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EFFECTS OF SUPPLEMENTATION WITH PIGEON PEA (*Cajanus cajan*), COWPEA (*Vigna unguiculata*) AND LABLAB (*Lablab purpureus*) ON FEED INTAKE, BODY WEIGHT GAIN AND CARCASS CHARACTERISTICS OF WOLLO SHEEP FED ON GRASS HAY

MSc Thesis

By

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Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Animal Production Studies

June, 2015

Bishoftu, Ethiopia

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A Thesis submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Tropical Animal Production and Health

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As members of the Examining Board of the final MSc. open defense, we certify that we have read and evaluated the Thesis prepared by **Hunegnaw Abebe** entitled **"Effects of Supplementation with Pigeon Pea (*Cajanus cajan*), Cow pea (*Vigna unguiculata*) and Lablab (*Lablab purpureus*) on Feed Intake, Body Weight Gain and Carcass Characteristics of Wollo Sheep Fed on Grass Hay"** and recommend that it be accepted as fulfilling the thesis requirement for the degree of Masters of Science in Tropical Animal Production and Health.

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STATEMENT OF THE AUTHOR

First, I declare that this thesis is my *bonafide* work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced (MSc) degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ADG	Average Daily Weight gain
ARC	Agricultural Research Council
BoARD	Bureau of Agriculture and Rural Development
BW	Body weight
$BW^{0.75}$	Metabolic body weight
CP	Crude protein
CSA	Central Statistic Authority
DAGRIS	Domestic Animal genetic Resources Information System
DM	Dry matter
EPA	Ethiopian Privatization Agency
FAO	Food and Agricultural Organization
FCE	Feed conversion efficiency
HWoARD	Habru Woreda Agriculture and Rural Development
EIAR	Ethiopian Institute of Agricultural Research
ME	Metabolisable energy
MRR	Marginal rate of return
NDF	Neutral detergent fiber
NR	Net return
OM	Organic matter
RCBD	Randomized complete block design
SAS	Statistical Analysis System
T	Treatment
TEOC	Total edible offal components
TNEOC	Total non-edible offal components
TR	Total return
TVC	Total variable cost

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ABSTRACT

An experiment was carried out using sixteen male yearling Wollo Tumele lambs with an average body weight of 18.8±0.35 kg. The objective was to investigate the effect of supplementation with pigeon pea (*Cajanus cajan*), *cow pea* (*Vigna unguiculata*) *and lablab* (*Lablab purpureus) on feed intake, body weight change and carcass parameters lambs fed a basal diet of grass hay in a study that lasted for 90 days. The treatments consisted of ad libitum feeding of natural pasture grass hay plus 200 g dry matter (DM) of wheat bran for all groups additional supplementation with 243, 260 or 225 g DM per head per day of pigeon pea, cow pea and lablab for T2, T3 and T4*, respectively. *A randomized complete block design (RCBD) was used. The experimental lambs were categorized into four blocks of four lambs based on their initial body weight and the four feed treatments were randomly assigned to each animal in a block. There were significant differences (P<0.001) in total DM, CP and NDF intakes between the control (T1) and forage legume supplemented groups (T2, T3 and T4). Grass hay intake was significantly depressed (p<0.001) as a result of forage legumes supplementation. Lambs in the control consumed more DM of grass hay as compared to the legume supplemented groups*. S*ignificantly (P<0.001) higher average daily weight gain of 49.36 g/d recorded in lambs supplemented with wheat bran (200 g/d) and lablab (225 g/d). A positive average daily gain (3.1 g/d) was obtained in lambs that received control diet. Feed conversion efficiency (FCE) was higher (P<0.001) in forage legumes supplemented lambs compared to the control lambs.* The *smallest hot carcass weight (5.08 kg) was recorded for lambs on the control treatment, whereas the highest hot carcass weight (9.60 kg) was recorded for lambs in the group supplemented with lablab (T4). Dressing percentage on slaughter weight (SW) base was significantly higher (P<0.001) in supplemented lambs than the control group. A significantly higher dressed carcass weight (P<0.001) was achieved in forage legumes supplemented lambs compared to the control. A significantly higher (P<0.001) rib eye muscle area was observed in supplemented lambs compared to the control. When the forage legumes protein supplements were ranked based on CP, average daily gain (ADG) and FCE, it was concluded that supplementation of lablab under the feeding condition resulted in the best live weight gain, nutrient intake, carcass traits and economic return of feeding Wollo Tumele lambs.*

Keywords, **Body weight, cowpea, carcass, feed intake, lablab, pigeon pea, supplementation, Wollo *Tumele* lambs**

1. INTRODUCTION

Ethiopia has one of the largest livestock inventories in Africa with a national herd size estimated at 49.2 million cattle, 46.8 million small ruminants, and 9 million pack animals. Livestock currently support and sustain livelihoods for 80% of all rural poor (MoARD, 2007). Although there exist 25.97 million heads of sheep in Ethiopia, the production and productivity is very low, as expressed by annual population growth rate of 1% and off-take rate of 35% (CSA, 2010). The same source indicated that the average daily growth rate of indigenous meat sheep is 50 g, while the average carcass yield is 10 kg per animal. The low performance of local sheep in terms of body weight gain and carcass yield is mainly due to inadequate nutrition (Betsha, 2005) associated with reliance on sole natural pasture, crop residues and/or stubble grazing, which are inherently low in nutrients (Solomon *et al*., 2008). Temporally abundance of forage during short rainy season is followed by long dry periods with feed deficit leading to a cycle of live weight gain and loss of animals. Thus, sheep often take longer period to attain market weight, lowering its production efficiency.

Due to seasonal changes, there is serious shortage of feedstuffs that result in the fluctuation of animal production and therefore many farmers in Ethiopia feed their livestock with crop residues, mainly various straws. However, the use of such straw has limitations due to their low nutritive value indicated by their high cellulose, hemi-cellulose and lignin contents, and their low protein content and digestibility. Also, tropical grasses are usually deficient in crude protein (CP). As a result, high levels of production cannot be obtained only from such feeds that hardly meet even the maintenance requirement of animals, particularly during dry season.

On the other hand, the present export market (to the Middle East countries) for Ethiopian live sheep and mutton demands animals weighing between 25 and 30 kg at yearling age. However, under traditional farmers' management system, most local sheep slaughtered at this age weigh between 18 to 20 kg (IAR, 1991), due to mainly low quality and quantity of feeds that are considered to be the major constraints hampering productivity of small ruminants. Thus, lack of consistent supply of sheep at the required body weight and age has remained a major challenge for mutton and live sheep exporters.

Supplementation with palatable feed resources, mainly agro-industrial by-products has been used in many developed countries for improving locally available nutrients of feed resources (Xianjun *et al*., 2012). Supplementing protein source concentrates and/or agro-industrial by products to low-quality tropical grass hay is known to improve intake and digestibility of roughages (Nurfeta, 2010).

However, the use of such protein supplements is limited under smallholder livestock production systems due to the availability and high cost. Consequently, there is limited prospect for using agro-industrial by product protein source supplements such as oil seedcakes as livestock feed by smallholder farmers. In order to mitigate the problems associated with the lack of protein supplements due to reasons of availability and high cost, there is a need to look for alternative protein sources such as supplementation with forage legumes that farmers can produce at their own farms. Among the forage legumes, pigeon pea (*Cajanus cajan*), cow pea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) could be easily grown at farmers levels and play an important role in supplementing diets of growing lambs as alternative to oil seedcake supplements.

These forage legumes can improve the growth performance of young ruminant animals on fibrous diets through the provision of more nutrients and optimization of fermentative digestion in the rumen. The growth performance of animals on poor-quality roughage can vary with the protein source. The factors responsible for variations in animal response may include solubility, rate and extent of degradability of protein in the rumen (McDonald *et al*., 2002). There is a considerable interest in protein sources that are slowly degraded in the rumen. These relatively resistant protein sources (RUP) or intestinal digestion can have special value for young growing ruminants whose protein requirements are relatively high (Tamminga, 1979). On the other hand, dietary protein consumed by ruminants that is degraded in the rumen (RDP) is available for use by the rumen microbes to make microbial protein (McDonald *et al*., 2002). When formulating diets for ruminants, various criteria can be used to select the protein supplements including palatability, ruminal protein degradability, protein quality, intestinal absorption of amino acids and impact on animal performance (ARC, 1980).

This implies that among other things, it is important to supplement growing sheep with an appropriate protein source in order to increase the efficiency of growth to the desired market weight so that the economic benefit of sheep production can be enhanced. This study was designed to assess the effects of supplementing pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) hay on performance of lambs with the following specific objectives.

- To evaluate the effect of supplementation with pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) hay on feed intake, body weight gain and carcass characteristics of Wollo *Tumele* sheep fed grass hay basal diet with wheat bran, and
- To assess the economic feasibility of supplementation of the candidate forage legumes to grass hay based diets for mutton production.

2. LITERATURE REVIEW

2.1. Status and Role of Sheep Production in Ethiopia

In Ethiopia, sheep are reared mainly by smallholder farmers and grazed in small flocks on open natural pasture (CSA, 2004). Ethiopia's sheep population is estimated at 26.12 million (CSA, 2008). This is the third largest in Africa (FAO, 2004) with more than 18 breed types (DAGRIS, 2004). The diverse sheep genetic resource is distributed in the highland and lowland areas. The production potential of different indigenous sheep breeds has not been properly studied. However, from the available limited information, indigenous sheep breeds have small body size, produce low quality wool, and have low lamb growth rate and quite high lamb mortality (Markos *et al.,* 2006).

The annual off take rate of sheep flock in Ethiopia is estimated to be 33% (EPA, 2002), with an average weight of about 10 kg (FAO, 2001; CSA, 2004) which is the second lowest in Sub Saharan Africa. Awet (2007), Mulu *et al.* (2008), Abebe (2008) and Tesfay and Solomon (2008) reported carcass yield of 9.7, 9.6, 10.8 and 9.6 kg in different indigenous breeds of sheep on different types of feeds, respectively. It has been estimated that most of the local sheep breeds have a very low post weaning average body weight of 15-20 kg (Kasahun, 2000). This shows that there is scope for improvement through management practice such as improved feeding and veterinary service.

Even if, the productivity of indigenous breeds is low compared with temperate breeds, their ability to survive and produce in the harsh and mostly unpredictable tropical environment is remarkable. In mixed crop-livestock system, sheep represents less than 10% of farm capital invested in livestock, yet contribute as much as 23-63% to the net cash income and 19-23% to the food subsistence value derived from livestock production (Zelalem and Fletcher, 1991). The total mutton produced in the country is 551,000 metric tons and small ruminant meat export from Ethiopia is 21,000 metric tons (FAO, 2006). Small ruminants are useful to rural households during periods of cyclical and unpredictable food shortages. The small size and early maturity of sheep give them several distinct economic advantages in smallholder farming situations, such as that found in Ethiopia. They can efficiently utilize marginal and small plots of land; the risk on investment is reduced by smaller individual size, allowing more production units per unit of investment; and there is a faster turnover of capital because they mature early and younger at slaughter (Chipman, 2003). Smaller weight of carcasses is also easier to market and can be consumed in a short period of time in situations that allow less opportunity for preservation. This is important as most rural areas lack proper storage facilities.

2.2. Feed Resources

In the commonly found mixed crop livestock farming system as in the highlands of Ethiopia, the feed resources available depend on the type and manner of crop production. In such areas, the major available feed resources are natural pasture, crop residues and crop aftermaths (Solomon *et al*., 2008). Crop residues are fibrous materials that are by-products of crop cultivation. Crop residues have low crude protein content in the range of 3–13% of the dry matter. This is a basic limitation in residues such as straw and bagasse with crude protein contents around the border-line level of 6–7% required to create an appropriate rumen environment to promote dry matter digestibility and intake. Most residues are deficient in fermentable energy and minerals.

To some extent agro-industrial by-products and cultivated improved forage crops are also used. However, natural pasture does not fulfill the nutritional requirement of animals, particularly in the dry season, due to poor management and inherent low productivity and poor quality (Alemayhu, 2003). The same source indicated that crop residues which are the major livestock feeds, particularly in the dry seasons provide 40 to 50% of the total annual livestock feed. A survey conducted in 56 districts of Amhara Regional State showed that feeds obtained from grazing land were inadequate for livestock in the region both in quantity and quality during wet and dry seasons of the year (Fentie and Solomon, 2008).

Among feed resources, hay is forage harvested during the growing period and preserved by drying. The aim of hay making is to reduce the moisture contents of green crops to 15-20% to inhibit the action of plant and microbial enzymes (Banerjee, 1998). Despite its several advantages, hay has some shortcomings. It varies in nutrient content and palatability more than any other feed, late hay harvest affects its quality (Ensiminger *et al*., 1990). This level of CP content reduces feed intake and affects digestibility (Kidane, 1993). Feeds low in digestible protein such as mature dry native grasses require supplementation with some kind of nitrogenous feed (Devendra and Mcleroy, 1982). Natural pasture would be adequate for body maintenance and weight gain during wet season, but would not support maintenance level for the rest of the year (Zinash *et al*., 1995). Similar findings were also reported by Yihalem *et al.* (2006). Maximum production cannot be achieved on hay alone. According to FAO (1997) annual and perennial grasses from natural pasture consumed during the dry season and often at late stage of maturity together with the straw and stalk from cereal crops constitute low quality forages, with high lignified cell wall and poor nitrogen.

Therefore, for reasonable level of production, animals subsisting on hay require supplementary protein, which can be obtained from different sources such as from, forage legumes, oil seed cakes or non- protein nitrogenous (NPN) and energy sources (Kabaija and Little, 1988). The quality of hay prepared varies with grass legume proportion, leaf to stem ratio and physiological development of the forage up on harvest. Mature grasses, especially those that are weather leached or bleached are low in digestible energy and protein, as well as in soluble carbohydrate, carotene and some of the minerals (Ensminger *et al*., 1990). In experiments conducted on feeding hay alone and concentrate supplementation, lambs that were fed hay alone with CP content of 3.5% lost 9 g/day (Fentie and Solomon, 2008). Similarly, Mulu *et al.* (2008) and Jemberu (2008) reported that sheep fed hay alone lost 3 g/day and 7.7 g/day, respectively with the CP content being 42 and 52 g/kg, respectively. Therefore, hay alone may not be even enough to satisfy the maintenance requirement of animals.

2.3. Role of Supplementation

According to FAO (1997), the objective of supplementation is to ensure additional supply of nutritional elements to the animals to allow them to develop target performance levels and to increase their feed intake. The purpose of supplementation is to provide rumen microorganism optimum readily degradable energy, nitrogen and/or minerals that will enhance activity of microorganisms and rumen function. Supplementation of low quality feeds with concentrates or forage legumes enhances the utilization of the basal diet, thereby improving the performance of ruminants. For instance, Washera sheep achieved weight gain in the range 25- 35.3 g/day due to supplementation with 200-400 g concentrate mix in urea treated rice straw feeding regime (Abebe, 2008). Abebaw and Solomon (2008) also reported better body weight gain for Farta sheep supplemented daily with 300 g noug seed cake, rice bran and brewery dried grain mixtures.

According to Pond *et al.* (1995), consumption of low quality roughages such as straw and poor grass hay can be increased markedly by the addition of protein supplements. Therefore, supplementation especially with protein sources is critical particularly for young, rapidly growing and lactating animals, as protein sources can determine the quantity or the quality of protein (essential amino acids) reaching the small intestine that are required for growth and milk production (McDonald *et al.*, 2002). These amino acids must come from either microbial protein synthesized in the rumen or from dietary protein that is not degraded in the rumen. Dietary protein consumed by ruminants is categorized as rumen degradable protein (RDP) or rumen un-degradable protein (RUP). The RUP has sometimes been referred to as rumen by-pass protein or simply escape protein. The RDP is available for use by the rumen microbes to make microbial protein (McDonald *et al.*, 2002).

2.3.1. Wheat bran as a supplement

The wheat grain consists of about 82 percent endosperm, 15 percent bran and 3 percent germ. In modern flour millings, the objective is to separate the endosperm from the bran and germ (McDonald *et al*., 2002). According to Lonsdale (1989), wheat bran is described as the outer fibrous layer of the grain. This separated portion predominantly consists of the husk or coarse bran and the thin paper layer from around consists the starch or fine bran. But very little starch (endosperm) is found with the bran. It is quite palatable, and is well known for its laxative characteristics because of its swelling and water holding capacity. These characteristics of wheat bran are due to its fiber and non-starch carbohydrate content (Cheeke, 1991). It consists of about 17% CP (Devendra and Meleroy, 1982) and is relatively good source of most of the water soluble vitamins except for niacin, which is entirely unavailable (Pond *et al*., 1995). It is not considered to be a suitable feed for pigs and poultry because of its high fiber content (McDonald *et al*., 2002).

Lonsdale (1989) nutritionally described wheat bran as low in density flaky ingredient which has traditionally been used to lighten meals, excellent ingredient in coarse mixes for young growing ruminants and quite palatable. The CP in wheat bran has a relatively high digestibility coefficient with degradability ranges of 0.50 to 0.70 (Lonsdale, 1989). Fiber and metabolizable energy (ME) contents vary slightly depending on variety of wheat being milled and the processing method used. Wheat bran, one of the energy sources concentrates contains linked polysaccharides. Feeds with such linkages are readily degraded in the rumen and have high levels of ME (Chesworth, 1992). According to Solomon (2001), wheat bran contained relatively lower level of CP, soluble phenolics, condensed tannins and higher neutral detergent fiber. It can increase the total DM, and the digestible organic matter when added to ruminant ration.

2.3.2. Pigeon pea (Cajanus cajan)

Pigeon pea produces forage quickly and can be used as a short-lived perennial forage crop. The leaves and young pods can be fed to the animals fresh or they can be harvested and conserved. The dried husks, cracked seeds, leaves and trash of the plant have been found to be palatable to livestock. The inclusion of trash at rates of up to 500 g/kg of the ration improves overall digestibility and intake of accompanying low quality hays in sheep (Quirk, 1979). Under good grazing management, pigeon pea can survive up to five years and with intensive management, forage yields can exceed 50 t/ha/annum. Regeneration of foliage is moderate when the plant is younger but it becomes poorer as the plant becomes woodier near the end of its life. The crop cannot tolerate frequent or severe cutting or heavy defoliation through continuous grazing, although regrowth occurs even when rationed as low as 15 cm. According to (Duke, 1981), the leaves of pigeon pea can also be a substitute for alfalfa in animal feed formulations.

The present high cost of animal sourced protein in feeds makes pigeon pea ideal as a good plant protein substitute as it is less expensive. The high protein content of pigeon pea leaves suggests that the optimum use of the crop for forage may be as a supplement protein source in compound diets to low quality forage (rice or wheat straw). The perennial habit of the crop makes it valuable as a stand over high-protein fodder for those times of the year when protein shortage is the major limit to production. Wijnberg (1983) reviewed the forage quality of pigeon pea and concluded that its leaf nitrogen level is consistently high having an average of 2.9% probably due to the perennial habit and reduced leaf senescence of the crop. Accordng to Belete *et al*., (2012), the chemical composition of pigeon pea was 94.5% DM, 9.45% ash, 33.8% NDF and 29.4% ADF.

2.3.3. Cowpea (Vigna unguiculata)

Crop residues make up a major component of livestock diets in mixed crop–livestock systems and, therefore, improving the use and nutritional quality of crop residues is important to enhancing farm productivity and profitability. Cowpea is an important component in mixed systems and in semi-arid regions of the tropics and is valued for its potential to produce high levels of fodder for livestock in addition to grain for people. A number of studies have been conducted to evaluate additions of cowpea fodder as a supplement to poorer quality hay and stover. Cowpea haulm addition improves nutrient supply and growth of livestock over the use of low quality forages alone but degree of weight change varies relative to total nutrient supply (Baloyi *et al.,* 2008). It should be noted that only a limited number of studies reported the specific variety of cowpea used and animal response has been reported to differ with variety and its associated forage quality (Anele *et al.*, 2010). Singh *et al.* (2003) reported higher weight gain in rams supplemented with the cowpea haulms of variety IT90K-277-2 compared to Dan Ila. Akinlade *et al*. (2005) reported increased milk yield in cows supplemented with cowpea haulms of variety IT96D-716 compared to 994-DP.

Residues of cereal crops are generally nutritionally inadequate to produce high yields of meat and milk. The greater nutritional quality of legume residues allows them to be used as a supplement to livestock diets based on cereal stover and other low-quality forage. One benefit of the use of cowpea and other legume fodders as a supplement is the provision of nitrogen to the rumen microbes, allowing them to improve utilization of the low quality forage. At some levels of supplementation, nitrogen becomes surplus to available carbohydrates for microbial growth and additional nitrogen may be wasted. An example of this diet development is found in the study of Koralagama *et al.* (2008) who fed either 150 or 300 g/d haulms from either a forage- or dual purpose-type cowpea to Ethiopian sheep fed a basal diet of maize stover.

Dietary nitrogen was increased by cowpea haulm addition and higher levels of cowpea feeding resulted in higher nitrogen intakes. Total feed intake increased with increasing levels of cowpea supplementation and diet digestibility was greater for diets containing cowpea haulms. The results of the study indicated that nitrogen level for the lower levels of cowpea supplementation likely matched the needs of the rumen microbes for the type of carbohydrate found (fiber) in these diets. This is also supported by increased urinary nitrogen excretion in sheep fed cowpea at 300 g/d compared to 150 g/day, indicating that some nitrogen was likely leaving the rumen as ammonia nitrogen rather than being incorporated into microbial cells. Sheep in these studies gained between 32 and 51 g/d when supplemented with cowpea. Chakeredza *et al.* (2002) found a 22.7% increase in microbial protein supply when cowpea haulms were added to a diet of maize stover which also illustrates how cowpea improves nitrogen supply for rumen microbes. This hypothesis supports the results of the study reported by Singh *et al.* (2003), in which additions of about 200 g cowpea haulms were shown to be the most economically viable level in feeding systems based on cereal stover compared to feeding either 400 or 600 g of supplemental haulms.

Although increasing amounts of cowpea in a diet based on sorghum stover resulted in increased gains, the amount of increase diminished with each subsequent increase, resulting in the lowest level of cowpea addition (200 g) being the most economical. This is also consistent with economic theory that the economically optimal supplementation level will always be somewhat less than the maximum biological efficiency from supplementation (Torrell and Rimbey, 2010).

Maintenance intake is the level of feed intake that provides adequate nutrients for bodily functions such as respiration and digestion, without excess nutrients for use in weight gain or other non-essential functions. To support productive functions such as growth, milk production, and pregnancy, it is necessary to increase intake above maintenance. To provide options for optimal mixes of sorghum stover and cowpea haulms, Savadogo *et al.* (2000) fed 21 kg rams varied levels of cowpea haulms in addition to sorghum stover at levels that allowed selective consumption of stover.

This allowed rams to select between sorghum leaf and stem, a factor that affects digestibility and intake of the diet. The researchers then calculated the varied amounts of cowpea haulms needed to reach various levels of maintenance intake up to two times maintenance. For example, maintenance intake was reached with 61 g organic matter (OM) per $kg^{0.75}$ body weight (BW) for sorghum stover and an additional of 48 g cowpea OM/$kg^{0.75}$ BW was required to reach two times maintenance. The studies showed the wide range in stover–cowpea combinations that could result in the same level of maintenance intake. This approach provides information useful for mixing diets relative to targeted production goals and can be used in combination with feed price information to develop diets producing the best economic returns. The use of low-quality forage, such as cereal stover, as the major feedstuff in ruminant diets can limit both energy density and intake. Supplementation of low-quality forage with legumes will increase diet utilization to some extent, but for higher levels of production increased dietary energy density through the use of higher quality forage and some grain may become of interest to livestock producers. Legume fodders such as cowpea can remain an important part of these higher energy diets. Though there are limited studies previously reported on the DM yield of cowpea, 3.4 ton DM/ha are recorded in Ghana (Aikins and Afuakwa, 2008).

2.3.4. Lablab (Lablab purpureus)

Lablab is a dual-purpose legume crop that has high seed and forage yield as well as good hay curing ability (Adu *et al*., 1990) and it is a source of major minerals, which are likely to be deficient in the dry season fodder residues (Minson, 1993). As to its growth habits, it is a climbing or erect annual or short lived perennial legume which grows up to one meter high (Bogdan, 1997). Lablab is a fast growing legume and grazing or cutting can start at 7-10 weeks after sowing. It has been well accepted in food security and soil and water conservation programs. It is commonly under sown in maize or sorghum at mid to high altitudes (Alemayehu, 1997), can provide forage for dry periods, could be a useful pioneer component of many pasture mixtures and also could serve as green manure (Skerman and Riveros, 1990). Once established, it is moderately tolerant to frost, has good drought tolerance and can survive where there is only 400 mm annual rainfall. On the contrary, lablab is intolerant to flooding and salinity, but it can grow on a wide range of soils (Alemayehu, 1997).

Nsahlai and Umunna (1996) reported that the nitrogen in lablab is rapidly degradable in the rumen which is useful to meet the requirements of rumen microorganisms for efficient degradation of low quality roughages. Similarly, Adu *et al*. (1990) reported that lablab supplementation to sorghum stover significantly improved CP digestibility and generally improved rumen fermentation of the test diets and improved live weight gains of sheep. Though not significant, the digestion of dry matter, organic matter and NDF generally increased with increasing levels of lablab supplementation. In this regard, Solomon (2004a) reported that lablab had better digestibility of N, ADF and ADL than graded levels of *L. pallida*, while it was lower in the digestibility of DM, OM and NDF than graded levels of *L. pallida.* On the other hand, the author also reported that lablab contained lower ADL and had higher ADF compared to *L.pallida.* Still in another experiment conducted by Solomon (2004b), it was indicated that lablab supplemented rams had higher urinary N excretion and urinary N excretion as a proportion of N intake and lower faecal and total N excretion as well faecal N excretion as proportion of N intake than *L. pallida*. As to the chemical composition of lablab, Taye (2004) reported values of 17.4%, 47.9%, 38.6%, 7.1% and 7.9% for CP, NDF, ADF, ADL and ash, respectively for lablab cut at 90 days.

2.4. Nutrient Requirements of Sheep

Energy, protein, lipids, mineral, vitamins and water are the main nutrients required by sheep, similar to other animals. The nutrient requirements are the values considered necessary for maintenance, optimum production, and prevention of any signs of any nutritional deficiency. As an example, the energy and protein requirements for growth of sheep weighing between 20-40 kg are given in Table 1.

Table 1. Energy and protein requirements for growing sheep

Nutrient	Live weight (kg)	Gain (g/day)			Calculated requirement per BW $^{0.75}$	
		0	50	100	Maintenance	For gram gain
ME (MJ/day)	20	4.1	5.1	6.2	0.43	0.02
	30	5.6	7.0	8.5	0.44	0.03
	40	7.0	8.7	10.7	0.44	0.04
Protein (g/day)	20	30	40	60	3.17	0.30
	30	45	55	65	4.76	0.20
	40	45	70	85	2.83	0.40

Source: ARC (1980)

The energy need of sheep is mainly attained through the consumption and digestion of roughage, pasture and hay. The micro flora action in the rumen of sheep efficiently converts roughages into suitable energy sources provided they have adequate supply of nitrogen. The energy requirement of sheep is affected by body weight and rate of growth (gain) and protein content of the ration. Large animals require higher energy to attain their maintenance requirement than smaller animals. This is because of the increased rate of metabolism for energy in large animals. Moreover, fast rate of growth demands energy rich feeds or consumption of large amount feed (ARC, 1980).

All growing animals including sheep need protein for maintenance and growth. Moreover, sheep need protein for the production of wool. The protein requirement of growing sheep is affected by growth rate, weight for age, body condition, rate of gain and protein to energy ratio. To achieve fast growth, adequate amount of protein should be supplied. Poor body conditioned animals require protein rich feeds to compensate for their growth. Rate of gain and protein to energy ratio affects growth, and increasing CP level in a diet increased the weight gain and retention of protein (ARC, 1980).

2.5. Influence of Nutrition on Body Weight and Carcass Composition of Sheep

Plane of nutrition is the major factor influencing the fat deposition pattern of animals whereby high plane of nutrition promotes earlier fattening while a low plane results in a delayed or slower fattening process. It is possible to manipulate growth paths of lambs maintained on relatively poor quality pasture to produce carcasses of better quantity and quality (Thatcher and Gaunt, 1992).

Fat is deposited only if surplus nutrients are available. According to Gatenby (1986), the higher the level of nutrition or the lower the growth capacity, the more fat is deposited in lambs at any given age and body weight. In carcass merit evaluation, dressing percentage is an important trait. However, according to the review by Ruvuna *et al.* (1992), dressing percent is known to be affected by breed, age, castration and it is also highly affected by feeding and degree of fattening. They have also reported that proportion of lean and fat in carcasses increased with age while the proportion of bone decreased. Gruszecki *et al.* (1994) have reported that the carcass composition of Polish Lowland sheep and its crosses, whose slaughter weights range from 38- 40 kg, to be in the range of 61-63 % lean, 17-20 % fat and 19-22 % bone.

In a similar investigation on mutton-type lambs of diverse genetic background, Streitz *et al.* (1994) observed that lean and fat contents of carcasses were 62.4 % and 16.8%, respectively for those lambs which had below 30 kg live weight and 58.2 % and 3.6%, respectively for those above 30 kg live weight.

Ruminant production is a function of nutrition, health, genetics, climate and management among which nutrition plays an important role (Seyoum *et al.*, 1996). These authors showed the influence of nutrition on growth rate and body composition in their systematic investigation of the course of growth in 30 crossbreed sheep that had restricted and free access to feed. Moreover, the energy content of weight gain was lower and the protein and water content higher in the restricted group maintained on the low plane of nutrition.

Season of birth of lamb was also found to have some influence on the proportion of the major body chemical compositions. In general, the body of lambs born in the wet season, the season when adequate feed is to be found, contains a little more fat and less protein than lambs born into the dry season. Although some of the differences between lambs born in the different seasons were not significant, there seems to be some advantage of lambing in the wet season as lambs were able to maintain good body condition throughout the growth period.

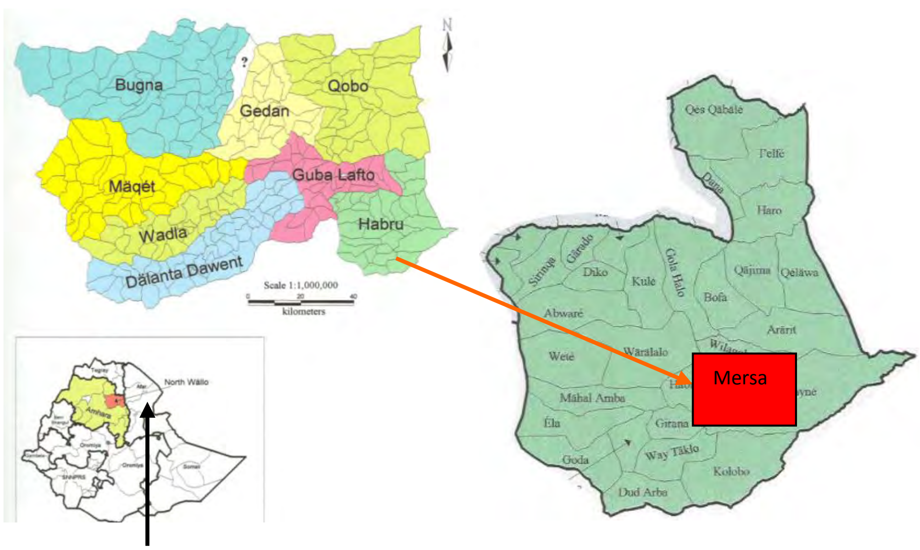
Ulfina *et al*. (1999) reported a significant effect on omental and kidney fat, back fat thickness and rib-eye muscle area for a pre-market supplementary feeding of old Horro ewes. Sibanda *et al.* (1989) reported similar results on water, fat, and protein contents of the carcass by feeding different levels of dietary protein to lambs. The work done by Awet (2007) significantly improved most carcass and non-carcass parameters like empty body weight, and hot carcass weight; omental fat and total edible offal component for supplemented ones. Tesfay and Solomon (2008) have also reported higher improvement for most carcass and non-carcass parameters of supplemented Afar rams than the control ones.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Mersa Agricultural Technical and Vocational Educational Training (ATVET) College located at 491 km from Addis in Habru district, North Wollo administrative zone of the Amhara Region, Ethiopia. Mersa is situated at an altitude ranging from 1200-2350 m.a.s.l (HWoARD, 2010) at 39^0 38'E longitude and $11^0$35'N latitude in the semi-arid tropical belt of north-eastern Ethiopia (MoA, 1998). Its mean annual maximum and minimum temperatures are 28.5 ^{0}C and 15 ^{0}C, respectively (HWoARD, 2010), whereas the mean annual rainfall of the district varies from 750 to 1000 mm. It receives a bimodal rainfall, namely the main rainy season and short rainy season. The main rainy season extends from the beginning of July to mid of September while the short rainy season starts by the end of January and lasts up to the end of April (SARC, 2008 unpublished).

North Wollo



Ethiopia

Habru

Figure 1. Map of the study area.

3.2. Forage Establishment

Three forage species namely, pigeon pea *(Cajanus cajan)* accession 11560, cowpea *(Vigna unguiculata)* accession 9333 and lablab *(Lablab purpureus)* accession 147 were established on well prepared land for the experiment in the study area through rainfed and irrigation. A total of 1 hectare of land was allocated for forage establishment. Land clearing, ploughing, seeding, fertilization, weeding, harvesting, preservation (hay making) and proper storage were applied following the recommendations for each forage species. The forages were harvested at 50% flowering.

3.3. Chemical Analysis

Samples of treatment feeds (basal feed and supplements) were taken for chemical analysis before the start of the feeding trial. After the feeding trial was commenced, samples of refusals were collected daily for each animal and pooled for each treatment. The collected samples of the basal feed and supplements and the refusals were thoroughly mixed and sub-samples were taken (Debre Birhan Agricultural research center) and ground to pass through 1 mm sieve screen. Then, the ground sub samples of feeds and refusals were dried in an oven for 48 h at 105^0C to determine the DM, Ash and N contents were determined according to the standard procedure of AOAC (1990). The ash content was determined by burning/igniting feed samples in a muffle furnace at 550^0C and N content of feeds was determined according to Kejldhal procedure and the crude protein (CP) was calculated as N*6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to the procedure of Van Soest and Robertson (1985). Hemicellulose (HC) and cellulose (C) contents were calculated as NDF minus ADF and ADF minus ADL, respectively.

3.4. Animals and their Management

For the current study, the Central Highland sheep which are believed to be crosses of highland Wollo sheep and lowland Afar sheep and commonly called by the community Wollo *Tumele* sheep were used for the trial. Because there is no specialized local sheep in that area the regional government of Amhara demarcated the area from Shewa Robit (Semen Shewa) up to Kobo (North Wollo) areas as Dorper-Boer valley and started project work to satisfy this initiation (Solomon Tiruneh, personal communication).

According to Solomon (2009), Wollo sheep are characterized by short, fat tail with short twisted/coiled end, occasionally turned up at end; well-developed wooly undercoat; small size; predominantly black, white or brown, either plain or with patches of white, black or brown; long hair with wooly undercoat; horned males. While the Afar sheep have small ears and usually have a dewlap and thick layers of fat on the brisket. The fat tail has a wide base and reaches below the hocks. Hair is short and coarse, the predominant color being solid blond with other colors ranging from shaded white to light brown. There are a few exceptions of animals with spotted color patterns and/or dark brown hair. The average observed wither height for adult rams is 66 centimeters (cm) while that for adult ewes is 61 cm. Afar sheep weigh about 2.5 kg, 13 kg and 25.8 kg at birth, weaning (90 days), and one year of age, respectively. Ewe mature weight is about 31.6 kg. Twin births are not common (Kassahun and Solomon, 2008).

The experiment was conducted using sixteen intact yearling growing indigenous lambs (Wollo *Tumele* sheep) with an average body weight of 18.8±0.35 kg (mean ± SD). The age of the animals was determined by dentition and the information obtained from the owners. The sheep were purchased from the local markets of Mersa and Habru Woredas in North Wollo; Amhara Regional State, and quarantined for 3 weeks. They were drenched with a broad spectrum anthelmintic (albendazole) against internal parasites, sprayed with accaricide (diazzinole) against external parasites and vaccinated against anthrax and pasteurelosis. Following the quarantine period, the initial body weights of all animals were measured. The lambs were kept in well ventilated individual pens equipped with watering and feeding troughs, and identified with neck collars and adapted to the respective experimental diets for 2 weeks. The experimental animals were carefully observed for the occurrence of any ill health and records were taken for any physiological disorder during the experimental period.

3.5. Feeds and Feeding Management

Purchased locally available natural pasture grass hay constituted the basal diet, whereas the three forage species namely, pigeon pea *(Cajanus cajan)*, cowpea *(Vigna unguiculata)* and lablab *(Lablab purpureus)* in hay form were used as protein supplements. Wheat bran was purchased from Dessie town and was used as energy source across all treatments. The supplement forage species were harvested at flowering stage from the established plots and dried under shade to make hay. The grass hay and forage hays were manually chopped to a size of approximately 3-5 cm to encourage intake. The forages were dried and stored under shade until used to maintain their quality. Lambs were adapted for 15 days to the treatment diets and experimental pens before the start of the actual feeding trial that lasted for 90 days. The daily amounts of natural pasture grass hay, forage legumes and wheat bran were offered in separate troughs, wheat bran once a day at 8:00 AM, whereas the hay and forage legumes twice a day at 8:30 AM and 14:00 PM. The lambs had free access to clean, fresh water and common salt at all the time.

3.6. Experimental Design and Treatments

The experiment was conducted in randomized complete block design (RCBD) with four dietary treatments, each replicated with four lambs. The experiment comprised of feeding of a basal diet (natural pasture grass hay), and/or supplementation of the basal diet with wheat bran alone (control), and additionally supplementing one of the three forage species to the rest of the treatments, each representing a treatment. An equal amount of wheat bran was supplemented across all treatments to provide source of energy. The treatments were:

Treatment 1 (T1) = Grass hay ad *libitum* + 200 g Wheat bran (Control)

Treatment 2 (T2) = Grass hay *ad libitum* + 200 g Wheat bran + 243 g Pigeon pea

Treatment 3 (T3) = Grass hay *ad libitum* + 200 g Wheat bran + 260 g Cowpea

Treatment 4 (T4) = Grass hay *ad libitum* + 200 g Wheat bran + 225 g Lablab

The treatments consisted of *ad libitum* feeding of grass hay plus 200 g DM wheat bran (control), and the rest of the treatments, T2, T3 and T4 were additionally supplemented with 243 g pigeon pea, 260 g cowpea and 225 g DM lablab per head per day, respectively. The amounts of forage supplements were fixed to supply 43.1 g CP per day required for sheep weighing between 20-25 kg (ARC, 1980). The amount of wheat bran supplemented was based on the recommendation of Mullu *et al*. (2008). The four treatment diets were randomly assigned to each animal in a block giving four lambs per treatment.

3.7. Feed Intake, Body Weight Gain and Feed Conversion Efficiency (FCE)

The daily amount of feeds offered and the refusal were weighed for each animal and recorded to determine the amount of feed consumed as a difference between the feed offered and refused.

Body weight of the animals was taken at the beginning of the trial and every 10 days during the 90 days of feeding period. All animals were weighed in the morning hours after overnight fasting using suspended weighing scale with a sensitivity of 100 g. 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. Feed conversion efficiency (FCE) was calculated by dividing average daily gain (ADG) by daily total DM intake.

3.8. Carcass Analysis

All experimental animals were fasted overnight, weighed and slaughtered at the end of the feeding trial. The animals were killed by severing the jugular vein and the carotid artery with a knife. The blood was drained into a bucket and its weight was recorded. The skin was carefully flayed to prevent fat and tissue attachments. The skin was weighed with ears after the removal of legs below the fetlock joints. The gastro-intestinal tract with the exception of the oesophagus were removed with its contents and weighed. The gastro-intestinal track was reweighed after emptying its contents. Gastro-intestinal tract and kidney fats were removed and individually weighed. Internal organs, namely, empty gut, heart and kidney were removed and weighed. The hot carcass weight was estimated after subtracting weights of the head, thorax, abdominal and pelvic cavity contents as well as legs below the hock and knee joints (Gilmour *et al.,* 1994).

After evisceration, the carcass were weighed and cut perpendicular to the back bone between the 12^{th} and 13^{th} ribs to measure the cross-sectional area of the rib-eye muscle area. The rib- eye area was traced first on to a transparent paper then by counting the number of squares lying on the traced picture in the square paper and multiplied by the area of the single square. The empty body weight was calculated as gut content deducted from slaughter weight. The percentage of total edible offal components (TEOC) was taken as the sum of heart, empty gut, kidney, testis, head and tongue, testicle, tail and fat (omental, kidney knob and channel fat). Percentages of total non- edible offal component (TNEOC) were taken as the sum of blood, skin, feet, penis, and gut content. The dressing percentage was calculated as a proportion of hot carcass weight and empty body weight and/or slaughter body weight (Gilmour *et al.,* 1994).

3.9. Partial Budget Analysis

Partial budget analysis was performed to evaluate the economic advantage of the different treatments by using the procedure of Upton (1979). The partial budget analysis involved the calculation of variable costs and benefits. The selling price of rams in each treatment before and after the experiment was considered as total return (*TR*) in the analysis. For the calculation of the variable costs, the expenditures incurred on various feedstuffs were taken into consideration. The cost of the feeds was computed by multiplying the actual feed intake for the whole feeding period with the prevailing market price. The prevailing price of the feeds at the time of feed purchasing including the transportation cost incurred to move them to the experimental site were recorded. Partial budget method measures profit or loss, which is the difference between gains and expenses for the proposed change and includes calculating net return (NR), i.e., the amount of money left when total variable costs (TVC) are subtracted from the total returns (TR):

NR = TR-TVC

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

ΔNR = ΔTR-ΔTVC

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

MRR% = (ΔNR/ΔTVC) X 100

3.10. Data Analysis

All data related to feed intake, body weight change, feed conversion efficiency and carcass parameters were analyzed using the General Linear Model Procedure of SAS (SAS, 2001). Significant differences were declared at $P \leq 0.05$. Treatment means were separated using least significance difference test. The model used for the analysis of feed intake, body weight change, feed conversion efficiency and carcass parameters was:

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

Where;

Y_{ij} = Response variable

μ = Overall mean

T_i = the fixed effect of feed

B_j = block effect

e_{ij} = effect of random error

4. RESULTS

4.1. Chemical Composition of Experimental Feeds

The chemical compositions of the experimental diets used in the experiment are indicated in Table 2. The DM content of the basal diet, native grass hay, was 90%.

Based on the results, the DM, Ash, CP, NDF, ADF and ADL contents of wheat bran offered were 89%, 5.56%, 17.77%, 22.22%, 13.33%, and 6.03%, respectively.

Table 2. Chemical composition of experimental feeds on DM basis

Feeds	Chemical composition (%)					
	DM%	Ash	CP	NDF	ADF	ADL
		%DM				
Hay	90	12.22	7.78	66.66	55.55	22.22
WB	89	5.56	17.77	22.22	13.33	6.03
Pigeon pea	89	8.87	17.5	46.66	33.33	14.55
Cow pea	89	13.33	16.69	23	20	15.55
Lablab	89	11.11	19.23	40	24.44	6.66

ADF=Acid detergent fiber; ADL=Acid detergent lignin; CP=Crude protein; DM=Dry matter; NDF=Neutral detergent fiber and WB=Wheat bran

When the chemical composition of the basal natural grass hay was compared with that of the pigeon pea, cow pea and lablab, the grass hay basal diet had higher proportions of NDF, ADF and ADL while it had lower proportions of CP than pigeon pea, cow pea and lablab.

When the chemical compositions of feed refusals were considered, the NDF, ADF and ADL contents of the refusals of the grass hay and forage legumes were higher than the corresponding contents of feeds offered, whereas the ash and CP contents of the refusals were lower than the corresponding contents of feeds offered. The high ADL content in refusals of lablab is difficult to explain, although the refusals mainly constituted the stem part of lablab, which indicates that the lignin in lablab must have been mainly contained in the stem than the leaves and twigs.

Table 3. Chemical composition of feed refused on DM basis

Feeds	Chemical composition (%)					
	DM%	Ash	CP	NDF	ADF	ADL
		%DM				
Hay	89	7.78	3.01	77.77	60.00	24.44
Pigeon pea	90	5.56	7.68	69.22	73.33	22.22
Cow pea	89	7.78	11.05	73.67	68.88	37.77
Lablab	89	7.72	9.33	80	60	44.44

ADF=Acid detergent fiber; ADL=Acid detergent lignin; CP=Crude protein; and DM= Dry matter

Refusals mainly constituted stem parts of the feed as the result of the stem of the lablab must have been containing higher lignin content than the rest of the feeds.

4.2. Feed and Nutrient Intake

The daily DM and nutrient intakes of Wollo *Tumele* lambs fed natural pasture grass hay and legume supplements are presented in Table 4. There were significant differences ($P<0.001$) in total DM, CP and NDF intakes between T1 and the selected forage legume supplemented diets (T2, T3 and T4). The ADF intake of the lambs in T1 and forage legume supplemented groups was in the order of T1<T4<T3<T2. There were significant differences ($P<0.001$) in total ADL intakes between the lambs in T1 and lablab supplemented (T4). But there were no significant differences ($P>0.001$) in total ADL intakes between cow pea supplemented group (T3) and pigeon pea supplemented group (T2).

Table 4. Daily feed intake and nutrients of Wollo *Tumele* sheep fed grass hay and supplements

DMI, g	T1	T2	T3	T4	SL	SEM
Grass hay	352.33[a]	264.85[b]	263.65[b]	263.96[b]	***	7.77
Pigeon pea		215.93[c]				
Cow pea			219.98[a]			
Lablab				217.74[b]		
Wheat bran	200[a]	200[a]	200[a]	200[a]	ns	0
Total	552.33[b]	680.78[a]	683.63[a]	681.70[a]	***	8.18
Nutrients intake, g						
CP from grass hay	30.62[a]	22.76[b]	23.11[b]	23.14[b]	***	0.13
CP from pigeon pea		43.24[b]				
CP from cow pea			42.04[c]			
CP from Lablab				47.58[a]		
CP from wheat bran	34.88[a]	34.88[a]	34.88[a]	34.88[a]	ns	0
Total CP	65.50[c]	100.88[b]	100.03[b]	105.61[a]	***	1.33
NDF from grass hay	261.48[a]	196.09[b]	202.04[b]	194.70[b]	***	63.14
NDF from pigeon pea		112.06[b]				
NDF from cow pea			112.74[a]			
NDF from Lablab				112.94[a]		
NDF from wheat bran	44.44[a]	44.44[a]	44.44[a]	44.44[a]	ns	0
Total NDF	305.92[b]	352.59[a]	346.74[a]	352.08[a]	***	30.01
ADF from grass hay	217.62[a]	162.68[b]	161.56[b]	162.55[b]	***	3.68
ADF from pigeon pea		76.57[a]				
ADF from cow pea			43.37[c]			
ADF from Lablab				57.85[b]		
ADF from wheat bran	26.66[a]	26.66[a]	26.66[a]	26.66[a]	ns	0
Total ADF	244.278[b]	265.91[a]	231.59[c]	247.06[b]	***	5.52
ADL from grass hay	87.03[a]	64.82[b]	65.11[b]	65.05[b]	***	0.50
ADL from pigeon pea		36.42[a]				
ADL from cow pea			35.49[b]			
ADL from Lablab				14.21[c]		
ADL from wheat bran	13.32[a]	13.32[a]	13.32[a]	13.32[a]	ns	0
Total ADL	100.35[b]	114.55[a]	113.93[a]	92.58[c]	***	0.50

a, b, c, d = means within a row not bearing a common superscript letter significantly differ, (***)=P<0.001; ns = not significant; DMI= dry matter intake; SEM= standard error of mean; CPI= crude protein intake; ADLI= acid detergent lignin intake; NDFI=neutral detergent fiber intake; ADFI=Acid detergent fiber intake; SL= significant level; T1 = hay+200 g wheat bran; T2 = hay +200 g wheat bran +243 g pigeon pea; T3= hay +200 g wheat bran +260 g cow pea; T4 = hay +200 g wheat bran + 225 g lablab.

The crude protein intake (CPI) of lambs in T1 was lower (P<0.001) than CPI of lambs in T2, T3 and T4. Similarly, neutral detergent fiber intake (NDFI) of lambs in T1 was also lower (P<0.001) than the NDFI of lambs supplemented with the selected forage legumes. The daily acid detergent fiber intake (ADFI) of lambs in T1 was lower (P<0.001) than ADFI of lambs in T2, T3 and T4. The daily acid detergent lignin intake (ADLI) also of lambs in T1 was lower (P<0.001) than ADLI of lambs in T2 and T3. But higher (P<0.001) than lambs in T4. On the other hand, the variations in DMI and NDFI among T2, T3 and T4 were insignificant (P>0.001). However, there were significant (P<0.001) variations in CPI and ADFI among lambs fed the forage legumes (T2, T3 and T4). The variations in ADLI between T2 and T3 were insignificant (P<0.001). But variations in ADLI among T2, T3 and T4 were significant (P<0.001). Compared to lambs fed the legume supplemented diets, lambs fed natural grass hay supplemented with wheat bran (T1) had lower (P<0.001) daily DM, CP and NDF intakes.

Lambs supplemented with the forage legumes (pigeon pea, cow pea and lablab) revealed the highest (P<0.001) daily DMI and CPI than lambs fed natural grass hay supplemented with wheat bran. The higher (P<0.001) intakes of DM and CP of lambs fed the legume supplemented diets was indicative of the better nutritive values of the legume supplemented diets than the basal diet supplemented with wheat bran alone (T1).

4.3. Body Weight Change and Feed Conversion Efficiency

The mean initial and final body weight, average daily body weight gain (ADG) and feed conversion efficiency (FCE) are presented in Table 5. The final body weight of the lambs in the control group (T1) was lower (P<0.001) than final body weights of lambs fed cow pea, pigeon pea and lablab. Among the supplemented legumes, lablab resulted in higher (P<0.001) final body weights than T2 and T3. Following the variations in the final weights of lambs fed the experimental diets, there were also significant (P<0.001) variations in average daily weight gains (ADG) of lambs on the different diets. Accordingly, lambs fed the basal diet supplemented with wheat bran (T1), had significantly lower (P<0.001) ADG than lambs fed diets supplemented with cow pea, pigeon pea and lablab (T3, T2 and T4). Lambs supplemented with pigeon pea and lablab had the highest (P<0.001) ADG and FCE (T4>T2>T3). The ADG of lambs increased with the increase in crude protein contained in the experimental forage legumes.

Table 5. The effect of experimental diets on body weight change

Parameter	**T1**	**T2**	**T3**	**T4**	**S.L**	**SEM**
IBW(kg)	18.95	19.19	19.01	18.71	ns	0.02
FBW(kg)	19.23^{d}	22.34^{b}	20.84^{c}	23.16^{a}	***	0.04
BWC(kg)	0.28^{d}	3.15^{b}	1.83^{c}	4.44^{a}	***	0.02
ADG(g/d)	3.1^{d}	34.97^{b}	20.33^{c}	49.36^{a}	***	3.17
FCE	0.006^{d}	0.053^{b}	0.031^{c}	0.075^{a}	***	7.30

a, b, c, d Means with different superscripts in the same row differ significantly; (***) = P<0.001; ADG=average daily gain; BWC=body weight change; FBW=final body weight; FCE = feed conversion efficiency; IBW=initial body weight; S.L =significance level; T1 = hay+200 g wheat bran; T2 = hay +200 g wheat bran +243g pigeon pea; T3= hay +200 g wheat bran +260 g cow pea; T4 = hay +200 g wheat bran + 225 g lablab.

Generally, lambs fed the natural pasture grass hay supplemented with wheat bran (T1) had lower final body weights than lambs fed the legume supplemented diets (T2, T3 and T4). Likewise, lambs in T1 had the lowest (P<0.001) ADG than lambs fed the legume supplemented diets. The higher final body weight and ADG of lambs supplemented with lablab was attributed to the higher CP content of the lablab. The differences in the FBW and ADG among treatments was possibly attributed to the higher CP and low ADL contents, and possibly due to better protein quality in lablab that promoted increased DMI and improved feed utilization efficiency of lambs.

4.4. Carcass Characteristics

The average slaughter weight (SW) and empty body weight (EBW) were significantly (P<0.001) higher for lambs supplemented with 225 g lablab as compared to lambs supplemented with 260 g cowpea, 243 g pigeon pea and the control treatment (Table 6).

Table 6. Carcass characteristics of Wollo *Tumele* lambs fed grass hay and supplements

Parameter	T1	T2	T3	T4	S.L	SEM
Slaughter weight (kg)	18.00^{d}	21.15^{b}	19.02^{c}	22.82^{a}	***	0.06
Empty body weight (kg)	12.00^{d}	16.07^{b}	13.89^{c}	16.65^{a}	***	0.04
Hot carcass weight (kg)	5.08^{d}	8.74^{b}	7.53^{c}	9.60^{a}	***	0.02
Dressing percentage on						
Slaughter weight base	28.22^{d}	41.34^{b}	39.59^{c}	42.07^{a}	***	0.87
Empty body weight base	42.08^{c}	54.39^{b}	54.22^{b}	57.66^{a}	***	1.87
Rib-eye area (cm^2)	3.54^{d}	7.03^{b}	6.63^{c}	8.29^{a}	***	0.03

a, b, c. d = means within a row not bearing a common superscript letter differ significantly; (***) = P<0.001; SEM = standard error of mean; SL= significant level; T1 = hay+200 g wheat bran; T2 = hay +200 g wheat bran +243 g pigeon pea; T3= hay +200 g wheat bran +260 g cow pea; T4 = hay +200 g wheat bran + 225 g lablab.

The DP on slaughter body weight basis in the current study was higher (P<0.001) for the lambs supplemented with pigeon pea and lablab, whereas the DP on the basis of empty body weight was higher (P<0.001) for the lambs supplemented with lablab.

4.5. Edible Offal Components

Edible offal components of Wollo *Tumele* lambs supplemented forage legumes are given in Table 7. Heart, kidney, empty gut, total fat, head and tongue, testis and tail are considered as edible offals. Where as gut content, blood, penis, skin and feet are considered as non-edible offals based on the eating habit of people in the study area.

The weight of heart was significantly higher (P<0.001) for the supplemented treatments compared to the control treatment. Kidney was significantly higher (P<0.001) for T4.

Table 7. Edible offal components of Wollo *Tumele* lambs fed grass hay and supplements

Parameter	T1	T2	T3	T4	S.L	SEM
Heart (g)	49.12^{d}	65.95^{b}	64.24^{c}	71.50^{a}	***	0.49
Kidney (g)	38.62^{d}	54.37^{b}	48.02^{c}	56.25^{a}	***	0.79
Empty gut (g)	1115^{d}	1342.50^{b}	1215^{c}	1415^{a}	***	264.58
Total fat (g)	36.18^{d}	121.50^{b}	82.87^{c}	154.75^{a}	***	2.35
Head and Tongue (g)	1385^{a}	1392.50^{a}	1405^{a}	1402.50^{a}	**ns**	245.83
Testis (g)	185.99^{a}	186.25^{a}	188.75^{a}	187.25^{a}	**ns**	1.07
Tail (g)	71.83^{d}	722.50^{b}	496.57^{c}	839.50^{a}	***	7.60
TEOC (g)	2794.97^{d}	2960.58^{b}	3510.46^{c}	3271.75^{a}	***	506.87

a, b, c, d means the same row with different superscripts differ significantly; (***) = P<0.001; ns = not significant; TEOC= total edible offal component; SL= significant level; SEM= Standard error of mean; T1 = hay+200 g wheat bran; T2 = hay +200 g wheat bran +243 g pigeon pea; T3= hay +200 g wheat bran +260 g cow pea; T4 = hay +200 g wheat bran + 225 g lablab.

4.6. Non-Edible Offal Components

Non-edible offal component of Wollo *Tumele* lambs fed on forage legumes are given in Table 8. Penis, skin and feet and TNEOC did not differ (p>0.001) due to forage legumes supplementation. The total non-edible offal (TNEO) was numerically higher for T2 and T4 as compared to T1 and T3.

Table 8. Non-edible offal components of Wollo *Tumele* lambs fed grass hay and supplements

Parameter	T1	T2	T3	T4	S.L	SEM
Gut content(g)	5895^{a}	4872^{a}	4967^{a}	4865^{a}	**ns**	233.33
Blood (g)	369.90^{d}	761.50^{b}	460.92^{c}	798.25^{a}	***	1.53
Penis (g)	50.06^{a}	50.40^{a}	50.96^{a}	51.00^{a}	**ns**	0.15
Skin and feet (g)	1445^{a}	1440^{a}	1450^{a}	1540^{a}	**ns**	325
TNEOC (g)	6959.96^{a}	7123^{a}	6927^{a}	7254^{a}	**ns**	609.59

a, b, c, d means the same row with different superscripts differ significantly; (***) = P<0.001; ns = not significant; TNEOC= total non-edible offal component; SL= significant level; SEM= Standard error of mean; T1 = hay+200 g wheat bran; T2 = hay +200 g wheat bran +243 g pigeon pea; T3= hay +200 g wheat bran +260 g cow pea; T4 = hay +200 g wheat bran +225 g lablab

4.7. Partial Budget Analysis

The cost of feeds used in the experiment was indicated in Table 9, and the result of partial budget analysis is shown in Table 10.

Table 9. Feed cost used in the conduct of the experiment

Feed Item	Cost
Natural pasture hay	50 ETB/qt
Wheat bran	380 ETB/qt
Pigeon pea hay	63 ETB/qt
Cow pea hay	65 ETB/qt
Lablab hay	65 ETB/qt

ETB= Ethiopian Birr, QT=quintal

The result of partial budget analysis revealed that the high level of CP% (lablab, 19.23) resulted in higher profit margin than low (cow pea, 16.69), medium (pigeon pea, 17.50) and the control. Lambs fed natural pasture grass hay with wheat bran had the lowest net return and lablab group recorded the highest net return.

Table 10. Partial budget analysis of Wollo *Tumele* lambs fed grass hay and supplements

Parameter	T1	T2	T3	T4
Number of animals	4	4	4	4
Purchase price of sheep (ETB)	650	650	650	650
Total basal diet intake (kg)	126.84	95.35	94.91	95.02
Total pigeon pea intake(kg)	-	77.73	-	-
Total cow pea intake(kg)	-	-	79.19	-
Total lablab intake(kg)	-	-	-	78.39
Total wheat bran intake (kg)	72	72	72	72
Cost of basal diet (ETB/head)	15.85	11.92	11.86	11.88
Cost of pigeon pea (ETB/head)	-	12.24	-	-
Cost of cow pea (ETB/head)	-	-	12.87	-
Cost of lablab (ETB/head)	-	-	-	12.74
Cost of wheat bran (ETB/head)	68.4	68.4	68.4	68.4
Additional labor cost (ETB/head)	-	55	50	53
Total variable cost	84.25	147.56	143.13	146.02
Selling price of sheep (ETB/head)	675.00	950.00	900.00	1000.00
Total return	25.00	300.00	250.00	350.00
Net return(ETB/head)	-59.25	152.44	106.87	203.98
Change in net return		148.38	107.24	201.46
Change in total variable cost		63.31	58.88	61.77
Marginal rate of return		2.34	1.82	3.26

The results suggested that supplementation of lambs fed hay basal diet with a forage legume; lablab was more profitable than supplemented with pigeon pea and cow pea. The difference in the net return among treatments could be possibly attributed to increased ADG due to the high CP and low ADL contents and possibly better protein quality in lablab that improved feed utilization efficiency of lambs.

5. DISCUSSION

5.1. Chemical Composition of Experimental Feeds

The DM content of the basal diet was comparable to the DM contents of 89% reported by Nigussie (2008) for Napier grass hay and 91.06% reported by Aschalew and Getachew (2013) for natural grass hay. On the other hand, the DM content of the basal diet was lower than 92.3% DM contained in dried grass hay (Biru, 2008). The observed CP content of the natural pasture grass hay was lower than 11.5% CP reported by Tessema (2000). However, the CP content of basal diet in the present study was higher than 6.70% reported by Aschalew and Getachew (2013). Meanwhile, the CP content of the basal diet was comparable to 7.7% and 7.9% CP reported by Taye (2004) and Nigussie (2008), respectively.

Even though the CP content of the basal feed, grass hay was lower than the other treatment diets as expected, its CP content was higher than the lower limit of 7% CP required for optimum rumen function (Van Soest, 1994). As a result, the natural pasture diet (T1) can be considered as adequate for maintenance requirement of animals in terms of its CP content. As reported by Topps (1995), when the CP content of roughages is below 7%, there will be impaired rumen function resulting in poor digestion of feeds, low DM intake and poor animal performance.

The NDF content of natural pasture grass hay observed in this study, was lower than 73.96% Aschalew and Getachew (2013) but higher than 62.50% (Biru, 2008). The ADF and ADL contents of native grass hay in the present study were also higher than 48.70% ADF and 8.51 % ADL and 43.6 ADF and 18.0% ADL contents reported by Aschalew and Getachew (2013) and Biru (2008) for natural pasture grass hay, respectively.

Based on the results, the DM, Ash, CP, NDF, ADF and ADL contents of wheat ban offered were 89%, 17.77%, 5.56%, 22.22%, 13.33%, and 6.03%, respectively. The DM, CP, ash and ADF were similar to the contents of 90.5%, 16.9%, 5.4% and 13.7% reported by Yenesew *et al*. (2013). While the DM, CP and ADF were lower than 93.5% DM, 23.08% CP and 43.83% ADL contents reported by Awet (2007), but higher in 87.38% DM, 3.96% ash, 8.27% ADF and 2.15% ADL contents reported by Fentie (2007). The variation might be due to the effect of processing in milling industries, the variety and the quality of the original grain used in the milling industries.

The DM, CP, ash, NDF, ADF and ADL contents of pigeon pea in this experiment were 89%, 17.5%, 8.87%, 46.66%, 33.33% and 14.55%, respectively, which were lower than 94.5% DM, 9.45% ash, but higher than 33.8% NDF and 29.4% ADF (Belete *et al*., 2012). The DM, CP, ash, NDF, ADF and ADL contents of cow pea in this experiment was 89%, 16.69%, 13.33%, 20%, 20% and 15.55%, respectively. According to Ajebu *et al*. (2013), higher (53.7 %) NDF, comparable (33.9%) ADF and lower ash (7.56%) contents obtained in cow pea. Solomon and Kibrom (2014) reported higher 13.6% ADL cow pea accession 12668, 12.1% ADL cow pea white wonder, 14.1% ADL cow pea accession 9333, 13.9% ADL cow pea small seed and 11.6% ADL cow pea black eyed varieties. The chemical composition of lablab in this study was 89% DM, 11.11% ash, 19.23% CP, 40% NDF 24.44% ADF and 6.66% ADL which was lower than 17.4% CP and 7.9% ash, but higher than 47.9% NDF, 38.6% ADF and 7.1% ADL Taye (2004). The reasons for the difference in the chemical composition of experimental forages used in the previous studies might be due to season, soil fertility and post harvesting management.

A review made by Andrea *et al*. (1999) on the nutritive values of *Lablab purpureus*, indicated that CP content of lablab leaves, which ranged from 14.3-38.5% was higher than the CP content of its stems, which ranged from 7.0-20.1%. The author also reported that lablab leaves contained 37.3%, 23.4%, and 4.4% NDF, ADF and ADL, respectively, which were lower than 61.9%, 49.4% and 9.1% NDF, ADF and ADL, respectively contained in the stems.

5.2. Feed and Nutrient Intake

The daily DM intake (DMI) of lambs fed the basal diet (T1) was lower ($P<0.001$) than daily DM intakes of lambs fed pigeon pea, cow pea and lablab diets (T2, T3 and T4). Lambs in the control consumed more DM of grass hay as compared to the legume supplemented treatments, because lambs were seeking to meet their nutrient requirement through the intake of relatively more grass hay than the other treatments, which had an alternative source of feed, concentrate supplements. The daily DM intake of sheep fed grass hay (T1) was lower than 540.5, 447.4 and 610.12 g reported by Fentie (2007), Bimrew (2008) and Abebaw (2007), respectively. The increase in total DM intake in the present study was in agreement with the result reported by Biru (2008). The feeding value of roughages such as natural pasture grass is usually limited because they are low in nitrogen, are high in ligno-cellulosic compounds and, therefore, low in fermentable carbohydrates (Preston and Leng, 1987). The higher nutrient intakes particularly higher CP intakes helped the lambs acquire protein required for growth better than the lambs on natural grass hay supplemented with wheat bran indicating the advantages of legume supplementation to improve intake of nutrients specially protein than basal diets. The increase in DMI and CPI as a result of supplementation of legumes to grasses was reported by (Abraha, 2013).

5.3. Body Weight Change and Feed Conversion Efficiency

The final body weight of the lambs in the control group (T1) was lower ($P<0.001$) than final body weights of lambs fed cow pea, pigeon pea and lablab. Among the supplemented legumes, Lablab resulted in higher ($P<0.001$) final body weights than T2 and T3. Nsahlai and Umunna (1996) reported that the nitrogen in lablab is rapidly degradable in the rumen which is useful to meet the requirements of rumen microorganisms for efficient degradation of low quality roughages. Similarly, Adu *et al*. (1990) reported that lablab supplementation to sorghum stover significantly improved CP digestibility and generally improved rumen fermentation of the test diets and improved live weight gains of sheep. The results of this study also agreed with the finding of

Negussie (2008) in lambs supplemented with napier grass with greenleaf desmodium or lablab, Aschalew and Getachew (2013) in lambs supplemented with raw, malted and heat treated grass pea (*lathyrus sativus*) grain, Getahun (2014) in Ethiopian lowland Afar and Blackhead Ogaden lambs supplemented with concentrates, Abebe *et al.* (2011) on body weight and carcass characteristics in Washera lambs fed urea treated rice straw supplemented with graded levels of concentrate mix, Melese *et al.* (2014) on feed intake and body weight change of Washera lambs fed urea treated finger millet straw, Yeshambel *et al.* (2012) in lambs fed mixtures of lowland bamboo (*Oxytenanthera abyssinica*) leaves and natural pasture grass hay, Abadi *et al,* (2014) in lambs supplemented with faba beans *(Vicia faba L.)* hulls and wheat bran on body weight change and carcass characteristics of Afar lambs fed hay as basal diet.

The ADG of lambs fed natural grass hay supplemented with wheat bran (T1) in the present study was higher than -5 g average daily weight gain of Tigray (Raya District) lambs fed sole natural grass hay (Abraha, 2013). Moreover, it was also higher than - 13.3 g/d ADG for lambs fed sole Rhodes grass hay (Feleke *et al.*, 2009), which was reported to be due to the low intake and low N content of the hay. The low CP and high NDF and ADF content of the hay offered in his study was not possibly enough to satisfy the maintenance requirement of animals and supplementation with protein sources could help in alleviating the possible body weight loss of the lambs.

5.4. Carcass Characteristics

The hot carcass weight (5.08 kg) recorded for lambs on the control treatment were smaller than the hot carcass weight (9.60 kg) recorded for lambs supplemented with lablab (T4). The average slaughter weight (SW) and empty body weight (EBW) were significantly ($P<0.001$) higher for lambs supplemented with 225 g lablab as compared to lambs supplemented with 243 g pigeon pea, 260 g cow pea and the control treatment . The dressing percentage (DP) were also significantly ($P<0.001$) higher for lambs supplemented with 225 g lablab as compared to sheep supplemented with 243 g pigeon pea, 260 g cow pea and lambs in the control treatment. The DP of lambs in T2 and T3 did not vary on empty body weight basis. Lambs in the control treatment had smaller rib-eye muscle area compared to those supplemented with forage legumes.

In agreement with the present study, Ermias (2008) reported that supplementation with barley bran; linseed meal and their mixtures of Arsi-bale lambs fed a basal diet of faba bean haulms had significantly higher slaughter weight, hot carcass weight, and dressing percentage than the non-supplemented lambs. Moreover, Mulugeta and Gebrehiwot (2013) also reported that sesame cake supplementation of lambs fed on wheat bran and teff (*eragrostis teff*) straw had significantly increased slaughter weight, hot carcass weight, and dressing percentage than the non-supplemented lambs. Berhan and Asnakew (2015) reported that the carcass yield of goats as measured by the average values of slaughter weight (SW), empty body weight (EBW), hot carcass weight (HCW), dressing percentage (DP) and rib eye area (REA) was superior for concentrate-supplemented groups. Biru (2008) reported that rib-eye muscle area was improved in Adilo lambs supplemented with sweet potato tuber and haricot bean screenings. Hirut *et al*. (2011) also reported that rib-eye muscle area was increased in Hararghe Highland lambs fed on concentrate supplementation. Assefu (2012) observed that rib-eye muscle area was increased in Washera and Horro lambs fed different roughage to concentrate ratio.

The control group had significantly lower ($P<0.001$) DP on empty body weight basis than the supplemented treatments, but there was no significant ($p>0.001$) difference between T2 and T3 supplemented treatments. The Dressing percentage values on empty body weight basis was higher than on slaughter weight basis, implying the influence of digesta (gut fill) on dressing percentage. In agreement with this study, Hirut *et al*. (2011) reported that heavier empty body weight for the supplemented group than the control.

There was a significant difference ($P<0.001$) due to supplementation on empty gut, total fat, tail and TEOC. In line with the present study, Hirut *et al*. (2011) reported relatively lower TEOC which were 2.22 kg for the control and 4.19 kg for supplemented group. Abadi (2014) reported higher TEOC, 3605 g for T1 (control) and 6044 g for 45 g NSC + 200 g WB + 100 g FBH supplemented lambs. Amare (2007) reported comparable TEOC, 2.38 kg for the control and lower TEOC 3.17 kg for the supplemented. Ermias (2008) also reported significantly higher TEOC in Arsi-bale lambs supplemented with barley bran, linseed meal and their mixtures than fed basal diet of faba bean haulms (4.2 kg vs. 2.5 kg).

The amount of blood was significant higher ($p<0.001$) for T4>T2>T3>T1. There was no a significant difference ($p>0.001$) in gut content due to forage legumes supplementation. The lack of significant difference in gut content between control and supplemented lambs in the current study might be due to similarity in the degradability and escape of the forage legumes that neither of the feeds staying longer in GIT. In this study most of the non-edible offal components were not significantly affected ($p>0.001$) by diet.

In line with the present study, Assefu (2012) reported that gut content of lambs fed different roughage to concentrate ratio was similar between all the treatment groups. Biru (2008) reported TNEO was not significantly different ($p>0.001$) in lambs fed on sweet potato tuber and haricot bean screenings in Adilo lambs. Similar results were reported by Mulugeta and Gebrehiwot (2013), who studied on effect of sesame cake supplementation on feed intake, body weight gain, feed conversion efficiency and carcass parameters in the ration of lambs fed on wheat bran and teff (*eragrostis teff*) straw.

5.5. Partial Budget Analysis

The marginal rate of return indicated that each additional unit of 1 ETB per sheep cost increment resulted in 1 ETB and 2.34, 1.82 and 3.26 ETB benefit for T2, T3, and T4, respectively.

The net return from the supplemented experimental treatments was 152.44, 106.87 and 203.98 ETB per head for T2, T3 and T4 respectively. The difference in net return was in a similar trend with their weight gain, i.e., lambs in control group almost remain the same weight and resulted in the lowest net return, while lablab group resulted in higher ADG and recorded the highest net return. Generally, lambs that have a better nutrient intake had superior ADG, as a result of which they fetched higher sale price, and earn higher net return. The difference in the control and treatment was due to the difference in live weight change of the lambs in each treatment, which was a function of differences in feed quality and feed conversion efficiency. The higher net return in T4 was due to the quality of protein and the lower ADL (6.66%) contained in lablab supplementation, which resulted in higher body weight gain (49.36 g/day/lambs) as compared to the other treatments that had body weight gain of 3.1 g/day/sheep, 34.97 g /day/ lambs and 20.33 g /day/ sheep for T1, T2 and T3 respectively. This indicates that lambs fed with better quality feed perform well and have higher body weight gain and sold at maximum price and earn better net return.

Similar to this result, Mulugeta and Gebrehiwot (2013) studied on the effect of sesame cake supplementation on feed intake, body weight gain, feed conversion efficiency and carcass parameters in the ration of sheep fed on wheat bran and teff (*eragrostis teff*) straw had shown good economic return in the supplemented group, Abebe (2006) also observed that supplementation with linseed (*Linum usitatissimum)* cake, wheat bran and their mixtures on feed intake, digestibility, live weight changes, and carcass characteristics in intact male Arsi-bale sheep were economically beneficial, Tesfa *et al.* (2013) studied on effect of supplementing grazing Arsi-bale sheep with molasses-urea feed block on weight gain and economic return under farmers' management condition, Aschalew and Getachew (2013) observed that better economic return sheep fed on raw, malted and heat treated grass pea (*Lathyrus sativus*) grain.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This experiment was conducted to study the effects of supplementation with forage legumes namely: pigeon pea, cowpea and lablab on feed intake, body weight change and carcass parameters of lambs. Sixteen intact male Wollo *Tumele* lambs with an average initial live weight of 18.8±0.35 kg (mean ± SD) were used in the feeding trial. The feeding treatments consisted of *ad libitum* feeding of natural pasture grass hay plus 200 g DM wheat bran (control) and T2, T3 and T4 were additionally supplemented with 243, 260 or 225 g DM per head per day of pigeon pea, cowpea and lablab, respectively. A randomized complete block design (RCBD) was used to conduct the feeding trial. Carcass evaluation was made at the end of feeding trial.

The CP content of natural pasture grass hay was sufficient to meet the maintenance requirement, but was relatively low meet the growth demands of lambs, indicating the need for supplementation for body weight gain. The chemical analyses results of the protein supplements showed that the supplements forages were high in CP content.

A superior daily live weight gain was recorded in lambs supplemented with lablab (49.36 g/d) followed by pigeon pea (34.97 g/d) and cowpea (20.33 g/d). On the other hand, the average daily gain of the lambs in the control group was inferior. However, a positive average daily gain (3.1 g/d) was also achieved for lambs in the control group indicating that the kind of natural pasture grass hay used in the current trial supplemented with 200 g wheat bran was adequate to meet the growth requirements of the lambs. Feed conversion efficiency (FCE) was 0.006, 0.053, 0.031 and 0.075, respectively for the control, pigeon pea, cow pea and lablab treatments. The FCE was significantly higher ($P<0.001$) in the order of lablab followed by pigeon pea and cow pea supplemented lambs compared to the control group. Similarly, slaughter weight, empty body weight, hot carcass weight and dressing percentage on slaughter weight basis were higher in lambs supplemented with lablab, pigeon pea and cow pea as compared to control group.

The mean rib eye muscle area was 3.54 cm^2 for control lambs and 7.03 cm^2, 6.63 cm^2 and 8.29 cm^2 for T2, T3 and T4, respectively. The results of this study showed that there was a significant difference ($P<0.001$) due to supplementation on heart, empty gut, total fat, tail and TEOC. But, the control lambs had similar ($P>0.001$) head and tongue and testis. Gut content, penis, skin and feet and TNEOC did not differ significantly ($p>0.001$) due to forage legumes supplementation.

The assessment of the feeding value of the forage legumes would be simpler when looking at the feed efficiency and differences in weight gains between lambs supplemented with the forage legumes and the control.

Therefore, the forage legume supplements were ranked based on CP. According to this ranking and the feed conversion efficiency data, it was concluded that supplementation of 225 g/d lablab with 200 g/d wheat bran under the feeding conditions where this study was conducted resulted in a better live weight gain, total DM and/or nutrient intake and carcass yield of Wollo *Tumele* lambs. Therefore, lablab, pigeon pea and cowpea could be recommended in that order to supplementing intact Wollo *Tumele* lambs for improved feed intake, growth and carcass characteristics.

6.2. Recommendations

Based on the study results, the following could be recommended.

- Awareness should be created among farmers about the significance of supplementing forage legumes particularly, lablab.
- Grass hay based feeding of lambs should be supplemented with low cost supplementary feeds (lablab, pigeon pea and cowpea) for higher economic return.
- A study on the digestibility and rumen degradability characteristics of experimental forage legumes (lablab, pigeon pea and cowpea) should be carried out to better understand the significance of forage legume supplements for feeding ruminants.

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8. APPENDICES

Appendix table 1. Analysis of Variance of DMI (g) in feeding trial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	50493.44755	16831.14918	2056.37	<.0001
Error	12	98.21862	8.18488		
Corrected Total	15	50591.66617			

Appendix table 2. Analysis of Variance of CPI (g) in feeding trial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	5338.884698	1779.628233	1339.52	<.0001
Error	12	15.942669	1.328556		
Corrected Total	15	5354.827367			

Appendix table 3. Analysis of Variance NDFI (g) in feeding trial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	6039.590063	2013.196688	67.08	<.0001
Error	12	360.129449	30.010787		
Corrected Total	15	6399.719512			

Appendix table 4. Analysis of Variance ADFI (g) in feeding trial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2409.044831	803.014944	145.33	<.0001
Error	12	66.305578	5.525465		
Corrected Total	15	2475.350409			

Appendix table 5. Analysis of Variance ADLI (g) in feeding trial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1385.461107	461.820369	930.02	<.0001
Error	12	5.958861	0.496572		
Corrected Total	15	1391.419968			

Appendix table 6. Analysis of Variance of initial body weight (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.64602500	0.54867500	18.36	.0843
Error	12	0.20955000	0.01746250		
Corrected Total	15	1.85557500			

Appendex table 7. Analysis of Variance of final body weight (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	37.77172500	12.59057500	285.37	<.0001
Error	12	0.52945000	0.04412083		
Corrected Total	15	38.30117500			

Appendix table 8. Analysis of Variance of total body weight gain (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	38.18945000	12.72981667	493.16	<.0001
Error	12	0.30975000	0.02581250		
Corrected Total	15	38.49920000			

Appendix table 9. Analysis of Variance of ADWG (g) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	4714.746914	1571.582305	493.16	<.0001
Error	12	38.240741	3.186728		
Corrected Total	15	4752.987654			

Appendix table 10. Analysis of Variance of slaughter weight (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	95.46907500	31.82302500	514.03	<.0001
Error	12	0.74290000	0.06190833		
Corrected Total	15	96.21197500			

Appendix table 11. Analysis of Variance of empty body weight (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	131.1571687	43.7190562	1058.95	<.0001
Error	12	0.4954250	0.0412854		
Corrected Total	15	131.6525937			

Appendix table 12. Analysis of Variance of empty body weight (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	46.33302500	15.44434167	751.09	<.0001
Error	12	0.24675000	0.02056250		
Corrected Total	15	46.57977500			

Appendix table 13. Analysis of Variance of dressing percentage on slaughter weight basis (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	280.6465407	93.5488469	107.26	<.0001
Error	12	10.4659086	0.8721591		
Corrected Total	15	291.1124493			

Appendix table 14. Analysis of Variance of dressing percentage on empty body weight basis (kg) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	34.18317147	11.39439049	6.10	0.0092
Error	12	22.42739859	1.86894988		
Corrected Total	15	56.61057006			

Appendix table 15. Analysis of Variance of rib-eye muscle area (cm^2) of sheep

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	48.84031875	16.28010625	526.47	<.0001
Error	12	0.37107500	0.03092292		
Corrected Total	15	49.21139375			