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Effect of Supplementation on Feed Intake and Body Weight Gain of *Abergelle* Goats in Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author MR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TG and TA managed the analyses of the study. Author TA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The feeding trial was conducted at Abergelle Agricultural Research Center breed evaluation and distribution site which is located in central zone of Tigray, North Ethiopia. The objective of this study was to determine the optimum supplementation option that can promote better feed utilization and animal performance. Twenty-four yearling uncastrated male growing Abergelle goats were purchased from the local market. The average initial weight of the purchased goats was 14.2 ± 1.09 kg. A randomized complete block design was employed and goats randomly assigned to any of the three feeding options (dietary treatments). The three experimental rations were composed of different industrial by-products made as treatment1 (43% wheat bran + 35% cotton seed cake + 20% molasses), treatment2 (43% wheat bran + 35% noug seed cake + 20% maize grain) and treatment 3 (33% wheat bran + 45% dried brewery grain + 20% molasses). The supplementary feeds were formulated according to the growth requirements of the experimental animals considering their body weight. The experiment was conducted for 90 days of feeding, 14 days of adaptation trial, 7 days of digestibility and 3 days of adaptation trial for carrying fecal collection bags. Grass hay and clean water were offered adlibitum to each animal. Data were collected on feed intake, nutrient intake; digestibility and body weigh change following appropriate procedures. The collected data were subjected to analysis of variance (ANOVA) with least significant difference mean separation. No variation was seen on feed intake and nutrient digestibility among the treatments ($p > 0.05$). The body weight gain and feed conversion efficiency were affected by the supplementation feeds ($p < 0.05$) with higher for goat group in treatment two. The marginal rate of return (MRR) was also higher for the same animal group when compared with treatment one and

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treatment three, showing the economic benefit to the producer. Animal producers are advised to use supplementation option treatment two and treatment three in that order based on the local availability of the feeds.

Keywords: Abergelle goats; carcass parameters; supplementation; Ethiopia; grass hay.

1. INTRODUCTION

Sheep and goats constitute the majority of the ruminant population in developing countries and contribute significantly to the household economy. In developing countries, sheep and goats are mainly kept under the traditional grazing system with low feed inputs [1]. Goats are kept in a wide range of agro-ecological zones and management systems in Africa. They are widely distributed and are of great importance as a major source of livelihood of the small farmer and the landless in rural communities in tropical Africa [2]. The production system in Ethiopia is characterized by poor feeding, housing, breeding, and health management and consequently very low [3] returns from sale. When the quality of the fodder is low, animals are not able to eat what is required to put on weight. Because of the slow growth rate, the animals become old before they reach the desired live weight for sale. Shortage of feed is also one of the limiting factors for increasing production and productivity of small ruminant in most agro-ecological zones of Ethiopia.

Besides to feed deficit, feed shortage is expressed in terms of seasonality of feed availability, quality of the available feed and feeding practices. The feed deficit is further aggravated by erratic rainfall in the lowlands. The common feeds in Ethiopia such as crop residues and matured natural pasture are inherently low in CP, digestibility, and minerals. Poor nutritive values of feeds lower the production capacity and fertility potential of animals. There is also inefficient collection, conservation and utilization of available feeds which is mainly expressed in the lack of adopting feeding technologies to improve the nutritive value and palatability of crop residues and grazing lands which are the major feed resources in most production systems and agro-ecologies. There is a significant potential for feeding livestock from occasional surplus grains such as sorghum and agro-industrial by-products like cotton seed cakes, noug seed cake, dried brewery grains, wheat bran, molasses and maize grains [4].

Increasing the current level of productivity is essential to provide meat to the ever-increasing human population, to increase export earnings and household income thereby improving the living standard of smallholders [5]. Thus, in order to increase the productivity, the quality and quantity of the nutrient input must increase or management practices where external stresses such as diseases, parasites, feed limitations should be minimized to provide an environment that tends to enhance net output [6].

According to [7], most of the Ethiopian indigenous goats have not been evaluated and characterized in terms of growth and their carcass yield, showing little information on whether the growth characteristics of Ethiopian indigenous goats are differently influenced by nutritional regimes. In order to effectively use their potential, and to attain the international standard of slaughter weight identifying the potential performance body weight of the breed through concentrate supplementation is mandatory to fulfill the demand of the breed to domestic and export market. Hence, this study was made to focus on identifying the best supplementation option that can promote better feed utilization and animal performance by combining different agro-industrial by-products. Searching the better combination option is necessary for efficient use of local feeds.

2. MATERIALS AND METHODS

2.1 Study Area Description

The feeding trial was conducted at *Abergelle* Agricultural Research Center breed evaluation and distribution (BED) site (Fig. 1), which is located at 13°14' 06" N latitude and 38° 58' 50" E longitude. The area is categorized as hot to warm sub-moist lowland (SM1 - 4) sub-agro ecological zone with an altitudinal range of 1300 - 1800 m.a.s.l. The mean annual rainfall ranges from 300 to 650 mm which is characterized by low and erratic nature. The area is designated as Mono-modal that is dominated by single maximum rainfall pattern in the wet season (June to September). The mean annual temperature ranges from 28 - 42°C.

According to the Wereda office of agriculture, the total land coverage of the area is about 144,564 ha (1,444.64 km²), of which 29,466 ha is cultivable land, 15,381.7 ha is enclosed and the remaining 99,716.3 ha is uncultivated (includes bare lands, marginal lands, rocky, roads and very steep and unproductive land). Crop production is predominantly carried out under rain fed condition, which sometimes elicit uncertainty. Beyond this, crop production in the area is essentially subsistence and the agricultural practice is an outdated farming system giving less attention for proper land/crop management. The major crops grown in the study area include sorghum, maize, cowpea, teff and groundnut. Crops are grown mainly for their grains and to make use of crop residues for animal feed. The crop residues are used as animal feed and for house construction.

According to the Wereda office of agriculture, there are a total of 264,596 goats, 78,244 sheep, 81,649 cattle, 15,732 equines, 104,496 poultry and 11,220 hives of honey bees. Hence, the district is well noted for its high population potential in small ruminants. Beyond this, the area is well endowed with economically important tree species such as *Boswellia papyrifera* which is the source of frank incense and many other acacia species which are essentially used for browsing and fuel wood.

2.2 Management of Experimental Animals

Twenty-four yearling uncastrated male growing *Abergelle* goats were purchased from the local market based on their dentition and information obtained from the owners. The animals were then drenched with a broad spectrum anti helmentic (Albendazol) drug against internal parasites and sprayed against external parasites and vaccinated against common diseases like anthrax, and goat sheep pox. The experimental animals were fed hay grass and clean water on free choice, while, different supplementation feeds and salt were offered daily in their individual pens. The experimental animals were adapted to the feeds, feeding schedule and pen environment for about 14 days prior to the beginning of the experiment. Moreover, animals were closely observed for the occurrence of any ill health and disorders during the experimental period. In general, the animals were kept for 114 days on the experimental feeds with individual housed pens for 90 days, 14 days of adaptation period, 3 days for adaptation of carrying fecal bags and 7 days for digestibility trial.

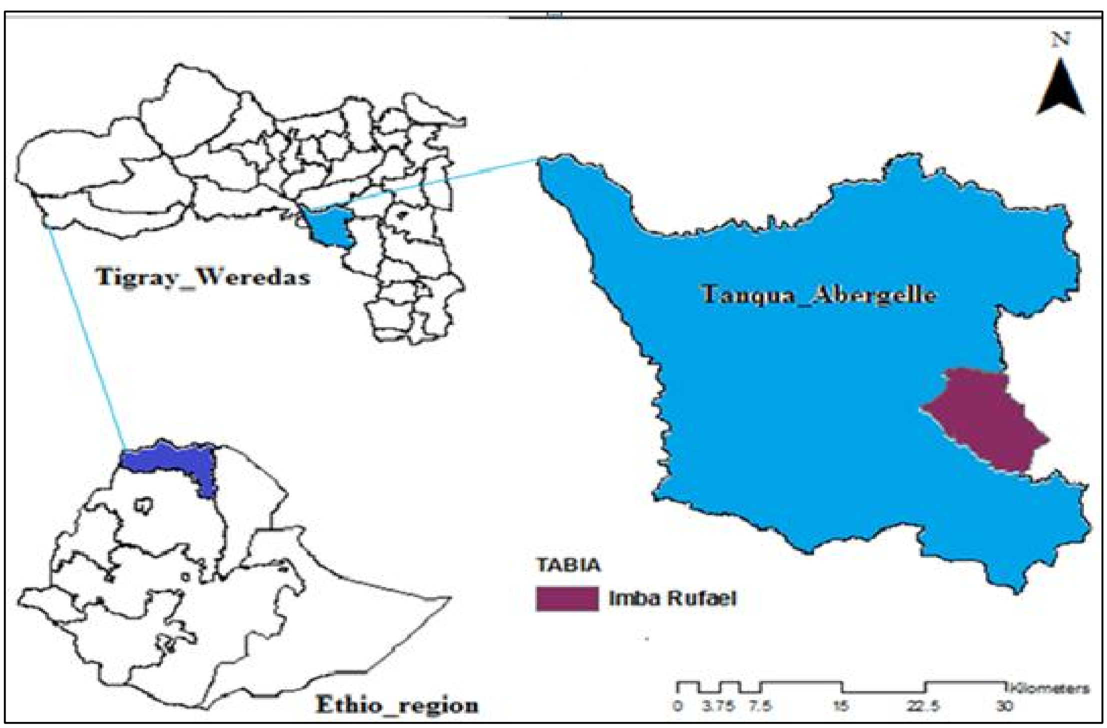

Fig. 1. Location map of the study area

Table 1. Treatment diets used in the experiment

Ingredients	Treatments		
	T_1	T_2	T_3
Grass hay (GH)	Adlibitum	Adlibitum	Adlibitum
Wheat bran (WB)	151 g (43 %)	151 g (43%)	119 g (33%)
Cotton seed cake (CSC)	123 g (35%)	-	-
Noug seed cake (NSC)	-	123 g (35%)	-
Maize grain (MG)	-	70 g (20%)	-
Dried brewers grain (DBG)	-	-	158 g (45%)
Molasses	70 g (20%)	-	70 g (20%)
Salt	7 g (2%)	7 g (2%)	7 g (2%)

2.3 Experimental Design and Treatments

The experiment was designed in a randomized complete block design (RCBD) with three treatments and eight replications. The experimental animals were blocked into three blocks of eight animals each based on their initial body weight (14.2 ± 1.09 kg). Treatment diets were randomly assigned to each animal and each animal in a block was getting equal chance to receiving one of the treatment diets. The supplemental feed mixture offered approximate value of 63% of energy sources, 35% of protein sources and 2% of salt on DM basis per head per day. The supplemented feeds were offered in two equal portions twice a day at 10:00 am and 4:00 pm after the animals well fed the basal feed and taking clean water through all the experimental period.

The experimental animals were considered to be fed according to their initial body weight and increase the amount of the feed depending on daily body weight gain within the recommendation of [8] for each experimental animal. The diets were furnished according to the growth requirements of the experimental animals based on the recommendations of the [9] and by considering their body weight and the expected weight gain. Therefore, to set the feed allowance a maximum daily weight gain of 100 g of small mature weight goats was considered.

The experimental animals were considered to be fed according to their initial body weight and increase the amount of the feed depending on daily body weight gain within the recommendation of [9] for each experimental animal. In addition to this, the ration was formulated as iso-nitrogenous. This does mean that each experimental animal had received approximate equal CP amount. Thus, feed supplementation provision was adjusted fortnightly depending on live weight increment of the animals based on weighing weekly measurement. The treatment combinations are indicated in the Table 1.

2.4 Experimental Feed Preparation

The basal diet (grass hay) and molasses were obtained from Abergelle agricultural research center breed evaluation and distribution (BED) site. The supplement feeds like, cotton seed cake (CSC), noug seed cake (NSC), maize grain (MG), salt and wheat bran (WB) used for the experiment were purchased from the nearby local market. However, the dried brewery was purchased from Raya brewery factory. After preparing all the required supplementation inputs, the feeds were thoroughly mixed at the given proportion after proper grinding.

2.5 Data Measurements

Representative samples of daily feed offers, refusals and feces were collected and ground to pass through a 1 mm sieve screen size. The ground samples were analyzed for contents of DM, ash, OM, CP, ADF, ADL and NDF. Sample of feed and feces were analyzed for content of nitrogen using the procedure of [10]. The CP was computed as N * 6.25. The crude fiber (CF) and acid detergent fiber (ADF) were analyzed following the procedure of [11] at Haramaya University.

2.6 Feed Intake

Daily offered and refusal of each treatment diet was measured and recorded throughout the experimental period for each experimental animals. The amount of feed offered and refused was weighed for each animal and recorded to determine the feed consumed as a difference between that of offered and refused. Daily feed intake of individual animal was calculated as a difference between the feed offered and the refusal feeds. Simply it was calculated as:

Daily feed intake = feed offered – feed refusal (1)

2.7 Feed Conversion Efficiency

The feed conversion efficiency was calculated as a proportion of daily live weight gain to daily feed intake. Simply it was calculated as:

$$\text{Feed Conversion Efficiency (\%)} = \frac{\text{Daily Body Weight Gain}}{\text{Daily Dry Matter Intake}} * 100 \qquad (2)$$

2.8 Live Weight Change

Initial body weight of the experimental animals were measured at the beginning of the experiment at two consecutive weighting after overnight fasting by using 50 kg weighing spring balance. Body weight of each animal was measured at 14 days interval, after overnight fasting at 6:00am before daily feed offering. Average daily live weight gain (g/d) was calculated as the difference between final live weight and initial live weight of the animal divided by the number of feeding days. This was calculated by the following formula:

$$\text{Average Daily Body Weight Gain (ADBWG)} = \frac{\text{FBW} - \text{IBW}}{\text{Feeding trial days}} \qquad (3)$$

2.9 Digestibility Trial

The digestibility trial was undertaken at the last 14 days of experimental period to the treatment feeds of each experimental animal. The feces collection was undertaken for 7 consecutive days after 3 days of adapting the animals to the fecal collection bags. The collection of fecal was performed daily and weighed every morning before offering the feed. In the digestibility trial, the feed under investigation was given to the animal in known amounts and fecal output was measured from three animals of each treatment. During this period, daily feed offered, refusal and feces voided was weighed and recorded. The total feces collected were sampled (10%) and stored in a deep freezer at -20^{o}C over the seven days of collection period. Samples of feed offered from each treatment diet and feed refusal of each animal and feces of each animal was taken each day in the morning and weekly composite samples were formed. At the end of the seventh day, fecal samples were thoroughly mixed and sub-sampled and were stored in ice-box containers. The samples were then partially oven dried at 65^{0}C for 48 hours, packed and sent to Haramaya University for chemical analysis. The apparent digestibility coefficient (DC) of DM, CP, NDF and ADF was calculated using the general formula for the calculation of digestibility coefficients as below [12].

$$\text{Digestibility of Nutrient (\%)} = \frac{\text{Nutrient intake} - \text{Nutrients excreted in the feces}}{\text{Nutrients intake}} * 100 \qquad (4)$$

2.10 Chemical Analysis of Samples

Representative samples of daily feed offers and refusals were collected during the experimental period and stored in air tied plastic bags. Fecal samples were also collected for digestibility trial analysis. The feed and feacal samples were dried on an oven at 105°C overnight for dry matter (DM) determination according to the standard procedures of [11]. Crude protein was determined based on nitrogen content (N*6.25). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to the procedures of [11]. Energy value of the treatment feeds was also estimated according to [12]; Metabolizable energy (MJ/kg DM) = 0.0157* DOM; where DOM being gram digestible OM intake per kilo gram DM and Total digestible nutrient (TDN) was driven from TDN= 82.38-(ADF%*0.7515) [9]. Ash content was determined by igniting the DM residue at 600^{0}C for 4 hours in muffle furnace [10].

2.11 Partial Budget Analysis

Economic analysis was conducted using standard partial budget analysis guideline of [13]. The partial budget analysis involved calculation of the variable costs and benefits. At the beginning of the experiment, the purchase price of animals and feeds were recorded. In addition, at the end of the experiment the price of the animals were evaluated and recorded. The partial budget analysis method measures profit or losses, which are the net benefits or differences between gains and losses for the proposed change and includes calculating net return (NR), i.e., the amount of money left when total variable costs (TVC) are subtracted from the total returns.

NR (Birr) = TR-TVC (5)

Total variable costs include the costs of all inputs that change due to the change in production technology. The change in net return (ΔNR) was calculated by the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC), and this is used as a reference criterion for decision on the adoption of a new technology:

ΔNR = ΔTR- ΔTVC (6)

The marginal rate of return (MRR) measures the increase in net income (ΔNR) associated with each additional unit of expenditure (ΔTVC) which is expressed in percentage as follows;

MRR (%) = ΔNR /ΔTVC X 100 (7)

2.12 Statistical Analysis

The data on feed intake, live body weight gain, digestibility, feed conversion ratio and carcass parameters were subjected for analyses of variance (ANOVA) using the General Linear Models (GLM) procedure [14]. Significant differences were determined using LSD mean separation. Mean differences were considered significant at P < 0.05. Results were summarized and presented using tables and figures. The statistical model used for the analysis of all parameters was;

$$Y_{ij} = \mu + a_i + b_j + e_{ij.} \quad (8)$$

Where: Y_{ij} = response variable (DMI, BWG, digestibility, FCE), μ = overall mean, a_i= i^{th} treatment effect (diet), b_j= j^{th} block effect and e_{ij}= random error

3. RESULTS AND DISCUSSION

3.1 Chemical Composition of Feed Ingredients

Chemical compositions of feed ingredients and treatment diets are presented in Table 2. The DM (91.7%) and OM (89.6%) content of the basal diet grass hay used in the experiment was relatively similar with the other supplements except for molasses. The CP content of the grass hay (7.3%) was lower than the other feeds. Unlike, the lowest CP content, higher NDF content was recorded in the basal diet (62.1%) as compared to the other feed ingredients. The current study showed NDF (19.56%) and ADF (4.7%) content of MG were lower than any of the other ingredients next to molasses. The NSC (34.5%) and CSC (32.5%) followed by DBG (23.5%) were the feeds that exhibited relatively the highest CP content in that order. [15] reported lower CP content (28.2%) of NSC while similar with DM (92.1%) and OM (87.9%) contents of this research result. [4] reported lower crude protein (6.4%) contents of grass hay compared to the findings of this study.

According to [12], feeds that contain large proportion of ADF have least availability of nutrients due to ADF being negatively correlated with feed digestibility. In addition to this, Lonsdale (1989) classified feeds according to their protein contents as feedstuffs having > 20%, 20% - 12% and < 12% to be high, medium and low, respectively. Hence, according to this classification grass hay followed by cotton seed cake revealed the highest ADF contents indicating that the availability of nutrients in these feeds is low.

Based on the CP content NSC, CSC and DBG are classified as high protein content that can be used as protein supplements regardless of their nutrient availability to the experimental goats. According to [16] classification wheat bran and maize grain are among the supplement feed sources with medium level of CP content, while the grass hay used in this study belong to the low CP content feeds. The NDF values of the experimental feeds could be classified as poor feed for grass hay (62.1%) followed by dried brewery grain (51.49%) and relatively good quality feeds for all other ingredients. According to [17] the NDF contents of grass hay and dried brewery grain is high to limit dry matter intake and digestibility. The NDF is only partially digestible by any species of animals, but can be used to greater extent by such animals as ruminants which depend on microbial digestion for utilization of most fibrous plant components [18].

Molasses in the current study showed the highest value of soluble carbohydrate as compared to the other feeds. This is obviously known, because molasses has no/little fiber content. The CP content of the dietary treatments were comparable across the three treatments with slightly, increasing tendency to T_3 (20.01%), T_1 (22.3%) and T_2 (23.89%), in that order. Similarly, the estimated metabolic energy (EME) of the current study was also comparable with treatment diets.

Table 2. Chemical compositions of feed ingredients and dietary treatment rations

Parameters	Feed ingredients							Treatment diets		
	GH	WB	CSC	NSC	DBG	MG	Mol	T_1	T_2	T_3
DM (%DM)	91.7	89.6	90.8	91.9	92.4	88.1	74.5	84.95	89.87	85.5
Ash (%DM)	10.4	5	5.9	9.7	9.56	10.2	8.89	7.3	6.1	8.56
OM (%DM)	89.6	95	94.1	90.3	90.44	89.8	91.11	92.7	93.9	91.44
CP (%DM)	7.3	15.9	32.5	34.5	23.5	12.25	4.82	22.3	23.89	20.01
NDF (%DM)	62.1	33.21	34.51	31.6	51.49	19.56	-	31.87	33.5	34.89
ADF (%DM)	43.4	14.8	27.3	25.8	24.1	4.7	-	17.02	15.1	14.35
ADL (%DM)	5.8	3.7	6.1	12	5.9	2.6	-	10.8	6.1	10.7
TDN (%)	49.8	71.3	61.9	63.0	64.3	78.8	-	69.6	71.0	71.6
ME (MJ/kg DM)	7.5	10.8	9.4	9.5	9.7	11.9	2.47	10.5	10.7	10.8

GH = grass hay, WB = wheat bran, NSC = noug seed cake, CSC = cotton seed cake, DBG = dried brewery grain, MG = maize grain, Mol = molasses, T_1= molasses 20% + wheat bran 43% + cotton seed cake 35% , T_2 = maize grain 20% + wheat bran 43% + noug seed cake 35%, T_3 = molasses 20% + wheat bran 33% + dried brewers grain 45% , DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, ME = Metabolizable energy; MJ = mega joule; TDN = total digestible nutrient

The CP content of wheat bran of this study was comparable to the values of 16.5%, 16.41%, 16.82% reported by [19,20] respectively, but lower than the values of 17.2%, and 19.9% reported by [21,22] respectively. The variation might be due to the effect of processing in milling industries and the quality of the original grain used in the milling industries. The CP content of the cotton seed cake (CSC) was 32.5%. This is higher than the CP content of CSC reported by [12,23] which were 23.9 and 26.8 %, respectively and lower than the result 44.5%, reported by [24].This difference could be attributed to the absence of dehulling during the process of oil extraction. Here, the CP contents of the three treatment rations were comparable with slight variation (20.01-23.89%). The ADF (27.3%) of cotton seed cake in this study was very low compared to the results of [25,22], (35.27% and 41.2%), respectively.

3.2 Dry Matter and Nutrient Intake

The dry matter and nutrient intake of the three dietary treatments is presented in Table 3. There was no statistically significant difference in nutrient intake of the concentrate organic matter and crude protein. However, the total organic matter intake was higher in treatment group two and one as compared to the treatment group three. Similarly, higher NDF and ADF results were revealed in treatment group one and three (Table 3). There was no statistically significant variation ($p > 0.05$) in concentrate intake between the treatments (346-352 g/day). Similarly, there was no significant difference ($p > 0.05$) in hay DMI (326 - 352 g/day) and TDMI (674 - 717 g/day) between treatments. Similar results (384.5 to 397 g/day) were reported by [26] through feeding hay and supplemented with different level of oat grain and lentil for Menz sheep.

Despite the non-significant difference in total DMI, the difference in feed conversion efficiency of goats in the three treatment diets were significant ($p < 0.05$). The highest feed conversion efficiency was obtained in goats fed on T_2 (Table 3). This is attributed to the higher body weight gain. The daily DMI of hay ranged between 326.4 to 364.7 which was comparable with the results of [27] who reported 323.2, 344.9 and 317.5 g/day for Bati, Hararghe and Somali goats; respectively.

The total dry matter intake of the experimental goats (674 to 717.1) was comparable with (529.3 to 713.6 g/d) reported by [28] while higher than the values 523.8, 540.9 and 496.8 g/d reported for Bati, Hararghe and Somali goats [27], respectively.

Even though the daily body weight gain of the goats was not significantly affected by the total dry matter intake, about 49.7% of the variability in body weight gain was explained by the total dry matter intake (Fig. 2).

The feed conversion efficiency was the most important factor which significantly explains 56% of the variability in the daily body weight gain of the experimental goats (Fig. 3).

Table 3. Daily feed and nutrient intake of *Abergelle* goats fed different supplement feeds

Parameters	Treatments			SEM	LS
	T_1	T_2	T_3		
DMI (g/day)	-	-	-	-	-
Grass hay DMI	353.6	364.7	326.4	8.13	NS
Supplement DMI	346	352.3	347.5	8.06	NS
Total DMI	699.58	717.05	673.96	10.2	NS
Total DMI (g/kg $W^{0.75}$)	69.96	71.71	67.4	0.95	NS
Total DMI (% BW)	4.43	4.14	4.16	29.21	NS
Nutrient intake (g/day)	-	-	-	-	-
Grass hay OMI	316.83^a	326.77^a	292.45^b	1	*
Supplement OMI	310.02	315.66	311.36	0.88	NS
Total OMI	626.85^a	642.43^a	603.81^b	0.6	*
Grass hay CPI	25.81	26.62	23.83	3.67	NS
Supplement CPI	25.26	25.72	25.37	1	NS
Total CPI	51.07	52.34	49.2	1.27	NS
NDF intake	219.59^a	202.69^b	226.48^a	0.016	*
ADF intake	153.46^a	141.66^b	158.28^a	0.654	*
ADL intake	20.51^a	18.93^b	21.15^a	0.018	*
ME (MJ/kg DM)	5.8	6.2	5.7	0.35	NS

*Significant at ($P < 0.05$); = *, ($P<0.01$); = **,($P < 0.001$); = ***, T_1= molasses 20% + wheat bran 43% + cotton seed cake 35% , T_2 = maize grain 20% + wheat bran 43% + noug seed cake 35% , T_3 = molasses 20% + wheat bran 33% + dried brewers' grain 45% , DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, ME= Metabolizable energy; MJ= mega joule, LS= level of significance*

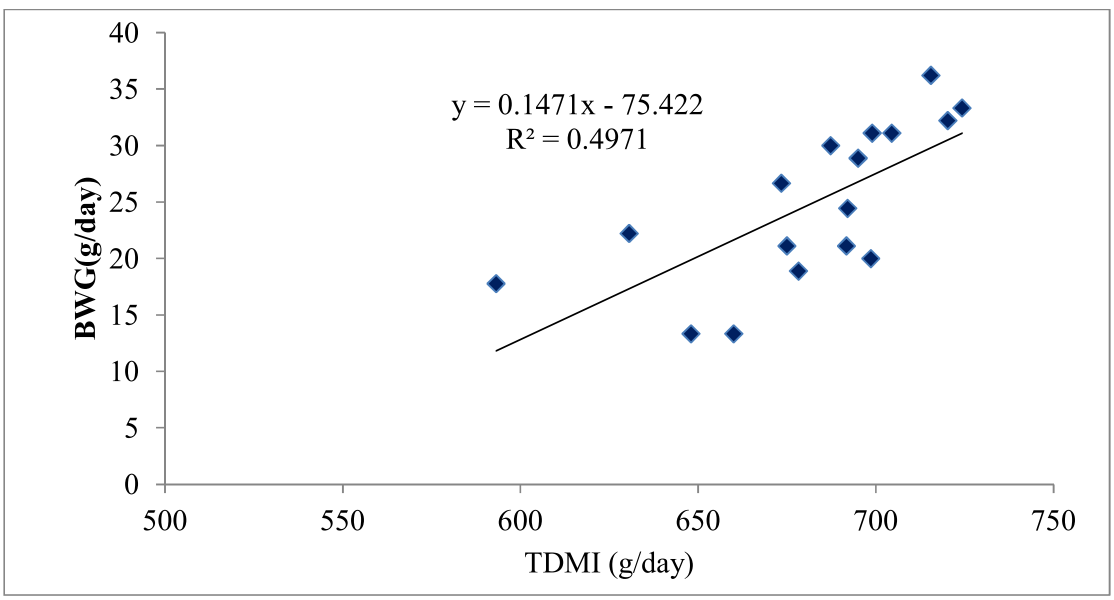

Fig. 2. Daily body weight gain as explained by total dry matter intake of the feed

3.3 Dry Matter and Nutrient Digestibility

There was no significant difference (p>0.05) in DM digestibility across the rations (56.8-63.68%). Similarly, no variation was seen in all nutrients (OM, CP, NDF and ADF) digestibility (p < 0.05). But, a slight variation was observed in ADF digestibility (49-54%). This may be due to the similar effect of the concentrate mix in the rumen fermentation and microbial growth for the deliberate equal nitrogen supplementation (i.e. iso-nitrogenous dietary treatments). [29] reported that any increase in protein intake may lead to an increase in the apparent digestibility of crude protein especially if the intake is marginally sufficient in protein.

Table 4. Dry matter and nutrient digestibility of *Abergelle* yearling goats

Digestibility (%)	Treatments				
	T_1	T_2	T_3	SEM	LS
DM	56.8	63.68	62.4	0.054	NS
OM	58.5	61.3	60.5	0.08	NS
CP	68.5	72.8	64.7	0.035	NS
ADF	51.69	49.72	54.26	0.67	NS
NDF	65.46	64.42	66.67	3.86	NS

T_1= hay + Wheat bran (43%) + cotton seed cake (35%) + Molasses (20%) + salt (2%); T_2 = hay + Wheat bran (43%) + Noug seed cake (35%) + Molasses (20%) + salt (2%); T_3= hay + Wheat bran (33%) + dried brewery grain (45%) + Molasses (20%) + salt (2%), LS = level of significance

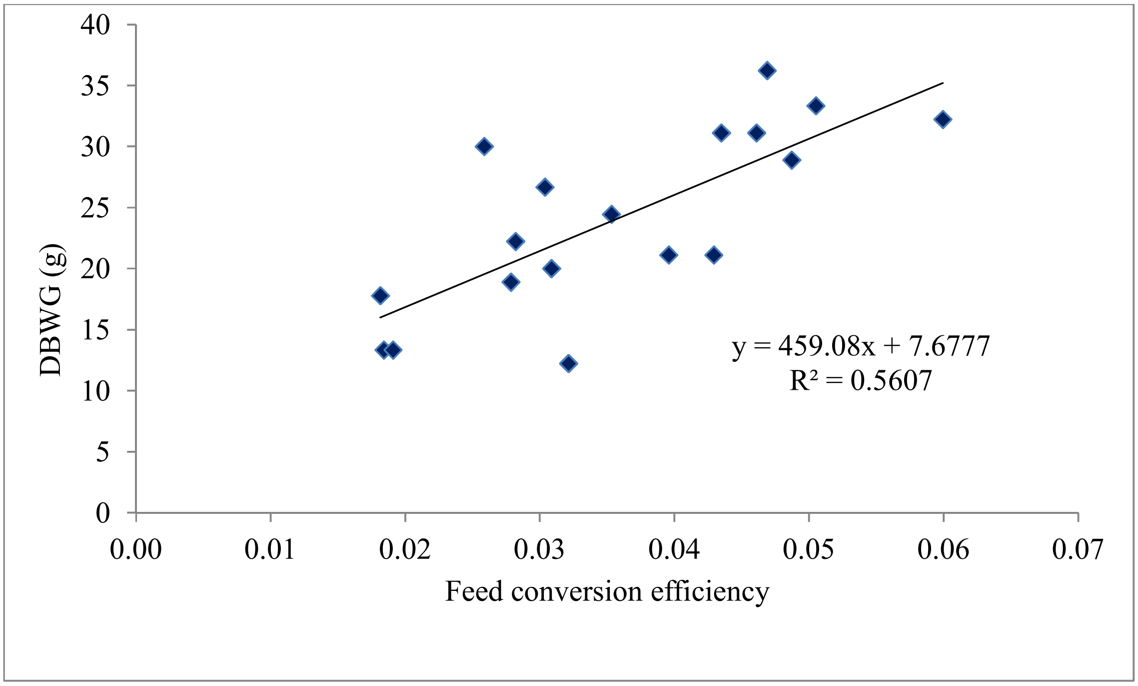

Fig. 3. Daily body weight gain as explained by the feed conversion efficiency of the feed

Table 5. Initial weight, final weight and average daily weight gain of the experimental goats across the different experimental rations

S/N	Variables	Treatments				
		T_1	T_2	T_3	SEM	LS
1	IBW (kg)	14.17	14.50	14.33	0.17	NS
2	FBW (kg)	15.8^b	17.3^a	16.2^b	0.5	*
3	ADBWG (g/d)	20.56^b	31.30^a	21.48^b	1.82	**
4	FCE (g ADG/g TDMI)	0.03^b	0.048^a	0.032^b	0.001	*

*Significant at (P < 0.05); = *, (P < 0.01); = **, (P < 0.001); = ***, IBW = initial body weight, FBW = final body weight, ADBWG = average daily body weight gain and FCE = feed conversion efficiency, T_1= hay + Wheat bran (43%) + cotton seed cake (35%) + Molasses (20%) + salt (2%); T_2= hay + Wheat bran (43%) + Noug seed cake (35%) + Molasses (20%) + salt (2%); T_3 = hay + Wheat bran (33%) + dried brewery grain (45%) + Molasses (20%) + salt (2%)*

The ADF digestibility of all treatments was comparable with the results of [28] who found an ADF digestibility value (40.2 to 54.3%) for air dried and wood ash soaked acacia saligna leaves. The results were even similar with the NDF values of the same authors.

Table 6. Partial budget analysis of the different concentrate fed *Abergelle* goats

Description	Treatments		
	T_1	T_2	T_3
Number of goats	7	7	7
Average purchasing price per goat (birr)	520	530	525
Cost of feeds (birr)			
Wheat bran	6.9	6.9	5.4
Cotton seed cake	10.1	-	-
Noug seed cake	-	7.4	-
Dried brewery	-	-	6.5
Maize grain	-	2.8	-
Molasses	4.2	-	4.3
Hay	18.5	23	20
Total variable cost (birr)	39.7	40.1	36.2
Selling price (birr)	580	615	595
Return			
Total return (birr)	60	85	70
Net return (birr)	20.3	44.9	33.8
Change in net income (birr)	-	24.6	13.5
Change in total variable cost (birr)	-	0.4	-3.5
MRR (%)	**-**	**112.2**	**93.4**

T_1= hay + Wheat bran (43%) + cotton seed cake (35%) + Molasses (20%) + salt (2%); T_2= hay + Wheat bran (43%) + Noug seed cake (35%) + Molasses (20%) + salt (2%); T3= hay + Wheat bran (33%) + dried brewery grain (45%) + Molasses (20%) + salt (2%), MRR= marginal rate of return

3.4 Live Weight Change

The initial weight, final weight and average daily gain of goats during the 90 days feeding trial are presented in Table 5. The overall mean of initial weight, final weight and average daily weight gain were 14.2 ± 1.09 kg, 16.4 ± 0.96 kg and 24.4 ± 8.1 g/day, respectively. There was no statistically significant difference ($p > 0.05$) in initial body weight of the goats among treatments, while, there was statistically significant difference in the final weight and average daily body weight gain of the experimental goats ($p < 0.05$). The effect of supplementation on final body weight and average daily body weight gain obtained in this study was in agreement with reports of [30,7] who found increased final weight and gain as level of concentrate supplementation increased in the diets.

Goats supplemented with mixtures of maize grain, wheat bran and noug seed cake (T_2) had significantly ($p < 0.05$) higher final body weight (17.3 kg) and average daily body weight gain (31.3 g/day) than goat groups supplemented with mixtures of molasses, wheat bran and cotton seed cake (T_1) and molasses, wheat bran and dried brewery (T_3). However, the two treatment groups which are supplemented with mixtures of molasses, wheat bran and cotton seed cake (T_1) and molasses, wheat bran and dried brewery (T_3) were not statistically different ($p > 0.05$) from each other reflecting the fact that the supplements were comparable in their potentials to supply nutrients for growth of the yearling goats. The obtained daily body weight gain in all treatments (20.56 – 31.3 g/day) was comparable with the results of [31] who reported a growth rate from 12 to 24 g/day with supplementation of indigenous browse trees which was conducted in the same area with the same goat breed. Moreover, similar growth rate (14 to 34 g/day) was reported by [32] in which goats were supplemented with *Acacia tortilis* and Rhodes grass hay. However, the result of this study is lower than many other studies such as [33] in his study using sheep fed maize Stover supplemented with different oil seed cakes reported an average daily body weight gain of 46.7 and 45.4 - 90 g/d, respectively for noug seed cake and cotton seed cake supplemented animals. [34] also reported an average daily body weight gain of 44 and 52 g, respectively for CSC and NSC supplemented animals in their study in sheep fed maize Stover supplemented with iso-nitrogenous amounts (40 g CP) of CSC, NSC and sunflower cake. The variation in growth rate could be due to the response of the goat breeds to various feeding systems and partly because of the differences in nutrient concentration and characteristics of the supplements used.

3.5 Partial Budget Analysis

The result of the partial budget analysis indicated that the net return obtained in this trial was 20.3, 44.9 and 33.8 ETB/goat for T_1, T_2 and T_3 diets, respectively. Accordingly, goat fed on concentrate mixture of (T_2) resulted in higher net return (44.9 ETB/goat) as compared to the other supplemented groups. On the other hand, goat fed on the first treatment diet (T_1) resulted in 24.6 and 13.5 ETB/goat lower returns as compared to T_2 and T_3, respectively. The lower net return in T_1 could be attributed to the lower feed conversion efficiency of the goats supplemented with treatment one. The net returns from T_2 and T_3 supplement diets (Table 6) were 44.9 and 33.8 ETB/goat with marginal rate of return (MRR %) of 112.2 and 93.4 respectively. Marginal rate of return measures the increase in net income and effects of additional investment in a new technology on additional net return.

Hence, investing on supplementation of concentrate feeds to goats was found to be economically feasible. Hence, from the partial budget analysis result; treatment two revealed the highest MRR which could be recommended for supplementation of goats followed by treatment three concentrate feeds based on their local availability. The difference in MRR value is due to the cost of the concentrate mixture among the treatments and selling price as influenced mainly by body condition of the goats. Producers are advised to feed their fattening animals with concentrate mixes of maize grain (20%), wheat bran (43%), and noug seed cake (35%) provided that the feed resources are easily available in the given area.

4. CONCLUSION

The crude protein and energy contents of the experimental feeds were higher when compared with the basal diet (grass hay). The total organic matter intake was higher in treatment group two and one as compared to the treatment group three. Similarly, higher NDF and ADF results were revealed in treatment group one and three. There was statistically significant difference in the final body weight and average daily body weight gain of the experimental goats. Higher body weight gain and feed conversion efficiency was achieved by goat group in treatment two. Hence, taking the obtained final body weight gain and partial budget analysis in to consideration, supplementation of goats with concentrate mixes of maize grain (20%), wheat bran (43%), noug seed cake (35%) and salt (2%) is recommended as best option to be practiced by farmers. However, supplementation of molasses (20%), wheat bran (33%), dried brewer (45%) and salt (2%) could also be used as second option depending on the local availability of the feed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix. Some photos which were taken during the study

Weighed grass hay offered to each experimental goat

Goats while feeding the supplementation feed (concentrate feeds)