility was highest (P<0.05) in animals fed 100FSF diet followed by 67FSF and lowest in the control diet. Nonetheless, no significant differences (P>0.05) were detected among the treatment groups in CP digestibility.

Nitrogen balance

Table 4 shows the nitrogen balance of the experimental sheep determined during the digestibility trial. Fecal N loss was higher (P<0.05) in control than in the supplemented animals. On the other hand, the urinary N loss was highest (P<0.05) in animals fed 0FSF diet followed by the 67FSF and 33FSF diets whereas the animals fed the control diet had the lowest (P<0.05) urinary N loss followed by those fed the 100FSF diet. N retention was higher (P<0.05) in animals fed 100FSF and 67FSF diets than those fed 0FSF and control diets. In general, there was an increasing trend of N retention with increasing level of FSF inclusion in the diet.

Table 4. Nitrogen balance of sheep fed natural pasture hay supplemented with different proportions of FSF and OG

	Treatments						
Variables	Control	100FSF	67FSF	33FSF	0FSF	SEM	P-level
N intake (g/day)							
Basal hay	3.36	3.51	3.44	3.41	3.37	0.07	0.076
Noug seed cake	8.05	8.05	8.03	8.03	7.99	0.03	0.061
Total	11.4	11.6	11.5	11.4	11.4	0.07	0.074
N excreted (g/day)							
Fecal	6.11^{a}	5.26^{b}	5.22^{b}	5.25^{b}	5.30^{b}	0.02	0.001
Urinary	1.10^{d}	1.39^{c}	1.56^{b}	1.57^{b}	1.71^{a}	0.02	0.001
Total	7.21^{a}	6.65^{c}	6.78^{b}	6.82^{b}	7.00^{a}	0.03	0.001
N retention (g/day)	4.18^{c}	4.89^{a}	4.69^{a}	4.60^{ab}	4.34^{bc}	0.07	0.001

[abcd]Means in the same column with different superscript are significantly different; N= nitrogen; FSF=Ficus sur fruits; SEM= standard error of the mean; Control treatment = fed natural pasture hay ad libitum; 100FSF = supplemented with 100% FSF and 0% oats grain (OG); 67FSF = supplemented with 67% FSF and 33% OG; 33FSF = supplemented with 33% FSF and 67% OG; 0FSF = supplemented with 0% FSF and 100% OG as energy sources. Noug seed cake (NSC) was supplemented to all animals at isonitrogenous level.

Live weight change

The body weight change of lambs fed the different treatment diets is presented in Table 5. The final body weight (FBW) was higher ($P<0.05$) in animals fed 100FSF diets than those fed 67FSF diet, which in turn had higher ($P<0.05$) final body weight than the animals fed 0FSF and control diets. The total body weight gain (TWG) and average daily gain (ADG) were highest in animals fed 100FSF diets followed by 67FSF diets and were lowest in animals fed the control diet.

Table 5. Growth performance of sheep fed natural pasture hay supplemented with different proportions of FSF

	Treatments						
Growth parameters	Control	100FSF	67FSF	33FSF	0FSF	SEM	P-level
Initial body weight (kg)	14.5	14.8	14.1	14.3	14.0	0.25	0.617
Final body weight (kg)	18.4^{c}	21.4^{a}	19.8^{b}	19.3^{bc}	18.5^{c}	0.29	0.001
Total weight gain (kg)	3.90^{d}	6.62^{a}	5.67^{b}	5.03^{bc}	4.50^{cd}	0.16	0.001
Average daily gain (g)	43.3^{d}	73.5^{a}	63.0^{b}	55.8^{bc}	49.9^{dc}	1.73	0.001

^{abcd}Means with different superscript in the same row are significantly different. FSF=*Ficus sur* fruits; SEM= standard error of the mean. Control treatment = fed natural pasture hay *ad libitum*; 100FSF = supplemented with 100% FSF and 0% oats grain (OG); 67FSF = supplemented with 67% FSF and 33% OG; 33FSF = supplemented with 33% FSF and 67% OG; 0FSF = supplemented with 0% FSF and 100% OG as energy sources

Discussion

Chemical composition and energy value of feeds

The similarity of the experimental diets in CP content is the reflection of the formulation of the diets on isonitrogenous basis. The tendency of having relatively higher ash content in the diets with higher FSF content may indicate contamination of the FSF with soil since the fruits were collected as they drop from the fig tree to the ground. The tendency of increasing fiber content and decreasing ME content with decreasing level of FSF in the diets, though not significant, indicates that the FSF was lower in fiber and higher in ME content than the oats grain. Thus, based on the chemical composition, FSF appears to be a better alternative source of energy supplement than oats grain.

Voluntary feed intake

Voluntary feed intake is among many other factors which affect animal performance and it depends, in one way or another, on the nature and type of the diet. The small feed intake in the control diet was due to lack of energy concentrate supplement that resulted in low rumen microbial activity and then low digestion rate in the rumen. At low digestion rate, passage rate is also low and this must have resulted in low voluntary feed intake (Nurfeta et al., 2008). This implies that rumen microbial growth needs both energy and protein supplements in a proportion that supports optimum ruminal ecology. Pittroffet al.(2006) noted the necessity to develop feeding regimes that optimize a balance of protein and energy supply in support of better animal performance. In similar way Dutta et al.(2009) suggested that balanced feeding in terms of energy and protein optimizes animal performance. The importance of meeting energy requirements as a primary goal in the control of voluntary feed intake was also highlighted by Adugna and Sundstøl (2000a).

The highest feed intake observed in lambs fed 100FSF could be an attribute of lower NDF content of FSF compared to OG. Higher fiber content of feeds lowers digesta passage rate and reduces feed intake as occurred in sheep fed with 0FSF diets in the present study. In accordance with the present study, forage diet with long particle cuts and having higher NDF content reduced passage rate and DM intake of animals (Yang and Beauchemin, 2006). Wang et al (2011) noted that higher NDF in the diet of dairy cows increased chewing activity resulting in lowered passage rate, thereby feed intake. Likewise, Almaz et al (2012) found lower dry matter intake in Ethiopian highland sheep when fed diets that contained the highest NDF. Consistent with the results of the current study, Lloyd et al.(1992) and Rowe and Coss (1994) revealed that supplementation of oats grain to roughage diets resulted in reduced feed intake. Moreover, Tadesse (2011) noted high fiber concentration in OG and suggested the importance of treatment to improve its nutritive value. Accordingly, malting OG was found to slightly increase CP and decrease fiber fractions, which resulted in improved digestibility and animal performance when supplemented with NSC (Hailu, 2012). This confirms that OG has less soluble components compared to FSF. The best energy supplement is that which support optimum intake of the basal diet to which it was supplemented. In this regard, higher levels of FSF supplementation resulted in higher voluntary feed intake compared to OG. The similarity in mean CP intake between the dietary treatments was due to supplementation of the diets at isonitrogenous levels.

Apparent nutrient digestibility

The least apparent DMD, OMD and NDF digestibility in lambs fed the control diet may be due to lack of adequate energy supplement. This was in agreement with ME values for control diets indicated under Table 1. Energy supplements in the form of soluble carbohydrates enhance rumen microbial growth which gradually increase in population and colonize the fibrous mats in the rumen. According to Lascano et al (2009) the amount of live rumen bacteria count increased with increased level of energy concentrate in the diet of dairy heifers while the dead count of the same bacteria decreased. Even in the presence of protein supplement, microbial protein production and N efficiency would most likely be affected by the relative degradability of carbohydrate source diets or energy concentrates (Eriksson et al., 2009). This may be a reason for the relatively low values of nutrient digestibility in the present study, except for CP digestibility which did not differ among the treatments.

The higher apparent digestibility of DM and OM for 100FSF diet compared to 0FSF (100 OG) diet was mainly due to less ADF and ADL contents of FSF compared to OG. The DM digestibility of diets containing high levels of FSF in the present study is comparable to the digestibility for pods of tropical legume (*A. pennatula;* 66.8%) in sheep (Chay-Canulb et al., 2012). The OM digestibility was also comparable to a diet of sheep fed maize stover supplemented with 450 g of *Desmodium intortum* hay per head per day (Adugna and Sundstøl, 2000a). But the digestibility in the former was higher than the apparent digestibility of perennial Pangola grass (*Digitaria decumbens)* pasture (62.8-65.7% %) harvested at 28, 42 and 56 days of re-growth and fed to sheep (Archimede et al 2000). It is also higher than cowpea haulms (54 - 60%) supplemented *P. purureum* grass fed to sheep (Anele et al., 2010).

The higher digestibility of NDF in lambs that consumed 100FSF is attributed to the higher nutrient intake in this group. This shows that FSF supplement is likely to improve rumen environment for more efficient microbial fermentation of ingested feeds. Hence, the higher nutrient digestibility in lambs fed higher levels of FSF is indicative of higher supplementary value of this feed resource. The similarity in CP digestibility among the different treatments is attributable to supplementation of Noug seed cake at isonitrogenous levels to all experimental animals.

Nitrogen balance

All the lambs achieved positive N balance indicating that the animals obtained the amount of N above their maintenance requirement. The similarity of N intake between groups of lambs under the different treatments was due to equal provision of N in their diet. However, the significantly higher N retention in lambs fed 100FSF was presumably due to higher N microbial activity and higher microbial N supply. In addition, FSF might have contributed to higher amount of microbial cells for digestion in lower gut and hence more N retained in the body of lambs supplemented with higher proportion of FSF. The relatively lower amount of N excreted in urine of lambs with higher levels of FSF supplementation has important implication for natural resources management and sustainability because of reduced ammonia emission to the environment (Kaitho et al., 1998; Adugna and Sundsøl, 2000b). In general, the level of N retention found in the present study was neither deficient nor in excess, rather it was indicative of just sufficient and optimum level of N supply for maintenance and growth of the lambs (McDonalds et al, 2010).

Growth performance of lambs

Higher performance of the lambs raised on FSF and OG supplements as compared to those fed only control diet indicates that protein supplement alone is not enough to optimize lambs performance and that additional energy concentrate supplement is necessary (Dutta et al., 2009; Pittroff et al., 2006; Adugna and Sundstøl, 2000a). Higher growth performance in sheep supplemented with higher proportion of FSF is a reflection of the higher feed intake, higher metabolizable energy intake, higher nutrient digestibility and higher N retention of diets with higher FSF inclusion.

The daily body weight gain of lambs fed 100FSF in the present study was 36.1% higher than that of local lambs fed maize stover at different maturity stages as basal diet supplemented with 450 g day^{-1} *Desmodium intortum* hay (Adugna and Sundstøl (2000a). This may, among others, be due to lack of energy diets supplementation in the later study. It was also about 16.1% higher than the average daily weight gain of lambs of the same breed, Haraghe highland sheep, fed urea treated maize stover supplemented with graded levels of concentrate mix (Hirut et al., 2011). However, the daily weight gain in the current study was about 12.9% lower than that of the same breed of lambs fed natural pasture hay basal diet supplemented with mixtures of onion leaves, noug seed cake, and wheat bran at different proportions (Tsehai, 2012). This may presumably due to more number of supplementation mix that might have helped the lambs obtained different nutrients in the later case. Generally the better growth performance of lambs fed 100FSF in the present study indicates FSF to be a promising energy supplement than OG in sheep nutrition.

Conclusion

The results in the present study showed that lambs offered control diet performed poorer in every metabolic parameter studied compared to those supplemented with FSF and OG. The voluntary feed intake, apparent digestibility, N retention and live weight changes were highest for sheep offered diet consisting maximum level of FSF, implying that FSF supplied better ME to growing sheep than OG. Hence, it can be concluded that FSF can be used as energy supplement in the diets of growing lambs with better efficiency than OG.

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