BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

ON-FARM EVALUATION OF THE EFFECT OF PROCESSED SWEET LUPIN GRAIN SUPPLEMENTATION ON GROWTH PERFORMANCE AND ECONOMIC FEASIBILITY OF DOYOGENA SHEEP IN DOYOGENA DISTRICT, SOUTHERN ETHIOPIA

MSc Thesis Research

By

Habite Tilaye Wassie

November 2021

Bahir Dar, Ethiopia

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSc) IN FEEDS AND ANIMAL NUTRITION

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THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Sciences (MSc) thesis open defense examination; we have read and evaluated this thesis prepared by **Habite Tilaye Wassie** entitled "**On-Farm Evaluation of the Effect of Processed Sweet Lupin Grain Supplementation on Growth Performance and Economic feasibility of Doyogena Sheep in Doyogena District, Southern Ethiopia**''. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc) in **Feeds and Animal Nutrition**.

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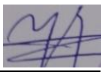
Yeshambel Mekuriaw (Dr.)		30/10/2021
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DECLARATION

This is to certify that this thesis entitled **"On-Farm Evaluation of the Effect of Processed Sweet Lupin Grain Supplementation on Growth Performance and Economic feasibility of Doyogena Sheep in Doyogena District, Southern Ethiopia"** submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in "**Feeds and Animal Nutrition** "to the Graduate Program of the College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Habite Tilaye Wassie** (ID.No.BDU1100818) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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STATEMENT OF THE AUTHOR

The author declares that this thesis is his bonafide work and that all sources of materials were 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 Bahir Dar University and deposited at the University Library and available to borrowers under the rules of the Library. The author declares 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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This thesis work is one of the greatest achievements of my life and I dedicate it to my parents; Mr. Tilaye Wassie, Mrs. Ehitnesh Mesfin, and Mrs. Mulu Tilaye for their love, support, and interest for me to complete my study.

LIST OF ABBREVIATIONS/ACRONYMS

ADF	Acid Detergent Fiber
ADG	Average Daily Gain
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BDU	Bahir Dar University
BW	Body Weight
CBBP	Community-Based Breeding Program
CF	Crude Fiber
CP	Crude Protein
CGIAR	Consultative Group on International Agricultural Research
CPY	Crude Protein Yield
CRP	CGIAR Research Program
CSA	Central Statistical Agency
DM	Dry Matter
DE	Digestible Energy
DDANRO	Doyogena District Agricultural and Natural Resource Office
DOM	Digestible Organic Matter
EE	Ether Extract
FAO	Food and Agricultural Organization of the United Nations
FBW	Final Body Weight
FCE	Feed Conversion Efficiency
GDP	Gross Domestic Product
GLM	General Linear Model
IBW	Initial Body Weight
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
NPH	Natural Pasture Hay
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SNNPR	Southern Nation, Nationalities, and Peoples' Region

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By

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ABSTRACT

The study was carried out in Doyogena district, Kembata Tembaro Zone, southern Ethiopia. The objective of the study was to evaluate the effects of supplemental processed sweet lupin grain on feed intake, nutrient digestibility, and growth performance of yearling Doyogena sheep and estimate the economic return of processing options when the sheep fed a basal diet of natural pasture hay. Twenty-four yearling male sheep with initial body weight of 27.53 ± 2.67 kg (mean ± SD) were used for the experiment. Before starting the experiment, the animals were quarantined for 21 days and vaccinated for common small ruminant diseases including anthrax and pasteurellosis, de-wormed, and sprayed against internal and external parasites. Afterward, all experimental sheep were adapted for 15 days to the treatment feeds. The experiment involved 90 days and followed by a digestibility trial of 7 days. The experiment was laid out in a randomized complete block design (RCBD) with six blocks consisting of four animals per block based on their initial body weight. Animals in each block were randomly assigned to one of four dietary treatments. The dietary treatments were comprised of supplementation of concentrate mixture (T1), roasted coarsely ground sweet lupin grain (T2), soaked sweet lupin grain (T3), and steamed sweet lupin grain (T4). The concentrate portion was composed of noug (Guizotia abyssinica) cake (30%), wheat bran (35%), coarsely ground maize grain (35%), and salt (1%). Natural pasture hay was offered as a basal diet ad libitum (~20% refusal). The amount of supplement offered was 440 g/day/head-on dry matter basis. The daily supplement was divided into two equal portions, with the first provided in the morning and the second in the afternoon. Water and salt licks were available freely. The pasture hay used as a basal feed in the current study contained 6.8% crude protein (CP), 73.1%

*neutral detergent fiber (NDF), and 43.6% acid detergent fiber (ADF).The mean processed sweet lupin grain contained 33.75% crude protein, 88% digestible protein, and 85% metabolizable energy content. Sheep consumed control diet was lower ($p<0.001$) basal dry matter intake (378.79 g/day/head) as compared to the sweet lupin supplemented group (T2-T4). Total DM intake was higher for the sheep under the (T2-T4 treatments) compared to the control (T1). Sweet lupin supplementation significantly improved the digestibility of DM, OM, CP, NDF, ADF, final body weight(FBW), feed conversion efficiency(FCE), and average daily gain($P<0.001$). Economic analysis showed that supplementation with T4 resulted in the highest net returns followed by T3 and T2. The sheep fed steamed sweet lupin grain in (T4) had the highest net return was observed in (*3111.92 *ETB) and highest MRR in ratio (*53.35*). The sheep supplemented with concentrate mixture in (T1) had the lowest net return (*1695.89 *ETB) as compared to the other supplemented treatments. Thus, it can be concluded that supplementation of processed sweet lupin grain could enhance animal performance through improved intake, digestibility, and weight gain. From this study, it appears that supplementation of natural pasture hay with 440g/day/ head processed sweet lupin grain is biologically efficient and potentially profitable in the feeding of Doyogena sheep.*

Key Words*:-Body weight gain, Digestibility, Doyogena sheep, Feed intake, processed sweet lupin grain*

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Chapter 1. INTRODUCTION

1.1. Background and Justification

Ethiopia has the largest livestock population in Africa with an estimated population of 70 million cattle, 52.50 million goats, 57 million poultry, 42.9 million sheep, 13.33 million equines and 8.1 million camels, (CSA, 2021). This immense untapped livestock resource is scattered across diverse agro-ecologies. According to the report of (FAO, 2017) and (CSA, 2021), livestock plays a vital role in generating income for farmers, creating job opportunities, ensuring food security, providing services, and sustaining livelihoods. The livestock sub-sector still has an unlimited contribution to the country's economic development and livelihoods of many households. The sector serves as a major source of currency earnings and delivers important products and services (FAO, 2017) and thus has an enormous contribution to the national economy and livelihood of lots of Ethiopians.

On the other hand, the current livestock output and contribution to the country's economy are lower than its expected value and the productivity remained too low to satisfy the food requirement of the ever-growing human population in the country (CSA, 2021). This is related to several complex and inter-related factors like poor husbandry, inadequate supply of quality feed and inefficient use of locally available feed resources (Netra P Osti, 2020), widespread diseases, the poor genetic potential of local breeds, and inefficiency of livestock development services relating to credit, extension, and infrastructure (Tamrat Gebiso, 2018).In addition, the demand for livestock products still did not match the supply, due to urbanization, increasing population, and an improving economic situation (CSA,2020).

Thus, to exploit this huge potential of livestock products and productivity, the country needs to address the major technical and non-technical constraints of the livestock sector. One of the major technical constraints that hinder animal production and productivity is the shortage of feeds in terms of both quality and quantity (FAO,2018) and (CSA,2020). and its accessibility and quality are not favorable year-round, hence body weight gains made in the wet season are totally or partially lost during the dry season (Alemayehu Mengistu, *et al*., 2017).

In Ethiopia, sheep has a multipurpose role for smallholder farmers as sources of income, meat, skin, manure, and long hairy fleece (Hizkel Kenfo, 2021). As a result, increasing the current level of productivity of sheep is essential to meet the food and non-food demands of the increasing human population (Mesfin Lakew *et al.*, 2018). However, sheep production in the country is characterized by low productivity in terms of growth rate, meat production, and reproductive performance (Kefyalew Alemayehu, 2018). Due to reasons that include inadequate feed and nutrition, widespread diseases, poor breeding practices, and inadequate livestock development policies relating to extension, marketing, credit, and poor infrastructure (Diriba Lelisa and Kebede Taye, 2020).

Besides, the low performance of sheep in terms of LW gain and carcass yield is mainly due to inadequate nutrition associated with reliance on sole natural pasture, crop residues, and stubble grazing, which are inherently low in nutrients availability, being subjected to great seasonal variations (Ata & Obeidat, 2020). Temporally abundance of forage during short rainy season followed by long dry periods with feed deficit leads to diminish live weight gain and loss of animals. As a result, farmers get low benefit from selling live animals that are in poor body condition. In Ethiopia, most sheep reared by farmers have low body weight and poor body condition especially during the dry period where there are not enough protein supplemental feeds.

Furthermore, consumers did not get normally high quality and quantity meat from these animals. For this reason, introducing promising sheep fattening practices can increase efficient utilization of available feeds to improve animal's body condition, increase the meat yield and quality which consequently increases the income of farmers. Agro-industrial by-products are often limited in availability and when available, the costs are increasing at a very fast rate for producers (Demissie Negash, 2018). This problem can be mitigated by supplementation of protein source and agro-industrial by-products (commercial concentrate) to low-quality (tropical grass hay) to improve the intake and digestibility of roughages that increase daily weight gain and FCE of sheep (Ajebu Nurfeta, *et al.,* 2018). Commercial concentrates and agro-industrial by products are commonly available to improve the quality of feed rations; however, their cost is prohibitive to most farmers. Thus, it is imperative to identify indigenous good-quality supplemental feed resources that are locally available to livestock farmers.

Lupin (*Lupinus spp*.) is a rich source of proteins, lipids, minerals, dietary fibers, vitamins, polyphenols, and bioactive peptides which are easily consumed and digestible by livestock and humans compared to that of other legumes proteins (Pastor Cavada *et al.,* 2009). Sweet lupin is one of the leguminous crops that were recently introduced in Ethiopia. Sweet blue lupin (*Lupinus angustifolius* L.) grain cultivar Sanabor has the potential to substitute commercial concentrate in the diet of sheep due to its high crude protein content, high palatability, and low alkaloid content relative to the better white lupin (*Lupinus albus* L.) (Likawent Yeheyis *et al*.,2012). As opposed to the local bitter lupine variety which has high alkaloid content sweet lupine has minimal levels of secondary metabolites, and the grain's CP content is high (35%); this makes suitable for use as food and feed (Melkamu Bezabih, *et al*.,2021). It is widely adapted to different soil types and has relatively good performance across various locations compared to the other crop species in the country (Fikadu Tessema, 2017). It has a grain yield of 2.98 t/ha in mid altitudes regions of Lemo district, Hadiya zone, southern Ethiopia (Fikadu Tessema, 2017).

Sweet lupin grain can be used as an alternative home-grown protein supplemental feed to alleviate the livestock feed shortage problem in the country (Molla Haile, *et al*., 2017). It has a relatively high content of CP (34.35 %), and digestible organic matter (86.28%), and a low alkaloid content relative to the better domestic lupin (Lupinus spp.)(Yenesew Abebe *et al*., 2015). In a study conducted for 69 days using Washera sheep offered 290 g/head/day sweet lupin grain as a supplement, an average daily gain of 74 g was reported (Likawent Yeheyis *et al*., 2012). The same authors reported that this ADG is within the range of 73.7 - 91.3 g/day attained when alternative protein supplements like concentrate mixture and sweet blue lupine seed are fed to Washera sheep. However, considering the high content of CP, processed sweet lupin grain may have the potential to affect higher ADG. It is hypothesized that processing sweet lupin may make the CP in the grain more available and improved the intake and digestibility of the sheep.

Domestic processing methods, like soaking, cooking (traditional roasting, microwave, pressure), and baking and industrial processing, autoclaving, baking, and extrusion are used to improve the consumption of legumes seeds/grains (Drulyte & Orlien, 2019). The same authors reported that the protein digestibility increases after processing by the different methods. Thus, sweet lupin is one of the grain legumes which can be processed in the form of roasted and coarsely ground, soaked, and steamed.

However, sheep fattening performance under using processed sweet lupin grain was scanty which otherwise can solve critical nutrient problems for sheep. Therefore it was much curtailed to investigate the comparative roles of different processed sweet lupin grain as a supplement for fattening local sheep.

1.2.Statement of the Problem

Natural pasture, crop residues, agro-industrial by-products, improved forage, and stubble grazing are the major feed resources for ruminant livestock in Ethiopia (Alemayehu Mengistu, *et al*; 2017; CSA,2018). Nevertheless, they have low nutritional value and accessibility. Consequently, the poor performance of livestock in the country is due to seasonal inadequacy of feed, both in quantity and quality. These deficiencies have rarely been corrected by preservation and supplementation, often for lack of infrastructure, technical know-how, and poor management. Besides, many feed resources that could have a major impact on livestock production remain underutilized and underdeveloped.

Sweet lupin grain is an important source of proteins, carbohydrates, fiber, vitamins, and some minerals (Likawent Yeheyis *et al.*,2011). Ethiopia produces from 2.2 to 4.8 tons per hectare of sweet lupin grain annually depending on the agro climatic zone and other environmental factors cited by (Fikadu Riga,*et al*., 2021). However, lupin species contain quinolizidine alkaloids (Reinhard H, *et al.*, 2006). They are often referred to as “bitter” when the total content of alkaloids is higher or equal to 10,000 mg/kg dry seeds and “sweet” when the content is lower or equal to 500 mg/kg dry seeds. It can cause toxicity in sheep through either alkaloid poisoning or mycotoxicosis (Waghorn GC *et al.*,2002) .The quinolizidine alkaloid poisoning affects sheep to a greater extent than goats or cattle and can be a major cause of mortality in sheep (Waghorn GC *et al.*,2002) .

Various processing practices can be used to reduce the alkaloids (Gremigni, P *et al*., 2001). Some of the practices include soaking, roasting, boiling, germination, fermentation, alkaline treatment (Joray *et al*., 2007). According to (Erbas and Uslu ,2004), most alkaloids present in lupin are water-soluble and the alkaloid level was (0.5 - 4%) can various processing practices such as soaking in running water and by scalding. Traditional processing methods of lupin seeds in Ethiopia have been reported to improving the nutrient content and reducing the alkaloid content of the seed (Likawent Yeheyis, *et al*., 2011). Various methods are used to process better white lupin for use as feed for livestock's as well as human beings. However, there are no studies on the effects of the various processing options of sweet lupin grain, nor has the economic feasibility of the processing options been studied.

1.3. Objectives

1.3.1. General objective

The overall objective of the study was to evaluate the effect of processed sweet lupin grain supplementation on the growth performance of Doyogena sheep and the economic feasibility of the processing options in Doyogena district, Southern Ethiopia.

1.3.2. Specific objectives

- To evaluate the dry matter intake ,nutrient digestibility and growth performance of sheep supplemented with processed sweet lupin grain
- To estimate the cost-benefits of different processing options of sweet lupin grain in the diet of fattening rams

Chapter 2. LITERATURE REVIEW

2.1. Status and Sheep Production Systems in Ethiopia

The domesticated sheep has a diversity of genotypes that are adapted to a wide variety of environments ranging from the tropics to the extreme seasonality of the high latitudes and from deserts to high rainfall areas. This diversity of genotypes (with over 2000 breeds) means that the species is highly adaptable to environmental or climate extremes, and to some degree, this adaptability is also expressed in variation in the expression of natural behaviors (Morris., 2017). Among these, Ethiopia has a diverse sheep population and its distribution is paralleled with its diverse ecology. Ethiopia's sheep population is estimated at 42.9 million (CSA,2021).It is grouped into 14 indigenous sheep populations with more than 18 breed types widely distributed across the different agro-ecological zones (Solomon Gizaw *et al.*,2007). However, sheep are reared mainly through smallholder farmers and grazed in small flocks on open natural pasture and crop residue (CSA, 2021). According to the report of (Petrovic..*et al*.,2011), indigenous sheep breed productivity and performance are varied due to environmental factors. These variations in performances of sheep in Ethiopia are also aroused from within and between breeds, management practice, and across the agro-ecologies. Furthermore, sheep production and productivity are low in the country due to several technical (genotype, feeding, and animal health), institutional, environmental, and infrastructural constraints (CSA,2021).

In the country, indigenous sheep breeds have great potential to contribute more to the livelihoods of the people (Meseret Molla, 2020). However, the total annual meat production that comes from sheep is (25%) (FAO, 2009). At the national level, sheep and goats are contributed to 90% of the live animal or meat and 92% of skin and hide export trade value (FAO,2009). In addition, in the lowlands, sheep meat consumption with other livestock is the basis of the pastoral livelihoods. Beside, sheep and goats provide about 12% of the value of livestock products consumed and 48% of the cash income generated at the farm level, 25% of the domestic meat consumption, and 46% of the value of national meat production. Both Sheep and Goat, contribute 20.9 and 16.8% of the total ruminant livestock meat output or about 13.9 and 11.2% of the total domestic meat production, with a live animal and chilled meat export surpluses respectively (FAO,2009).

According to the report of Ameha Sebsibe, (2008), per capita consumption of sheep and goat meat (kg/person per year) in Ethiopia is 8 kg while the global average is 38 kg (104g/day). They are the major suppliers of meat for rural communities, especially during periods of public festivals (Tsedeke Kocho, 2007). However, the annual off-take rate for sheep is estimated to be 33% (EPA, 2002) with an average carcass weight of about 10 kg, which is the second-lowest of the sub-Saharan African countries (FAO, 2009). Additionally, sheep production provides an opportunity for smallholder farmers that requires low initial capital and can use the marginal land as well as crop residues for feeding and care-taking of sheep can be carried out by any family members. Similarly, Getachew Animut *et al*., (2010) reported that sheep enterprise in Ethiopia is getting used as a cash income and provides social security within the bad crop years. In general, many scientific findings have been conducted by various researchers on the biological and socioeconomics of indigenous sheep in the country. This diverse sheep genetic resource is distributed in the highland and lowland areas in the country(Solomon Gizaw *et al*.,2009).

Moreover, sheep production systems are one of the major parts of the livestock production system in Ethiopia (Adane Mezgebu, 2017). They are classified using criteria that included a level of integration with crop production and contribution to livelihood, level of input and intensity of production, agro-ecology, length of the growing period, and relation to land and type of commodity to be produced (Getachew Molla, *et al.*,2017). Based on the above classification criteria, the sheep production system practiced in the country is Highland sheep-barley system, mixed crop-livestock system, pastoral and agro-pastoral production system, ranching, and Urban and peri-urban sheep production system (Worku Anteneh and Yadav ., 2017).

Commonly, in the country, there are three major sheep production system such as highland sheep–barley system, mixed crop-livestock system, and pastoral and agro-pastoral production systems and two minor production systems (not currently practiced widely) such as ranching and urban and peri-urban (landless) sheep production system are described (ESAP, 2017). The same author reported that the major sheep production system in Ethiopia particularly SNNPR is a mixed Enset (Kocho) crop-livestock system with farmers keeping especially ruminants to different extents in small areas.

2.1.1. Mixed crop-livestock farming system

In the mixed farming systems of the highlands, sheep mostly depend on grazing fallow lands, natural pasture, and crop residues with no extra supplement and receive minimum health care. In humid, sub-humid, and highland agro-ecological zones, sheep are kept by smallholders and graze together with goats and other livestock such as cattle (Yoseph Mekasha, 2007). Thus, productivity is low due to nutritional stress for much of the year and carry heavy internal and external parasite burdens (EARO 2000). Beside, the increased human population has led to decreased farm size and a gradual shift from keeping large to small ruminants, mainly sheep (Peacock, C 2005) in central Ethiopia.

2.1.2. Agro pastoral and pastoral system

In the pastoral system, even if there is cultivation in some areas, livestock production forms an integral part of socio-economic life for the vast and diverse human population (Alemayehu Mengistu, 2017). In the lowlands of Ethiopia, livestock is comprised of large flocks and herds of sheep and goats, cattle and camels mainly transhumant, where the only surplus is sold at local markets or trekked to major consumption centers. Sheep are highly produced in pastoral and agro-pastoral systems. Relatively larger flocks are maintained in the lowland (agro-pastoral systems). The major feed resources for sheep include grazing on communal natural pasture, crop stubble, fallow grazing, roadside grazing, crop residues, browses, and non-conventional feeds (household food leftovers, weeds, crop tillers, and fillers). Production of improved forages, improvement of low-quality feed sources such as crop residues, and supplementary feeding (except fattening) are almost non-existent (Solomon Gizaw, *et al.*,2008).

2.1.3. Urban and peri-urban (landless) system

This system is the production of small ruminants within and at the periphery of cities. Quantitative data is not available on the importance of urban and peri-urban production systems but it is common to observe sheep and goats in urban areas including the capital city of the country, Addis Ababa. Feed resources are usually leftovers from home, market area, mill by-products, and roadside grazing (particularly in the peri-urban system) (Solomon Gizaw *et al.*, 2008).

2.1.4.Highland sheep-barley system

This production system prevails in the high altitude areas (above 3000 m.a.s.l.) where the major crops grown are barley and pulses such as faba beans, lentils, etc. Sheep are the dominant livestock species. The main feed resource-base includes wasteland grazing, stubble, and sometimes straw. Sheep flock sizes range from 30 to several hundred heads. Although sheep are reared mainly for meat, skins and coarse wool production for the cottage industry of the central highlands are subsidiary products (Solomon Abegaz, *et al.*, 2008).

However, in southern Ethiopia, particularly in Doyogena district, Enset based farming or mixed crop-livestock production system is an indigenous and sustainable agricultural system (Belay Elias *et al* ., 2018). The district has favorable agro-ecology for sheep producing and they follow enset-crop-livestock production system (Feleke Assefa *et al*.,2015). Enset ventricosum is a staple food in the area. The same author states that the local breeds have better productive and reproductive potentials. However, due to the shortage of capital, lack of credit on required time, land scarcity, feed shortage, awareness problem and poor husbandry system, the district in general and the rural sheep producing households in particular have not been sufficiently benefited from the sheep production sub sector.

2.2.Description of Doyogena Sheep Breed

Doyogena sheep are among the sheep breeds reared in the Enset crop-livestock production system in Kembata Tembaro zone, SNNPR state; Ethiopia. The earlier studies showed that this breed was known by different names, for instance, Tibbo Markos,(2006) reported that sheep population found in the Kembata Tembaro zone under the Arsi Bale breed, and also Tsedeke Kocho,(2007) reported that Doyogena sheep named as Adilo or Kembata area sheep population. https://www.slideshare.net/ILRI/ethiopia-vct-updatejun 2014, in the report of (Deribe Gemiyo *et al.*, 2014), Doyogena sheep was named by Wolyita sheep ecotype. Previously in 2013, a team of researchers from Areka Agricultural Research Center partnership with ICARDA conducted a value chain analysis of Doyogena sheep Ashenafi Mekonnen *et al.*,(2013). The report indicated that the Doyogena district is the main source of sheep where as Adilo is a large sheep market place sourced from Doyogena, Alba, and Wolyita area. For the most part, sheep flocks including lambs, ewes, and rams from the Doyogena market are transported to the Adilo market, and then purchased by big and small traders. Accordingly, smallholder farmers found in and around the Adilo area purchase sheep to fatten or for breeding purposes from Doyogena. For that reason, the sheep is named after the market place (Adilo). However, in the report of Melesse Aberra *et al.*, (2013), the morphologic and qualitative traits of the sheep population found in the Kembata Tembaro zone were significantly different from the sheep found in the Wolyita area. In the report of Zelalem Abate, (2018), Doyogena sheep were distributed through Wolyita, Hadiya, and Kembata Tembaro zones, called Adilo sheep some year ago, and currently called Doyogena sheep.

Similarly, Doyogena sheep, named Adilo sheep, are a breed of sheep reared in Kembata Tembaro zone in Doyogena district of Southern Nations Nationalities and Peoples Regional (SNNPR) state, Ethiopia (Solomon Gizaw *et al*.,2007). It is one of the common sheep found in the Doyogena district, extending to Wolyita, Kembata, and Hadiya peoples in the region. They are potential breeds of Ethiopia reared in the mixed perennial crop and livestock production system with better market preferences in the local market, Shashemene market, and Addis Ababa (Tsedeke Kocho, 2007).

According to the previous study of (Mengiste Taye, *et al*.,2016), Doyogena sheep is characterized and well known for its twining ability. The sheep have attractive morphological features grouped in the long fat-tailed and a great potential for twining and fattening. As compared to other local breeds of the country, Doyogena sheep is better in most of the morphological characteristics and their growth performance. The birth weight, weaning weight, and 6-month weight of Doyogena sheep were 3.05±0.025, 14.8±2.49, and 22±0.22 kg respectively.

Figure 2.1. Typical castrated, fattened, and marketing Doyogena sheep breed in the market (Photo courtesy by author)

In addition, the sheep was characterized as being large, horned with a long fat tail. The mean age at first breeding of Doyogena sheep is 241 and 240 days for female and male sheep, respectively. The same author reported the twinning rate of Doyogena sheep to be 1.45±0.45. In the other study, Tsedeke Kocho, (2007) reported age at first lambing of this sheep is 378 days for lambing.

Doyogena ewes are prolific with high incidences for multiple births with occasional triplet and quadruplet's (Ayele Abebe, 2018). Through the introduction of CBBP for the Doyogena sheep breed for the last six years, more than 600 breeding rams were produced from the Doyogena sheep breeder cooperative and distributed in different agro-ecologies of the region. Survey report indicated that Doyogena rams were more preferred by the farmer for their ability to mate more ewes, for their attractive coat color, and for their ability to produce multiple births compared with Bonga and Dorper rams (Kebede Habtegiorgis, 2017). The breed has attractive morphological features with a great potential for fattening (Mengiste Taye, *et al*., 2016). However, like other breeds of Ethiopia, the productivity level is below its genetic potential due to low level of management, high incidence of disease, and lack of knowledge of farmers to use an appropriate breeding strategy that is suitable for the production system under which the breed is kept (ESGPIP,2008), (Tesfaye Getachew *et al*.,2010), (Mengistie Taye *et al.*,2016).

2.3. Sheep Feed Resources and their Nutritive Value in Ethiopia

There are different types of livestock feed resources in Ethiopia, most of the feeds are subjected to seasonal availability and poor quality. Hence, there are no sufficient and quality feed resources throughout the year in the country; which leads to feeding deficiency of 25 percent of DM, 45 percent of ME, and 42 percent CP in the mixed - livestock production system (FAO, 2018). The major obtainable livestock feed resources in country are natural pasture, crop residues, and browses followed by agro-industrial by-products and improved forage crops (Alemayehu Mengistu, 2003).Furthermore, the other feed resources in the country include crop stubble, fallow grazing, roadside grazing, browses, grains, improved forages, and non-conventional feeds including household food leftovers, weeds from crop fields, tillers from dense crop fields, fillers (crops intentionally planted on a part of croplands or around the homestead to be used as feed) and traditional brewers grains (referred to as Atella (Solomon Gizaw *et al.,* 2010). According to a CSA, (2021) report, the feed usage incident of smallholders in the rural areas of the country was green fodder (54.54%) and followed by crop residue (31.13 %), hay(7.35%), and by-products (2.03 %) from the total feed resource. However, low level of improved feed (0.57%) was used as animal feed in the country.

Feed shortages vary with altitude, temperature, humidity, rainfall, soil type, and cropping intensity (Adugna Tolera *et al.*, 2009) ,and nutrient deficiencies are prevalent both in the highlands and lowlands of the country during the dry season (CSA, 2018). For instance, very small amount of improved feed only (0.31%) was used as animal feeds. Besides, it also low nutritional value like crude protein (CP), vitamin, and metabolizable energy (ME) content (Yenesew Abebe *et al* .,2015). Hence supplementation of CP, readily fermentable energy sources, and minerals are essential to bringing better animal performance using crop residue and a natural pasture-based diet (CSA, 2016).

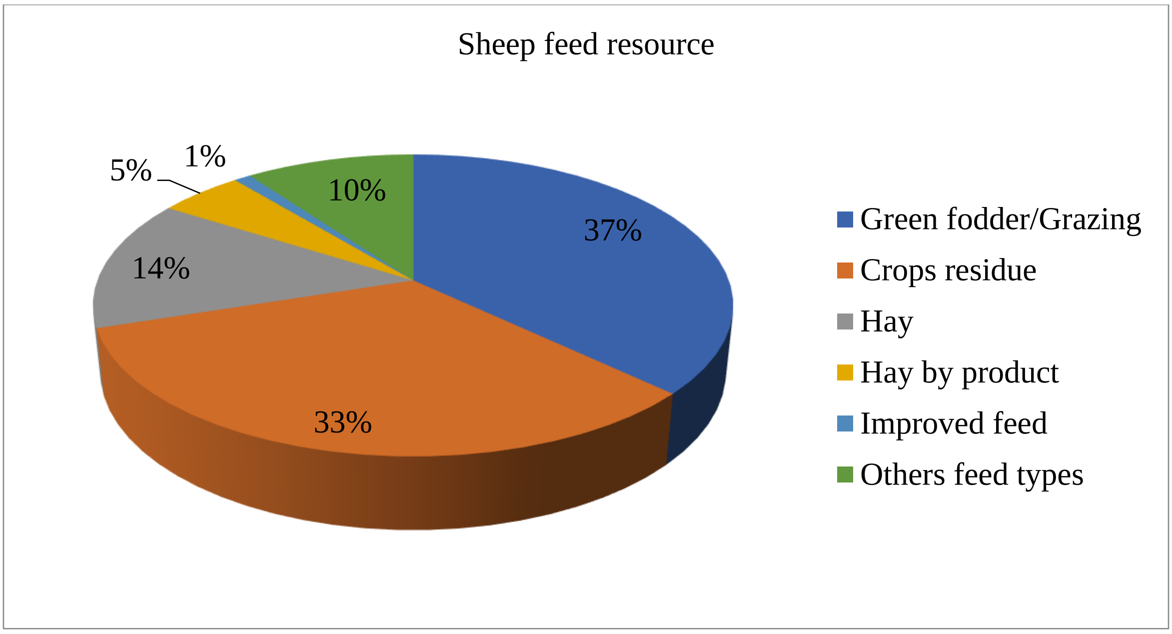

Figure 2.2 Sheep feed resource in Ethiopia (*Source:* CSA, 2021)

2.3.1.Natural pasture

Natural pastures are naturally occurring grasses, legumes, herbs, trees, and shrubs that are used as animal feed. It is conserved for dry season use when feed supply is low and serves as the main source of energy and protein during this period. Natural pasture accounts for about 25% of the total landmass of the country (Ulfina Galmessa, *et al.*, 2013). However, its productivity and quality in most parts of Ethiopia are extremely low outstanding to the seasonal fluctuation of rainfall, poor pastureland management, expansion of conversion of pasture land into croplands, and inaccurate traditional native grassland management systems such as late hay harvest.

Natural pasture hay is the main source of energy and protein in conserved fodder for dry season use when feed supplies in the field are low. Most of the natural pasture hay that animals consume is as 'standing hay' or forage that has matured in the field, which has a very low nutritive value due to the high cell wall and lignin contents (CSA,2018). The critical CP content for ruminant production is (8.5 and 7%) for temperate and tropical grass, respectively (Payn, 1990). According to the study of Eneyew Kassa, (2020), the chemical composition of natural pasture hay in Zenzelima was 6.06%, 64.5%, 42.4%,for CP,NDF and ADF, contents respectively. On the other hand, (Biru Kefeni, 2008), documented that the chemical composition of hay harvested in the Wolyita Soddo area was characterized by low 3.8%, 62.1%, and 43.6% for CP,NDF and ADF content respectively. In general, different scholars agree the CP values of hay were equivalent to the maintenance requirement of sheep (7.01%, 7.2%, 7.2%, 7.8 and 7.13%)reported by (Berhanu Alemu *et al*., 2014)and (Desta Tekle *et al*., 2017) respectively.

2.3.2.Crop residue

Crop residue includes cereal and legumes residue like wheat straw, barley straw, teff straw, faba bean straw, field pea straw, and maize Stover, etc. It represents a large proportion of feed resources in mixed crop-livestock production systems in the country (Malede Birhan and Takele Adugna, 2014). The total annual production of crop residues at the global and national level is estimated to be about 1.14 billion (FAO, 2017) and 30 million (Adugna Tolera, *et al*., 2012) tons of DM, respectively of which 70% is utilized as livestock feed. It is providing a considerable quantity of dry season feed in most farming areas of the country (Selamawit Demeke, *et al*., 2017), and contributed up to 30-80% of the total feed DM available for animals in the highlands of Ethiopia(Africa RISING, 2014). Nevertheless, quality and digestibility are very low with less than 50% digestibility, high fiber content(more than 70% NDF) and low crude protein(<15% CP (Limma Gizachew and Smit G.N, 2005) and the CP content of crop residues ranges between 3.3 to 13.3% (Deribe Gemiyo, 2015). Therefore, Crop residues which are serving as the main source of roughage during the dry season in the country but low in their nutrient content (Deribe Gemiyo, 2015)

The conversion of grazing land to cropland is increasing from time to time resulting in more biomass crop residues, which contribute about 50 % (that grow up to 80% in the months from December to April) of ruminant feed. It becomes the most important feed resource covering a significant amount of livestock feed in the highlands of Ethiopia, especially during the dry season (Adugna Tolera and Yami Abebe, 2012).

2.3.3. Improved forage

There are several improved forage varsities of both grass and legume species suitable for various agro-ecologies (Solomon Abegaz *et al*., 2008). They are important as adjuncts to crop residues and natural pastures and may be used to fill the feed gaps during periods of inadequate crop residues and natural pasture supply Alemayehu Mengistu, (2004) and

Abebe Mekoya, (2008). Even in the presence of abundant crop residues, which are often free-fed to ruminants, forage crops especially legumes are needed to improve the utilization of crop residues. Moreover, forage legumes also provide benefits such as soil fertility through their nitrogen-fixing ability and are also useful in breaking insect, weed, or disease cycles, which are likely to occur when they are not supplemented in many situations, however, forages compete with other crops.

2.3.4. Agro-industrial by-products

Agro-industrial by-products are the by-products of the primary processing of crops and they're by-products, including the bran and related by-products of flour mills, oilseed cakes from small and large-scale oil processing plants, and by-products of the sugar factory such as molasses. Agro-industrial by-products along with grazing and scavenging are an important source of feed ingredients for sheep production and they can be grouped according to their nutrient contents namely: energy-rich supplements (<20% CP and <18% CF), protein-rich supplements (≥ 20% CP and < 18% CF), and miscellaneous by-products mostly supply minerals as well as energy and protein such as by-products from brewery, fruit and vegetable industries (Ranjhan ,2001).

Agro-industrial by-products such as noug seed cake, linseed meal, and barley and wheat bran are an important source of protein and energy for supplementing basal diet (Getahun Kebede, 2006). It is high in nutritive value, but they are expensive and less accessible to the small-holder farmers in rural areas. Therefore, looking for other alternative homegrown protein supplements is crucial to improve livestock production and productivity. Growing and using legume crops like sweet lupine that have high nutritive value is one option to solve the feed shortage problem (Yenesew Abebe *et al*., 2015).

2.3.5. Other Feed Resources

Livestock feed resources are classified as conventional and non-conventional, where the nonconventional ones vary according to feed habit of the community and other. Non-conventional feed resources refers to all those feeds that have not been traditionally used for animal feeding either by farmers or by feed manufactures in commercial feeds (Singh

AK ,2018).They are not used in the ration of commercially produced animals. These include e.g. vegetable refusals, the agricultural and industrial by products used in animal feeds at certain percentage depending on their palatability, nutritional value and toxic factors or anti nutritional factors (Amata, IA,2014) and (Singh AK ,2018). Related to this anything used as livestock feed in the area additionally was added into the production of the feed resources to estimate its dry matter production (Alemayehu Mengistu, 2003).

2.4.Nutrient Requirements of Sheep

Nutrition plays a major role in the overall productivity, health, and well-being of the sheep flock (Umberger SH, 2009). Nutritive value is a function of feed intake and the efficiency of nutrient extraction from the feed during digestion (McDonald, *et al.*, 2010). The partition of the nutrient is an exceptionally complex process controlled by the animal's genotype, stage of development, quantity, and quality of feed, and environmental factors (Reddy DV, 2006). The nutritive value of feeds should be ranked on: voluntary consumption, digestibility, and skills to support high rates of fermentative digestion, microbial protein synthesis within the rumen, and skills to support bypass nutrients for absorption from the small intestine (McDonald *et al*., 2010). Feeds contain five main types of nutrients, namely: protein, energy, vitamins, minerals, and water. However, protein and energy are the most factors affecting sheep productivity (Umberger SH, 2009).

2.4.1.Protein requirements of sheep

Proteins are the principal constituents of the animal body and are continuously needed in the feed for growth and cell repair (McDonald, *et al*., 2010). It enhances the growth of rumen microorganisms which play a vital role in facilitating digestion of fibrous feeds and serving as a source of microbial protein. According to the report of (McDonald, *et al*., 2010) protein is a critical nutrient, particularly for young rapidly growing animals and for maturing, lactating animals. The CP requirements for growing and fattening lambs with 20 and 10 kg BW are 85 and 127 g per day respectively and moderately growing early-weaned lambs with 10 and 20 kg BW have CP requirements of 26.2 and 16.9%, respectively (Cheeked, 1991). Moreover, (McDonald, *et al*., 2010) reported that male sheep of about 20 kg with an average daily weight gain of 150g requires 6.4MJ/kg ME, 76 g/day MP, and 0.56 kg dry matter feed. In addition, the average daily protein requirement of a 19.1 kg body weight sheep for maintenance is 38g CP were also reported (NRC 2000). Thus, trying to find locally available protein sources like sweet blue lupin grain is indispensible which has a relatively high CP content and a high digestibility(Yenesew Abebe *et al*.,2015). Sweet lupin grain as a supplement at 290 g/ head per day on Washera sheep showed that the animals can gain 74 g/ head per day and 5.1 kg/ head in 69 days (Likawent Yeheyis *et al.,* 2012).

2.4.2.Energy requirements of sheep

The major sources of energy for sheep are hay, pasture, silage, and grains, barley, corn, oats, and wheat also can be used to raise the energy level of the diet when necessary. The micro-flora action in the rumen of sheep efficiently converts roughages into suitable energy sources provided they have an adequate supply of nitrogen. The energy requirement of sheep is affected by the bodyweight of sheep and the protein content of the diet (Ensminger, 2002). The most recent NRC recommendation for energy concentration for lambs are for 70% TDN or 3.2 Mcal/kg of DE for early-weaned lambs, 64% TDN (2.8 Mcal DE/kg) for lambs of 30 kg, 67% TDN (3.0Mcal DE/kg) for lambs weighing 35 kg and 70%TDN (3.2Mcal DE/kg) for lambs weighing 40 kg or more (Church DC, 1986).However, energy deficiencies result in reduced growth or weight loss, reduced reproductive efficiency, reduced milk, and reduction in resistance to infectious disease and parasites, and increased mortality (Pond, *et al.,* 1995).

Table 2.1. Energy and protein requirement of growing sheep

Sheep class	Nutrient	DWG in (g/day)				DMI(kg/day)
		0	50	100	150	
Female	ME(MJ)	3.4	4.5	5.8	6.5	0.56
	MP(g)	21	45	58	71	
Castrated Male Sheep	ME(MJ)	3.4	4.5	5.7	6.2	0.56
	MP(g)	21	47	61	76	
Growing Male Sheep	ME(MJ)	3.9	4.8	5.8	6.4	0.56
	MP(g)	21	47	61	76	

Source: (McDonald, *et al*., 2010)

2.4.3.Recommended Rations for Sheep Fattening

Fattening is that the deposition of unused energy in the form of fat within the body of the animal (Perry *et al.*, 2003). The objective of fattening is to make the meat tender, juicy, and of good flavor. Fattening increases the need for protein to encourage good digestion. Fattening animals are usually full-fed because the energy which is beyond the maintenance requirement is available for fattening. In general, growth may be a less expensive sort of gain than fattening. Bodyweight gain in growth is in the form of protein and bone while fattening it is in the form of fat. About 2.25 times the maximum amount of net energy is required to make form a kg of body fat as is required to form a kg of body protein (Perry *et al*., 2003). Young animals make more efficient and fewer expensive gains than older animals since their gain is within the sort of growth.

On the other hand, older animals are fattened more easily than younger animals. In older animals, a bigger part of the energy consumption is out there for fattening. To get rapid gains, the surplus supply of nutrients beyond maintenance requirements is needed by fattening animals. But the nutrient requirement for fattening depends on the age of the animals. Young animals require more protein, vitamins, and minerals than mature animals during fattening (Perry, *et al*., 2003). More supply of nutrients is important to get rapid gains. Besides, rapid gains shorten the fattening period and so it decreases the cost of labor and other expenses. According to (Ranjhan, 1997) growing lambs (15 – 30 kg) consume 73.7 g/ kg $W^{0.75}$. The same author stated that for lamb fattening of 30 kg BW, to get 150 g gain per day, 10.9 g CP ,60% TDN, 2.16 Mcal of ME, 6.0% DCP, and 0.22% Ca are required. It is also reported that a lamb of 30 kg BW consumes 1350 g DM per day. According to (Pond, W.*et al*., 1995), a lamb weighing 30 kg and gaining 295 g per day requires 0.94 kg TDN and 191 g CP. Also, the animal is assumed to consume DM at 4.3% of its BW per day amounting to 1.3 kg DM per day of feed. Moreover, 6.6 g Ca and 3.2 g P are needed by such animals. These recommendations are based on exotic sheep breeds abroad. According to (Solomon Abegaz, *et al*.,2005), an on-farm fattening study was carried out in east Wollega using 49.5% ground maize, 49.5% noug seed cake, and 1.0% common salt, revealed that finished rams were 16.3% (4.0 kg) heavier than the control group. Also, it was observed that the supplemented group gained approximately 49 g/ day. A net return of Birr 40.24 / head / 84 days was estimated to be obtained. Generally, the authors concluded that supplementation of yearling Horror rams at a rate of 400 g/head/day for 3 months is profitable if finishing is completed at an appropriate time.

2.5.History and uses of sweet lupin grain as Animal feed

Lupin (locally in Amharic referred to as “Gibto” in Ethiopia) is widely used to describe seeds of different domesticated Lupine species. Lupine is the seed of Lupinus species in the family Fabaceae (*or Leguminosae)* and subfamily *Papilionoidea* ,there are four major agricultural important lupin species namely Lupinus angustifolius, Lupinus albus, Lupinus luteus and *Lupinus mutabilis* Lupines are members of the genus Lupinus L. in the legume family (Fabaceae). Taxonomically, lupin belongs to the class of *Magnoliophyta Angiospermae*), subclass Magnoliatae (Dicotyledoneae), and order Fabales (Kurlovich, 2002). The same author indicated that lupin production is about 2000 years old and it began in the Mediterranean basin. There are about over 300 species of the genus Lupines (L.).

The grain has high protein content, but many have high levels of alkaloids (bitter-tasting compounds) that make the grain unpalatable and sometimes toxic to humans as well as livestock (Yenesew Abebe *et al.*, 2015). The same author reported that historically, lupin alkaloids have been removed from the seed by soaking in water for a long period.

Due to the high alkaloid content of the available lupin species, Plant breeders in the 1920s in Germany produced the first selections of alkaloid-free or sweet lupin; this can be directly consumed by humans and livestock. Currently, sweet lupin is produced in many countries as forage or grain legumes. Although bitter white lupin is a traditional pulse crop in Ethiopia, its use as livestock feed and human food .

Grain legumes are important sources of significant amounts of nutrients like proteins, carbohydrates, fiber, vitamins, and some minerals. They are used in many parts of the world for both animal and human nutrition (Likawent Yeheyis *et al.*, 2011). As a protein source, they are obtained cheaply compared to animal protein sources. Moreover; they are fairly good sources of thiamin, niacin, calcium, and iron (El-away.T,2000). Predominantly their consumption is widespread in areas like the developing countries of Asia, Africa, and South America. In these countries, legumes play a major role as a protein source (El-Adawy *et al.*, 2000). Lupin like other legumes has some anti-nutritional factors which inhibit its consumption. So, there is a need of designing studies worldwide to develop lupin-based convenient food products (Joray *et al*., 2007).

In the direction of make white lupin edible various modern and traditional processing methods are developed. The main processing practice was Soaking after roasting and boiling, germination, fermentation, alkaline treatment are some of them (Joray *et al.*, 2007). The three species of lupin can be distinguished according to the color of their flowers; namely *Lupinus angustifolius* (blue), *L. Albus* (white) and *L. luteus* (yellow) are the main sources of feed both humans and livestock's (Komarek *et al.*, 2012). The seed and vegetative parts of lupin are a rich source of protein and energy, and the seed can be fed as a whole or ground grain, making it an invaluable resource for both monogastric and ruminant production systems. Sweet lupin (*L. angustifolius* and *L. albus*) have been introduced as a legume crop in the winter rainfall region of South Africa, and it is estimated that approximately 20000 tons of lupin are produced annually. As a result, lupines (Lupinus angustifolius) were successfully identified as an economical alternative plant protein source that can be cultivated and fed to animals at a positive profit margin.

Besides when you compare lupin grain from other grains it has 12.6% more NDF than soybean oilcake meal. However, NDF is a measure of the fibrous plant parts that make up the structural components (lignin, Hemicellulose, and cellulose, but not pectin) in plant cells. The fibrous seed coat and NDF content of lupin will affect the digestibility of the meal and is often not desired (McDonald *et al*., 2010). The use of lupin in livestock farming systems for both ruminants and monogastric has many advantages. They can be used in animal diets either as a concentrate (whole seeds, ground seeds, or other processed seeds (Sedlakova, e*t al*; 2016) or as forage (whole-crop, silage, or hay) (Borreani G *et al*., 2009)Beyond the nutritional value. Lupin is characterized by high grain productivity (Chiofalo, B *et al*., 2012) and they are adapted to poor and barren soils, they have fewer requirements than other crops (Bolland & Brennan, 2008) and finally, they are an excellent rotation crop (Fumagalli, P. *et al* ., 2014).

Furthermore, (White, C.L *et al,* 2007) suggested that dairy farmers in Australia prefer to use lupin as a supplementary feed source because they are generally cheaper than oilseed proteins, and they are easy to store and handle. The lupine meal can be directly used as feed for livestock, fish, and poultry, and can be finely ground into lupine flour or coarsely ground into lupine grits. Lupine flour is a super source of protein and other important nutrients, ideal for use in baby foods, cereals, and various low-calorie foods and drinks. Lupines are one among several plant protein resources that have been witnessed to provide sound nutritional value to aquaculture species, pig, dairy, and beef, sheep, goat, and poultry. It also an important crop for organic livestock farms by playing the role of soya bean meal (Likawent Yeheyis *et al.*,2011).

2.5.1.Chemical Composition of Sweet Lupin grain

Legume grain is an abundant source of protein, among them, lupine is one of the richest (Kohajdova, Z.*et al*.,2011). Although lupine grains have been used for human consumption for thousands of years, their utilization in modern food production is still limited. Nevertheless, lupine is attracting interest worldwide as a potential high protein food ingredient suitable for animal and human consumption (Torres, A., *et al.*,2005).

The nutritional content or the Chemical composition of lupine is influenced by, location management, genetics, and species. Thus white Lupine is a genetically improved legume, high in protein, fiber, and other nutrients. The crude protein content of the grain was reported to be 35.8 % (Glencross, B.D., 2001) 38.8% (Mikic1, A.*et al*.,2009) and (Sofia, S., 2008) also reported that lupine grain had high protein (30-40%) and dietary fiber (30%) and low fat (6%) contents. (Gebru Tefera, 2009) also documented the crude protein (CP) content of white lupine as 38.5%. (Glencross, B.D.,2001) also reported the chemical composition of Lupines albus (white lupine) on a DM basis as 95 g/kg Crude Fat, 428 g/kg nitrogen-free extract (NFE), 103 g/kg crude fiber (CF), 143 g/kg acid detergent fiber (ADF), 172 g/kg neutral detergent fiber (NDF) and 33 g/kg ash. (Vladimir, V.*et al*., 2008) documented the ADF, NDF, and NFE content of lupine seed/grain as 179.5 g/kg, 198 g/kg, and 371 g/kg, respectively. In addition, according to the report of (Nahom Ephrem *et al.,* 2015) the nutrient content of (ADF ,NDF, CP,DM, Ash, OM,ADL sweet lupin seed was 177.7g/kg,260.8g/kg, 308.6g/kg, 920g/kg, 118g/kg,882g/kg,65g/kg obtained respectively.

Table 2.2. Average seed yield, protein, and alkaloid content for the local and introduced Sweet lupin varieties in Ethiopia

	Variety	Origin	Average seed yield(t/h)	Protein content (%)	Alkaloid content (%)
White lupin	Local	Ethiopia	3.1	39	1.10
Blue lupin	*Sanabor*	Germany	3.7	33	0.02
Blue lupin	*Vitabore*	Germany	3.8	31	0.02
Blue lupin	*Bora*	Germany	3.3	31	0.10
Blue lupin	*Probor*	Germany	3.2	34	0.04

***Source* :(** Likawent Yeheyis, 2017)

2.5.2.Utilization of sweet lupin (*Lupinus angustifolius*) grain for sheep fattening

Sweet lupin grain has a great potential to be used as a supplement to sheep fattening. It is highly palatable and easily digestible. The performance of animals that were fed sweet lupin is promising. The performance of old animals that were fed sweet lupin was less than young animals. The lupine grain contains a high amount of protein (32.2%), fiber (16.2%), oil (5.95%), and sugar (5.85%) (Naskar *et al*., 2012 and)(Erbas, M. *et al.*, 2004). As there is poor availability and the high price of agro-industrial by-products to the smallholder farmers, growing and feeding sweet lupin to fattening sheep is one alternative to solve the current problem. One of the benefits of sweet lupin is its low level of alkaloid content which is 0.003% (Wasche, *et al*., 2001).

White lupin (*Lupinus albus L*.) is among the lupin species currently produced by smallholder subsistent farmers in Ethiopia(Likawent Yeheyis *et al*.,2010). It is a valuable multipurpose, but underutilized, plant through it has a potential contribution to improve soil fertility, food for humans, and animal feed. However, due to the presence of high alkaloid content(Likawent Yeheyis *et al*.,2011) and the raw seed of local white lupin is bitter, unpalatable, and often toxic for humans and livestock.

Due to this factor, the livestock producer is used as an alternative lupin cultivar like sweet lupin (*Lupinus angustifolius L*.) has been introduced to Ethiopia. The adaptability and productivity of lupin in the country (both forage dry matter and seed yield) were studied and currently it is produced by smallholder farmers with an increasing interest in a wider utilization of this legume seed (Likawent yeheyis *et al*., 2012). Even though the information about the feeding value of sweet lupin grain in sheep nutrition in the study area as well as in Ethiopia is limited. However, the use of sweet lupin(*Lupinus angustifolius)* grain supplementation is usually limited under smallholder livestock production systems due to inaccessibility and high cost of such feed ingredients (Likawent yeheyis *et al.*,2012).

2.6.Supplementation effect of processed Sweet lupin Grain for Sheep Fattening

Sweet lupin grain has a great potential to be used as a supplement to sheep fattening in different agro-ecology of the country. Lupin grain/seed was highly palatable and easily digestible for ruminant's livestock. Due to these causes, the performance of animals that were fed sweet lupin is promising and fattened in a short period. Lupin is an ideal feedstuff for livestock production and it is completely safe to feed and it is rich in both protein and energy having a crude protein value of about 30% and a metabolizable energy value of 13-13.5 mega joules per kg of dry matter Smit and Kenney, 1987).

The performance of old animals that were fed sweet lupin was less than young animals due to age, rate of consumption and absorption, and other different factors. The chemical composition of the grain of lupin in different authors was obtained different results CP(32.2%), CF (16.2%), oil (5.95%), and sugar (5.85%) (Naskar *et al*., 2012 and)(Erbas, M. *et al.*, 2004). Due to that high nutritional content, the sheep were easily consumed and digested for gaining body weight in a short period. Moreover, as there is poor availability and the high price of agro-industrial by-products to the smallholder farmers, growing and feeding sweet lupin to fattening sheep is one alternative in the country. Lupin is highly valued as animal feed but has been underutilized as human food yet the seed/grain are reported to be a rich source of protein with a range value of 33 - 47% and oil 6 - 13% (William P, 2000).

In Ethiopia, specifically in the Amhara region west Gojam zone, the evaluation experiment result of sweet lupin grain was the highest (29.11%) and the lowest (17.98%) CP content was recorded at Upper Gana and Jewe Kebeles respectively (Fikadu Tesema *et al* .,2017) Furthermore, data on invitro OM digestibility of sweet lupine grain in Upper Gana Kebele gave the highest in vitro OM digestibility (80.49%), than Jewe Kebele (78.16%)(Fikadu Tessema, 2017). Besides the CP content of sweet lupine grain at the mid-latitude location was lower than the reports of (Glencross, B.D., 2001) (35.8%), (Mikic1, A., *et al* 2009) (38.8%) and (Sofia, S., 2008) (30-40%).

2.6.1.Feed Intake and Digestibility in Sheep

Feed intake is the first parameter that determines animal production and productivity (Savadogo M.*et al*, 2000) which is likely to be influenced by the animal, characteristics of the feed, and other environmental factors. The dry matter intake is dependent upon many factors like the density of energy in the diet, digestibility, succulence, amount of crude fiber, and the physical nature of the feed (Reharhie M *et al*., 2003). (Schoenian.S, 2003) reported that the exact percentage of DM intake varies according to the size of the animal, with smaller animals needing a higher intake to maintain their weight and intakes per unit of BW decrease because of the size increase.

Also, Feed intake in ruminants consuming fibrous forages is primarily determined by the level of rumen fills, which in turn is directly related to the rate of digestion and passage of fibrous particles from the rumen (McDonald.*et al*., 2002). According to (Cronje *et al*., 2000) feed intake was affected by different factors like the composition of the feed, climate variables, and changes in management procedures. Feed that is low in protein and high in fiber content results in low digestibility and voluntary feed intake (Adugna Tolera, *et al.* 2012), and voluntary feed intake declines in forages containing less than 7% CP (NRC,2000). Proper supplementation can improve their feed intake, as maximizing feed intake is critical to increasing animal performances total nutrient supply is the summation of intake and digestibility, which depend on adequate dietary nitrogen. 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 the intake and digestibility of roughages (Ajebu Nurfeta, 2010). According to the report of (Mekeya Bedru, 2018), the total DM intake in different feed resources and different studies could be attributed to the difference in BW of the experimental sheep.

The digestibility of a feedstuff is that the proportion of the feed or of any single nutrient of the feed which isn't recovered in feces (Ranjhan, S.K,2001). Although the potential value of a feed can be 28 approximately determined by proximate analysis, the actual value of the feed to the animal can be determined only if the digestibility is known. The digestibility coefficients of various nutrients from the same feedstuffs are affected by species of the animal, age of the animals, level of feeding, feed composition, (Ranjhan, S.K, 2001). The primary chemical composition of feeds that determines the rate of digestion is the neutral detergent fiber which is itself a measure of cell wall content; thus there is a negative relationship between the neutral detergent fiber content of feeds and the rate at which they are digested. The fiber fraction of feed has the greatest influence on its digestibility (McDonald, *et al.*,2010).

The digestibility of a feed is influenced not only by its composition but also by the composition of other feeds consumed with it. For the ruminant to express their full genetic potential for growth the apparent digestibility should exceed 70% on a dry weight basis. For satisfactory digestion of poor roughage, an adequate amount of supplementation is needed. The addition of a small amount of high-quality concentrate had increase rumen digestion. The extent and rate of digestion of fibrous feeds are increased by nitrogen supplements, resulting in a greater dry matter intake. The total DM intake noted in this study was comparable to the range of values of, 666-788 g/day reported for Farta sheep fed hay supplemented with wheat bran, noug seed cake, and their mixtures (Lemecha, T *et al*.,2013). The total DM intake and digestibility of Afar lamb supplemented with 450gm concentrate 824 and 683.4 g/head/day respectively (Getahun Kebede, 2014). According to (Ajayi F *et al*.,2008), showed that forage legume supplementation significantly improved dry matter, organic matter, crude protein, and acid detergent fiber digestibility because forage legumes enhance efficient rumen fermentation which optimizes microbial growth for increased digestibility.

The feeding value of a feed is also influenced by its digestibility, nutritional factors, physical nature, intake level, its interaction effects when included in a ration, and the physiological status of the animals (Lund, 2002). However, supplementation of Washera lambs with sweet lupin seed increased the total dry matter, crude protein, and organic matter intakes. Supplementation with Sweet lupin seed also significantly improved the apparent digestibility of nutrients, average daily gain, and feed conversion efficiency of the sheep. The increment was not significant for feed intake when expressed in terms of percentage of body weight (Nahom Ephrem *et al*., 2015).

Feeding Sweet blue lupin has a relatively high CP content and high digestibility in the sheep. Due to the low alkaloid content of the grain sweet lupin, the consumption and rate of intake by sheep were increased. A study conducted for 69 days using sweet lupin grain as a supplement at 290 g/ head per day on Washera sheep shows that the animals can gain 74 g/ head per day and 5.1 kg/ head per 69 days (Likawent Yeheyis *et al*., 2012). The same study shows that sweet lupin (cultivar Sanabor) has the potential to substitute commercial concentrate feed supplements in Ethiopia. Sweet lupin yields better than the local one and is very palatable by livestock. Also, sweet lupin is gaining more attention from small-holder farmers due to its value as human food.

During supplementation of sweet lupin for domestic sheep, there was no palatability problem observed and we provided lupin seed and the sheep consumed it directly (Likawent Yeheyis, *et al*., 2010). According to a survey work done by (Likawent Yeheyis, *et al*., 2010), the local white lupin is an important multipurpose crop in the north-western part of Ethiopia. However, it is not palatable to be used as livestock feed due to its high alkaloid content (bitter taste). The same authors report that the absence of palatability problem on sweet blue lupin seed used in the experiment as opposed to the local landrace showed the antagonistic role of alkaloids on the palatability of lupin seeds for livestock feed. The alkaloid contents of sweet blue lupin seed (Sanabor) and bitter white lupin seed (local landrace) grown at Kossober, Ethiopia are 178 and 11,426 mg/kg dry matter respectively. The same authors reported crude protein content (in grams per kilogram DM) of 331 and 334 from forage and seed of cultivar Sanabor, respectively. Hence, the relatively high crude protein content and lower alkaloid content coupled with its palatability show the potential of sweet blue lupin seed to be used as an alternative protein source feed in the traditional lupin-growing areas of Ethiopia. As the proportion of lupin in the supplement increased, the supplement dry matter intake decreased. This was related to the crude protein content of lupin seed which resulted in a decrease within the amount of supplement feed at a higher lupin seed proportion. According to (McDonald, *et al*.,2002) in ruminant nutrition quality of feed, rate of digestion of a feed, and voluntary feed intake have a positive relationship.

2.6.2.Bodyweight change of sheep

Feeding of sweet lupin in a small ruminant was increased the daily weight gain of the experimental sheep. According to (Molla Haile *et al*., 2017) report feeding of 290g/d/h sweet lupin grain supplementation increases the live weight of experimental animals on average from 21.9kg to 29.4kg. The final body weight, body weight change and daily weight change obtained in the study was higher than the result obtained by (Likawent Yeheyis *et al.*, 2011) with similar experiments, it may be due to the supplementation period difference.

Fattening of washera sheep using sweet lupin grain with hay as a basal diet has a daily gain of 0.09kg/day weight change (Molla Haile *et al*.,2017). (Gebru Tefera ,2010) reported that 17.6, 18.2, 18.6 and 18.0 kg for Washera sheep supplemented with white lupin grain in its raw, raw soaked de-hulled, roasted, or raw soaked form, respectively.

Besides, According to the report of CASCAPE Project on-farm trial experiment of animal evaluation of sweet lupin grain or (Yenesew Abebe, *et al*., 2015) the average daily gain (ADG) of the sheep fed sweet lupin ranges from 64 to 67g per head per day. The variation might be due to the cultivars of lupin and the type of processing on the grain used for

supplementation (Nahom Ephrem, *et al*., 2015). According to (Stanton *et al.,* 2006) the level of protein included in the diet affects final body weight, ADG, and FCE.
In a country where feed shortage is at its worst, especially during the dry seasons, animals lose body weight. Consequently, it takes animals long to reach slaughter weight, with different environmental and economic implications for the smallholder farmers in the tropics and subtropics (Nahom Ephrem *et al*., 2015). Besides the daily weight gain performance of sheep supplemented with the high level of lupin seed was similar with 76 g/day weight gain in Washera sheep supplemented with 400 g concentrate mix for a 105-day feeding trial (Taye, 2009). Whereas the daily weight gain result in this study was higher than the daily weight gain reported on Farta sheep (58 g/day) (Abebew Nega and Solomon Melaku, 2009) and Sidama sheep (51 g/day) (Dessie yigzaw, 2019). These similar and higher daily weight gain results from lupin seed supplement compared to other supplement feed studies showed that lupin has the potential to be used as a concentrate supplement feed the diets of growing Washera sheep.

However, the observed daily weight gain result from lupin feeds trail was lower than 119 g/day in Washera sheep supplemented with 500 g concentrate mix for a 93-day feeding trial (Berhanu Alemu, 2014). The major reasons for lower body weight gain observed for Washera sheep in the previous study could be associated with the relatively shorter experimental period and low CP content of the hay used in this experiment. For instance, (Fychan *et al*., 2008) reported a daily weight gain of 229 g from a feeding trial on lambs by using 25% of the concentrate as lupin seed. Similarly, (Weise *et al.,* 2003) reported a daily weight gain of 233 g for lambs offered a diet in which lupines provided 49% of the nitrogen. (Hill G, 2005) in his review paper reported a range of weight gain between 77 and 264 g/day for lambs fed on lupin seed as part of their diet. Even though there were variations in daily weight gain reports, all the authors concluded that lupin seed can substitute the protein-rich soya bean (Glycine max) meal and can be used as an alternative protein source in the diets of sheep.

Growth in animals is defined as an increase in body cells achieved through the growth and differentiation of body cells (Orr, 1988)). Growth rate and body size along with changes in body composition are of great economic importance for the efficient production of meat animals. Forage-based sheep production systems like those found in the tropics and subtropics are usually associated with lower weight gains, but the total cost of gain may be less than those in the more intensive systems. The lamb supplemented with 450, 350g concentrate mix per day average daily weight gain of 72.27, 60g/day (Getahun Kebede, 2014) respectively.

The growth rate of lambs is strongly influenced by breed (genotype) and the environment under which the animals are maintained including the availability of adequate feed supply in terms of both quantity and quality. In meat production, a rapid rate of growth of animals is desirable because it minimizes the overhead cost of maintenance per unit of meat produced. The plane of nutrition is the major factor influencing the fat deposition pattern of animals whereby a high plane of nutrition promotes earlier fattening while a low plane results in a delayed or slower fattening process (McDonald, *et al*., 2010).

Partial budget analysis :-sheep fed finger millet straw without supplementing, sheep lost their body weight, due to the low quality of finger millet straw, which resulted in BW loss of sheep. 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 3.07 ETB (Almaz Ayenew *et al*.,*2012*) .Supplementation of noug seed cake and higher proportion of noug seed cake: atella concentrate mixture was not efficiently utilized by rumen microbes and resulted in excess energy and protein loss through feces and higher cost of the concentrate feeds (49.7 and 60.5 ETB/head (Almaz Ayenew *et al*.,2012) as compared to the other treatments attributed in lower MRR. However, new technologies normally require investment, therefore, additional capital is necessary. When capital is limited, the extra (or marginal) cost should be compared with the extra (or marginal) net benefit. But with regard to economic profitability the results of this study suggested that supplementation of finger millet straw with 300 g Atella is potentially more profitable and economically beneficial than the other supplement feeds (Almaz Ayenew *et al*.,2012).
The difference in the net return among treatments could be attributed mainly to feed conversion efficiency. In addition, the marginal rate of return below which farmers will not accept a new technology is usually between 50 and 100% (Awoke Kassa, 2015).The higher net return mainly due to the lower nitrogen content of fruit in supplementation than leaf and their mixture. Supplementation of tree leaf and fruit in ruminant nutrition provides nutrients in the diet resulting in enhancement of microbial growth and digestion of cellulosic biomass in the rumen, source of undegradable protein, source of vitamins and

minerals to complement deficiencies in the basal feed resource. It could also weakness the competition for conventional concentrates, reduced cost of production and maximized economic returns (Awoke Kassa, 2015). Sheep which had a better nutrient intake had superior ADG as a result of this, had a higher sale price to earn higher net return. On other side, the prices of the feed determine net profit/income.

The net return from the supplemented experimental treatments was higher than un - supplemented (Hunachew Abebe, 2015). The difference in net return was in a similar trend with their weight gain, i.e., lambs in un supplemented 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. 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 (Hunachew Abebe, 2015).

Chapter 3. MATERIAL AND METHODS

3.1. Description of the Study Area

The study was conducted at Anicha Sedecho Kebele, in Doyogena district, Kembata Tembaro Administrative Zone of SNNPRS, Ethiopia (Figure 3.3). The district is located 258 km South-West of Addis Ababa, the capital city of Ethiopia, at an altitude ranging from 1900 and 2748 m.a.s.l. located between $7^0$16'20''-$7^0$30'0''N latitude and $37^0$45'33''-$37^0$48'51''E longitude (Ethio-Arc GIS, 2019). The topography of the study area is characterized by 64% moderately sloping (undulating to rolling plains), 25 % plateau and rugged terrain slope, and 11% flat to gently sloping plains. It constitutes 17 Kebeles, which are sub-divided into 13 rural and 4 urban Kebeles (DDANRO, 2020). The average landholding size of the district is 0.5 hectares per household, which is less than the national average of 1.01 ha. The average annual rainfall is 1400 mm with a bi-modal distribution from February to April and from June to September and the average annual minimum and maximum temperature are 10 and 16°C, respectively (DDANRO, 2020). It has a total land area of 17,263 hectares. The land use pattern is shown in Table 3.3. There are two major agro-ecologies, Dega/highland (70%) and Woinadega/midland (30%). About 10% of the district is plain land while the remaining 90% is mountainous or hilly. The soil type is mostly black clay loam, rich in organic matter.

The district has a predominantly mixed farming system (crop production and livestock rearing). The major cultivated crops in the highlands of the district include enset (*Ensete ventricosum*), cabbage, potato, barley, wheat, faba bean, and field pea. At the lower altitudes of the district, farmers cultivate sugar cane and maize. According to the annual report of (DDANRO, 2020), the livestock population estimated in the study area is 46,703 cattle, 13,822 sheep, 1,444 goats, 6,343 equines, and 27,253 poultry.

Table 3.3 Land use pattern of Doyogena district, the study area

Land-use type	Area in hectare (ha)	Total area (%)
Potentially cultivated land	11,418.14	66.14
Perennial crop	2,960.6	17.15
Grazing land	281.51	1.63
Forest and bushes	86.31	0.50
Degraded land	424.68	2.46
Others	2,092.35	12.12
Total	17, 263.59	100

Source: (DDANRO, 2020)

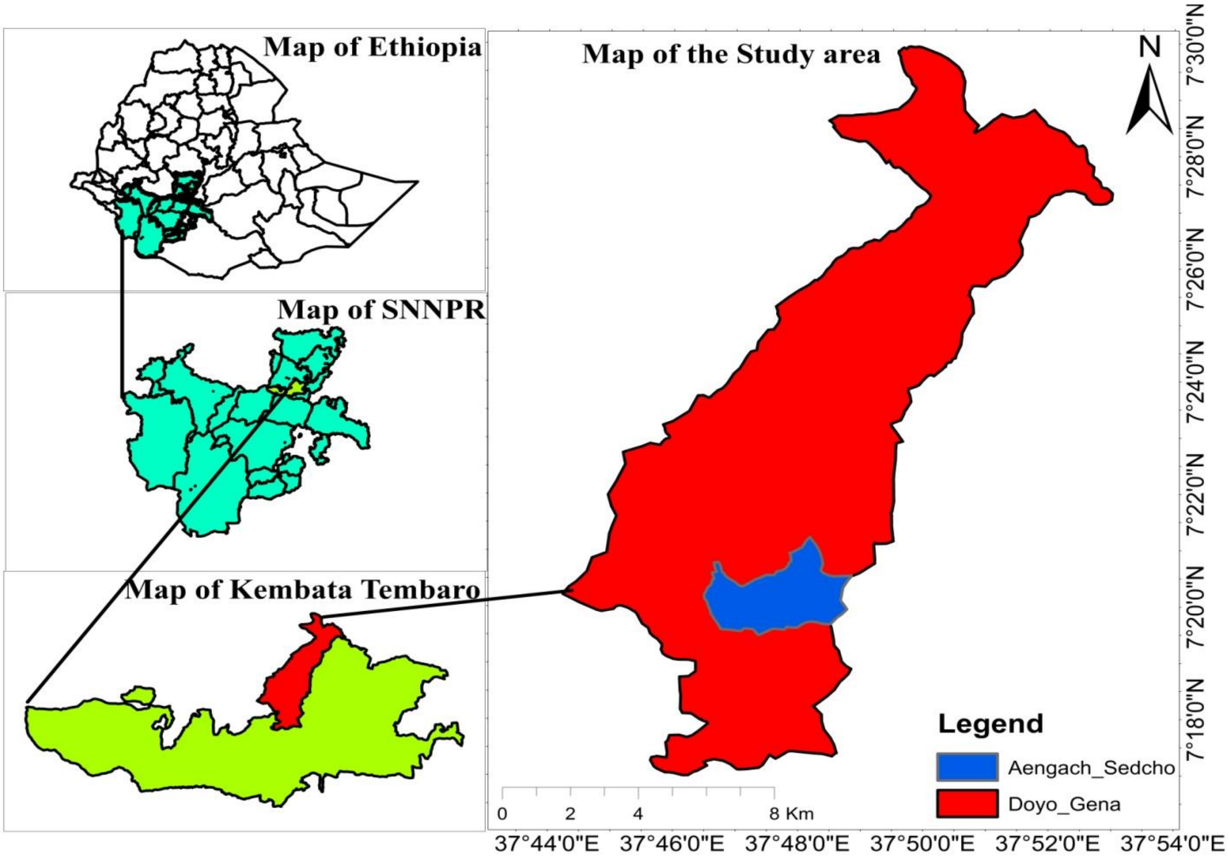

Figure 3. 3 .Map of the study area (Doyogena district)

3.2.Peasant Association and Farmers Selection

For the present study one of the rural PAs, Anicha Sedicho, was selected purposively based on the availability of a sufficient sheep population, farmers' interest, and farmers' willingness to participate. Subsequently, from the total households of Anicha Sedecho PA, eight volunteer farmers found in four different villages in the PA and owned more than 10 sheep were selected for the trial. Afterward, three growing intact male sheep were selected from the flock of each farmer based on uniformity of body weight, physical performance, and health status. Short-term training was undertaken before the commencement of the trial. All participant farmers and agricultural development agent workers were trained on the purpose of the research, how to supplement the animal, feed storage, and improved housing and feeding management.

3.3.Experimental Sheep and their Management

Twenty-four yearling intact male Doyogena sheep with an initial body weight of 27.53±2.67 kg (mean ± SD) were used. The age of the experimental sheep was estimated based on their dentitions and information obtained from the owners of the sheep. The experimental house was prepared at farmer's farmstead with separate pens for individual experimental rams. Each pen was provided with adequate floor space and equipped with a feeding trough and a watering trough for each sheep. Pens were disinfected and well-ventilated. They were under each farmer's management with regular visits were made by the researcher.

Sheep were quarantined for 21 days to get them adapted to the new environment and to observe their health status. During this time, each experimental sheep was vaccinated against ovine pasteurellosis, sheep pox, blackleg, and anthrax with 1 ml ovine pasteurellosis vaccine, 1 ml sheep pox vaccine, and 1/2 ml anthrax vaccine and de-wormed against internal parasites (flatworms and roundworms) and drenched with anti-helminthes and sprayed against external parasites (tick and mange) before the beginning of the experiment. At the end of the quarantine period, sheep were adapted to the experimental feeds before the beginning of the experiment for additional 15 days. Sheep were ear-tagged and grouped into six blocks based on initial body weight and randomly assigned to the treatments within each block. The initial weight of sheep was taken at the beginning of the experiment and continued at weekly intervals using a suspended spring balance. Sheep were weighed in the morning following overnight fasting to avoid gut content variation. They were closely observed for any incidence of ill health and disorders during the preliminary period of the trial experiment. All sheep had free access to clean ground water and salt throughout the experimental period.

3.4.Experimental Feed preparation and Management

The experimental feed consisted of a basal diet of natural grass hay and processed sweet lupin grain and commercial concentrate mix in the proportion of (30% noug seed cake, 35% wheat bran, 35% coarsely ground maize grain, and 1% salts). Natural pasture hay was purchased from available area and transported to the experimental site and properly stored in a fenced dry area until feeding of experimental ram. Before distribution to the participant farmer, the hay was chopped to 5 to 15 cm using sickle manually to improve feed intake for experimental animals.

The commercial concentrate mixture that comprised of wheat bran, coarsely ground maize grain, and noug seed cake was purchased from Hossana town at Lecha Farmer Co-operative animal feed processing factories and stored in a cool and dry place until it was incorporated into experimental ration. Experimental feeds were distributed to the owners of the experimental sheep on daily basis. Sweet lupin seed was purchased from Andassa Livestock Research Center and Hossana, Africa Rising Project.

3.4.1.Sweet lupin grain processing and management

Sweet lupine grain was processed using typical Ethiopian food and feed preparation methods. This included roasting and coarsely grinding the grains, soaking in water, or steaming. These processes altered the physical form or particle size of the grain and thereby prevent spoilage, improve palatability, increase surface area to avoiding sorting by animals and increase digestibility. Roasting was done on a flat surface (locally known as *Mitad*) by continuously mixing and stirring the seeds to ensure uniformity until several black spots are observed. The average plate surface temperature was 144.5^{o}C and the average period for roasting was 13 minutes. Roasted grain was ground in an attrition mill.

After roasting and crashing the grain, the soaking process followed throughout the experimental period, in three days intervals. Raw grains were soaked in tap water for 72 hours, seed (kg) to water (liters) ratio of 1:2. This process softens the grain (swells during the process), reduces alkaloid content, and makes the grain more palatable. This sweet variety of lupin contains lower levels of alkaloids and didn’t need much time for soaking. After soaking, the water was drained off and the seeds were immediately fed to the experimental sheep. The other form of feed processing was steaming. Sweet lupine grain was steamed in tap water at a grain (kg): water (liter) ratio of 1:2.5 for 30 to 40 min. Soaking and steamed raw sweet lupin grain was processed throughout the experimental period at three days intervals to avoid molding due to the high moisture content.

3.5.Experimental Design and Treatments Diets

The experimental design was a randomized complete block design. Experimental sheep 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 measured and recorded as an average of three consecutive weightings after overnight fasting. Dietary treatments are shown in Table 3.4. The supplements (440 g), on a fed basis, were offered twice a day in equal proportion in morning and afternoon to each sheep at the start of the feeding trial up to the end of the experimental period. Natural pasture hay was offered as ad *libitum*.

Table 3 .4 Dietary Treatments

Treatment group	Basal diet	Supplement (g /day as fed basis)
T1: Con.mix (positive control)	Hay *ad libitum*	440g
T2: R&CSLG	Hay *ad libitum*	440g
T3: SSLG	Hay *ad libitum*	440g
T4: St.SLG	Hay *ad libitum*	440g

Where: Con.mix=concentrate mix(30% noug cake, 35% wheat bran, 35% maize, 0.5% salt) (RCSLG=roasted and crashed sweet lupin grain, SSLG=Soaked sweet lupin grain, St.SLG=Steamed sweet lupin T=treatment

3.6.Feeding Trial

The Feeding trial was conducted for 90 days (excluding quarantine and adaptation period) before the digestibility trial.

3.6.1.Feed Intake

The treatment feeds were offered to individual sheep two times a day in the morning and afternoon. Basal diet refusals were collected and weighed every morning to get an estimate of intake. A daily record of feed intake was maintained throughout the experiment. The sheep were exposed for 15 days of adaptation to experimental diets and the actual data collection was continued for 90 days. The amount of sweet lupin grain and natural pasture hay offered and refused were recorded daily to estimate intake. A sub-sample of refusal feed was used for chemical analysis. Experimental sheep were weighed on the first day of the feeding trial and subsequently at weekly intervals before offering the morning feed on the same day of the week after withholding feed and water overnight.

Feed intake was calculated by measuring the daily offered and refusal of each treatment diet throughout the experiment. The daily feed intake of a small ruminant is calculated as a difference of daily fed offers and refusals for each experimental Sheep, using the formula of (McDonald *et al*., 2010).

$$\text{Feed intake} = \text{feed offers} - \text{feed refused}$$

3.6.2. Bodyweight changes and feed conversion efficiency

Initial body weights of the experimental animals were taken at the beginning of the study after three consecutive weightings in the morning before feeding. Sheep were weighed on the first day of the feeding trial and subsequently at weekly intervals after overnight fasting. Bodyweight was measured using a suspended 100 kg Salter scale. Bodyweight changes were determined as the difference between the final and initial body weight during experimentation. Daily body weight gain is calculating the difference between final live weight and initial live weight divided by the number of days. It had been measured using the formula according to McDonald, *et al.* (2010). The average daily gains of the sheep were estimated to determine feed efficiency. Feed conversion efficiency (FCE) was calculated according to McDonald, *et al.*(2010).

$$\text{Average daily weight gain(ADG)} = \frac{(\text{Final live weight} - \text{Initial liveweight})}{\text{Number of trial days}}$$

$$\text{Feed conversion efficiency} = \frac{\text{Average daily live weight gain (g)}}{\text{Average daily Feed Intake(g)}}$$

3.7.Digestibility Trial

The digestibility trial was conducted after 90 days of the feeding trial. It comprised of three days of adaptation to carrying fecal collecting bags followed by a seven-day feces collection period. Sheep were maintained on the experimental diets. Feces were collected and weighted every morning before morning feeding. The daily feces collected from each animal were weighed, mixed thoroughly, and 20% sub-sampled, kept in airtight plastic containers and stored at -20 ^{0}C. In, addition, the amount of feed offered, and refusals were collected, weighed, and recorded every morning. At the end of the digestibility trial, the fecal samples were thawed, thoroughly mixed and subsamples were taken, weighed, and dried at 60 ^{o}C for 48 hours. Collected fecal samples were air-dried and kept in tightened polyethylene bag until oven drying at 105 ^{0}C. The partially dried feces were ground to pass through a 1 mm sieve, stored in plastic bags pending laboratory analysis. Percentage of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF), and acid detergent lignin(ADL)were determined using the formula according to Mc Donald *et al.* (2010).

$$Nutrient\ digestability = \frac{N\text{utrient intake} - \text{Nutrient excreted in feces}}{Nutrient\ intake} * 100$$

3.8.Chemical Analysis

Representative (composite) samples of feed offered, refusal, and fecal samples were transported to ILRI Animal Nutrition Laboratory, Addis Ababa for laboratory analysis. Samples of feeds offered, refusals and feces were dried at 60°C for 48 hours in a forced draft oven and ground to pass through 1 mm sieve size using Wiley mill and packed into paper bags and stored pending further laboratory works. The samples were determined for DM, Ash, CP, NDF, ADF, ADL, IVOMD, using the Near-Infrared Reflectance Spectroscopy (NIRS) prediction equation of sweet lupin. Crude protein (CP %) of feed samples was determined by multiplying the N content of the samples with the conversion factor of 6.25. Metabolizable energy (ME) was estimated from digestible energy (DE) and IVOMD using regression and summation equations developed by NRC (2001): First DE (Digestible energy) had been obtained using the formula of:

DE= (0.01*(OM/100)*(IVOMD+12.9)*4.4)-0.3 then metabolizable energy could be calculated as follow: ME (Mcal/kg) =0.82*DE had been calculated and converted to Kilogram ME (MJ/Kg) =4.184*ME (Mcal/kg).

Where: DE=digestible energy; IVOMD= Invitro organic matter digestibility; ME= metabolizable energy; MJ= mega joule; Mcal= Mega calorie and kg=kilo gram

3.9.Partial Budget Analysis

The partial budget analysis of the current experiment was performed using the procedure of Upton M. (1979). Partial budget analysis is used to determine the profitability of the feeding regime on the experimental sheep. Partial budget analysis was calculated from the variable costs and benefits. The purchase price of experimental feed was recorded and the market price of experimental sheep at the beginning and the end of the experiment was assessed in the local animal market. Three experienced local sheep dealers were purposively selected to estimate the selling price of each experimental sheep before and after supplementation and the average of the three-estimation prices were taken. Then, the variable costs were calculated from supplementary feeds, which are provided for each experimental sheep treatment costs. The total returns (TR) were determined by calculating the difference between the estimated selling prices and purchasing price of experimental sheep and the cost of the supplemented feed. Net return (NR) was calculated as:

$NR = TR - TVC$,

The change in net return (ΔNR) was calculated by using the change in total return (ΔTR) and therefore the change in total variable costs (ΔTVC) (supplemented feed),

$\Delta NR = \Delta TR - \Delta TVC$.

The marginal rate of return (MRR) measures the rise in net income (Δ NR) as related to each other additional unit of expenditure (Δ TVC) was calculated as $MRR = (\Delta NR / \Delta TVC) \times 100$.

3.10. Statistical Data Analysis

All data on feed intake feed quality (nutritional content of feed) and live weight gain, FCE, and others were summarized and managed with MS-Excel (2010) and then subjected to analysis of variance (ANOVA) in a randomized complete block design using the general linear model procedure of SAS (2002) version 9.2. Individual differences between means had been tested using the Tukey HSD test. The model used for the analysis of all parameters of the experiment is as follows:

$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$

Where: Y_{ij}= response variable (feed intake, body weight gain, digestibility and economic feasibility)

μ = overall mean;

α_i = ^{ith} treatment effect (effect of supplement);

β_j= block effect; ε_{ij}= ^{it}h random error (undefined factors).

Chapter 4. RESULTS AND DISCUSSION

4.1. Chemical Composition of Experimental Feeds

The chemical composition of experimental feeds offered, and refusals are given in Table 4.5. The result showed that the DM content of natural pasture hay was 91.21%. The CP and OM contents of natural pasture hay were 6.8 and 85.7% respectively. The values of CP and OM were lower than the figures of 8.75% CP and 91.9 % OM reported for natural pasture hay by Yilkal Tadele *et al*., (2014) in other parts of the country. However, the CP contents of natural pasture hay in the current result is in line with the value of 6.85% reported by Wude Tsega, (2020), but higher than the values 5.1% reported by Yalew Demoze, (2020) in the area different from the current source of natural pasture. The NDF content of natural pasture hay of 66.7% is in line with the values of 66.39% Alemu Tarekegn,(2016) and, 67.77 % Ansha Ali, *et al*.,(2017) but lower than 79.4% reported by (Shashie Ayele 2017), 71.2% reported by (Daniel Taddesse *et al*. 2014) and 73.51% reported by Yalew Demoze, (2020). However, the NDF (66.7%) content of natural pasture hay in the current study is higher than 64.6, and 58.7% reported by Nigatu Dejene,(2017) and (Endalew Mekonnen, 2019) respectively. The ADF content of natural pasture hay (40.9%) used in this study was lower than 47.3% reported by Yalew Demoze, (2020), but in line with the values 41.15 % reported by (Kahsu Atsbha, *et al.*, 2021). The ADL content of natural pasture hay (6.7%) used in the current study was lower than the value of 7.45 and 9.25 % reported by Yalew Demoze, (2020) and Kahsu Atsbha, *et al*., (2021) respectively.

The differences between the chemical composition of natural pasture hay used in the current study as compared to previous results might be related to variations in species composition, harvesting stage, and environmental factors such as geographical location, fertility of the soil and level of fertilization, sowing season, and rainfall (Adugna Tolera *et al.,* 2012). The CP content of natural pasture hay in this experiment is below that required for maintenance CP (7%) requirement by ruminants. The CP contents of the supplement feed ingredients, i.e., concentrate mixture, roasted and coarsely ground sweet lupin grain, soaked sweet lupin grain, and steamed sweet lupin grain were 17.6, 36.2, 39.3, and 28.2% respectively. The CP content of processed sweet lupin grain in the current finding ranged between 28.2-39.3% on DM basis comparable with the content of sweet lupin grain range with 31-37% DM basis respectively reported by (Abraham EM,*et al*., 2019). The variation of CP in the chemical composition of supplemental processed sweet lupin grain used in the current study might be associated with differences in processing method. In addition, the variation of CP in the current result of the chemical composition of concentrate mixture is with related to ingredient composition in the diet.

Table 4.5 .Chemical composition of experimental feed offers and refusals

Feed offered	Chemical composition in (DM %)									
	Nutrient Parameters (%)									
	DM	ASH	OM	CP	NDF	ADF	ADL	ME	IVOMD	HC
NPH	91.2	14.3	85.7	6.8	66.7	40.9	6.7	6.9	47.7	25.8
Con.Mix	92.3	5.6	94.4	17.6	32.1	16.3	3.9	9	62.8	15.8
R&CGSLG	94.3	4.4	95.6	36.2	30.2	16.8	2.0	11.3	80.6	13.4
SSLG	93.3	4.5	95.5	39.3	30.3	14.7	1.1	11.3	81.7	15.6
St.SLG	93.1	3.9	96.1	28.2	38.7	25.3	1.6	10.2	72.8	13.4
Hay refusals (%)										
T1	91	12.3	87.7	6.1	70.3	44.5	7.5	6.5	44.1	28.5
T2	91	12.3	87.6	5.9	69.8	43.5	7.1	6.6	45	26.3
T3	90.9	12.5	87.5	6.5	68.5	44.4	7.2	6.4	43.9	24.1
T4	91	12.8	87.1	6.4	68.3	43.7	7	6.7	45.1	24.6

Where; DM= dry matter; OM=organic matter; CP= crude protein; NDF=neutral detergent fiber; ADF=Acid detergent fiber; ADL= acid detergent lignin; NPH=Natural Pasture Hay; HC:Hemicellulose , T1:Con.mix=concentrate mixture (30%, 35%, 35% and 1% Noug seed cake, coarsely ground maize grain, wheat bran, and salt respectively); T2:RCGSLG=Roasted and coarsely ground sweet lupin grain; T3:SSLG=Soaked sweet lupin grain; T4:St.SLG=Steamed sweet lupin grain.

The CP content (6.80%) of natural pasture hay recorded in the current study was comparable to 6.70% reported by (Aschalew Assefa and Getachew Animut, 2013), and 6.85% the report of (Wude Tsega, 2017). Meanwhile, the CP content of the basal diet was higher than (3.01%) and 6.45% of CP reported by (Hunegnaw Abebe, 2015) and (Yalew Demoze,2020). But the observed 6.8% CP content of the natural pasture hay was lower than 7.2% and 7.2% reported by (Desta Tekle, *et al*., 2017) and (Lemma Gulilat, *et al*.,2017) respectively. 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.

The crude protein and ME content of the natural pasture hay in the current study varied from what was reported by Ansha Ali *et al*., (2017), Nigatu Dejene, (2017), Yalew Demoze, (2020), Firisa Woyessa *et al*.,(2013), Shewangzaw Addisu *et al*., (2013), yet, it was low (i.e. <7%) and cannot support the nutrient requirements of sheep fattening Van Soest, (1994). Accordingly, the grazing sheep need energy and protein supplementation to meet their requirements for maintenance and growth. In general, the sweet lupin grains used in the current study is a high content of CP and ME (28.2-39.3% and 10.2 -11.3 MJ/kg of DM). The nutritional content of sweet lupin grains in the current study is comparable to the literature Prandini, *et al*.,(2005) ,Gebru Tefera *et al*., (2015), with some variation which could be due to biotic and abiotic factors.

Whereas ADL contents of natural pasture hay in the current study 6.67% was lower than 7.45% of natural pasture hay, reported by Yalew Demoze, (2020). The distinction of the current finding from the other study was the availability and quality aspect of forages from native pasture is governed by different factors that directly and indirectly influence the nutrient content such as species composition, i.e. climate (rainfall and temperature), altitude, soil, and farming intensity Malede Birhan and Takele Adugna, (2014). The natural pasture hay had low CP (5.5%) and high NDF (76.3%), ADF (39.7%) and ADL (7.8%) contents Firisa Woyessa, *et al*.,(2013) were more contradict in the current finding due to by different factors affecting the nutritive value of natural pasture hay such as varietal differences, location or climate, the fertility of the land, stage of maturity at harvest, morphological fractions (e.g. leaf to steam ratio), harvesting and transporting practices, length, and condition of storage time Firisa Woyessa *et al*.,(2013).

The ME content of natural pasture 6.89 MJ/kg DM of the current study is lower than 10MJ/Kg DM reported by (Shewangzaw Addisu *et al*., 2013). However, this indicates that pasture hay can satisfy the energy requirement (6.4 MJ/kg DM) of growing male sheep with 20kg live body weight and 150g mean daily gain, but require protein supplement to satisfy the metabolizable protein requirement (61-76g) of the same class of animal (McDonald, *et al.*, 2010).

The DM, OM, CP, ash, NDF, ADF, ADL, and ME content of the hay refusals were almost similar among all treatments. Comparison between the chemical composition of hay offered and refused revealed that the basal diet hay offered had higher CP, ash, and ME than refusals but lower DM, OM, NDF, ADF, and ADL values which may be because experimental sheep selected more edible portions of the basal diet (such as leaves and shoots) and left the more woody parts (such as stems) of the grass which had higher fiber (NDF, ADF, and ADL) fractions.

On the other hand, in the current study, the DM content of the control treatment (T1) concentrate mixture (92.26%) was lower than for all processed sweet lupin grain (T2, T3, and T4). Above and beyond, the DM, OM, and CP contents of processed sweet lupin grain such as (T2, T3, and T4) were higher than the concentrate mixture (T1). Nonetheless, it had the lowest ash content compared to the other feeds. The NDF, ADF, ADL, and ash contents of the hay were higher than the contents of lupin grain and concentrate feed, whereas CP and OM contents of the hay were the lowest. However, the concentrate mixture (T1) supplement feed had the lowest ADL content than the other treatment (T2, T3, and T4) feeds.

The DM content of the concentrate mixture (92.3%) used in this study was slightly lower than 95.75% reported by(Abraham Teklehaymanot, 2018) but, the CP content(17.6%) of the concentrate mixture in the present study was lower than the values 20.84% reported by Kahsu Atsbha, *et al*., (2021). Hence, this much amount of variation might arise from variations in the proportion, classifications, preparation, ingredient particle size, and the ingredient nutrient content of the feed. According to the document of Lonsdale. C 1989) stated that feeds are classified according to the energy and protein contents of the ingredients. Hence, feedstuffs having more than 200g/kg of DM of CP are categorized as protein high feeds and feedstuffs containing less than 120g/kg of DM of CP are categorized as protein low feeds. Similarly, feedstuffs containing more than 12.0 MJ/kg of DM of metabolizable energy are classified as high energy feed and feedstuffs containing less than 9.0 MJ/kg of DM of metabolizable energy are classified as low energy feeds. Hence, according to this classification, the concentrate mixture and processed sweet lupin grain used in the present study could be classified as high energy and protein quality supplement capable of supporting animal growth performance.

In the current on-farm study, the CP content of the control treatment (T1) as well as for all processed sweet lupin grain diets was above the maintenance requirement of CP for a small ruminant. Therefore, sheep gave a fed for the control diet to gain sufficient body weight, it was significant ($p<0.001$), which necessitates a little supplementation but lower than for all processed sweet lupin grain (T2, T3, T4). The DM (92.3%), OM (94.37%), and CP(17.60%) content of concentrate mixture (T1) in the current finding was lower than for the other three treatments whereas NDF(32.10%) content was higher than with roasted and coarsely ground sweet lupin grain and soaked sweet lupin grain but lower than steamed sweet lupin grain(T4). The concentrate mixture supplement feed had the highest ADL content than the other treatment feed. This variation could be due to the increment of the CP and lower fiber friction content of all processed sweet lupin grains.

The DM content of processed sweet lupin grain used in the current study higher than 91% reported by Gdala & Buraczewska, (1996) and comparable with 93.06% and 93.8% documented by Paulos Getachew, (2009) and Yilkal Tadele *et al*., (2014) respectively. the DM content of roasted and coarsely ground sweet lupin grain 93.4 (T2) was lower than 94.1 reported by Gebru Tefera *et al*., (2015), and the DM content of raw soaked sweet lupin grain 93.3 % (T3) was higher than 92.5% documented by Gebru Tefera *et al*., (2015). The OM contents of processed sweet lupin in this study were higher than 89% reported by Gebreu Tefera, *et al*., (2015) and lower than 97% reported by Tizazu Haile and Shimelis Emire, (2010). In the dry matter of seeds of lupin varieties approved in the Czech Republic (*Lupinus albus, L. angustifolius, L. luteus*) individual constituents are in a relatively wide range, depending on the variety and climatic conditions organic matter content (951.8–966.2) and ADF (133.1–209.3)g/kg of dry matter respectively documented by Sedlakova, *et al.,* (2016).

The CP and metabolizable energy content of processed sweet lupin grain in the current finding were ranged 28.2-39.3% and 10.2 -11.3 MJ/kg of DM comparable with the content of sweet lupin grain range with 31-37% and 12-13 MJ/Kg of DM respectively reported(Abraham EM *et al*., 2019). In the dry matter of seeds of lupin varieties approved in the Czech Republic (Lupinus albus, L. angustifolius, L. luteus) individual constituents are in a relatively wide range, depending on the variety and climatic conditions (Sedlakova, *et al* 2016) (g/kg) CP content was ranged with 31.7.1–45.89 %. Furthermore, lupin grain was a valuable source of nitrogen and energy owing to their high contents of crude protein (300–500 g kg^{-1}) which vary highly depended on species, variety, genotypes, location, and their processing practice (Calabro *et al.,* 2015) and (Abraham *et al.*, 2019).

Moreover, roasted and coarsely ground sweet lupin grain(T2) (36.15%) in the current study was comparable with 35.05% reported by (Prandini, *et al*.,2005) and 36.2% reported for raw lupin grain by (Gebru Tefera *et al*., 2015). However, lower than 58.3% for soaked de-hulled lupin reported by (Gebru Tefera, *et al*., 2015). On the other hand, the CP content of soaked sweet lupin grain(T3)(39.26%) in the current study was lower than 58.3% for soaked de-hulled lupin reported by (Gebru Tefera, *et al.*,2015). However, soaked sweet lupin grain in the current study was higher CP content than the others.

In addition, processed sweet lupin grains have a good nutritional property; however, the nutritive value of this processed sweet lupin grain is varied due to the different factors, like species, genotypes, location, and processing practice. 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 differences of the species, processing practice, and Environmental differences (Hill., 2005).

The NDF contents of processed sweet lupin grain in the current study was higher than 19.8% reported by (Vladimir *et al*.,2008) and 27.3% reported by (Niwiska and Rzejewski, 2011) and lower than 58.8% reported by (LoLopez, *et al*.,2005) nevertheless, ADF content of processed sweet lupin grain in this study was lower than 28.2% for roasted lupin grain by (Gebreu Tefera, 2009) and 42% reported by (Lo Lopez, *et al*., 2005).

Generally, in the current study, processed sweet lupine grain was a high proportion of nutritional value which could be potential feed for a small ruminant. This study was in line with (Brenes, 2002) who also reported that processing is improved the nutritional value of lupine.

4.2.Dry Matter and Nutrient Intakes

The daily dry matter and nutrient intake of Doyogena sheep ad libitum fed natural pasture hay with concentrate mixture and processed sweet lupine grain supplementation is given in Table 4.6. Steamed sweet lupin grain (T4) had a significantly higher DMI of hay compared to the other treatments (T1, T2 and T3). The DMI of the sheep in this study was close to the previous reports on washera sheep (Yilkal Tadele *et al.,* 2014), (Likawent Yeheyis *et al*., 2012). Roasted and coarsely ground sweet lupin grain (T2) had the highest intake of grains followed by T3, T4, and T1. However, when the total dry matter intake was normalized to the live weight, there was no significant difference among the dietary treatments. That means use of processed sweet lupin grains had no effect on the diet palatability. It seems that processing the grains did not result in any change in the palatability. Since, lupin provides greater metabolizable energy content to ruminants, as well as, containing high fiber content which is easily fermented in the rumen (Dixon & Hosking, 1992). Other studies reported that the supplementation with lupin had positive effects on ruminants feed intake (Yilkal Tadele *et al*., 2014) and (Nahom Ephrem *et al.*, 2015) as noticed an increase in CP, NDF, and ADF intake for animals supplemented with lupin grains.

Moreover, increased CP intake by supplemented groups was due to the improvement of total DM intake and CP content of the lupin offered as reported by (Foster *et al*., 2009). According to the report of (Yilkal Tadele *et al*., 2014), the total DM, CP, NDF, and ADF intake was enhanced by the supplementation of lupin grain to lambs feed. They referred to this result to the fact that the supplementation of processed sweet lupin grain was enhanced fermentation of roughage and thus increased the protein synthesis by rumen microbes. The researchers also noticed that the fibrous feed digestion rate may increase by the supplementation of nitrogen ensuring greater DM intake.

The experimental sheep placed, and daily weight change as well as in TDMI (g/kg) on the treatment diets containing 440 g (T1), 440 g (T2), and 440g (T3) lower than the amounts consumed by the groups placed on 440 g (T4) steamed sweet lupin grain with Adlibitum of natural pasture hay. This result indicates that processed sweet lupin grain in the form of steamed was superior in nutritive value as well as palatability to compare the other concentrate mix and processed sweet lupin grain. Sheep fed a ration in processed sweet lupin grain consumed was significantly higher than other concentrate mixture feeding of sheep. Thus there was a significant ($P<0.01$) and proportional increase in the daily DM intake of the experimental sheep. The highest total daily DM intake was obtained from the group fed on steamed sweet lupin grain T (4) whereas the lowest TDMI was obtained from the group feed on concentrate mixture (T1). This distinction came due to the high availability of fiber and slightly content of CP in the feed and their processing of the diet.

The total DM (784.76- 805.46g/day) intake of sheep in the current study was comparable to the results of (Yilkal Tadele *et al.,* 2014) reported for supplementation with Different forms of Processed Lupin (Lupinus albus) grain in Hay Based Feeding of Washera Sheep. However, the total DM intake was lower than the reports of (Likawent Yeheyis *et al*., 2012) studied in sweet blue lupin (*Lupinus angustifolius L.*) seed as a substitute for concentrate mix supplement in the diets of yearling washera rams fed on natural pasture hay as basal diet. The observed difference in total DM and CP intake among treatments was significant $p<0.05$. The total NDF, ADF, and ADL intake were significantly different ($P<0.05$) among the four treatment groups. Thus they had a positive relationship was observed between hay DM intake and the different fiber fraction intake. As a result, the fiber fraction intake (NDF and ADF) for the T4 treatment group was higher than the other groups but ADL content was lower than the other treatment diets. This is due to the effect of the processing practice of the diet. The observed difference in ash intake was significantly different ($P<0.01$) with the difference to the ash intake among treatment groups, sheep under T4 had the highest ($P<0.001$) OM intake. However, there was a significant difference ($P<0.001$) in OM intake among all treatment groups. Total dry matter intake as a percent of live body weight varied significantly ($P<0.01$) among treatment groups.

Table 4.6. Dry matter and Nutrient intake of Doyogena lambs fed natural pasture hay basal feed and supplemented with processed sweet lupin grain.

Dry matter intake(g/kg)	Treatments					
	T1	T2	T3	T4	SEM	SL
Hay DMI	378.79^{b}	385.14^{ab}	382.21^{ab}	395.8^{a}	2.81	**
Supplement DMI	405.23^{d}	411.04^{a}	410.56^{b}	409.61^{c}	0.41	***
Total DMI	784.76^{b}	796.18^{ab}	792.77^{ab}	805.46^{a}	2.92	**
DMI (% BW)	4.60^{a}	5.01^{a}	4.90^{a}	4.89^{a}	0.18	Ns
DMI (g/kg W $^{0.75}$)	53.60^{a}	50.46^{a}	51.43a	51.53^{a}	1.84	Ns
Nutrient intake(g/day)						
Total ASH	84.03^{b}	79.74^{c}	80.16^{c}	99.46^{a}	1.71	**
Total OM	770.83^{b}	782.51^{ab}	779.32^{ab}	794.77^{a}	2.94	**
Total CP	105.68^{d}	187.68^{b}	200.97^{a}	153.59^{c}	7.67	***
Total NDF	418.24^{b}	414.52^{b}	412.82^{b}	459.75^{a}	4.4	***
Total ADF	241.57^{bc}	246.18^{b}	236.07^{c}	288.82^{a}	4.49	***
Total ADL	444.98^{a}	36.67^{b}	32.78^{c}	36.11^{b}	0.95	***

Where; a-d Means with different superscript in the row are different P<0.05 (*); p<0.01(**); p<0.001(***); BW=body weight of live animal; DMI=Dry matter intake, OMI=organic matter *intake; NDF=neutral detergent fiber intake; ADF=acid detergent fiber; ADL=acid detergent lignin; CP=crude protein intake; SEM=standard error mean; SL=significant level. Ns=none significance*

Figure 4.4 showed that the average dry matter intake for all treatments was contradict to each other once week increased and the next one also decreased throughout the experimental period for sheep in all treatments. However, the total dry matter intake of sheep in T2, T3 and T4 becomes slightly deference between them for the periods of the experiment. This indicated that sheep in these treatments reached the maximum level of intake.

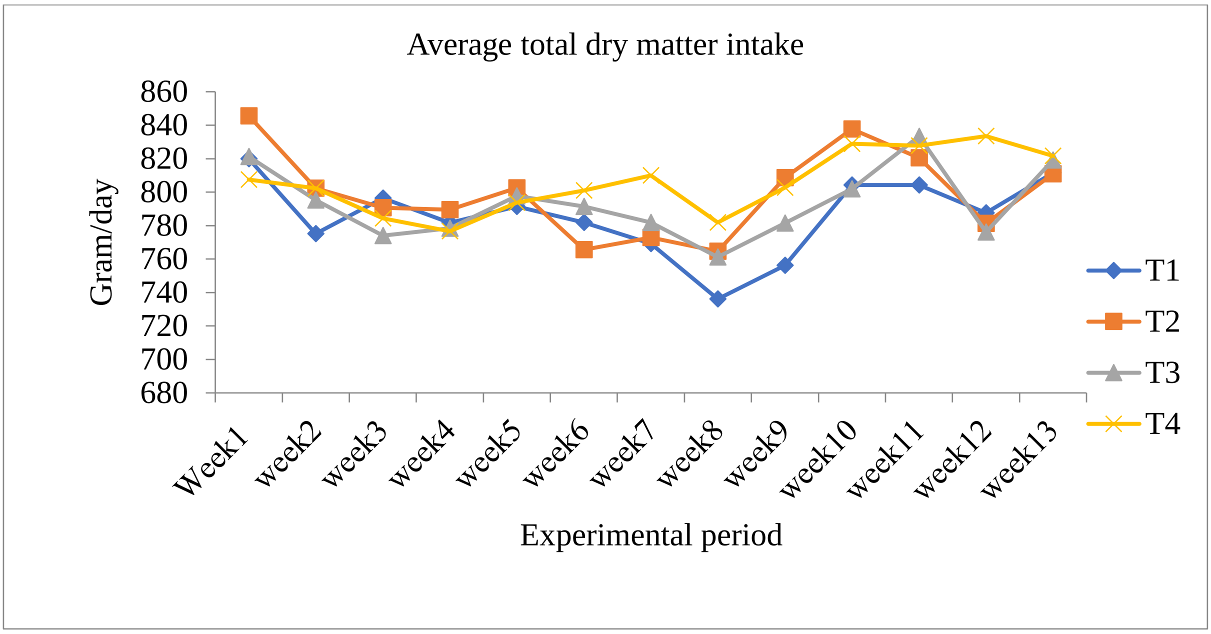

Figure 4.4. Trends dry matter intake over the experimental days for Doyogena sheep feed natural pasture hay as a basal diet and supplemented with processed sweet lupin grain and commercial concentrate mixture

4.3.Dry Matter and Nutrients Digestibility

The apparent nutrients and DM digestibility of Doyogena sheep fed natural pasture hay and supplemented with processed sweet lupin grain was presented in Table 4.7. According to the report of (McDonald, *et al*., 2010), digestibility refers to the extent to which a nutrient is absorbed in the animal body as it passes through an animal's digestive tract and varies greatly with the type of feedstuff and the type of animal concerned. All the processing methods were significantly (P<0.001) improved nutrient digestibility and nutrient digestible intake. Steamed sweet lupin grain (T4) had significantly (P<0.01) the best digestibility and nutrient intake of DM, OM, CP, NDF, and ADF. The energy intake (ME) improved significantly (P< 0.001) in the treatments compared to the control; however, T4 had significantly the highest improvement among all of the treatments. This is in agreement with Petterson (2000) who reported that steaming lupin grains improved digestibility by inactivating tannins and saponin and alkaloids.

In this current study, the DM and ADF digestibility were improved by the supplementation of processed sweet lupin grain as well as the CP and NDF digestibility were improved for lambs fed different processed sweet lupin grain. This study was comparable with (Nahom Ephrem *et al*., 2015) noticed that DM and CP digestibility was increased for supplemented sheep while NDF and ADF digestibility was not affected by the supplementation of lupin grains to the diets. In the present study, CP digestibility in the control group was lower than the other processed sweet lupin grain supplemented group this is due to the processing and slight CP intake compared with the supplemented group. The lower digestibility of CP in the concentrate mixture treatment group might refer to the lower CP intake and greater NDF content in the diet which affects the rumen microbial activity (McDonald *et al*.,2010). The impact of supplementation on the digestibility of the forage may be influenced by the relative amounts of forage and concentrate in the ration, the feed chemical composition, and the level of feeding (McDonald, *et al*., 2010). The Digestibility of NDF might be affected by its chemical structure since it is not considered as a homogenous component, this may lead to digestibility fluctuation in the rumen which may range from lower than 25 % to higher than 75 % of digestion (Kendall *et al*., 2009). Nutrients digestibility improvement resulted from the grinding of grain to reduce the feed particle size and increase the surface area of rumen microbes' exposure to the feed (Yilkal Tadele *et al*., 2014). (Van Barneveld, 1999) summarized the effect of lupin supplementation on the improvement of nutrients digestibility by the excess amount of N provided from lupin that will enhance the microbial protein synthesis in the rumen during microbial fermentation. As well as, the greater metabolizable energy content of lupin and lower fiber digestion disturbance that often pairs with cereal starch fermentation.

The dry matter nutrient digestibility of feed supplemented with steamed sweet lupin grain and roasted (T4) and coarsely ground sweet lupin grain (T2) had a higher value than the other treatments while dry matter nutrient digestibility of feed supplemented with concentrate mixture in treatment one had lower dry matter digestibility as compared to the other treatments. The crude protein nutrient digestibility of steamed sweet lupin grain (T4) was higher than all other treatments. The result has shown that highly (P<0.001) significant differences were observed in apparent OM and CP digestibility coefficient among treatments. This is due to the differences in the nitrogen content of the supplements in different treatment groups. The apparent digestibility coefficient of DM, OM, NDF, and ADF-soaked sweet lupin and steamed sweet lupin grain was higher than the other treatments. The apparent digestibility coefficient of CP was higher in steamed sweet lupin grain (T4) than in all other treatments. This result was in line with the report of (Nahom Ephrem *et al.,* 2015) with supplemented the graded level of sweet lupines and concentrate mixtures. The higher DM digestibility in T3 was not compared to other treatments might be due to their lower average feces voided dry matter and lower NDF and ADF intake in this treatment group.

The result of the current study showed that DM digestibility was adversely influenced by the lignin concentration in the experimental diet. The digestibility of a feed is determined largely by the chemical composition of the feed (Khan *et al.,* 2003). In T3, higher CP content results could have created a better environment by providing more nitrogen for rumen microorganisms, which was, make higher digestibility of DM for this treatment (Asmamaw Yinesu and Ajebu Nurfeta, 2012). Besides (McDonald, *et al.,*2010) reported that the primary chemical composition of feeds that determines the rate of digestion is neutral detergent fiber (NDF). The apparent digestibility of feeds should exceed 70% on a dry weight basis for the good performance of the animals and when apparent digestibility is 60%, the performance will be intermediate and the minimum range of apparent digestibility to assure body maintenance needs is 42-45%, whereas at animals loss weight (McDonald, *et al.,*2010). Based on this classification the feed used in the present study in T2, T3, and T4 were classified as excellent digestibility of feeds whereas only T1 were classified as medium digestibility.

Experimental lambs in T4 showed a higher DM digestibility coefficient (0.84) than the other treatment. Generally, DM's apparent digestibility is superior to that of most other processed sweet lupin grain. The apparent CP digestibility coefficient of T4 and T2 were higher (P<0.001) than T1 and T3. Moreover, apparent CP digestibility was higher (P<0.001) for T4 as compared to T1, T2, and T3. This significant difference between treatments was (p<0.001) due to the higher CP content of the seed as well as the feed processing practice than other feed. Since high CP intake is usually associated with better CP digestibility (McDonald, *et al.*,2010) Generally, the CP digestibility was higher than other chemical compositions due to the high nitrogen content (McDonald, *et al.*,2010).

The apparent NDF digestibility of T2 and T4 was highly significant (P<0.001) than T1 and T3. The NDF digestibility and apparent ADF digestibility coefficient of T4 were highly significant (P<0.001) among treatments.

Table 4.7.Apparent digestibility coefficients of nutrients in Doyogena sheep fed on hay and supplemented with processed sweet lupin grain.

Digestible Nutrient(g/d)	Treatments					
	T1	T2	T3	T4	SEM	SL
DM	502.23^{d}	633.82^{b}	578.82^{c}	677.65^{a}	13.45	***
OM	585.19^{c}	698.25^{a}	656.02^{b}	721.13^{a}	13.44	***
CP	72.08^{c}	173.88^{a}	172.32^{a}	141.75^{b}	2.46	***
NDF	325.60^{c}	367.89^{b}	349.64^{bc}	416.78^{a}	10.36	**
ADF	162.13^{c}	162.13^{b}	182.39b^{c}	254.80^{a}	7.21	**
Digestibility Coefficient						
DM	0.53^{d}	0.78^{b}	0.69^{c}	0.84^{a}	0.029	***
OM	0.73^{d}	0.87^{b}	0.80^{c}	0.91^{a}	0.028	***
CP	0.66^{c}	0.92^{a}	0.84^{b}	0.92^{a}	0.063	***
NDF	0.74^{d}	0.86^{b}	0.79^{c}	0.91^{a}	0.039	***
ADF	0.63^{d}	0.80^{b}	0.72^{c}	0.88^{a}	0.063	***

Where; a-b means in the same raw with different superscript differ significantly, SE=standard error, DM= dry matter, CP=crude protein, OM=organic matter, NDF=neutral detergent fiber, ADF=acid detergent fiber, SL=significance level, NS=note significance, T1=concentrate mixture, T2=roasted and coarsely ground sweet lupin grain, T3=soaked sweet lupin grain, T4=steamed sweet lupin grain.

4.4.Bodyweight Change and Feed conversion Efficiency

The mean initial and final body weight, live weight change, average daily body weight gain (ADG), and feed conversion efficiency (FCE) of Doyogena sheep fed on natural pasture hay basal feed and supplement of processed sweet lupin grain are presented in Table 4.8. Among all treatment groups sheep in T4 had significantly higher (p<0.05) final body weight than other treatment groups. The variations in the bodyweight change of Doyogena sheep fed the experimental diets, there was also a significant (P<0.001) variations in average daily weight gains (ADG) of sheep on the different processed diets.

Accordingly, sheep fed the basal diet and supplemented with processed sweet lupin grain (T2, T3, and T4), had highly significantly ($P<0.001$) ADG but, lower than sheep fed basal diets and supplemented with concentrate mixture with the same basal diet taken ad libitum. This is might be due to the difference in CP contents of the supplement feed. The average daily body weight gain and feed conversion efficiency increased due to the different sweet lupin processing practices. Though there were variations in body weight change parameters among treatment groups, there was a significant difference among treatments for all bodyweight change parameters. Numerically, sheep under treatment groups with concentrate supplement (T1) fewer than other processed sweet lupin seed/grain supplements and (T4) had the highest values for all bodyweight change parameters among the other treatment group. Sheep under T2 had the second-highest values for body weight change parameters. Similar to body weight change parameters, there was a significant difference among treatments in feed conversion efficiency (FCE). However, numerically, T2 and T4 had the highest FCE values than T1 (concentrate mixture). Sheep supplemented with pure concentrate mixture (T1) had the lowest daily weight gain throughout the experiment however sheep was fed processed sweet lupin grain had gradually increased body weight gain as well as (FCE) throughout the experiment. The daily weight change for sheep under T1 showed a slightly increasing trend throughout the experiment period. However, for the other three treatments, the daily weight change started to end of the experiment rapidly increased. During the last 3 weeks of the experiment, the daily weight change showed an increasing trend in treatment (T4) rapidly followed to T2 and T3 respectively.

Table 4.8. Bodyweight parameters and feed conversation efficiency of Doyogena sheep fed on natural pasture hay and supplemented with processed sweet lupin grain.

Parameters	Treatment					
	T1	T2	T3	T4	SEM	SL
IBW(kg)	27.4^{a}	28.16^{a}	28.23^{a}	26.38^{a}	0.55	Ns
FBW(kg)	36.08^{a}	39.88^{a}	38.83^{a}	39.41^{a}	0.86	Ns
BWC(kg)	8.71^{b}	11.72^{ab}	10.56^{ab}	13.03^{a}	0.58	**
ADWG(g)	96^{b}	130^{ab}	117^{ab}	145^{a}	0.006	***
FCE	0.123^{b}	0.163^{ab}	0.148^{ab}	0.180^{a}	0.008	**

*a, b, c, d=means within rows having different superscript are significantly different at,***=*

*P<0.001; ** = P<0.01; IBW=initial body weight; FBW=final body weight; FCR=feed conversion efficiency; SEM= standard error of mean; SL=significance level; BWC= body weight change; kg=kilo gram; g=gram's=treatment*

The mean daily body weight gain of Doyogena lambs ranged from (96-145g/day) brought by the groups fed on the basal diet natural pasture hay containing the inclusion of processed sweet lupin grain was significantly higher (P<0.001) than all others. The body weight change of Doyogena lambs fed natural pasture hay basal diet and processed sweet lupin grain concentrate mix supplement had similar development with the average daily body gain.

This study illustrates that supplementation of processed sweet lupin grain improves the performance of animals due to positive body weight gain of Doyogena lambs. Hence the current on-farm study was a higher Bodyweight change than 290g/d/h sweet lupin grain supplementation increases the live weight of experimental animals on average from 21.9kg to 29.4kg. in the current on-farm study, the final body weight, body weight change and daily weight change obtained in the current study was higher than the result obtained by (Likawent yeheyis *et al*., 2011), this due to the supplementation period difference as well as the processing practice of the experimental diet.

The current on-farm study conducted for 90 days using processed sweet lupin grain supplementation was higher body weight gain than a study conducted for 69 days using sweet lupin grain as a supplement at 290 g/ head per day on Washera sheep shows that the animals can gain 74 g/ head per day and 5.1 kg/ head per 69 days(Likawent Yeheyis *et al.*, 2012) and on-farm trial by CASCAPE Project, the average daily gain of local male sheep that were fed sweet lupin at 290 g per head per day ranges from 64 to 67g per head per day. The average daily gain (ADG) of the sheep in the current study was higher than when it is compared with other studies(Likawent Yeheyis *et al.*, 2012) This variation was obtained due to the distinction of management of the experimental animals by the farmers as well as the processing practice of the experimental diet.

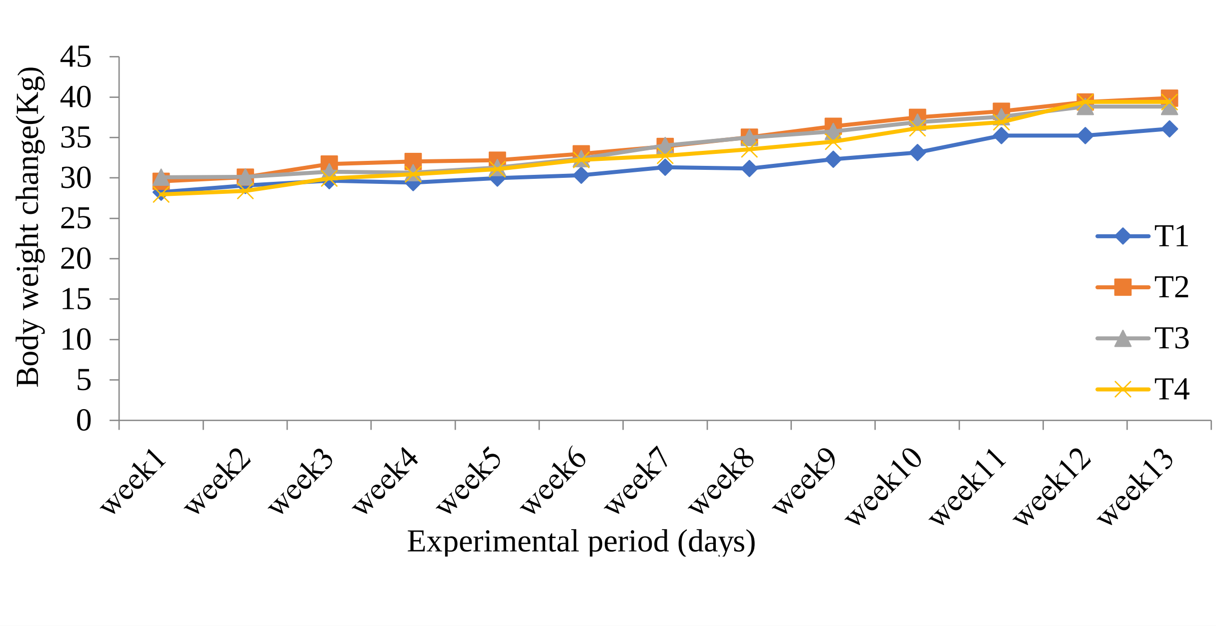

Figure 4.5. Bodyweight change of Doyogena sheep fed on hay and supplemented with different forms of processed sweet lupin grain.

4.5.Correlation among Nutrients Intake, Apparent Digestibility, and Daily Body Weight gain of Doyogena Sheep

The correlation among nutrient intake, apparent digestibility, and daily body weight gain yearling Doyogena sheep of the current study is shown in Table 4.9. Dry matter intake and digestibility were positively correlated ($P<0.05$) with CP, OM, NDF, and ADF intake and digestibility and with each other. The ADMI and ADMD were positively correlated with mean body weight gains and the organic matter intake was positively correlated with ACP, ANDF, AADF digestibility which was significantly ($P<0.05$) correlated with ADG. The result of the correlation analysis indicated that daily body weight gain was positively ($P<0.05$) correlated with TDM, TOM, TCP, TNDF, and TADF intake and digestibility which is in agreement with previous results obtained from the feeding trial conducted with Washera Sheep (Assefu Gizachew, 2012 and Awoke Kassa, 2015) and Gumuz breed of Sheep (Alemu Tarekegn, 2016) in northwestern Ethiopia. The correlation among TNDFI TADFI, ADMD, AOMD, ACPD, ANDFD, and AADFD were significant ($P<0.001$), the correlation between TNDFI and ADG was negative. Hay dry matter intake had a positive correlation with all nutrient intake parameters but the concentrate dry matter intake had a positive correlation with the total dry matter, organic matter, and ash intakes. However, both hay and concentrate had a significant correlation with daily weight gain ($P<0.001$). Total dry matter intake and organic matter intake had a positive correlation with all the nutrient intake parameters and daily body weight change ($P<0.01$). The only fiber fraction neutral detergent fiber (NDF) intake and digestible organic matter intake had also a positive correlation ($P<0.001$) with daily weight gain. Among all parameters evaluated, the ash intake had a higher positive correlation ($P<0.001$) with all the nutrient intake parameters and daily weight gain.

Table 4.9. Correlation between nutrient intake, apparent digestibility, and Average daily body weight gain in Doyogena lambs fed natural pasture hay and supplemented with processed sweet lupin grain and natural pasture hay as a basal diet.

	TDMI	TOMI	TCPI	TNDFI	TADFI	ADMD	AOMD	ACPD	ANDFD	AADFD	AMED	ADWG
TDMI	1											
TOMI	0.993**	1										
TCPI	0.998**	0.998**	1									
TNDFI	0.997**	0.999**	0.999**	1								
TADFI	0.997**	0.998**	0.999**	0.999**	1							
ADMD	0.486*	0.505**	0.496*	0.499*	0.498*	1						
AOMD	0.517**	0.539**	0.529**	0.532**	0.531*	0.952**	1					
ACPD	0.510**	0.530**	0.520**	0.524**	0.522**	0.870**	0.925**	1				
ANDFD	0.474**	0.503**	0.489**	0.493*	0.492*	0.905**	0.974**	0.855**	1			
AADFD	0.475*	0.506	0.491*	0.496*	0.494*	0.903**	0.928**	0.783**	0.970**	1		
AMED	0.466*	0.483*	0.475*	0.478**	0.477**	0.982**	0.947*	0.911**	0.881**	0.841**	1	
ADWG	-0.038^{ns}	0.023*	0.268*	0.189*	0.321*	0.576**	0.526**	0.389*	0.541**	0.543**	0.563**	1

*** Correlation is significant at the 0.01 level, *correlation is significant at the 0.05 level, TDMI= total dry matter intake, TOMI= total organic matter intake, TCPI = total crude protein intake, TNDFI = total neutral detergent fiber intake, TADFI = total acid detergent fiber intake, ADMD = apparent dry matter digestibility, AOMD = apparent organic matter digestibility, ACPD= apparent crude protein digestibility, ANDFD= apparent neutral detergent fiber digestibility, AADFD =apparent acid detergent fiber digestibility, and ADWG= average daily weight gain.*

4.6.Partial Budget Analysis

Partial budget analysis of Doyogena sheep fed on hay basal diet and supplemented with different forms of processed lupin grain is given in Table 4.10. The partial budget analysis was used to evaluate the economic advantage of different forms of supplement feeds. It involves calculating the costs and benefits of small changes 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 withT2, T3, and T4, sheep in T1 gained lower BW as a result of lower nutrient intake that consequently resulted in lower net return.

Among the treatments, 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 T3 was higher than the net return for T2. The difference in the net return between T3 and T2 has been attributed to the difference in BW change of sheep which intern was due to the processing methods employed in each treatment.

Generally, in the current study, sheep that had a better nutrient intake had superior average body weight gain and had a higher sale price to earn a higher net return.

The marginal rate of return ratio for supplemented sheep in T2, T3, and T4 was 3.497, 0.637, and 53.357 respectively. This indicates that to attain the required BW by supplement feeding, each additional unit of 1ETB increment per Sheep to purchase supplement feed resulted in a profit of 3.497 ETB for T2, 0.637 ETB for T3, and 53.357 ETB for T4. However, new technologies normally require investment, therefore, additional capital is necessary. When capital is limited, the extra (or marginal) cost should be compared with the extra (or marginal) net benefit. This technology was needed for the processing of sweet lupin grain. Thus, even though sheep in T2, T3, and T4 showed good performance in BW gain as well as found to be economically feasible compared to the other supplemented treatments. Thus, from the biological point of view, these three treatments T2, T3, and T4 resulted from better final and average body weight gain and were recommended. However, concerning economic profitability, the results of this study were suggested that supplementation of natural pasture hay with steamed sweet lupin grain/seed is potentially more profitable and economically beneficial than the other supplement feeds.

Table 4.10. Partial budget and marginal rate of return analysis for Doyogena sheep supplemented with processed sweet lupin grain on hay-based feeding.

Parameters	Treatments			
	T1	T2	T3	T4
Number of Animals	6	6	6	6
Purchase price of sheep(ETB/head)	2025	1952.8	2147.2	2175
Total hay consumed(kg/head)	34.88	35.46	35.19	36.45
Feed Cost for hay(ETB/head)	116.15	118.08	117.18	121.37
Total concentrate consumed(kg/head)	50.5	-	-	-
Cost for concentrates (ETB/head)	484.8	-	-	-
Total sweet lupin consumed(kg/head)	-	50.5	50.5	50.5
Total Cost of sweet lupin(ETB/Kg/head)	-	1515	1515	1515
Labor cost (ETB/head)	30	83.33	155.5	155.5
Medication cost(ETB/head)	62.04	62.04	62.04	62.04
Gross income (selling price of sheep)	4413.88	5816.65	6127.77	6383.33
Total return(ETB/head)	2388.88	3863.85	3980.57	4208.33
Total variable cost (ETB/head)	692.99	1020.95	1092.22	1096.41
Net return(ETB/head	1695.89	2842.9	2888.35	3111.92
∆NR	-	1147.01	45.45	223.57
∆TVC	-	327.96	71.27	4.19
MRR (%)	-	3.497	0.637	53.357

Where: ETB, Ethiopian Birr; ∆NI, change in net income; ∆TVC, change in total variable cost; MRR, marginal rate of return

The marginal rate of return or ratio for supplemented sheep in T2, and T4 was 3.497, and 53.357 ETB, respectively. The result achieved in the present study was higher than 1.22 reported by (Molla Haile *et al*.,2017) but lower than on sheep supplemented soaked sweet lupin grain(T3). This may be the variations in the purchasing price of sheep, current market situation and selling price of sheep, variations in sheep breeds used, and differences in basal diet and supplements used in different experiments. In general, in the current finding result feed supplements, which had low cost a better ADG to earn higher net returns.

Chapter 5. CONCLUSION AND RECOMMENDATIONS

5.1.CONCLUSION

According to, the result in chemical analysis of the treatment diets was, CP, NDF, and ADF contents of NPH were 6.8, 66.7, and 40.9%, respectively. The CP contents of the treatments concentrate mixture(30% Nuge seed cake,35% wheat bran 35% coarsely ground maize grain, and 1% salt), roasted and coarsely ground sweet lupin grain, soaked sweet lupin grain, and steamed sweet lupin grain were 17.6, 36.2, 39.3, and 28.2, respectively.

The percentage BW and NDF intake was higher (P<0.001) for Steamed sweet lupin grain (T4) than the other treatment feeds but lower CP content than T2 (roasted and coarsely ground sweet lupin grain and Soaked sweet lupin grain (T3). Intake of OM in T4 was estimated metabolizable energy and basal feed were highly significant (P<0.0001) among the treatments. Sheep-fed T2, T3, and T4 diets were had significantly higher CP intake as compared to sheep-fed diet concentrate mixture (T1). The CP intake was higher (P<0.005) for sheep in T3 than in T1.T2 and T4. The apparent DM digestibility coefficient for T4 was higher (P<0.05) than T1, T2, and T3. The CP had the highest digestible nutrient than other nutrient compositions. There were significant (P<0.05) differences among the treatments in final body weight. The partial budget analysis result of the current study showed, the use of concentrate mixture instead of processed sweet lupin grain was displayed it reduced feed cost and increased net return. In conclusion, from an economic point of view, T2, T3, and T4 exhibited optimum feed increased net return than other treatments (T1), and therefore, it is recommended. However, all supplements were used in this study induced favorable average daily gain and net return and thus can be employed in feeding systems depending on their availability and relative cost. Thus, this on-farm study revealed that sheep fattening was most profitable when sheep were supplemented fed 440g/day of as feed basis on processed sweet lupin grain with the basal feed of natural pasture hay. Processed sweet lupin grain can be used as an alternative home-grown protein supplement feed to solve the feed shortage of the region as well as the country. Based on the result of the study, supplementation with different forms of processed sweet lupin grain at the on-farm level has generally a positive effect on feed intake and nutrient digestibility on Doyogena sheep. Among the different forms of processed grain supplements such as soaked sweet lupin grain (T3) and roasted coarsely ground sweet lupin grain (T2), and steamed sweet lupin grain (T4) had higher CP value and brought higher body weight gain in the experiment but from the point of getting a total return and higher profit by supplement of processed sweet lupin grain in treatment (T2, T3, and T4) were recommended.

5.2.RECOMMENDATIONS

Based on the result of the current experiment the following point is forwarded

- Farmers showed an interest and demand were created by the farmers on the demonstrated area to use processed sweet lupin grain for small and large ruminant fattening practice as well as human consumption.
- Awareness should be created among producers about the significance of supplementing processed sweet lupin grain.
- Supplementation with low-cost supplementary feeds such as processed sweet lupin grain would be economically profitable to sheep fattening farmers through higher economic returns.
- A study on the utilization, awareness, and characteristics of processed sweet lupin grain at the on-farm level should be carried out to better understand the significance of processed sweet lupin grain supplements for feeding ruminants.
- Further research will investigate nutrient intake, digestibility, growth performance, carcass quality, and their economic returns of Doyogena lambs at the on-farm level to know the quality of meat and to get real profit by experiment.

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7. APPENDICES TABLE AND FIGURES

7.1 APPENDICES TABLE

Table7.1.Summary of ANOVA for the dry matter and nutrient intake of Doyogena sheep fed natural pasture hay basal diet and supplemented with processed sweet lupin grain

Parameter	DF	MS	F value	Pr>F	SL
HDMI	15	326.066	1.92	0.1590	**
SDMI	15	31.666248	Infty	<.0001	***
TDMI	15	441.123613	2.60	0.0808	**
TASHI	15	516.475907	123.67	<.0001	***
TOMI	15	590.681997	3.94	0.0233	*
TCPI	15	10829.25326	11467.8	<.0001	***
TNDFI	15	3009.069219	33.12	<.0001	***
TADFI	15	3493.87925	102.27	<.0001	***
TADLI	15	161.6479910	176.33	<.0001	***
MEI(MJ/kg	15	159.5737248	159.46	<.0001	***
DMI(%BW)	15	0.18507337	1.20	0.3422	Ns

*Where;***= P<0.001; ** = P<0.01;*=p<0.05, DF= degree of freedom; MS= mean square of treatments; SL = significance level, ns= non-significant, HDMI=hay dry matter intake, SDMI=Supplement dry matter intake TDMI=total dry matter intake, OMI=organic matter intake, CPI=crude protein intake, NDFI=neutral detergent fiber intake, ADFI= acid detergent fiber intake, BW=body weight and ME=metabolizable energy.*

Table 7.2.Summary of ANOVA for the dry matter and nutrient intake digestibility of Doyogena lambs fed natural pasture hay basal diet and supplemented with processed sweet lupin grain

Parameter	DF	MS	F value	Pr>F	SL
DMDI	15	26317.8935	22.46	<.0001	***
OMDI	15	9362.22544	10.73	<.0001	***
CPDI	15	5136.37991	124.48	<.0001	***
NDFDI	15	4055.39785	7.15	0.0006	***
ADFD	15	3770.98666	11.05	<.0001	***
MEDI	15	266.435851	49.29	<.0001	***

*Where;***= P<0.001, ** = P<0.01, *=p<0.05, DF= degree of freedom, MS= mean square of treatments, SL = significance level, ns= non-significant, DMD=dry matter digestible, OMD=organic matter digestible, CPD=crude protein digestible, NDFD=neutral detergent fiber digestible and ADFD=acid detergent fiber digestible*

Table 7.3.Summary of ANOVA for the apparent dry matter and nutrient digestibility coefficient of Doyogena sheep fed natural pasture hay basal diet and supplemented with processed sweet lupin grain

Parameter	DF	MS	F value	Pr>F	SL
DMD	15	0.04129742	67.96	<.0001	***
OMD	15	0.01418524	41.33	<.0001	***
CPD	15	0.03357569	13.34	<.0001	***
NDFD	15	0.01302585	17.70	<.0001	***
ADFD	15	0.02647147	11.23	<.0001	***
MED	15	0.02535495	70.49	<.0001	***

*Where;***= P<0.001, ** = P<0.01,*=p<0.05, DF= degree of freedom; MS= mean square; SL = significance level, ns= non-significant, AOMDD =Apparent organic matter digestibility, ACPDD= Apparent crude protein digestibility, ANDFDC=Apparent neutral detergent fiber digestible coefficient, AADFDC=Apparent acid detergent fiber digestible coefficient and ADMD=Apparent dry matter digestibility*.

Table 7.4.Summary of ANOVA for the body weight gain change and feed conversion efficiency of Doyogena lambs fed natural pasture hay basal diet and supplemented with processed sweet lupin grain.

Parameter	DF	MS	F value	Pr>F	SL
IBW	15	4.476	0.59	0.6283	Ns
FBW	15	17.387	0.98	0.4234	Ns
BWC	15	20.043	3.17	0.0467	*
ADG	15	0.002	3.17	0.0467	*
FCE	15	0.003	2.58	0.0822	Ns

*Where;***= P<0.001, ** = P<0.01, *= p <0.05, DF= degree of freedom, MS= mean square, SL = significance level, ns= non-significant, ADG=Average daily body weight gain, BWC=Body weight change, and FCE=feed conversion efficiency.*

Table 7. 5.Summary of experimental feed costs used in the conduct of the experiment (price of items at the time of experimental period)

Feed items	Cost in (ETB)
Natural pasture hay	3.33 ETB/Kg
Sweet lupin grain/seed	30 ETB/kg
Concentrate mixture	9.6 ETB/Kg

Where; ETB=Ethiopian Birr

7.2. APPENDIX FIGURE

Appendix figure 7.1 Stemming process and stemmed sweet lupin grain in the study area

Appendix figure 7.2 Traditional feed processing practice (roasting practice and roasted) sweet lupin grain

Appendix figure 7.3. Experimental sheep treatment during quarantine period in the study area

Appendix figure 7.4. Feeding of experimental animals under the temporary farmer’s house throughout the experimental period

Appendix Figure 7.5.The weighting and recording of experimental sheep during experimental period

Appendix Figure 7.6 Fecal collection of experimental sheep during experimentation and experimental feed sample grounding at ILRI international animal nutrition laboratory

Appendix figure 7. 7.Field day demonstration at the end of experimentation in Doyogena district (study area)

8. AUTHOR'S BIOGRAPHY

The author, Mr.Habite Tilaye was born on March 30, 1995 at Lay Gayint District, South Gondar Zone Amhara National Regional State, Ethiopia from his father Ato Tilaye Wassie and his mother W/ro Ehitnesh Mesfin.

He attended his elementary education (Grade 1 to 8) in Kulitamba Primary School from 2004 to 2011. He continued his high school education (grade 9 to 10) at Sali Senior Secondary School from 2012 to 2013 and completed Preparatory School from 2014 to 2015 at Nefasmewucha Preparatory School. After passing the Ethiopian High School Certificate Examination successfully, he joined University of Gondar, College Of Veterinary Medicine and Animal Science, Department of Animal Production and Extension in 2016 and graduated with a BSc degree in Animal Production and Extension in June 2018.

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Consent Statement: "Personal information including Name, Business title, Email, Phones, Images and GPS points included in this thesis have been authorized in writing or verbally by the data subject" *Habite Wassie*