Effect of Different Levels of Soybean /*Glycine Max*/ Meal Supplementation on Feed Intake, Digestibility, Live Weight Changes, and Carcass Characteristics of Black Head Ogaden Sheep

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Abstract: Sheep is an important animal kept as livestock in Ethiopia. However, productivity of the animal is constrained by scarcity of feed. Therefore, an experiment was carried out using twenty-four yearling male Black Head Ogaden sheep with an initial body weight of 12.95 ± 1.79 kg (mean ± SD) to evaluate the effect of different levels of soybean meal supplementation to natural pasture hay on feed intake, digestibility, average daily body weight gain, and carcass characteristics. The experimental sheep were blocked into six blocks of four animals based on initial body weight and randomly assigned to one of the four treatments. Treatments were *ad libitum* feeding of natural pasture hay and + 50 g/day wheat bran (T_1) supplemented with 125 g/day soybean meal (T_2), 250 g/day soybean meal (T_3), 375 g/day soybean meal (T_4). The experiment consisted of 90 days of feeding and 7 days of digestibility trials followed by evaluation of carcass. Supplementation of SBM increased dry matter and crude protein digestibility but neutral detergent fiber and acid detergent fiber digestibilities decreased with increasing levels of SBM supplementation. Average daily body weight gain and hot carcass was significantly increased as soybean supplementation increased. Dressing percentages both on pre-slaughter (37.3, 44.6, 46.4 and 48.6% (SEM = 0.94) and empty body weight (48.4, 51.9, 54.2 and 59.7% (SEM = 0.94)) basis for T_1, T_2, T_3 and T_4, respectively were highest for T_4, intermediate for T_3, and T_2, and the lowest for T_1. It could be concluded that feeding the Black Head Ogaden sheep on natural pasture hay supplemented with 375 g/day soybean meal resulted in superior biological as well as economic productivity.

Keywords: Body Weight Change; Digestibility Dressing Percentage; [Glycine max (L.) Merr.]

1. Introduction

Sheep in Ethiopia have many advantages over some other classes of livestock and are particularly well adapted to many agro-ecological zones of the country. However, sheep productivity very low and lag behind the growth of the population. Among the various factors constraining the productivity of sheep, feed scarcity is a core problem. Sheep productivity is also constrained by disease, inadequate utilization of indigenous sheep breeds, lack of infrastructure, lack of market information and lack of trained personnel (Markos, 2006).

Natural pasture and crop residues are the major feed resources for livestock in Ethiopia. However, such feed resources are characterized by high fiber, low protein, low minerals, and low vitamin content (Kayongo *et al.,* 1993). Thus, it is imperative to explore alternative, highly nutritious feed resources that could increase the total dietary value and eventually enhance animal performance (Yoseph, 2007).

One of the feasible methods of improving the nutritive value of natural pasture and crop residues is through strategic concentrate supplementation with energy and/or protein rich sources which can increase digestibility, nutrient supply and feed intake (Preston and Leng, 1987). Feed sources originated as by-products of various agro-industries are good sources of easily fermentable energy and protein (Ensminger *et al.*, 1990).

Agro-industrial by-products such as oil seed cakes and cereal bran are potential supplements to animals on grazing (Shapiro *et al.*, 2004) to alleviate qualitative deficiencies of feeds. Indeed the use of agro-industrial by-products that are locally available and complement each other is an advantage in utilization of nutrients, thereby improving animal performance. Soybean meal is one of the best plant protein sources for animals (McDonald *et al.*, 2002). Griffiths (2004) found that soybean meal, in addition to being an excellent source of lysine, is also a rapidly degradable protein source. Soybean meal contains 46% CP, 5% CF, 18% fat and 84% TDN (McDonald *et al.*, 2002). Soybean [Glycine max (L.) Merr.] was introduced in to Ethiopia in 1950. During that time its production and distribution was very low. But nowadays it is distributed to many regions of the country including Oromia, Tigray, Southern Nations, Nationalities and Peoples' Regional State (SSNNPRS), Amhara, and Benishangul Gumuz Regional States (MOA, 2009).

Soybean meal is commonly used as supplementary feed for small ruminants in many parts of the world.

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But it is not commonly available in Ethiopia due to lack of modern soybean processing technologies. However nowadays huge modern oil extracting factories have been established at different parts of the country. Response of indigenous sheep breeds to improved feeding has not been widely investigated. As an example, the Black Head Ogaden sheep breed has not so far been exhaustively studied with regard to its response to different types of supplementation with agro-industrial by-products such as soybean meal that may enhance its productivity. This study, was therefore conducted with the objective of assess the response of Black Head Ogaden sheep to feeding on natural pasture hay and 50g/day wheat bran on dry matter basis, supplemented with different levels of soybean meals.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Haramaya University's sheep farm on the main campus. Haramaya University is located at the distance of about 515 km east of Addis Ababa, at 9° N latitude and 42° E longitude. The site is situated at 2050 meters above sea level has a mean annual rainfall of 790 mm and a mean annual temperature of 16 °C (Mishra *et al.*, 2004).

2.2. Experimental Animals and Management

Twenty-four yearling male Black Head Ogaden sheep with initial body weights of 12.95 ± 1.79 kg (mean ± SD) were purchased from the local market in Babile district in eastern Ethiopia. The age of the animals was estimated by dentition. The sheep were quarantined for 21 days to adapt to experimental site (Haramaya University). During the period of adaptation all sheep were ear-tagged for identification, and drenched with 300 mg alebendazole against internal parasites and sprayed with acaricide against external parasites. The animals were vaccinated against anthrax and parasites based on the recommendation of the veterinarian. Then all sheep were transferred to individual pens and adapted to the experimental diets and pens for 15 days prior to the commencement of data collection.

2.3. Feeds and Feeding Management

The natural pasture hay (with majority of naturally cultivated grass hay) was collected from Haramaya campus. It was then it chopped to an approximate size of 4-5 cm, weighed and offered to the experimental animals *ad libitum*. Wheat bran was purchased from Dire Dawa food complex factory where as the soybean meal was purchased from Addis Ababa health care food manufactures private limited cooperation factory. The wheat bran and soybean meal were air dried to avoid moisture. Mineralized salt block and water were made available to the animals all the time, whereas different levels of soybean meal were offered in line with the treatments. The animals were offered the supplement feed in two equal halves at 8:00 and 16:00 hours daily.

2.4. Experimental Design and Treatments

The experimental design was completely randomized block design (RCBD). The experimental animals were grouped into six blocks of four animals based on their initial body weight. Initial body weight for blocking was taken after an overnight fasting by the animals at the end of the quarantine period. The four experimental treatment diets were randomly assigned to each animal in a block.

Table 1. Experimental treatment feeds.

Treatment	Natural	WB	SBM (g)
T1	*Ad libitum*	50	0
T2	*Ad libitum*	50	125
T3	*Ad libitum*	50	250
T4	*Ad libitum*	50	375

DM = Dry matter; SBM = Soybean meal; WB = Wheat bran.

2.5. Measurements and Observation

2.5.1. Feeding trial

The feeding trial lasted 90 days (from 1 January to the end of March 2011) following an acclimatization period of 15 days to the experimental conditions. The amount of feed offered and refused for each sheep was recorded daily throughout the experimental period. For an accurate estimation of nutrient digestibility, samples of feed offered were collected daily per batch and samples of feed refused were collected per animal and pooled over treatment, and sub sampled for chemical analysis. Daily feed intake of experimental animals was calculated on DM basis as the difference between the feed offered and refused.

Body weight of each animal was measured at the beginning of the feeding trial and every 10 days after overnight fasting. Body weight changes were estimated as a difference between the final and initial body weights. Average daily body weight gain (ADG) was calculated as the difference between final body weight and initial body weight divided by the number of feeding days. The feed conversion efficiency of the experimental animals was determined by the dividing ADG by the amount of daily feed consumed.

2.5.2. Digestibility

After the feeding trial, all sheep were harnessed with fecal bag to collect feces. After three days of adjustment period to fecal collection bags, feces were collected for seven days. In the morning total fecal output was weighed and recorded daily. Out of the total feces voided, 20% was sub-sampled and stored frozen at -20 °C to form a composite of fecal sample for each animal.

Samples of feed offered to and rejected by each animal were collected daily to form a composite of offered feed samples and refused or rejected feed samples. Refusal samples were bulked over treatments to form one refusal per treatment whereas a composite sample from each feed was collected and ground to pass through a 1 mm sieve. Fecal samples were dried in an oven at 60 °C for 72 hours and ground to pass through a 1 mm sieve. The samples were stored in an airtight plastic pending chemical analysis. Then the apparent digestibility coefficient (DC) of nutrients was determined using the following equation:

$$\mathrm{DC}\,(\%) = \frac{(\text{Total amount of nutrients in feed} - \text{Total amount of nutrients in feces})}{\text{Total amount of nutrients in feed}} x\ 100 \quad 1$$

2.5.3. Carcass characteristics

At the end of the digestion trial, all the experimental sheep were made to fast for 12 hours and slaughtered for carcass analysis. Each sheep was weighed immediately before slaughtering. The sheep were slaughtered by severing the jagular vein and carotid arteries with a knife. The esophagus was tied close to the head to avoid leaking of gut contents. After dressing and evisceration, hot carcass weight was recorded to assess dressing percentage on slaughter and empty body weight basis. The hot carcass weight was estimated after removing the weight of the skin, head, thorax, abdominal, and pelvic cavity contents as well as legs below the hock and knee joints. Rib eye area was traced on transparency paper and measured by using plani-meters after cutting the vertebrae between the 12 and 13th ribs. Percentages of total edible offal components were taken as the sum of blood, tongue, heart, liver, bile, kidney, empty gut, omental fat, and kidney knob channel fat.

2.6. Chemical Analysis

Chemical analysis of the experimental feeds and feces was conducted at Haramaya University's animal nutrition lab. The chemical analysis of the experimental feeds, refusals, and feces was carried out after taking representative samples. The DM, ash, and CP (crude protein) contents of the feed was estimated as N*(6.25) after the analysis according to AOAC (1990) procedure. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed following the procedure described by Van Soest and Robertson (1985).

2.7. Statistical Analysis

Data on feed intake, body weight change, and digestibility, and carcass characteristics were subjected to analysis of variance (ANOVA) by using the general linear model procedure of SAS (2003), version 9. When treatment effect was significant, the Least Significant Difference (LSD) Test were used to locate differences between the treatment means. The model for data analysis was:

$$Y_{ij} = \mu + \alpha_i + b_j + e_{ij2} \quad 2$$

Where:
Y_{ij} = Response variable
μ = Over all mean
α_i = Treatment effect
b_j = Block effect
e_{ij} = Random error

2.8. Partial Budget Analysis

The partial budget analysis was performed to evaluate the economic advantage of the different treatments by using the procedure of Upton (1979). The analysis involved the calculation of the variable costs of experimental sheep, feeds, and benefits gained from the result. The price range of the experimental sheep was between 200 and 300 Birr and the average purchase price of 250 Birr was used for the analysis of partial budget. At the end of the experiment, experienced sheep dealers from local market estimated the selling price of each experimental sheep. In the analysis, the total return (TR) wasdetermined by calculating the difference between selling and purchasing price of sheep in each treatment before and after the experiment. The cost of feeds was computed by multiplying the actual feed intake for the whole feeding period with the prevailing prices. The partial budget 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 the total variable costs (TVC) are subtracted from the total returns (TR), mathematically estimated as:

$$\mathrm{NR} = \mathrm{TR} - \mathrm{TVC}. \quad 3$$

Total variable costs include the costs of all inputs that change due to the change in production technology. The change in net return (∆NR) was calculated as the difference between the change in total return (∆TR) and the change in total variable cost (∆TVC), and this is to be used as a reference criterion for decision on the adoption of a new technology. The marginal rate of return (MRR) measures the increase in net income (∆NI) associated with each additional units of expenditure (∆TVC). This is expressed in percentage as:

$$\mathrm{MRR\%} = (\Delta\mathrm{NR} \div \Delta\mathrm{TVC}) \times 100 \quad 4$$

3. Results and Discussion

3.1. Chemical Composition

The chemical composition of treatment feeds is presented in Table 2. The Crude Protein (CP) content of the natural pasture hay used in this study was 4.67% which is below the 8% CP required to meet the maintenance need of the animals for protein (Van Soest, 1982). This low CP content of the natural pasture hay might be due to the maturity of hay at harvest. As a plant matures, the cell wall constituent or the structural carbohydrates such as cellulose and other components like lignin increases and the percentage of CP decreases (McDonald *et al.*, 2002).

The Neutral Detergent Fiber (NDF) content of the natural pasture hay used in this study was 80.33%. It is only partially digestible by any species of animals, but can be used to a greater extent by ruminants, which depend on microbial digestion for utilization of most fibrous plant components (Pond *et al.*, 1995, McDonald *et al.*, 2002). The high content of Acid Detergent Fiber (ADF) in the natural pasture hay which was (50.97%) in the basal diet, might be an indication for low availability of nutrients in it since, ADF is negatively correlated with feed digestibility (McDonald *et al.*, 2002). In general, the chemical composition of natural pasture hay used in this study was characterized by high NDF, ADF, ADL (Acid Detergent Lignin) and low CP contents.

Table 2. Chemical composition of experimental feeds on DM basis.

Feed	Chemical composition				
	CP (% DM)	NDF (% DM)	ADF (% DM)	ADL (% DM)	Ash (% DM)
Hay	4.67	80.33	50.97	8.47	5.29
Wheat bran	15.20	50.68	15.05	4.76	5.12
SBM	39.76	19.03	10.10	3.31	5.67
Refusals					
Hay T_1	2.92	84.17	55.19	10.32	6.99
Hay T_2	2.94	85.16	57.93	10.14	6.30
Hay T_3	2.96	85.11	55.39	9.80	6.71
Hay T_4	2.99	86.83	57.09	8.88	6.60
SBM T_2	33.08	24.68	11.83	3.30	5.87
SBM T_3	33.69	20.97	8.85	1.82	5.81
SBM T_4	33.31	23.57	9.72	1.97	5.89

ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin; CP = Crude Protein; DM = Dry Matter; NDF = Neutral Detergent Fiber; OM = Organic Matter; SBM = Soybean meal; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

The NDF content of natural pasture hay used in this study was comparable to the value of 79.22% reported by Fentie (2007), but higher than the 70.7% and 71.8% reported by Asnakew (2005) and Getachew (2005), respectively. The CP, NDF, ADF and ADL of SBM used in the current study were slightly different from previous findings (Wilson *et al.*, 1995; McDonald *et al.*, 2002; Chumpawadee *et al.*, 2007). The variation in nutritional composition of SBM is dependent upon the amount of hull that is removed and processing method that is being used (Bedawy *et al.*, 2009). Furthermore, there are many factors that affect chemical composition and mineral content of feedstuffs such as oil extraction process (Mara *et al.*, 1999), stage of growth and maturity, species or variety (Keyserlingk *et al.*, 1996; Promkot and Wanapat, 2004), drying method, growth environment and soil types (Thu and Preston, 1999).

3.2. Dry Matter and Nutrient Intake

The mean daily dry matter and nutrient intakes of the experimental sheep during the feeding trial are presented in Table 3. The daily dry matter intake of natural pasture hay was significantly higher ($P < 0.05$) in non-supplemented sheep than in the supplemented ones, and decreased with increasing levels of SBM supplementation, indicating a positive substitution of SBM to the hay, and as such intake of pasture hay was not improved by supplementation. Thus, the higher intake of natural pasture hay for the control treatment as compared to the SBM supplemented ones might be an attempt to extract sufficient nutrients through relatively more natural pasture hay intake to satisfy nutrient requirements. When there is high CP inclusion in the animal feed, there could be substitution effect that could be satisfied with a limited amount of basal diet intake. However, when supplements were less in quantity, it might enhance the intake of basal diet to satisfy the nutrient requirement of animals (Nguyem *et al.*, 2008).

Total dry matter and organic matter intakes increased significantly ($P < 0.05$) with the increasing level of soybean meal (SBM) supplementation. Total dry matter intake increased by 5.25, 17.34 and 25.74% for T_2, T_3 and T_4 as compared to the non-supplemented group. The addition of supplementary SBM to wheat straw based diets increased the total dry matter intake since dietary protein supplementation increases intake by increasing the supply of nitrogen to rumen microbes that would consequently increase microbial population and efficiency (McDonald *et al.*, 1995; Willem, 2010).

Sheep in the control treatment had a lower ($P < 0.05$) CP intake than the supplemented ones. As supplementation increased, the CP intake also increased across the treatments. This increment in the CP intake with graded levels of supplementation might be due to the increased total dry matter intake and higher CP content of the supplement. Protein supplementation increases the supply of nitrogen to the rumen microbes, which have a positive effect on the rate of fermentation of the digesta (Van Soest, 1994). As the rate of degradation of digesta increases, feed intake is accordingly increased. According to NRC (1981), the average daily protein and energy requirements of a 19.1 kg body weight animal for maintenance were 38 g CP and 4.0 MJ metabolic energy (ME), respectively. Based on this recommendation, the result of the current study showed that the average daily CP intake of 33.84 g for 13.28 kg body weight sheep in the control group was above the maintenance requirement and that is why sheep in the control treatment showed positive body weight gain. The estimated ME obtained by multiplying digestible organic matter intake with the coefficient of 0.0157 (McDonald *et al.*, 2002) was 6.3, 6.4, 7.5 and 8.3 MJ ME/head/day (SEM = 0.06) for T_1, T_2, T_3 and T_4, respectively and energy intake was above the maintenance requirement.

Table 3. Daily dry matter and nutrients intake of Black Head Ogaden sheep fed natural pasture hay supplemented with different levels of soybean meal.

Intake (g/day)	Treatment					SEM
	T_1	T_2	T_3	T_4	P- Value	
Hay DM	561.9^a	471.1^b	421.1^c	367.2^d	P < 0.0001	15.70
SBM DM	-	122.9^c	246.9^b	352.2^a	P < 0.0001	22.77
Total DM	611.9^d	644.0^c	718.0^b	769.4^a	P < 0.0001	13.83
OM	562.6^d	595.3^c	666.4^b	716.3^a	P < 0.0001	13.36
CP	33.8^d	78.5^c	125.4^b	164.8^a	P < 0.0001	10.31
NDF	471.2^a	422.9^b	406.5^b	383.7^c	P < 0.0006	7.73
ADF	471.2^a	422.9^b	406.5^b	383.7^c	P < 0 .0007	7.73

$^{a-d}$ Means with in a row with different superscripts differ (P < 0.05); ADF = Acid detergent fiber; ADL = Acid detergent lignin; CP = Crude protein; DM = Dry matter; OM = Organic mater, NDF = Neutral Detergent Fiber; SBM; = Soybean meal; SEM = Standard Error of Mean; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

The total NDF and ADF intakes were greater (P < 0.05) for the control group than the supplemented groups. The basal diet used in this study, was 80% NDF and 51% ADF. This high content of fiber in the pasture hay used in this study coupled with the greater intake of hay for T_1 presumably resulted in more intakes of NDF and ADF for SBM non-supplemented group as compared to SBM supplemented ones.

3.3. Digestibility

The apparent digestibility of dry matter and nutrients are given in Table 4. The dry matter and organic matter digestibility was significantly impacted by treatment (P < 0.05), and was in the order of $T_4 = T_3 > T_2 > T_1$. The CP was also significantly affected by treatment and was increased as the level of SBM supplementation increased (P < 0.05); on the other hand NDF and ADF digestibility decreased (P < 0.05) with increasing level of SBM supplementation.

Digestion in the rumen is dependent on the activity of rumen microorganisms. Rumen microbes require energy, protein and other micro-nutrients to grow and multiply and in the due course efficiently perform the ruminal digestion of feeds (Ranjhan, 2001). Thus, the digestibility of dry matter and CP would expectedly increase when diets rich in CP are consumed (Broster, 1973), which presumably is the main reason for dry matter and CP digestibility differences among treatments observed in this study. Although soybean meal protein is degraded relatively rapidly in the rumen, much of such protein tends to bypass ruminal digestion, making it available for enzymatic digestion in the small intestine (Khorasani *et al.*, 1990). The digestibility of dry matter and CP was shown to increase in response to increase the amount of rumen undegradable protein in the diet of ruminants (Haddad *et al.*, 2005), which can be also another reason for the improvements observed in the dry matter and protein digestibility with SBM supplementation in this study. However, fiber digestibility in this study decreased in response to increasing the level of SBM supplementation in the diet despite the expected improvement in fiber digestibility with protein supplementation as noted before (Banamana *et al.,* 1990). However, if most of the SBM protein bypasses ruminal fermentation as noted above, the possible incremental effect of the additional dietary protein intake in ruminal fiber digestion could not have been achieved. On the other hand, the protein supplied by the 50 g wheat bran might have been sufficient to induce significant digestion of fiber especially in treatments with low intake of total dry matter and/or nutrients so that ruminal microbes extract sufficient nutrients from SBM and wheat bran that can satisfy their demand.

Table 4. Apparent digestibility of nutrients in Black Head Ogaden sheep fed on natural pasture hay supplemented with different levels of soybean meal.

Digestibility (%)	Treatment					SEM
	T_1	T_2	T_3	T_4	P-value	
DM	69.1^c	71.0^b	72.6^a	73.4^a	P < 0.0007	0.39
OM	70.8^c	72.7^b	74.3^a	75.1^a	P < 0.0017	0.39
CP	61.3^d	83.9^c	87.1^b	89.3^a	P < 0.0001	2.30
NDF	70.3^a	66.9^b	63.8^c	59.3^d	P < 0.0001	0.88
ADF	73.1^a	70.1^b	66.9^c	62.4^d	P < 0.0001	0.87

$^{a-d}$ Means with in a row with different superscripts differ (P < 0.05); ADF = Acid Detergent Fiber; CP = Crude Protein; DM = Dry Matter and OM = Organic Matter; NDF = Neutral Detergent Fiber; SEM = Standard Error of Mean; SL= Significance Level; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

3.4. Body Weight Change

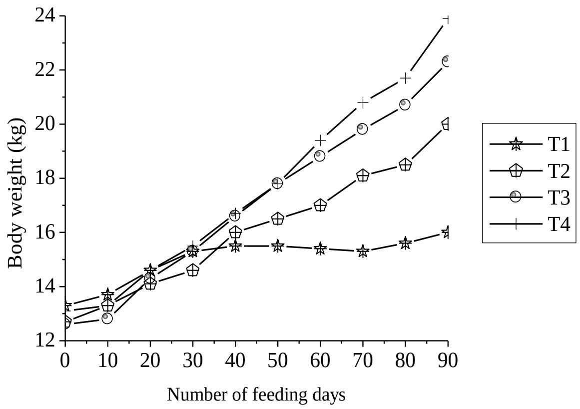
The body weight parameters of the experimental sheep are presented in Table 5. Initial body weights were similar (P > 0.05) among treatments. Final body weight and average daily body weight gain (ADG) increased (P < 0.05) in response to increasing the levels of SBM supplementation. Feed conversion efficiency (FCE) was lower for T_1 as compared to the SBM supplemented groups, and was significantly (P < 0.05) higher for T_3 and T_4 as compared to T_2. A positive ADG in SBM non-supplemented sheep in the present study indicated that the addition of 50 g wheat bran to natural pasture hay was more than the maintenance requirement of the animals. Improvements in growth rate and FCE with SBM supplementation in the current study was obviously associated with better dry matter and CP intake and digestibility that might have increased nutrient supply for growth in SBM supplemented sheep. According to Brown *et al.* (2001), animals that have high feed conversion efficiency are considered efficient users of feed. Therefore, among supplemented treatments, sheep in T_3 and T_4 were best feed converters. The improved FCE observed in the current study due to supplementation agreed with results from other similar studies (Solomon and Solomon 1995). The present experiment indicated that SBM supplementation promoted better ADG and FCE.

Table 5. Body weight change of Black Head Ogaden sheep fed natural pasture hay supplemented with different levels of soybean meal.

Parameter	Treatment					SEM
	T_1	T_2	T_3	T_4	P-value	
Initial BW (kg)	13.3	12.7	12.6	13.1	P < 0.4409	0.38
Final BW (kg)	16.0^d	20.0^c	22.3^b	23.9^a	P < 0.0001	0.69
ADG (g/d)	30.3^d	80.9^c	104.0^b	116.2^a	P < 0.0001	6.89
FCE (g ADG/g DMI)	0.05^c	0.13^b	0.14^a	0.15^a	P < 0.002	0.009

$^{a-d}$ Means with in a row with different superscripts differ (P < 0.05); ADG = Average Daily body weight Gain; BW = Body Weight; DMI = Dry Matter Intake; FCE = Feed Conversion Efficiency; SEM = Standard Error of Means; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

Body weight change of the experimental animals increased similarly until the animals became well adapted to SBM. However after the animals got well adapted to SBM. Supplemented animals significantly (P < 0.05) higher in body weight gain compare to non-supplemented animals. During the last 30 days of feeding regime, the control group showed little body weight change, after a pause between 30 and 70 days of the experiment, while the supplemented group showed increasing trend throughout the experimental period. This might be due to the insufficient amount of nutrients available for animals in T_1 as their requirement increase with increase in body weight.



T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

Figure1. The trends in body weight changes over the feeding days.

3.5. Carcass Characteristics

The pre-slaughter body weight (PSW), empty body weight (EBW), hot carcass weight (HCW), dressing percentage as a proportion of PSW and EBW and rib-eye muscle area were significantly ($P < 0.05$) higher for SBM supplemented group than the non-supplemented group (Table 6). Among the SBM supplemented treatments, PSW, HCW and rib eye muscle area increased with the increasing level of SBM supplementation. The dressing percentages as a proportion of EBW were eleven percent higher than the dressing percentages as a proportion of PSW due to effect of gut content. Black Head Ogaden sheep with pre-slaughter weight ranging from 20.1-23.9 kg had a dressing percentage of 38.8-44.9% and 53.1-57.3% on PSW and EBW basis, respectively (Embet, 2008), which are comparable with the results of the current study. Similarly, lamb slaughtered at 11.8-19.4 kg body weight had dressing percentages of 49.8-50% and 55.3-57.5% on PSW and EBW basis, respectively, (Manufredini *et al.,* 1988), which was also comparable with the results of current study.

Table 6. Carcass characteristics of Black Head Ogaden sheep fed on natural pasture hay supplemented with different levels of soybean meal.

	Treatment				
Carcass parameter	T_1	T_2	T_3	T_4	SEM
Pre-slaughter BW (kg)	15.8^d	20.0^c	22.3^b	23.9^a	0.72
Empty BW (kg)	12.2^c	17.2^b	19.1^a	19.5^a	0.67
Hot carcass weight (kg)	5.9^d	8.9^c	10.4^b	11.6^a	0.48
Dressing percentage (%)					
Pre-slaughter BW basis	37.3^c	44.6^b	46.4^b	48.6^a	0.94
Empty BW basis	48.4^c	51.9^b	54.2^b	59.7^a	0.94
Rib-eye muscle area (cm^2)	4.5^d	6.8^c	8.8^b	10.8^a	0.51

$^{a\text{-}d}$ Means with in a row with different superscripts differ; ($P < 0.05$); BW = Body Weight; SEM = Standard Error of Means; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

Generally, SBM supplementation improved dressing percentage, which is in line with the report of Ulfina *et al.* (1999), in which feeding aged Horro ewes on a concentrate improved carcass weight and dressing percentage.

Greater rib-eye muscle area with SBM supplementation in this study indicates that supplemented sheep were able to develop better muscling than the non-supplemented sheep. In agreement with the results of this study, Black Head Ogaden sheep fed on a basal diet of common bean haulms and supplemented with mixtures of wheat bran and brewers dried grain showed rib-eye muscle area of 8.2-10.4 cm^2 for supplemented treatments and 6.7 cm^2 for the control (Emebet, 2008). But rib eye muscle area in the control group of this study was slightly lower than results reported by this author. This could be attributed to the variation in slaughter body weight and feed type.

3.5.1. Main carcass components

The main carcass components of Black Head Ogaden sheep fed on a basal diet of natural pasture hay supplemented with different level of soybean meal are presented in Table 7. All main carcass components of the SBM supplemented treatments were significantly ($P < 0.05$) higher than the non-supplemented group, and values increased significantly ($P < 0.05$) with increasing level of SBM supplementation. Among the total main carcass components, the hind quarters made the highest share (35.94 -37.23%) of the hot carcass weight, followed by the forequarters (31.49-31.91%) and the third was the ribs that constituted 20.32-21.54% of the hot carcass weight.

Table 7. Main carcass components of Black Head Ogaden sheep fed on natural pasture hay and supplemented with different levels of soybean meal.

	Treatment				
Carcass parameter (kg)	T_1	T_2	T_3	T_4	SEM
Forequarter	1.2^{d}	1.7^{c}	2.0^{b}	2.3^{a}	0.09
Sternum (brisket)	0.4^{d}	0.7^{c}	0.8^{b}	0.9^{a}	0.04
Hind quarter	1.4^{d}	2.1^{c}	2.5^{b}	2.7^{a}	0.10
Ribs	0.8^{d}	1.1^{c}	1.4^{b}	1.5^{a}	0.06
TMCC	3.8^{d}	5.6^{c}	6.7^{b}	7.4^{a}	0.30

$^{a-d}$ *Means with in a row with different superscripts differ; (P < 0.05); SEM = Standard Error of Means; TMCC = Total main carcass components;* T_1 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran;* T_2 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal;* T_3 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal;* T_4 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.*

3.5.2. Edible offal components

Edible offal component of Black Head Ogaden sheep fed on the basal diet of natural pasture hay and supplemented with different levels of soybean meal are listed in Table 8. All edible offal components measured in this study showed significant ($P < 0.05$) difference among the treatments. Total edible offal components (TEOC) increased significantly ($P < 0.05$) with increasing level of SBM supplementation. Generally supplementation had a positive effect on the weight of most edible offal components which agrees with the report of Tesfaye (2007) in which supplemented Afar sheep had higher weight of visceral organs than the non-supplemented ones.

Table 8**.** Edible offal components of Black Head Ogaden sheep fed on natural pasture hay and supplemented with different levels of soybean meal.

	Treatment				
Edible offals	T_1	T_2	T_3	T_4	SEM
Blood (g)	707.2^{c}	753.3^{c}	892.3^{b}	997.8^{a}	26.59
Liver (g)	163.8^{d}	306.7^{c}	340.0^{b}	408.7^{a}	19.26
Kidney (g)	47.3^{c}	59.3^{b}	65.2^{a}	69.3^{a}	2.11
Heart (g)	71.7^{c}	83.5^{b}	84.7^{b}	123.5^{a}	4.34
Tongue (g)	50.8^{b}	55.5^{a}	56.2^{a}	56.3^{a}	0.71
Kidney fat (g)	17.7^{d}	33.8^{c}	40.2^{b}	50.7^{a}	2.54
Abdominal fat (g)	38.3^{d}	75.0^{c}	123.3^{b}	170.7^{a}	10.53
Reticulum (g)	57.2^{c}	64.2^{c}	73.0^{b}	80.3^{a}	2.17
Rumen (g)	344.8^{d}	442.8^{c}	481.2^{b}	540.3^{a}	15.38
Omasum (g)	59.7^{c}	66.5^{bc}	73.3^{ab}	80.5^{a}	2.04
Abomasums (g)	69.0^{c}	77.8^{b}	82.8^{b}	93.8^{a}	2.34
Small intestine (g)	281.0^{c}	447.7^{b}	476.5^{ab}	512.3^{a}	19.30
Large intestine (g)	236.7^{d}	272.0^{c}	292.3^{b}	324.5^{a}	7.15
TEOC (kg)	2.2^{d}	2.7^{c}	3.1^{b}	3.5^{a}	0.11

$^{a-d}$ *Means with in a row with different superscripts differ; (P < 0.05);SEM = Standard Error of Means; TEOC = Total Edible Offal components;* T_1 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran;* T_2 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal;* T_3 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal;* T_4 *= Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.*

3.5.3. Non-edible offal components

Similar to that of edible offal components, all non-edible offal components also significantly ($P < 0.05$) differed among the treatments, and the total non-edible offal weight excluding the gut contents increased significantly ($P < 0.05$) in response to increasing the level of SBM supplementation (Table 9). Gut fill was 3.53 kg (22.41% of PBW) for T_1 and within the range of 2.78-4.42 kg (13.91-18.49% of PBW) for supplemented treatments. This might be due to the fact that animals on poor quality feed are compelled to fill their gut with less digestible roughage, and consequently, have proportionally bigger gut contents (Van Soest, 1994; Pond *et al.*, 1995). In the current study, it was observed that the proportion of gut fill to PBW of the control group is higher than the supplemented groups.

Table 9. Non-edible offal components of Black Head Ogaden sheep fed on natural pasture hay and supplemented with different levels of soybean meal.

Non edible offals	Treatment				SEM
	T1	T2	T3	T4	
Skin (g)	1256.3^{d}	1965.0^{c}	2401.5^{b}	2597.0^{a}	109.47
Feet (g)	367.5^{c}	415.2^{b}	424.4^{b}	466.8^{a}	8.15
Head without tongue (g)	1280.0^{b}	1303.2^{b}	1491.7^{a}	1527.2^{a}	25.13
Penis (g)	33.7^{d}	39.0^{c}	44.8^{b}	47.7^{a}	1.25
Testicles (g)	220.3^{c}	256.0^{b}	261.7^{b}	289.8^{a}	5.98
Lung and trachea (g)	181.0^{c}	205.2^{b}	216.5^{b}	240.7^{a}	5.48
Esophagus (g)	58.8^{b}	70.0^{a}	66.2^{a}	68.7^{a}	1.33
Spleen (g)	19.8^{d}	32.3^{c}	37.8^{b}	49.3^{a}	2.26
Gall-bladder with bile (g)	16.5^{c}	21.3^{b}	23.5^{ab}	25.8^{a}	0.85
Bladder (g)	13.8^{c}	14.2^{c}	17.8^{b}	20.8^{a}	0.68
TNEOC (g)	3447.7^{d}	4321.4^{c}	4985.9^{b}	5333.8^{a}	152.62
Gut fill (g)	3534.8^{b}	2782.8^{c}	3211.8^{b}	4421.2^{a}	143.55

$^{a\text{-}d}$ Means with in a row with different superscripts differ; ($p < 0.05$); = SEM = Standard Error of Means; TNEOC = Total None Edible offal Components; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

3.6. Partial Budget Analysis

As shown in Table 10, feed cost was the major cost of the feeding trial and selling price of sheep increased with increasing SBM supplementation. In this study, it was realized that the economic return of the feeding trial mainly depends on feed cost, purchasing and selling price of the experimental sheep. The most and important parameters of partial budget analysis are the change in net income (ΔNI) and MRR. These is due to the fact that MRR measures the net return increment associated with each additional units of expenditure (ΔTVC) and ΔNI shows the net return of the feeding regime by considering expense costs and return changes Upton (1979). Supplementation of different levels of SBM resulted in increments in NI and ΔNI. Animals that have high feed conversion efficiency are considered efficient users of feed (Brown *et al.*, 2001). Therefore, among the supplemented treatment groups, T_4 was the best recommended supplementation level based on biological performances and practical budget analysis. Therefore, natural pasture hay basal diet based feeding system for sheep should be supplemented with a good protein supplement like soybean meal to obtain good net income (profit) within a shorter duration.

Table 10. Partial budget analysis of Black Head Ogaden sheep fed on natural pasture hay and supplemented with different levels of soybean meal.

Parameter/Treatment	T_1	T_2	T_3	T_4
Purchase price of sheep (ETB/sheep)	250	250	250	250
Natural pasture hay consumed (kg/sheep)	50.6	42.4	37.9	33.0
Wheat bran consumed (kg/sheep)	4.5	4.5	4.5	4.5
SBM consumed (kg/sheep)	-	12.94	22.22	31.98
Cost of Natural pasture hay (ETB/sheep)	56.17	47.06	42.07	36.63
Cost of Wheat bran (ETB/sheep)	9	9	9	9
Cost of SBM (ETB/sheep)	-	80.54	138.2	198.26
Total feed cost (ETB/sheep) (TVC)	65.17	136.60	189.27	243.89
Selling price of sheep (ETB/sheep)	285	395	455	525
TR (ETB/sheep)	35	145	205	275
NR (ETB/sheep)	-30.17	8.40	15.73	31.11
ΔNI	-	38.57	45.90	61.28
ΔTVC	-	71.43	124.1	178.72
MRR	-	54.0	37.0	34.3

ETB = Ethiopian Birr; TR = Total Return; ΔTR = Change in total return; TVC = Total Variable Cost; Δ TVC = Change in Total Variable cost; NR = Net Return; ΔNI = Change Net Income; MRR = Marginal Rate of Return; SBM = Soybean meal; T_1 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran; T_2 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran +125 g DM/day Soybean meal; T_3 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 250 g DM/day Soybean meal; T_4 = Natural pasture hay ad libitum + 50 g DM/day Wheat bran + 375 g DM/day Soybean meal.

4. Conclusions

The result of this study have demonstrated that soybean meal (SBM) supplementation has a positive effect on feed intake, FCE, average body weight gain, carcass parameters and economic feasibility. The effects are more pronounced at the highest level of SBM. Thus supplementing natural pasture hay with 375 gm of dry matter soybean meal resulted in better biological and economic performances in the production of Black Head Ogaden sheep in the study area.

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