

Feed Intake, Growth, and Carcass Composition of Black Head Somali Sheep Fed On Different Dietary Protein and Energy Levels

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Abstract

The experiment was conducted to assess the importance of different levels of dietary protein and energy supplements on feed intake, growth, and carcass composition of Black Head Somali sheep. A randomized complete block design was employed with 5 treatments and 6 blocks. The average initial weight of experimental sheep was 22.19 ± 0.21 kg. The basal feed was grass hay supplemented with concentrate feed formulated from groundnut cake, brewery-dried grain, and wheat bran. Treatment feeds were formulated to provide different levels of dietary crude protein and metabolizable energy. The treatment feeds were: T1- Control (8.3 MJ ME / Kg DM and 9.1% CP), T2 (8.6 MJ ME / Kg DM and 11.5% CP), T3 (9.1 MJ ME / Kg DM and 13% CP), T4 (9.55 MJ ME / Kg DM and 15% CP) and T5 (10.2 MJ ME / Kg DM and 17.5% CP). The experiment lasted for 90 days which was preceded by a two-week adaptation period. Sheep consuming control treatment (grass hay) had higher dry matter intake for grass hay ($P < 0.01$) than the supplemented groups. However total dry matter intake was higher ($P < 0.01$) with increasing levels of supplementation. Higher total CP intake (TCPI) and total estimated ME intake (TEMEI) were significantly higher ($P < 0.01$) with increasing levels of supplementation. Slaughter body weight, empty body weight, hot carcass weight, and dressing percentage were higher ($P < 0.01$) for the supplemented groups compared to the control. The group with the highest level of protein and energy supplementation (T5) had higher ($P < 0.01$) hot carcass weight, empty body weight, rib eye muscle area, lean meat, and fat weight compared to the other supplemented treatment groups. Bone weight was statistically non-significant for all treatments ($P > 0.05$). The financial return obtained from T5 was 3876 Birr, being higher than the other groups. The marginal rate of return percentage was increasing at a decreasing rate for all treatments except T4. Treatment 5 with the highest level of energy and protein had the highest return and is recommended for further study to establish the optimum dietary protein and energy levels.

Keywords: Carcass, Dietary Energy & Protein, Dressing Percentage, Feed Intake, Sheep.

Introduction

Ethiopia has a large Sheep population estimated at 40 million (Central Statistical Agency, CSA, 2020a). Primarily Sheep are raised for meat, and provide a crucial source of protein, especially during religious festivals and celebrations (Gebremariam *et al.*, 2010). Sheep wool and skins are also utilized for making traditional clothing, blankets, and other items, further contributing to household incomes (CSA Ethiopia, 2018). Sheep manure is an important organic fertilizer, enhancing soil fertility and crop yields, which is vital for subsistence farming. Beyond these practical uses, sheep serve as a form of economic security, acting as financial reserves that can be sold during emergencies to cover expenses such as medical bills or school fees. Culturally, sheep hold significant importance and are often used in traditional ceremonies and rituals, symbolizing wealth and status in many communities (Gebremariam *et al.*, 2010). Thus, sheep are integral to both the economic and social fabric of Ethiopian rural life.

Despite their relevance and large population, the productivity of sheep in Ethiopia is very low. The slaughter weight of mature rams is 25kg with an average carcass weight of about 10kg, thus the country has the second lowest slaughter weight in sub-Saharan African countries (FAO, 2009). The low performance of local sheep in terms of live weight, body weight gain, and carcass yield is mainly due to inadequate nutrition (Betscha, 2005). Feed supply in Ethiopia is mainly based on natural pasture, hay, and crop residues. Despite their vast use as livestock feed, these feed sources are naturally low quality and do not fulfill the nutrient requirement of animals. The maintenance CP and ME requirement for small ruminants is typically around 8-12% and 8.0 to 10.5 MJ/kg dry matter (DM) of their diet respectively. This value differs depending on breed, sex, physiological state, age, and environment (NRC, 2007). These nutritional benchmarks are essential for maintaining body weight, supporting immune function, and ensuring overall well-being. Providing adequate CP and ME is particularly important in tropical environments, where heat stress and forage variability can challenge sheep's nutritional status. (Please give this requirement). However, the average crude protein (CP) content of hay is about 5.9% (Frontiers, 2022). Also, the metabolizable energy (ME) content ranges from 5 to 7 MJ/kg dry matter (DM) (ILRI, 2022). Crop residues, including those from cereals like maize, teff, sorghum, wheat, and barley, generally have lower nutritional values. The CP content of crop residues ranges from 2 to 5%, and their ME values are between 5 to 7 MJ/kg DM, making them relatively poor in nutritional quality (AICCRA, 2022; ILRI, 2022). There for supplementing with good CP and ME, source feed increases the productivity of animals.

One of the feasible methods of improving the nutritive value of these poor-quality feeds could be through strategic supplementation with concentrated feed of enough energy and/or protein content. Supplementation of poor-quality feed for fattening sheep is necessary to attain the required body weight and carcass quality in a fixed period (Mengistu *et al.*, 2020 Tadesse *et al.*, 2014). Agro-industrial by-products are good supplementary sources of protein and energy. The most commonly known and commercially available agro-industrial by-products are brewery by-products, wheat bran, and oil seedcakes (Gizachew, 2012). These by-products are relatively readily available around towns and cities where these industries are located. However, the utilization and value of locally available agro-industrial by-products as a source of energy and protein supplement and their interaction at different inclusion rates in the dietary feed of finishing sheep on feed intake and carcass parameters is not sufficiently evaluated and documented.

Thus, the objectives of the present study were:

- To investigate importance of different levels of energy and protein supplementation on feed intake and carcass composition of Blackhead Somali sheep, and
- To determine economically optimum level of protein and energy supplementation for Black Head Somali sheep based on mixture of agro-industrial by-products (wheat bran, groundnut cake and brewery dried grain)

Materials and Methods

Study Site

The experiment was conducted at Haramaya University Sheep Farm. The University is located on the eastern escarpment of the Rift valley at about 515 km East of Addis Ababa, at latitude of 9°26'N, longitude of 42°03'E and altitude of 1950 m. The mean annual rainfall and temperatures is 790 mm and 16.0 °C, respectively, (Mishra *et al.*,

2004).

Experimental Animals and their Management

Thirty (30) yearling intact male Blackhead Somali sheep were taken from Haramaya University Sheep farm based on their age. The sheep were adapted to experimental diets and management conditions for two weeks. The animals were vaccinated against common diseases using clostridial vaccine, to protect against various clostridial diseases such as enterotoxemia (overeating disease) and tetanus and the *Paste des Petits Ruminants* (PPR) vaccine for protecting from highly contagious viral diseases affecting small ruminants, including sheep. and dipped in acaricide (diazinon), to treat external parasites and drenched with broad-spectrum anthelmintics (Albendazole) to treat internal parasites before the onset of the feeding trial. Experimental animals were housed in individual pens and fed concentrate feeds based on the treatment protocols and grass hay was offered *ad libitum* and they had free access to water and salt block with minerals purchased from Agri Feeds PLC.

Experimental Feeds and Feeding

Roades grass hay obtained from the Haramaya University campus was used as a basal diet. The hay was chopped, weighed, and offered *ad libitum* with every weekly adjustment to obtain a 10 % refusal. Refusals of hay were collected and weighed every morning before the next day feed was offered.

Supplementary feed was offered two times a day divided into two equal portions at 8:00 AM and 4:00 PM, supplementary feeds were mixed and formulated to provide 60 to 100 g CP/d and about 5 to 7 MJ ME/d from the total daily dry matter intake of basal and supplement feeds. Samples of offers from hay were collected daily and bulked over 90 days. Samples of the concentrate diet were obtained from a batch immediately after mixing and formulating, bulked, and sub-sampled at the end of the experiment. Refusal from hay was collected every morning bulked over the experimental period and a sub-sample was taken for chemical analysis.

Experimental Design and Treatment

A randomized complete block design was employed with the initial weight of the animals as a blocking factor. The experiment diets consisted of five treatments and each was replicated with in the six blocks which are blocked by weight, and sheep in a block were randomly assigned to each of the dietary treatments. The treatment diets were formulated to have different levels of CP and ME using Double Pearson's square method (Ensimiger, 2002).

Treatment Diets Lay Out

Treatment Feeds					
T1	T2	T3	T4	T5	Remark
Grass hay (control) (9.1 % CP & 8.3 MJME/Kg DM)	Grass hay +170g concentrate mix (CP11.5% &8.6 MJ ME/ Kg DM)	Grass hay +230g concentrate mix (13% CP & 9.16 MJ ME Kg DM)	Grass hay +290g concentrate mix (15 % CP &9.55 MJ ME / KM)	Grass hay + 350g concentrate mix (17.5% CP & 10.2 MJ ME/Kg DM)	concentrate mixes are formulated using person square method to get the indicated CP and ME levels

**The concentrate feeds provided in each treatment were formulated to vary in levels of dietary protein and energy for the experimental animals. Specifically, the concentrate feeds for each treatment contained 20% crude protein (CP) and 1.70 MJ metabolizable energy (ME) per kilogram of dry matter (DM) for T2, 23.5% CP and 2.6 MJ ME/Kg DM for T3, 28.5% CP and 3.6 MJ ME/Kg DM for T4, and 32.4% CP and 4.8 MJ ME/Kg DM for T5. Treatment T1 served as the control group, receiving no supplementary concentrate feed.*

Feed Intake

The supplementary feed was administered to each animal twice daily, totaling 170 grams for T2 and consecutively adding 60 g for each treatment increasingly, given at 8 AM and 4 PM, with no instances of refusal observed. Basal feed was provided *ad libitum*, and refusals were collected and recorded per individual animal throughout the study period to assess daily feed intake. Dry matter and nutrient intake from the basal feed were calculated based on the

difference between the amounts offered and refused for each animal. Total dry matter intake was determined by adding the dry matter intake from both the basal and supplementary feeds. The average daily dry matter intake was computed by dividing the total dry matter intake over the experimental period by the number of days fed. Daily average nutrient intake was also calculated based on the average daily intake of nutrients from both basal and supplementary feeds on a dry matter basis.

Carcass Composition

At the end of the experiment, four sheep from each treatment were randomly taken, fasted overnight, weighed, and slaughtered for carcass evaluation. The animals were slaughtered by severing the jugular vein and the carotid artery with a knife. The blood was drained into a bucket and its weight was recorded. The skin was carefully flayed to prevent fat and tissue attachments. Offal's were separated from the dressed carcass and their weights were recorded. The gastrointestinal tract was removed with its contents and weighed. The gut fill was emptied and reticulo-rumen, omasum-abomasum, and small and large intestines with omental and intestinal fats were weighed. Internal organs, namely, lung-trachea-esophagus, heart, liver, kidneys, spleen, and pancreas were removed, weighed, and kept separately.

Slaughter weight, hot carcass weight (kg), and dressing percentage were recorded for each animal. Dressing percentage was calculated based on slaughter and empty body weight as follows:

$$= \frac{\text{Hot carcass weight}}{\text{Slaughterbodyweight}} \times 100 \text{ and}$$

$$= \frac{\text{Hot carcass weight}}{\text{Emptybodyweight}} \times 100, \text{ respectively.}$$

The empty body weight was calculated as slaughter weight minus gut content. Carcass composition was computed as the total weight of fat plus lean plus bone. Rump fat was dissected into fat and bone and weighed separately. The total weight of fat was obtained from the weight of abdominal fat, kidney fat, testicular fat, tail fat, rump fat, and subcutaneous fat.

Rib-eye muscle area was taken from both the right and left halves. The carcasses were cut between the 11th and 12th ribs perpendicular to the backbone to measure the cross-sectional area of the rib-eye muscle. The rib-eye muscle area was traced first on transparency paper. The area on transparency paper was then traced on graph paper and the area was measured by using a mechanical polar planimeter (model series 20). Total edible offal component (TEOC) was taken as the sum of the lung with trachea and esophagus, liver with gall bladder, empty gut, visceral fat (kidney fat + omental fat), kidneys, and tongue. Total non-edible offal component (TNEOC) was computed as the sum of blood, spleen and pancreas, head, skin, testis, penis, total gut fill, and feet. Total usable product (TUP) was taken as the sum of hot carcass weight, TEOC, and skin.

Chemical Analysis

Nutritional analysis for basal and treatment diets was done at Holeta Nutrition Laboratory. Samples of feed offers and refusals were analyzed for dry matter (DM) according to procedure of AOAC (1990). Metabolizable energy was determined according to Menke & Steingass. (1988) and computed using gas production method; ME (MJ/kg DM) = 2.2 + 0.136 GP + 0.057 CP + 0.0029 CP² (for concentrate feeds) and ME (MJ/kg DM) = where GP is 24 h net gas production in ml/200 mg DM. CP was estimated by the micro-Kjeldahl method, CP = N x 6.25. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed as described by Van Soest *et al.* (1991).

Statistical Analysis

Data on feed intake and carcass composition were analyzed using statistical tools of SAS (Year) software and Duncan multiple Range test (DMRT) was used for mean separation at α 0. 05. Regression analysis between feed intake and levels of CP and ME supplementation were undertaken (Minitab, 2007). Correlation analysis between carcass yield components and level of CP and ME supplementation computed using Pearson method.

The model for the experiment was:

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

where:

Y_{ij} = the response variable/observation in i^{th} treatment and j^{th} block

μ = the overall mean

T_i = The treatment effect/ the effect of i^{th} level of feeding

B_j = the block effect/the effect j^{th} body weight

E_{ij} = the random error

Result and Discussion

Chemical Composition of Experimental Diets

The chemical composition of experimental feeds is indicated in Table 1. The major nutrients in the feed, CP content of the experimental treatments (T2, T3, T4, and T5) was 20, 25, 30, and 35, respectively this was done implicitly to realize the effect of different levels of dry matter supplement with different level of CP and ME content of the supplement ration. CP and ME content of the control diet in the current experiment were enough to satisfy maintenance requirements and to allow the animal to grow.

Table 1: The chemical composition of grass hay in the control diet concentrate supplement in each treatment of the experimental diets

Variables	Treatments				
	T1	T2	T3	T4	T5
DM (%)	93.3	87.5	87.5	87	88.5
Ash (%DM)	8.9	4.7	6	4.7	5
OM (%DM)	91.2	95	94	95.4	95
CP (%DM)	9.1	20	23.5	28.5	32.4
NDF (%DM)	71.1	31.1	34.2	35.1	33.8
ADF (%DM)	49.3	29.4	30.6	29.4	32.4
EME (MJ/kg DM)	8.3	9.6	11.5	12.5	13.8
Hemicelluloses	21.8	1.7	3.6	5.7	1.4

DM = dry matter, OM = organic matter, CP = crude protein, Ash = ash, NDF = neutral detergent fiber, ADF = acid detergent fiber, EME = estimated metabolizable energy; MJ = mega joule T1 = grass hay (Control); T2-T5 indicates the chemical composition of concentrate / supplement feed in the treatment diets

The ash content of various feed ingredients used in the treatments, including hay, groundnut cake, wheat bran, and brewery dried grain, can significantly impact the overall mineral or ash composition of the treatments. 8.9, 4.7, 6, 4.7, and 5 % respectively. This variation may be because of the proportion of the ingredients in each treatment. Treatments from T1- T5 is Treatment T1 is composed entirely of hay at 100%. In contrast, all other treatments lack hay for the chemical analysis of ash content. Treatment T2 comprises 68.61% brewery dried grain, 29.73% wheat bran, and 1.66% groundnut cake. Treatment T3 includes 50.87% wheat bran, 27.39% groundnut cake, and 21.74% brewery dried grain. Treatment T4 contains 49.83% groundnut cake, 33.45% wheat bran, and 16.72% brewery dried grain. Lastly, Treatment T5 primarily consists of 73.35% groundnut cake, with 16.33% wheat bran, and 10.32% brewery dried grain. This variability is due to the differing ash content of the ingredients. Hay typically has a high ash content, ranging from 7-10%, due to its substantial mineral content from soil and plant structure (NRC, 2001). Groundnut cake, on the other hand, has a relatively low ash content, generally between 2-4%, as reported by Esmail (2012) and Adeyemi *et al.* (2008). Wheat bran, known for its high mineral content, exhibits an ash content ranging from 5-7% (McDonald *et al.*, 2011). Brewery dried grain, a byproduct of the brewing industry, has a moderate ash content, typically around 3-5%, according to Mussatto *et al.* (2006). The grass hay used in the current experiment was characterized by medium CP and ME, high NDF and ADF contents. The high content of Neutral Detergent Fiber (NDF) can imply a lower intake of the basal diet, as NDF is a major factor regulating forage intake due to its impact on rumen fill content. This relationship is well-documented in the literature (Van Soest 1994).

Dry Matter and Nutrient Intake

Proper understanding of animal feed intake and nutrient requirement is very important to manage over or under feeding of the animal and through that to make efficient utilization of feeds. As a result, to find the optimum level of energy and protein intake for fattening of sheep, dry matter and nutrient intake of the current study is given in Table 2. In this study the average daily DMI of the basal diet was higher ($P<0.01$) for the control than the supplemented treatment. The low nutrient content of the basal feed compared to the other treatments was expected to provide less amount of nutrient that would not satisfy the nutrient requirement of the animal. Hence, the animals could meet their nutrient requirement only through the intake of relatively more GH (grass hay) than the supplemented groups, which had an alternative nutrient source from the concentrate they consumed. TDMI was higher for supplemented rams as compared to the control group ($P<0.001$). Moreover, there was also difference ($P<0.001$) in TDM intake between the supplemented groups due to the increasing levels of supplementation. Accordingly, sheep in T5 had the highest ($p<0.01$) TDMI as compared to those in the other treatments. This indicates that there was substitution effect of concentrate supplementation over the basal feed grass hay, whereas the level of supplementation increased the DM intake of grass hay decreased but the total DM intake of sheep increased.

Table 2: Daily dry matter and nutrient intake of Black Head Somali sheep fed on a basal diet of GH and supplemented with different levels of energy and protein

Intake	Treatment Feeds					SEM	Mean	SL
	T1	T2	T3	T4	T5			
GH DMI (Kg/d)	0.71 ^a	0.61 ^b	0.6 ^c	0.6 ^c	0.6 ^c	0.0023	0.26	***
Supplement DMI (Kg/d)	0	0.17	0.23	0.29	0.35			NA
TDMI (supp + GH) (Kg/d)	0.71 ^e	0.78 ^d	0.83 ^c	0.89 ^b	0.95 ^a	0.002314	0.833810	***
TDMI (% BW)	3.1 ^d	3.1 ^d	3.24 ^c	3.5 ^b	3.6 ^a	0.037938	3.276803	***
CPI (GH) (Kg/d)	0.065 ^a	0.06 ^b	0.054 ^c	0.055 ^c	0.055 ^c	0.000211	0.056960	***
CPI (Supplement) (Kg/d)	0	0.0339	0.0533	0.0803	0.111			NA
Total CPI (kg/d)	0.065 ^e	0.090 ^d	0.108 ^c	0.135 ^b	0.166 ^a	0.000211	0.112732	***
EME I, GH (MJ/d)	5.897 ^a	5.077 ^b	5.002 ^c	4.992 ^c	4.986 ^c	0.019205	5.195215	***
EME I, Supp (MJ/d)	0	1.626	2.611	3.523	4.742			NA
Total EMEI (MJ/d)	5.897 ^e	6.703 ^d	7.613 ^c	8.515 ^b	9.728 ^a	0.019205	7.695399	***
TCP % in the diet	9.1 ^e	11.5 ^d	13.0 ^c	15.15 ^b	17.5 ^a	0.020521	13.23023	***
Substitution effect	-	0.07	0.12	0.18	0.24			

Means within the same row and with different letter supper script differ significantly; * = ($P<0.05$); ** = ($P<0.01$), *** = ($P<0.001$), NA; not applicable; DMI= dry matter intake; TDMI= total dry matter intake; GH= grass hay; SEM= standard error of mean; CPI= crude protein intake, TCP%= total crude protein percentage in the consumed diet EMEI= estimated metabolizable energy intake; MJ= P,0.001mega Joule; SL= significant level; Supp= supplement.

Carcass Weight

The carcass trait of indigenous black head Somali sheep supplemented with different levels of energy and dietary protein is given in Table 3. The control groups had lighter ($P<0.01$) slaughter body weight, empty body weight and hot carcass weight than the supplemented groups. The group supplemented with the highest ME and CP diet (T5) recorded heavier ($P<0.01$) slaughter weight, empty body weight, and hot carcass weight than the sheep fed other treatments. In line with the findings of this study, research by Saini *et al.* (2014) on the optimal crude protein (CP) level showed that feeding lambs with CP ranging from 0.12 kg/d to 0.18 kg/d resulted in significantly higher carcass weights for those on higher protein diets compared to those on lower protein diets.

Dressing percentage reflects the proportion of a live lamb weight that results in carcass weight and is calculated by dividing carcass weight by live weight and multiplying by 100. The dressing percentage is influenced primarily by the amount of gut fill. The dressing percentage calculated on empty body weight was higher than the mean dressing percentage calculated on a slaughter weight basis at all treatment levels in the current experiment. This is an indication of the effect of gut fill on dressing percentages. Based on the study by Khan *et al.* (2020), examined the effects of dietary fiber levels on carcass traits, including dressing percentage computed by empty body weight and hot carcass weight in fattening lambs indicates that gut fill, influenced by dietary fiber levels, can impact dressing percentage calculations. Higher gut fill, potentially influenced by fiber intake, may lead to variations in the dressing percentage when computed using empty body weight. This implies that prediction of dressing percentage seems

more precise when it is computed based on empty body weight than slaughter body weight basis as the influence of gut fill would be removed. In the present study, the dressing percentage showed a statistically increase ($p < 0.01$) in the supplemented group, whether calculated based on slaughter weight or empty body weight.

Table 3: Carcass traits of Black Head Somali sheep fed on GH and supplemented with different levels of protein and energy

Treatments	SB W (kg)	EBW (kg)	HCW (kg)	Dressing %	
				Based on slaughter wt.	Based on empty body wt.
T1	20.6 ^c	15.4 ^c	8.1 ^c	39.1 ^c	52.5 ^b
T 2	24.1 ^b	18.3 ^b	10.6 ^b	43.3 ^b	56.9 ^a
T 3	24.1 ^b	18.6 ^b	10.8 ^b	44.8 ^{a b}	58.1 ^a
T4	25.7 ^{a b}	19.9 ^{a b}	11.8 ^{a b}	45.9 ^{a b}	59.4 ^a
T5	26.1 ^a	20.8 ^a	12.6 ^a	48.1 ^a	60.3 ^a
SL	**	**	**	**	**
SEM	0.4	0.5	0.3	1.8	1.1

Means within same column with different superscript letters differ significantly; SBW= slaughter body weight; EBW=empty body weight; HCW= hot carcasses weight; SEM = standard error of the mean; SL=significance level; ** = ($P < 0.01$).

The difference in carcass traits in the current study could be attributed to the difference in the nutrient level offered for the experimental animals. Taylor and Murray (1991) indicated that the level of nutrition is known to influence body condition or carcass composition significantly. Body weight is the main determinant of carcass composition of animals of the same breed and sex regardless of age or level of nutrition (Turgeon *et al.*, 1986). Treatments that received high levels of supplement (T4 and T5) had heavier body weight and higher performance in carcass traits than the control and low level of CP and M E supplemented rams. This is in line with the report of (Carrasco *et al.*, 2009b; Papi *et al.*, 2011; Fernandes *et al.*, 2011), which indicates that greater levels of energy and protein in the diets of finishing animals influence the carcass traits positively. The increasing intake of dietary energy and protein levels with the increase of DM intake concentrate supplementation also affects the consumption of roughage feeds this may be related to superior carcass traits in the supplemented group of animals.

Carcass Composition

Table 4 shows the carcass composition of the experimental sheep. In this study, sheep receiving the highest level of energy and protein supplementation (T5) had significantly heavier lean weights ($P < 0.01$) compared to those on other treatments. Similarly, Asnakew (2005) found that the supplemented groups had higher lean weights than the control group. Kassahun (2000) reported even higher lean weights of 8.6 kg and 8.9 kg for Menz and Horro sheep breeds, respectively, with an average CP intake of 125 g/d and an ME intake of 12.5 MJ/d. In the present study, the T5 group had a CP intake of 166g/d and an ME intake of 9.7 MJ/d, resulting in a lean meat weight of 6.3 kg. This lower lean weight could be due to the lower ME to CP ratio and breed differences. Abebe *et al.* (2013) found that Menz and Horro sheep breeds exhibit superior growth performance compared to other Ethiopian breeds under similar finishing conditions. Similarly, an investigation by Edea *et al.* (2012) noted that Black Head Somali sheep, although adapted to harsh environments, generally show lower growth performance in finishing systems compared to Menz and Horro breeds. This may indicate that the lower lean weight obtained in the current study could be due to the breed differences.

Table 4 indicates the carcass composition of the experimental sheep. In the current experiment, heavier lean weight ($P < 0.01$) was observed at higher level of energy and protein supplementation (T5) than the sheep on the other treatments. Asnakew (2005) also reported higher lean weight in the supplemented group than control group. Feeding on an average CP (125g/d) and ME (12.5 MJ/d) Kassahun (2000) obtained higher lean weights (8.6 kg and 8.9 kg for Menz and Horro sheep breed, respectively) than the current study. The CP intake was 166g/d and the ME intake was 9.7 MJ/d for the higher level of supplementation T5 and the lean meat weight obtained was 6.3 Kg this may be because of the proportion of ME to CP content which is lower lean weights recorded in the current study might be due to lower dietary energy to protein ratio. This information is supported by the research of Abdel-Bary *et al.* (2020), who found that finishing lambs fed diets containing 12-13 MJ/kg DM of ME and 14-15% DM of CP demonstrated the highest growth rates and best feed conversion ratios. This dietary combination enhances nutrient utilization, resulting in improved weight gain and carcass quality. Breed differences might also explain the lower

lean weight. According to Gizaw *et al.* (2007) and Tibbo *et al.* (2006), Horro and Menz sheep exhibited higher growth rates and superior feed conversion efficiency, which resulted in better finishing, improved meat characteristics, and higher slaughter weights. The lean plus fat-to-bone ratio was higher for the supplemented group ($P<0.01$) than the control. The result of the current study was in agreement with the result of Asnakew (2005) and Simret (2005) who reported a higher ratio for supplemented groups as compared to the control.

Table 4: Carcass composition of Black Head Somali Sheep fed on GH and supplemented with different levels of protein and energy

Parameter	Treatments						
	T1	T2	T3	T4	T5	SL	SEM
Fore limb(kg)	1.5 ^b	1.8 ^a	2.0 ^a	2.0 ^a	2.1 ^a	**	0.1
Hind limb (kg)	2.0 ^c	2.4 ^b	2.5 ^b	2.8 ^b	3.5 ^a	**	0.2
Rib-eye muscle area (cm ²)	5.0 ^c	7.3 ^b	7.3 ^b	9.2 ^{a b}	10.1 ^a	**	0.6
Lean wt (kg).	4.4 ^c	5.0 ^{b c}	5.3 ^b	5.4 ^b	6.3 ^a	**	0.2
Rump wt (kg)	0.4 ^c	0.9 ^b	0.9 ^b	1 ^b	1.3 ^a	**	0.6
Fat wt. (Kg)	1.2 ^c	2.7 ^b	3.4 ^{a b}	3.6 ^a	3.5 ^a	**	0.2
Bone wt (kg)	2.1	2.1	2.3	2.1	2.1	ns	0.2
Lean to bone	2.1 ^c	2.4 ^{b c}	2.7 ^{a b}	3.0 ^{a b}	3.0 ^a	**	0.1
Fat to bone	0.5 ^b	1.3 ^a	1.6 ^a	1.7 ^a	1.6 ^a	**	0.1
Lean to fat	4.7 ^a	2.2 ^b	1.7 ^b	1.5 ^b	1.9 ^b	**	0.6
Lean + fat to bone	2.7 ^c	3.7 ^b	4.4 ^{a b}	4.3 ^{a b}	4.6 ^a	**	0.2

Means within same column with different superscript letters differ significantly; ** = ($P<0.01$); SEM = standard error of mean; SL=significance level.

Rib-eye muscle area (REA) was higher in T5 compared to T1-T4 ($P<0.01$). There was no difference between T2, T3, and T4 groups in this parameter ($P>0.05$) all of which have higher REA than the control group. An experiment on Angora goats by Shahjalal *et al.* (1992) emphasized that adequate energy and protein intake are crucial for optimal growth and lean tissue deposition in ruminants. They noted that a diet with balanced energy and protein levels enhances muscle growth and improves the lean-to-fat ratio in the carcass, thus increasing the overall meat quality and yield. They also pointed out that insufficient energy intake, even with high protein levels, can limit growth performance and lean tissue deposition due to energy being a limiting factor for protein utilization. In addition, Wolf *et al.* (1980) also further supported these findings by demonstrating that rib-eye muscle area, which is a critical indicator of the proportion of lean in the carcass, is directly associated with the animal's lean-to-bone ratio.

Fore limb and hind limb weights were higher ($P<0.01$) in the supplemented sheep than in the control group. Sheep in T5 had heavier ($P<0.01$) hind limb and rump weight than the rest of the supplemented groups.

Heavier total fat weight was recorded ($P<0.01$) in the high level of energy and protein supplement (T4 and T5) group than the low level of supplementation (T1 and T2) ($P<0.01$). This finding is in line with Ebrahimi *et al.*, (2007) report which investigated the effects of different energy levels and lysine ratios in concentrate diets on the growth performance and carcass characteristics of fat-tailed lambs fed a high forage diet and found that lambs receiving concentrate supplementation had higher fat deposition compared to those fed only grass hay, indicating that concentrate supplementation promoted greater fat accumulation in the carcass. Kassahun (2000) reported lower fat weight (2.9 kg and 2.8 kg for Menz and Horro sheep, respectively), than the experimental animals supplemented with medium and higher level of CP and ME in the current experiment. The lower value recorded in previous work might be due to breed differences. Carsten *et al.* (1991) reported that increase in dietary energy intake could enhance the proportion of body fat deposition in animals. This may be because of higher nutrient intake which connected to a better starch digestion, increased ruminal propionate production, higher insulin secretion, and improved fat synthesis (Bines and Hart, 1992).

Fat to bone and lean to bone ratio is higher for the supplemented group ($P<0.01$) than the control. This indicates that energy and protein supplementation had no significant effect on bone weight, but it has linear relation between fat and muscle component of the carcass. Lean to fat ratio was higher ($p<0.01$) for the control group than supplemented animals. Fat component of the carcass may be related to the CP and ME intake of the animal. in slow-

growing animals, the impact of ME and CP supplementation on lean to fat ratio may be less pronounced. while the relationship between ME, CP supplementation, and lean to fat ratio is generally positive in fast-growing animals, the effects can differ substantially in slow-growing counterparts (Davis & White, 2018). The result of the current study was in agreement with Simret (2005) who reported that supplementation increases fat content of the carcass.

Edible Offal's

Edible offal components of Blackhead Somali Sheep supplemented with different level of dietary energy and protein are given in Table 5.

Table 5: Edible offal components of Black Head Somali Sheep fed on grass hay and supplemented with different level of energy and protein

Parameter	Treatments						
	T1	T2	T3	T4	T5	SL	SEM
Empty gut (kg)	1.3	1.3	1.5	1.4	1.5	ns	0.3
Heart (g)	69	73.3	73.5	83.5	83.5	ns	5.5
Omental fat (g)	26.5 ^{ab}	22 ^b	24.5 ^{ab}	31 ^a	28 ^{ab}	*	2.6
Omasum- abomasum (g)	172 ^b	169 ^b	185.5 ^{ab}	199 ^{ab}	214.5 ^a	*	11.7
Reticulo-rumen (g)	515.5 ^c	616 ^{ab}	663.3 ^a	545 ^{bc}	595.5 ^{ab}	*	29.2
Tongue (g)	67.5	71	70.5	65.5	79	ns	5.4
HT(Kg)	1.4 ^b	1.6 ^a	1.6 ^a	1.6 ^a	1.5 ^a	*	0.2
Liver with gal bladder (g)	256.5 ^b	326 ^{ab}	308 ^{ab}	322.5 ^{ab}	386 ^a	*	19.8
Spleen plus pancreas (g)	47 ^b	48 ^b	55 ^{ab}	57 ^{ab}	65 ^a	*	4.2
TEOC (kg)	3.1	3.5	3.6	3.5	3.6	ns	0.8

Means within the same column with different superscript letters differ significantly, * = ($p < 0.05$), ** = ($p < 0.01$); ns = not significant; TEOC = total edible offal component; SL = significant level; HT = head without tongue.

In the current study, most of the total edible offal components (TEOC) were lower ($P < 0.001$) in the control treatment compared to the supplemented groups. However, there was no difference ($P > 0.05$) among the latter ones. Kirton *et al.* (1972) reported that the live weight and nutritional status of the animals can affect the production efficiency of carcass offal's. Liver with gall bladder ($P < 0.05$) and head without tongue ($P < 0.05$) were heavier ($P < 0.05$) for T5 when compared to the control. However, there was no difference ($P > 0.05$) among the other treatments. Shashie *et al.*, (2017) also found no significant differences in omental, kidney, or mesenteric fat deposits among the treatment groups. t. However, Burrin *et al.* (1990) reported a positive relationship between nutrition level, visceral organ size, and metabolic activity; whereby the level of feed intake changes the relative proportion of visceral organs to body mass. Similarly, in the current study also indicates omasum-abomasum was higher in T5 compared to the low level of supplement (T2) and the control group.

Correlation between Feed Dry Matter and Nutrient Intake, Body weight change and Carcass composition in Black Head Somali Sheep

The correlation analysis result of the present study presented in Table 6 indicates that daily body weight gain was highly and positively correlated with DM, ME and CP intake. Similarly, CP intake and ME were positively correlated with parameters such as TDMI, dressing percentage, hot carcass weight, lean meat, fat weight and rib eye muscle ($P < 0.01$). Total DMI was also positively correlated ($P < 0.01$) with daily body weight gain. Body weight gain was highly correlated ($P < 0.01$) with carcass parameters. This explains that high level of CP and ME supplemented groups have higher TDMI and recorded higher body weight gain. Galal *et al.* (1979a) also observed positive correlation between slaughter weight, carcass weight and dressing percent in Ethiopian Highland sheep. Rib-eye muscle area had a positive and significant ($P < 0.01$) associate with slaughter weight, hot carcass weight and empty body weight.

Table 6: Correlation between EMEI, CPI, DBWG and Carcass parameter

	EMEI	CPI
EMEI	1	
CPI	0.75	1
DMI	0.98**	0.97**
HCW	0.79**	0.80**
DP (% sw)	0.69**	0.71**
DP(% ebw)	0.68**	0.72**
Lean	0.84**	0.84**
FAT	0.69**	0.71**
REA	0.81**	0.83**

** = ($P < 0.01$); EMEI= Estimated metabolizable energy intake; CPI = crud protein intake; DMI=dry matter intake; HCW = hot carcass weight; DP (% sw) = dressing percentage based on slaughter weight; DP (% ebw) = dressing percentage based on empty body weight; REA = rib-eye muscle area.

Partial Budget Analysis

The partial budget analysis of experimental feeds presented in Table 7 provides a comprehensive comparison of five different treatments (T1 to T5) for feeding rams. The analysis includes parameters such as the purchase price of rams, hot carcass weight (HCW), total feed consumption, feed costs, total costs, selling price of hot carcass, return, change in net return (ΔR), change in total variable cost (ΔTVC), marginal rate of return (MRR), and MRR percentage.

The purchase price of rams varied slightly among treatments, with T2 having the highest cost (2214.00 ETB) and T4 the lowest (2050.00 ETB). The HCW increased progressively from T1 (8.10 kg) to T5 (12.60 kg), indicating that higher levels of supplementation might lead to greater carcass weights. Total hay consumption decreased as the level of concentrate supplementation increased, with T1 consuming the most hay (68.80 kg) and T3 the least (58.30 kg). Conversely, the total mixed concentrate consumed increased from 0.00 kg in T1 to 34.90 kg in T5, showing the increased feed input in higher supplementation treatments.

Table 7. Partial budget analysis of experimental feeds

Parameters	cost/kg	Treatments				
		T1	T2	T3	T4	T5
Purchase price of rams (ETB/head)		2110.00	2214.00	2117.00	2050.00	2130.00
HCW in kg		8.10	10.60	10.80	11.80	12.60
Total hay consumed (kg/head)		68.80	59.60	58.30	58.70	60.00
Total mixed concentrate consumed (kg/head)		0.00	17.49	23.00	29.30	34.90
GNC consumed (kg/head)	30	0.00	0.29	6.30	14.60	25.60
BDG consumed (kg/head)	20	0.00	12.00	5.00	4.90	3.60
WB consumed (kg/head)	20	0.00	5.20	11.70	9.80	5.70
Cost for GH (ETB)	10	688.00	596.00	583.00	587.00	600.00
total Cost GNC (ETB)		0.00	8.70	189.00	438.00	768.00
total Cost for BDG (ETB)		0.00	240.00	100.00	98.00	72.00
total Cost for WB (ETB)		0.00	104.00	234.00	196.00	114.00
Total feed cost (ETB/ head)		688.00	948.70	1106.00	1319.00	1554.00
Total cost (feed + purchase of sheep)		2798.00	3162.70	3223.00	3369.00	3684.00
Selling price of HC (ETB/kg)	600	4860.00	6360.00	6480.00	7080.00	7560.00
Return (ETB/ head)		2062.00	3197.30	3257.00	3711.00	3876.00
ΔR		-	1135.30	59.70	454.00	165.00
ΔTVC		-	364.70	60.30	146.00	315.00
MRR (Ratio)		-	3.11	0.99	3.11	0.52
MRR (%)		-	311.30	99.00	310.96	52.38

ΔR = change in net return; ΔTVC = change in total variable cost; MRR = marginal rate of revenue; ETB=Ethiopian birr; WB=wheat bran; BDG= brewery dried grain; GNC=ground nut cake, HC= hot carcass

Feed costs varied significantly, with the cost for groundnut cake (GNC), brewery dried grain (BDG), and wheat bran (WB) being higher in treatments with higher concentrate levels. For instance, the total cost for GNC ranged from 8.70 ETB in T2 to 768.00 ETB in T5. The total feed cost also reflected these changes, rising from 688.00 ETB in T1 to 1554.00 ETB in T5. Consequently, the total cost (including feed and purchase of sheep) ranged from 2798.00 ETB in T1 to 3684.00 ETB in T5.

The selling price of the hot carcass was consistent across treatments at 600 ETB/kg, but the revenue from carcass sales increased with higher carcass weights, from 4860.00 ETB in T1 to 7560.00 ETB in T5. This resulted in higher net returns per head, increasing from 2062.00 ETB in T1 to 3876.00 ETB in T5. The changes in net return (ΔR) and total variable cost (ΔTVC) show that T2 had the highest increase in net return (1135.30 ETB) compared to T1, while T5 had the lowest (165.00 ETB).

The marginal rate of return (MRR) indicates the return per unit of additional cost. T2 and T4 had the highest MRR (3.11), suggesting these treatments yielded the most favorable economic return relative to the additional costs incurred. T5 had the lowest MRR (0.52), indicating a less efficient return on investment despite the higher carcass weight and net return.

More over the partial budget analysis of experimental feeds, Treatment 5 (T5) yields the highest economic return. This treatment shows the highest net return per head, with a return of 3876.00 ETB. The carcass weight is also the highest for T5, at 12.60 kg, leading to the greatest revenue from carcass sales (7560.00 ETB). Although the total costs for feed and purchase are also the highest in T5 (3684.00 ETB), the substantial revenue generated from the higher carcass weight results in the highest net return among all treatment

Summary and Conclusion

Based on the findings of this study, it is recommended that Treatment Five (T5), which involves a supplementation of grass hay and 350 grams of a concentrate mix containing 17.5% crude protein (CP) and 10.2 MJ metabolizable energy (ME) per kilogram of dry matter intake (DMI), be adopted by urban and peri-urban feedlot sheep producers who have access to agro-industrial by-products. This feeding strategy has shown to provide the highest economic return, making it a viable alternative feeding package for small ruminant finishing programs in the country. Additionally, this study can serve as a benchmark for future research on the effects of varying levels of energy and protein supplements on the productive performance of small ruminants. Since the current study did not identify the biological and economic optimum levels, further research is recommended to explore alternative levels of dietary energy and protein supplementation using the same feed ingredients and different concentrate feed ingredients.

Further research areas include:

- Conducting detailed studies on different proportions of energy and protein supplementation using various feed sources for both supplement and basal diets.
- Investigating the effects of different CP levels and ME at various ages in the current and other indigenous sheep breeds

In conclusion, Treatment Five (T5) demonstrates significant potential for providing higher economic returns to sheep producers with access to agro-industrial by-products. This treatment could be integrated into small ruminant finishing programs across the country. The study also highlights the need for further research to fine-tune the levels of energy and protein supplementation to achieve optimal biological and economic outcomes.

Contribution by Authors

All co-authors contributed equally.

Conflict of Interests

There is no conflict of interest.

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