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Effect of supplementing graded levels of wet brewery grain by-product to natural pasture hay and wheat bran based diet on the performance of Tigray highland sheep, Northern Ethiopia

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Abstract

A feeding trial was conducted for 84 days followed by 7 days of fecal collection to determine performance and also digestibility of nutrients at Maichew ATVET College in Tigray, North Ethiopia using 24 yearling intact male local sheep grouped into six blocks of four sheep based on their initial body weight and each block assigned to each of the four treatments diets. The basal diet was composed of natural pasture hay (ad libitum), wheat bran (309 g/sheep/d) and salt (3 g/head/d) and test diet (graded levels of wet brewery grain by-product=WBGB). Treatment diets were: T1 (basal diet+0g WBGB/head/day), T2 (basal diet + 210g WBGB/head/day), T3 (basal diet + 280g WBGB/head/day) and T4 (basal diet + 350g WBGB/head/day). ANOVA of data was conducted using General Linear Model (GLM) procedures of SAS; and means compared using Tukey's HSD test ($p<0.05$). Dry matter, organic matter and crude protein intake and digestibility significantly increased ($p<0.05$) with increasing levels of supplementation. Higher average daily body weight and feed conversion efficiency ($p\leq 0.05$) were recorded in T4 followed by T3, T2, and T1. Hot carcass weight (9-11 kg), rib eye muscle area as a sign of degree of muscling (7.20 -10.70cm^2), net return and marginal rate of return (MRR) were higher ($p<0.05$) in supplemented than in T1 fed sheep, with best results in T4. It can be recommended that sheep can be supplemented up to 124 g dried BGB or 350 g WBGB because it gave better body weight and carcass performances and MRR.

Keywords: natural pasture hay, wheat bran, wheat brewery grain by-product, intake, digestibility, performance of local sheep

Introduction

In Ethiopia, agriculture is a corner stone of the economic and social life of the people. The sector employs 80-85 % of the population and contributes 40 % to the total GDP.[1] Ethiopia has the largest livestock population in Africa and an estimated population of about 59.5 million cattle, 30.7 million sheep, 30.2 million goats, 1.21 million camels, 56.53 million poultry, 2.16 million horses, 0.41 million mules and 8.44 million donkeys.[2] The major feed resources in Ethiopia are crop residues and natural pasture, with agro industrial by-products and manufactured feed contributing much less.[3] The availability and nutritional quality of the feed resources are among the most important factors that determine the productivity of livestock.[4] Acute shortage of feed supply during the dry season and very poor quality of the available feeds are the prime limiting factors for increasing production and productivity of small ruminant in most of the agro-ecological zones in Ethiopia.[5] Dietary nutrients, especially energy and protein, are the major factors affecting the productivity of sheep. The lowest energy density at which sheep do not lose weight is between 8 and 10 MJ ME/kg DM and the minimum protein level required for maintenance is about 8% of DM, while productive animals such as rapidly growing lambs and lactating ewes need about 11%, which are considerably higher than the average values found in natural pastures and crop residues.[6]

There are several by-products that can be obtained from production of beer such as brewers' grains (wet or dried) and brewers dried yeast. Brewer's grain is the material that is remaining after fermentation of grain, during beer making process. These materials are considered to be good sources of un-degradable protein and water soluble vitamins. They have been used in feeding both ruminant and monogastric animals. The nutritional content of the material will vary from plant to plant and depending upon the type of substrate (barley, wheat, corn, etc.), extent of fermentation and type of fermentative process.[7] Brewers grains are quite rich in protein (27-33% DM), which makes them a valuable source of protein. The protein value can be affected by the heat applied during the brewing process, which can be beneficial to ruminants but tend to be detrimental for monogastric animals. Brewers grains are also relatively rich in fiber (ADF 17-26% DM), which makes them suitable for ruminants fed concentrate-rich diets, but less so for pigs and poultry. Wet brewers' grains are bulky feeds with low energy content, which can limit their use.[8] Currently, use of brewery by-products to ruminant is relatively limited but the feed is very palatable and offers a good source of protein.[7]

In southern zone of Tigray, there is Raya beer industry. This industry produces high amount of brewery by-product, however it is not utilized by livestock owners wisely for feeding of their animals due to lack of awareness and knowledge. So the use these industrial by-products are very important to increase production and productivity of livestock. Therefore, this study was designed to evaluate the nutritional value of WBGB on the performance of highland sheep in Maichew District, Southern zone of Tigray.

Materials and methods

Description of the study area

The experiment was conducted at Maichew Agricultural TVET College which is located in southern zone of Tigray region 660 km North-east of Addis Ababa, Ethiopia.[9]

Experimental design and treatments

After grouping the intact male lambs in to six blocks of four on initial body weight, one lamb from each block was assigned to each of the four treatments diets randomly (RCBD). To determine initial body weight, the lambs were weighed for two consecutive times after overnight fasting at the end of the quarantine period, and they were placed in individual pens. The layout of the trial is shown in Table 1. Wet brewery grain by-product (WBGB) was supplemented at the rate of 0, 25, 33 and 41% of the total dry matter intake of basal diet.

Table 1 Experimental treatment diets

Treatments	Feed ingredients				TDMI (g/head/d)
	Grass hay	Wheat bran (g)	Salt (g)	Total supplement (DM/head/d)	
T1	*Ad libitum*	309	3	-	791
T2	*Ad libitum*	309	3	25%TDMI	842
T3	*Ad libitum*	309	3	33%TDMI	852
T2	*Ad libitum*	309	3	41%TDMI	861

Experimental sheep and their management

The experiment was conducted using 24 yearling local male sheep (18.8 ± 1.15 kg, mean ± SD) bought from local market of the study area. Age of lambs was identified by dentition and information from the owners. After 14 days of acclimatization, lambs were fed for 84 days and then after 3 days of adaptation to faecal collection bags faeces were collected for 7 days. The lambs were vaccinated against common diseases and were sprayed and drenched with broad spectrum acaricide and anthelmintic against external and internal parasites, respectively. Lambs were kept in individual pens.

Natural pasture hay (*ad libitum)* and wheat bran (309 g/head/d) were used as a basal diet. The hay offered was chopped to a length of approximately 3-5 cm. The WBGB was collected from Raya Brewery Industry every seven days and stored properly in plastic jars to avoid spoilage until it was fed. Experimental lambs were acclimatized to the experimental diets and pens for 14 days before commencement of the actual data collection. Hay and water were fed *ad libitum* and wheat bran and WBGB were fed in the recommended proportion to the experimental lambs twice a day at 8:00 am and 4:00 pm throughout the feeding trial. The amount of feed offered for each lamb was recorded daily. Wheat bran and salt offered were fed separately with no refusal. The grass hay offered was adjusted within two days by ensuring a refusal of ≥20% based on previous days' intake of individual lambs. Hay refused was collected every morning before fresh feeds were offered, weighed and recorded individually for each sheep. Wet brewery gran by-product was fed on separate feeder with no refusals throughout the experimental period. Samples of feed offered were collected every week and pooled over the trial period and sub samples were taken for chemical analysis. The initial and final body weights of experimental lambs were measured in the morning before provision of feed and water. To determine the trend in weight change, subsequent body weight measurements were taken at 14 days interval throughout the experimental period. Feed conversion efficiency (FCE) was calculated as average daily gain divided by daily DM intake.

Digestibility trial was conducted at the end of the feeding trial. All of the 24 lambs were harnessed with fecal collection bags and were allowed to adapt to the bags for 3 days followed by 7 days of fecal collection. Feces were collected and weighed every morning before provision of feed and water. Of the daily feces collected 10% was taken for immediate DM determination and 10% for chemical analysis from each lamb separately. Fecal samples were placed in airtight polyethylene plastic bags and stored in deep freezer (–20°C) up to the completion of the digestibility trial. Samples were weighed, partially oven dried at 65°C for 48 hours, ground to pass through 1mm sieve and stored in airtight polyethylene plastic bags pending chemical analysis. The other 10% was also sub-sampled, weighed and dried at 105°C overnight to estimate the absolute dry matter content. The apparent digestibility (%) of DM, OM, CP, NDF, and ADF was determined according to the formula: [*DM (nutrient) intake – fecal DM (nutrient) output*]/*DM (nutrient) intake x 100*.

Chemical analysis

Dry matter, crude protein and ash contents of feed offered, feed refusals and fecal samples were analyzed[10] and organic matter computed by deducting ash from DM content of samples. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined.[11,12] Metabolizable Energy (ME) of the experimental diets was determined based on the prediction equation of Donker (1989) as follows: ME (Mcal/kg DM) = 2.76 – 0.00165 g ADF/kg DM.[13]

Carcass parameters

At the end of the feeding trial, sixteen representative lambs were selected and fasted overnight, weighed (SW) and slaughtered by severing the jugular vein and carotid arteries with a knife for carcass evaluation. Blood was collected into plastic buckets, weigh and record. The skin was carefully flayed and weighed. The whole gastro intestinal tract (GIT), except esophagus, was removed and weighed with and without its contents. Based on the eating habit of Ethiopians, non-edible offal (NEO) such as, skin, feet, spleen, penis and penis fat, lung with trachea and esophagus, bladder and gut contents; and the edible offal (EO) namely head, blood, liver with bile, heart, kidney, tail, reticulo-rumen, omasum and abomasum, small and large intestine, total fat (omental, heart and kidney), testes and tongue were weighed and recorded separately. The total non-edible offal (TNEO) and total edible offal (TEO) components were also computed. Empty body weight (EBW) of each lamb was determined by subtracting weight of digesta/gut content from slaughter weight. Hot carcass weight (HCW) was computed by excluding weight of thoracic, abdominal and pelvic cavity, head, skin, and limbs. Dressing percentage (DP) was calculated as (EBW/SW) x 100. The cross section of rib-eye muscle area (REMA) were measured from each side on transparency paper after cutting perpendicular at the 12th and 13th ribs of the back bone and measured by tracing the transparency paper on graph paper. The measure of the left and right cross sectional areas were taken as average REMA.

Partial budget analysis

At the end of the experiment, partial budget analysis was performed to evaluate the economic profitability of the treatment feeds following standard procedures.[14] The analysis involves calculation of the variable costs of experimental lambs, feeds and benefits gained from the result. Purchasing and selling prices of lambs, purchasing price of basal diets and supplement feed were recorded. Other expenses such as cost of transport (lambs and feeds), mineral licks, housing, labor (feeder and cleaner) and veterinary services, which were common for all treatments, were not considered in calculation of partial budget analysis. The total cost associated with each lambs during the experimental period in each treatment were added and average was taken as a total variable cost (TVC). Net return (NR); was calculated by subtracting TVC from total return (TR) as: NR=TR-TVC. Change in net return (ΔNR) was calculated by subtracting change in total variable costs or expenditure (ΔTVC) from the change in total return (ΔTR) as: ΔTR - ΔTVC. MRR was generally expressed in percentage as: MRR (%)=(ΔNI/ΔTVC)*100.

Data analysis

Data for the feeding and digestibility trials and carcass parameters were subjected to analysis of variance based on the model for Randomised Complete Block Design (RCBD) using the Statistical Analyzing System (SAS) software. Treatment means comparison was done using Tukey's Student zed Range (HSD) test. The statistical model used for analysis of the data collected from the feeding and digestibility experiments was:-Yi = μ +Ti +Bi +ei where: - Yi = response variable; μ = overall mean; T_i= ith effect of treatment; B_i = effect of block and ei = ith random error.

Results and discussions

The chemical compositions of feed ingredients are given in Table 2. Grass hay has lower CP (8.8%) and higher NDF and ADF content than wheat bran and brewery grain by-product whereas, the ADL content was higher than wheat bran but lower than brewery grain by-product. Brewery grain by-product was higher in CP, NDF, ADF and ADL content than wheat bran. However, the ADL content of wheat bran was lower than that of hay and WBGB. The lower content of NDF, ADF and ADL were recorded from wheat bran compared to hay and brewery gain by-product. The ash content of grass hay was highest followed by wheat bran and brewery grain by- product.

Table 2 Chemical composition of the feed ingredients of the diets

Feed offered	DM (%)	Nutrient content (%DM)							
		OM	Ash	CP	NDF	ADF	ADL	Ca	P
Grass hay	93.59	90.94	9.06	8.80	67.26	45.30	11.50	0.37	0.16
Wheat bran	91.02	91.25	8.75	15.56	45.60	18.86	4.60	0.30	1.20
Wet brewery grain by-product	35.50	93.09	6.91	19.80	56.50	39.40	15.80	1.60	0.80

DM, Dry Matter; OM, Organic Matter; CP, Crude Protein; NDF, Neutral Detergent Fiber; ADF, Acid Detergent Fiber; ADL, Acid Detergent Lignin

The DM, OM and ash contents of hay in this study were similar to results reported for hay in previous studies that was fed as a basal diet for Tigray highland sheep.[15–17] The CP content (8.8%) of hay in this study was in line with earlier results[18] but lower than other results.[16,17,19] and higher than results earlier reported.[15,20] Differences in nutritional composition of hay were attributed to differences in species composition, harvesting time, stage of maturity and environment[21] The NDF, ADF and ADL contents of hay in this study were similar to values (74.42%, 46.5% and 11.46%, respectively] earlier reported.[18] Higher NDF (78.74%), ADF (53.90%) and ADL (14.53%) values of hay were also reported.[16] The higher NDF, ADF and ADL content of hay might be due to the result of over maturity of hay at harvest. The CP content of wheat bran used in the present study was in line with the 15.01%, 16.06 % and 16.2% CP reported earlier[17,22,23] respectively. The NDF, ADF and ADL contents of wheat bran used in this study was equivalent to earlier report of 44.9 % NDF, 12.7% ADF and 3.8% ADL[24] and 42.8% NDF, 17.82% ADF and 4.35% ADL.[25] Lower NDF, ADF and ADL content of wheat bran were also reported.[15,17] The DM of WBGB for the present study was in line with the 19.2-32.8%DM previously reported. [26] The OM value of WBGB is relatively high and comparable to that earlier reported.[22] The CP content of WBGB noted in this study was similar to 19.8% and 19.45% earlier reported[19,27] respectively. Higher (25.05%, 25.5%)[25,28] respectively and lower CP values (<20%) of WBGB were also reported.[29] The NDF and ADF contents of WBGB of the present study was relatively similar (47.1% and 28.4%) to those earlier reported[19,30] respectively; however lower NDF and ADF values as well were reported.[25,29] The ADL content of WBGB in this study was also in line with the 14.7% documented.[28] The nutritional content of the WBGB may vary from brewing plant to plant, types of grain used in the initial brewing process as well as proportions being fermented and fermentative process being used (Table 3).[31]

Table 3 Dry matter and nutrient intakes of local sheep fed experimental diets

Intake (g/head/day)	Treatment diets				SEM	SL
	T1	T2	T3	T4		
Dry matter (DM)						
Grass Hay DM	510[a]	486[b]	472[cb]	455[c]	14	***
Wheat Bran DM	281	281	281	281	0	***
Wet brewery grain DM	-	75[c]	99[b]	124[a]	0	***
Total DM	791[b]	842[a]	852[a]	861[a]	14	***
Nutrient Intake (g/head/day)						
Organic matter	720[b]	768[a]	778[a]	786[a]	13	**
Ether extract	15.5[c]	16.9[b]	17.2[ab]	17.5[a]	0.3	***
Crude protein	81[b]	90[a]	92[a]	95[a]	3	***
Neutral detergent fiber	429[b]	454[a]	458[b]	461[a]	9	***
Acid detergent fiber	258[b]	276[a]	279[a]	282[a]	6	***
Acid detergent lignin	65[c]	74[b]	76[ab]	78[a]	2	***
ME (MJ/head/day)	11.2[a]	11.9[a]	12.1[a]	12.2[a]	0.2	***

[a-d]mean values in a row having different superscripts differ significantly; ME MJ, Metabolized Energy; m, Mega Joule; SEM, standard error mean; ns, not significant; ***, significant at p<0.001; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB/day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB/day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB/day

The mean daily DM and nutrient intakes of Tigray highland sheep is presented in Table 3. Sheep in T4 consumed significantly lower amount of hay ($p< 0.001$) than those of T1 and T2 but T3 had significantly lower hay intake than that of T1 ($p<0.001$); with no significant differences in hay intake between T2 and T3; and T3 and T4. The total DM and OM intakes were in decreasing ordered of T4 > T3> T2 >T1 whereas NDF, ADL and ME intakes in increasing ordered of T4 > T3 > T2 > T1. Sheep in T1 had lower CP intake ($p<0.001$) as compared to the supplemented ones. As supplementation increased, the CP intake also increased across treatments. All the treatments were significantly different among each other in nutrient intakes ($p<0.001$). The grass hay DM intake for the present study was highest in T1 followed by T2, T3 and T4 since the supplemented feed was inversely adjusted. Low hay DM intake in T4, T3 and T2 could be associated with the larger amount of DM supplemented to these groups. Results similar to that of the present study[19,32] were reported where higher intake of basal feeds took place when sheep were not fed with supplement diets.

The average total DM intake of Tigray highland sheep in this study was equivalent to results obtained in previous studies for different Ethiopian sheep breeds.[20,24,33] Contrary to the present study, low total DM intakes were reported for Tigray highland sheep,[15–18,23] The variations and similarities of total DM intake noted in this study could be due to differences in the type and amount of basal diets, supplements, breed and age of the sheep, environmental condition and other factors. High DM intake as the proportion of WBGB increased might be due to increasing levels of crude protein content. Consistent with the result in this study, improved DM intake as a result of improved rumen function was reported when high quality feed was supplemented with a protein source like brewers' grain.[35] The control (T1) group had lower CP intake as compared to the supplemented ones, differences could be due to the WBGB that had high protein and digestible fiber value.[35] This slight variation in CP intake within supplemented treatment groups could be associated with differences in the amount of supplemented diets consumed. The metabolisable energy (ME) intakes of T1, T2, T3 and T4 were significantly different due to high ME content of WBGB. The ME requirement for a 20 kg lamb gaining 50-150 g/day is 3.7-6.4 MJ/day for diets with a metabolisability of 0.65[36] and the maintenance and growth (50-200 g gain) ME requirement for the same weight lamb is 4.5-7.9 MJ/day.[37] Moreover, a 10 kg live weight sheep requires 2 MJ/day for maintenance and 2.7-4.5 MJ/day for growth.[38] Therefore, the estimated ME content of the treatment diets (11.2-15.5 MJ/ head/day) in the present study satisfies the energy requirement for maintenance and growth (51.59-62.5 g gain/day) of the experimental sheep.

The mean DM and nutrient digestibility of diets fed to local lambs are presented in Table 4. Apparent digestibility of DM of T4 was significantly lower than those of T1, T2, and T3 whereas no significant differences were noted among T1, T2, and T3. Digestibility of OM of T1 was significantly lower ($p<0.001$) than that of T2, T3 and T4, but among T2, T3 and T4 there were no significant differences. Apparent digestibility of CP of T1 was significantly lower ($p<0.001$) than that of T3 and T4 but was similar with that of T2. No significant differences in apparent digestibility of CP were noted between T3 and T4. The apparent digestibilities of NDF and ADF were increased with increasing level of supplementation of WBGB, where T1 had significantly ($p<0.001$) lower values than those of T2, T3 and T4 whereas; no significant differences among T2, T3 and T4. The apparent digestibility of DM, OM, NDF and ADF of those supplemented with WBGB in this study was comparable to the digestibility of these nutrients reported for effect of feed additives in growing lambs fed diets containing wet brewers' grains.[38] Apparent DM and OM digestibilities were increased with increasing level of WBGB (Table 4). This may be related to an increase in feed retention time in the rumen due to high NDF in diets with WBGB. Similar to the present study it was reported that the main cause of digestibility variation in diets is retention time of particles in the rumen i.e., a lower DM intake leads to a reduction in passage rate and a consequent increase in its apparent digestibility (Table 4).[40]

Table 4 Apparent dry matter and nutrient digestibility of experimental diets fed to local sheep

Apparent digestibility %	Treatment diets					
	T1	T2	T3	T4	SEM	SL
Dry matter	56.6^{a}	54.8^{a}	54.9^{a}	50.4^{b}	2.2	***
Organic matter	65.6^{b}	71.4^{a}	73.7^{a}	73.9^{a}	1.6	***
Crude protein	82.9^{b}	86.4^{ba}	87.6^{a}	87.9^{a}	2.2	***
Neutral detergent fiber	60.2^{b}	66.2^{a}	67.8^{a}	68.9^{a}	2.6	***
Acid detergent fiber	50.5^{b}	60.7^{a}	62.7^{a}	64.8^{a}	4.1	***

$^{a-c}$mean values in a row having different superscripts differ significantly; SEM, standard error mean; ns, not significant; ***, significant at p<0.001; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB/day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB/day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB/day

The digestibility of CP was increased with increasing level of supplementation of WBGB. In the present study, higher CP digestibility was recorded with T4 ($p<0.001$) than T1, T2 and T3. This was due to high CP content of WBGB. This result was similar with earlier findings where supply of higher dietary protein leads to better CP digestibility.[25,41,42] Protein supplementation increases the supply of nitrogen to rumen microbes, which have a positive effect on rate of fermentation of the digesta.[43] Conversely, lower digestibility of CP (61.2-76.1%) than those results were reported[19] for intact Wogera lambs fed hay as basal diet and supplemented with 100, 200 and 300g/day of brewery dried grain.

There was no significant variation among different proportion of WBGB supplemented groups in apparent NDF and ADF digestibility in the present study. Earlier it was also found that supplementation had no effect on fiber digestibility.[19] The body weight measurements of Tigray highland sheep fed the treatment diets are presented in Table 5. Initial body weight (IBW) was not significantly different among treatments ($p>0.05$). Lambs fed T2, T3 and T4 were not different in final body weight (FBW) but T1 had significantly lower ($p<0.01$) FBW compared to that of T3 and T4; but was similar with that of T2. Body weight change (BWC) and average daily gain (ADG) of sheep on T4 were significantly higher ($P < 0.001$) than those on T1 and T2, but were similar with those on T3. However, there were no significant differences between T1 andT2; T2 and T3; and T3 and T4. The feed conversion efficiency (FCE) of T1 was significantly lower ($p<0.05$) than that of T4 but was similar with that of T2 and T3. As the level of WBGB increased in the diets, the FBW and ADG were also increased (Table 5). In the present study, higher FBW and thus also BWC were obtained from lambs fed with dietary T4, T3 and T2 than T1. Similar to the result in the present study Polish lowland lambs consuming 35% of wet brewery grain added in their daily ration gained 0.45 kg higher than the control diet.[29] Local intact Wogera sheep fed grass hay as a basal diet and supplemented with different levels of dried brewery grain resulted in a higher FBW and ADG than control diet (Table 5).[19]

Table 5 Body weight change and feed conversion efficiency of local sheep fed treatment diets

Parameters	Treatment diets					
	T1	T2	T3	T4	SEM	SL
Initial body weight (kg)	18.75	18.92	19.0	18.67	0.24	Ns
Final body weight (kg)	23..08^{b}	23.58^{ab}	23.83^{a}	23.92^{a}	0.33	**
Total body weight change (kg)	4.33^{b}	4.67^{b}	4.83^{ab}	5.25^{a}	0.32	***
Average Daily Gain (g/day)	52^{b}	56^{b}	58^{ab}	63^{a}	3.9	***
FCE (ADG/TDMI)	0.065^{b}	0.066^{ab}	0.068^{ab}	0.073^{a}	0.004	*

$^{a-b}$mean values in a row having different superscripts differ significantly; SEM, standard error mean; FCE, Feed conversation Efficiency; ADG, average daily gain; TDMI, total dry matter intake; ns, not significant; *, significant at p<0.05; **, significant at p<0.01; p<0.001; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB/day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB/day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB/day

Higher BWC and ADG were obtained from lambs fed T3 and T4 than T1 and T2. This might be due to the high energy contents, low fiber contents, high total DM and CP intake and high nutrient digestibility of WBGB. The live weight change and average daily gain of lambs of the present study over the experimental period was increased as supplementation of WBGB increased. Similar results were reported earlier of sheep fed industrial brewery grain by-product and local brewery grain by-product called *Atel.la*[18,19,44] The ADG (44.4-93.99 g/day) reported for intact Wogera lambs fed grass hay (100,200 and 300 g/day) of brewery dried grain slightly agree with the results of the current study. Whereas average daily gain of 45 g/day reported for Tigray highland lambs fed grass hay with 330 g/day of local brewery dried grain by-product (*Atella*)[18] was lower than the result obtained in the present study. The FCE of lambs fed T4 was better than that of the other treatments. This result is similar to FCE of 0.06 for Tigray highland sheep fed local brewery grain by–product.[18] The FCE of present study was lower than the result (0.0 – 0.14) reported for intact Wogera lambs fed grass hay and graded level of brewery grain by-products (Table 6).[19]

Table 6 Carcass characteristics of local sheep fed treatment diet

Carcass characteristics	Treatment diets				SEM	SL
	T1	T2	T3	T4		
Slaughter weight (kg)	22^{c}	23^{b}	24^{ba}	24^{a}	0.48	**
Empty body weight (kg)	18^{b}	19^{ba}	20^{a}	20^{a}	0.44	*
Hot carcass weight (kg)	9^{b}	10^{a}	11^{a}	11^{a}	0.31	**
Dressing percentage:						
Slaughter weight basis (%)	43.63	44.04	44.26	44.31	1.26	Ns
Empty body weight basis (%)	52.08	53.69	53.53	53.99	1.69	Ns
Rib eye muscle area (cm^2)	7.20^{b}	9.10^{ba}	10.70^{a}	10.30^{a}	1.14	*

$^{a-c}$mean values in a row having different superscripts differ significantly; *, significant at p<0.05; **, significant at p<0.01; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB wet brewery grain by-product /day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB wet brewery grain by-product /day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB wet brewery grain by-product /day

The carcass characteristics of Tigray highland lambs fed treatment diets are presented in Table 6. The slaughter weight (SW) of T4 was higher (P<0.01) than that of T1 and T2, but it was not significantly different from T3 and difference between T2 and T3 was also not significant. Empty body weight (EBW) was increased as the level of supplementation in the diet increased. EBW (p<0.05) of T3 and T4 were higher than T1 whereas differences between T4 and T3; T3 and T2; and T2 and T1 were not significant. The hot carcass weight (HCW) due to T2, T3 and T4 were higher (p<0.01) than that of T1 but no significant difference among T2, T3 and T4. There were no significant differences among treatments in dressing percentage on both slaughter weight and empty body weight bases. The rib -eye muscle area (REMA) of lambs fed T4 was significantly higher (p<0.05) than that of T1 and T2 but all other differences were not significant.

According to the feeding habit of the people around the study area, the offal were categorized in to edible (head, blood, tongue, heart, kidney, tests, liver, reticulo-rumen, omasum and abomasum, large and small intestine, tail and fat from kidney, omasum and heart) and non-edible offal (skin, penis, feet, lung and trachea, spleen, bladder and gut contents). Dressing percentage is affected by age, sex, feeding system, feed type, breed and environmental condition. In this study dressing percentage (DP) on EBW basis was similar to results (51.83-54.69 and 47-53%) in previous studies reported[15,45] respectively but lower than values (55.4 -56.4%, 58.5-60% and 57.1 - 59.1%) in other reports[17,18,46] respectively and higher (45.50-48.4%) than that recorded for Tigray highland sheep.[23] In this study, DP at SW bases in line with the research findings (39.7-45.2%; 35.29-45.03) for Tigray highland sheep[46,47] respectively. The DP on SW basis in the present study were lower than those earlier reported of Wogera and local sheep (36-38.4%, 32-38% and 38-39.6%)[48–50] respectively. Higher than the DP in the present study (46-49%) on SW basis were also reported[18] for Tigray high land sheep fed local brewery grain by-product. The DP on EBW basis found in the present study was in line with the results (44-55%) in a previous study[47] for Tigray highland sheep fed wheat bran and teff straw as basal diets and supplemented with sesame cake. Higher than the DP in the present study (57-60%) on SW basis was reported[18] for Tigray high land sheep fed local brewery grain by-product. Lower than to the present study (45-48%) on EBW basis was reported for Tigray highland sheep fed wheat straw and supplemented with mixtures of wheat bran and cotton seed cake.[23]

The rib eye muscle area (REMA) is an indicator of muscling and amount of lean meat in the carcass. The REM found in the present study is similar to results reported (8.2-10.4 cm^2) earlier in black head Ogaden sheep fed haricot bean, mixtures of wheat bran and brewery dried grain.[44] In contrast to the current study, higher REMA (13-19.5 cm^2) in black head Ogaden sheep fed different levels of brewery dried grain were reported.[48] The former studies showed that supplementation of rich protein source feeds had significant and positive effect on REMA and are causes of differences as described by several authors may be due to variations in the amount and quality of supplement proteins, and variations in sheep breeds used (Table 7).

The edible offal components of Tigray highland sheep fed grass hay, wheat bran and supplemented with graded level of WBGB are presented in (Table 7). The result of the present study indicated that supplementation with WBGB had no positive effect on most of the edible offal components whereas significant differences of testes ($p<0.05$), omasum and abomasum ($p<0.05\%$), tail ($P < 0.001$) were obtained. This agrees with earlier findings for testes ($p<0.01$) when cotton seed cake, dried *Acacia saligna* and *Sesbania sesban* were supplemented to Begat sheep in north Ethiopia;[17] for omasum and abomasum ($p<0.05\%$) supplemented with air dried foliage of African wild olive and red thorn to Tigray highland sheep[46] and for tail ($p<0.001$) when local brewery grain *(Atella)* was supplemented to Tigray highland sheep.[18] The edible offal components such as head, blood, heart, tongue, liver with bile, total fat, reticulum and rumen, large intestine, small intestine, kidney and empty gut were not significantly different among treatments. However, the total edible offals (TEOs) were significantly different ($p<0.01$) between supplemented and control group nevertheless no significant difference among the supplemented sheep. The highest value of TEOs was recorded from T4 followed by T3, T2 and T1. Generally, the results of present study for TEO of supplemented sheep were significantly higher ($P < 0.01$) than control. The variations in carcass traits in this and previous studies may be due to differences in age, breed and quantity and quality of basal diets and supplement feeds used in the experiments. It was noted that nutrition, age, sex, genetics, season and other related factors affect the growth and carcass traits of animals (Table 8).[31]

Table 7 Edible offal components of local sheep fed experimental diets

Edible offal	Treatment diets					
	T1	T2	T3	T4	SEM	SL
Head (kg)	1.20	1.33	1.35	1.43	0.12	Ns
Blood (g)	725	655	588	858	128	Ns
Heart (g)	98	97	92	93	22	Ns
Tongue (g)	74^{b}	101^{a}	84^{ba}	95^{ba}	10	*
Testes(g)	208^{b}	221^{a}	298^{a}	240^{ab}	31	*
Liver + Bile (g)	273	269	273	295	27	Ns
Omental fat (g)	176	235	111	217	111	Ns
Reticulum-Rumen (g)	459	488	478	501	68	Ns
Oma-Abo (g)	179^{ba}	162^{ba}	149^{b}	208^{a}	25	*
Large intestine (g)	183	235	220	229	88	Ns
Kidney (g)	55.25	55.25	65	53	11	Ns
Small intestine (g)	437	513	512	387	138	Ns
Tail (g)	521^{c}	775^{bc}	1100^{a}	1025^{ba}	119	***
Empty gut (Kg)	1.25	1.40	1.35	1.33	0.12	Ns
Total edible offal (Kg)	5.84^{b}	6.53^{a}	6.67^{a}	6.95^{a}	0.25	**

$^{a-c}$mean values in a row having different superscripts differ significantly; SEM, standard error mean; ns, not significant; *, significant at p<0.05; **, significant at p<0.01;***, significant at p<0.001; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB/day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB/day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB/day

Partial budget analysis done in order to determine the economic importance of supplementing WBGB to Tigray highland sheep is presented in Table 8. The total return obtained in this trial was progressively increasing for sheep fed dietary T1 to T4. Consequently, the net returns obtained followed similar trend. Sheep offered T4 gave highest net income followed by T3, T2 and T1. Differences in total return and net return may be related with the differences in selling and buying price of the sheep, changes in intake and cost of the supplement and its transportation. Similar result was reported earlier.[50] The marginal rate return was 40%, 119% and 117% for T2, T3 and T4, respectively. Meaning, for each additional one Birr spent per sheep resulted in one Birr plus additional 0.4, 1.19 and 1.17 Birr benefit for T2, T3 and T4, respectively as compared to the sheep in T1. So, from this study it can be concluded that supplementation of sheep with 280 and 350 gram WBGB daily is economically cost-effective.

Table 8 Partial budget analysis of Tigray highland sheep fed treatment diets

Parameter	Treatment diets			
	T1	T2	T3	T4
Number of animals	6	6	6	6
Purchase price of sheep (ETB/head)	1051.60	1058.30	1008.30	1046.30
Total grass hay intake (kg/head)	42.83	39.92	37.51	31.79
Total wheat bran intake (kg/head)	26	26	26	26
Total wet brewery grain intake (kg/head)	-	17.60	23.50	29.40
Total cost of grass hay (ETB/ head)	42.83	39.92	37.51	31.79
Total cost wheat bran (ETB/head)	152.00	152.00	152.00	152.00
Total cost of wet brewery grain (ETB/head)	-	55.80	74.50	93.20
Total variable cost (ETB)	194.75	247.76	263.99	276.91
Sale of sheep (ETB/ head)	1500.00	1581.34	1608.30	1673.30
Total return (ETB/head)	448.40	523.04	600.00	627.00
Net return (ETB/head)	253.65	275.28	336.01	350.09
∆NR in ETB/head)	-	21.63	82.36	96.44
∆TVC in ETB/head	-	53.01	69.24	82.16
MRR% (∆NR/∆TVC)	-	40.80	118.95	117.38

ETB, Ethiopian Birr; ∆TR, change of total return; ∆NR=change of net return; ∆TVC, change of total variable cost; MRR, marginal rate of return; T1, Hay ad libitum + 309 g wheat bran gram/day; T2, Hay ad libitum + wheat bran 309 g+210g WBGB/day; T3, Hay ad libitum + 309 g wheat bran +280 g WBGB/day; T4, Hay ad libitum + 309 g wheat bran + 350 g WBGB/day

Summary and conclusion

This study was conducted with the objective of determining the response of Tigray highland sheep supplemented with graded level of wet brewery grain by-product (WBGB) on feed intake, nutrient digestibility, body weight gain, carcass yield and economic profitability. It was found out that T3 and T4 are economically feasible and up to 350 g of WBGB can be supplemented to sheep daily. Feeding value of the brewery grain by-product could also be studied on other classes of livestock found in the study area.

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None.

Conflicts of interests

Authors declare that there is no conflict of interests.

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