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Growth Performance and Carcass Characteristics of Arsi-Bale Lambs Fed on Effective Microbes and Urea-Molasses-Treated Tef Straw

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Abstract

This experiment evaluated the growth performance and carcass characteristics of 30 Arsi-Bale yearling male sheep (initial body weight: 18.1 ± 1.6 kg) fed diets based on molasses and Effective Microbe (EM)-treated teff straw. Using a randomized complete block design based on initial weight, sheep were assigned to five dietary treatments for 90 days: natural pasture grass hay ad libitum (T1), untreated teff straw ad libitum (T2), urea-molasses-treated teff straw ad libitum (T3), and teff straw treated with either 2.5% (T4) or 5% (T5) activated EM solution ad libitum. All groups received 400 g of concentrate supplementation daily. Chemical analysis revealed crude protein (CP) contents of 3.5%, 2.1%, 4.2%, 1.7%, and 2.1% for T1, T2, T3, T4, and T5, respectively. Total dry matter intake was significantly higher ($P < 0.01$) in the grass hay group (T1) than in all teff straw groups. Similarly, CP intake was higher in T1 and T3 compared to T2, T4, and T5. Total weight gain and average daily gain were significantly greater ($P < 0.05$) in T1 than in T2 and T3. Conversely, feed conversion efficiency did not differ significantly ($P > 0.05$) across treatments. Carcass parameters, including slaughter weight, hot and cold carcass weights, ribeye area, dressing percentage, and tissue proportions (lean meat, fat, bone, and trimmings), remained unaffected ($P > 0.05$) by the diets. Ultimately, treating teff straw with urea-molasses or EM did not improve its nutritive value. Therefore, utilizing untreated teff straw combined with 400 g of concentrate supplement is recommended for fattening lambs during seasonal grass hay scarcity.

Introduction

In Ethiopia, indigenous sheep breeds provide farm households with cash income, meat, fiber, manure, and other services (e.g., skin). Compared to cattle, sheep have shorter production cycles, faster growth rates, ease of management, and require lower capital investments (Tadesse et al. 2015). Additionally, sheep are crucial for producing export goods, such as skins and live animals, which generate foreign income. Despite the large number of breeds and the importance of sheep in Ethiopia, their productivity is low owing to several factors. Feed shortages, in terms of quality and quantity, are the most important problems. According to CSA (2025), the major feed resources in Ethiopia are natural pastures, crop residues, agro-industrial byproducts, improved forages, and nonconventional sources. However, the dominant ruminant diets in the country are generally based on roughage feeds with low digestibility and deficiencies in protein, minerals, and vitamins. These characteristics maintain a low intake and digestibility, resulting in a reduced potential for productivity.

The main cause of feed scarcity is the decrease in grazing land due to various factors. As a result, one of the numerous strategies that need to be addressed is the construction of the best zero-grazing feeding system (EIAR, 2018). Developing the best feed for indoor sheep meat production is essential, especially if this activity is to be included in efforts to improve food security and create jobs. Indoor feeding of sheep with fresh or green hay is advantageous in many ways. However, grass hay-based sheep fattening is not frequently practiced nowadays because of the limited supply and high costs. Therefore, alternative feed options, such as crop residues, are becoming increasingly important as sources of roughage feed for ruminants. Teff straw is one of the most common feed resources for sheep. However, *teff* straw

requires improvement as its nutrient content is very low. Concentrate supplementation, urea-molasses, and effective microbes (EM) treatments are among the options to develop the best teff straw-based sheep meat production system.

The leaflet distributed by Woljeejii Agricultural Industry Private Company Limited, Bishoftu, Ethiopia, a well-known EM solution supplier, indicated that it is good to treat straw by activating the EM solution at 2.5% of the straw. However, based on this general information, it is imperative to approve this recommendation for specific straw and livestock types, which need to be evaluated using well-designed feeding trials. Different findings indicated different results of EM level application for straw treatment, and the company's baseline was not studied with specific animals. Treating crop residues with urea-molasses solution is another known option for improving crop residue utilization. Thus, further experiments must be conducted to compare the advantages of the EM and urea-molasses treatment techniques. Therefore, this experimental study was designed to determine the growth performance and carcass characteristics of Arsi-Bale sheep fed urea-molasses and effective microbe-treated tef straw-based feed packages.

Materials and Methods

Description of Study Area

The feeding trial was conducted at the Debre Zeit Agricultural Research Center in Ethiopia. The study area is located 47 km east of Addis Ababa at approximately 08°44' N latitude and 38°58' E longitude, with an altitude of 1860 m above sea level. The area receives an annual average rainfall of 1100 mm and has mean minimum and maximum temperatures of 8.9°C and 28.3°C, respectively. The area is characterized by fertile soil and is dominated by mixed crop and livestock production systems. The major crops grown in the area are *tef* (*Ergrostis tef)*, wheat, chickpea, and lentil. Cattle, sheep, and poultry are the major livestock raised in the study area (DZARC 2003).

Experimental Feeds and Feeding Management

The feed sources used in this experiment were local markets for grass hay, *Teff* straw, and concentrate feeds; the Wonji sugar factory for molasses; and the Woljeejii Agricultural Industry Private Company Limited for EM. The EM solution was activated by mixing 5% EM, 5% molasses, and 90% water in a 20 L container. The amount of activated EM solution used to treat *Teff* straw was 2.5% and 5% of *Teff* straw for T4 and T5, respectively. The EM solution-treated *Teff* straw was ensiled for 24 h in an airtight container. The urea-molasses solution was prepared from 5% urea, 10% molasses, and 85% water and used for 100 kg of straw. The urea-molasses-treated tef straw was ensiled for 3 weeks by mixing it with urea-molasses solution in an airtight container. The concentrate mix was composed of 69% wheat bran, 30% noug seed cake, and 1% salt on a DM basis to attain the CP level recommended by Ensminger (2002) for moderately growing lambs weighing 10–20 kg. All experimental animals were offered *ad*

libitum their respective treatment feed and supplemented with 400 g concentrate. Water was available to the experimental lambs at all times during the experiment, while the supplement was offered in two equal portions at 8:00 and 16:00 hours twice a day.

Experimental Animals and their Management

Thirty male Arsi-Bale yearling lambs were used as experimental animals. The experimental animals were purchased from local market. The age of the lambs was determined by asking the owner and based on their dentition (Elbeltagy et al., 2016). The lambs were treated with albendazole for endoparasites and ivermectin and cypermethrin for ectoparasites and were vaccinated against ovine pasteurellosis and sheep pox. The lambs were blocked based on their initial body weight into six blocks of five lambs each and placed in a well-ventilated experimental barn in individual pens with a feeding trough for natural grass hay and tef straw and plastic buckets for water and concentrate. The experimental lambs were allowed an adaptation period of 15 days before the actual data collection to adapt to the experimental diet and pens. The experimental lambs were carefully observed for the occurrence of any illness, and records were maintained for any physiological disorders during the entire experimental period.

Experimental Treatments and Design

The treatments were

T_1 = Natural pasture grass hay
T_2 = Untreated *teff* straw
T_3 = *Teff* straw treated with urea-molasses solutions
$T_{4=}$*Teff* straw treated with 2.5% activated EM solution
$T_{5=}$*Teff straw* treated with 5% activated EM solution

The experiment was conducted using a randomized complete block design (RCBD) with five treatments and six replicates. The lambs were divided into six blocks based on their initial body weight, and each lamb within each block was randomly assigned to one of five dietary treatments using a lottery method.

Feed Intake Measurements

The feeding trial was conducted for 90 days, following an acclimatization period of 15 days to allow the animals to adapt to the experimental diets and pens. The daily feed offered and the refusals were weighed for each lamb and recorded to ascertain feed consumption, calculated as the difference

between the feed offered and the refusals. Feed samples were collected for each treatment, while refusals were sampled per animal and aggregated per treatment over a period of 90 days. These samples were then thoroughly mixed and subsampled for chemical analysis.

Body Weight Measurements

The body weights of the lambs were measured initially at the beginning of the feeding trial and during the feeding period at 14-day intervals after overnight fasting before offering the daily ration using a 100 kg movable weighing scale with a precision of 0.5 kg throughout the experimental period. The changes in the body weight of the lambs were determined as the difference between the final and initial body weights. The average daily weight gain was calculated as the difference between the final and initial body weights of the lambs divided by the number of feeding days.

Feed Conversion Efficiency

Feed conversion efficiency (FCE) was used to determine the efficiency with which lambs convert feed into meat. It was determined as the average daily body weight gain divided by the average daily DM intake, according to Gulten et al. (2000). FCE = Daily body weight gain (g) / daily feed intake (g).

Carcass Parameters Evaluation

At the end of the feeding trial, the experimental sheep were fasted overnight, and 20 lambs were slaughtered to determine carcass characteristics. The skin was carefully flayed to avoid adherence of fat and muscle tissue. The skin was weighed with the legs below the fetlock joints. After flaying, the non-carcass components were recorded. The alimentary tracts were weighed full, and then the contents were emptied and reweighed to determine the weight of the contents by difference. The empty body weight (EBW) was calculated as the difference between the slaughter weight and gut contents. The hot carcass weight was estimated after removing the weight of the head, thorax, tail fat, skin, and leg below the hock and knee joints. The dressing percentage (DP) was computed as the proportion of hot carcass weight to slaughter weight. The carcass was split down the vertebral column into two sides as symmetrically as possible, weighed, and the left part was used for deboning and rib-eye muscle area (REA) determination. The dissection of muscle, bone, and fat and the trimming of each lamb were weighed and recorded (Dismas et al., 2013). The REA of each lamb was determined by tracing the cross-sectional area of the 12th and 13th ribs after cutting perpendicular to the backbone. The rib eye muscle area was traced first on transparent paper, then by counting the number of squares lying on the traced picture on the square paper and multiplying by the square area.

Feed Cost Analysis

The experimental feed costs were computed by multiplying the actual feed intake for 90 days with the current feed market price. The feed cost per unit of live weight gain was determined by dividing the cost of the ingredients for each treatment feed by the live body weight gain of the respective treatment.

Feed Sample Analysis

Experimental feed and refusal sample analyses were performed at the Debre-Zeit Agricultural Research Centre. The feed samples were partially dried at 60°C in a forced-draft oven for 48 h and ground to pass through a 1 mm sieve for chemical analysis. The DM, ash, and N contents were determined according to the AOAC (2005). Crude protein (CP) content was determined using the Kjeldahl procedure by multiplying N by 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed according to Van Soest and Robertson (1985). The organic matter (OM) content was calculated as the difference between the DM and ash contents.

Data Analysis

The data collected on feed intake, feed conversion efficiency, body weight change, and carcass parameters were subjected to one-way ANOVA using the General Linear Model (GLM) procedure of SAS. Duncan's Multiple Range Test (DMRT) was used to test the treatment means that significantly differed from each other. The model used was

$Yij = \mu + a_i + bj + e_{ij}$, where Y_{ij} is the response variable; μ is the Overall mean; a_i is the treatment effect; b_j is the block effect; e_{ij} is the random error

Results and Discussions

Nutrient Composition of Experimental Feeds And Refusals

The nutrient compositions of the experimental feeds and refusals are presented in Table 1. The CP content of the hay used in the current study was relatively comparable to that reported by Berhan and Asnakew (2015) and was lower than the CP content of 6.04%, 6.23%, and 6.8% reported by Tesama (2013) and Abadi *et al*. (2014), respectively. A neutral detergent fiber content above 55% has been reported to limit DM intake and directly interfere with animal productivity (Van Soest, 1985). In this regard, the NDF value (75.82%) of hay in the current study was of low quality. The untreated teff straw had a lower CP content (7%) than the minimum CP required for rumen microbial function (Van Soest, 1994); therefore, it had poor nutritional potential and could not fulfill the maintenance requirements of sheep.

The crude protein (CP) content of tef straw treated with 2.5% EM solution was lower than that of untreated straw. This may be attributed to the limited ensiling duration of 24 h and the small quantity of EM used. Specifically, the CP content in tef straw treated with 2.5% EM was 1.7%, which was lower than the 2.1% observed in straw treated with 5% EM, suggesting that increasing the amount of EM can enhance the CP content. The acid detergent fiber (ADF) content of untreated tef straw in this study was

similar to that reported by Kumsa and Eshetu (2018) and Ardeo and Musimba (2003), but lower than the 48.17% reported by Zewdie (2010). Additionally, tef straw treated with urea molasses had a higher CP content (4.18%) than untreated straw (2.1%). The improvement in the CP content of straw treated with urea molasses is attributed to the urea granules in the solution, which are often known for their higher concentrations of elemental nitrogen. Urea molasses treatment did not affect NDF content, but ADF and ADL were higher in the untreated teff straw. The hay and urea-molasses-treated teff straw had almost similar CP contents. Similarly, there was no difference in CP content between untreated *Tef* straw (2.1%) and effective microbe-treated Tef straw (1.7–2.1%).

Table 1
Chemical composition of experimental feed ingredients and refusal

Feed	**Chemical composition**						
	DM	**Ash**	**OM**	**CP**	**NDF**	**ADF**	**ADL**
Grass hay	89.8	8	81.8	3.7	75.8	57.9	13.16
Teff straw	87.5	5	82.5	2.1	79.7	46.2	7.3
Urea-molasses-treated straw	58.2	7	51.2	4.2	78.2	54.8	8.4
Treated straw with 2.5% EM	64.0	6	58	1.7	80.7	52.7	7.5
Treated straw with 5% EM	53.4	6	47.4	2.1	80.2	51.4	6.7
Noug seed cake	89.8	5	84.8	9.9	54.6	16.3	4.4
Wheat bran	93.9	10	83.9	23.2	40	27.0	12.9
Concentrate mix	91.3	6.5	83.7	13.8	48.4	19.1	6.9
Grass hay refusal	82.2	7	75.2	3.3	74.6	54.0	11.9
Tef straw refusal	85.5	5	80.5	2. 1	73.7	47 .0	8.3
Urea-treated straw refusal	54.6	6	48.6	3.4	76.3	48.2	11.0
Treated straw with 2.5% EM	78.8	6	72.8	1.3	71.4	63.3	8.3
Treated straw with 5% EM	59.4	5	54.4	1.4	81.4	57.6	8.2

EM = Effective microorganism; DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin

In the current study, the CP content of wheat bran was lower than the values of 11.2% and 13% reported by Gebregziaber (2010) and Wagi (2018), respectively. The NDF content (54.6%) of wheat bran was higher than the values of 44.7% and 50% reported by Wagi (2018) and Dejene (2010), respectively, but lower than the values of 80% and 61% reported by Emebet (2008) and Takle (2010), respectively. The ADF content of wheat bran in the current study was comparable to the values of 15.56% and 17.11% reported by Hayat (2021) and Fekadie et al. (2022), respectively.

The CP content of noug seed cake in the current study was 23.15%, which is comparable to that reported by McDonald (2002) but lower than the values of 25.7% and 26.8% reported by Dessie (2008) and Wagi (2018), and higher than the value of 20.15% reported by Solomon *et al. (*2016). The NDF and ADF contents of the noug seed cake were 40%, which is comparable to the value of 39.4% (Dida *et al*, 2020). The ADF and ADL contents were lower than those reported by Amdae (2015). The variations in feed nutrient content between the current and previous studies may be due to variations in varieties, soil fertility, environmental factors, type of fertilizer applied, harvest time, post-harvest management, storage methods, and stage of maturity. In support of this idea, Morrison (1984) stated that feed samples of the same variety from the same region may vary by 10% in terms of protein content.

Feed and Nutrient Intake of Experimental Lambs

The average daily feed dry matter (DM) intake of the experimental lambs fed natural pasture hay, untreated and treated *teff* straw, and concentrate supplementation is presented in Table 2. The intake of grass hay (T_1), teff straw treated with effective microorganisms (T_4 and T_5), urea-molasses solution-treated (T_3), and untreated (T_2) *teff* straw by experimental lambs was significantly different ($P < 0.01$). The intake of grass hay (475.9 g/day) was higher ($P < 0.01$) than that of lambs fed on untreated and treated *teff* straw (302.7–383.1 g/day). However, there was no significant difference ($P > 0.05$) in the average daily roughage DM intake between T2, T3, T4, and T5. The total feed DM intake of lambs was higher ($P < 0.02$) in the grass hay groups than in the treated and untreated *teff* straw groups. However, neither urea-molasses nor effective microbe solution treatment resulted in a significant difference ($P > 0.05$) in total feed intake compared to untreated teff straw.

Table 2
Average daily feed intake of sheep as affected by roughage feed types

Treatments	Feed Intake (g)		
	Roughage	**Concentrate**	**Total DMI**
T_1	475.9[a]	365.2	841.1[a]
T_2	302.7[b]	365.2	667.9[b]
T_3	340.4[b]	365.2	705.6[b]
T_4	331.2[b]	365.2	696.4[b]
T_5	383.1[b]	365.2	748.3[b]
SEM	77	0	77
P-value	0.0065	ns	0.0065

Means within a row with different superscripts (ab) differ significantly ($p < 0.05$); T_1 = Natural pasture grass hay; T_2 = Untreated teff straw T_3 = Tef straw treated with urea-molasses solutions; T_4=Teff straw treated with 2.5% activated EM solution; T_5 = Teff straw treated with 5% activated EM solution; SEM=standard error of mean

Feed consumption plays a vital role in determining sheep weight gain. The group that was given hay showed a significantly higher average intake of roughage DM ($P < 0.05$), whereas no notable differences ($P > 0.05$) were found among the other groups. This observation is consistent with the findings of Yalew *et al.* (2018), who found no variation in intake when dairy cows were provided with concentrate and fed on both urea-molasses-treated and untreated straw. In this study, the average total DM intake of the lambs (667.9–841.1 g/day) was higher than the figures (650–727 g/day) reported by Asmare (2016). The differences in total DM could be due to variations in the body weight of the animals and dietary compositions used in different experiments. Furthermore, this variation might be affected by internal and external factors, such as breed type, health status, age, digestible energy levels, and environmental conditions.

Table 3
Nutrient intake of Arsi Bale lambs as affected by roughage feed types

Nutrient Intake (g)	Treatments					SEM	P
	T_1	T_2	T_3	T_4	T_5		
TCPI	68.8[a]	56.6[b]	69.9[a]	56.9[b]	58.3[b]	2.2	0.0001
TNDFI	530.3	412.4	444.6	452.1	447.4	58	0.1263
TADFI	331.3[a]	200.8[c]	263.0[b]	225.8[bc]	266.4[b]	40	0.000
TADLI	81.7 [a]	48.8[b]	51.0[b]	45.5[b]	53.2[b]	7	0.0001

Means within a row with different superscripts (a–c) differ significantly (p < 0.05); TCPI=Total crude protein intake, NDFI = Total neutral detergent fiber intake, ADFI = Total acid detergent fiber intake, ADLI = Total acid detergent lignin intake; T_1 = Natural pasture grass hay; T_2 = Untreated teff straw T_3 = Tef straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 = Teff straw treated with 5% activated EM solution

The nutrient intake of lambs was affected by the type of roughage feed, as presented in Table 3. The crude protein intake of lambs was higher (P < 0.00) in the T_1 and T_3 groups. Neutral detergent fiber intake was similar (P > 0.05) among all treatment groups. Acid detergent fiber and acid detergent lignin intake were higher (P < 0.01) in T1 than in T5, T3, T2, and T4. However, there were no significant (P > 0.05) differences among the other treatments on CP, ADF, and ADL intakes. The higher CP intake of animals in T1 and T3 was due to the greater DM intake of hay and relatively better CP content of urea-molasses-treated teff straw. The variation in CP intake is associated with differences in DM intake, type of feed used, sheep breed, and environmental differences. The total CP intake of sheep in this experiment (56.6–69.9 g/d) was within the range of 45.7–85.8 g, as reported by Zewdie (2011).

Body Weight Change and Feed Conversion Efficiency

The effects of hay, untreated teff straw, effective microorganisms, and urea-molasses treatment on body weight change and feed conversion efficiency (FCE) of lambs are presented in Table 4. The initial body weights of the experimental animals were similar (P > 0.05) between the dietary treatment groups. However, the final body weight was higher (P < 0.05) in animals fed the T1 diet. This improvement in weight gain could be due to the higher dry matter and CP intake. Total and daily body weight gains were higher (P < 0.05) for T1 than for T2 and T3, whereas there was no difference (P > 0.05) between T2, T3, T4, and T5. The FCE was not significantly (P > 0.05) different among the treatments.

Average daily gain (ADG) and feed conversion efficiency are two important indices for evaluating the production performance of sheep, which mainly depend on the quality of feed provided. In this study, the highest (p < 0.01) ADG (72.2g/day) was observed in lambs fed natural pasture hay compared to those fed T2 and T3. This may be due to enhanced DM intake and nutrient supply through improved intake and

nutrient digestibility as a result of the low fiber content of supplemental hay. Animals in the other group had similar performance (P > 0.05) in terms of body weight gain and final weight. This indicated that the treatment of teff straw with urea molasses or EM did not improve the weight gain of sheep. However, lambs fed EM-treated teff straw (T4 and T5) had similar total weight gain and average daily weight gain compared with lambs fed hay. Consistent with this result, there was no significant difference in the final body weight among cows due to urea and EM treatment of rice straw (Lemma and Endalew, 2017).

Table 4
Live weight changes of Arsi Bale lambs as affected by roughage feed types

Parameters	**Treatments**					**SEM**	**P**
	T1	**T2**	**T3**	**T4**	**T5**		
IBW (kg)	18.3	18.1	18.1	17.9	18.3	1.6	0.9933
FW (kg)	24.3^{a}	22.8^{b}	22.4^{b}	23.3^{b}	23.4^{b}	2.1	0.03478
TWG (kg)	6.5^{a}	4.8^{b}	4.3^{b}	5.2^{ab}	5.3^{ab}	1.1	0.0323
DWG (g)	72.2^{a}	52.8^{b}	48.3^{b}	57.3^{ab}	59.3^{ab}	12.5	0.0323
FCE	0.08	0.08	0.07	0.08	0.08	0.01	0.4081

Means within a row with different superscripts (ab) differ significantly (p < 0.05); IBW = Initial body weight; FW = Final body weight; TWG = Total body weight gain; DWG = Daily body Weight gain; FCE = Feed conversion efficiency (BWG/DMI); T_1 = Natural pasture grass hay; T_2 = Untreated teff straw T_3 = Tef straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 =Teff straw treated with 5% activated EM solution

The mean daily gain in the current study was comparable to that reported by Awet (2007), who reported 65-88.2g/day in Afar rams supplemented with 150–350 g wheat bran. However, Feyisa (2016) reported a lower average daily gain (64.6 g/day) was reported by Feyisa (2016) for the same sheep breed fed faba bean straw with a concentrate mixture. The FCE results were consistent with those of Gezachew (2012) and Asmare (2016). The variation with other studies could be due to differences in dietary ingredients, the quality of the basal diet, form of feed preparation and handling, type and amount of the supplement used, environment, breed, and age.

The body weight change trend of the experimental lambs during the feeding trial is shown in Fig. 1. Lambs allocated to T1 (hay with concentrate) showed increased body weight gain at a high rate between the 14th and 28th days, then at a low rate from the 28th to the 42nd day, at a high rate from the 42nd to the 56th day, and no change from the 56th to the $70^{th\ day}$. The body weight change for the T2 and T3 diet groups increased at an increasing rate from the initial days of the 14th (18 kg/day) to the 42nd (20 kg/day) and then from the 56th day to the end of the experiment at a slow rate. The lambs assigned to T4 and T5 showed similar progress, but T5 showed a relatively better rate in the initial days of the experiment until the end of the experiment.

Carcass Characteristic of Arsi-Bale Lamb

The carcass components of the experimental animals are presented in Table 5. Slaughter weight, hot carcass weight (HCW), cold carcass weight (CCW), rib eye area (REA), and dressing percentage (DP) were not significantly different ($P > 0.05$) among the treatments. Slaughter weight is an important index for evaluating the growth performance of meat animals. In this study, the lack of significant ($P > 0.05$) differences in carcass parameters between treatments indicated that all roughage feeds used in this experiment were equally important. In contrast, sheep fed EM-treated tef straw supplemented with concentrate showed improvements in slaughter body weight, empty body weight, and hot carcass weight (Tibebu *et al*., 2019). Furthermore, sheep-fed diets containing by-products treated with EM had significantly ($p < 0.05$) higher SBW, HCW, and DP than sheep-fed diets based on untreated roughages (Begna *et al.*, 2013). The slaughter weight was in the range of 18.4–26.2 kg, as reported by Alemu (2016) for Gumuz sheep supplemented with different proportions of wheat bran and noug seed cake.

There was no difference ($p > 0.05$) in carcass weight among all treatments; however, the lambs fed hay exhibited numerically greater carcass weight than those in the other treatments. The hot carcass weight ranged from 5.9 to 9.3 kg, as reported by Ayele et al. (2017) for Wollo sheep supplemented with lablab, pigeon pea, and cowpea pellets. Dressing percentage is both a yield- and value-determining factor and is, therefore, an important parameter in assessing the performance of meat-producing animals. The dressing percentage in the current study was higher than the results (31.5–37.3%) reported by Feyisa (2016). Conversely, this result was lower than the value of 37.5–48.4% reported by Salo *et al.* (2016). These observed differences between the current and previous studies could be due to differences in sheep breed, environment, feed treatment procedures, and feed types.

Table 5
Main carcass yield of Arsi-Bale sheep as affected by roughage feed types

Parameter	**Treatment**					**SEM**	**P**
	T_1	**T_2**	**T_3**	**T_4**	**T_5**		
SW (kg)	25.4	23.3	21.8	23.5	23.9	2.2	0.2836
HCW (kg)	9.6	8.8	8.6	8.5	8.8	0.6	0.1792
CCW (kg)	9.6	8.6	8.6	8.5	8.7	0.8	0.2890
DP (%)	37.9	38	39.7	36.3	36.9	2.2	0.2341
REA (cm^2)	24.9	21.1	17.8	20.0	17.8	4.9	0.2554

Means within a row with different superscripts (a–c) differ significantly ($p < 0.05$); SW= Slaughter weight; HCW = Hot carcass weight; CCW= Cold carcass weight; DP = Dressing percentage; REA = Rib eye area; *T_1 = Natural pasture grass hay; T_2 = Untreated teff straw T_3 = Tef straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 =Teff straw treated with 5% activated EM solution*

The advantage of measuring rib eye area is to investigate muscle growth, which is expected to increase through weight gain of the animal. The rib eye area is also an indicator of meat leanness, carcass desirability, and muscle development (Wolf *et al.*, 1980). As the rib-eye muscle area increases, the amount of muscle in a carcass increases, and the yield grade tends to improve (USDA, 2009*)*. The results showed that the rib-eye area was similar (P > 0.05) among all treatment groups. This may be due to the similar body growth responses of lambs among the treatment groups. The rib-eye muscle area is positively correlated with slaughter weight and can be affected by nutrition (Tibebu *et al*., 2019). The rib-eye muscle area observed in the present study (17.8–24 .9 cm^2) was greater than that reported previously (Tibebu *et al*., 2019).

The amount and proportion of lean meat, fat, bone, and trimming of lambs were not significantly (P > 0.05) different among the treatments (Table 6). However, the proportion of lean and fat carcasses was better in lambs fed hay with concentrate supplement than in lambs fed urea-molasses and 5% EM-treated teff straw. The fat content was higher (P < 0.05) in T1 than in the other groups, whereas there was no difference between the other treatments. The carcasses had more red meat from lambs fed hay than from those fed other diets.

Table 6
Lean meat, bone, and fat yield of carcasses as affected by roughage feed types

Parameter	**Treatment**					**SEM**	**P**
	T1	**T2**	**T3**	**T4**	**T5**		
Red meat (kg)	3.1	2.8	2.7	2.8	2.8	0.5	0.2333
Bone (kg)	1.4	1.1	1.3	1.2	1.3	0.2	0.3838
Fat (kg)	0.5^a	0.32^b	0.4^b	0.31^b	0.4^b	0.2	0.0492
Trim (kg)	0.15	0.12	0.13	0.12	0.14	0.1	0.5780
Red meat (%)	64.7	64.8	61.5	63.7	65.5	5.9	0.2626
Bone (%)	23.3	22.8	23.8	25.1	24.3	2.9	0.8285
Fat (%)	9.6	5.9	8.3	8.1	6.7	2	0.1457
Trim (%)	1.4	1.7	2.4	2.5	1.6	1	0.5115

Means within a row with different superscripts (a–c) differ significantly (p < 0.05); T_1 = Natural pasture grass hay; T_2 = Untreated teff straw; T_3 = Teff straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 =Teff straw treated with 5% activated EM solution

The edible offal components of Arsi-Bale lambs fed hay, untreated teff straw, and treated teff straw with urea molasses solution and effective microorganisms are presented in Table 7. In the current study, there were no significant (P > 0.05) differences among treatments in any of the edible offal components, except for tail fat, which was lower (P < 0.01) in T3 than in T1. Although there was no significant

difference between the other treatments, there was less (P < 0.01) kidney fat in the T2 and T4 groups. Consistent with this result, edible offal was similar to that of sheep fed biologically treated roughage-based diets (Begna *et al.*, 2013). In contrast to this study, sheep fed EM-treated teff straw supplemented with concentrate showed improvements in edible offal components (Tibebu *et al*., 2019).

The current result for non-edible carcass components was not significant (P > 0.05) in all treatments, except for the lung and trachea. Biological treatments had no significant effect on individual non-carcass edible components (Begna *et al.*, 2013). As indicated by Riley *et al.* (1989), internal organs are more influenced by age, sex, and breed than diet, which supports the current result. The value of the lung with the trachea varied from 300–500 g in the current study, which was higher than the result of 268–440 g reported by Hayat (2021).

Table 7
Edible offal yield of Arsi-Bale sheep as affected by roughage feed types

Parameters	**Treatment means (kg)**					**SEM**	**P**
	T_1	**T_2**	**T_3**	**T_4**	**T_5**		
Head + tongue	1.5	1.7	1.5	1.5	1.6	0.2	0.7046
EGIT	2.2	2.0	1.91	2.1	1.92	0.2	0.4180
Liver	0.41	0.38	0.39	0.36	0.37	0.1	0.5574
Heart	0.15	0.18	0.16	0.13	0.19	0	0.5215
Kidney	0.12	0.11	0.13	0.15	0.17	0	0.5597
Kidney fat	0.13^{a}	0.043^{b}	0.14^{a}	0.042^{b}	0.12^{a}	0	0.0759
Tail fat	0.6^{a}	0.4^{ab}	0.3^{b}	0.5^{ab}	0.4^{ab}	0.1	0.0968

Means within a row with different superscripts (a–bb) differ significantly (p < 0.05); EGIT = Empty gastrointestinal tract; T_1 = Natural pasture grass hay; T_2 = Untreated teff straw; T_3 = Teff straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 = Teff straw treated with 5% activated EM solution

Feed Cost per Live Weight Gain

The costs of the experimental feed ingredients, total feed cost during the experimental period, and cost incurred per kg live weight gain are presented in Table 8. The effect of the roughage feed type was significant (P < 0.05) on the total feed cost required per day per sheep and the total cost incurred per kg of sheep live weight. The total feed cost was higher (P < 0.05) in T5 (5% EM-treated straw-fed group) than in T1, T2, T3, and T4. However, the cost incurred per unit live weight (birr/kg) was lower (P < 0.05) in T1 and T2 than in the other treatments. Numerically, the highest feed cost per kg live weight gain (210 birr/kg gain) was recorded for T5, and the lowest feed cost per kg gain (147 birr/kg gain) was recorded

for the hay with concentrate-supplemented groups (T1). The results of the present study indicated that concentrate supplementation with either urea-molasses-treated straw or EMS can improve body weight gain but maximizes the feed cost required to produce a unit amount of live weight.

Table 8
Feed cost per day per sheep and kg live weight gain as affected by roughage types

Cost (Birr)	Treatments					SEM	P
	T_1	T_2	T_3	T_4	T_5		
Roughage	5.30^b	2.60^c	4.60^b	4.40^b	5.90^a	0.9	0.0001
EM	0.00^c	0.00^c	0.00^c	0.56^b	1.47^a	0.1	0.0001
Urea	0.00^b	0.00^b	0.46^a	0.00^b	0.00^b	0.03	0.0001
Molasses	0.00^b	0.00^b	0.12^a	0.00^b	0.00^b	0.01	0.0001
Concentrate	5.9	5.9	5.9	5.9	5.9	0	0
Total feed cost	11.2^b	8.5^b	11.8^b	10.8^b	13.3^a	1	0.0001
Feed per kg WG	147.9^b	157.1^b	209.0^a	197.3^a	210.8^a	32	0.0038

Means within a row with different superscripts (a–b) differ significantly ($p < 0.05$); T_1 = Natural pasture grass hay; T_2 = Untreated teff straw; T_3 = Tef straw treated with urea-molasses solutions; T_4 = Teff straw treated with 2.5% activated EM solution; T_5 = Teff straw treated with 5% activated EM solution

Conclusion

In this study, treating teff straw with urea-molasses and effective microbes did not result in a better feed value than grass hay and untreated teff straw for sheep fattening. Numerically, the highest feed cost per kg live weight gain (210 birr/kg gain) was recorded for T5, and the lowest feed cost per kg gain (147 birr/kg gain) was recorded for the hay with concentrate-supplemented groups (T1). The results of the present study indicate that feeding treated straw with supplementation can improve body weight gain, but maximizes the feed cost required to produce a unit amount of live weight. Therefore, when there is no grass hay, feeding fattening sheep with untreated teff straw *ad libitum* and a 400 g concentrate supplement is recommended. However, further studies are needed to evaluate the effect of treated straw at higher amounts of urea-molasses and effective microbes' solutions and ensiling time.

Declarations

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Author contributions

Y. Y.: investigation, methodology, writing—original draft preparation; S. S. and W. T.: analysis, supervision, resources, writing—review, and editing.

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Data availability

Data supporting the results of this study can be shared by the first author upon a reasonable request.

Ethics approval and consent to participation

The study was approved by the Research and Ethics Committee of Wachemo University in accordance with the Ethiopian National Research Ethics Guidelines.

Consent for publication

Not applicable**.**

Competing interests

The authors declare no conflicts of interest.

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Figures

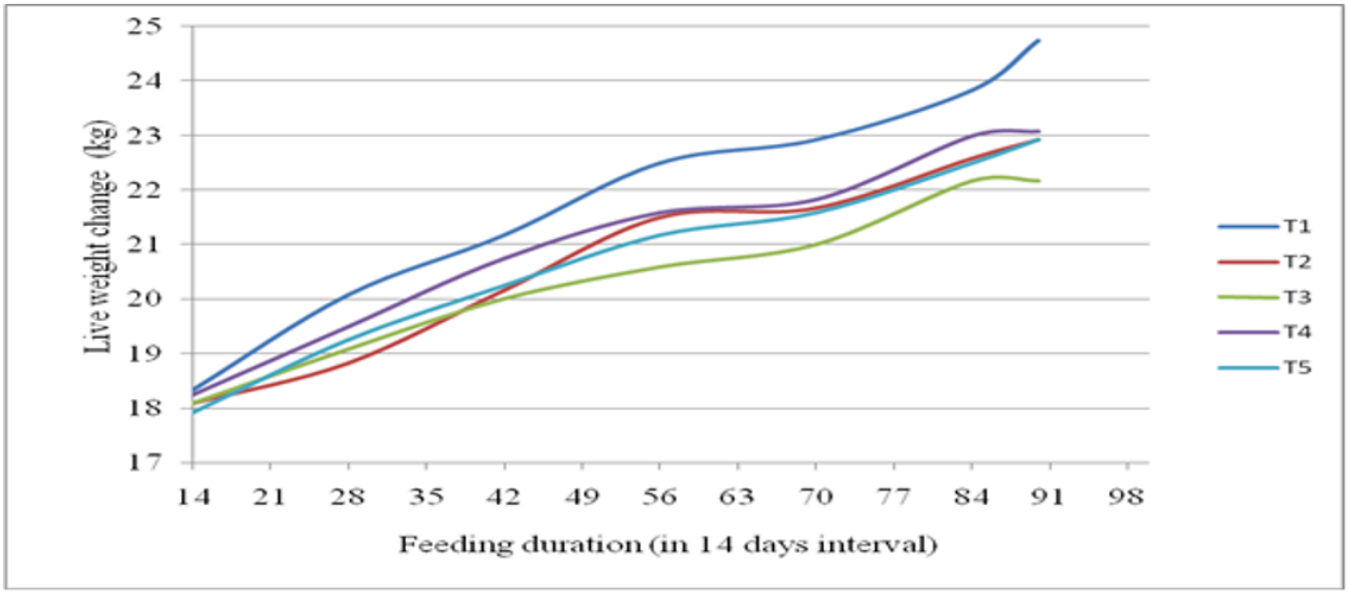


Figure 1

Trends of experimental animals' body weight change as affected by treatment diets and feeding days