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Research Article

Effect of replacing wheat bran with urea molasses-treated groundnut hull on the performance of Gumuz Goats at Pawe Agricultural Research Center

***Atala Marie* [1*], *Yeshambel Mekuriaw* [2], *Likawent Yeheyis* [3] *and Habtie Arega* [1]**

[1]Ethiopian Institute of Agricultural Research, Pawe Agriculture Research Center, Pawe, Ethiopia
[2]College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia
[3]Amhara Region Agricultural Research Institute, Bahir Dar, Ethiopia
***Corresponding author:** atalamarie2008@gmail.com

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Abstract: *In this experiment, urea molasses-treated groundnut hull (UMTGH) was evaluated as a replacement for wheat bran (WB) on the basis of nutrient utilization, body weight change, carcass characteristics, and economic feasibility of Gumuz goats fed on natural pasture hay (NPH) as a basal diet in Ethiopia. The study was conducted using 20 yearling intact male Gumuz goats with an initial body weight of 15.36 ±0.87 kg (mean ±SD). The feeding trial was conducted for 90 days, followed by a 10-day digestibility trial. The treatments were ad libitum feeding of NPH supplemented with 493 g UMTGH (T1), 360 g UMTGH + 76 g WB (T2), 240 g UMTGH + 152 g WB (T3), 120 g UMTGH + 228 g WB (T4), and 312 g WB (T5) on iso-nitrogen basis. Urea molasses treatment improved crude protein (CP) by 50% and reduced fibers by 20% of the ground nut hull. Crude protein (CP) intake and nutrient digestibility were significantly increased as the UMTGH increased. Body gain, hot carcass weight, and dressing percentage were the highest in T4. The economic feasibility test showed that T4 returned a higher net income (464.1ETB/goat) than the other treatments. It was concluded that 120 g UMTGH+228g WB (T4) could be used as supplement feed in the diets of Gumuz goats to reduce the cost of concentrate feed by partially replacing WB.*

Keywords: Carcass characteristics, Goat performance, Groundnut hull, Native grass
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1. Introduction

Ethiopia has diverse agro-ecology and livestock types with different adaptations, productivity, and use in the farming systems. The country has an estimated goat population of 52.5 million, and this is the first time that the goat population in Ethiopia is more than the sheep population of 42.9 million (CSA, 2021). Goats are predominantly available in the mid and low-altitude areas of Ethiopia. Livelihood, food and nutrition, cash income, serving as a savings bank, and export are some of the recognized socioeconomic benefits of goat production in the country. In Ethiopia, goats supply approximately 16% of the total ruminant livestock meat output (Adane and Girma, 2008; Legesse and Fadiga, 2014). Although goats provide considerable benefits to smallholder farmers and the country's economy, their present contribution to poverty reduction and food security is far below their potential because of poor nutrition, genotype, and prevalence of diseases. However, the most important factor affecting the performance of small ruminants is poor nutrition (Legesse *et al*., 2010). Moreover; goats have been given less attention in feed and nutrition research and development compared with sheep.

The main feed sources of livestock in Ethiopia are grazing (54.54%) and crop residue (31.13%), both of which are poor in quality and cannot satisfy the maintenance level of the animal (Mekuriaw *et al*., 2012). Therefore, supplementation of a protein source is one of the methods to improve the efficiency of utilization of available roughage feed resources (Lamaro *et al*., 2016). Commercial concentrates and individual agro-industrial by-products such as oil seed cakes and wheat bran are inaccessible and unaffordable to the majority of goat producers in the country. Moreover, the improved forage as livestock feed contribution in Ethiopia is very low; after almost five decades of research and development effort (CSA, 2021). Moreover, the majority of the natural browses in Ethiopia used for goat production have declined because of deforestation activities (Mohammed and Zewdu, 2020).

This critical feed shortage leads to impairing sustainable and profitable goat production in the country. To benefit from the goat potential, it is commendable that the goat producers should practice a semi-intensified goat production system by providing better feed in response to growing the animal to reach the marketable weight for both domestic and exportable sizes. Hence, looking for alternative protein sources that could replace expensive protein feed is commendable for sustainable and profitable goat production. Particularly in the Benishangul-Gumuz Region, where this study was conducted livestock feed shortage both in quantity and quality is exacerbated by uncontrolled fire, encroachment of pasture lands by invasive weeds, and poor culture of feed conservation practice (Agza *et al*., 2013; Oumer and Wondimu, 2016). Looking for alternative protein sources of feedstuff that can be available locally; adaptable to the area and familiar with the producers are encouraged. Groundnut hull is a promising by-product of groundnut production.

Groundnut (*Arachis hypogea*) is widely cultivated in Ethiopia, particularly in Benishangul-Gumuz, where this study was conducted. The estimated production area in hectares and the mean average yield of groundnut were 84,237.01 ha and 1.711 tons/ha, respectively and the leading groundnut production areas in Ethiopia are Oromia (50,121.08 ha); and Benishangul-Gumuz (17,174.96 ha) (CSA, 2019). The Metekel zone is one of the potential groundnut-producing zones in the Benishangul-Gumuz region, which stood first in terms of area cultivated and groundnut production (Tesfay and Woundefiraw, 2021). Therefore, there is an abundant groundnut hull in the area to be used as a supplement source for ruminant nutrition. However, because of a lack of research on the nutritional advantages of ruminant nutrition to the resource, the majority of the groundnut hull has been burnt and dumped in the Benishangul-Gumuz region (Gebregziabher *et al*., 2021). Ahmed *et al*. (2017) reported that the haulm of groundnut in Eastern Ethiopia is used for animal feed and some of the respondents use the hull or shell as firewood. However, it is a fibrous by-product and requires feed treatment technologies to be effectively used for ruminant production.

The results of different previous studies have shown that urea molasses-treated groundnut hull can be used as a supplement feed in the diets of livestock, particularly ruminants and rabbits (Abusuwar *et al*., 2012; Khan *et al.*, 2017). Abdel *et al.* (2013) reported that urea-treated groundnut hulls improve sheep performance, but Worku and Urge (2014) reported that urea-treated groundnut hull fed by Somali goats was reflected in low growth performance; which might be a lack of fermentable energy in the basal diet. This variation in the performance of ruminants fed treated ground hulls requires further research. Overall, there is limited knowledge on groundnut hulls treated with urea molasses in the country, especially with the inclusion of molasses which could have profound advantages as a source of fermentable energy source in the rumen and as a sweetener. This study aimed to evaluate nutrient utilization, body weight, carcass characteristics, and economic performance of Gumuz goats fed urea molasses-treated groundnut hull as a replacement for wheat bran supplement.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted at the Pawe Agricultural Research Center (PARC) station, located in the Metekel Zone, Pawe District of Benishangul-Gumuz Region, and northwest Ethiopia. The center has individual feeding pen facilities and was used for this study. It is located 572 km northwest of Addis Ababa at latitudes and longitudes of 11°09 'N and 36°03 'E, respectively, with an elevation of 1120 m.a.s.l and annual minimum and maximum temperatures of 17.3 and 34.1°C, respectively. The average annual rainfall of the center is 61.86 mm and the mean relative humidity is 50.3. It covers an area of approximately 150,000 ha (Mohammed, 2017). The location is characterized by a hot to warm moist agro-ecological zone and is known for sorghum, maize, mango, soybean, and groundnut crop production. In addition, goat, cattle, and sheep production are common practices of smallholder farmers in the area (Shitaneh *et al*., 2021).

2.2. Experimental feed preparation

Natural pasture hay, wheat bran, and urea-molasses-treated groundnut hull were used in the experiment. The groundnut (*Arachis hypogea*) hull was collected from villages of Pawe district, specifically villages 28 and 30. Natural pasture hay was harvested at 50% flowering from the natural pasture of Pawe Agricultural Research Center, and the fresh biomass was air-dried until the required moisture content was attained. The collected groundnut hull and natural pasture hay were chopped and stored. Wheat bran, urea, and molasses were purchased from Bahir Dar city and transported to the Pawe Agricultural Research Center. A total of 300 kg of groundnut hulls used in two rounds were treated with 4% urea, and 8% molasses using 80 liter of water per 100 kg of groundnut hull. The treated groundnut hull was placed in airtight plastic bags and ensiled for 21 days as described previously (Al-masri and Guenther, 1999).

In brief, a uniform spray of urea molasses solution was applied to weighed groundnut hulls over the ground plastic sheet batch by batch. Accordingly, the hull was treated and compacted until it was filled to the bag capacity. Finally, the bag was made airtight and left unopened for twenty-one days. By the end of the treatment period, the treated groundnut hull was spread on a polyethylene sheet for one day to allow the evaporation of the ammonia. Before the experiment began, samples of supplement ingredients urea molasses-treated groundnut hull, wheat bran, and natural pasture hay were analyzed for the chemical composition of crude protein (CP) content at the Pawe Agricultural Research Center. Based on the chemical composition, the supplement ratios were developed to make the experimental diets iso-nitrogenous. UMTGH and WB were thoroughly mixed before being provided to the experimental animals.

2.3. Experimental animals and their management

Twenty intact male yearling full milk teeth Gumuz goats with an initial body weight of 15.36 ±0.87 kg (mean ± SD) were used in the experiment. The animals were purchased from the local market. The age of the animals was determined by looking at their teeth and asking their owners. The animals were quarantined for 15 days to acclimatize them to the new environment and observe their health conditions. Moreover, the study animals were prophylactically treated against infectious diseases and, internal and external parasites based on veterinarian recommendations.

At the end of the quarantine period, the animals were ear-tagged for identification purposes, blocked into four blocks of five animals based on their initial live weight, and randomly assigned to one of the five treatment rations. The animals were housed in individual pens and had access to *ad libitum* NPH supplemented with UMTGH and WB during the acclimatization period. The pens were equipped with a feeding trough for NPH and supplements and a plastic bucket for watering separately. NPH, water, and common salt were offered *ad libitum*, while a mixture of UMTGH and WB was offered twice a day at 8:00 AM and 4:00 PM in equal proportions throughout the experiment period.

2.4. Experimental design and treatment setup

Twenty goats were randomly assigned to five feed treatments, based on their initial live weight. A randomized complete block design (RCBD) was used with five treatments and four replications. The treatment diets are presented in Table 1.

Table 1: Treatment diets used in the feeding experiment

	Feed offered g/day (DM basis)		
Treatment	NPH	UMTGH	WB
T1	Ad libitum	493	-
T2	Ad libitum	360	76
T3	Ad libitum	240	152
T4	Ad libitum	120	228
T5	Ad libitum	-	312

T1 (Negative as control) = 100% urea molasses treated groundnut hull (UMTGH) + ad lib natural pasture hay (NPH); T2 = 75% UMTGH + 25% wheat bran (WB) + ad lib NPH; T3 = 50% UMTGH + 50%WB + ad lib NPH; T4 = 25% UMTGH + 75% WB + ad lib NPH; T5 (Positive) = 100% WB+ add lib NPH

2.5. Measurements

2.5.1. Feed and nutrient intake

The feeding trial lasted for 90 days followed by 15 days of adaptation. The amount of feed offered and refused was weighed and recorded for each goat daily. Dry matter (DM) and nutrient intakes were determined as the difference between the amount offered and the amount refused. A spring weighing balance (Timbangan gantang 50kg) was used for measurement. Representative samples of the feed offered and refusal were collected per batch. Refusal samples for each goat were collected and pooled for each treatment for chemical analysis.

2.5.2. Feed digestibility

The digestibility trial was conducted 90 days after the feeding trial. Three days of adaptation for harnessing a fecal bag, was followed by a total fecal collection for seven consecutive days. Feces collected in the fecal bags were weighed, recorded, and sampled for each animal every day in the morning before feeding and drinking water. Sampling from the daily collected feces of each animal was performed by taking 20% of the feces after thoroughly mixing it in the plastic bags and stored at -20^{0}C. After the seventh day, the faecal samples were withdrawn from the freeze, thawed, and thoroughly mixed days' feces. Then, the samples were dried in an oven to a constant weight at 65^{0}C for 72 h. The partially dried samples of feed and feces were ground using a laboratory mill to pass through a 1-mm sieve. The ground samples were stored in an airtight plastic bag and transported to the Holleta Agricultural Research Center for chemical analysis.

The apparent digestibility coefficient of DM and nutrients organic matter (OM), crude protein (CP), natural detergent fiber (NDF), and acid detergent fiber (ADF) was determined as a proportion of the nutrient intake not recovered in feces using the following formula (McDonald *et al.*, 2002).

$$DMD(\%) = \left(\frac{\text{DMI}-\text{Faecal DM excreated}}{\text{DMI}}\right) * 100 \qquad [1]$$

Where, DMD is dry matter digestibility percentage and DMI is dry matter intake.

Similarly, the apparent digestibility of major nutrients was calculated following the formula below.

$$ADCN = \left(\frac{NI-NE\ in\ feces}{NI}\right) x\ 100 \qquad [2]$$

Where ADCN is apparent digestibility coefficient of nutrient; NI and NE are nutrient intake and excreted in feces, respectively.

2.5.3. Body weight change and feed conversion efficiency

The initial and final body weight of each animal was measured at the beginning and end of the experiment after overnight fasting. To determine the weight change, the live weight of individual animals was measured every 10 days intervals in the morning before the provision of feed and water. The body weight of the goat was measured using a hanging sensitive balance. The average daily body weight gain (ADG) was calculated as the difference between the final and initial body weights and divided by the number of feeding days. The feed conversion efficiency (FCE) of the experimental animal was calculated by dividing ADG by daily total DM intake.

2.5.4. Carcass parameters

At the end of the feeding and digestibility trial, all experimental goats were slaughtered after overnight fasting. Edible offal components (EOC) such as blood, heart, kidney, liver, tongue, empty stomach, empty intestine, testicle, kidney fat, tail fat, heart fat, omental fat, mesenteric fat, and inedible offal (skin, feet, penis, head without tongue, lungs with trachea, oesophagus, spleen, pancreas, urinary and gall bladder and gut content) were weighed and recorded. Total edible offal component (TEOC) was taken as the sum of (heart, tongue, small and large intestine, liver, kidney, blood, empty gut, stomach (reticulo-rumen, omasum, and abomasum), tongue, testicle, and fat (kidney and genital)). The total weight of the non-edible offal component (TNEOC) was obtained as the sum of the head without tongue, penis, urinary bladder, lungs with the trachea, oesophagus, spleen, feet with skin, gall bladder, and gut fill.

Total edible products (TEP) were taken as the sum of total edible offal components and hot carcass weight (HCW). The dressing percentage was calculated as the ratio of hot carcass weight to slaughter weight. Empty body weight (EBW) was defined as SBW minus gut contents. Dressing percentage on the SBW basis (DPSBW) and dressing percentage on the EBW basis (DPEBW) were calculated as (HCW/SBW)*100 and (HCW/EBW)*100, respectively. The rib eye area of the muscle was traced on graph paper between the 12^{th} and 13^{th} rib of the right half of the carcass and the area was measured (Khan *et al*., 2003). All procedures followed the ethical standards of the responsible committee on animal experimentation.

$$DP\ based\ on\ SW = \left(\frac{HCW(kg)}{SW(kg)}\right) * 100 \quad [3]$$

Where, DP is dressing percentage and HCW and SW are hot carcass weight and slaughter weight, respectively.

2.5.5. Chemical composition analysis of the experimental feed

The samples collected from daily offered and refused feeds, including that of feces from each treatment, were analyzed for DM, OM, CP, NDF, ADF, and ADL at the Holleta Agricultural Research Center nutrition laboratory. The DM, OM, and nitrogen (N) were analyzed according to the procedures of (AOAC, 2005). Crude protein was calculated as N x 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed using the method described in (Van Soest, 1994).

2.5.6. Partial budget analysis

Partial budget analysis was performed to evaluate the profitability of the different experimental diets. To estimate the economic benefits of feeding UMTGH to goats, calculations were performed according to the procedure of Upton (1979). The total return (TR) was calculated as the difference between the selling and purchasing prices of the experimental animals. At the end of the experiment, the selling price of each experimental goat was estimated by three experienced local goat dealers, and the average of the estimated price was used. The variable costs were calculated from the supplementary feed ingredients, basal feed, and medicament costs that were supplied for each experimental goat. The total returns (TR) were determined by calculating the difference between the estimated selling and purchasing prices of the experimental goat. The net return (NR) was calculated as;

$$NR = TR - TVC \quad [4]$$

The change in net return (ΔNR) was calculated as the difference between the change in total return (ΔTR) and the change in total variable costs (ΔTVC) as indicated below.

$$\Delta NR = \Delta TR - \Delta TVC \quad [5]$$

2.5.7. Statistical analysis

The data collected on feed intake, digestibility, body weight change, feed conversion efficiency, and carcass characteristics were analyzed and subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedures of the Statistical Analysis Software Version 9.0 (SAS, 2002). Treatment means were separated using Tukey's HSD test when the F value showed significant differences. Statistical significance was established when the probability is ≤ 0.05 level of significance.

The statistical model was:

$$Yij = \mu + Ti + \beta j + \varepsilon ij \quad [6]$$

Where: Yij = response variable; μ = Overall mean; Ti = ith treatment (test diets) effect; βj = jth block effect; εij = the random error.

3. Results and Discussion

3.1. Chemical composition of the feeds

The chemical composition of the feeds used in the present study is shown in Table 2. For all the experimental feeds, the dry matter (DM) and organic matter (OM) contents were comparable. However, variation was observed in the remaining nutrient components, particularly in crude protein (CP) and fibers. As expected, the refusal from all treatment groups recorded lower CP and higher fiber content in supplementary feeds except T1, which was lower in ADF and ADL, indicating selective feeding by goats. Urea molasses treatment improved the CP content of the groundnut hull. However, the improvement was lower than the CP required for microbial protein synthesis in the rumen. Urea molasses treatment of the groundnut hull adds more N to the rumen microbes. This may reduce the rumen retention time by increasing the outflow rate and stimulating intake (Abdulrazak *et al*., 2005). Similarly, urea molasses treatment decreased the OM, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) contents of the groundnut hull. Urea molasses treatment of groundnut hull in this study reduced NDF, ADF, and ADL content by 19, 19.8, and 23.9%, respectively.

The current study indicates that the cell wall components of the hull may be broken through the application of urea molasses treatment. It reduces the fiber (NDF, ADF and ADL) and increases the CP content of the groundnut hull, due to the binding of ammonia with crop residues and softening of hemicelluloses by the action of ammonia evolved from urea (Misra *et at*., 2006). The crude protein content of urea molasses-treated groundnut hull in this study was lower than the values of 9.85, 11.4 and 12.4% reported by Hameed (2012), Worku and Urge (2014 and Alnour (2017), respectively. This discrepancy may be attributed to the variety, agronomic practice, soil type, and the type of treatment applied to the hull. Similarly, the fiber content reduced by urea molasses treatment in this study was better than the fibers of groundnut hull treated by urea (Worku and Urge, 2014). According to Millam and Abdu (2017), the groundnut shell treated with urea and lime improved the CP content by 8.53% and decreased the NDF, ADF, and ADL by 8.6, 30, and 12.39%, respectively. This chemical composition difference could be attributed to differences in the treatment and genotype and growing conditions of the biomass used for the experiment. According to Abdel *et al*. (2013) the NDF, ADF, and ADL were reduced by 12.87, 7.25, and 12.04%, respectively, which is lower than the current result but with higher CP, which improved by 6.16% on the effect of urea treatment on the chemical composition and rumen degradability of groundnut hull.

The current result is lower in the CP than the finding of Abusuwar *et al.* (2012), which increased the CP by 10.86% on the effect of feeding treated groundnut hulls with 30% molasses ensiled for 30 days on the performance of desert sheep during late summer in the arid rangelands of western Sudan. On the other hand, the CP increased by 2.2% using alkali-treated groundnut shells with Xylanase in rations of Yankasa rams (Millam *et al*., 2021).

Overall, the urea molasses treatment changed the chemical composition of the groundnut hull, although variation in figures was reported among scholars. This might be attributed to many factors such as the level of urea, molasses and the genotype, and weather during treatment. The natural pasture hay used in the present study contained lower levels of CP (7%), which is less than the CP required for microbial protein synthesis in the rumen (Van Soest, 1994). The CP value of natural pasture hay is comparable to 7.07 and 7.12% reported by Tulu *et al*. (2018) and Mezgebu *et al*. (2019) respectively, but slightly higher than 6.8 and 5.87% reported by (Kuraz *et al* 2021, and Bainesagn *et al*., 2021) respectively. The difference in protein content of natural pasture hay harvested from the same and different areas among reports might be due to differences in the stage of maturity at the time of harvesting, harvesting season, types of grass composition, hay drying management, nutrient content of the soil, and climatic conditions of the area (Dereje, 2016; Kumsa *et al*., 2019). The crude protein content of wheat bran in this study was comparable to the value of 15.98% reported by Tulu *et al*. (2018), but lower in terms of NDF (46.08%). In the present study, the same author reported lower ADF (14.74%) and ADL (3.93%). This discrepancy might be due to the genotype, agronomic, and level of urea and molasses used for treatment.

Table 2: Chemical composition of the experimental diets

	Chemical compositions in percentage						
	DM	OM	Ash	CP	NDF	ADF	ADL
Feeds offered							
NPH	91	94	6	7	70	37.6	5.6
UMTGH	92	97	3	6	72	62.9	38
T1	93	95	5	9	53	43.1	14.1
T2	92.5	95	4.97	10.75	49.5	33.93	11.25
T3	92	95	4.95	12.5	46	24.75	8.4
T4	91.5	95	4.92	14.25	42.5	15.58	5.55
T5	91	95	5	16	39	16.4	2.7

ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; DM = dry matter; NDF = neutral detergent fiber; OM = organic matter; WB = wheat bran; UMTGH = urea molasses treated groundnut hull; NPH = natural pasture hay; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 = NPH supplemented with only 312 g WB.

3.2. Dry matter and nutrient intake

The mean values of daily DM and nutrient intake of Gumuz goats fed natural pasture hay and supplemented with a mixture of different proportions of urea molasses-treated groundnut hull and wheat bran are presented in Table 3. All parameters of the intakes were significantly ($P<0.001$) different among treatments. High basal diet DM, ADF, and ADL intake was observed in T1 compared with the rest treatments. The higher natural pasture hay intake in T1 could be due to the lower intake of supplements, and in T5, the lower ADF content in the supplement diet results in better total DM intake. High supplement diet DM, total DM, DM (g/kg$W^{0.75}$), OM, and CP intake were recorded in T5 compared with other treatments. Among the urea molasses-treated groundnut hull (UMTGH) and wheat bran (WB) supplemented groups; the CP intake increment was consistent with the increment of WB level in the supplementary diet. This may be attributed to the higher CP content of WB used in this experiment. The decreased CP intake with increasing proportions of urea molasses-treated groundnut hull supplementation is attributed to the lower CP content of urea molasses-treated groundnut hull compared with wheat bran. Higher fiber (ADF and ADL) intake might influence the nutrient digestibility of goats assigned to T1.

Table 3: Feed intake of Gumuz goats that fed natural pasture hay and supplements with different proportions of urea molasses-treated groundnut hull and wheat bran

	Treatments						
Parameters	**T1**	**T2**	**T3**	**T4**	**T5**	**SEM**	**SL**
NPH DM intake (g/d)	208.5^{a}	146.4^{c}	136.4^{d}	178.2^{b}	140.3^{d}	0.722	***
SDM intake (g/d)	114.8^{e}	202.8^{b}	159.2^{d}	182.7^{c}	283.5^{a}	0.789	***
Total DM intake (g/d)	323.3^{d}	349.1^{c}	295.6^{e}	360.9^{b}	423.8^{a}	0.772	***
DM intake ($g/kgW^{0.75}$)	32.1^{d}	37^{b}	33.4^{c}	33.3^{c}	40.5^{a}	0.117	***
OM intake (g/d)	285^{c}	326.7^{b}	279.2^{c}	352.3^{b}	401.5^{a}	4.970	***
CP intake (g/d)	25.1^{d}	30.7^{c}	30^{c}	40.6^{b}	56.7^{a}	0.194	***
NDF intake (g/d)	178.9^{c}	206.3^{a}	169.8^{d}	199.6^{b}	209.1^{a}	0.655	***
ADF intake (g/d)	133.4^{a}	117^{b}	72.5^{d}	77.1^{c}	70.8^{d}	0.372	***
ADL intake (g/d)	31.3^{a}	29.3^{b}	13.1^{e}	14^{d}	15.8^{c}	0.219	***

Means with different superscripts in a row are significantly different***(p<0.001); ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; DM = dry matter; NDF = neutral detergent fiber; NPH=natural pasture hay; OM = organic matter; SDM = supplemental dry matter; SEM = standard error of mean; SL= significant level; WB = wheat bran; UMTGH = urea molasses treated ground nut hull; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 = NPH supplemented with only 312 g WB

3.3. Dry matter and nutrient digestibility

The apparent DM and nutrient digestibility percentages of the experimental feeds are shown in Table 4. A significant difference (P<0.001) was observed among the treatments in terms of DM, OM, CP, NDF, and ADF digestibility in the current study. The apparent DM and CP digestibility for T1, T4, and T5 was higher than those for T2 and T3. The apparent OM and NDF digestibility for T1 was significantly higher than that for the other treatments, and the ADF digestibility was higher for T1 and T5 than for T2, T3, and T4. In the current study, urea molasses treatment of the groundnut hull improved the CP by 50% and enhanced the digestibility of the groundnut hull. In addition, it increased the feed intake and productivity of animals. This treated feed resource is rich in nutrients such as carbohydrates, proteins, and minerals (FAO, 2010). The current study indicated that urea molasses treatment of groundnut hull enhanced the ruminal degradability of nutrients by reducing the fibrous content.

This is in agreement with Van Soest (1994) who reported that feeding low nutritive value of the high level of lignified material limited ruminal degradation of the carbohydrates and affected its value for ruminants. In addition, Wanapat (*et al*., 2009) who reported that by treating straw with urea or calcium hydroxide or by supplementing straw with protein; intake and degradability can be enhanced, compared with untreated straw. The higher DM digestibility in T1 as compared with other treatments might be due to their higher rumen digestible crude protein and lower NDF intake. The current study showed that DM digestibility was adversely influenced by the lignin concentration in the experimental diet. The digestibility of a feed is largely determined by chemical composition (Khan *et al*., 2003). The apparent DM digestibility of T1, T5, and T4 in the present study was higher than that of 74.9% reported by Mulisa *et al*. (2019) in Gumuz goat breed fed on Rhodes grass hay and supplemented with dry pigeon pea (*Cajanus cajan*) and neem (*Azadirachta indica*) leaves.

Feedstuffs with nutrient digestibility of 70% are better, and the animals fed on these feeds could express their genetic potential, whereas when apparent digestibility is 60%, the animal performance will be intermediate. Therefore, the minimum range of apparent digestibility to ensure animal body maintenance needs is 42-45%. Based on this classification, the feed used in the present study T1, T4, and T5 might be classified as feeds performing better for growth, and T2 falls within the range of feeds that immediately improve the growth of animals. Higher CP intake resulted in T5 having created a better environment by providing more nitrogen for rumen microorganisms, which made higher digestibility of DM for this treatment (Asmamaw and Ajebu, 2012). McDonald *et al*. (2002) reported that the primary chemical composition of feeds that determines the rate of digestion is NDF, which is a measure of cell wall content. Thus, there is a negative relationship between the NDF content of feeds and the rate at which they are digested, which agrees with the results of the current study. Similarly, Millam *et al*. (2021) reported that alkali-treated groundnut shells with Xylanase in rations of Yankasa ram improve the CP content growth performance and nutrient digestibility, although this is less than the current finding.

The apparent CP digestibility of T1, T4, and T5 was higher (P<0.001) than that of T2 and T3. The significant improvement in CP digestibility with only WB and the mix of 25% UMTGH with 75% WB supplement diet might be due to the higher CP content of the WB and the UMTGH-WB mixes because high CP intake is usually associated with better CP digestibility (McDonald *et al*., 2002). This result is higher than the range values of (62.85-80.63%) reported for urea-treated groundnut shells in growing rabbits by (Khan *et al*., 2017). Similarly, the apparent NDF and ADF digestibility values of T4, and T5 were higher (P<0.001) and followed by T1. The result of this study showed that in most nutrient digestibility of goats were decreased in T2 and T3; at the higher UMTGH mixture level. This might be associated with the combination of the two diets at this ratio influenced the activity of rumen microorganisms. Generally, this study revealed that supplementation of sole UMTGH, sole wheat bran, and the mixture of urea molasses-treated groundnut hull and wheat bran in the proportion of (25%: 75%) significantly improved the apparent CP and DM digestibility.

Table 4: Nutrient utilization of Gumuz goats fed on natural pasture hay and supplemented with different proportions of urea molasses-treated groundnut hull by replacing wheat bran

Digestibility (%)	T1	T2	T3	T4	T5	SEM	SL
DM	78.8^{a}	60.2^{b}	57.3^{c}	80.1^{a}	79.9^{a}	1.890	***
OM	78.8^{a}	59.4^{c}	59.1^{c}	79.9^{b}	89.7^{ab}	1.928	***
CP	78.7^{b}	71.9^{b}	60.6^{c}	87.1^{a}	89.4^{a}	1.267	***
NDF	58.1^{b}	49.0^{c}	45.7^{c}	62.7^{a}	68.1^{a}	2.586	***
ADF	43.6^{bc}	39.9^{c}	39.2^{c}	51.1^{b}	60.4^{a}	2.962	***

Means with different superscripts in a row are significantly different ***(p<0.001); ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; DM = dry matter; NDF = neutral detergent fiber; NPH = natural pasture hay; OM = organic matter; SDM = supplemental dry matter; SEM = standard error of mean; SL = significant level; WB = wheat bran; UMTGH = urea molasses treated ground nut hull; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 NPH supplemented with only 312 g WB

3.4. Body weight gain

The mean initial body weight (IBW), final body weight (FBW), body weight change (BWC), and average daily body weight gain (ADG) of Gumuz goats are presented in Table 5. The initial body weight of the animals in this study was non-significant (P>0.05) among the treatments. The results indicated that the effect of supplementing urea molasses-treated groundnut hull with wheat bran in different proportions to natural pasture hay as a basal diet was highly significant on average daily body weight gain, final body weight, body weight change (P<0.001) and feed conversion efficiency (P<0.05). Final BW, BW change, ADG, and FCE were observed to be higher for T4 followed by T5 and T1. However, in terms of FCE, T1, T4, and T5 were similar; this is still reflected from the nutrient digestibility point of view.

The daily BW gain observed in the current experiment was higher than the value of 20-43.33 g/d gain reported by Hailemariam *et al.* (2016) for short-eared Somali goat; 31.5-60.2 g/d reported by Dejene (2010) for Haraghe Highland goat; 37-44 g/d reported by Mohammed *et at.* (2012) for Rift Valley and Haraghe Highland goat; 38.7-50.9 g/d reported by Dereje *et al*. (2016) for short-eared Somali and Bati goat; and 22.8-43.5 g/d reported by Mulisa *et al.* (2019) for Gumuz goat supplemented with different concentration mixture levels. The mean daily BW gain of goats in this study in T4 (95.6 g/d) was higher than the value of 51.6 g/d observed by Debela *et al.* (2020) for Gumuz goats in the same area. The daily BW gain in this study was also higher than the report of 52.67-77.71 g/d weight gain reported by Bainesagn *et al*. (2021) for Gumuz goats fed on substitution of natural pasture hay by Stylosanthus humulis and cowpea in different proportions in a similar area.

The higher growth performance of goats receiving dietary T4 followed by T5 could be linked to the higher crude protein (CP) content. CP content can directly contribute to better feed intake and digestibility and improve the performance of animals (Negesse *et al*., 2001). When ruminants are offered treated low-quality roughage, there will be increased voluntary intake; and a gain in body weight because of the ability to meet both energy and protein requirements. Increasing protein and energy levels in the diet also improves the average daily BW gain and feed conversion efficiency of animals (Tekletsadik, 2008).

Table 5: Body weight of Gumuz goats fed on natural pasture hay and supplemented with different proportions of urea molasses-treated groundnut hull by replacing wheat bran

Parameters	T1	T2	T3	T4	T5	SM	SL
Initial Body Weight (kg/h)	15.9	14.9	15	15.4	15.7	0.195	Ns
Final Body Weight (kg/h)	21.7^{c}	19.9^{d}	18.3^{e}	24^{a}	22.9^{b}	0.054	***
Body weight change (kg/h)	5.9^{c}	5.0^{c}	3.3^{d}	8.6^{a}	7.2^{b}	0.183	***
Average daily weight gain (g/d)	65.4^{c}	56.0^{c}	37.0^{d}	95.6^{a}	80.0^{b}	0.002	***
FCE	0.0002^{ab}	0.0002^{bc}	0.000^{c}	0.000^{a}	0.0002^{ac}	0.000	*

Means with different superscripts in a row are significantly different at p<0.05; * = (p<0.05); ** = (p<0.01) and *** (p<0.001); BW = body weight; FCE = Feed conversion efficiency; Ns = non-significant; SEM = standard error of means; SL = significance level; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 = NPH supplemented with only 312 g WB

3.5. Carcass characteristics

The slaughter body weight (SBW), empty body weight (EBW), hot carcass weight (HCW), dressing percentage (DP) as a proportion on slaughter and empty body weight basis, and rib-eye muscle area (REA) of the experimental animals are presented in Table 6. Similar to the body weight and FCE performance, the SBW, EBW, HCW, and DP on slaughter and empty body weight base were significantly ((P<0.05) higher in T4 followed by T5 and T1; however, it was non-significant for REA. This might be due to higher DM and CP digestibility that improved feed intake, which favored the improvement in tissue deposition and weight gain as well as the FCE of goats. In addition, leguminous fodder increases protein supply to the host animal by increasing the supply of both degradable and non-degradable protein and by creating a favorable rumen environment, resulting in enhanced fermentation of the basal roughage and thus increased microbial protein synthesis (Osuji *et al*., 1995).

Generally, the supplementation groundnut hull treated with urea molasses in different proportions with wheat bran improved slaughter weight, empty BW, hot carcass weight, and dressing percentage of Gumuz goat. The current finding agrees with the value ranges of 11.3−15.7 kg EBW and 5.7−8.8 kg HCW reported by Asmamaw and Ajebu (2012) for the effects of supplementing *E. brucei* leaf as a replacement for cottonseed meal on growth performance and carcass characteristics of Sidama goats fed a natural pasture hay basal diet. The current finding is also in line with the value ranges of 6.1−7.7 kg HCW (Mulisa *et al.*, 2019) and 8.13 kg HCW (Debela *et al.*, 2020) for Gumuz goat supplemented with different concentrations of concentrate mix. However, it was lower than the finding of Bainesagn *et al*. (2021) who reported 17.6−21.31 kg EBW and 7.86−11.62 kg HCW.

The difference between the current results and previous findings might be associated with the variation in CP digestibility and the breed of goat used for the experiment. In this study, the DPSW bases ranged between 38.4%−47.0%, which is in agreement with the 36.5%−44% value reported by Asmamaw and Ajebu (2012), and 45.5%−46.0% reported by Dereje (2016). The DPSW reports of 38.2−43.7% by Mulisa *et al*. (2019) and 37.05−46.31% by Bainesagn *et al. (*2021) for Gumuz goats also agree with the present finding. In the current study, the DPEBW bases ranged between 57.8% and 69.9%, which is higher than the 47.1−53.4% and 46.02−56.23% values reported by Mulisa *et al*. (2019) and Bainesagn *et al. (*2021) for Gumuz goats, respectively. Debela *et al.* (2020) also documented lower DPEBW values for Arab (53.1%), Felata (54.81%), and Gumuz (55.74) goats. Generally, the variations in carcass traits in this study and other results of previous studies might be due to variations in nutrition, age, sex, genetics, season, and other related factors that affect the growth and carcass traits of animals.

Table 6: Carcass characteristics of Gumuz goats fed on natural pasture hay as a basal diet and supplemented with different proportions of urea molasses-treated groundnut hull and wheat bran

Parameters	T1	T2	T3	T4	T5	SEM	SL
SBW (kg)	16.3^{a}	14.5^{bc}	14.3^{c}	15.9^{ab}	16.3^{a}	0.2	*
EBW (kg)	10.8^{a}	10.4^{ab}	9.4^{b}	10.8^{a}	11.6^{a}	0.2	*
HCW (kg)	6.3^{b}	6.0^{b}	6.3^{b}	7.5^{a}	6.9^{ab}	0.1	*
Dressing percentage on							
SBW base	38.4^{c}	41.1^{bc}	44.1^{ab}	47.0^{a}	42.2^{abc}	0.8	*
EBW base	58.3^{bc}	57.8^{c}	67.5^{ab}	69.9^{a}	59.5^{bc}	1.4	*
Rib-eye muscle area (cm^2)	45.4	34.8	34.6	39.2	38.8	1.5	Ns

Means with different superscripts in a row are significantly different at p<0.05; * = (p<0.05); Ns = non-significant; SEM = standard error of means; SL = significance level; SBW = slaughter body weigh; EBW = empty body weight; HCW = hot carcass weight; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH +76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 = NPH supplemented with only 312 g WB.

3.6. Edible and non-edible offal

The edible and non-edible non-carcass components of Gumuz goats fed on natural pasture hay and supplements with different proportions of urea molasses-treated groundnut hull and wheat bran are presented in Table 7. Non-carcass components (offals) are categorized into edible and non-edible parts based on the culture of goat meat consumption and their preference in the study area. Due to differences in taste and eating habits, the salable and edible proportions of the carcass in one area of the country may not be the same in another (Getahun, 2001; Seid, 2011). The current study showed that the weight of the tongue, heart, kidney, liver with gall bladder, testicle, small intestine (SI), large intestine (LI), skin with feet, oesophagus, spleen, and gut fill was not significantly different (P≥0.05) among treatments.

In agreement with this study, Mulisa *et al*. (2019) reported no significant difference in weight of similar non-carcass components for Gumuz goat supplemented with different levels of concentrate mix, which is comparable with the current study. Dereje *et al*. (2016) also showed that supplementation of concentrate mix did not affect the weight of kidney, heart, and spleen in Bati, Haraghe Highland, and Short-Eared Somali goats, which agrees with the current study. Furthermore, Bainesagn *et al.* (2021) reported no effect of supplementation of different levels of concentrate mix on the weight of the heart, liver, small intestine, large intestine, kidney, skin, feet, genital organ, urinary bladder, and spleen in Gumuz goats which is in agreement with the current result.

There were significant differences among treatments in terms of TEOC, TNEOC, and TEP. Higher values were recorded for these parameters in goats assigned to T1, T4, and T5. The weight of the penis, TNEOC, and TEOC were also significantly different among the treatments ($P \leq 0.01$). Blood, pancreas, kidney fat, stomach, genital fat, lung with the trachea, urinary bladder, and head without tongue were also significantly ($P \leq 0.001$) different between the treatments.

Table 7: Non-carcass components of Gumuz goats that fed on natural pasture hay and supplements with different proportions of urea molasses-treated groundnut hull and wheat bran

Parameters	T1	T2	T3	T4	T5	SEM	SL
Blood (g)	664.3[a]	609.0[c]	580.8[e]	654.0[b]	5998.3[d]	0.001	***
Tongue (g)	60.3	59.3	57.3	57.3	63.8	0.002	ns
Heart (g)	84.3	85.3	85.0	90.8	86.5	0.001	ns
Kidney (g)	53	54.3	56	58.3	59	0.001	ns
Pancreas (g)	15.3[b]	21.0[a]	22.8[a]	21.5[a]	15.8[b]	0.001	**
Liver + gallbladder (g)	311	297.8	275.3	330.8	339.5	0.011	ns
Testicle (g)	150.3	151.0	158.0	154.5	157.8	0.001	ns
Kidney fat (g)	30.3[a]	33.0[a]	14.3[c]	25.3[b]	31.5[a]	0.001	***
Stomach (g)	600.8[ab]	488.8[c]	545.8[bc]	639.8[a]	638.0[a]	0.012	**
SI and LI (g)	722.0	625.0	552.0	715.3	726.5	0.025	ns
Genital fat (g)	112.0[c]	47.0[d]	31.3[e]	144.3[b]	191.0[a]	0.002	***
TEOC (kg)	2.8[a]	2.5[b]	2.4[b]	2.9[a]	2.9[a]	0.039	*
Head without tongue (g)	1003.0[d]	793.3[e]	1180.3[b]	1106.3[c]	1232.0[a]	0.005	***
Skin + Feet (g)	1888.8	1827.0	1627.5	1911.3	1972.3	0.040	ns
Esophagus (g)	31.3	27	31	25.8	26.8	0.001	ns
Spleen (g)	17.8	25	23.3	19.8	24.3	0.001	ns
Urinary bladder (g)	13.8[c]	23.3[b]	64.8[a]	25.8[b]	14.3[c]	0.001	***
Penis (g)	33.3[a]	21.8[b]	27.0[ab]	36.0[a]	30.0[ab]	0.001	*
Gut fill (g)	3741.3	2992.8	3716.3	3575.3	3308.5	0.089	ns
Lung + trachea (g)	184.0[c]	192.0[b]	282.0[a]	186.3[bc]	187.5[bc]	0.001	***
TNEOC (kg)	6.9[a]	5.9[b]	7[a]	6.9[a]	6.8[a]	0.105	*
TEP (kg)	9.1[bc]	8.5[c]	8.7[c]	10.4[a]	9.8[ab]	0.151	**

Means with different superscripts in a row are significantly different at (*) $p<0.05$); **($p<0.01$) and ***($p<0.001$); ns = non-significant; SEM = standard error of mean; SL = significance level; SI = small intestine; LI = large intestine; TEOC = total edible offals component; TNEOC = total non-edible offals component; TEP = total edible products; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 = NPH supplemented with only 312 g WB

3.7. Proportion of different carcass parameters

The proportions of different carcass parameters of different feed treatments on Gumuz goats are presented in Table 8. The results showed that gut fill to slaughter weight (GF:SW), total edible offal components to total non-edible offal components (TEOC:TNEOC), and total non-edible offal components to empty body weight (TNEOC: EBW) among the treatment groups were highly significant ($P<0.01$) but total edible offal components to empty body weight (TEOC:EBW) was non-significant among the treatments. In the current study, T3 was found to be higher than other treatments in GF: SW and TNEOC: EBW. On the other hand, T3 is lower than T1, T2, T4, and T5 in the proportion of TEOC: TNEOC.

The TEOC: EBW ratio was non-significant ($P>0.05$) between the treatments. This agrees with the report of Mulisa *et al*. (2019) in Gumuz goat breed fed on

Rhodes grass hay and supplemented with dry pigeon pea (*Cajanus cajan*) and neem (*Azadirachta indica*) leaves. Tekletsadik (2008) also showed that supplementation did not increase the TEOC:EBW ratio in Arsi-Bale sheep fed faba bean haulms and supplemented with linseed meal, barley bran, and their mixtures, which agrees with the current study. The author also reported that supplementation increased the weight of visceral organs without increasing the proportion of TEOC: EBW, indicating that all visceral organ components show similar change in the body weight according to nutrition.

Table 8: Proportions of carcass parameters (%) of Gumuz goats fed on natural pasture hay and supplemented with different proportions of urea molasses treated groundnut hull by replacing wheat bran

Parameters	T1		T3	T4	T5	SEM	SL
GF: SW	22.9^{b}	21.0^{b}	26.1^{a}	22.6^{b}	20.5^{b}	0.4	**
TEOC: TNEOC	40.6^{a}	42.1^{a}	34.2^{b}	42.1^{a}	42.8^{a}	0.6	**
TEOC: EBW	26.2	25.0	25.6	27.1	25.5	0.6	ns
TNEOC: EBW	64.4^{b}	58.9^{b}	75.0^{a}	65.0^{b}	59.5^{b}	1.0	**

Means with different superscripts in a row are significantly different at *($p<0.05$); **($p<0.01$); GF = gut fill; SL = significant level; ns = not significant; SEM = standard error of means; SW = slaughter weight; TEOC = total edible offal components; TNEOC = total non-edible offal components; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 NPH supplemented with only 312 g WB.

3.8. Partial budget analysis

The results of the partial budget analysis for the performance of Gumuz goats on replacement of wheat bran with urea molasses-treated groundnut hull fed a natural pasture hay basal diet are presented in Table 9. The result indicated that a higher total return (464.1ETB/goat) was obtained from the goat supplemented with urea molasses-treated groundnut hull mixed with wheat bran (25:75%) (T4); followed by T1, T2, T3, and T5 in decreasing order. The net return were 462.6, 411.8, 259.7, 461.1, and 244.5 ETB/goat for T1, T2, T3, T4, and T5, respectively. This result indicated that there was no loss of ETB/goats in all treatments, and this might be due to the weight gain shown by the experimental animals because of better feed intake and good crude protein and energy content of the experimental feeds used for the trial period. This was mainly due to the higher weight gain obtained, feed conversation efficiency, and higher selling price of animals in this treatment group than the others. Generally, T4 outweighs the other treatments based on the net profit obtained.

Table 9: Economics of feeding Gumuz goats fed on natural pasture hay supplemented with different proportion of urea molasses-treated groundnut hull by replacing wheat bran

Variables	T1	T2	T3	T4	T5
Number of goats	4	4	4	4	4
Purchase price of goat (ETB/goat)	1725	1700	1725	1713	1775
Natural pasture hay consumed(kg/goat)	18.8	13.2	12.3	16	12.6
Wheat bran consumed(kg/goat)	0	6.2	12.4	18.7	25.5
UMTGH consumed(kg/goat)	10.3	22.2	16.2	9.7	0
Total supplement consumed (kg/goat)	10.3	28.4	28.6	28.4	25.5
Total feed consumed(kg/goat)	29.1	31.4	26.6	32.5	38.1
Cost of natural pasture hay (ETB/goat)	6.3	4.4	4.1	5.4	4.3
Cost of wheat bran (ETB/goat)	0	57.3	114.5	172	235.4
medicinal cost (ETB/goat)	45	45	45	45	45
labor cost (ETB/goat)	450	450	450	450	450
Cost of UMTGH(ETB/goat)	1.1	2.3	1.7	1	0
TVC (ETB/goat)	502.4	559	615.3	673.4	734.7
Gross income (Selling price) (ETB/goat)	2690	2670.8	2600	2850	2754.2
Total Return (ETB/goat)	965	970.8	875	1138	979.2
Net Return (ETB/goat)	462.6	411.8	259.7	464.1	244.5
ΔTR	-	5.8	-90	172.5	14.2
ΔNR	-	-50.8	-202.9	1.5	-218.1
ΔTVC	-	56.6	112.9	171	232.3

ΔNR = Change in net return, ΔTR = Change in total return, ΔTVC = Change in total variable cost, ETB = Ethiopian Birr, TVC = Total variable cost, UMTGH = urea molasses treated groundnut hull; ; T1 = NPH supplemented with 493 g UMTGH; T2 = NPH supplemented with 360 g UMTGH + 76 g WB; T3 = NPH supplemented with 240 g UMTGH + 152 g WB; T4 = NPH supplemented with 120 g UMTGH + 228 g WB; T5 NPH supplemented with only 312 g WB

4. Conclusion

The results of this experiment showed that the use of urea molasses-treated groundnut hull and wheat bran at different proportions instead of sole wheat bran resulted in better and similar nutrient utilization, body weight, and carcass characteristics. In terms of economic returns, urea molasses-treated groundnut hull supplementation was highly recommended. Thus, the lower proportion (T4) of treated groundnut hull can be used as a supplement by replacing wheat bran in a small ruminant feeding strategy to reduce the cost of feeding particularly in the rural smallholder production system where commercial concentrate are not accessible and not affordable.

Data availability statement

Data will be made available on request

Conflicts of interest

The authors declared that there is no conflict of interest.

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