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Supplementation with Different Forms of Processed Lupin (Lupinus albus) Grain in Hay Based Feeding of Washera Sheep: Effect on Feed Intake, Digestibility Body Weight and Carcass Parameters

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ABSTRACT
The digestibility and feeding trial study was conducted using twenty four intact yearling washera sheep with mean initial body weight of 17$\pm$ 0.81 (mean $\pm$ STD).The objective of the study was to assess the effect of supplementation with different forms of processed lupin grain on feed intake, body weight (BW) change, apparent nutrient digestibility, feed conversion efficiency (FCE), carcass characteristics as well as economic return of the feeding regime in washera sheep fed a basal diet of natural pasture hay. A completely randomized block design consisting of four treatments and six blocks was used. The sheep were blocked based on their initial BW and they were randomly assigned to one of the four treatment feeds within a block. The sheep were adapted to the treatment feeds for two weeks followed by seven days of digestibility trial. The feeding trial was conducted for ninety days and carcass parameters were determined at the end of the study. The treatments consisted of adlibitum feeding of natural pasture hay (non-supplement) and supplementation with 300 g/head/d roasted coarsely ground lupin grain, roasted soaked lupin grain and roasted soaked coarsely ground lupin grain in DM basis. The CP and OM contents of hay used in the study were 8.75% and 91.9% on DM basis respectively. The CP contents of different forms of lupin grain, namely, roasted coarsely ground(T_2); roasted soaked(T_3) , and roasted soaked and coarsely ground(T_4)were 30.5% ,36% and 36.8 % on DM basis. Non-supplemented sheep consumed higher ($P<0.05$) pasture hay DM (608.8 g/head/day) as compared to the supplemented treatments (464.4-519.5 g/h/d).Supplementation of T_2, T_3 and T_4 increased ($P<0.05$) total DM (728.9-764.4) g/head/day) and crude protein (CP) (109.3-150.9 g/head/day) intake. Similarly supplementation improved ($P<0.05$) the apparent digestibility coefficient of DM (0.69), OM (0.7-0.71) and CP (0.81-0.89.) Sheep Supplemented with T2, T3 and T4 gained weight of 34.1, 54.3 and 63.7g/day while those non supplemented gains only slightly (5.7g/day). Moreover, dressing percentage on slaughter weight basis, hot carcass weight, rib eye muscle area were higher ($P<0.05$) for supplemented sheep than the control. In general, supplementation improved feed intake, body weight gain, nutrient digestibility and carcass characteristics and its effect was more pronounced in sheep supplemented T4 than in the other treatments**.** Results from this study suggested that supplementation with roasted soaked and coarsely ground lupin grain showed better nutrient utilization, response in live weight gains and carcass parameters in washera sheep and returned the highest net profit compared to the other forms of the grain.
Keywords: carcass, feed conversion efficiency, processed lupin grain, weight gain Introduction

Livestock have several socio-economic values that are important for the livelihood of the farming communities. Their primary products such as meat, milk and egg are important sources of animal protein. Live animals, skins and hides are valuable sources of cash income. Moreover, skins, hides and horns are used as raw materials for making a range of household items, agricultural tools and ornaments. Their manure is used to fertilize backyards and crop fields. Sheep are the second largest livestock resources next to cattle in Ethiopia. However, the contribution of this sector to the national economy is far below its potential. The levels of foreign exchange earnings from livestock and livestock products are also much lower than would be expected, given the size of the livestock population (Berhanu et al 2007). Livestock productivity is influenced by a complex interaction of the genetic potential of the livestock breed kept, the production system and the production environment (Solomon et al 2010).

Feed, one of the environmental factor, is the most important input in livestock production and its adequate supply (quality & quantity) throughout the year is an essential prerequisite for any substantial expansion in livestock production (Samuel et al 2008). Livestock feed resources in Ethiopia are mainly from natural grasslands, crop residues and browses followed by agro-industrial by products, forage crops and improved pasture (Alemayehu 2003). The same report showed that the contributions of this feed resource vary greatly since the quantity and quality of native pasture varies with altitude, rain fall, soil and cropping intensity. Seasonality in feed availability and lack of appropriate conservation has created feed shortage both in the highland and lowland agro-ecological setup in Ethiopia.

Shortage of feed supply interms of quantity and quality is the main factor limiting productivity of the livestock sector in Ethiopia (Adugna 2008). Population pressure and expansion of crop land calls for alternative ways of feed production, conservation and utilization which could alleviate livestock feed problem. Introduction of improved forage is not a common practice because of shortage of land, planting material and lack of awareness by the farmers. As a result, in areas with limited grazing land and land scarcity for forage production, crop residues are used alternatively. In general, in order to ameliorate livestock productivity the nutritional value of low quality feed resources should be improved. One of the strategies commonly employed in this regard is supplementation with feed resources that contain better nutrients. One such supplement is white lupin known as Gibto in Ethiopia.

Gibto is a cool-season crop, relatively tolerant of spring frost, adapted to well-drained, coarsely textured, and neutral to acidic soils (Putnam et al 1991). The crop is grown in elevations ranging between 1500-3000 meters above sea level (m.a.s.l.). Its seeds are employed as a protein source for animal and human nutrition in various parts of the world (Kohajdova et al 2011). Lupin grain contains high amount of protein (32.2%), fiber (16.2%), oil (5.95%) and sugar (5.85%) (Erbas et al 2004). Gibto is produced by smallholder subsistent farmers in two regional states of Ethiopia: Amhara National Regional State and Benishangulgumuz National Regional State, the former being the largest producer. In the main production season (Meher season; June-December) of the year 2008, a total of 17, 241 tons of lupin grain, with a mean productivity of 0.84 t/ha, was produced in these two major lupin producing regional states (CSA 2009). Lupins (*Lupinus* spp.) are also grown on 679,999 hectares of land on a global scale (Mikić et al 2009). Although lupin has immense potential for feed, food and soil fertility maintenance, the Ethiopian local lupin cultivation, genetic improvement and utilization remains far behind as compared to the other pulse crops (Likawent et al 2010). Little is known about the nutritional value, physicochemical and functional properties of the crop.

Besides little information is available for farmers, processors and end-users in utilization of the resource capacity of lupin seeds in the Ethiopian context (Tizazu *and shimelis* 2010). This information gap does not allow intensive and extensive utilization of lupin as a value added product (food/feed) in the country. Inline with this the grain has a potential to grow in marginal lands where other food crops do not. It can be stored for long period without deteriorating in quality and this allows using it in the period of feed scarcity. Lupin seed storage and handling is easy as it is hardly attacked by pests. The only requirement for storage is dry condition that enables its storage for about four to ten years without deterioration in quality. Another important feature is that lupin grain is the cheapest grain legume in the lupin producing areas of Ethiopia (Likawent et al 2010). However, lupin has high alkaloid content which results in characteristically bitter taste making the crop unacceptable for food/feed (Martini et al 2008). It is therefore, essential to look for appropriate strategies (processing methods) that reduces its alkaloid content and thereby enhances its utilization as livestock feed. Chemical treatment of lupin grain is the most common processing method suggested to reduce alkaloid contents of the crop (Arslan and Seker 2002). Previous studies demonstrated that dehulling (Joray et al 2007) heating (Batterham et al 1986), roasting followed by soaking and boiling followed by soaking (Paulos 2009) reduce alkaloid content and improved feeding value of the crop.

Gebru (2009) also indicated that among the different forms of lupin grain (raw, raw soaked, roasted and raw soaked dehulled) supplemented for washera sheep in hay based feeding, roasted lupin grain had significantly higher intake (192g/day) as compared to raw lupin grain (133g/day). The same study showed that body weight gain of sheep supplemented with roasted lupin grain was significantly higher (25.3 g/day) as compared to those supplemented with raw lupin grain (16.4 g/day) but there was no significant ($P>0.05$) difference in feed intake and body weight changes between sheep supplemented with other forms of the grain. This shows that among the different processing methods employed, roasting improves feeding value of the crop and animal performance. Efforts should also be continued to search for alternative methods or combinations of the methods that result in a better performance.

Therefore, this study was intended to evaluate the effects of supplementation with roasted grain by further processing (roasting/grinding, roasting/soaking, and roasting/soaking/grinding) on the performance of sheep and there by ameliorate the use of lupin grain in animal feeding/fattening programs.

The objectives of the study were:

✓ To evaluate the effect of supplementation of different forms of processed lupin grain on intake, digestibility, body weight (BW) change and carcass parameters of Washera sheep fed hay.

To assess the economic benefit of different forms of supplementation by using partial budget analysis

Materials and Methods

Description of the Study Area

This study was conducted in Sekela District of West Gojjam Administrative Zone, Amhara National Reginal State. The study site is located at 466 km North West of Addis Ababa. The site has an altitude ranging between

2013 and 3257 m.a.s.l. The average annual rainfall is 1738 mm with a bi-modal distribution from February to April and from June to September. The average annual minimum and maximum temperature are 8 and 21 °C, respectively (World clim 2009). The topography of Sekela is undulating landscape with degraded farmlands. Mixed crop- livestock production is the typical farming system in the District with tree growing (Eucalyptus) as a common practice around farmlands and homesteads. According to Sekela Agricultural and Rural Development Office, the average land holding per household is 0.75 hectares (SARDO 2009).

Experimental Animals and Management

Twenty four intact yearling male Washera sheep with initial body weight of 17.0$\pm$ 0.81 kg (mean $\pm$ SD) were purchased from local markets of Gish Abay. The age of the animals was determined by dentition and information from the owner. The animals were quarantined for two weeks to get them adapted to the new environment and to observe their health status. During this period animals were vaccinated against sheep pox, black leg, and ovine pasturolosis and dewormed against internal parasites. The animals were also sprayed with acaricides against external parasite during the same period. The animals were adapted to the experimental feeds prior to the beginning of the experiment for additional two weeks. A house was rented and partitioned in to pens for use throughout the experiment. The animals were housed in individual pens and fed separately. The pens were equipped with feeding and watering troughs. For feeding of hay, bamboo basket (made from locally available plant) was used while concentrate and water were offered in plastic buckets purchased from market. Hay, mineral licks and water were offered *adlibitum*. Dietary treatments constituted different forms of processed lupin grain. Supplements were offered at 300 g on DM basis per day in two equal portions at 0800 h and 1600h.

Feed Preparation and Feeding

Natural pasture hay *was* purchased from surrounding farmers and stored in a shade to maintain its quality and used as basal diet throughout the experimental period. The hay was chopped, weighed and offered to the experimental animals at 25% refusal adjustment throughout the experiment. Refusals of hay were collected and weighed every morning before fresh feed is offered throughout the experimental period. Lupin grain wa*s* purchased from the locality and processed. The total amount of the grain was purchased before the start of the experiment, bulked and the amount required for preparation of the different forms was taken from the bulked feed. Processing of the grain was made by roasting and soaking in a river as farmers do in the locality. The roasting was done on flat surface (Mitad) by continuously mixing and stirring the seeds to ensure uniformity and until a number of black spots was observed. The average roasting plate surface temperature was measured, using a thermometer and was found to be 145 ^{0}C, and the process lasted for an average of 12 minutes. Following the roasting process, the grain was soaked in water until its bitter tasting was minimized. Soaking in a river lasts for five days. The advantage of soaking in a river (running water) over soaking in a house using a pot was that the running water has washing power which reduces the bitter tasting of lupin within short period of time. After soaking, the grain was allowed to dry on sunshine. Grinding was done in an attrition mill where people use for grinding of grains/cereal crops for food. The animals were offered *ad libitum* hay and supplemented with 300 g of the supplement feeds.

Experimental Design and Treatments

The experiment was laid down in a completely randomized block design. Experimental animals were blocked into six groups based on their initial body weight (BW) and randomly assigned to one of the four dietary treatments. Before commencement of the experiment, initial BW was determined as a mean of two consecutive weighing after withholding of feed and water over night. The experimental treatments are shown in table 1.

Table 4.Experimental treatments

Treatments	Basal diet	Supplement (g/d on DM basis)
Treatment 1	Hay *ad libitum*	0
Treatment 2	Hay *ad libitum*	300g RCG
Treatment 3	Hay *ad libitum*	300g RS
Treatment 4	Hay *ad libitum*	300g RSCG

RCG=roasted and coarsely ground lupin grain; RS=roasted soaked Lupin grain; RSCG=roasted soaked and coarsely ground lupin grain.

Digestibility Trial

After an adaptation period of 15 days to the treatment diets, sheep were fitted with a fecal collection bag to collect feces. After adjustment period of additional three days to the carrying of fecal bags, feces was collected for seven days, each day's collection of feces per animal was weighed and 20% was sub-sampled and stored frozen at -20 ^{0}C, and pooled over the collection period. Composite samples of feces was thawed to room temperature, mixed thoroughly and dried at 60^0C to a constant weight. The dried samples of feces was ground through 1 mm sieve and stored in airtight polyethylene bag until analyzed. The feeding management of the experimental sheep was similar during both the digestibility trial and feeding trial experiments. Feed sample was also taken during the digestion period for chemical analysis. BW was measured at the beginning and end of the collection period. The digestion coefficient (DC) was calculated as follows;

$$DC = \frac{\text{Total amount of nutrients in feed- Total amount of nutrients in feces}}{\text{Total amount of nutrients in feed}}$$

Feeding Trial

The feeding trial followed digestion trial and lasted 90 days. During this period, animals reared on the same treatment diet. Hay was offered allowing 25% refusal. The supplements were offered at 08:00 h and 16:00 h in two equal partitions. Samples were taken from batches of feed offer, thoroughly mixed and sub-sampled for chemical analysis. Feed refusal samples were taken per animal, pooled on treatment basis, mixed thoroughly and was sub-sampled for DM determination and chemical analysis. Daily feed intake was calculated as the difference between quantity of feed offer and refusal. The average DM intake of the feed was also estimated as the total feed consumed on DM base divided by the number of days. Substitution rate of the supplement levels was calculated as the difference between basal diet intake of the control and supplemented treatments divided by the supplement intake of supplemented sheep. .

$$\text{Substitution rate} = \frac{\text{Hay DM intake in the control treatment -Hay DM intake of the Supplemented sheep}}{\text{Supplement intake of supplemented sheep}}$$

Initial body weight of the experimental animals was taken at the beginning of the study by two consecutive weighing in the morning before feeding. Body weight (BW) measurements thereafter were taken at ten days interval individually during the entire feeding trial period after overnight fasting and before offering the daily ration. BW measurements were done by using a suspended spring balance capable of reading up to 50kg. Average daily gain was calculated as the difference between final live weight and initial live weight divided by the number of days of the feeding trial. Feed conversion efficiency (FCE) of experimental animals was determined by dividing the daily body weight gain to the quantity of dry matter consumed by the animal.

Determination of Carcass Parameters

At the end of feeding trial, all sheep meant for the study were slaughtered to assess the carcass parameters. The animals were deprived of feed and water overnight before the slaughtering. Slaughter weight (SW) was measured before slaughtering. The slaughtering was done by severing the jugular vein and carotid artery with knife. The sheep were suspended head down over the container placed to collect blood and the collected blood was weighed. After slaughter and flaying process is completed, the skin was weighed. The entire gastro intestinal tract with contents (stomach, small and large intestine) was removed and weighed. Internal organs such as lung, heart, kidney, liver, spleen, genital organs, and other parts like head and tail were removed and measured. The weight of hot carcass was measured after removing all offal's (head, thoracic, abdominal and pelvic contents) as well as legs below the hock and knee joints. Empty body weight was calculated as slaughter weight less gut contents. The rib-eye muscle area of each animal was determined by tracing the cross sectional area between 12^{th} and 13^{th} ribs after cutting perpendicular to the back bone. The left and right rib-eye muscle area was traced on a transparent waterproof paper and the area was calculated using squared graph paper. The mean of the right and left cross sectional areas was taken as a rib-eye muscle area.

Chemical Analysis

Feces collected during the digestibility trial was taken to Bahir Dar University Food Engineering Laboratory with cold ice box and dried in forced air draft oven at 60 °C for 72 hours for partial DM determination. Samples of, partially dried feces, feed offered and refused were taken to Haramaya University Nutrition Laboratory for analysis of DM, NDF, ADF, ADL and ash. The partially dried samples of feces, samples of feed offered and refused were milled to pass through 1 mm screen. The samples were subjected to laboratory analysis for DM, nitrogen and Ash following the procedure of AOAC (1990). The Acid detergent fiber (ADF), Neutral detergent fiber (NDF) and Acid detergent lignin (ADL) components of each feed and feces were determined according to the procedures of Van Soest and Robertson (1985). Nitrogen content of the feed offered, refusal and feces was analyzed in Addis Ababa University and crude protein (CP) was estimated as N×6.25. Hemicellulose was calculated in g/kg DM as follows: hemicelluloses= NDF-ADF.

Partial Budget Analysis

Partial budget analysis was made following the procedure of Upton (1979) procedure, net return (*NR*) was calculated as the amount of money left when total variable costs (*TVC*) are subtracted from the gross returns (*GR*):

$$NR = GR - TVC$$

Total variable costs include the costs of all inputs that change due to the change in production technology. The most important criterion in deciding whether or not to adopt a new technology is the change in net return (*ΔNR*). This amount is the difference between the change in gross return (*ΔGR*) and the change in total variable costs (*ΔTVC*)

$$\Delta NR = \Delta GR - \Delta TVC$$

The marginal rate of return (*MRR*) measures the increase in net income (*ΔNR*) associated with each additional unit of expenditure (*ΔTVC*) and calculated as:

$$MRR = \Delta NR/\Delta TVC$$

Statistical Analysis

Data collected on intake, digestibility, body weight gain and carcass parameters was analyzed using the General Linear Model procedure of SAS (SAS 1998). Treatment means were separated by using least significant difference (LSD).

The model used was $y_{ij} = \mu + t_i + b_j + e_{ij}$.

Where; y_{ij} = response variable, μ = overall mean
t_i = treatment effect, b_j = block effect
e_{ij} = random error

Results and Discussion

Chemical Composition of the Experimental Feeds

Chemical composition of the experimental feeds is shown in Table 2.The DM content of hay used in this study was comparable with 91.4% reported by Bimrew (2008), 92.2% reported by Wondwosen (2008) and 92.7% reported by Jemberu (2008). The CP content of hay offered to the experimental animals in the current study was higher than 7.02, 4.2 and 5.6% of CP reported by Abebaw (2007), Mulu (2005) and Getachew (2005), respectively. The CP content of hay in the present study lies within the range of 7.5-10.9% reported for natural pasture hay harvested at 90 and 170 days from Andasa area (Yihalem et al 2004). It has been stated that CP value ranging from 7-7.5% is required to satisfy maintenance requirement of ruminant animals (Van Soest 1982). Hence, the observed CP content of grass hay in the current study was slightly above that demanded for maintenance requirements of sheep. The higher CP content of hay in the current study might be attributed to the harvesting of the pasture at early stage of maturity. The NDF component of hay used in the current study is comparable to the NDF content of 76.8, 75.68 and 76.75% reported by Mulu (2005), Jemberu (2008) and Fentie (2007), respectively, but higher than 69.7 reported by Bimrew (2008). The ADF content of hay used in this experiment was comparable with 46.8, 50 and 51 documented by Abebaw (2007), Zinash *et al.* (1998) and Jemberu (2008), respectively. The ADL content of hay used in the current study was higher than 5.6, 8.2 and 6.2 reported by Fentie (2007), Abebaw (2007) and Jemberu (2008) and lower than 18% reported by Biruh (2008). The difference in the ADL content might be due to the difference in the proportion of plant species available in the hay.

Table 5. Chemical composition of feeds used in the experiment.

Parameters	Treatment feeds			
	Hay	RCG	RS	RSCG
DM (%)	92.7	93.8	91	90.8
OM(%DM)	91.9	94.8	96	94
CP(%DM)	8.75	30.5	36	36.8
NDF(%DM)	76.5	45.4	43.9	44
ADF(%DM)	48.9	28.3	32.9	30.9
ADL(%DM)	13.4	9.8	6	8.4
Ash(%DM)	8.1	5.2	3.8	5.5
Hemicelluloses	28	17.1	11	13.1
Hay Refusals	(T1)	(T2)	(T3)	(T4)
DM (%)	93.5	93.4	93.3	93.8
OM(%DM)	94.5	92.9	93	93
CP(%DM)	4.2	6.3	6.7	7
NDF(%DM)	80.7	77.4	77.2	76.8
ADF(%DM)	55.2	53.2	50.15	49.2
ADL(%DM)	13.16	11.8	10.35	11.13
Ash(%DM)	5.52	7.06	7.04	6.9

DM= dry matter; OM=organic matter; CP= crude protein; NDF=neutral detergent fiber; ADF=Acid detergent fiber; ADL= acid detergent lignin; RCGLG: roasted and coarsely ground lupin grain; RSLG: roasted soaked Lupin grain; RSCGLG: roasted soaked and coarsely ground lupin grain.

The DM content of lupin grain used in the current study was comparable with 92.6% and 93.06% documented by Gebru and Paulos (2009), respectively. The OM contents of lupin in this study was higher than 89% reported by Gebru (2009) and comparable with 97% reported by Tizazu and shimelis (2010). The CP content of roasted soaked and coarsely ground lupin grain in the current study was comparable with 35.05% reported by Prandini et al (2005), 38.01% reported by Vladimir *et al.* (2008) and 36.2% reported for raw lupin grain by Gebru (2009) but lower than 56% reported by Lo´ pez et al (2005) and 58.3% for soaked dehulled lupin reported by Gebru(2009).

On the other hand the CP content of roasted and coarsely ground lupin grain was low as compared to the above reports but it was comparable with 32.2% and 30.8% reported by Erbas et al (2005) and EHNRI (1997), respectively. The difference in the CP contents of lupin grain used in this study from that used in the previous studies might be due to genetic difference of the crop and environmental differences (Hill 2005). The NDF contents of lupin grain in the current study was higher than 19.8% reported by Vladimir et al (2008), 31.4% reported for roasted lupin grain by Gebru (2009) and 27.3% reported by Niwiiska and rzejewski (2011) and lower than 58.8% reported by Lo´ pez et al (2005). The ADF content of lupin grain in this study was comparable with 28.2% for roasted lupin grain by Gebru (2009), and lower than 42% reported by lo`pez et al (2005).

Feed Intake

Daily feed intake of washera sheep fed on grass hay and supplemented with different forms of processed lupin grain is presented in Table 3. Hay DMI was significantly ($P<0.05$) higher for sheep in the control treatment (T_1) as compared to the supplemented ones. This is because the protein and energy content of this roughage feed is low. Therefore, the sheep consumed the basal diet as much as they can in attempt to fulfill their nutrient requirements. In the current study, sheep in T2, T3 and T4 consumed 14.6%, 19.7% and 23.7% less grass hay, respectively, than sheep in the control treatment. The low hay DM intake in the supplemented sheep might be due to the substitution effect of supplements and its high nutrient content, which might have satisfied the nutrient requirement of the experimental sheep without additional hay DM intake. The current result of hay DMI was higher than the finding of Mulu (2005) who observed 477 g/day DM intake in the control treatment, and 411-460 g/day in supplemented ones, when Wogera sheep was fed on grass hay as basal diet and supplemented with 100-300 g/day brewery dried grain. This might be due to the better palatability and relatively higher CP content of hay in the present study increases the supply of nitrogen to rumen microbes. The total DM intake in the current study was higher ($P<0.05$) for all supplemented treatments than the control (T_1). This might be due to the fact that supplementation might have created a favorable rumen environment resulting in enhanced fermentation of the basal roughage and thus increased microbial protein synthesis. The extent and rate of digestion of fibrous feeds increase by nitrogen supplementation resulting in a greater DM intake. During the experimental period, significantly ($P< 0.05$) highest total dry matter intake was observed in sheep supplemented with 300 g roasted soaked (T_3) and roasted soaked coarsely ground (T_4) lupin grains which might be due to this forms of processing lupin minimize the bitter tasting of the grain and enabled the animals to consume more feed by supplying more nitrogen to the rumen microbes. Lower than the current findings Simachew (2009) reported 427.4 - 706.5 g/day DM intake for Washera sheep breed fed on grass hay and supplemented with maize bran, noug seed cake and their mixtures at different proportions. The total daily DM intake of supplemented sheep in the present study was also comparable to 665.8-788 g/head/day reported for Farta sheep supplemented with wheat bran, noug seed cake (NSC) and their mixtures (Fentie and Solomon 2008), 690.4-720.3 g/head/day reported for sheep supplemented with NSC and rice bran (Abebaw and Solomon 2008). Comparable to the current findings, Almaz (2008) noted 2.6-3.6 DM intake (%BW) for local sheep fed finger millet straw alone or supplemented with mixtures of atella and NSC at different proportions. In the present study, supplementation significantly increased ($P<0.05$) intake of OM, CP, NDF and ADF.

Total organic matter intake was estimated as %OM in the feed multiplied by TDMI (total dry matter intake). Intake of total organic matter by sheep in all supplemented groups was significantly higher ($P < 0.05$) than sheep in the control (T_1). Higher than the findings of the current study, Biruh (2008) documented the total organic matter of Adilo sheep fed hay and supplemented with sweet potato tuber and haricot bean screenings to be in the range of 670.8- 1020.2g/day. Intake of neutral detergent fiber (NDFI) was estimated as % NDF in the feed ×DMI. Significant differences ($P<0.05$) were observed among treatments in total NDF and ADF intakes. The higher intake of NDF and ADF in the supplemented group might be associated with relatively higher contents of NDF and ADF in the supplement feeds but there was no significant ($P<0.05$) difference between T_2 and T_3 in NDF intake. Hay ADFI was significantly ($P< 0.05$) higher for control group compared to the supplemented sheep. There was no significant ($P<0.05$) difference in lignin intake between supplemented and non-supplemented sheep. Comparable to the present study Biruh (2008) reported NDF intake of 376.5- 522.4 g/day for Adilo sheep fed hay and supplemented with sweet potato tuber and haricot bean screenings. Lower than the present findings, Tesfaye (2008) reported the ADF intake of 168- 274.1 g/day for Arsi-Bale sheep fed urea treated maize cob supplemented with graded levels of noug seed cake and wheat bran mixture.

In the current study, the total average daily CP intake was lower ($P<0.05$) in control than supplemented sheep. Sheep in T_1, consumed 51.2%, 62.5% and 64.7% less CP than Sheep in T_2, T_3 and $T_{4,}$ respectively. However, there were differences ($P<0.05$) among the supplemented groups. Crude protein intake in the supplemented sheep was in the order of $T_4>T_3>T_2$. Though the CP contents of T_3 and T_4 was similar, significantly ($P<0.05$) higher CP intake in T4 was recorded which might be explained the grinding effect (T_4) which improves intake better than roasting and soaking in water alone(T_3). Generally CP intake was high in T_3 and T_4 , which was achieved as a result the high CP content of the feed, the processing method employed and high total dry matter intake. Lower than the CP intake of sheep in T_3 and T_4 in the current finding, Tesfaye (2008) reported 106.1-126.9 g/day CP intake of Arsi-Bale sheep fed urea treated maize cob and supplemented with graded levels of noug seed cake and wheat bran mixtures. Lower than the CP intake of sheep in T_3 and T_4 in the current finding, Simachew (2009) also reported 38.6-117.8 g/day for Washera sheep fed grass hay and supplemented with maize bran, noug seed cake and their mixtures at different proportions which was due to the lower CP content of the feeds used in these studies in one side and the processing methods employed on lupin grain improves the intake of total dry matter and hence protein on the other side.

Table 6. Daily feed intake of Washera Sheep fed on hay and supplemented different forms of processed lupin grain.

Feed intake(g/day)	Treatments					
	T1	T2	T3	T4	SEM	SL
Hay DMI	608.6[a]	519.5[b]	488.8[c]	464.4[c]	11.4	***
Supplement DMI	0	209.3[c]	275.7[b]	300[a]	24.62	***
Total DMI	608.6[c]	728.9b	764.5a	764.4a	13.4	***
DMI (% BW)	3.49[b]	3.62[a]	3.5[b]	3.36[c]	0.041	**
DMI (g/kgW $^{0.75}$)	71.33[c]	76.73[a]	75.65[a]	73.42[b]	0.74	***
Total OM	559.14[c]	665.9[b]	714.17[a]	710.1[a]	13	***
Total CP	53.3[d]	109.3[c]	142[b]	150.9[a]	8	***
Total NDF	467.8c	494.4a	496.6a	490.1b	2.4	***
Total ADF	297.4478[d]	313.3[c]	329.5[a]	319.6[b]	2.5	***
Digestible nutrient intake (g/d)						
DM	381.3[c]	507.5[b]	534.7[a]	534.9[a]	13.6	***
OM	356[c]	466.5[b]	503.5[a]	508[a]	13.1	***
CP	41.3[d]	91.2[c]	123.4[b]	137.5[a]	7.71	***
NDF	297[b]	319.9[a]	327.7[a]	320[a]	3.8	*
ADF	177.3[c]	202.4[b]	220.9[a]	200.6[b]	3.6	***
SR		0.42[b]	0.43[b]	0.48[a]	0.04	***

[a,-c]=means within rows having different superscript are significantly different *** P < 0.001; * P<0.05; **P<0.01. OMI=organic matter intake; NDF=neutral detergent fiber intake; ADF=acid detergent fiber; CP=crude protein intake;; SEM=standard error mean; SL=significant level. T1= hay; T2= hay + 300 g roasted coarsely ground lupin grain; T3=hay + 300 g roasted soaked lupin grain; T4= hay + 300g dm roasted soaked and coarsely ground lupin grain; SR= substitution rate

Digestibility

The apparent digestibility of different nutrients for the experimental animals fed on a basal diet of hay and supplemented with different forms of processed lupin grain is given in Table 4. The digestibility of DM, OM and CP were significantly higher (P< 0.05) for sheep in the supplemented treatments (T_2-T_4) compared to the control (T_1). There was no significant difference (P>0.05) in apparent digestibility of NDF among all the treatments used. Similar to the results of this study, Gebru (2009) reported that no significant difference in apparent digestibility of NDF was observed between supplemented and non-supplemented groups in Washera sheep fed hay basal diet and supplemented with 300 g DM/day of raw, raw soaked, raw soaked dehulled, roasted and raw soaked lupin grains. However, there was no significant difference in OM digestibility among the different forms of supplementation. Tesfaye and Solomon (2009) also reported that Afar rams fed teff straw supplemented with concentrate mix had significantly higher digestibility of DM than the control ones.

Table 4. Apparent digestibility coefficients of nutrient in Washera sheep fed on hay and supplemented with different forms of processed lupin grain.

Nutrients	Digestibility Coefficient					
	T1	T2	T3	T4	SEM	SL
DM	0.62^{b}	0.69^{a}	0.69^{a}	0.69^{a}	0 .0076	***
OM	0.64^{b}	0.70^{a}	0.71^{a}	0.70^{a}	0 .0075	***
CP	0.77^{c}	0.81^{b}	0.87^{a}	0.89^{a}	0.053	***
NDF	0.63	0.65	0.66	0.65	0 .0062	Ns
ADF	0.59^{b}	0.64^{a}	0.65^{a}	0.63^{ab}	0 .0075	**

$^{a-d}$ Means with different superscripts in row are significantly different; (***) = P<0.001; (**) = P<0.01; (*) =P<0.05 DM=dry matter; OM=organic matter; NDF= neutral detergent fiber; ADF=acid detergent fiber; CP=crude protein. T1= hay; T2= hay + 300 g roasted coarsely ground lupin grain; T3=hay + 300 g roasted soaked lupin grain; T4= hay + 300g dm roasted soaked and coarsely ground lupin grain

Contrary to the present study Solomon et al (2004) reported that mixtures of multipurpose trees supplemented to Menz sheep fed on tef straw did not improve the digestibility of DM. The DM digestibility of hay used in the current study is higher than 48.17% observed by Abebaw (2007) and 52.84% by Fentie (2007) for Farta sheep fed basal diet of hay and supplemented with concentrate supplements. Contrary to the current findings, Simachew (2009) reported higher OM digestibility (0.90-0.92) for Washera sheep fed on grass hay and supplemented with maize bran, noug seed cake and their mixtures at different proportions. In the present study it was observed that supplementation improved CP digestibility. The CP digestibility coefficient of the current study was higher in the order $T_4>T_3>T_2>T_1$. This indicates that concentrate supplementation significantly improved (P<0.05) CP digestion better than the control. Among the different forms of lupin supplementation, there was significantly higher (P<0.05) CP digestibility for roasted soaked and coarsely ground lupin grain(T_4), which might be due to the fact that grinding of the grain increases the nutrient digestibility by reducing the feed particle size and increasing the surface area of exposure to rumen microbes. Comparable to the present finding, Simachew (2009) reported CP digestibility of 90-96% in Washera sheep fed on grass hay and supplemented with maize bran, noug seed cake and their mixtures at different proportions. Gebru (2009) also reported CP digestibility in Washera sheep fed on Rhodes grass hay and supplemented with raw, raw soaked dehulled, roasted and raw soaked lupin grains respectively as 85%, 89%, 84% and 86%. Allan and Booth (2004) also reported the apparent crude protein digestibility coefficient of lupin grain as 0.91. The lower CP apparent digestibility for control treatment might be due to inadequate CP intake of sheep from the basal diet and the higher digestibility of CP in supplemented animals compared to non-supplemented ones could also be due to higher supply of dietary CP in the former. The result of the current study showed that as the grain processed further, so the apparent digestibility of crude protein. The increase in digestibility of nutrients for supplemented groups than the control ones was also observed by different researchers (Mulu 2005; Abebaw and Fentie 2007; Jemberu 2008 and Emebet 2008).

Body Weight Gain and Feed Conversion Efficiency

Mean initial and final body weight, average daily gain (ADG) and feed conversion efficiency (FCE) of the experimental sheep fed on the different treatment feeds are presented in Table 5. Supplemented sheep gained higher (P<0.05) body weight as compared to the non- supplemented ones. This was in agreement with Gatenby (1986) who reported that supplements improve animal performance through providing essential nutrients and enhancing the microorganism activity in the rumen. The increased body weight gain and average daily gain in animals supplemented with T_2, T_3 and T_4 might be explained by the higher total DM and CP intake. Meanwhile sheep fed on the basal diet only maintained weight and even showed slight gain indicating that the nutrients supplied might have enabled them to maintain their body weight. The result in the present experiment showed a positive effect of supplementation which is in agreement with many previous similar works (Mulu 2005; Almaz 2008 and Simachew 2009).Average daily gain was significantly different (P<0.05) among the supplement treatments. Thus sheep in T_4 had significantly higher (P<0.05) ADG and weight change followed by T_3 and T_2. Significantly higher(P<0.05) ADG and body weight changes recorded in sheep supplemented with roasted soaked and coarsely ground lupin grain (T_4) which might be due to the fact that this form of processing improves the digestibility and nutrient utilization than other forms of the grain. Comparable to the present finding, Hirut (2008) reported 32.2, 54.4 and 63.3g/day body weight gains for Hararghe highland sheep fed maize stover and supplemented respectively with 150, 250 and 350 grams of concentrate mix (peanut cake, breweries dried grain and wheat bran at a ratio of 1:1:3). Ermias (2008) also reported 55.5 g/day body weight gains of Arsi-Bale sheep fed faba bean haulms and supplemented with 300 gram barley bran. Rodehutscord et al

(1999) reported 56 g/day body weight gain for sheep supplemented with heat treated lupin grain. Body weight gains of sheep in this study was higher than 16.4, 21.8, 25.3 and 19.6 g/ day reported by Gebru (2009) for the same sheep breed fed on Rhodes grass hay and supplemented with 300 g/day raw, soaked de-hulled, roasted and raw soaked lupin grains respectively. This might be due to that the processing methods employed here increases the palatability of the grain, feed intake, digestibility and nutrient utilization which in turn brings higher average daily body weight gain. The result of the current study also revealed that as the grain processed further, the daily body weight changes of sheep increases. The body weight gain of sheep in the present study were also higher than the body weight gained (23.2-23.5 g/day) reported by Fentie (2007) on Farta sheep fed on hay and supplemented with noug seed cake (*Guizotia abyssinica)*, wheat bran and their mixtures. Lower mean average daily gain (25 and 27 g/day) than the present study was also reported by Field et *al*. (2000) for Merino weaner sheep supplemented with crushed and whole lupin seed gains, respectively. On the other hand, Bimrew (2008) reported an average daily body weight gain of 72.2 g/day for Farta sheep fed on hay and supplemented with 400 gram noug seed cake and wheat bran mixture. A higher mean average daily gain (104.11, 94.89 and 94.22 g/d) than the current study was also reported by Abebaw (2007) on Arsi-Bale Sheep fed hay and supplementation with linseed (*Linum usitatissimum)* cake, wheat bran and their mixtures which might be due to the higher supplement dry matter and CP intake than the current findings.

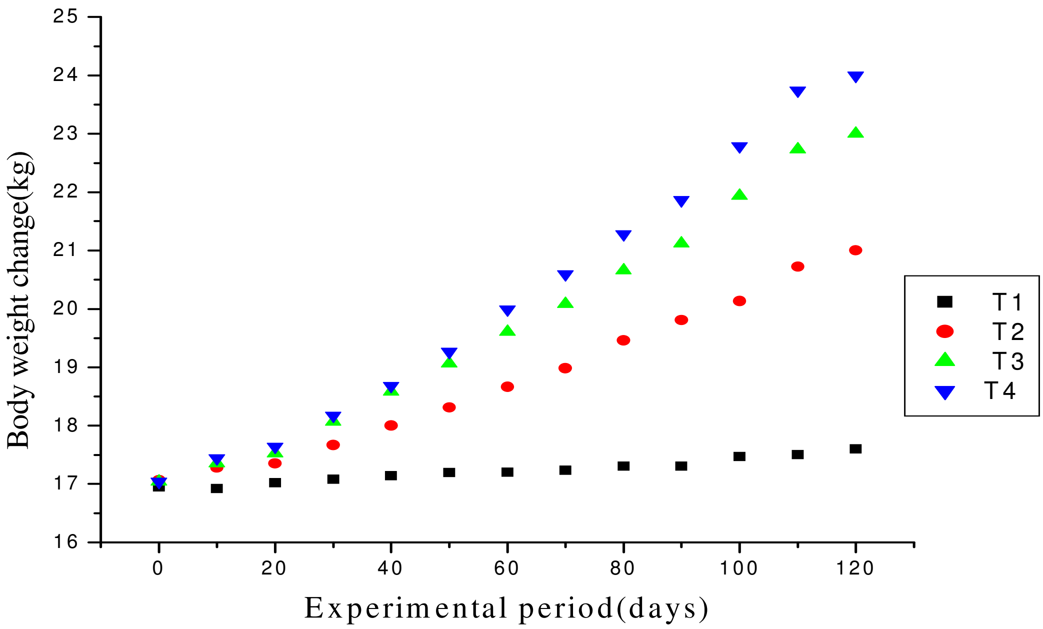
Table 7. Body weight change of Washera sheep fed on grass hay and supplemented with different forms of processed lupin grain.

Parameters	Treatment					
	T1	T2	T3	T4	SEM	SL
IBW(kg)	16.95	17.067	17.04	17.04	0.66	Ns
FBW(kg)	17.5^{d}	20.1^{c}	21.9^{b}	22.8^{a}	0.48	***
ADG(g)	5.7^{d}	34.1^{c}	54.3^{b}	63.7^{a}	4.77	***
Weight Change(kg)	0.52^{d}	3.1^{c}	4.9^{b}	5.7^{a}	4.42	***
FCE(gBWG/gDMI)	0.0094^{d}	0.047^{c}	0.071^{b}	0.083^{a}	0.0060	***

$^{a\text{-}d}$ Means with different superscript in the row are different P<0.05 (*) ;p<0.01(**); p<0.001(***);IBW=initial body weight; FBW=final body weight; FCR=feed conversion ratio; SEM= standard error of mean; SL=significance level; T1=control (sole hay); T2=hay+ 300 g roasted coarsely ground lupin; T3=hay +300 g roasted soaked lupin; T4=hay+ 300 g roasted soaked and coarsely ground lupin grain.

Supplemented sheep had significantly higher (P<0.05) feed conversion efficiency than the non-supplemented ones. Among supplemented sheep, feed conversion efficiency was significantly higher (P<0.05) in sheep supplemented with T_4 which had high daily body weight gain than others. This showed that further processing of the grain (roasting/soaking in water and grinding) allows the sheep to utilize nutrients in the feed effectively as compared to other forms of the grain. The low level of feed conversion efficiency observed in the non-supplemented sheep in the current study might be due to the result of the low nutrient intake since the basal diet hay had high fiber and low CP content.

Trends of body weight change across the feeding period for Washera sheep fed grass hay supplemented with different forms of processed lupin grain is presented in Figure 1. Body weight change of experimental sheep in the current study continued in an increasing trend throughout the experimental period. Sheep in T4 had higher body weight increment trend than sheep in all other treatments. In general, the daily body weight change of sheep in the current study showed increasing trend with the further processing of supplement feed.



T_1=Hay alone; T_2= hay+ roasted and coarsely ground lupin grain; T_3= hay+ roasted soaked Lupin grain; T_4= hay+ roasted soaked and coarsely ground lupin grain.

Figure 11.Trends in body weight change of Washera sheep fed on hay and supplemented with different forms of processed lupin grain.

Carcass evaluation

Mean slaughter weight (SW), empty body weight (EBW), hot carcass weight (HCW), dressing percentage and rib-eye muscle area (REMA) of Washera sheep fed grass hay and supplemented with different forms of processed lupin grain are presented in Table 6.

The growth and carcass traits can be affected by many factors such as nutrition, age, sex, genetics, season and other related factors should be considered (McDonald et al 2002). Dressing percentage is both a yield and value determining factor, and is therefore, an important parameter in assessing performance of meat producing animals (Massae and Mtenga 1990). There was significant difference ($P<0.05$) between supplemented and non-supplemented sheep in slaughter, empty body and hot carcass weights. Sheep supplemented with T_4 were significantly higher ($P<0.05$) in SBW, EBW and HCW than those supplemented with T3 and T2. This might be explained by the processing methods employed in T_4 (roasting followed by soaking in water and grinding), which have created a positive effect on feed intake, digestibility, nutrient utilization and there by better performance of sheep in weight gain and carcass parameters as compared to other forms of processing. Lack of significance difference in dressing percentage (empty body weight base) between T_3 and T_4 and between the control treatment (T_1) and T_2 in the present study may be due to variation of the gut content. Dressing percentage values on the empty body weight basis were higher than on slaughter weight basis indicating the influence of digesta (gut fill) on dressing percentage. As opposed to the current findings, various studies reported dressing percentages calculated on empty body weight basis as having no significant difference between supplemented and non-supplemented animals (Simret 2005; Abebe 2008; Wondwosen 2008). The current result clearly showed that supplementation had a positive effect on hot carcass, empty body weight and dressing percentage (slaughter weight basis). Comparable with this study, Abebe (2008) reported dressing percentages (slaughter weight base) in the range of 38.44-45.06 for Arsi-Bale sheep fed on hay and supplemented with linseed cake, wheat bran and their mixtures at different proportions. On the other hand, research conducted on Australian lambs fed on lupins, canola meal and urea as protein sources showed no significant differences in carcass weight, rib- eye muscle area and dressing percentage among the treatments (Wiese et al 2003). In agreement with the current result, Amare (2007) reported dressing percentages of Tigray Highland sheep fed on cactus-tef straw based diet and supplemented with cotton seed cake, noug cake or peanut cake in the range of 42.47- 48.55(slaughter weight base) and 53.25-57.28 (empty body weight base). Mulu (2005) reported dressing percentage(slaughter weight base) of 27, 36, 37.8 and 38% for Wogera sheep fed on basal diet of grass hay and supplemented with graded level of brewers dried grain (0, 100, 200 and 300 g). The dressing percentage in this experiment was increased as slaughter weight increased.

Table 8. Carcass parameters of Washera sheep fed on grass hay and supplemented with different forms of processed lupin grain.

Parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Slaughter weight (kg)	17.14^{d}	19.86^{c}	21.64^{b}	22.44^{a}	0.48	***
Empty body weight (kg)	12.66^{d}	15.9^{c}	17.34^{b}	18.73^{a}	0.55	***
Hot carcass weight (kg)	5.6^{d}	7.1^{c}	10^{b}	10.92^{a}	0.49	***
Dressing Percentages						
Slaughter weight basis	32.73^{d}	35.53^{c}	46.09^{b}	48.51^{a}	0.015	***
Empty body weight basis	44.34^{b}	44.404^{b}	57.57^{a}	58.20^{a}	0.015	***
REMA(cm^2)	7.43^{c}	9.07^{b}	9.8^{a}	10.27^{a}	0.26	***

$^{a-d}$ Means with different superscripts in row are significantly different (P<0.05); REMA (cm^2)=Rib-eye muscle area in cm^2 ; SEM =standard error of mean ; S.L = significant level; T1=Hay alone; T2= roasted and coarsely ground lupin grain; T3= roasted soaked Lupin grain; T4= roasted soaked and coarsely ground lupin grain.

The larger (P<0.05) rib-eye muscle area was obtained in supplemented sheep than the non-supplemented sheep. There were also treatment differences among the supplemented sheep. Sheep in Treatments, T3 and T4 had higher rib-eye muscle area as compared to other treatments. This might be due to the efficient utilization of feeds offered in the sheep supplemented with roasted soaked (T_3) and roasted soaked and coarsely ground (T_4) lupin grains. No significant (P<0.05) difference in rib-eye muscle area was observed between T_3 and T_4. Lower (P<0.05) rib-eye muscle area recorded in non-supplemented sheep probably be due to the lower CP and higher NDF value of the hay. Comparable to the results of the present study, Emebet (2008) reported rib-eye muscle area of 8.8 – 10.4 cm^2 for Blackhead Ogden Sheep fed haricot bean haulms alone or supplemented with different proportion of wheat bran and brewers dried grain. The current findings on rib-eye muscle area were lower than 13-19.5 cm^2 reported by Mulu (2005) for Wogera sheep fed on natural grass hay and supplemented with graded level of breweries dried grain. Contrary to this, Hararghe Highland sheep fed urea treated maize stover and supplemented with concentrate mix had rib-eye muscle area of 7-8.4 cm^2 (Hirut 2008). Tesfaye (2007) also reported that Afar rams supplemented with 150 g, 250 g and 350 g concentrate mix and weighing 21.5 kg, 24.1 kg and 23.7 kg had rib-eye muscle area of 7.97 cm^2, 9.38 cm^2 and 8.15 cm^2, respectively. Various studies showed that supplementation had significant and positive effect on rib-eye muscle area (Matiwos 2007; Abebe 2008; Wondwosen 2008).

Non-edible offals

Non-edible offals of Washera sheep fed on a basal diet of hay and supplemented with different forms of processed lupin grain are given in Tables 7 and 8. Carcass offal components were categorized into edible and non- edible based on tradition and culture of the people in the study area. Heart, liver, kidney, empty gut, visceral and kidney fat, tongue and tail were considered as edible offals. Blood, gut content, spleen, testicles and penis, skin-feet and head without tongue were categorized as non-edible offals.

Edible offal components

Higher weight of omasum-abomasum, small and large intestines, reticulo-rumen, liver, heart and tail were recorded in T_4 followed by T_3. Kidney and visceral fats were also significantly (p<0.05) higher for supplemented sheep than non-supplemented sheep. This may be due to the fact that supplement feed had more energy content and promoted higher internal fat deposition, whereas animals fed on hay alone did not get adequate energy even to deposit fat. Similarly, it has been demonstrated that, Arsi-Bale sheep fed on hay and supplemented with linseed cake, wheat bran and their mixtures at different proportion had gained heavier weight of visceral fat and kidney fat (Abebe 2006).

Table 9. Response to supplementation with different forms of processed lupin grain on total edible carcass offals of washera sheep fed on a basal diet of hay.

Edible offals	Treatments					
	T_1	T_2	T_3	T_4	SEM	SL
Liver	307.5^d	383.5^c	398.667^b	418.83^a	9.11	***
Kidney	60.167^c	86.5^b	102.75^a	103.58^a	3.79	***
Heart	72.33^d	83.5^c	96.0^b	103.5^a	2.61	***
Tongue	79.33^b	83.33^b	95.083^a	100.292^a	2.18	**
K-fat	32.5^d	72.17^c	79.83^b	95.92^a	4.96	***
V-fat	48^d	96.83^c	115.83^b	125.67^a	6.39	***
SLI	540.17^d	668.50^c	740.67^b	785.33^a	21.14	***
R-Rumen	426.8^d	487^c	542.83^b	550.75^a	10.86	***
Omas-abom	169.83^d	192.17^c	209.25^b	226.17a	4.54	***
Tail	332.50^d	537.67^c	650^b	745.17^a	32.90	***
TEOC	2069.17^d	2691.17^c	3030.92^b	3255.21^a	94.57	***

[a-d] Means in the same row with different superscripts differ significantly; SL: significant level; SEM: standard error of mean; TEOC: total edible offal component; T_1= hay *ad libitum*; T_2= hay *ad libitum* + 300 g Roasted coarsely ground lupin; T_3= hay *ad libitum* + 300 g DM roasted soaked lupin; T_4= hay *ad libitum* + 300 g roasted soaked coarsely ground lupin. K-fat= kidney fat; V-fat= visceral fat; SLI= small and large intestine;R-rumen=reticulo-rumen; Omas-abom=Omasum & abomasums;TEOC= total edible offal component.

Weight of empty gut (small and large intestines, reticulo-rumen and omasum-abomasum) was significantly higher for supplemented sheep as compared to non-supplemented sheep, which was in agreement with the findings of different authors (Mulu, 2005; Abebe 2006; Amare 2007; Hirut 2008). Tail weight showed a significant ($p<0.05$) difference among treatments and it was in an increasing order of $T_1<T_2<T_3<T_4$. There was a significant ($p<0.05$) difference in total edible offal components (TEOC) among the treatments. T_4 had significantly higher TEOCs than all other treatments followed by T_3 and T_2.

Non-edible offal components

The gut fill in the present findings shows significantly ($P< 0.05$) higher weight for the sheep in non-supplemented group than sheep in T_2, T_3 and T_4. There was also significant ($P< 0.05$) difference among all other treatments (T_2- T_4). Animals fed on hay alone consumed more roughage in order to maintain their energy requirement, which increased the amount of digesta in the gut. The lower gut content in T_4 could be attributed to the expected higher rate of digestion and faster passage rate of the diet through the gastro intestinal tract. Emebet (2008) also reported 4800, 5200, 5000 and 53000 grams of gut fill for Blackhead Ogaden sheep fed on haricot bean (*Phaseolus vulgaris*) haulms and supplemented with mixtures of wheat bran and brewers dried grain. However, non significant differences in gut fill (4820, 5080, 4840, 4860 and 5540 g/head) were observed for Arsi-Bale sheep fed faba bean haulms and supplemented with linseed meal, barley bran and their mixtures (Ermias, 2008). Head without tongue, skin and feet, blood and testicles ($P<0.05$) were lower for non supplemented sheep than supplemented sheep. In addition to this, T4 resulted in higher weight of blood and testicles ($P<0.05$) than T_3 and T_2. No statistical difference were observed between T_3 and T_4 regarding the weight of head without tongue, lung with trachea and esophagus, spleen and penis. All supplemented sheep had larger ($P<0.05$) size of testicles, lower percentage ($P<0.05$) of total non edible offals (TNEO) and higher percent of total edible offals compared to the non-supplemented animals. The weight of testicles in the current finding was lower than 118.5-273.0 g reported by Abebe (2006) for Arsi-Bale Sheep supplemented with linseed (*linum usitatissimum)* cake, wheat bran and their mixtures.

Table 10.Effect of supplementation with different forms of processed lupin grain on total non-edible carcass offals of Washera sheep fed on a basal diet of hay.

Non-edible offals	Treatments					
	T_1	T_2	T_3	T_4	SEM	SL
Head	761.17^c	829.33^b	873.17^a	880.17^a	11.61	***
Skin and feet	1549^d	1816.33^c	1995^b	2149^a	50.11	***
Penis	47.83^b	52.33^b	56^{ab}	65.50^a	2.34	*
Testicles	132.33^d	180.6^c	233.62^b	244.8^a	9.44	***
LTE	304.17^c	328^{bc}	338.67^{ab}	368.17^a	6.34	**
Gut fill	5340^a	4218.17^b	3994.33^c	3514.17^d	145.47	***
Blood	702.33^d	795.5^c	871.33^b	887.67^a	19.34	***
Spleen	42^c	51^{bc}	53.83^{ab}	62.67^a	2.26	**
TNEOC	8879.4^a	8271.3^{bc}	8416^b	8172.1^c	72.29	***

[a-d] Means in the same row with different superscript differ significantly *** P < 0.001; * P<0.05; **P<0.01; SEM=standard error of mean; SL=significance level. T1= hay *ad libitum*; T2= hay *ad libitum* + 300 g Roasted coarsely ground lupin; T3= hay *ad libitum* + 300 g DM roasted soaked lupin; T4= hay *ad libitum* + 300 g roasted soaked coarsely ground lupin.LTE=lung trachea and esophagus; TNEOC= total non-edible offal components.

Contrary to the findings of Simret (2005) and Matiwos (2007), who reported none significant effect of supplementation, the current study showed positive effect of supplementation on the weight of lung with trachea and esophagus and penis. Skin and feet weight of the non-supplement sheep was lower (P<0.05) than the supplemented treatments. For the same parameter, significant differences (P<0.05) were observed among T_2, T_3 and T_4. Sheep in T_4 had also significantly higher Skin and feet weight than T_2 and T_3 which was attributed to the processing methods employed on lupin grain in T_4. In contrast to the current study, Mulu (2005) and Abebe (2008) reported higher skin and feet weights.

Correlation among Feed Intake, Digestibility, Body Weight Change and Carcass Parameters

Results of correlation among feed dry matter intake, digestibility and body weight change are presented in Table 9. The total DM intake was positively correlated (P<0.05) with CP intake and CP digestibility (P<0.05) of the experimental diets. The positive associations among these parameters reflect the improved fermentation and passage rate which leads to improved intake as the result of dietary treatment. Solomon *et al.* (2003) reported that increased CP intake resulted in increased CP digestibility which had a positive association with body weight gain. Tesfaye (2008) also reported that DM intake was positively associated (P<0.05) with EBW, HCW, TEOCs and TNEO. Organic matter intake was strongly and positively associated (P<0.05) with DM intake, CP intake, average daily body weight gain, empty body weight, hot carcass weight and TEOC. Dry matter and crude protein intake was positively correlated (P<0.05) with body weight gain, SW, EBW, HCW and TEOCs. Therefore, nutrient intake and their digestibility are the major factors that positively affect daily body weight gain and carcass characteristics.

Table 11. Correlation between feed intake, digestibility, body weight change and carcass parameters of washera sheep fed on hay and supplemented with different forms of processed lupin grain

Parameters	TDMI	DCDM	TOMI	DCOM	TCPI	DCCP	BWG	SW	EBW	HCW	TEOC	TNEOC
TDMI	1											
DCDM	0.84***	1										
TOMI	0.99***	0.82***	1									
DCOM	0.85***	0.99***	0.84***	1								
TCPI	0.98***	0.79***	0.99***	0.81***	1							
DCCP	0.88***	0.76***	0.89***	0.79***	0.93***	1						
BWG	0.93***	0.69**	0.94***	0.72***	0.96***	0.93***	1					
SW	0.85***	0.58**	0.85***	0.61**	0.87***	0.86***	0.94***	1				
EBW	0.83***	0.56**	0.83***	0.59**	0.85***	0.84***	0.90***	0.98***	1			
HCW	0.80***	0.53**	0.82***	0.58**	0.87***	0.88***	0.92***	0.96***	0.94***	1		
TEOC	0.95***	0.74***	0.96***	0.76***	0.98***	0.95***	0.97***	0.91***	0.90***	0.91***	1	
TNEOC	0.71***	-0.61**	-0.69**	-0.61**	-0.68**	-0.65**	-0.64**	-0.51*	-0.52**	-0.48*	-0.68**	1

*= ($P<0.05$);** = ($P<0.01$);***= ($P<0.001$); ADG= average daily gain; CPD= crude protein digestibility; DCDM= digestibility coefficient of dry matter; DCCP= digestibility coefficient crude protein; DCOM= digestibility coefficient organic matter EBW= empty body weight; HCW= hot carcass weight; ns= non significant, TCPI= total crude protein intake; TDMI= total dry matter intake; TOMI= Total organic matter intake; ADG= Average daily gain;TEOC = total edible offal component; TNEOC= total non edible offal components

Partial Budget Analysis

Partial budget analysis of Washera sheep fed on hay basal diet and supplemented with different forms of processed lupin grain is given in Table 10. Partial budget analysis was used to evaluate the economic advantage of different forms of supplement feeds. It involves tabulating the costs and benefits of small change in the farm practice. Partial budget analysis of the present study showed that net return per animal was higher for the supplemented sheep than non-supplemented ones.

Compared with T_3 and T_4, sheep in T_2 gained lower BW as a result of lower nutrient intake that consequently resulted in lower net return. Among the treatments, T_4 was found to be more profitable considering the net return. The net return from the supplemented treatments was 29.3, 66.7 and 107.9 ETB/head. In this study, supplementation with T_4 improved body weight change of sheep and correspondingly increased the net income from the sale of sheep at the end of the feeding trial. The marginal rate of return (%MRR) for supplemented sheep in T_2, T_3 and T_4 was 60, 173.5 and 253.4, respectively. This indicates that to attain required BW by supplement feeding, each additional unit of 1 ETB increment per sheep to purchase supplement feed resulted in a profit of 0.6, 1.74 and 2.5 for sheep in T_2, T_3 and T_4, respectively.

As can be observed from the results of feed intake, digestibility, and body weight change and feed conversion efficiency in the present study, sheep were affected by the methods of processing of the feed in the supplemented treatments, which in turn affected the net return per sheep. The net return for T_3 was higher than the net return for T_2. The difference in the net return between T_3 and T_2 was attributed to the difference in BW change of sheep which intern was due to the processing methods employed in each treatment. Generally, sheep which had a better nutrient intake had superior average body weight gain and had a higher sale price to earn higher net return. Hence, in the present study, it can be concluded that processing lupin grain (roasting followed by soaking in water and grinding) improves nutrient utilization, reduced cost of body weight gain and maximized economic returns from feeding of sheep.

Table 12. Partial budget and marginal rate of return analysis for Washera sheep supplemented with different forms of processed lupin grain on hay based feeding.

Parameters	Treatments			
	T1	T2	T3	T4
Purchase price of sheep(ETB/head)	210	210.7	211	210.5
Total hay consumed(kg/head)	54.7	46.76	43.99	41.79
Feed Cost for hay(ETB/head)	32	28	26.4	25
Total concentrate consumed(kg/head)	0	18.84	24.8	27
Cost for concentrates (ETB/head)	0	32	44.7	48.6
Cost of feed(ETB/Kg)	0.75	1.7	1.8	1.85
Total feed cost(ETB/head)	32	60	69.3	73.6
Gross weight gain (kg/head)	0.5	3	4.9	5.7
Gross income, (ETB/head)	245	290	347	392
Total return, ETB/head	35	89.3	136	181.5
Net return, ETB/head	3	29.3	66.7	107.9
ΔNR	0	17	64.7	105.4
ΔTVC	0	28	37.3	41.6
MRR (%)	0	60	173.5	253.4

ETB, Ethiopian Birr; ΔNI, change in net income; ΔTVC, change in total variable cost; MRR, marginal rate of return. T1= hay *ad libitum*; T2= hay *ad libitum* + 300 g Roasted coarsely ground lupin; T3= hay *ad libitum* + 300 g DM roasted soaked lupin; T4= hay *ad libitum* + 300 g roasted soaked coarsely ground lupin

Conclusion

Supplementation with different forms of processed lupin grain has generally a positive effect on feed intake, nutrient digestibility and carcass parameters on washera sheep. Among the different forms of processed grain supplements, roasted soaked (T3) and roasted soaked and coarsely ground (T4), reduces the bitter tasting of the grain and increases its feeding value. However, the processing method employed in T4, resulted in a significantly higher (P<0.05) intake, which intern was attributed to the higher performance of the sheep than T3.

Scope for future work

- On farm research on the supplementation effect of processed lupin grain need to be undertaken to see the supplementary effects of the grain on performance under actual farmers' conditions.
- Though lupin is an important crop for feed and food and has a potential to grow in marginal lands where other crops do not, its production is limited to some part of the country. Therefore, efforts should be done to expand cultivation of the crop in the country.
- The available varieties of the genus *Lupinus* should be studied and development of the sweet varieties of the species should be carried out.
- Lupin grain has to be evaluated as a source of protein in the diets of ruminants and monogastric animals.

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