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RESEARCH ARTICLE

Effect of Commercial and Non-conventional Feeds, Leaves of Indigenous and Improved Multipurpose Tree Supplementation on Feed Intake, Digestibility and Growth Performance of Sheep

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Abstract:

Background:

Acute shortage of feed and very poor quality of the available feeds during the dry season are the prime limiting factors for increasing the production and productivity of small ruminants in most agroecological zones of Ethiopia. Thus, the study evaluated the effect of concentrate mixture of wheat bran and Sesame seed cake (T_1), *Atella* (T_2), *Faidherbia albida* (T_3) and *Sesbania sesban* leaves (T_4) on feed intake, digestibility, body weight change and economical profitability of local sheep.

Methods:

Twenty-four yearling intact local male sheep with mean Initial Body Weight (IBW) of 18 ±1.55 kg (mean ± SD) were used for the experiment. The study was conducted using randomized complete block design and sheep were blocked into six based on their IBW. Sheep within a block were randomly assigned to treatments. The experiment had 90 days feeding trial and 7 days digestibility trial after 15 and 3 days acclimatization period, respectively. The amount of supplements offered was 300 (T_1), 330 (T_2), 360 (T_3) and 280 (T_4) g/day on DM basis, each calculated to supply 73.6 g/day Crude Protein (CP).

Results:

Hay intake in T_1, T_2 and T_4 (397-400 ±1.44g/day) were significantly ($P < 0.001$) higher than T_3 (375±1.44 g/day). Total DM intake was in the order of $T_2 = T_3 > T_1 > T_4$ ($p<0.001$) (698, 730, 735 and 677 g/day for T_1, T_2, T_3 and T_4, respectively. Digestibility of CP was in the order of $T_1 > T_2 > T_4 > T_3$ ($p<0.001$), while the value in T_2 differed only with T_3 (75.6, 73.4, 60.2 and 67.9 for T_1, T_2, T_3 and T_4, respectively). Average Daily Gain (ADG) was 50, 45, 38 and 42 g/day for T_1, T_2, T_3 and T_4, respectively and differed only between T_1 and T_3. The partial budget analysis indicated that, sheep supplemented with *Atella* returned higher net income (5.46 US$) than T_1 (1.93 US$), T_3 (2.56 US$) and T_4 (3.2 US$); similarly, MRR was also higher in T_2 (93.7%) compared to T_3 (56.1%) and T_4 (50.4%).

Conclusion:

Sheep producers can use the supplement feeds in the order of T_2, T_4 and T_3, respectively, based on their availability.

Keywords: *Atella*, Digestibility, *Faidherbia albida*, Intake, Performance, Sheep.

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1. INTRODUCTION

Acute shortage of feed and very poor quality of the available feeds during the dry season are the prime limiting factors for increasing the production and productivity of small ruminants in most agro-ecological zones of Ethiopia [1]. Thus, supplementation of commercial concentrates, herbaceous and fodder trees legumes usually improve the supply of protein, which is limited in fibrous feeds, and this, in turn, increases animal productivity [2, 3].

Supplementation of high producing animals fed low quality feeds with agro-industrial byproducts, which are rich in

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protein and/or energy contents or both and low in fiber content, enables them to perform well due to higher nutrient density to correct the nutrient deficiencies in the basal diet [4, 5]. However, agro-industrial by-products and improved forages are mainly used for dairy, fattening and commercial poultry production, and the scope for their wider use by smallholder producers is low due to availability and price [3 - 5]. Hence, supplementation of easily accessible and year-round available multipurpose trees and non-conventional feeds instead of the expensive concentrate feeds can be a possible option to alleviate protein deficiency in poor quality feeds during periods of feed scarcity [6].

Non-conventional by-products such as traditional brewery or liquor residues (locally called *Atella*) are widely used by livestock rearing farmers, because of their low cost and accessibility in most household localities [7]. Moreover, *F. albida* and *S. sesban* are among the browses widely used for supplementation purposes. *F. albida* can serve as a good and cheap source of plant protein supplement to support animal performance because of its higher CP content [8] and improved total intake and apparent digestibility of DM and growth performance than un-supplemented sheep [9 - 11].

Currently, because of their wider availability and distribution, these feeds are serving to bridge the gap in feed supply in times of feed scarcity, especially for small ruminants. However, information on the comparative supplementation effect of locally available protein source feeds (*Atella, F. albida* and *S. sesban* leaves) with those commercially produced concentrate feeds (mixtures of wheat bran and sesame seed cake) on the performance of growing local sheep is not available. Therefore, the objective of this study was to compare the effect of supplementation with is onitrogenous levels of concentrate mixture, *Atella*, *F. albida* and *S. sesban* leaves on feed intake, digestibility and body weight change of sheep fed hay basal diet as well as to determine the economic profitability of treatment diets.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted at Shire Endaslassie, North-West Zone of Tigray, which is located 279 Km distance from Mekelle, the capital city of the Tigray region. Shire Endaslassie is located at 14 06` to 14 07`N latitudes and 38 16' to 38 17'E longitudes and an altitude of 1953 meters above sea level with average annual temperature and rainfall of 25C and 850 mm, respectively.

2.2. Management of Sheep

Twenty-four yearling intact male sheep with an average initial body weight of 18 ± 1.55 kg (mean ± SD) were used to conduct the study. Quarantine of sheep in the experimental area was done for 21 days. Moreover, sheep were sprayed and de-wormed against external and internal parasites, respectively; and vaccinated against the diseases prevailing in the area.

2.3. Feed Preparation

Hay from Natural pasture was used as a basal diet. Concentrate mixture (75% wheat bran and 25% sesame seed cake) was also purchased from Shire Endaslassie.. *Atella* was collected from traditionally "*Tella*" brewing individuals in Shire Endaslassie, which was prepared from finger millet and the wet *Atella* was dried for 3-4 consecutive days by the sun. The leaves of *F. albida* and *S. sesban* were collected by hand stripping and air-dried for 2-3 days.

2.4. Experimental Design and Dietary Treatments

The experiment was conducted using Randomized Complete Block Design (RCBD) and based on their Initial Body Weight (IBW), sheep were blocked into six blocks of four sheep each and sheep within a block were assigned randomly to one of the four treatment diets.

Based on the research findings of Zemichael and Solomon [12] for Arado sheep, the amount of concentrate mixture in this study was determined to be 300g on a Dry Matter (DM) basis. The supplement for the other three treatments was on an isonitrogenous basis. Samples of treatment feeds were analyzed for DM and Crude Protein (CP) content before the start of the experiment to determine the amount of the experimental rations, as given in Table **1**.

Table 1. Dry matter and crude protein content of treatment feeds.

Supplement Feeds	Feed Composition	
	%DM	%CP on a DM Basis
Concentrate mixture	93.47	24.53
Atella	93.82	22.32
F. albida	94.22	20.28
S. sesban	93.09	26.37

Thus, the 300 g concentrate mixture supplied 73.6 g/day CP on a DM basis. For sheep in the other three treatments, 330g DM *Atella*, 360g DM *F. albida* leaf and 280g DM *S. sesban* leaf were offered daily to supply the same amount of CP on the isonitrogenous basis (*i.e*., 73.6 g/day). The layout of the experimental treatments was:

T_1 = Hay *ad libitum* + 300 g DM concentrate mixture

T_2 = Hay *ad libitum* + 330 g DM sun-dried *Atella*

T_3 = Hay *ad libitum* + 360 g DM *Faidherbia albida* leaf

T_4 = Hay *ad libitum* + 280 g DM *Sesbania sesban* leaf

2.5. Measurements and Laboratory Analysis

2.5.1. Feeding Trial

Sheep were acclimatized to the experimental diets and environment for 15 days, and the feeding trial continued for 90 days. Basal feed, salt block and water were available *ad libitum* to the sheep. Supplementary feeds were offered twice a day at 0800 and 1700 hours. The amount of feed offered and refused for each sheep was recorded daily throughout the experimental period. Daily feed intake of experimental animals was calculated on a DM basis as the difference between the feed offered and refused. Samples of feed offered were collected daily and samples of feed refused were collected per animal and pooled overtreatment, and sub-sampled for chemical analysis.

2.5.2. Body Weight Change

The initial and final body weights of the sheep were measured using the suspended weighing balance at the beginning and end of the experiment, respectively for two consecutive measurings after overnight fasting, which was done in the morning before the provision of feed and water. Body Weight Changes (BWC), Average Daily Gain (ADG) and Feed Conversion Efficiency (FCE) are calculated as:

$$\text{BWC} = \text{Final Body Weight (FBW)} - \text{Initial Body Weight (IBW)}$$

$$\text{ADG} = \frac{\text{FBW} - \text{IBW}}{\text{Number of feeding days}}$$

$$\text{FCE} = \frac{\text{ADG (g)}}{\text{Daily DMI (g)}}$$

Where: DMI= Dry matter intake

2.5.3. Digestibility Trial

A digestibility trial was conducted after completion of the feeding trial. All sheep were harnessed with fecal collecting bags to collect faeces for digestibility determination. Sheep were allowed to acclimatize to the faecal collecting bags for 3 days and this was followed by a collection of feces for 7 days. The collected feces were weighed daily and 20% of the daily feces voided by each animal was sampled and pooled over the collection period for each sheep separately and stored in a deep freezer (-20^{o}C) using plastic bags. At the end of the digestibility trial, the collected fecal samples were thoroughly mixed, and 10% of the total collected sample from each animal was sub-sampled, weighed, partially dried at 60°C for 72 hours, ground and stored in airtight polyethylene plastic bags pending chemical analysis. During the digestibility period, hay offered and refused was recorded daily and samples from feed offered and refusals from each animal were taken daily to make a composite sample. The apparent digestibility of DM, OM, CP, NDF, and ADF was determined by the following equations:

$$\text{Apparent digestibility (\%)} = \frac{\text{DM (Nutrient) intake} - \text{Fecal DM (Nutrient) output}}{\text{DM (Nutrient) intake}} \text{ X } 100$$

Where: DM = dry matter

2.5.4. Chemical Analysis

All representative samples of the daily feed offer and refusals during the feeding and digestibility trial and partially dried fecal samples were ground to pass through 1mm screen for the chemical analysis of Dry Matter (DM), ash and Kjeldahl N following the procedures of AOAC [13]. The Crude Protein (CP) was determined by %N*6.25, and OM was estimated by subtracting ash from 100. The Neutral Detergent Fiber (NDF) and acid detergent fiber (ADF) contents for offered and refused feeds and feces samples and Acid Detergent Lignin (ADL) for offered feed samples were analyzed following the procedures of Van Soest and Robertson [14]. The energy value of the treatment feeds was also estimated according to McDonald *et al*. [15] as Metabolizable energy (MJ/kg DM) = 0.016 * DOMD; where DOMD being gram digestible OM intake per kilogram DM.

2.6. Partial Budget Analysis

The partial budget analysis was performed to evaluate the economic profitability of the treatment feeds using the procedures of Upton [16]. The analysis involved the calculation of the variable costs of sheep, feeds and benefits gained from the result. Purchasing and selling prices of sheep, purchasing price of the hay, concentrate mixture, *Atella* and the labor cost for *F. albida* and *S. sesban* leaves collection were recorded. Other expenses such as the cost of transport (sheep and feed), mineral licks, housing, labor (feeder and cleaner) and veterinary services, which was common for all treatments, were not considered in the calculation of partial budget analysis. The selling price of each sheep was determined by inviting well experienced three sheep dealers, who know the prevailing market price of sheep in the Shire Endaslassie market. Therefore, the average price determined by the dealers was used as the selling price of the sheep. The cost of feeds was computed by multiplying the actual DM intake of feed for the whole feeding period (90 days) with the current purchase price of each treatment feeds. The total cost associated with each sheep during the experimental period in each treatment was added and the average was taken as a Total Variable Cost (TVC). The Marginal Rate of Return (MRR) measures the increase in Net Return (ΔNR) associated with each additional unit of expenditure (ΔTVC). The change in a Total Variable Cost (ΔTVC), Total Return (TR), change in Total Return (ΔTR), Net Return (NR), change in Net Return (ΔNR) and Marginal Rate of Return (MRR) were calculated as follows:

$$\text{TR} = \text{SP} - \text{PP}$$

$$\Delta\text{TR} = \text{TR of } T_2, T_3 \text{ and } T_4 - (\text{TR of } T_1)$$

$$\text{NR} = \text{TR} - \text{TVC}$$

$$\Delta\text{TVC} = \text{TVC of } T_2, T_3 \text{ and } T_4 - (\text{TVC of } T_1)$$

$$\Delta\text{NR} = \Delta\text{TR} - \Delta\text{TVC}$$

$$\text{MRR (\%)} = \frac{\Delta\text{NR}}{\Delta\text{TVC}} \text{ X } 100$$

Where; SP = Selling price of sheep; PP = purchasing price of sheep

2.7. Statistical Analysis

Data obtained from intake, digestibility and body weight change were subjected to analysis of variance using the General Linear Model procedure of SAS version 9.2 [17]. Tukey`s Studentized range test was used to separate treatment means. The model used for data analysis was:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

Where; Y_{ij} = response variable, μ = overall mean, T_i = treatment effect, B_j = block effect, e_{ij} = random error

3. RESULTS AND DISCUSSION

3.1. Chemical Composition of the Experimental Feeds

The chemical composition of treatment feeds is given in Table **2**. Hay had lower CP and higher NDF and ADF content than the supplemental feeds. Although *F. albida* was slightly lower and that of *S. sesban* was a bit higher in CP content, the four supplemental diets are generally rich sources of CP. However, the NDF and ADF levels in *S. sesban* were lower than the other supplemental diets, and the ADL content was lower for the concentrate mixture.

Table 2. Chemical Composition of Treatment Feeds.

Feed Offer	Chemical Composition (% for DM and % DM for Others)					
	DM	OM	CP	NDF	ADF	ADL
Hay	94.35	90.00	7.56	74.42	46.55	11.46
CM	93.47	93.33	24.53	40.24	18.26	4.13
Atella	93.82	92.67	22.32	49.92	24.32	9.89
Faidherbia albida	94.22	92.87	20.28	56.13	37.18	16.24
Sesbania sesban	93.09	86.35	26.37	22.43	19.64	8.78
Hay Refusal						
Hay (T_1)	94.11	91.93	4.25	77.08	49.12	
Hay (T_2)	94.65	91.92	4.73	76.53	48.56	
Hay (T_3)	94.81	92.33	4.66	75.94	49.43	
Hay (T_4)	95.23	92.25	5.01	76.71	47.85	

CM = concentrate mixture (75% wheat bran and 25% sesame seed cake); T_1 = Hay *ad libitum* + 300 g DM CM /day; T_2 = Hay *ad libitum* + 330 g DM *Atella*/day; T_3 = Hay *ad libitum* + 360 g DM *F. albida*/day; T_4 = Hay *ad libitum* +280 g DM *S.sesban*/day

The CP content of the refusals of the basal diet observed in the present study was lower by 43.8, 37.4, 38.4 and 33.7% in T_1, T_2, T_3 and T_4, respectively compared to the CP content of hay offered. Conversely, hay refusals in all treatments had relatively higher NDF and ADF content than the offered. The lower CP and higher cell wall fiber content in hay refusals as compared to the offered might be associated with selective feeding of sheep for more palatable and nutritious parts of hay than the unpalatable and lignified parts of the feed.

The CP content of the hay used in this study was comparable with [18]; but lower [19, 20] and higher [21, 22] CP values as compared to the value noted in this study were also reported. The differences in the nutritive value of hay, including CP content, could be attributed to differences in species composition of the harvested hay, stage of maturity during harvesting period and the growing environment [23].

The CP content of concentrate mixture used in this study appeared to be comparable to 26.14% CP content noted by Zemichael and Solomon [12]. Similarly, the NDF, ADF and ADL values of the concentrate mixture used in this study were comparable to 36.84% NDF, 12.12% ADF and 2.67% ADL reported by the same author.

The CP content of *Atella* used in this study is comparable to 21%, 21.2% and 21.8% [7, 11, 24], respectively; and is higher than 10.2% [25]. Similarly, NDF and ADF contents of *Atella* are relatively in agreement with 60.2% and 22.5%, and 54% and 29% noted by Wondatir *et al*. [24] and Solomon [7], respectively; but higher than 32.7% NDF and 16.4% ADF reported by Guesh and Mengistu [25]. The ADL content of *Atella* is also comparable with 11% [7, 24]; but slightly higher than 5.9% and 7.3% [11, 25], respectively. Differences among results in *Atella* nutrient composition might be associated with differences in the ingredients used for *Tela* preparation and the methods of preparation followed by communities in different areas.

The ash content of *F. albida* was within the range of 5.7-7.2% reported by Solorio and Solorio [26], and Shayo and Uděn [27], but lower than 9.49% [9]. The CP content of *F. albida* in this study is in agreement with the findings of Takele and Getachew [8] and Gebreselassie *et al.* [9] who reported 19.5% and 20.8% CP, respectively; but lower than 25.3% CP [28]. The NDF, ADF and ADL content of *F. albida* in the current study are similar to the results of Gebreselassie *et al.* [9], who reported 51.3% NDF, 35.6% ADF and 15.6% ADL content. The differences in the nutritional composition of *F. albida* among studies may be associated with different factors including the age of the tree, maturity stage of *F. albida* leaves and twigs, the plant parts used for chemical analysis and feeding, the season of sample collection, soil fertility and other climatic factors. In line with this, Patricia [28] demonstrated considerable variations in NDF and ADF content of *F. albida* leaves in different seasons.

The CP content of *S. sesban* leaf in this study is within the range of 23.8-31.7% indicated by Mekoya [3]. The value was also comparable with 24.8% noted by Manaye *et al.* [29]; but slightly higher than the 23.9% and 22.1-23.1% reported by Sabra *et al.* [30] and Solomon *et al.* [31], respectively. On the other side, higher values of *S. sesban* leaf CP than the one in the present study were recorded by Debela *et al.* [32] who reported 29.7% CP. The NDF and ADF content of *S. sesban* leaf in this study is lower than 39.9% and 29.9% [32]. On the other hand, ADL content of *S. sesban* noted in this study was in agreement with 4% and 5.1-5.7% indicated by Mekoya [3] and Debela *et al.* [32], respectively; but lower than the 27.2-28.2% noted by Solomon *et al.* [1]. All the above differences in nutritional composition of *S.sesban* may be attributed to differences in accession, stage of plant growth, cutting frequency and harvesting regimen, soil type and fertility status [3], and parts of the plant (leafs, twigs, whole forage and green pods, *etc*.) included during feeding and chemical analysis [32].

3.2. Dry Matter and Nutrients Intake

The daily DM and nutrient intake of local sheep are given in Table **3**. The DM intake of supplements were 300, 330, 360 and 280 g DM/day for concentrate mixture (T_1), *Atella* (T_2), *F. albida* (T_3) and *S. sesban* (T_4), respectively (each calculated to give 73.6 g CP on isonitrogenous basis) and the intake was 100% of the supplement offer for all treatments. This indicates the variation in intake among the supplements was because of differences in CP content. The hay DM intake was lower ($P < 0.001$) for T_3 as compared to the other three treatments that had similar values among each other. The lower hay DM intake for T_3 could be associated with the relatively greater amount of supplement DM fed to this group that might have resulted in a substitution effect on hay intake.

Total DM and OM intakes appeared to be highly impacted by the supplemental DM intake in this study. As such total DM and OM intakes were the lowest for T_4, intermediate for T_1 and highest for the other two treatments ($P < 0.001$). Total NDF intake was in the order of $T_3 > T_2 > T_1 > T_4$ ($P < 0.001$) and that of ADF intake was in the order of $T_3 > T_2 > T_4 > T_1$ ($P < 0.001$), both of which appeared to be associated with the level of NDF and ADF in the supplemental diets.

Table 3. Daily dry matter and nutrient intakes of local sheep fed hay and supplemented with a concentrate mixture, *Atella, Faidherbiaalbida* and *Sesbania sesban* leaves.

Intake (g/day)	Treatment Feeds					
	T_1	T_2	T_3	T_4	SEM	SL
DM						
Hay DM	398^a	400^a	375^b	397^a	1.4	***
Supplement DM	300	330	360	280	-	-
Total DM	698^b	730^a	735^a	677^c	1.4	***
Nutrient Intake (g/day)						
OM	631.9^b	660.1^a	664.6^a	593.4^c	1.38	***
CP	104^a	104^a	102^b	104^a	0.11	*
NDF	406.7^c	454.1^b	474.6^a	350.7^d	1.18	***
ADF	231.8^d	260.3^b	299.4^a	236.5^c	0.78	***
ME (MJ/day)	8.5	8.7	7.3	7.5	0.30	ns

$^{a-d}$ mean values in a row having different superscripts differ significantly; *** = significant at $P < 0.001$; ns= not significant; SL= significance level; SEM = standard error of the mean; ME = metabolizable energy; MJ = mega joule; T_1 = Hay *ad libitum* + 300 g DM CM /day; T_2 = Hay *ad libitum* + 330 g DM *Atella*/day; T_3 = Hay *ad libitum* + 360 g DM *F. albida*/day; T_4 = Hay *ad libitum* +280 g DM *S.sesban*/day

Generally, the total DM intake of sheep in this study was about 700 g/day, which was comparable with the results of many studies [19, 33 - 35] with different Ethiopian sheep breeds. Conversely, lower total DM intake [9, 25] and higher total DM intake [21, 36] by sheep as compared to the one noted in this study has been reported. Of course, variations in the type and amount of the basal diet as well as the supplement, breed of sheep, growth stage of the animal and other similar factors may contribute to differences in DM intake observed among the studies.

Although T_3 had slightly lower CP intake as compared to the other three treatments, the numerical difference is not as such too big. This slight variation in CP intake is associated with differences in the basal diet DM intake. The estimated Metabolizable Energy (ME) intake was similar among the treatments in this study. The ME requirement for a 20 kg lamb gaining 50-150 g/day is 3.7-6.4 MJ/day for diets with a metabolizability of 0.65 [15]; and according to ARC [37] the maintenance and growth (50-200 g gain) ME requirement for the same weight lamb is 4.5-7.9 MJ/day. Thus, based on these assumptions the estimated ME of the treatment diets (7.5-8.7 MJ/day) in the present study satisfies the energy requirement for maintenance and growth (38-50 g/day gain) of the sheep.

3.3. Apparent Dry Matter and Nutrient Digestibility

The mean apparent digestibility of DM and nutrients in local sheep are given in Table **4**. Apparent digestibility of DM was similar ($P > 0.05$) among treatments. The apparent digestibility of CP was lowest for T_3 and values for T_1 were greater than those in T_4 but similar to T_2.

Table 4. Dry matter and nutrient digestibility of local sheep fed hay and supplemented with a concentrate mixture, *Atella, Faidherbiaalbida* and *Sesbania sesban* leaves.

Apparent	Treatment Feeds				SEM	SL
Digestibility (%)	T_1	T_2	T_3	T_4		
DM	67.5	65.6	61.1	63.8	1.65	ns
OM	75.7^a	73.5^a	59.3^b	69.3^{ab}	2.75	**
CP	75.6^a	73.4^{ab}	60.2^c	67.9^b	1.63	***
NDF	67.2^a	65.7^a	50.4^b	61.5^a	1.99	***
ADF	59.6^a	58.4^a	40.1^b	51.8^a	2.23	***

Digestibility of OM was lower for T_3 as compared to T_1 and T_2 ($P < 0.01$), but the value for T_4 was similar to all other treatments. Digestibility of NDF and ADF was lower ($P < 0.001$) for T_3 as compared to the other treatments. The lower apparent digestibility of CP, OM, NDF and ADF in *F. albida* supplemented sheep (T_3) may be associated with the higher fiber (ADF, NDF and ADL) content and the possible presence of anti-nutritional factors like tannins in the feed, which might have affected the availability of these nutrients for the sheep. The lack of significant differences in the apparent digestibility of NDF and ADF in most of the treatments (T_1, T_2 and T_4), except in T_3, are in agreement with the findings of Kaitho and Kariuki [38], who concluded that supplementation had little or no effect on fiber digestibility. Moreover, many researchers also found no significant effect of supplementation on the apparent digestibility of NDF and ADF [36, 39].

Improved digestibility values of DM, OM and CP with concentrate supplementation is in agreement with the findings of Kaitho and Kariuki [38]. The OM and CP apparent digestibilities of the group supplemented with *Atella* (T_2) are within the range of 73.6-79% OM and 69.6-76% CP digestibility reported by Mulu *et al.* [40] for Wogera sheep fed hay basal diet and supplemented with different proportions (100-300 g/day) of brewery dried grain. Apparent digestibilities of DM, OM, CP and ADF of the group supplemented with *Atella* in this study are somewhat comparable to the digestibilities of these nutrients reported [11], for lambs fed finger millet straw and supplemented with 100% *Atella*, and mixtures of 70% *Atella* and 30% Noug seed cake. Conversely, higher digestibility of CP (75.5-82.2%) than the result in T_2 was also reported by Guesh and Mengistu [25] for Black Head Ogaden sheep supplemented with urea-*Atella* block (30-50% ratio of *Atella* in the block).

3.4. Body Weight Change and Feed Conversion Efficiency

The Initial (IBW) and Final Body Weight (FBW), Bodyweight Change (BWC), Average Daily Body Weight Gain (ADG) and Feed Conversion Efficiency (FCE) of local sheep are presented in Table **5**. In the present study, Initial Body Weight (IBW) was similar (P > 0.05) among treatments. However, treatments differ in FBW, BWC, ADG and FCE (P < 0.05). Sheep that received a commercial concentrate mixture (T_1) had higher FBW and FCE (P < 0.01), BWC and ADG (P < 0.05) than those supplemented with *F. albida* leafs (T_3), but differences in BWC, ADG and FCE among T_1, T_2 and T_4 were not significant (P > 0.05).

Table 5. Body weight change and feed conversion efficiency of local sheep fed hay and supplemented with concentrate mixture, *Atella, Faidherbia albida* and *Sesbania sesban* leaves.

Parameters	Treatment Feeds				SEM	SL
	T_1	T_2	T_3	T_4		
Initial body weight (kg)	18.00	18.03	18.05	18.02	0.130	ns
Final body weight (kg)	22.5^a	22.11^{ab}	21.45^b	21.79^b	0.160	**
Body weight change (kg)	4.50^a	4.08^{ab}	3.40^b	3.78^{ab}	0.210	*
ADG (g/day)	50^a	45^{ab}	38^b	42^{ab}	2.3	*
FCE (g ADG/g TDMI)	0.07^a	0.06^{ab}	0.05^b	0.06^{ab}	0.003	**

$^{a,\,b}$ mean values in a row having different superscripts differ significantly; ns= not significant; *= significant at P < 0.05; **= significant at P < 0.01; SL= significance level; SEM = Standard error of the mean; TDMI= total dry matter intake; T_1 = Hay *ad libitum* + 300 g DM CM /day; T_2 = Hay *ad libitum* + 330 g DM *Atella*/day; T_3 = Hay *ad libitum* + 360 g DM *F. albida*/day; T_4 = Hay *ad libitum* +280 g DM *S.sesban*/day

The performance of ruminants is influenced by the level of nutrients in the feed [41]. The higher performances (FBW, BWC and ADG) of sheep in T_1 as compared to sheep in T_3 might be due to the higher energy density, lower cell wall fiber contents, higher total and digestible CP intake and higher nutrient digestibility in the concentrate mixture than the *F. albida* containing diet. Moreover, the lower growth rates in this study in sheep that received *F. albida* leaves than sheep supplemented with concentrate mixture may be in part attributed to anti-nutritional factors like tannins found in the leaf of *F. albida*. This is supported by the research findings of Ibrahim and Tibin [42] who reported that as the level of *F. albida* pod supplementation increased from15% (157.5 g/day) to 30% (306 g/day) and 45% (454.5 g/day), the ADG was decreased from 55 to 44 and 39 g/day, respectively, which could be due to the decreased efficiency of feed utilization associated with an increase in the intake of antinutritional factors. However, the results of BWC, ADG and FCE in T_1, T_2 and T_4 were not significantly different (P > 0.05) from each other. There were also similarities among T_2, T_3 and T_4 in BWC, ADG and FCE, which reflected that the supplements were comparable in their potential to supply nutrients to improve the weight gains of sheep. Several studies on small ruminants in Ethiopia [8, 9, 11, 12, 19, 25, 33, 40] showed a significant change in body weight gain when sheep on poor quality roughages are supplemented with diets rich in energy or protein or both.

The ADG of sheep in T_2 was within the range of 31-55.5 g/day gain indicated by Guesh and Mengistu [25] for Black Head Ogaden sheep fed hay and supplemented with urea-*Atella* block (30-50% *Atella* ratio). Similarly, Wogera sheep fed grass hay and supplemented with 100 g brewers dried grain gain 44.4 g/day [21], which is also very close to the present study (45 g/day) in T_2. Moreover, a comparable result (51 g/day) to the current study was also recorded by Almaz *et al.* [11] for sheep fed finger millet straw and supplemented with sole *Atella.* In agreement with the current study in T_2, Emebet [43] also reported 41.8 and 44.6 g/day gain for Black Head Ogaden sheep fed haricot bean haulms and supplemented with wheat bran and brewers dried grain mixture (2:1) and sole brewers dried grain, respectively. However, higher gains of 56.4 g/day; and 56.7, 63 and 60 g/day than the current result in T_2 were recorded by Emebet [43] for sheep supplemented with wheat bran and brewers dried grain mixture (1:2); and Almaz *et al.* [11] for sheep groups supplemented with mixtures of 70% *Atella* and 30% NSC, 70% NSC and 30% *Atella* and sole NSC, respectively.

The mean daily gain of sheep in T_3 (38 g/day) is also within the range of 28-42 g/day stated by Takele and Getachew [8] for Horro lambs fed vetch haulm and supplemented with wheat bran and *A. albida* leaf mixtures, and *A. albida* leaf alone. Similarly, a gain of 36 g/day reported by Gebreselassie *et al.* [9] for sheep fed barley straw and supplemented with *F. albida* leaf alone is very close to the current results in T_3.

The mean daily gain (42 g/day) of sheep in T_4 in the present study is slightly higher than the findings of Solomon *et al.* [31], who reported 33.4-35.7 g/day gain for Menz sheep fed *teff* straw and supplemented with sole *S. sesban*; but it is comparable to 38.4 and 40.7 g/day gain for sheep groups supplemented with mixtures of *S. sesban* and *A. angustissima*, and mixtures of *S. sesban* and *Leucaena pallida*, respectively in the same experiment. Contrary to the ADG in T_4, Manaye *et al.* [29] reported higher ADG (83.3-99.8 g/day) for local sheep fed mixtures of 70-90% Napier grass and 10-30% *S. sesban.*

3.5. Partial Budget Analysis

The partial budget analysis for the feeding trial is presented in Table **6**. Sheep received *Atella* (T_2) supplement returned higher net income followed by sheep fed *S. sesban* (T_4) and *F. albida* (T_3); and the lowest net return was scored for sheep supplemented with concentrate mixture (T_1). The differences in total return, net return and marginal rate of return (MRR) among the treatments are mainly associated with the differences in the selling price of the sheep and differences in intake and cost of the supplement feed among the treatments.

The MRR Table **5** implies that each additional unit of one US$ per sheep cost increment resulted in one US$ and an additional 0.937, 0.561 and 0.504 US$ benefit for T_2, T_3 and T_4, respectively as compared to the sheep in T_1. Therefore, from this study, it can be said that, when available, supplementation of sheep with sun-dried *Atella* (T_2) is recommended as economically profitable considering the net return and MRR. However, for areas where availability of *Atella* is scarce, supplementation of either *S. sesban* or *F. albida* or both, especially for smallholder farmers, who are involved in integrated agroforestry farming systems, can be recommended because of their multipurpose uses.

Table 6. Partial budget analysis of local sheep fed hay and supplemented with a concentrate mixture, *Atella, Faidherbia albida* and *Sesbania sesban* leaves.

Parameter	Treatments			
	T_1	T_2	T_3	T_4
Number of animals	6	6	6	6
Purchase price of sheep (US$/head)	14.72	14.72	14.72	14.72
Total grass hay intake (kg/head)	44.75	45.02	42.19	44.68
Total supplement feed intake (kg/head)	27.00	29.70	32.40	25.20
Total cost of grass hay (US$/head)	1.50	1.51	1.41	1.49
Total cost of supplement feed (US$/head)	4.63	0.85	3.58	2.11
Total variable cost (TVC in US$)	6.12	2.36	4.99	3.60
Change in total variable cost (ΔTVC in US$)		-3.76	-1.14	-2.52
Selling price of sheep (SP in US$/ head)	22.77	22.53	22.27	21.52
Total return (TR in US$)	8.05	7.82	7.55	6.80
Change in total return (ΔTR in US$)		-0.24	-0.50	-1.25
Net return (NR in US$)	1.93	5.46	2.56	3.20
Change in net return (ΔNR in US$)		3.53	0.64	1.27
MRR% (ΔNR/ΔTVC)		-93.74	-56.06	-50.36

US$ = United States Dollar; T_1 = Hay *ad libitum* + 300 g DM CM /day; T_2 = Hay *ad libitum* + 330 g DM *Atella*/day; T_3 = Hay *ad libitum* + 360 g DM *F. albida*/day; T_4 = Hay *ad libitum* +280 g DM *S.sesban*/day

CONCLUSION

Generally, the total intake of DM and OM was higher in T_2 and T_3 than T_1 and T_4. Similarly, the intake of NDF and ADF was higher in T_3 than others. However, the total CP intake and apparent digestibilities of DM, CP, NDF and ADF for T_3 were slightly lower than the other three treatments. Results of body weight parameters in the current finding outlined that, *F. albida* leaf as a sole supplement is comparable to the supplementary value *S. sesban* and *Atella* to improve sheep performance. This leads us to the conclusion that *F. albida* leaf can substitute the feeding value of improved tree legumes and protein-rich non-conventional feeds. Similarly, *Atella* and *S. sesban* can also replace the highly valued commercial concentrate feeds because of their similar performance effects on local sheep in this experiment. Results of the partial budget analysis also demonstrated that sheep supplemented with *Atella* (T_2) returned higher net income than T_1, T_3 and T_4. The MRR was also higher in T_2 compared to T_3 and T_4. Thus, it is economically feasible and advantageous to use the locally available non-conventional feeds (*Atella*), indigenous and improved multipurpose trees and shrubs (*F. albida* and *S. sesban* leaf) as supplements to improve the productivity of sheep.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study received ethical approval from the ethical review committee of Aksum University, College of Agriculture, Ethiopia.

HUMAN AND ANIMAL RIGHTS

No humans were used in this research. The reported experiments were in accordance with the standards set forth in the 8th Edition of Guide for the Care and Use of Laboratory Animals (http://grants.nih.gov/grants/olaw /Guide-for-thecare-and-use-of-laboratory-animals.pdf) published by the National Academy of Sciences, The National Academics Press, Washington DC, United States of America.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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CONFLICT OF INTERESTS

The author declares no conflict of interest, financial or otherwise.

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