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SHEEP AND GOAT HUSBANDRY PRACTICES IN EASTERN TIGRAY, AND EFFECTS OF SUBSTITUTION OF MULBERRY (*Morus alba*) LEAF MEAL FOR CONCENTRATE MIX ON GROWTH AND CARCASS TRAITS OF TIGRAY HIGHLAND LAMBS IN BARLEY STRAW BASED FEEDING

PHD DISSERTATION

BY

GEBREKIDAN TESFAY WELDESLASSE

ADDIS ABABA UNIVERSITY
COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE
DEPARTMENT OF ANIMAL PRODUCTION STUDIES
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Sheep and goat husbandry practices in Eastern Tigray, and effects of substitution of mulberry (*Morus alba*) leaf meal for concentrate mix on growth and carcass traits of Tigray highland lambs in barley straw based feeding

A Dissertation Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Animal Production

By

Gebrekidan Tesfay Weldeslasse

June, 2018
Bishoftu

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

As member of the Board of Examiners of the PhD Dissertation Open Defense Examination, we certify that we have read and evaluated the Dissertation prepared by Gebrekidan Tesfay Weldeslasse titled: "Sheep and goat husbandry practices in Eastern Tigray, and effects of substitution of mulberry (*Morus alba*) leaf meal for concentrate mix on growth and carcass traits of Tigray highland lambs in barley straw based feeding" and recommend that it be accepted as fulfilling the Dissertation requirement for the Degree of Doctor of Philosophy in Animal Production.

Dr. Gebeyehu Gosh (PhD, Assoc. Prof) Chairman	_____ Signature	_____ Date
Dr. Ashenafi Mengistu (PhD, Assoc. Prof) Internal Examiner	_____ Signature	_____ Date
Dr. Getachew Animut (PhD) External Examiner	_____ Signature	_____ Date

I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Prof. Birhan Tamir (PhD) Major advisor	_____ Signature	_____ Date
Dr. Gebreyohannes Berhane (PhD, Assoc. Prof) Co-advisor	_____ Signature	_____ Date
Prof. Birhan Tamir (PhD) Department chair	_____ Signature	_____ Date

DEDICATION

Dedicated to the Father, and to the Son and to the Holy Spirit

Thank You for blessing me with my talents and opportunities in life; for the loving support and being there for me in the hard and happy times in life; for being available any time of the day to listen to me and giving me what I need at the time I need it the most; for dying on the Cross to forgive our sins and making a sinner's heart Your home; for blessing me with the most wonderful family through which You give me loving support and unconditional love. I want to thank You, Lord God our Heavenly Father and Redeemer.

STATEMENT OF THE AUTHOR

I first, declare that this dissertation is my bonafide work and that all sources of materials used for this dissertation have been duly acknowledged. This dissertation has been submitted to the requirements for PhD Degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University's Library to be made available to borrowers under rules of the Library. I solemnly declare that this dissertation is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Gebrekidan Tesfay Weldeslasse
Signature_____
College of Veterinary Medicine and Agriculture
Date of Submission: _____

BIOGRAPHICAL SKETCH

I, Gebrekidan Tesfay, the author of this Dissertation, was born in Adigrat, Tigray Regional State on January 20, 1979. I attended my elementary education at Gutin Elementary School. I completed my high school education at Nekemte Meskerem '2' Secondary School. After successfully completing my high school education, I joined Mekelle University and received Bachelor of Science degree in Animal and Range Science in July 2002. Immediately after graduation, I was employed by the Ministry of Agriculture to serve in Wukro Agricultural Technical and Vocational Educational Training (ATVET) College, Tigray Regional State and served for four years as Instructor and Department Head. In November 2006, I joined Aksum University and served as lecture and student Dean of the University for 2 years. Then, I joined Bahir Dar University to pursue my Msc degree in Animal Production in 2008 and received Msc degree in 2010. From July 2010 to July 2012, I worked for Aksum University, College of Agriculture, Shire Campus as a lecturer and Academic Affairs vice Dean of the college. In August 2012, I was transferred to Adigrat University and served as lecturer and Dean, College of Agriculture and Environmental Sciences, till I joined Addis Ababa University, College of Veterinary Medicine and Agriculture in 2015 to pursue my PhD study in Animal Production. I attended a Seminar on Higher Education Administration for Anglophone African Countries from Nov. 8 to Nov. 28, 2013 in Zhejiang Normal University, Jinhua, China. I successfully attended the International Training Programme on Dairy Nutrion from Oct. 3 to Dec. 12, 2014 in Ghent University, Belgium. Moreover, I won the U.S. – Ethiopian University Linkage Seed Money grant and had the opportunity to visit some modern dairy farms and milk processing plants in Texas and New Mexico States, USA. During my service, I published 7 articles in reputable journals, 2 in Proceedings, 1 Chapter in Book and 1 Review article.

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LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
ADG	Average daily gain
ADL	Acid detergent lignin
AFRC	Agricultural Food and Research Council
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CF	Crude Fiber
CP	Crude protein
CSA	Central Statistical Agency
DM	Dry matter
DMD	Dry matter degradability
DMI	Dry matter intake
DOMI	Digestible organic matter intake
ED	Effective Degradability
EE	Ether extract
FAO	Food and Agriculture Organization of the United Nation
FCE	Feed conversion efficiency
g	Gram
GLM	General linear Model
HCl	Hydrochloric acid
HSD	Honesty Significant Difference
ILRI	International Livestock Research Institute
IVDMD	*In vitro* dry matter digestibility
IVOMD	*In vitro* organic matter digestibility
Kg	kilo gram
ME	Metabolizable Energy
MJ	Mega Joule
NDF	Neutral Detergent Fiber

LIST OF ABBREVIATIONS (Continued)

NRC	National Research Council
NSC	Noug Seed Cake
OMD	Organic Matter Digestibility
OMI	Organic Matter Intake
PD	Potential Degradability
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SEM	Standard Error of Mean
SPSS	Statistical Package for Social Science
TEOW	Total Edible Offal Weight
TNEOW	Total Non Edible Offal Weight

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Sheep and goat husbandry practices in Eastern Tigray, and effects of substitution of mulberry (*Morus alba*) leaf meal for concentrate mix on growth and carcass traits of Tigray highland lambs in barley straw based feeding

Gebrekidan Tesfay Weldeslasse

Ph.D. Dissertation

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ABSTRACT

The purpose of this study was to assess the existing husbandry practices of sheep and goats in Eastern Tigray and evaluate effects of partial or full substitution of mulberry leaf meal for concentrate mix on in vitro organic matter digestibility, in sacco dry matter degradability and on performances of Tigray highland lambs fed barley straw based diet. 299 Households who owned at least two adult sheep and goats and at least two years of experiences in small ruminant production were interviewed using structured questionnaire to assess the husbandry practices and major constraints hindering sheep and goat production in highland (HL), midland (ML) and lowland (LL) agro-ecological zones. Thirty intact yearling Tigray highland male lambs (average initial body weight of 17.8±0.95 kg) were grouped into six groups based on their live weight, which were then assigned to one of the five treatment diets, that were: T1: 300 g concentrate mix alone, T2: 225 g concentrate mix + 86.6 g mulberry leaf meal, T3: 150 g concentrate mix + 173.1 g mulberry leaf meal, T4: 75 g concentrate mix + 259.7 g mulberry leaf meal and T5: 346.2 g mulberry leaf meal alone. The mix was prepared from noug seed cake and wheat bran at 1:2 ratio, respectively. After three weeks of quarantine, lambs were adapted to experimental diets for 15 days, and after adaptation period, digestibility as well as feeding trials were conducted. Survery results indicated that the source of household income was the most important purpose of keeping sheep and goats across all agro-ecologies. Results revealed that 56.5% respondents from the HL and 58.9% from ML agro-ecological zones sourced their foundation stock from markets/purchasing while the rest was home born. On the other hand, home born (67.3%) followed by purchasing (16.4%) accounted sources of sheep and goats in the LL. The proportion of respondents who made use of crop-residues, improved forages and the commercially purchased feeds in wet season was higher in the highland than in the lowland. The importance of crop aftermath becomes prominent during the dry season next to grazing on natural grazing land particularly in both HL and ML agro-ecological zones. However, browses remain the second most important feed sources for the LL farmers during the dry season. Unlike the respondents from HL and ML, respondents in LL did get water from distant during the dry season. The proportions of respondents who provided water once a day were higher ($p<0.05$) in HL (58% and 59.4%, respectively for dry and wet seasons) and ML (48.2% and 58.9%, respectively for dry and wet seasons) than the LL (30.9% and 45.5%, respectively for dry and wet seasons). Majority of the (65.2%, 64.3% and 54.5% for HL, ML and LL, respectively) respondents across the study area indicated that own rams were the main sources of breeding males followed by breeding

*rams from neighboring households. However, own breeding bucks accounted the higher proportion in ML (51.8%) and LL (67.3%) whereas neighboring bucks in the HL (55.1%) agro-ecological zones. The majority of respondents (89.9%, 91.1% and 94.5% for HL, ML and LL, respectively) used uncontrolled mating. The results of the experiment revealed that chemical composition of mulberry leaf meal compared favorably with that of the concentrate mixture in most of the nutrients. The ash content of mulberry leaf meal (15.7%) was more than double to that of the concentrate mixture (*7.7%). *Similarly, the calcium value of mulberry leaf meal (2.1%) was more than threefold to that of calcium content of concentrate mixture (0.6%). Mulberry leaf meal alone had the highest values for slowly degradable fraction (b) than the diets with less proportion of mulberry leaf meal. Whereas, mulberry leaf meal alone (T5) and 75g concentrate mix + 259.7g mulberry leaf meal (T4) had significantly ($p<0.05$) less soluble fraction (a), and effective degradability (ED) values as compared to the diets with less proportion of mulberry. All the treatment diets accorded more than 66% DM degradability at 24 hours, which implied that they were all highly degradable in the rumen. Sole mulberry leaf meal showed higher ($p<0.05$) total dry matter, organic matter, NDF and ADF intake than the sole concentrate mix. The growth performance parameter results were comparable across all the treatment diets. The slaughter weight (24.3 vs 23.0 kg) and empty weight (20.5 vs 19.3 kg) were higher ($p<0.05$) in sole mulberry leaf meal as compared to whole concentrate mix supplemented lambs, respectively. Higher ($p<0.05$) weights of total edible offal components (5.30, 5.31 and 5.31 kg, respectively for T3, T4 and T5 vs 5.15 and 5.10 kg for T1 and T2) and rib-eye muscle area (9.9, 9.8 and 9.6 cm2, respectively for T3, T4 and T5 vs 9.0 and 9.3 cm2 for T1 and T2) were observed as a result of a higher level of mulberry leaf meal supplementation than the sole concentrate mix, respectively. Feed shortage was the top ranked constraint of sheep and goat production across all the surveyed agro-ecologies. Respondents (42.0, 44.6 and 20% for HL, ML and LL, respectively) showed a great deal of interest to supplement their sheep and goats with concentrates. However, less accessibility and high cost were the most important restraining factors that impeded them from purchasing the supplements. The results of the present study indicated that substitution of mulberry leaf meal for concentrate mix could be used effectively without affecting the growth performance as well as the carcass parameters that could be achieved by sole concentrate mix supplementation. Hence, the finding revealed that mulberry leaf meal alone could potentially be used to substitute the costly and even less accessible commercial concentrate mix in feeding Tigray highland lambs fed a barley straw based diet by smallholder rural farmers.*

Key words: Concentrate mix**,** Digestibility, Feed intake, Growth performance, Husbandry, Mulberry leaf meal, Small ruminants, Substitution

1. INTRODUCTION

Ethiopia is endowed with diverse agro-ecological zones and is believed to have the largest livestock population in Africa. Ethiopia is estimated to possess 59.5 million cattle, 30.7 million sheep and 30.2 million goats, believed to be the largest livestock population inventory in Africa (CSA, 2017). Livestock plays vital roles in generating income to farmers, creating job opportunities, ensuring food security, providing services, contributing to asset, social, cultural and environmental values, and sustain livelihoods. Although, Ethiopia has the highest livestock population in Africa, the productivity level is one of the lowest. Average yields per animal slaughtered are estimated to be 110 kg of beef and 10 kg of mutton (Adugna *et al*., 2012). The per capita consumption of meat in Ethiopia is about 10 kg which is less than one tenth of that consumed in the United States of America (FAO, 2004). Furthermore, the annual total meat demand of the Middle Eastern countries is about 207 thousand tons of meat and 12 million heads of animals; however, live animals and livestock products such as meat, hides and skins constitute only 15% of the export revenue of the country (Behnke, 2010). These figures are among the lowest in the world and are clear testimonies of the very low production performance and/or utilization efficiency of the livestock in Ethiopia.

Sheep and goat production in Tigray Regional State; as in many parts of Ethiopia, is traditional (Yayneshet, 2010) and the region benefited little from the sub-sector. The region is believed to have 2.04 million sheep and 4.58 million goats (CSA, 2017). But the low productivity and the absence of market-oriented production system limit the volume of marketable livestock (Hailemariam *et al*., 2008; Belete *et al*., 2010). Feed shortage and poor quality of the available feed resources constrain animal output (Yayneshet, 2010; Adugna *et al*., 2012). The major feed resources in Eastern Zone of Tigray region include natural pasture, straws and cactus for feeding small ruminants. The existing feedstuffs often provide low energy, protein, minerals and vitamins to support optimum animal productivity (Yayneshet, 2010). In Ethiopian smallholder livestock production system, including Tigray region, 85% of the feed intake is used to meet maintenance requirement of the animal and only 15% is used for production (Adugna *et al*., 2012). In such a system, there appears to be a tremendous potential for improvement.

Under such conditions, there is a need to look for locally available alternative feed resources to improve the livestock production and to maximize the benefits from the sub-sector. One potential way for increasing the availability of feeds for smallholder farmers could be through the use of fodder trees and shrubs (Ajebu *et al*., 2013). The use of tree forages as components of diets is a widespread practice in many tropical countries (Singh and Makkar, 2002). These feed resources have good nutritive values, and positively impact rumen function and microbial yield (Leng, 1997). As a result, fodder trees and shrubs gained great attention for improving livestock productivity in developing countries, including Ethiopia (Franzel *et al*., 2014). One of the forage plants that can contribute significantly to feed resources to supplement low quality roughages is white mulberry (*Morus alba*). It is a shrub or a tree, which belongs to Moraceae family (FAO, 1990). Multipurpose plants like mulberry which are familiar with the smallholder farmers, adapt to local environments and produce with minimum inputs can be used to fill gaps in the feeding of livestock.

Statement of the Problem

Under the prevailing economic circumstances of smallholder farmers in the tropics, upgrading of poor quality crop residues through supplementation with fodder trees rather than the more costly commercial concentrate feeds can be a feasible alternative, and such efforts can make a breakthrough to the traditional animal feeding practices. Mulberry cultivation and sericulture in East Africa including Ethiopia has a history of more than 30 years. However, productivity and product quality of sericulture is low and the market is limited, so that mulberry cultivation and silk production has not grown even as local industry (JAICAF, 2007). Production of silk thread from silkworms occurs in Ethiopia but their operations are in the extremely immature phase and silk as raw materials for traditional handcrafts are poorly supplied to the local market (JAICAF, 2007). Hence, alternative ways of using mulberry foliage would be welcomed by farmers when income from sericulture is low. Mulberry leaves are relished by sheep and goats and have a high nutritive value with protein content of about 20 % of dry matter (FAO, 1998). Roothaert (1999) observed that dairy heifers had higher voluntary intake, and thus higher potential of milk production, when consuming mulberry fodder than cassava

tree (*Manihot glaziovii*) and leucaena (*Leucaena diversifolia*). Therefore, mulberry leaves could be considered as an appropriate supplement for sheep fed a basal diet of straw, replacing partially or totally the concentrate mix, which are often expensive and/or unavailable for the small scale farmers. Despite the availability of this plant in different parts of Ethiopia largely for silkworm farming (Sanchez, 2002), no or little research if any has been conducted regarding its role as feed for livestock in the country. Therefore, this study was aimed at addressing the following objectives:

General research objective

The general research objective was to generate information on the existing husbandry practices of small ruminants in Eastern Tigray, and examine the effect of substituting mulberry leaves for concentrate mix on feed intake, body weight change, nutrient digestibility and carcass characteristics in Tigray highland lambs fed straw based diet.

Specific objectives

The specific objectives were to:

- assess the existing small ruminant husbandry practices in Eastern Tigray.
- determine the effect of partial and full replacement of concentrate mix with mulberry leaf meal in barley straw based feeding on chemical composition, and *in vitro* organic matter digestibility and *in sacco* dry matter degradability.
- determine the effect of partial and full replacement of concentrate mix with mulberry leaf meal in barley straw based feeding on feed intake, digestibility and body weight gain of Tigray highland lambs, and
- evaluate the effect of partial and full replacement of concentrate mix with mulberry leaf meal in barley straw based feeding on carcass characteristics of Tigray highland lambs.

2. LITERATURE REVIEW

2.1. Importance of Small Ruminants in Ethiopia

Small ruminants in Ethiopia contribute significantly to the economy and food security of the country. Nevertheless, small ruminants in Ethiopia and most developing regions are kept under traditional extensive systems (Solomon *et al.,* 2010). In addition to their ability to thrive and reproduce in harsh environments, sheep and goats for many of the small farm holders are the major or only source of income and wealth. Regardless of the harsh environmental conditions, small ruminants are important in feeding the rapidly expanding population of the developing world (Tibbo *et al*., 2006). In addition to their adaptation to the harsh environment, they require low initial capital and maintenance costs, are able to use marginal land and crop residues, produce milk and meat in readily usable quantities, and are easily cared by most family members. Small ruminants provide meat and milk to the smallholders and are considered as insurance mainly against crop failure, as saving, socio-cultural and ceremonial purpose (Tibbo, 2006; Adane and Girma, 2008; Habtemariam *et al*., 2012). Hence, small ruminants are important to the livelihood of smallholder farmers and to the economy of the country.

Small ruminants are relatively cheap and often the first asset acquired by a young family or by a poor family recovering from a disaster. In the subsistence sector, farmers depend on small ruminants for much of their livelihood, often to a greater extent than on cattle, because sheep and goats are generally owned by the poorer sectors of the community (Habtemariam *et al*., 2012). Being small sized animals, small ruminants require small initial investment (Adane and Girma, 2008). Their small size, together with early maturity, makes them more flexible and suitable for meeting subsistence needs of the rural family for meat and milk (Tibbo, 2006; Adane and Girma, 2008). The short generation interval of sheep and goats coupled with high frequency of multiple births allow for rapid increases in animal numbers. This builds financial capital and allows the sale of surplus animals for cash that can be used for other agricultural enterprises, school fees, medical bills, etc (Yenesew *et al*., 2013; Zergaw *et al*., 2016). Very often, there are no banking facilities in rural areas and an easy way to store cash for future

needs is through the purchase of sheep and goats and in some areas small ruminants have been described as the "village bank" (Adane and Girma, 2008; CSA, 2017).

The sheep enterprise in the Ethiopian highland where crop and livestock production are integrated, is the most important form of investment and cash income and provides social security in bad crop years. Despite the economic importance of small ruminants to the farming household and overall economic development of a country, efforts to improve the productivity and production systems of small ruminants are lacking (MFED, 2010). Hence, given these multifaceted advantages, small ruminants have to be researched and opportunities for enhancing their productivity explored.

2.2. Feed Resources for Small Ruminants

The feed resources available for livestock in Ethiopia are natural grazing and browse, crop residues, improved pasture, forage crops and agro-industrial by-products (Adugna, 2007; Yayneshet, 2010; Solomon *et al*., 2017). Similarly, in the highland and mid altitude areas of Tigray, cereal and pulse crop residues, and limited oil crops are providing considerable quantity of dry season feed supply for livestock (Yayneshet, 2010). However, the major use of crop residues and cultivated forages are restricted to cattle (especially draught oxen) and small ruminants have low chance of being fed on these feeds (Ben Salem *et al*., 2004; Yayneshet, 2010). Other reports also demonstrated that, grazing on communal natural pasture, private pastures, fallow grazing, road sides, crop stubble and residues, browses, improved forages, and non-conventional feeds including household food leftovers, weeds from crop fields, tillers from dense crop fields, fillers (crops intentionally planted on part of crop lands or around homestead to be used as feed) and traditional brewers grains (locally known as *Atella*) serves as feed resources for sheep and goats in Ethiopia (Ahmed *et al*., 2010; Solomon *et al.,* 2010; Yayneshet, 2010; Solomon *et al*., 2017). The availability and utilization extent of feed resources by small ruminants depend on the type of agro-ecosystem, cropping patterns and intensity, prevailing animal production system, farmers' livestock management practice and the production environment (Solomon *et al.,* 2010).

2.2.1. Grazing and browsing on natural grazing lands

Grazing resources include grazing land properly designated as communal grazing lands, small private lands mainly kept for hay production rather than grazing, hillsides and hill tops, bush lands and stubble as well as fallow grazing (Yayneshet *et al*., 2016; Solomon *et al*., 2017). Moreover, natural pasture refers to naturally occurring grasses, legumes, forbs, shrubs, and tree foliages used as livestock feed. Grazing lands accounting for about 57% of the Ethiopia's total land area contributes 80-90% of the total livestock feed supply (Fekede *et al.*, 2011). However, the current scenarios indicate significant reduction in both area and productivity of grazing lands especially in the highland mixed farming systems due to expansion of cropping to meet subsistence needs of the ever increasing human population; expansion of urbanization (housing and recreational areas, industrial developments, various development investments) at the expense of grazing lands; and poor management and utilization systems (over grazing) leading to serious land degradation, loss of valuable species and dominance by unpalatable species (Solomon *et al*., 2017). Thus, grazing lands are restricted to areas that have little value or farming potential such as hill tops, swampy areas, road sides and other marginal lands (Yayneshet, 2010). Therefore, forage availability and quality are not favorable year round and hence gains made in the wet season are totally or partially lost in the dry season. This is particularly evident in the mixed farming highlands and mid altitudes of Ethiopia (Solomon *et al*., 2017).

The common feed resources in Ethiopia (crop residues and matured natural pasture) are inherently low in crude protein, minerals and digestibility. Poor nutritive values of these feeds lower the production capacity and fertility potential of animals (Solomon *et al.*, 2010; Yayneshet, 2010; Solomon *et al*., 2017). The highest quality of grasses is reached during stem elongation and the quality decreases after heading thus, higher fiber content becomes detrimental because, rumen micro-organisms are unable to cope with its degradation. This makes pastures with high fiber content low in nutritive value and hence unable to support the nutrient requirements of small ruminants (Ahmed *et al*., 2010). Although, native grasses are better than crop residues if timely cut and proper handling and storage measures are applied, their feeding value declines when the dry season advances (Yayneshet, 2010). Therefore, the

yield and quality of natural pastures can be improved by changing the species composition and by improving management practices of the natural pasture (Ibrahim, 1998).

2.2.2. Crop residues

Crop residues refer to the portion of the harvested crop, which remains after the grain or marketable portion of the crop are, removed. The crops grown are mainly used as household consumptions as well as a means of income generation whereas residues from cereal and pulse crops are the major source of livestock feed which contribute approximately 40% of dry matter of the total diet (Dawit *et al*., 2012). Crop residues play a significant role as animal feed in almost all areas of crop livestock mixed farming system (Yayneshet, 2010; Adugna *et al*., 2012). The annual production of crop residues in Ethiopia is estimated to be 30 million tons dry matter, out of which 70% is utilized for livestock feeding (Adugna *et al*., 2012). In Tigray central and eastern zones, the average cereal crop residues produced was 1,199,947 and 2,038,046 quintals, respectively and about 63% of the total crop residue in the region is contributed from the eastern zone (Solomon *et al*., 2017). Based on the existing trend of grazing land conversion for crop cultivation, increase in crop residues based livestock production is highly expected (Peter *et al*., 2010; Solomon *et al*., 2017). However, crop residues tradeoffs (using crop residues for different uses) such as household energy source, house construction, and industrial use for particle board preparation may lead to competition with livestock production. These residues provide fodder at low cost, since they are byproducts of existing crop production systems (Yayneshet, 2010). Consequently, ruminants including sheep and goats feed largely on crop residues as their basal diet. On average, crop residues provide 10-15% of the total livestock feed intake in Ethiopia, and in some areas the estimate is up to 50% (Alemayehu, 2003).

The high contribution of crop residues to livestock feeding reflects the level of integration between crop and livestock farming. It was estimated that crop residues in the central and eastern zones of Tigray could sustain livestock for 7-12 months, and contribute to 50-75% of the livestock demand of an average household (Solomon *et al*., 2017). Moreover, Hassen *et al*. (2010) also indicated that crop residues can contribute 50–80% of the total feed supply for

ruminants. This indicates, the contribution to livestock feeds from grazing land, conserved and standing hay, improved forages and agro-industrial by-product is lower than the share of crop residues. However, there are variations in the contribution of crop residues among different places. The types of crop residue available vary with agro-ecology, type of crop produced and intensity of cultivation, and the prevailing farming systems in different areas (Ben Salem *et al.*, 2004). In the highlands and mid altitude areas of Ethiopia, various food crop residues, pulse crop residues, oil crop residues and rejected vegetables are providing a considerable quantity of dry season feed (Yayneshet, 2010). On the other hand, maize, sorghum, and millet crop residues are dominant in the mid and lowland agro-ecologies.

Table 1. Chemical composition and *in vitro* dry matter digestibility of barley straw (%)

Parameters	Values	Literature	Values	Literature
DM	95.2	Solomon *et al*. (2008)	92.9	Mekuanint and Girma (2016)
	92.1	Mengstu *et al*. (2016)	93.1	Kasahun *et al*. (2016)
Ash	5.6	Solomon *et al*. (2008)	9.7	Mekuanint and Girma (2016)
	11	Mengstu *et al*. (2016)	5.8	Kasahun *et al*. (2016)
CP	4.0	Solomon *et al*. (2008)	4.0	Mekuanint and Girma (2016)
	4.4	Mengstu *et al*. (2016)	4.08	Kasahun *et al*. (2016)
NDF	80.7	Solomon *et al*. (2008)	72.3	Mekuanint and Girma (2016)
	81.9	Mengstu *et al*. (2016)	68.8	Kasahun *et al*. (2016)
ADF	56.2	Solomon *et al*. (2008)	48.5	Mekuanint and Girma (2016)
	56.8	Mengstu *et al*. (2016)	37	Kasahun *et al*. (2016)
ADL	12.5	Solomon *et al*. (2008)	9.0	Mekuanint and Girma (2016)
	5.5	Mengstu *et al*. (2016)	6.6	Kasahun *et al*. (2016)
IVDMD	44	Solomon *et al*. (2008)	48.3	Mekuanint and Girma (2016)
	-		53.5	Kasahun *et al*. (2016)

Although crop residues provide the bulk of livestock feed, they are invariably often fibrous and low in nutritive value (Ben Salem *et al.*, 2004; Yayneshet, 2010). Crop residues are characterized by their low levels of CP (in the range of 2-5% CP on DM basis), which are below the maintenance requirements (>7% CP) for adult ruminants, low fermentable

carbohydrates, high fiber content (>700 g of cell wall material/kg DM), low mineral nutrients and low to moderate digestibility (<30.45% OM digestibility), and low metabolizable energy content (5.5-9.6 MJ ME/kg DM) (Ben Salem *et al.*, 2004; Kassahun *et.al*., 2016). All these factors result in low voluntary intake of crop residues, which is often limited to less than 20 g DM/kg live weight (IAEA, 2002). This suggests a basic limitation in the value of some of the residues around the border line of the 6-7% dietary CP level required for promoting voluntary feed intake (Ben Salem *et al.*, 2004). Therefore, the potential digestibility of the cell wall in many cereal crop residues can be improved when adequate protein is supplied in the diet (Yayneshet, 2010).

2.2.3. Agro-industrial by-products

Agro-industrial by-products are the by-products of the primary processing of crops, including bran and related by-products of flourmills, oilseed cakes from small and large-scale oil processing plants and by-products of the sugar factory such as molasses. Agro-industrial by-products such as oilseed cakes, wheat bran and molasses are important sources of relatively high quality feeds mostly used in urban and peri-urban livestock production (Solomon *et al*., 2017). These by-products such as oilseed cakes, wheat bran and molasses are important components of the concentrate feeds. Most tropical forages are low in nutrient content and cannot supply adequate nutrient for optimum animal performance. Agro-industrial by-products along with grazing and scavenging are 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 cake, barley and wheat bran are important source of protein and energy for supplementing basal diet (Getahun, 2006). However, depending upon availability and price, the use of agro-industrial by-products by smallholder farmers is limited and only few farmers are reported to use small quantities of wheat bran and oilseed cakes mixed with other ingredients (Yayneshet, 2010; Adugna *et al*., 2012; Yayneshet *et al*., 2016). The low level of agro-industrial by-product use is mainly due to the high cost, limited

availability in the local market, and lack of awareness (Yayneshet *et al*., 2016; Solomon *et al*., 2017).

The most common agro-industrial byproducts in Ethiopia are milling byproducts (wheat bran, wheat middlings and wheat short); molasses from sugar factories; brewery byproducts; grain damaged during processing; oil seed cakes like noug seed cake, cottonseed cake, peanut seed cake, linseed cake, sesame seed cake, sunflower cake (Alemu, 2008a; Yayneshet, 2010). Supplementation of high producing animals fed low quality feeds with agro-industrial byproducts, which are rich in protein and/or energy contents or both and low in fiber content, enables them to perform well due to higher nutrient density to correct the nutrient deficiencies in the basal diet (Yayneshet, 2010; Adugna *et al*., 2012). Agro-industrial byproducts are mainly used for dairy, fattening and commercial poultry production and the scope for their wider use by smallholder producers is low due to availability and price (Yayneshet, 2010; Adugna *et al*., 2012). These products are also in high demand by the commercial farmers, who are mostly located in urban and peri-urban areas, thus, having an advantage over small-scale farmers not only in terms of purchasing power, but also in transport costs (Yayneshet, 2010). Moreover, the difficulty of the use of these feed sources as fresh material for extended periods and the lack of efficient ways for their integration in feeding calendars may account for their under-utilization (Ben Salem *et al*., 2004). Due to the nature of these byproducts, they often require special transportation and storage facilities (e.g., molasses) (IAEA, 2002). As a result, if these products are to be utilized by smallholder farmers, they have to be transported back to rural areas.

2.2.3.1. Oilseed cakes

Oilseed cakes are the residues remaining after removal of the greater part of the oil from oilseeds (McDonald *et al*., 2010). The residues of oilseeds are rich in protein (200–500 g/kg) and most are valuable feeds for farm animals (Abraham *et al*., 2015; Dereje, 2015; Desta *et al*., 2017). “About 950 g/kg of the nitrogen in oilseed meals is present as true protein, which has an apparent digestibility of 75-90% and is of good quality. When biological value is used as the criterion for judging protein quality, the oilseed proteins are considerably higher than that of the cereals. The quality of the protein in a particular oilseed is relatively constant;

however, the cake or meal derived from it may vary depending upon the conditions used for the removal of the oil. Oilseed cakes may also make a significant contribution to the energy content of the diet, particularly when the oil content is high. This depends on the process used and its efficiency. Two main processes are used for removing oil from oilseeds. One uses pressure to force out the oil, and the other uses an organic solvent, usually hexane, to dissolve the oil from the seed" (McDonald *et al.*, 2010).

Noug seed (*Guizotia abyssinica*) cake is one of the by-products of oil processing from noug seed that can be used as a protein supplement in animal feeding. Research report showed that noug seed cake contains 91.9% DM, 29% CP, 11.2% ash, 38.5% NDF, 28.3% ADF, 11.2% ADL and 7.1% EE (Wondwosen, 2008). Mesganaw (2014) observed the average daily gain of 45.1-64.4 g/day for Washera sheep fed grass hay as a basal diet and supplemented with field pea hull and concentrate mix (wheat bran and noug seed cake in 2:1 ratio). Sheep fed a basal diet of hay supplement with rice bran, noug seed cake and their mixtures at different proportions recorded mean daily body weight gain in the range of 55.5-57.8 g/day (Abebaw, 2007). Moreover, better response in live gain (78.4g/day) in Farta sheep fed grass hay and supplemented with noug seed cake and wheat bran at a ratio of 67:33 was recorded (Fentie, 2007). However, depending upon availability and price, the use of oilseed cakes by smallholder farmers is limited and only few farmers are reported to use small quantities of these feed resources mixed with other ingredients (Adugna, 2007; Yayneshet, 2010).

2.2.3.2. Wheat bran

Cereal by-products include bran and related byproducts of flour mills such as rice bran, wheat bran, wheat middling and screening. These byproducts are produced during milling of grain to produce flour for human consumption. The milling by products and grains are rich in starch and soluble carbohydrates and predominantly serve as a source of energy (Adugna, 2008). Wheat bran, which is a reddish-brown material and separated from wheat grain in the manufacture of wheat flour, consist primarily the seed coat (coarse outer covering) of wheat kernel with small amount of flour (McDonald *et al*., 2010). Wheat bran is very variable in composition with an average CP content of 17% (Ensminger, 2002). Tesfaye *et al*. (2001) reported 16.3% CP content of wheat bran which is more or less comparable result with the

above average value. However, these values are lower than 20.1%, 19.6% and 18.7% CP content reported by Simret (2005), Asnakew (2005) and Babiker *et al.* (2009), respectively. It has been also reported that, wheat bran has 89.8% DM, 4.6% ash, 95.3% OM, 83.2% IVOMD, 44.5% NDF, 12.1% ADF, 2.1% lignin and 21.2 MJ/kg DM gross energy (Yoseph *et al.*, 2011). Experimental results on Arado sheep indicated that supplementation of wheat bran with protein rich sesame seed cake gained 66-78.9 g daily (Zemichael, 2007).

2.2.4. Multipurpose fodder trees and shrubs

Fodder trees and shrubs provide a valuable feed supplement for ruminants, especially during the dry season. Their clear benefits have resulted in their widespread adoption in many parts of East Africa and these woody shrubs can be managed to provide nutritious fodder from their leaves, to supplement the diets of livestock, particularly ruminants (Singh and Makkar, 2002; Yayneshet, 2010; Solomon *et al*., 2017). The leaves contain much more protein than the rest of the animals' normal diet of grasses and crop residues, and this makes them able to boost up the performance of the animals. The fodder plants are usually managed by repeated pruning so that they are kept in the form of multi-stemmed shrubs, usually grown in rows to form a hedge. This is not, of course, the only possible way of managing them, but it is a system that has been thoroughly researched and tested, and has proved to be very well suited to the mixed small-scale farming system found in many parts of East Africa (Wambugu *et al*., 2006).

Multipurpose plants can be successfully integrated into production systems to provide additional feed resources for use in mixed diets of livestock (Ben Salem *et al*., 2004), and can produce at least a six month supply of fodder for on-farm livestock and have the capacity to complement the feeding of crop residues and natural pastures (Reij *et al.*, 2009). During dry season, the natural pastures and crop residues available for animals after crop harvest are usually fibrous and devoid of most essential nutrients (proteins, energy, minerals and vitamins) (Solomon *et al*., 2010). On the other hand, most browse species maintain their greenness and nutritive value throughout the dry season (Ben Salem *et al*., 2004).

Smallholder farmers in East Africa have kept their animals tethered or confined to small areas of pasture during the cropping period and free-ranging after the crops are harvested (Wambugu *et al*., 2006). However, the same author also noted that as population growth has led to smaller land holdings, it has started to become impossible to keep livestock under free ranging grazing systems. In response to this pressure, smallholders grow high-yielding fodder crops to feed the animals from an ever decreasing land area. Many farmers currently practice an intermediate system, in which the animals have some limited grazing but are also fed additional 'cut-and-carried' fodder (Wambugu *et al*., 2006). The shift towards zero grazing systems has created an immediate demand for reliable, easily accessible, year-round sources of fodder and fodder trees and shrubs can help to meet this demand. Moreover, as fattening or dairy enterprises increase in number, fodder shortages are expected to get worse, particularly in densely-populated areas. Many farmers address the problem by buying commercial concentrates. However, this is expensive, and farmers sometimes find these feeds to be inconsistent in availability. They may not be an economically viable option for the small holder farmers, especially in areas where live animals and their products are low. As a result, fodder trees and shrubs gained great attention for improving livestock productivity in developing countries, including Ethiopia (Franzel *et al*., 2014).

Fodder shrubs take up little land; this means that they can be managed as hedges on sites where food and cash crops are not planted, such as: external and internal farm boundaries, along farm paths, across slopes as soil conservation structures (Wambugu *et al*., 2006). The same author further explained that fodder trees can replace existing hedges which have no other productive purpose and when managed well, they do not reduce the yields of crops growing next to them. With more fodder trees and shrubs growing on the farm, there is less need to collect leaves from wild trees in the bush. This reduces the time and effort spent looking for fodder, which is particularly helpful to women, as well as reducing the pressure on nearby natural forest and bush land.

One of the forage plants that can contribute significantly as feed resources to supplement low quality roughages is white mulberry (*Morus alba*). It is a shrub or a tree, which belongs to Moraceae family (FAO, 1990). It is found from temperate to subtropical regions of the

Northern hemisphere to the tropics of the Southern hemisphere and can grow in a wide range of climatic, topographical and edaphic conditions (Ercisli and Orhan, 2007). Mulberry has been used traditionally as a major feed for silkworms in different parts of the world (Venkatesh and Chauhan, 2011). There is also evidence that indicates the potential of mulberry plant to be used as sources of high quality forage or protein banks when feed is scarce or when natural forages are of very low quality (Doran *et al*., 2007). According to García *et al*. (2006), mulberry also stands out from other multi-purpose trees by the particular characteristics of its nitrogenous fraction, since although it is comparable to that shown by the majority of tropical forage legumes, it has superior protein quality.

The nutritive value of mulberry is one of the highest found in products of vegetable origin and is far superior to traditional forages and is comparable to concentrates (Benavides, 2001). The foliage of mulberry is highly digestible and of excellent crude protein (CP) content reaching levels of 20 – 24% (Gonzalez and Milera, 2000). After evaluating the nutritive value of this plant Boschini (2002) concluded that leaf and cell wall contents, together with structural carbohydrates and ash indicate that mulberry is an excellent feed for high yielding animals and can be offered fresh or dried in compound feeds. Sanchez (2001b) also came to this conclusion and proffered that mulberry foliage can be used as a supplement to poor quality forage based diets or as the main component of a ration in livestock production systems.

Studies have found that mulberry is well comparable with leguminous multipurpose trees as a feed for ruminants (Sánchez, 2002; Kabi and Bareeba, 2008). Available literatures indicate the positive effects of feeding mulberry on milk yield (Benavídes *et al*., 2002; Singh and Makkar, 2002), growth rate of sheep (Liu *et al*., 2001) and goats (Omar *et al*., 1999; González and Milera, 2000). According to Singh and Makkar (2002), mulberry contains crude protein concentrations between 15 and 28% in the dry matter (DM); 15% crude fibre (CF); 33 to 46% neutral-detergent fibre (NDF); 28 to 35% acid-detergent fibre (ADF); 5% lignin; 2.42–4.71% calcium; and 0.23–0.97% phosphorus. Total contents of tannins and phenols reported are very low (1.8% as tannic acid equivalent) (Lourdes et al., 2017). Other studies have also shown the great potential of mulberry as a supplement in the diet of ruminants. Benavides (2001) reported live weight gains of 60, 75, 85 and 101 g/animal/day when mulberry was fed to

Blackbelly sheep at 0, 0.5, 1.0 and 1.5 percent of body weight on a dry matter basis with King grass as the basal ration.

Mulberry has been used successfully in the feeding of dairy cows and the yield of lactating dairy cows did not decrease significantly when 75% of grain concentrate was replaced by mulberry (Esquivel *et al*., 1996 cited by Sanchez, 2001b). Schmidek *et al*. (2001) using goats fitted with rumen cannula evaluated the degradation rate of mulberry leaves and they concluded that the high values of the soluble and potentially degradable fractions as well as the potential and effective degradation of leaves of the mulberry studied confirmed the high nutritive value of the plant and its great potential as a feed for goats. In the northern highlands of Tanzania mulberry leaves are used in their cut and carry feeding systems for sheep and goats (Shayo, 1997). The usefulness and potential of mulberry plant in animal production systems have been demonstrated in many other countries around the world. The increased need for efficiency and improved productivity in the local livestock sector warranted the investigation of this plant in Ethiopia.

Table 2. Energy value of mulberry leaf as compared with pangola hay and concentrate

Feeds	IVOMD (%)	GE (MJ/kg DM)	DE (MJ/kg DM)	ME (MJ/kg DM)
Pangola hay	44.79	15.15	7.54	6.11
Mulberry leaf	71.58	16.15	12.84	10.40
Concentrate	89.38	14.81	14.70	11.91

Source: Miller *et al.* (2005)

2.3. Small Ruminant Husbandry Practices in Ethiopia

Farmers are practicing animal husbandry in different production systems and agro ecologies. In a mixed farming systems, small ruminants are confined and tethered in a wooden hut during the night and are only allowed for grazing and browsing during the day under the supervision of a herdsman, particularly young men or women (Webb and Mamabolo, 2004; Tsedeke, 2007). The enclosure of livestock in huts or kraals is done mainly to protect them from theft and predation (Webb and Mamabolo, 2004). Tethering is common during wet

season until crops are harvested. During dry season almost all owners release their animals to roam around while during the rainy season animals are herded or tethered; tethering being more frequent for goats than for sheep (Jaitner *et al.*, 2001). Tethering in dry season and herding in wet season is reported for Goma Woreda of Oromia region (Belete, 2009). A sort of individual herding or hiring a person for an individual family or a group of families was reported for western part of the country (Alganesh *et al*., 2003).

Sheep fattening is a common practice in different parts of the country, though the degree of fattening and resource base differs markedly. Majority of the farmers sale their animals early before attaining optimum market weight (Solomon *et al*, 2005 and Getahun, 2008). The major management practice used to obtain stability of structure is selling or slaughtering of males not required for other production functions, for home consumption and/or performance of rituals (Webb and Mamabolo, 2004) and selling stock, supplementation and maintenance feeding as a strategy of management during drought (Alemu, 2008). Usually one or two bucks or rams are retained in the flock for breeding. Rams not required for breeding would be sold or castrated before puberty (Taye *et al.,* 2009); usually taken out of service for castration or for sale at the eruption of the second pair of permanent incisors, unless the rams are exceptionally good.

2.3.1. Feeding of small ruminants

Despite the large and diverse livestock genetic resources, the economic contribution of the livestock sector to livelihoods of the livestock keepers in Ethiopia is very low (Adugna, 2007; Aklilu *et al*., 2013). Among the major problems affecting livestock production and productivity in Ethiopia, feed shortage in terms of quantity and quality is the leading problem (Adugna, 2007). Feed cost accounts for over 50% of the total production and marketing costs in any livestock enterprise (Solomon *et al*., 2017). The same author further noted that the feasibility of livestock enterprises is, therefore, a function of the type of feed and feeding system and it is estimated that up to a five-fold increase in tropical livestock productivity can be attained if there is optimal locally available feed resource utilization. Sheep and goat production in Ethiopia suffers from feed shortages at all levels with an estimated 40% deficit

in the national feed balance (Alemu, 2008). This is aggravated by the seasonal availability of forage and crop residues in the highlands and by recurrent and prolonged drought in the lowlands (Alemu, 2008). Some authors also indicated that the feed types available and feed resource management and utilization practices of livestock keepers need to be identified and the feed balances for specific geographic regions and agro-ecological zones need to be estimated to develop appropriate market oriented intervention strategies (Solomon *et al*., 2017).

The major feed resources for sheep and goats include grazing on communal natural pasture, private pastures, crop stubble, fallow grazing, road side grazing, crop residues, browses, improved forages, and non-conventional feeds, including household food leftovers, weeds from crop fields, tillers from dense crop fields, fillers (crops intentionally planted on part of crop lands or around homestead to be used as feed) and traditional brewers byproducts (*Atella*) (Abraham *et al*., 2017). The importance of the different feed resources varies depending on the production system, farmers' livestock management practice and the production environment. In most production systems, agro-ecologies and geographic regions, extensive free grazing on communal grazing lands and stubble grazing are the most common practices of feeding sheep, while browses are commonly used for goat flocks (Solomon *et al*., 2010).

2.3.2. Water sources and watering

Rivers, springs, temporary wells, tap water and dam are the main sources of water during the dry season in most parts of the country (Berihu, 2016; Abraham *et al*., 2017; Solomon *et al*., 2017). Watering frequency varies with season and agro-ecology and sheep are commonly watered every three days and goats every 3–5 days during the dry season as nearby water sources dry-up. Animals are watered once in two days in moist lowlands and once a day in moist highlands and time taken to watering points range from 7.7–9 minutes in Gomma to 0.33–5 hours in Alaba, and distance ranges from 1.0 km (wet season) to 2–5 km (dry season) in Metema to 1.0–10 km in Dale (Solomon *et al*., 2010). Water shortage is a limiting factor in most lowland areas and to a limited extent in mid altitudes (Mesay *et al*., 2013; Yadeta, 2016;

Abraham *et al*., 2017). In eastern, north-eastern and south-eastern part of the country there is also critical shortage of water; however, there are breeds adapted to lowland agro ecologies through their physiological adaptation mechanisms (Belete, 2009).

Restrictions of water may result in poor nutrition and digestion, because there is a relationship that exists between water intake and consumption of roughages, particularly during dry season. Long distance travel of small and large ruminants in search of water was another problem whereas, during the rainy season pond and dams filled by the rainy water were the main sources of water and some farmers and pastoralists reported that they also use tap water during the rainy season (Mesay *et al*., 2013). It can be noted that there is a wide variation in time spent to get to water sources and watering frequencies. In Menz area, smallholder farmers get water at a distance of less than 1 km and about 92.5% sheep owners in Menz and 33.6% in Afar area watered lamb with adults (Tesfaye, 2008). The same author also noted that majority (75%) of the farmers in Menz area watered their sheep once in two days followed by once a day (22.5%) and some sheep flocks (2.5%) had access to water freely.

2.3.3. Housing

Good housing can determine productivity by reducing stress, disease hazards and making management easier. The finding of Berihu (2016) revealed that, most of the small ruminant holding households responded that they housed their livestock (small ruminants, cattle and poultry) separately but all animal groups (females, males and young animals) were kept in the same house regardless of the species, age, and health status. Majority of the respondents housed their sheep separately from other livestock; whereas, 8.4% of them housed sheep with cattle and/or goats under the same roof by making partition among/between them (Tesfaye, 2008). However, the study of Alubel (2015) in Ziquala and Tanqua Abergelle districts reported that majority of farmers confine their goats without roof and minority of them confine their goats in the family house. Whereas, almost all farmers in the western Amhara provide shelter for their goats and almost all respondents housed their goats together with other livestock species. Most of respondents housed kids together with adults during night time (Damitie *et al*., 2015).

Different farmers living in different agro-ecological settings, take up different housing practices. This implies that being a resident in highland agro-ecological zone, as compared to that of midland or lowland increases the probability of having crossbred animals and implementing shading practice (Tazeze *et al*., 2012; Fikeremaryam *et al*., 2016). However, farmers living in lowland agro-ecological zone are less likely to practice shading management and to feed their sheep and goats at home (Fikeremaryam *et al*., 2016). None of the respondents in western Tigray had provision for accommodating different age groups only sick ones and newly born kids/lambs were retained alone in sheds (Abraham *et al*., 2017). Sheds were constructed of locally available materials and were not permanent as animals migrate from place to place in search of feed and water. However, farmers in urban areas used permanent houses separated from or attached to their homesteads (Abraham *et al*., 2017).

2.3.4. Herding practices

Herding practices have an implication for designing genetic improvement programs and introducing improved sheep management such as strategic health interventions at village level (Solomon *et al*., 2014). The flock herding practices of the smallholder and large scale farmers reflects the breeding managements and has an impact on the flock size. The major type of herding practiced in the study areas was free grazing (Yohannes *et al*., 2017). The same author indicated that, about 51%, 31.7% and 17.2% of the smallholder farmers herd sheep together with goat, separate and either separate or sometimes with goat depending on the availability of hired labor, respectively. Separate herding of does and kids was dominant in Bale Zone and the reason is that milk is the main product for the society, which causes competition with kids (Belete *et al*., 2015) moreover, about 99.4% of male and female goats are herded together. These figures were different from the report of Tesfaye (2010) who reported that about 52% of goats in Shalla district were mixing kids with adult. About 45.8% of the respondents run their flock individually, while 54.2% of respondents mix their goats together with their neighbor (Belete *et al*., 2015). Similarly, the common herding management in western Tigary was free grazing where farmers herded their goats together with sheep (Abraham *et al*., 2017). According to the same author, there is also the possibility of mixing with other goats and sheep flocks in the nearby vicinity of villages. Because of their feeding

habit, farmers prefer to manage sheep separately, but the majority of the smallholder farmers keep sheep with other livestock because of the shortage of labor (Getachew *et al*., 2010). Hassen *et al*. (2014) reported that sheep and goats are herded together in Afar pastoral and agro pastoral system whereas, about 62% of the large scale farmers herd sheep separately and 38% rear sheep and goats flock together. According to Mekoya *et al*. (2000), sheep in the central highlands of Ethiopia are herded separately for grazing all year round using family members.

2.3.5. Breeding practices and selection criteria

There was less practice of controlled mating in eastern zone of Tigray by the small ruminant holding households and hence the breeding practices were dominated by natural mating in which the male animals run with females throughout the year (Berihu, 2016). According to Abraham *et al*. (2017), there was no report of controlled mating in western Tigary and bucks run with does throughout the year and castration was also an uncommon practice in the area so this resulted in indiscriminate and uncontrolled breeding. The study of Tesfaye (2009) in Metema woreda, Amhara region, of Ethiopia reported that 98% of the respondents retained bucks for breeding purposes and 72% of the farmers keep their own breeding bucks whereas the remaining (28 %) use neighbor's bucks. Farmers who had no breeding males, purchase buck from local markets or got buck service from their neighbors (Abraham *et al*., 2017). Tesfaye *et al*. (2011) and Fsahatsion *et al*. (2013) reported that majority of farmers reared their own ram and high degree of inbreeding expected in dega and weyna dega. Helen *et al*. (2013) in eastern Ethiopia reported the level of inbreeding might be high in mixed crop-livestock system where communal grazing is becoming less and less important.

Farmers have their own criteria for selection of breeding sheep or goats and the selection criteria used for male sheep and goat is different (Yadeta, 2016) for males, tail type, color and height are given the most emphasis for selection. Tesfaye (2008) in Menz and Afar area reported that appearance is a primary ram selection criterion in both crop-livestock and pastoral production system. Similarly, Zewudu *et al*. (2012) in Adiyo Kaka district of Kaffa zone of Southern Nations, Nationalities of Ethiopia reported ram selection based on body size.

The most common way of selecting goats as parents for the coming generations is to use the offspring of a chosen parent (buck and/or doe) and body size, growth rate and libido prioritized selection criteria (Abraham *et al*., 2017).

For breeding males, black colored, poor conditioned and small sized sheep are not preferred and culled at a young age (sold or slaughtered at home) (Helen *et al*., 2013). Furthermore, farmers in different production systems may have different trait preferences (Roessler *et al*., 2008) and they may also follow as diverse strategies as the agro-environments within which they perform (Solomon *et al*., 2010; Tadele, 2010). Understanding farmers' trait preferences provides insights into which traits are particularly important in their agro-ecosystem and how these can be incorporated in the design of sustainable breeding programs (Yadeta, 2016). Farmers also have different criteria in selection of female sheep and goats. Appearance, coat color and lamb survival were used in ewe selection in eastern Ethiopia (Helen *et al*., 2013). However, liter size and lamb growth were more important selection criteria in pastoral and agro-pastoral systems than in the mixed crop-livestock system which were considered highly associated with mothering ability (Gemeda *et al*., 2011). For breeding females, black colored, old aged, poor conditioned and those ewes which have long lambing interval are culled (Zewudu *et al*., 2012; Yenesew *et al*., 2013).

2.4. Small Ruminant Marketing System in Ethiopia

The Ethiopian live animal and meat export marketing system is operating in an environment characterized by several constraints that needs the attention and action of the government and other non-governmental development organizations (Hailemariam *et al*., 2008). Despite the contribution of livestock to the economy and to smallholders' livelihood, the production system is not adequately market-oriented. There is little evidence of strategic production of livestock for marketing except some sales targeted to traditional Ethiopian festivals (Ayele *et al*., 2003). Smallholder farmers and pastoralists are the main suppliers of small ruminants to domestic consumers and meat export slaughter houses; where, animals are kept under low input and output systems (Getahun, 2008; Hailemariam *et al*., 2008; Belete *et al*., 2010). The lack of market oriented production of the livestock sector is reported to significantly affect the

quantity and quality of marketable livestock for both domestic and export market (Belete *et al*., 2010; ESGPIP, 2011).

According to Ayele *et al*. (2003), the livestock marketing structure in Ethiopia follows a four-tier system. The main actors of the 1st tier are local farmers and rural traders who transact at farm level with very minimal volume, 1-2 animals per transaction irrespective of species involved. Those small traders from different corners bring their livestock to the local market (2nd tier). Traders purchase a few large animals or a fairly large number of small animals for selling to the secondary markets. In the secondary market (3rd tier), both smaller and larger traders operate and traders and butchers from terminal markets come to buy animals. In the terminal market (4th tier), big traders and butchers transact larger numbers mainly slaughter type animals. From the terminal markets and slaughterhouses, meat reaches consumers through a different channel and a different set of traders/businesses.

Livestock are generally traded by 'eye-ball' pricing that means there are no objectively set standards for selling and buying animals, except measuring live weight of sheep and goats in Borena area and visual observation of the animals, in most other areas (Hailemariam *et al*., 2008). Under such circumstances, the price of an animal will reflect not only the bargaining skills of both buyers and sellers but also the buyer's preference for the characteristics of animal and the seller's willingness to sell, sometimes leading to transaction failure (EARO, 2000; Ayele *et al*., 2003). Potential production and market opportunities for small ruminant meat have not been exploited because of scant knowledge of small ruminant demand patterns (Ehui *et al*., 2000). Almost all export abattoirs are complaining about shortage of sheep and goats supply for export market. Some of them were even unable to meet the already requested quantity by their customers, let alone searching new market for sheep and goat meat. Thus, government and non-governmental organizations have to provide with technical and financial supports, and small ruminant producers should be aware of these opportunities and be engaged in market-oriented production practices (Tsedeke, 2007; Belete *et al*., 2010).

2.5. Small Ruminant Production Constraints

In mixed crop-livestock systems, sheep and goat productivity is constrained by complex and interlinked technical, institutional and socioeconomic factors. Feed shortage, limited land, water shortage, diseases/parasites, shelter, drought, predators, labour shortage, inadequate extension support, inadequate veterinary service and limited market accesses are some of the constraints hindering small ruminant production.

2.5.1. Feed shortage

A major constraint to livestock production in developing countries including Ethiopia is the scarcity and fluctuating quantity and quality of the year round feed supply (Yayneshet, 2010; Solomon *et al*., 2017). The reasons for shortage of feed vary depending on the agro-ecology and production system. In densely populated areas where land resources are limited like Alaba, reasons given by farmers includes declining yields of grazing land, increase in livestock population, cultivation of grazing lands, drought and increase in human population (Solomon *et al*., 2010; Yayneshet, 2010). Lack of adequate feed resources as the main constraint to animal production was more pronounced in the mixed crop-livestock systems, where most of the cultivated areas and high human population are located (Yenesew *et al*., 2013). Many authors described the seasonal feed shortages, both in quality and quantity, and the associated reduction in livestock productivity in different parts of the country (Yeshitila, 2007; Getahun, 2008).

Feed shortage problem was similar throughout the country, being serious in high human population areas where land size is diminishing due to intensive crop cultivation and soil degradation. Study of Mesay *et al*. (2013) in Lemu-Bilibilo district in Arsi zone indicated that, shortage of feed at the end of dry season when all crop residues have been consumed and pasture growth is poor, was the major constraint for livestock production in the area. The feed shortage also appears even in the rainy seasons since more of the lands are occupied by crops. The feed deficit is further aggravated by seasonality of forage availability and crop residues in the highlands and by erratic rainfall in the lowlands (Solomon *et al*., 2010). There is also

inefficient collection, conservation and utilization of available feeds which is mainly expressed in the lack of adopting feeding technologies to improve the nutritive value and palatability of crop residues and grazing lands which are the major feed resources in most production systems and agro-ecologies (Solomon *et al*., 2010).

2.5.2. Health constraints

Diseases and parasites are the major constraints to improved small ruminant production and productivity in most production systems/agro-ecological zones. Hence, health problems cause high mortality and reduced reproductive and growth performances resulting in reduced output per animal and flock off-take rates (Solomon *et al*., 2010). Dereje *et al*. (2013) in Daro Labu district of west Hararghe reported that, 21.7% farmers in lowland and 6.7% farmers in midland area traveled more than 10 km distance to reach government clinics. The same author also indicated that 46.7% of the total respondents travelled more than 1 km of distance in order to obtain veterinary services for treatment of diseases. The high prevalence of diseases and parasites causes high mortality amongst kids and lambs, diminishing the benefits of their high reproductive performance (Tibbo, 2006). Sharif *et al*. (2005) and Girma *et al*. (2013) reported that kids were at higher risk of dying if they were not being separated from adult animals; this risk factor increases the accident and the contamination of the environment of neonates. Here animals with good adaptive potential are needed in these stressful environments to sustain the livelihoods of the communities (Solomon *et al*., 2010; Tadele, 2010; Zewudu *et al*., 2012; Helen *et al*., 2013).

2.5.3 .Water shortage

Water shortage is a limiting factor in most lowland areas and to a limited extent in mid altitudes. In eastern, north-eastern and south-eastern part of the country there is also critical shortage of water; however, there are breeds adapted to lowland agro ecologies through their physiological adaptation mechanisms (Belete, 2009). Restrictions of water may result in poor nutrition and digestion, because there is a relationship that exists between water intake and consumption of roughages, particularly during dry season. Long distance travel of small and large ruminants in searching of water was another problem (Mesay *et al*., 2013). Tsedeke

(2007) reported that problem of water shortage in mixed flock and goat dominating areas of Alaba Woreda.

2.5.4. Marketing constraints

The major problems in traditional management system were that the system is not market oriented, underdeveloped marketing and infrastructure system, and poor financial facility, etc. (Azage *et al*., 2006; Berhanu *et al*., 2006). The study of Yenesew (2010) in Burie woreda, west Gojjam, indicated that sheep sellers get market price information mainly from traders or their neighbors. There is no public market information source in the area for the producers, traders or consumers in general. This reduces the marketing system transparency and efficiency. In the sheep markets there is no weighing or grading of animals at the time of sale. Buyers and sellers judge the sheep they buy/ sell through physical observation only (Juma *et al*., 2010; Ramesh *et al*., 2012). This is a disadvantage especially for sellers. There is no precise method to know the quantity (in kg) as well as the quality (fat or lean meat) of produce sold or bought. This affects the production of quality sheep and goats in the smallholder system. The role of brokers in marketing small ruminants has two views; one group describes them favorably as they facilitate transaction between buyers and sellers while others see them as problems in marketing as they are the ones who mainly decide the price (Endeshaw, 2007; Tsedeke, 2007; Ramesh *et al*., 2012).

2.5.5. Housing constraints

Good housing can determine productivity by reducing stress, disease hazards and making management easier. According to Tesfaye (2009), all farmers kept suckling goats in the house during the first 24-72 hours after which the mother joins the flock for grazing. Farmers also tended to keep kids inside for periods of up to two months during the rainy and drought periods. The same author also indicated that lack of separation of new born kids from their dams and rest of flocks significantly affected pre-weaning kid. This may be associated with a high risk of miss mothering, injury, predators and insufficient ingestion of colostrums. The death of kids or lambs before weaning was perhaps the biggest cause of economic loss to

small ruminant farmers and may be reduced by improvements in the management and feeding of the kidding or lambing flock (Snyman, 2010; Girma *et al*., 2013).

2.6. Small Ruminant Production Opportunities

High demand for small ruminants in the local market as a result of population increase, urbanization, and increase purchasing power of the community can be considered as an opportunity for the small ruminant producers. Nowadays, many abattoirs flourish in the country; so agents and assemblers purchase small ruminant even at farm gate. Several development partners involved in higher learning, research and development are currently committed to sheep and goat developments (Betelehem, 2009; Matawork, 2016). The study of Okpebholo (2007) showed that low start-up cost as an important factor in providing opportunity for the development of a small ruminant production system by a small-scale farmer with limited resources. Sheep and goat breeds in the lowlands of the country were also in good demand in the Middle East markets (Solomon *et al*., 2010). Tsedeke (2007) and Zawudu *et al*. (2012) in western and south-western reported, gender participation is another sheep and goat production opportunities.

3. MATERIALS AND METHODS

The study consisted of the survey part that dealt with sheep and goat husbandry practices across different agro-ecological zones and the experimental study part that dealt with the effect of substitution of concentrate mix with mulberry leaf meal on growth performances and carcass characteristics evaluations of Tigray highland lambs.

3.1. Survey

3.1.1. Description of the study area

The study was conducted in Eastern Zone of Tigray National Regional State of Ethiopia. Eastern Tigray zone is bordered with Afar in the East, Southeast zone of Tigray in the South, Central zone of Tigray in the West and Eritrea in the North. The zone has seven districts and 94 *Kebeles*. The zone has been classified into three agro-ecologies: Highland (73.4%), Midland (12.6%) and Lowland (14%). Eastern zone is located between 13° 41' – 13° 46' N latitude and 39° 21' – 39° 34' E longitude. The altitude of the area ranges from 900-3200 meters above sea level (m.a.s.l) (EZARDO, 2010). The zone has a monomodal rainfall (June to early September) that ranges from 140 – 671 mm annually. Similarly, the annual temperature ranges between 10 – 30 ^{O}C (EZARDO, 2010).

The administrative center of the zone is Adigrat, one of the five zonal cities in Tigray National Regional State. From the five zonal cities, Adigrat has the largest human population in the region and this suggests the presence of good opportunity for the surrounding districts' sheep and goat production as population influences consumption of their products in restaurants, during national as well as cultural/religious holidays. Based on CSA (2007), this town has a total population of 57,588, of whom 26,010 are men and 31,578 women. The majority of the inhabitants practiced Ethiopian Orthodox Christianity, with 94.01%, while 3.02% of the populations are Catholics, and 2.68% are Muslim (EZARDO, 2010).

Eastern Tigray zone is a mountainous zone that spans all the *kolla*, *woina dega* and *dega* altitudes. Main crops cultivated in the area are barley, maize, hanfets, wheat and teff. Although, cactus does not make the main crop cultivated, it makes an important contribution to livestock as well as human consumption in this zone. The predominant production system in the area is mixed crop-livestock farming and small ruminants play important role in the livelihood of the society. Three districts (Ganta-Afeshum, Gulo-Mekada and Saesie Tsaeda-Emba) were selected based on their diversified agro-ecological setting, potential of sheep population and logistics purposively.

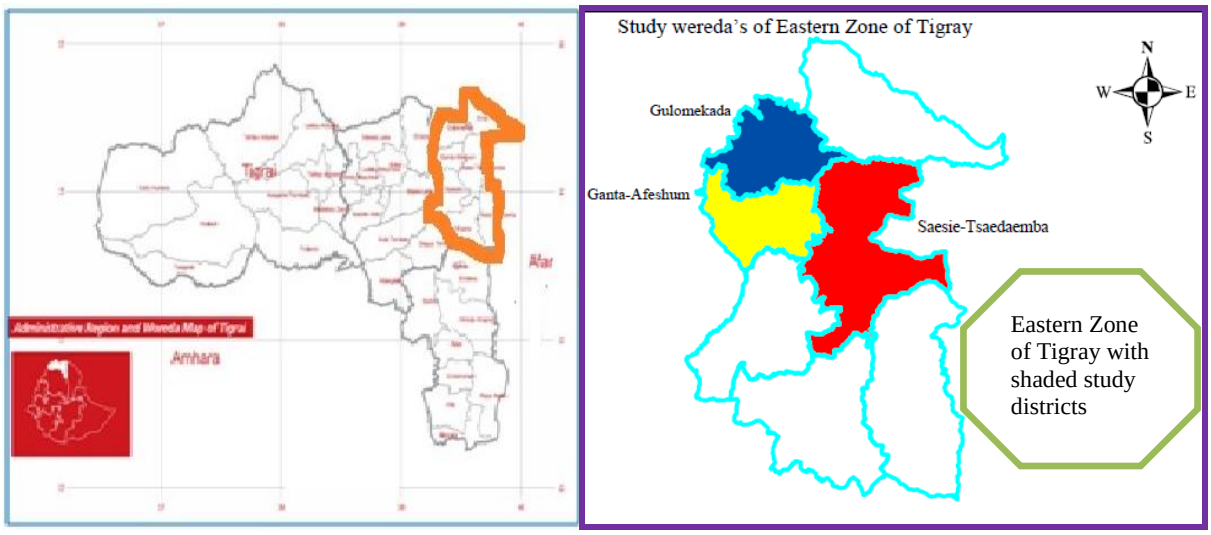

Figure 1. Map of the three study districts in Eastern zone of Tigray

3.1.2. Farming systems of the study area

Like in other parts of the country, the farming techniques used by most farmers in the study area are traditional and the dominant farming system is crop-livestock mixed farming. Livestock constitute an important part of the rural economy of the region and the zone as well. Livestock are kept partly as source of capital, which can be turned into cash when required. The types of livestock found in eastern zone of Tigray are small ruminants, cattle, poultry, and honey bee colonies. The sheep population in Eastern zone is larger than the other zones of the region (Table 3) indicating their immense importance for the community in the area.

Moreover, barley production has strong linkage with the feeding culture of the community. A local food "*Tihlo*", prepared exclusively from barley is well known as emblematic feature of Eastern zone of Tigray. On top of this, roasted barley (*Kollo*) selling is also well known as income generating means in the area. Hence, there is relatively a huge production of barley straw for dry season ruminant feeding.

Table 3. Livestock population of Tigray region by administrative zone

Administrative zone	Cattle	Sheep	Goats	Poultry	Beehives
Tigray region	4,613,475	1,637,697	3,948,276	6,329,501	263,961
Northwest Tigray	1,803,123	219,691	1,922,107	2,462,627	79,832
Central Tigray	771,425	387,751	893,506	1,397,424	79,373
Eastern Tigray	441,023	586,905	224,724	903,436	38,124
Southern Tigray	739,618	359,732	355,995	750,084	37,035
Western Tigray	858,286	83,618	551,943	815,93 0	29,597

Source: CSA (2016)

3.1.3. Sampling procedure

A multi-stage sampling procedure was used in the cross-sectional survey. In the first stage, the three study districts (Ganta-afeshum, Gulomekada and Saesie-Tsaedaemba) were chosen purposively based on their sheep population and diversified agro-ecological (lowland, midland and highland) setting apart from the logistics issues. According to the agro-ecological classification made by the Tigray Agriculture and Rural development Bureau (2002), highland, midland and lowland refer to areas having an altitude of 2300-3200, 1500-2300 and 500-1500 meters above sea level, respectively. In the second stage, *Kebeles* were stratified based on their agro-ecological zones in to HL, ML and LL and a total of 9 *Kebeles,* 3 from each agro-ecological zone were selected for the study. Third, since, the study was intended to describe the husbandry practices of sheep and goats, a list of households who owned at least two adult sheep and goats and at least two years of experiences in small ruminant production (target population) was obtained from the selected *Kebeles* with the help of livestock development agents. In the fourth stage, the final sample households who participated in the

cross-sectional survey were selected from the sampling frame using systematic random sampling technique.

Based on the sampling estimation made, 299 sample households were selected out of the total 4500 targeted household population. Out of 299 sample households; 115, 93 and 91 households were drawn from highland, midland and lowland agro-ecological zones, respectively. Sample size drawn from each agro-ecological zone was proportional to target household population in each respective agro-ecological zone as shown in Table 4. A representative sample size was estimated at 95% confidence level and below 1% error commitment, as shown below (Chand *et al*., 2012):

$$n = \frac{NZ^2P(1-P)}{N \cdot e + Z^2P(1-P)}$$

Where, n = is the sample size, N = is the target population size, Z = Confidence level at 95 %, Z = 1.96, P = Estimated population proportion (0.5), e = is the precision level (0.003).

Table 4. Sample size distribution by agro-ecological zones

Agro-ecological zone	Target population	Sample size
Highland	1725	115
Midland	1400	93
Lowland	1375	91
Total	4500	299

3.1.4. Data collection methods

Prior to the commencement of the household survey, an exploratory survey was conducted with livestock production experts, veterinarians and development agents to get an overview on the overall challenges and opportunities of the production system, small ruminant production objectives, feeds and feeding, watering and veterinary services. Information obtained from the discussions was used to prepare structured and semi structured questionnaires. The questions were framed in such a way that farmers could provide full

information on small ruminant production system. A cross-sectional survey was used in order to collect data on socio-economic characteristics of small ruminant producers, small ruminant husbandry practices and major constraints of small ruminant production. Pre-tested questionnaire was used in the cross-sectional survey. Pre-testing of the questionnaire was made before the actual data were collected on sampled households in order to modify the questionnaire and to minimize error by excluding the irrelevant data. For formal household interviews, Development Agents (DAs) were used as enumerators. The enumerators were trained and practiced by interviewing each other to ensure that they correctly understood each question. Enumerators were supervised by the researcher during household interviews.

The questionnaire included socio-economic characteristics of households, farmers' animal preferences, purposes of keeping small ruminants, feeds and feeding, watering and housing, small ruminant production and marketing constraints. Data collected using questionnaire was supplemented by information obtained from key-informants and secondary data derived from Bureau of Agriculture and Rural Development offices. Personal observations at the time of visits and supervisions were made to fill the information gap in the questionnaire survey particularly to describe some of the routine husbandry practiced by producers. In order to complement the information obtained using cross-sectional survey, focus group discussions were also conducted to obtain additional information on the feed resources and feeding, housing, animal healthcare, breeding systems, sheep fattening and overall challenges of small ruminant production in the study area. A total of three group discussions comprising of six to eight members were undertaken. In addition to this, secondary data were collected from governmental and nongovernmental organizations as well as published and unpublished materials.

3.2. Experimental Study

3.2.1. Experimental feeds preparation and feeding

The experiment was carried out at Adigrat town (zonal city) located at a distance 910 km from Addis Ababa, capital of the country and 124 km from Mekelle. Adigrat town located at elevation of 2457 masl with average temperature of 7 to 24 ^{O}C and average annual rainfall

range of 400 to 600 mm. the aim of the experiment was to determine the effects of full or partial substitution of concentrate mix with mulberry leaf meal on feed intake, digestibility, body weight change and carcass characteristics of yearling Tigray highland male lambs fed barley straw based diets. Leaves of mulberry collected from nearby farmers were dried under a shade for 4-5 days till the leaves were easily crushed when pressed in a hand and were packed in a sack for later use. Barley (*Hordeum vulgare*) straw was used as a basal diet and was purchased from local farmers. Lambs were fed *ad lib* of barley straw. The mulberry leaves were fed as meal in dry form. Mulberry leaf meal was supplemented at the rate of 0, 86.6 g, 173.1 g, 259.7 g and 346.2 g substituting for concentrate mix for T1, T2, T3, T4 and T5, respectively (Table 5).

According to different authors (EARO, 2001; Fentie and Solomon, 2008; Michael and Yaynshet, 2014), 250 g – 300 g of concentrate mixture on DM basis resulted in better feed intake, weight gain and carcass traits in straw based feeding of growing lambs compared to other supplementations. Hence, 300 g concentrate mix was used as a supplementation in this study. The concentrate mixture was comprised of wheat bran and noug seedcake at the ratio of 2:1 on DM bases, respectively. Treatment diets were given at 08:00 and 16:00 hrs in equal proportion and lambs had free access to water and mineral licks (mineral block) all the time. Treatment feeds were allotted to experimental lambs randomly. The basal feed was offered allowing 20% refusal and the amount of straw offered was adjusted once in a week when the straw refusal was less than 20%.

3.2.2. Experimental animals and management

Thirty yearling male lambs (Tigray highland sheep) were used for the experiment. The lambs were purchased from the local markets. The age was determined by dentition and information obtained from the owners. The lambs were quarantined for 21 days and were de-wormed and sprayed against internal and external parasites, respectively during the quarantine period. They were penned individually in well ventilated house and were identified with neck collars. Lambs were closely observed for occurrence of any ill health and any physiological disorders during the experimental period.

3.2.3. Experimental design and treatments

The lambs were allocated to five diet groups where concentrate mix was replaced by mulberry leaf meal at iso-nitrogenous level.

Table 5. Treatment combinations

Diet	**Treatment**				
	T1	**T2**	**T3**	**T4**	**T5**
Barley straw	*Ad lib*	*Ad lib*	*Ad lib*	*Ad lib*	*Ad lib*
Concentrate mix (g DM)	300	225	150	75	0
Mulberry leaf meal (g DM)	0	86.6	173.1	259.7	346.2

The design of the experiment was RCBD and lambs were blocked based on their initial body weight into six blocks of five treatments.

3.2.4. Digestibility Trial

The digestibility trial was conducted prior to the feeding trial and after 15 days of adaptation period. The lambs were fitted with fecal collection bags for fecal collection. They were adapted for three days to carrying the fecal collection bags followed by seven days of feces collection during which daily feed offered and refused for each animal was recorded for the determination of daily feed intake. Daily collected feces for each animal were weighed in the morning before feeding and 20% representative samples were taken and kept in deep freezer at -20^{O}C. On the last day of the collection period, the composite fecal samples for each lamb was thawed, thoroughly mixed and sub-sampled for chemical analysis. Apparent DM and nutrients digestibility were determined as the difference between nutrients intake and that recovered in feces expressed as a proportion of nutrient intake (McDonald *et al*., 2002).

$$DC\ (\%) = \frac{\text{nutrients in intake} - \text{nutrients in feces}}{\text{Nutrients in intake}} \times 100$$

3.2.5. Feeding trial

During the feeding trial of 90 days, daily feed offered and refused and body weight changes were recorded. The amounts of feed offered and refused were recorded daily for each animal and the daily feed intake was determined by difference. Representative samples of basal feeds offered and refused after thoroughly mixing on daily basis as well as noug seed cake and wheat bran per batch were collected and a sub-sample was taken for chemical analysis. The metabolizable energy intake (MJ/day) of experimental animals was estimated from digestible organic matter intake (DOMI) values by using the equation of AFRC (1993), as:
ME (MJ/day) = 0.016*DOMI.

The body weight of each lamb was taken at the beginning of the experiment by suspending them on a hook attached to a weighing balance (Salter scale) and every successive seven days thereafter. Lambs were weighed during morning hours before feeding and watering. Live weight was taken using suspended Salter weighing scale with sensitivity of 100 g. The weights were recorded for each lamb against its identification number on a weight registration notebook. Average daily body weight change was calculated as the difference between final and the initial body weights of the animals divided by the number of experimental days. Feed conversion efficiency (FCE) of the lambs was determined as a ratio of daily weight gain to the daily DM intake (Brown *et al*., 2001).

3.2.6. Chemical analysis

The chemical analysis of the experimental feeds, refusals and faeces were carried out in Holleta Agricultural Research Center nutrition lab, Ethiopia. Samples of feed offered, refused and feces were ground to pass a 1 mm sieve mesh. Samples of feeds offered and refused were analyzed for DM, ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). Feces was analyzed for DM, ash, CP, NDF and ADF. The DM and ash contents were determined according to the standard methods of AOAC (1990). Nitrogen was determined by the Kjeldahl procedure. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to the

procedure of Van Soest *et al*. (1985). Crude protein was estimated as N x 6.25. Calcium (Ca) concentration was determined by the atomic absorption spectrophotometer (AAS) with a Perkin-Elmer AAS 2380 (Perkin-Elmer, 1982). Phosphorus (P) concentration was determined by vanadomolybdate method and its concentration was read thereafter on the atomic absorption spectrophotometer (AOAC, 1990). Hemicellulose and cellulose contents were calculated as NDF minus ADF and ADF minus ADL, respectively (Table 6).

Table 6. Chemical composition of feeds used in the experiment

Chemical composition	Barley straw	Wheat bran	Noug seed cake	Mulberry leaf meal
DM (%)	96.00	84.40	94.40	91.80
OM (%DM)	92.50	95.40	89.10	84.30
Ash (%DM)	7.50	4.60	10.90	15.70
CP (%DM)	4.00	16.00	32.00	18.50
CF (%DM)	57.62	14.07	12.64	14.20
NDF (%DM)	78.60	53.80	30.20	38.00
ADF (%DM)	49.60	12.90	18.30	22.30
ADL (%DM)	8.60	3.50	2.70	4.20
EE (%DM)	1.30	2.90	9.00	4.20
HC (%DM)	29.02	40.90	11.90	15.70
C (%DM)	41.10	9.40	15.60	18.10
Ca (%DM)	0.36	0.01	0.93	2.10
P (%DM)	0.21	0.95	1.13	0.770

DM = Dry matter; OM = Organic matter; CP = Crude protein; CF = Crude fiber; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; EE = ether extract; Ca = calcium; P = phosphorus; C = Cellulose; HC = Hemicelluloses

3.2.7. In vitro organic matter digestibility

In vitro organic matter digestibility (*IVOMD*) was determined by the two-stage method of Tilley and Terry (1963). Samples from the five treatment diets excluding the basal feed were incubated for 48 hours with rumen fluid and buffer followed by another 48 hour digestion with pepsin and HCl, and the residue was burnt to an ash in a muffle furnace at 550 ^{O}C for 5

hour. Rumen fluid was obtained from rumen fistulated Boran x Holstein Friesian steers kept at maintenance dietary condition.

3.2.8. In sacco dry matter degradability

Rumen degradability of the samples (Samples from the five treatment diets excluding the basal feed) was determined by incubating samples in nylon bags in rumen fistulated animals. The feed samples were incubated for 0, 6, 12, 24, 48, 72 and 96 hours. Duplicate feed samples contained in nylon bags were incubated in three rumen fistulated Boran x Holstein Friesian steers kept at a maintenance diet containing hay supplemented with 4 kg of concentrate mixture comprised of 74, 25 and 1% wheat bran, noug seed cake (NSC) and salt, respectively by placing the samples at different hours and taking them out at the same time (sequential addition). At the end of the incubation period, samples contained bags, including zero hour bags were hand washed in a running tap water. The washed bags were then dried in an oven at 105 ^{O}C for 24 hours. The dried bags were then taken out of the oven and allowed to cool down in desiccators and weighed immediately. The ruminal *in socco* degradability of DM (DMD) was determined for each incubation time using the following formula (Ørskov and McDonald, 1979):

DMD (g/kg) = (DM in sample – DM in residue)/DM in sample

The DMD data were fitted to the exponential equation $p = a+b\ (1-e^{-ct})$ as described by Ørskov and McDonald (1979), where p is the amount of nutrient degraded (%) at time t, a is the intercept of the degradation curve at time zero and represent degradability of soluble fraction (%), b is the rumen-insoluble, but slowly degradable fraction (%), e is base for natural logarithm c is the rate constant for degradation of the b fraction (%/h) and t is the incubation time (h). Potential degradation (PD) was estimated as (A + B), while effective degradability (ED) of DM was calculated using the formula: ED = A + [B*c/(c + k)], where A, B and c are as described above and k is rumen outflow rate, which is assumed to be 0.03/h for roughage feeds (Ørskov and McDonald, 1979). The calculation of the values was carried out using the NEWAY Excel program (Chen, 1996).

3.2.9. Carcass characteristics evaluation

At the end of the feeding and digestibility trials, all lambs were fasted overnight, weighed and slaughtered for carcass evaluation. On slaughtering, the blood was collected in a container and weighed. After the lambs were decapitated, the skin was flayed cautiously to avoid adherence of fat and muscle tissue to the skin. The skin was weighed with legs below the fetlock joints. The weights of the edible and inedible components of the carcass were measured and recorded for each sheep. The empty body weight was calculated by subtracting the weight of the alimentary tract contents from the slaughter weight. Dressing percentage (DP) was calculated as a ratio of hot carcass weight to empty body weight or slaughter weight. The carcass was partitioned into hind and fore quarter between 9^{th} and 10^{th} ribs. The four ribs from 10^{th} to 13^{th} were chilled overnight in a deep freezer and the rib eye (*Longissimus dorsi*) area (cm^2) was measured at the 11^{th} and 12^{th} rib site (Galal *et al*., 1979).

The rib-eye area value was the mean of the left and right sides. The cross sectional area of the rib eye muscle (*longissimus dorsi*) area was traced first on plastic paper after it was cut at the 11^{th} and 12^{th} ribs perpendicularly to back bone. The rib-eye area was again traced on graph paper and computed using mechanical polar planimeter and cross checked with graph paper squares each with a size of 1mm x 1mm. The area of the squares that fall within the tracer mark was then counted on both sides and the average of the two sides was used to calculate rib-eye area in cm^2. Weights of edible and non-edible offal were recorded. The categorization of edible and non-edible offal was made based on the eating habit of the people in the locality where the experiment was conducted. Percentage of total usable product was taken as the sum of dressing percentage and percentage of total edible offal component.

3.2.10. Statistical analysis

Qualitative and quantitative data from the cross-sectional survey, which were collected in the local language (Tigrgna) were translated and entered to Microsoft Office Excel 2007. The same software was used for data edition, management, computation of percentages, and presentation of results in the form of charts and tables. Data were transported to and analyzed using SPSS 16.0 (SPSS, 2007) software. In all the comparisons, the level of significance was

set at $\alpha = 0.05$. Frequency distributions and graphic presentations were employed to summarize information related to descriptive data like sex, marital status, and religion, source of foundation stock, flock structure, feed sources, supplementary feeding, watering and housing. Whenever the data analyzed were based on a single response to questions, the percentage values should add up to 100%. In multiple answers, percentages will not add up to 100%. In all cases percentage was determined from the total sample size of the respective agro-ecology.

The Chi-square **(χ^2)** test was employed to test differences between the categorical variables like frequency of watering and events of slaughtering sheep and goats. ANOVA procedure was used to analyze the variation of continuous variables such as family size, land holding and livestock composition. When analysis of variance (ANOVA) declares a significant difference, mean comparison was made using Tukey test. In addition, ranking analysis was undertaken regarding the income sources, livestock species preference, purpose of keeping small ruminants, attributes of sheep and goats for selecting breeding stock and major constraints of small ruminants. Hence in the preference ranking method, index was computed with the principle of weighted average and indices were ranked each other using auto ranking with MS-excel 2007. The following formula was used to compute index according to Musa *et al*. (2006).

Index = $R_n*C_1 + R_{n-1}*C_2 \ldots + R_1*C_n / \sum R_n*C_1 + R_{n-1}*C_2 \ldots + R_1*C_n$;

Where, R_n= value given for the least ranked level (example if the least rank is 5^{th}, then $R_n = 5$, $R_{n-1} = 4$, $R_1 = 1$)

C_n = Counts of the least ranked level (in the above example, the count of the 5^{th} rank = C_n, and the count of the 1^{st} rank = C_1)

Moreover, qualitative information obtained from exploratory study, group discussion, cross-sectional survey and observations were analyzed using narrative (qualitative) analysis.

Data on feed intake, body weight change, apparent digestibility and carcass parameters were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure by Statistical Analysis Systems software (SAS, 2008) Version 9.2. When analysis of variance

(ANOVA) declares significant differences among treatment means, mean comparison was carried out using Tukey test. The statistical model used for analysis of data was:-

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

Where,

Y_{ij} = Response variable

μ = over all mean

α_i = the i^{th} treatment effect

β_j = the j^{th} block effect

e_{ij} = the random error

4. RESULTS

4.1. Survey

4.1.1. Socio-economic characteristics of the respondents

Various socio-economic factors, for instance farmers' sex, off-farm activity, level of education and training, and their occupation have direct or indirect influence on farmers' decisions as to whether they want to expand and improve their operations. Hence, it is important to see the sex, age, family size, occupation, religion and land holding of the respondents and triangulate them with the sheep and goat management practices.

4.1.1.1. Sex, occupation and religion of the interviewed respondents

Across all the studied agro-ecological zones, the majority of the sheep and goat owning households were male headed while only small proportions were headed by females (Table 7).

Table 7. Sex, occupation and religion of respondents across the different agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Sex						
Male	95	82.6	78	83.9	79	87.3
Female	20	17.4	15	16.1	12	12.7
Marital status						
Yes	102	88.4	83	89.3	79	87.3
No	13	11.6	10	10.7	12	12.7
Occupation						
Farmer	115	100.0	93	100.0	91	100.0
Religion						
Orthodox	105	91.3	83	89.3	73	80.0
Muslim	10	8.7	8	8.9	15	16.4
Catholic	0	0.0	2	1.8	3	3.6

All of the interviewed households across all the studied agro-ecological zones were farmers. Majority of the interviewed households were Orthodox Christians followed by Muslims in religion. There were also very few Catholic Christian respondents in lowland as well as midland agro-ecologies whereas, there was no respondent from the highland belonging to the Catholic Christian followers.

4.1.1.2. Family size and land holding

Average size of female children below eighteen years old was higher ($p<0.05$) in the lowland agro-ecological zone than the highland (Table 8). However, there were no ($p>0.05$) differences in average size of female children below eighteen years old between lowland and midland as well as midland and highland agro-ecological zones. Average numbers of male children less than eighteen years of age, adult males and adult females as well as total family sizes were comparable ($p>0.05$) across the three studied agro-ecological zones. Average landholding per household varied across the three study agro-ecological zones. Households in the lowland tended to have relatively larger ($p<0.05$) land than households in highland agro-ecological zones.

Table 8. Family size and landholding of the respondents across the different agro-ecologies

Variable	Agro-ecological zone (Mean ± SD)			
	Highland	Midland	Lowland	p-value
Male children (<18 years)	1.95 ± 0.86	1.96 ± 1.10	2.25 ± 1.38	0.277
Female children (<18 years)	1.89 ± 0.74[b]	2.34 ± 1.25[ab]	2.83 ± 1.53[a]	0.000
Male adult (>18 years)	1.48 ± 0.68	1.42 ± 0.70	1.22 ± 0.42	0.062
Female adult (> 18 years)	1.51 ± 0.79	1.34 ± 0.51	1.30 ± 0.48	0.151
Total family size	6.52 ± 1.72	6.80 ± 1.71	7.10 ± 1.87	0.199
Landholding (ha)	0.54 ± 0.22[b]	0.60 ± 0.22[ab]	0.69 ± 0.19[a]	0.000

SD: Standard deviation

4.1.1.3. Age category

As depicted in Figure 2, majority of the interviewed households across the assessed agro-ecological zones were in the age category of 41 to 60. The percentage of interviewed households from the age category of 20-30 to 31-40 tended to increase across the three studied agro-ecological zones and reached at its maximum at 41-50 and started to decrease thereafter. The proportion of interviewed households were in the order of LL > ML > HL for the first two age categories (20-30 and 31- 40). However, the opposite was true for 41-50 and 51-60 age categories.

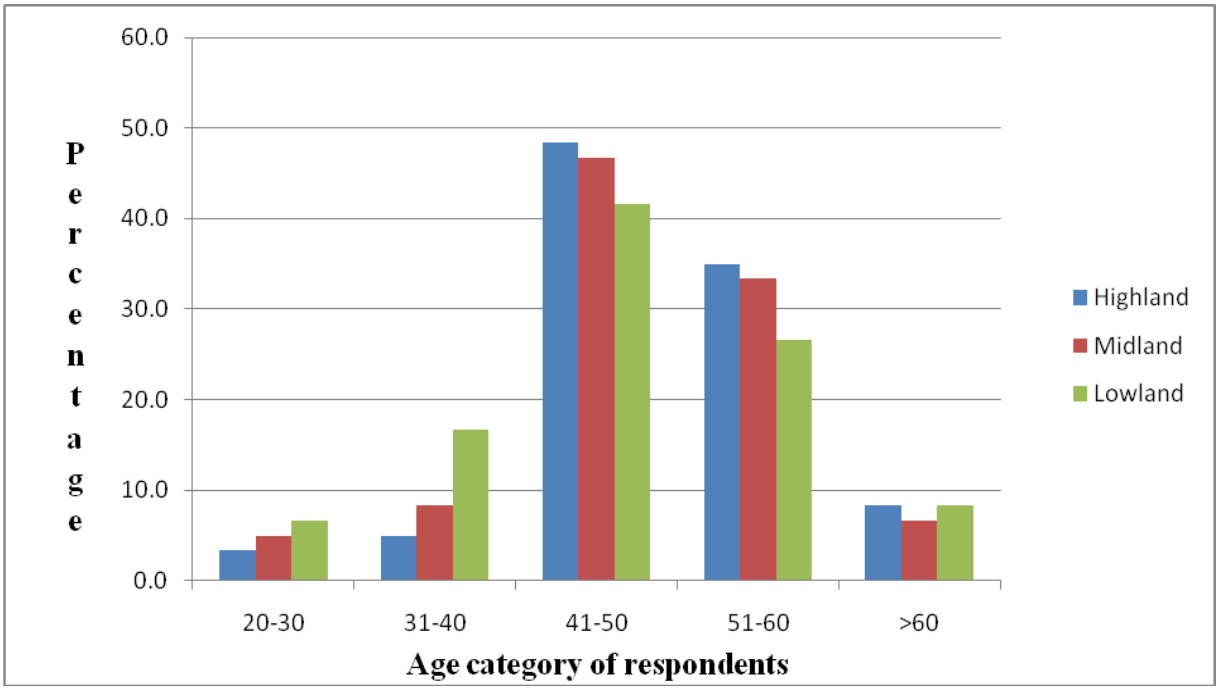

Figure 2. Age category of the respondents across the surveyed agro-ecologies

4.1.1.4. Educational status

Majority of the interviewed households across all the surveyed agro-ecological zones attended elementary school (less than eighth grade) followed by illiterates (cannot read and write) (Figure 3**)**. The percentage of illiterate interviewed sheep and goat holding households advanced from highland to lowland agro-ecological zones. However, the reverse was true for the proportion of tenth grade complete respondents which decreased from highland to

lowland. Across all agro-ecological zones, the percentages of twelve grade completed respondents were very small.

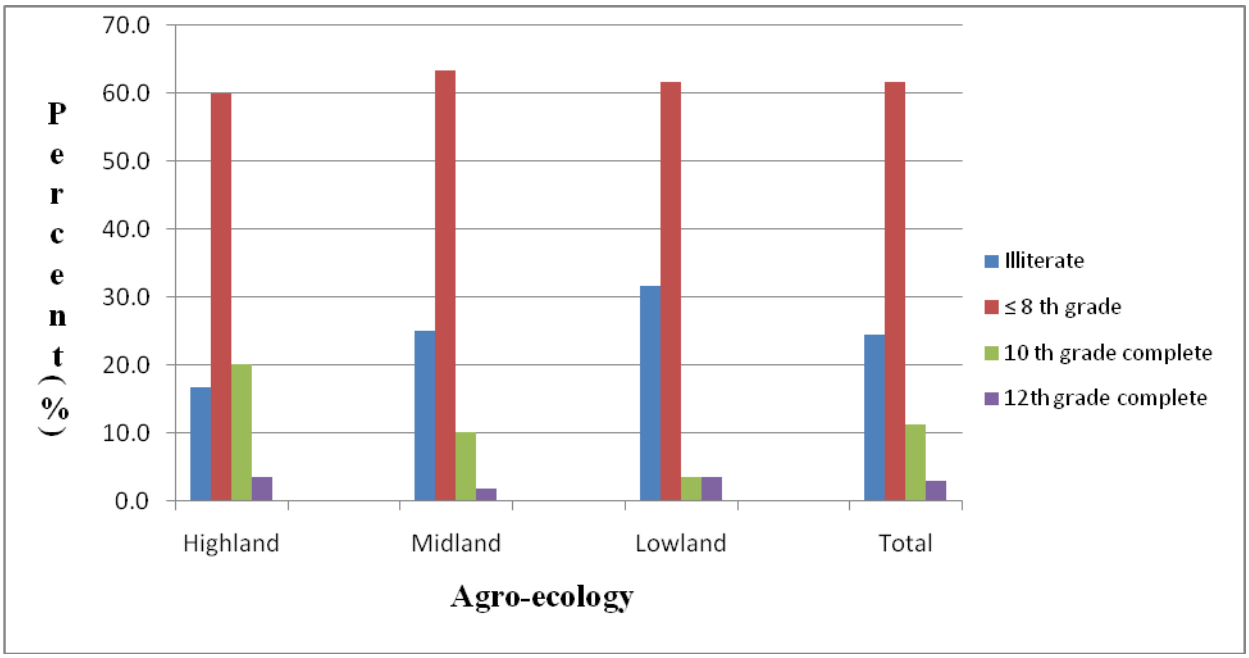

Figure 3. Educational status of the respondents across the surveyed agro-ecological zones

4.1.1.5. Income sources

All of the interviewed respondents across the three studied agro-ecological zones ranked crop production, livestock rearing and off farm activities as first, second and third, respectively for food and cash income. Interviewed households in highland, midland and lowland agro-ecological zones ranked crop production as the main source of income followed by livestock production including sheep and goats and off farm income sources (like petty trading, carpentery and masonry) (Table 9).

Table 9. Households' ranking of activities as their sources of income

Income source	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Crop farming	0.41	1	0.43	1	0.42	1
Livestock production	0.34	2	0.33	2	0.34	2
Off farm	0.25	3	0.24	3	0.24	3

4.1.2. Sheep and goat husbandry practices in the study area

4.1.2.1. Livestock holding

Sheep and goats like the other livestock production systems in Ethiopia have evolved largely as a result of the influence of the natural production environments and socio-economic circumstances of farmers rather than market forces. Hence, sheep and goats in the study area were kept mostly under traditional extensive systems and were largely produced in mixed crop–livestock farming systems. Except for chickens, honey bee colony and equines, the study indicated a significant ($p<0.05$) difference in the average holdings of cattle, sheep and goats across the three studied agro-ecological zones (Table 10).

Table 10. Livestock holding per household across the different agro-ecological zones

Variable	Agro-ecological zone (Mean ± SD)			p-value
	Highland	Midland	Lowland	
Cattle	4.89 ± 1.21^{b}	5.10 ± 1.82^{ab}	6.15 ± 2.23^{a}	0.001
Sheep	13.33 ± 11.06^{a}	9.17 ± 8.37^{ab}	8.04 ± 4.31^{b}	0.020
Goats	6.60 ± 4.07^{b}	10.67 ± 5.79^{a}	12.76 ± 5.54^{a}	0.000
Chicken	7.03 + 4.81	5.73 ± 3.79	6.16 ± 3.79	0.243
Honey bee colony	1.87 ± 1.22	1.93 ± 1.21	2.27 ± 2.05	0.566
Equine	1.60 ± 0.62	1.71 ± 0.77	2.13 ± 1.04	0.213

SD: Standard deviation

The average cattle and goat holding per household was noticeably ($p<0.05$) higher in lowland than in highland. However, the average cattle holding per household in midland was comparable to both highland and lowland agro-ecological zones. No significant difference in goat holding was observed between lowland and midland zones in the current study. Households in the highland kept higher number of sheep than households in the lowland. Nevertheless, the sheep holding of midland agro-ecological zone was comparable to both highland and lowland agro-ecological zones.

4.1.2.2. Livestock species preference

Interviewed households ranked cattle as the most prefered livestock species across all surveyed agro-ecological zones. In the highland and midland agro-ecological zones, sheep were ranked as the second most important livestock species next to cattle. However, in the lowland, goats were ranked as the second most prefered livestock species next to cattle (Table 11). Chicken were rated as the least prefered livestock species next to sheep in the lowland agro-ecological zones. On the other hand, chicken were ranked as the third most important livestock species followed by goats in the highland agro-ecological zone whereas, sheep received second rank in both the highland and the midland agro-ecological zones.

Table 11. Households' ranking of livestock species preference

Species preference	Agro-ecological zone					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Cattle	0.28	1	0.26	1	0.28	1
Sheep	0.26	2	0.25	2	0.23	3
Goat	0.21	4	0.25	3	0.27	2
Chicken	0.24	3	0.24	4	0.22	4

4.1.2.3. Purpose of keeping sheep and goats

Table 12 summarized reasons of keeping sheep and goats and the ranking of their purposes by interviewed sheep and goat holding households across the three studied agro-ecological

zones. The practice of sheep and goat owning in the study areas was quite common and they reared for different purposes such as immediate cash generation, meat and milk for home consumption, manure for farm use and insurance against emergency, skin for home use and sale, different gifts and ceremonies or celebrations. The most common and top ranked reasons of keeping sheep and goats in the surveyed areas are presented in this study. Source of household income was by far the most important purpose of keeping sheep and goats across all agro-ecologies. In the highland areas, keeping sheep and goats as a source of manure was the second followed by saving sheep and goats as live animal. However, saving as live animal, manure, for meat and milk were ranked from second to fifth in both midland and lowland agro-ecologies.

Table 12. Households' ranking of purpose of keeping sheep and goats

Purpose of keeping	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Income source	0.24	1	0.26	1	0.25	1
Saving as live animal	0.20	3	0.21	2	0.23	2
Manure	0.22	2	0.20	3	0.20	3
Consumption (meat)	0.19	4	0.17	4	0.17	4
Milk	0.15	5	0.16	5	0.15	5

4.1.2.4. Sources of foundation stock

Table 13 summarized sources of sheep and goats as foundation stock for the farmers across the different agro-ecological zones. Majority of the respondents from the highland and midland agro-ecological zones indicated market/purchasing followed by home born as the main sources of their foundation stock. On the other hand, home born followed by purchasing accounted higher as a sources of sheep and goats in the lowlands. The majority of the flocks were built through birth of their initial stock at home in the low land. Sharing of sheep and goats from family in the case of lowlands and loan from government in highland and midlands were also used to some extent as sources of foundation stock. The contribution of gift and sharing were minimal across the current surveyed agro-ecological zones.

Table 13. Sources of sheep and goats as foundation stock

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	(%)	N	(%)	N	(%)
Home born	27	23.2	18	19.6	61	67.3
Gift	0	0.0	3	3.6	2	1.8
Purchased	65	56.5	55	58.9	15	16.4
Shared	0	0.0	5	5.4	10	10.9
Loan	23	20.3	12	12.5	3	3.6

4.1.2.5. Flock structure of sheep and goats across the agro-ecological zones

Majority of the flocks of sheep were adult females followed by female lambs in the age category of less than six months across all the three surveyed agro-ecological zones (Figure 4). Female sheep of all age groups comprised the highest ratio. However, adult males were considerably small as compared to females in all surveyed agro-ecological zones. According to the current survey result, the ratio of sheep to goats was 2.91 in highland, 0.84 in midland and 0.42 in lowland.

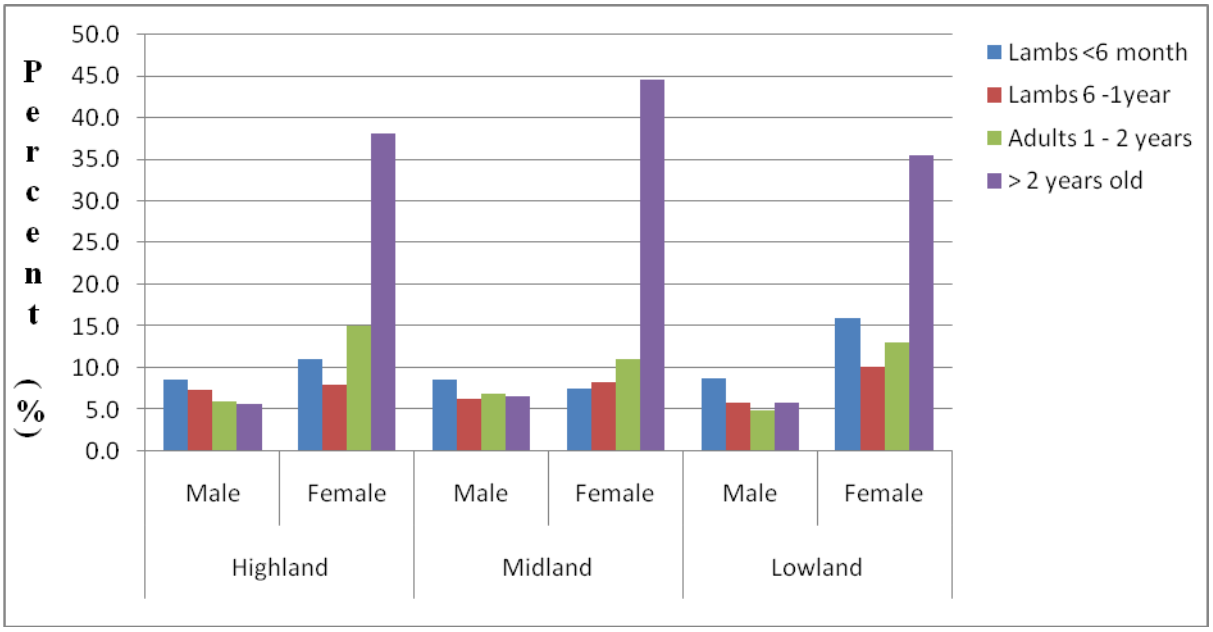

Figure 4. Flock structure of sheep in the three agro-ecological zones

The results of the current study revealed that the proportion of females represented the largest class where as adult males represented the lowest proportion. Similar with that of sheep, the holding of goats were predominantly of adult females in the age category of one year and above (Figure 5). Fortunately, female goats of all age categories were proportionally higher across all the studied agro-ecological zones compared to male goats of all age groups. The proportion of adult males comprised of the least in all the study areas. According to this survey result, the ratio of goats to sheep was 0.34 in highland, 1.19 in midland and 2.39 in lowland.

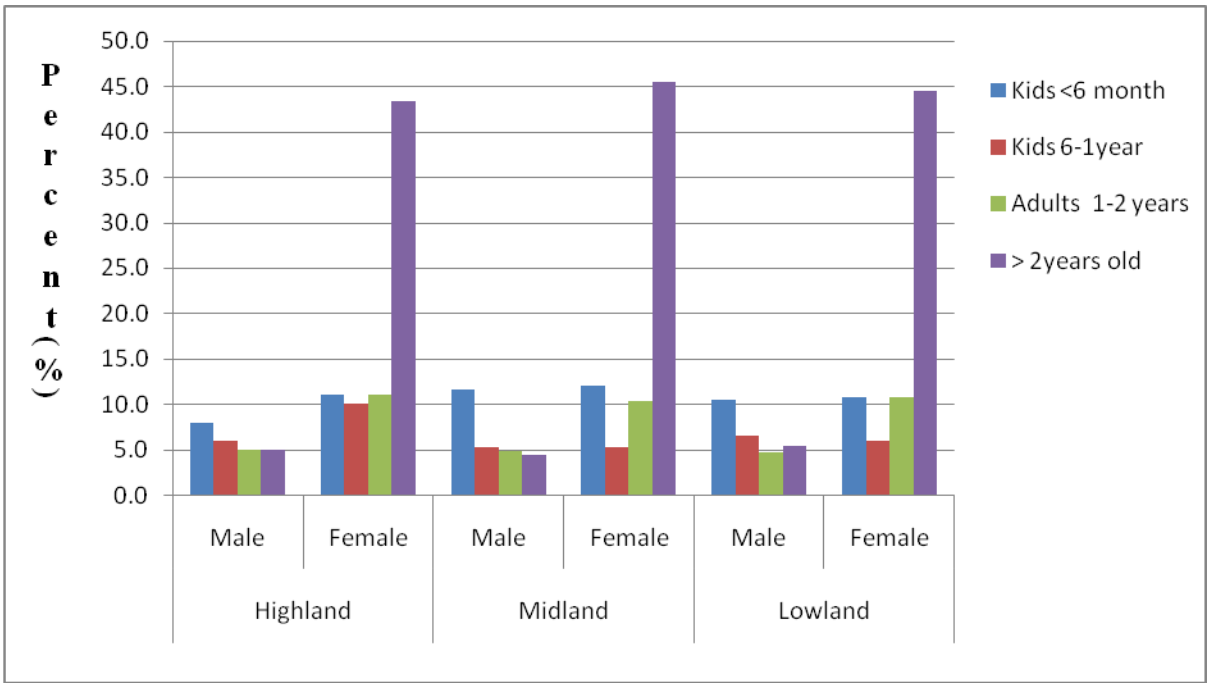

Figure 5. Flock structure of goats in the three agro-ecological zones

4.1.2.6. Feeds and feeding practices of sheep and goats

4.1.2.6.1. Major feed resources of sheep and goats in the wet season

As depicted in Table 14, the major wet season sources of feed for sheep and goats in the study area were grazing on natural grazing lands (including road side grazing, river side grazing, hill side grazing, and grazing on the boarders of crop lands), browse (like shrubs, bushes and

trees), weed, cactus (either its cladode or fruit peel), crop residues and purchased feeds like wheat bran and oil seed cakes and to some extent improved forage plants were also mentioned across the different studied agro-ecological zones. The proportions of respondents who used natural grazing land as a major source of feed were higher in midland and lowlands as compared to the highland respondents. Additionally, the proportions of respondents who made use of browse as their major wet season feed source were observed to decrease as the elevation increased.

Table 14. Major feed resources of sheep and goats in wet season

Feed types	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Grazing on natural pasture land	65	56.5	88	94.6	84	92.7
Crop residues	40	34.8	20	21.4	15	16.4
Improved forages	28	24.6	20	21.4	15	16.4
Weeds	45	39.1	40	42.9	35	38.2
Cactus cladode	13	11.6	2	1.8	0	0.0
Cactus fruit peel	42	36.2	35	37.5	40	43.6
Browse	48	42.0	51	55.4	68	74.5
Milling by-products	28	24.6	25	26.8	7	7.3
Oil seed cakes	22	18.8	15	16.1	7	7.3

N: Number of respondents

The proportion of respondents who reported in making use of crop-residues, improved forages and the commercially purchased feeds differed across the three study agro-ecological zones. The proportions of interviewed respondents in the highland who make use of these feed resources were relatively larger than those from the lowland. The proportion of respondents who grow improved forages decreased as the altitude decreased in the present study.

4.1.2.6.2. Major feed resources of sheep and goats in the dry season

The importance of crop aftermath across the three studied agro-ecological zones during the dry season becomes prominent next to grazing in natural grazing land particularly in both highland and midland agro-ecological zones (Table 15). However, browse remains the second

most important feed source for the lowland sheep and goat farmers during the dry season. Large proportions of interviewed respondents in the lowland indicated the utilization of browsing plants (trees, shrubs, bushes and tree pods) for sheep and goats than respondents of highland and midland agro-ecological zones. Utilization of conserved feed resources like hay has been observed to be very low (7.2%, 5.4% and 16.4% respectively for the highland, midland and lowland) across all the surveyed agro-ecological zones. Respondents also put cactus cladode from the top ranked feed resources across all the studied areas. The cactus fruit peel was also reported as an excellent livestock feed in all the surveyed agro-ecological zones despite its availability was limited to the wet season only.

Table 15. Major feed resources of sheep and goats in dry season

Feed type	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Grazing on natural pasture land	115	100.0	93	100.0	91	100.0
Crop residues	38	33.3	28	30.4	13	14.5
Aftermath	78	68.1	80	85.7	65	70.9
Improved forages	22	18.8	18	19.6	15	16.4
Weeds	7	5.8	15	16.1	8	9.1
Cactus cladode	58	50.7	40	42.9	36	40.0
Hay	8	7.2	5	5.4	15	16.4
Browse	22	18.8	43	46.4	68	74.5
Milling by products	38	33.3	30	32.1	10	10.9
Oil seed cakes	28	24.6	20	21.4	10	10.9

N: Number of respondents

Generally the utilization of industrial by-products and improved forages were less in the three surveyed agro-ecological zones. However, the proportion of respondents using industrial by-products was relatively larger in highland and midland than lowland during both wet and dry seasons.

4.1.2.6.3. Cultivation of improved forage crops

As depicted in Table16, the proportion of interviewed households who had experience of growing improved forages was larger in highland and midland than lowland agro-ecological zones. Sesbania (*Sesbania sesban*), Elephant grass (*Pennisetum purpureum)*, leucaena (*Leucaenia leucocephala),* pigeon pea (*Cajanus cajan*), alfalfa (*Medicago sativa*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) were the grown cultivated forage crops mentioned by the respondents across the three agro-ecological zones. Moreover, from personal observation during the survey period, sesbania, lucaenea and Elephant grass were the mostly widely planted and utilized forages in the study areas.

Table 16. Experience of growing improved forages and reasons for not growing.

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Experience of growing improved forages						
Yes	29	25.2	20	21.4	13	14.3
No	86	74.8	73	78.5	78	85.7
Reasons for failure to grow improved forages						
Land problem	47	40.9	38	40.9	32	35.2
Lack of planting materials	6	5.2	7	7.5	9	9.9
Water shortage	19	16.5	18	19.4	24	26.4
Seed availability	10	8.7	5	5.4	3	3.3
Limited awareness	4	3.5	5	5.4	10	11.0

N: Number of respondents

Majority of respondents who did not cultivate improved forages across all the surveyed agro-ecological zones indicated that shortage of land as the leading reason for not cultivating improved forage crops followed by shortage of water. Lack of planting materials and seeds were also mentioned by the highland and midland sheep and goat holding households. However, limited awareness and lack of planting materials were pointed out as reasons for not growing improved forages by lowland sheep and goat holding households. The commonly practiced forage development strategies observed across the three agro-ecological zones were backyard development, gully treatment, intercropping and alley cropping. According to the

information obtained from the group discussion, apart from those farmers who own shallow wells and irrigated farm, use of improved forages was rarely practiced in the three surveyed agro-ecological zones.

4.1.2.6.4. Use of purchased feeds to supplement sheep and goats

Table 17 summarizes proportion of respondents who purchased feed, types of feed purchased, reasons for not purchasing and to which animals are these purchased feeds supplemented. The proportion of respondents who purchased supplementary feeds for their sheep and goats in the highland and midland agro-ecological zones were more than double as compared to that of the respondents in the lowland. Wheat bran was relatively better used as supplement by the farmers in the highland and midland agro-ecological zones than farmers in the lowland agro-ecology. Interviewed households who had better access to the supplemental feed have observed to purchased and supplement their animals.

Table 17. Practices of supplementing sheep and goats

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Practice of supplementation	48	41.7	42	45.2	18	19.8
Type of supplement						
Crop residues	10	8.7	8	8.6	5	5.5
Wheat bran	27	23.5	23	24.7	10	11.0
Oil seed cakes	7	6.1	6	6.5	0	0.0
Others (like food left over)	4	3.5	5	5.4	3	3.3
Reason for failure to supplement						
Not available	40	34.8	35	37.6	43	47.3
Expensive	22	19.1	12	12.9	18	19.8
Less aware	5	4.3	4	4.3	12	13.2
Type of animal need supplement						
Pregnant	7	6.1	7	7.5	5	5.5
Lactating	18	15.7	15	16.1	7	7.7
Fattening	15	13.0	12	12.9	0	0.0
Emaciated	8	7.0	8	8.6	6	6.6

Other non-conventional feed sources like household wastes and refusals, *atella* (residues of local drink) and lentil screenings, mango by-products (like cull fruits (fresh fruits unsuitable for human consumption), mango seeds and mango peels) were observed during the survey period to be collected from juice houses and used as supplement for sheep and goats particularly by those farmers nearby the towns. Respondents pointed out that less accessibility and high cost were the most important restraining factor that impeded them from not using purchased feeds across all the surveyed agro-ecological zones. Moreover, considerable proportion of the respondents also indicated that the supplementary feeds were not affordable for them to purchase and supplement to their sheep and goats. Interviewed respondents in the highland and midland agro-ecological zones indicated that lactating, fattening and to some extent emaciated sheep or goats due to malnutrition received better priority when ever supplementation is required. Whereas, respondents in the lowland indicated that lactating, emaciated and pregnant sheep or goats received better priority for supplementation.

4.1.2.6.5. Grazing practices of sheep and goats

All of the interviewed sheep and goat holding households across all the surveyed agro-ecological zones practiced grazing (Table 18). Across all the study areas, sheep and goats during grazing are under close supervision by the herder throughout the day to prevent them from damaging crops and to protect them from predators as well. According to the focus group discussion, participants noted that un-herded grazing during the rainy season is totally uncommon in the three agro-ecological zones. Compared to the highland and midland agro-ecological zones, more proportion of respondents in lowland indicated the use of un-herded grazing. The practice of tethering sheep and goats was less practiced across all studied agro-ecological zones. Very few farmers used to tether their sheep and goats in highland and midland. In the highland agro-ecology where sheep are dominantly reared than goats, majority of the respondents kept them with other livestock while grazing. Nevertheless, higher proportion of respondents in the midland and lowland indicated that sheep and goats grazed separately from other livestock. Additionally, lambs or kids were used to graze with adults in the highland and midland agro-ecological zones whereas; they were separately grazed in the case of lowlands.

Table 18. Grazing practices in the different agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Grazing	115	100.0	93	100.0	91	100.0
Grazing type						
Herded	82	71.0	72	77.4	65	70.9
Unherded	20	17.4	18	19.4	26	29.1
Tethered	13	11.6	3	3.2	0	0.0
Grazing practices						
With other livestock	65	56.5	40	42.9	36	40.0
Separate	50	43.5	53	57.1	55	60.0
Grazing practices of lambs/kids						
With adults	87	75.4	68	73.2	41	45.5
Separate	28	24.6	25	26.8	50	54.5

4.1.2.6.6. Feed shortage seasons and their mitigation strategies

As depicted in Table19, majority of the respondents indicated that the critical seasons of feed shortage across the surveyed agro-ecological zones were during spring (March - May), winter (December - February) and summer, respectively. Nevertheless, the proportion of respondents who faced critical feed shortage during summer and autumn were less as compared to spring and winter. Feeding cactus, purchasing feeds, limiting the quantity of feed provided, destocking and providing the conserved feed, in their order of importance were the coping mechanisms for critical feed shortage for the highland sheep and goat holding households. However, feeding cactus, destocking, purchasing feeds, giving feeds in small quantities and providing the conserved feed for the midlands and feeding cactus, destocking and giving feeds in small quantities for the lowland were coping mechanisms for critical feed shortage seasons. The practice of feed conservation and purchasing feeds to mitigate critical feed shortage in the lowlands were very limited.

Table 19. Critical feed shortage seasons of the year and their mitigation options

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Feed shortage seasons						
Autumn (Sept. - Nov.)	7	6.09	11	11.8	9	9.9
Winter (Dec. - Feb.)	26	22.61	22	23.7	26	28.6
Spring (Mar. - May)	60	52.17	43	46.2	37	40.7
Summer (June - Aug.)	22	19.13	17	18.3	19	20.9
Mitigation strategies						
Destocking (Selling animals)	14	12.17	19	20.4	29	31.9
Purchasing feeds	25	21.74	15	16.1	3	3.3
Conserving feeds	12	10.43	11	11.8	6	6.6
Feeding in small quantities	17	14.78	14	15.1	22	24.2
Feeding cactus	47	40.87	34	36.6	31	34.1

4.1.2.7. Water sources and watering across the three agro-ecological zones

4.1.2.7.1. Water sources

As depicted in Table 20, the main source of water for sheep and goats in both dry and wet seasons were rivers, springs, micro dams and bore holes. Majority of respondents from highland used bore holes followed by rivers as their major water sources for their sheep and goats during the dry season. However, the reverse was true in the case of midland and lowland respondents where river took the leading role as a major water source followed by bore hole. In the case of rainy season, rivers and springs played a paramount role as a major source of water for the sheep and goat holding households across all the surveyed agro-ecological zones. The importance of micro dams was not insignificant in supporting farmers' drinking water for their animals in the current study.

Table 20.Water source in dry and wet seasons across the three agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Dry season						
Bore hole	35	30.4	18	19.6	12	12.7
Dam/pond	25	21.7	7	7.1	10	10.9
River	30	26.1	53	57.1	61	67.3
Spring	18	15.9	13	14.3	8	9.1
Pipe water	7	5.8	2	1.8	0	0.0
Wet season						
Bore hole	18	15.9	8	8.9	7	7.3
Dam/pond	18	15.9	12	12.5	8	9.1
River	47	40.6	51	55.4	61	67.3
Spring	32	27.5	20	21.4	15	16.4
Pipe water	0	0.0	2	1.8	0	0.0

4.1.2.7.2. Distance to watering points

As depicted in Table 21, majority of the respondents in highland and midland received water at a radius between one and five kilometers during dry season. Unlike the respondents from highland and midland agro-ecological zones who did get water at a shorter distance, majority of the respondents in lowland did get water at farther distance (between six and ten kilometers) during the dry season. Majority of the respondents across the surveyed agro-ecological zones received water for their sheep and goats within five kilometers radius during the wet season. Additionally, according to the information obtained from the focus group discussion, watering of sheep and goats at home is practiced mainly for sick and pregnant sheep and goats (which are in the last few weeks of parturition including few days after delivery) whereas, others search water outside of the house. Moreover, participants also emphasized that scarcity of water as one of the main constraints; as a result it is common to see farmers trekking their animals longer distances in search of water, particularly during dry season.

Table 21. Distance to nearest water point

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Dry season						
< 1 km	28	24.6	15	16.1	7	7.3
1 - 5 km	55	47.8	51	55.4	31	34.5
6 - 10 km	32	27.5	17	17.9	46	50.9
> 10 km	0	0.0	10	10.7	7	7.3
Wet season						
< 1 km	50	43.5	22	23.2	18	20.0
1 - 5 km	58	50.7	60	64.3	65	70.9
6 - 10 km	7	5.8	12	12.5	8	9.1

4.1.2.7.3. Frequency of watering

Water was offered to sheep and goats at different frequencies and was generally associated with season, availability and distance to watering points. As depicted in Table 22, frequency of watering sheep and goats during dry season varied noticeably ($p<0.05$) across the three surveyed agro-ecological zones. Majority of the respondents watered their sheep and goats once a day followed by once in two days particularly during the dry season. The proportions of respondents who provide water once a day were higher ($p<0.05$) in highland and midland than the lowland agro-ecological zone. Unlike the highland and midland agro-ecological zones, in the lowland, majority of the respondents reported that once in two days followed by once a day are the common frequency of providing water to their sheep and goats during the dry season. Generally, the frequency of providing water to the sheep and goats during the wet season was short as compared to the dry season.

Table 22. Frequency of watering

Variable	Agro-ecological zone						p-value	χ^2
	Highland		Midland		Lowland			
	N	%	N	%	N	%		
Dry season								
Freely available	0	0.0	10	10.7	25	27.3		
Once a day	67	58.0	45	48.2	28	30.9		
Once in two days	33	29.0	32	33.9	31	34.5		
Once in three days	15	13.0	7	7.1	7	7.3	0.000	22.29
Wet season								
Freely available	30	26.1	35	37.5	45	49.1		
Once a day	68	59.4	55	58.9	41	45.5		
Once in two days	17	14.5	3	3.6	5	5.5	0.000	19.31

Similar to the dry season, the frequency of watering sheep and goats during wet season also varied significantly ($p<0.05$) across the three surveyed agro-ecological zones. Once a day followed by freely available were the most common frequencies of watering sheep and goats in both highland and midland agro-ecological zones. Whereas the reverse was true (freely available followed by once a day) in the case of lowland agro-ecological zone.

4.1.2.8. Housing of sheep and goats across the three agro-ecological zone

The housing system was almost similar across the studied agro-ecological zones (Table 23). Respondents housed their sheep and goats in separate house from the main family house but adjacent to the main building. Though limited, there were also farmers who shared the same house with their sheep and goats in the three surveyed agro-ecologies. However, separate housing according to species and age was less commonly practiced in the present study areas. In the present study, most of the farmers housed their sheep and goats together with other livestock species. According to the respondents from highland and midland agro-ecologies in the current study, pregnant ewes or does followed by lambs and kids were given better priority during housing than the other categories. Unlike the respondents in highland and midland agro-ecological zones where pregnant ewes or does received better priority during housing, respondents from the lowland agro-ecological zone provided more priority to lambs or kids than the other age groups.

Table 23. Housing of sheep and goats across the three agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Housing system						
Share with family	8	7.2	5	5.4	7	7.3
Separate house	33	29.0	30	32.1	26	29.1
Share with other animals	73	63.8	58	62.5	58	63.6
Type of animal received more priority during housing						
Lactating	13	11.6	10	10.7	5	5.5
Pregnant	58	50.7	48	51.8	35	38.2
Lamb/kid	43	37.7	35	37.5	51	56.4

4.1.2.9. Breeding practices of sheep and goats

Interviewed sheep and goat holding households in the surveyed area indicated that sheep and goats were kept primarily for breeding to raise their number (Table 24). As a consequence, the critical importance of breeding sheep and goats in the surveyed area was for flock growth and maintenance, because they generally rely less on the market to build herd and flocks. According to the survey result, there was less selective or controlled mating system in all the surveyed agro-ecological zones. Majority of respondents across the surveyed agro-ecological zones revealed that they practiced uncontrolled mating.

Table 24. Type, season and sources of breeding males across the surveyed agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Type of mating						
Controlled	12	10.1	8	8.9	5	5.5
Uncontrolled	103	89.9	85	91.1	86	94.5
Mating season						
Wet season	40	34.8	27	28.6	28	30.9
Dry season	7	5.8	2	1.8	0	0.0
Year round	68	59.4	64	69.6	63	69.1
Source of breeding ram						
Own breed	75	65.2	59	64.3	50	54.5
Purchased	8	7.2	7	7.1	3	3.6
Neighboring	32	27.5	27	28.6	38	41.8
Source of breeding buck						
Own breed	43	37.7	48	51.8	61	67.3
Purchased	8	7.2	7	7.1	3	3.6
Neighboring	64	55.1	38	41.1	27	29.1

Majority of respondents in the current study indicated that mating occurred all year round usually in the field while grazing. Next to the year round mating, wet season was the season when the highest mating of sheep and goats occurred. However, participants during group discussion indicated that peak mating was observed mainly after the short rainy season when new growth of grasses has initiated due to rain and after main crops are harvested when ample stubbles, residues and crop aftermaths are available. In dry season, especially immediately after crops have been harvested from the cultivated or crop lands, ram and buck from different flocks while roam freely mates females within the same village or from other villages. Additionally, majority of the respondents across the study area indicated that own ram was the main source of breeding males followed by breeding rams from neighboring. However, own breeding buck accounted most in midland and lowland whereas neighboring for the highland agro-ecological zones.

4.1.2.9.1. Attributes of sheep and goats for selecting breeding stock

Selecting breeding rams

Across all the surveyed agro-ecological zones, conformation of rams was ranked as their first important criterion for selecting breeding rams (Table 25). Coat color was the second important criterion both in highland and midland agro-ecologies and hence, red, light brown, pied colors and grey were more preferred in the highland and midland agro-ecologies whereas pure black and pure white were less preferred colors across all the study sites. Participants of the group discussion also indicated that pure black and pure white colors had less demand in market across all the study sites. However, availability of the rams nearby their premises was the second ranked criterion next to the conformation in lowland.

Table 25. Attributes for selecting breeding rams

Criterion for selecting breeding rams	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Conformation	0.25	1	0.26	1	0.27	1
Coat color	0.23	2	0.22	2	0.21	3
Horn shape	0.17	4	0.14	5	0.14	5
Temper	0.15	5	0.15	4	0.15	4
Availability	0.20	3	0.22	3	0.23	2

Selecting breeding bucks

In the highland and midland agro-ecological zones, conformation followed by coat color received the top ranking in selecting breeding bucks (Table 26). However, coat color received less attention in the case of lowland rather availability of the breed nearby their premises ranked the second next to the conformation. Horn shape and temper ranked least in both highland and midland agro-ecological zones whereas, coat color and temper ranked least in the case of lowland.

Table 26. Attributes for selecting breeding bucks

Criterion for selecting breeding bucks	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Conformation	0.24	1	0.26	1	0.27	1
Coat color	0.24	2	0.21	2	0.19	4
Horn shape	0.17	4	0.17	4	0.20	3
Temper	0.15	5	0.15	5	0.15	5
Availability	0.19	3	0.21	3	0.20	2

4.1.2.9.2. Castration

More than half of the respondents in the midland and lowland revealed that they practiced castration of rams (Table 27). However, castration of rams in the highland was less commonly practiced. Conversely, majority of the respondents across all the surveyed agro-ecology castrated their bucks.

Table 27. Practices of castrating sheep and goats across the different agro-ecological zones

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Households castrating rams	22	19.1	50	53.8	57	62.6
Households castrating bucks	82	71.3	86	92.5	88	96.7
Method of castration						
Traditional	62	53.9	73	78.5	65	71.4
Modern	20	17.4	20	21.5	18	19.8
Age at castration for ram						
6 - 12 months	5	4.3	8	8.6	12	13.2
> 1year	17	14.8	42	45.2	45	49.5
Age at castration for buck						
6 - 12 months	2	1.7	6	6.5	22	24.2
> 1year	80	69.6	80	86.0	66	72.5

The proportion of respondents practicing castration in the highland was relatively less than midland and lowland areas. More than seventy percent of the households in the midland and lowland areas used traditional methods of castration by using locally available materials (woods, river-stones (*allelo*), ropes or stick to crash vas deference of the testes) and the remaining respondents used modern methods (Burdizzo). Majority of respondents in the current study castrated their sheep and goats aged above one year.

Reasons for castration

As depicted in Table 28, The interviewed sheep and goat holding households across the study area indicated that the most important reason of castration is to fatten and sale (fetching better income). In all the surveyed agro-ecological zones, castration of a ram and a buck was practiced with the intention of making the ram or buck fatter, control unwanted breeding and to tame them according to their importance. The other reason of castrating male sheep and goats was to avoid those animals with undesirable physical characteristics like black coat color and small body size at early age from mating females. Other respondents though ranked least, castrated rams and bucks to minimize noisy or aggressive characters.

Table 28. Reasons for castrating sheep and goats across the different agro-ecological zones

Reason for castration	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Fetching higher price	0.38	1	0.40	1	0.39	1
Controlling breeding	0.33	2	0.33	2	0.32	2
Improving temper	0.29	3	0.26	3	0.29	3

4.1.2.10. Sheep and goats fattening practices

According to the information obtained from the group discussion conducted across all the surveyed agro-ecologies, market oriented small ruminant fattening was less common (Table 29). Sheep and goat fattening activities were seasonal which was mainly associated with

market demand seasons for fattened sheep and goats and to a smaller extent due to feed availability for fattening. The proportion of respondents practicing fattening in the lowland was lowest compared to proportion of respondents from the highlands and midland ago-ecologies. About fifty percent of the interviewed sheep and goat holding households in the highland as well as midland in the present study practiced fattening. Stall-feeding throughout the fattening period accounted the larger proportion followed by grazing plus supplementation with some other purchased feeds in both highland and midland agro-ecological zones. However, sole grazing followed by grazing plus supplementation with some other purchased feeds made the larger proportion in the lowland agro-ecological zone.

Table 29. Fattening practices of sheep and goats

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Fattening	55	47.8	53	57.1	38	41.8
Method of fattening						
Stall-feeding	25	21.7	27	28.6	5	5.5
Grazing plus household wastes	7	5.8	8	8.9	7	7.3
Grazing plus supplementation	23	20.3	17	17.9	10	10.9
Grazing only	0	0.0	2	1.8	17	18.2
Fattening period						
Two months	27	23.2	12	12.5	0	0.0
Three months	17	14.5	28	30.4	25	27.3
Four months	8	7.2	8	8.9	7	7.3
More than four months	3	2.9	5	5.4	7	7.3
Fattening system						
Isolated from other herd	33	29.0	38	41.1	22	23.6
with other animals	0	0.0	2	1.8	0	0.0
with other animals but supplemented	22	18.8	13	14.3	17	18.2
Reason for not practicing fattening						
Feed shortage	20	17.4	10	10.8	10	11.0
Limited market	18	15.7	7	7.5	22	24.2
Purpose of rearing shoat	22	19.1	23	24.7	21	23.1

During the group discussion, it was noted that some farmers particularly in the highland and midland purchased few sheep or goats from farm gates and/or local markets to sale in other

surrounding markets whenever there is better demand like during holidays. There are usually farmers who run business often during off-farm seasons to generate income from trade of sheep and goats or other animals. Of the interviewed highland households who practiced fattening sheep and goats, majority of them fattened their sheep and goats for a period of two months. However, in the midland and lowland agro-ecological zones, larger proportion of interviewed households indicated that they fattened their sheep and goats for three months. Across all the surveyed agro-ecological zones, majority of the interviewed households who practiced fattening sheep and goats fattened their sheep and goats isolated from other herd followed by together/mixed with other animals but supplemented with other feeds. According to the respondents who do not practicing fattening, there are different underlining reasons for not practicing fattening. Some of the reasons mentioned include keeping sheep and goats are principally breeding oriented and sale when there is urgent income need to fulfill households' necessities. Moreover, they further explained that fattening is mostly practiced by few framers who have access to improved forage around irrigation areas and in the towns where there is relatively better access to supplementary feeds.

4.1.2.11. Events of slaughtering sheep and goats

Religious holidays, wedding, births at home and guests in that order were the most common events where sheep and goat holding households slaughter sheep or goats both in highland and midland agro-ecologies (Table 30). Whereas, slaughtering for guests was the most common practice of sheep or goat slaughtering next to religious holidays in the case of lowland agro-ecological zone. The practice of slaughtering sheep and goats during religious holidays showed higher ($p<0.05$) in lowland than highland and midland agro-ecological zones. The proportion of households who slaughter sheep or goats during the religious holidays was larger than the other events. Slaughtering sheep and goats during wedding and home birth showed less difference across the different agro-ecological zones. However, slaughtering sheep or goats for guests indicated higher ($p<0.05$) in lowlands than highland and midland agro-ecological zones. The sex preference differed across agro-ecological zones in the current study. The proportion of households who preferred males was higher ($p<0.05$)

in lowland and midland agro-ecologies than the proportion of households in the highland agro-ecology.

Table 30. Events of slaughtering sheep and goats across the different agro-ecologies

Variable	Agro-ecological zone						p-value	χ^2
	Highland		Midland		Lowland			
	N	%	N	%	N	%		
Events of slaughtering								
Religious holiday	75	65.2	55	58.9	88	96.4	0.000	2.33
Wedding	37	31.9	30	32.1	50	54.5	0.073	5.24
Birth in family	32	27.5	22	23.2	28	30.9	0.701	0.71
Guest	18	15.9	15	16.1	51	56.4	0.000	19.65
Sex preference								
Male	88	76.8	88	94.6	89	98.2		
No difference	27	23.2	5	5.4	2	1.8	0.001	14.13

Percentages exceed 100% as respondents mentioned two or more events for slaughtering

4.1.3. Major constraints of sheep and goat production

4.1.3.1. Production constraints

Identification of major constraints for a given livestock production system in a given area is thought to be a prerequisite to devise appropriate development intervention strategies for improving production and productivity of livestock. Hence, sheep and goat holding households were asked to indicate and prioritize the most important constraints of sheep and goats production in their respective agro-ecological zones (Table 31). According to the interviewed sheep and goat holding households, there were different constraints hindering productivity of sheep and goats in the study area. They included feed shortage, land problem, shortage of water, inadequate access to veterinary drugs and services, inadequate extension service, predator, market problems, drought and lack of knowledge and skills.

Table 31. Households' ranking of sheep and goat production constraints

Production constraint	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Feed shortage	0.14	1	0.15	1	0.16	1
Land shortage	0.13	2	0.13	2	0.13	3
Health problem	0.11	5	0.11	5	0.10	5
Labor shortage	0.10	7	0.10	7	0.10	6
Predator	0.10	8	0.11	4	0.13	2
Water scarcity	0.12	3	0.13	3	0.12	4
Market problem	0.11	4	0.11	6	0.10	7
Shelter	0.08	9	0.07	9	0.08	9
Poor extension	0.11	6	0.09	8	0.08	8

Feed shortage, limited land and water scarcity were ranked from first to third, in that order of importance, both in highland and midland agro-ecological zones. However, feed shortage, predator and limited land were the first three top ranked constraints identified by sheep and goat holding households in the lowland. Sheep and goat holding households also approved that land scarcity as their critical production problem and received second rank next to feed shortage in both highland and midland agro-ecologies. Whereas in the lowland agro-ecology, limited land size ranked third problem next to predator. Predator seemed very crucial problem as compared to land shortage to the lowland sheep and goat holding households. Problems of diseases, parasites and limited vet services were also mentioned among the constraints hindering sheep and goat production ranking fifth across all the surveyed agro-ecological zones. Shortage of water was also one of the scarcest commodities where farmers faced especially during the dry season. Hence, scarcity of water ranked as a third constraint followed by limited market and veterinary services in the highland agro-ecology. Similarly, limited water availability ranked third but followed by predator as a fourth constraint for sheep and goat production in the midland. Sheep and goat holding households in lowland agro-ecology ranked predators as the second most important constraint next to feed. However, predator seemed relatively less problem in the highland sheep and goats holding households.

4.1.3.2. Marketing constraints

According to the respondents in the highland and midland agro-ecological zones, low prices as well as seasonal fluctuations of demand were the two most important determinants of marketing sheep and goats. However, in the lowland, seasonal fluctuations of demand and market distance were the two top bottle necks that had an effect on sheep and goat marketing (Table 32). Since, the majority of the respondents across the surveyed agro-ecological zones were followers of Orthodox Christianity, demand for sheep and goats varied with the fasting and none fasting seasons. Demand for sheep and goats rise during none fasting and fall during the fasting periods (when the followers of Ethiopian Orthodox Christians refrain from consuming any animal-based food). According to the respondents across all the surveyed agro-ecological zones, broker interference was less in sheep and goat transaction.

Table 32. Sheep and goats market problems across different agro-ecological zones

Market problem	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Seasonal fluctuation of demand	0.23	2	0.24	1	0.26	1
Low price	0.23	1	0.24	2	0.21	3
Market distance	0.21	3	0.22	3	0.22	2
Broker interference	0.16	4	0.15	4	0.17	4
Others	0.16	5	0.15	5	0.15	5

4.1.4. Knowledge and utilization of mulberry

As depicted in Table 33, there were some sheep and goat holding households who had knowledge of the plant across all the surveyed areas. According to the information obtained from the discussion conducted with focus groups, the purpose of introducing the plant was first for silk worm rearing, where larger numbers of farmers had adopted the plant. After a while, however, the number of farmers cultivating mulberry decreased due to dwindled demand and attention given to silk worm rearing and its products. Respondents indicated that

training was given while disseminating the plant to selected farmers for the purpose of silk worm rearing. The experience of the majority of those farmers who had knowledge of the mulberry is within 5-10 years across the surveyed agro-ecological zones. According to the respondents, Bureau of Agriculture and Rural Development of the respective districts distributed the initial planting material to the farmers across all the surveyed agro-ecological zones.

Table 33. Knowledge of respondents about mulberry

Variable	Agro-ecological zone					
	Highland		Midland		Lowland	
	N	%	N	%	N	%
Knowledge about mulberry	38	33.0	23	24.7	26	28.6
Ways of gaining knowledge						
Through training	38	33.0	23	24.7	26	28.6
Mulberry known for						
<5 years	3	2.6	2	2.2	2	2.2
5 - 10 years	22	19.1	19	20.4	22	24.2
> 10 years	13	11.3	2	2.2	2	2.2
Initial source of the plant						
GO	25	21.7	18	19.4	26	28.6
NGOs	5	4.3	0	0.0	0	0.0
Others (like individuals)	8	7.0	5	5.4	0	0.0
Purpose of introduction						
Silk worm feed	38	33.0	23	24.7	26	28.6
Animal feed	0	0.0	0	0.0	0	0.0

GO: Governmental organization; NGOs: Nongovernmental organizations

4.1.5. Current purpose of growing mulberry in the surveyed agro-ecological zones

Respondents in highland and midland agro-ecological zones rated growing mulberry plant mainly for ruminant feed followed by fuel wood and fence purposes (Table 34). However, the opposite was true in the case of respondents from the lowland agro-ecological zone, the main purposes of growing mulberry was for fuel wood followed by animal feed and fence, respectively in that order of importance. The current purpose of growing mulberry as food for human consumption was ranked least across all surveyed agro-ecological zones.

Table 34. Purpose of growing mulberry plant across the different agro-ecology

Purpose of mulberry	Agro-ecology					
	Highland		Midland		Lowland	
	Index	Rank	Index	Rank	Index	Rank
Silk worm feed	0.18	4	0.21	3	0.18	4
Animal feed	0.24	1	0.22	1	0.23	2
Food	0.18	5	0.17	5	0.16	5
Fence	0.18	3	0.19	4	0.20	3
Fuel wood	0.22	2	0.21	2	0.23	1

4.2. Experimental Study

4.2.1. Feed chemical composition

The diets were formulated to meet the crude protein (CP) requirements of yearling Tigray highland lambs. The composition of mulberry leaf meal compared favorably with that of the concentrate mixture in most of the nutrients and even it was better in its ash content than the concentrate mixture. The dry matter content was almost similar across the different treatments where as the organic matter content declined as the proportion of concentrate mixture decreased. The ash content of mulberry leaf meal in the current study was more than double to that of the concentrate mixture. Similarly, the calcium value of mulberry leaf meal was more than threefold to that of concentrate mixture. Lambs had a complete consumption of the supplemented mulberry and concentrate mix offered. Hence, the refusal composition indicated to the refused barley straw only (Table 35). Barley straw contained lower CP and EE as compared to the other feed ingredients. However, barley straw contained higher CF, NDF, ADF and ADL than the others.

Table 35. Chemical composition of experimental feed offered and refused

Chemical composition	Treatment feed offered					Barley straw refused				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
DM (%)	90.2	89.5	89.2	89.5	91.8	94.1	94.6	93.8	94.8	92.3
OM (%DM)	92.3	89.7	86.1	85.6	84.3	92.62	92.52	92.64	92.7	92.82
Ash (%DM)	7.7	10.3	13.9	14.4	15.7	7.38	7.48	7.36	7.3	7.18
CP (%DM)	22	22.1	20	18.5	18.5	3.87	3.41	3.37	3.56	3.57
CF (%DM)	13.3	12.8	13.6	13.8	14.2	56.62	55.23	54.37	53.86	54.94
NDF (%DM)	35.2	34.2	35.2	36.8	38	75.59	76.36	78.29	76.05	77.28
ADF (%DM)	20.2	19.5	21.7	19.9	22.3	51.74	52.18	54.35	51.77	53.23
ADL (%DM)	3.4	3.4	3.4	3.8	4.2	8.87	9.23	8.79	9.17	9.21
EE (%DM)	7.2	6.3	5.9	5.3	4.2	1.2	1.25	1.01	1.25	1.16
Ca (%DM)	0.6	0.8	1.1	1.5	2.1	0.02	0.02	0.02	0.04	0.03
P (%DM)	1.02	0.8	0.9	0.8	0.8	0.19	0.21	0.19	0.21	0.19
HC (%DM)	15	14.7	13.6	16.9	15.7	23.85	24.18	28.94	24.28	24.05
C (%DM)	16.8	16.1	18.3	16.1	18.1	42.87	42.95	45.56	42.61	44.02

DM = Dry matter; OM = Organic matter; CP = Crude protein; CF = Crude fiber; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL=Acid detergent lignin; EE = ether extract; Ca = calcium; P = phosphorus; C = Cellulose; HC = Hemicelluloses;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.2. Apparent dry matter and nutrient digestibility

Apparent DM, OM, CP, NDF and ADF digestibility was affected by treatment (Table 36). The apparent DM and OM digestibility was higher ($p<0.05$) in sole mulberry leaf meal (T5) than that of full concentrate diet (T1). Except for T1 and T5, the other treatment diets showed no differences ($p>0.05$) in apparent DM and OM digestibility. A higher ($p<0.05$) apparent NDF digestibility was obtained when larger proportion of concentrate mixture was substituted by mulberry leaf meal than the other treatment diets.

Table 36. Dry matter and nutrient digestibility of the different treatment diets

Digestibility (%)	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
DM	66.8^{b}	68.0^{ab}	67.7^{ab}	68.5^{ab}	69.5^{a}	0.007	0.0117
OM	68.5^{b}	69.6^{ab}	69.4^{ab}	70.3^{ab}	71.1^{a}	0.007	0.0121
CP	73.8^{a}	72.8^{ab}	72.1^{b}	72.1^{b}	72.5^{ab}	0.005	0.0081
NDF	73.4^{c}	75.0^{bc}	75.2^{b}	77.2^{a}	77.4^{a}	0.006	<.0001
ADF	79.8^{c}	81.3^{ab}	79.4^{c}	80.6^{bc}	82.3^{a}	0.005	<.0001

[a-c]Means in the same row with different superscript differ significantly; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; SEM: standard error of mean and SL: significance level;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.3. In vitro organic matter digestibility and in sacco dry matter degradability

There were no ($p>0.05$) differences in *in vitro* organic matter digestibility (76.42-77.78%) across the different treatments (Table 37). All the tested diets resulted in more than 76% *in vitro* organic matter digestibility. The comparable digestibility of mulberry with the concentrate mixture ensures the potential of the leaf for ruminant production. The *in sacco* dry matter degradability characteristics of sole mulberry foliage and concentrate mix or their mixtures are presented in Table 37. The sole mulberry leaf meal (T5) had the greatest value for slowly degradable fraction (*b*) than the diets with less proportion of mulberry. Additionally, T5 and T4 had significantly ($p<0.05$) less soluble fraction (*a*) and effective degradability (ED) values compared to the diets with less proportion of mulberry. The washable materials were significantly ($p<0.05$) higher in T1 and T2, those with higher proportion of concentrate than the remaining treatments. The greatest and least soluble fraction (*a*) was recorded in the diet with higher proportion of concentrate mix and in the sole mulberry leaf meal, respectively. The insoluble but fermentable fractions increased as the proportion of mulberry leaf meal advanced. The potential degradability of T4 and T5 in the current study was significantly less than those of T1, T2 and T3. There was no ($p>0.05$)

difference in the rate of degradation across the different treatments in this study. Slight increase in degradation rate constant was observed up to T3, which then declined steadily at higher mulberry leaf meal level.

Table 37. Effects of substitution of mulberry leaf meal for concentrate mix on *in vitro* organic matter digestibility and *in sacco* dry matter degradability characteristics (%DM)

	Treatments						
Parameters	T1	T2	T3	T4	T5	SEM	SL
A	26.2^{a}	26.1^{a}	24.1^{b}	22.7^{c}	22.2^{c}	0.25	***
B	51.1^{b}	51.1^{b}	52.5^{ab}	52.6^{ab}	53.2^{a}	0.52	*
PD	77.0^{a}	77.2^{a}	76.6^{a}	75.3^{b}	75.3^{b}	0.30	***
ED	63.6^{a}	63.5^{a}	62.8^{a}	60.5^{b}	58.9^{c}	0.36	***
C/hr	0.087	0.089	0.090	0.086	0.084	0.00	NS
L (hr)	4.27^{b}	4.43^{b}	5.03^{a}	4.90^{a}	4.87^{a}	0.08	***
IVOMD	77.46	77.47	76.98	77.78	76.42	1.34	NS

[a-d] Means with different superscripts in a column within a category differ; *** = P<0.001;** = P<0.01; * = P<0.05; NS = Not significant; SEM = standard error of the mean; SL= significance level; A = rapidly soluble fraction; B = insoluble but fermentable fraction; PD = potential degradability; c = the rate of degradation of B; L = lag time; ED = effective degradability; DM = dry matter;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

The trend of degradation of different levels of mulberry leaf meal in combination with concentrate mixture showed a time dependent increase (Figure 6). The trend of degradability of T1 and T2 increased consistently up to 24 hours but it continued increasing steadily up to 48hrs. However, the progress seems constant beyond the 48 hours. Nevertheless, the trend of degradation for T3, T4 and T5 was slow up to 6 hours; later T3 increased rapidly to 12 hours compared to T4 and T5 and continues to increase exactly the same as T1 and T2. From 6 – 24 hours, T4 and T5 showed a similar increment. The degradation rate for T1, T2, T3 and T4 started to decline after 24 hours while the degradation rate for T5 (sole mulberry leaf meal) kept increasing up to 48 hours and continued increasing slowly till 72 hours. The extent of

degradation of all the treatment diets beyond 72 hours was similar. After 48 hours of incubation, the total dry matter degradability values showed less ($p>0.05$) difference across the different treatment diets. Additionally, T1, T2 and T3 showed significantly higher degradability values than that of T4 and T5 in 12 to 48 hrs incubation. In a nutshell, all the treatment diets recorded more than 66% DM degradability at 24 hours, which implied that they were all potentially degradable in the rumen.

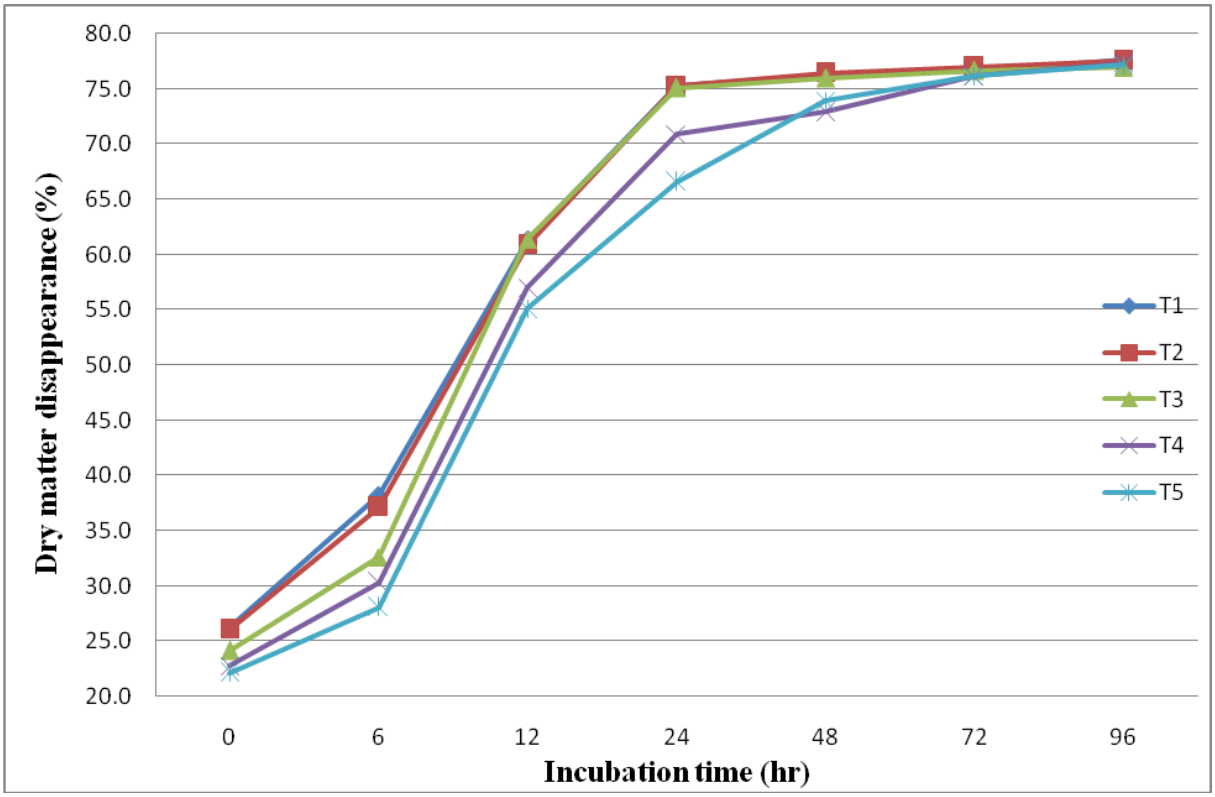

Figure 6. *In sacco* dry matter disappearances of the different treatment diets

4.2.4. Dry matter and nutrient intake

Results of mean daily dry matter and nutrient intake of different proportions of concentrate to mulberry leaf meal, sole concentrate mix as well as sole mulberry leaf meal supplemented to the experimental lambs are given in Table 38. All lambs had a complete consumption of the mulberry leaf meal and concentrate mix supplemented. Increasing the substitution rate of concentrate mix by mulberry leaf meal improved ($p<0.05$) the dry matter intake of lambs. Total dry matter intake declined ($p<0.05$) when the proportion of mulberry leaf meal in the

diet decreased, and was lower when sole concentrate mix was supplemented. Complete substitution of concentrate mix by mulberry leaf meal resulted in a higher (p<0.05) total dry matter intake than those supplemented with whole concentrate mixtures.

Table 38. Daily intakes of Tigray highland lambs supplemented with graded levels of mulberry leaf meal and concentrate mix

Intake (g/d)	Treatments					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Dry matter							
Barley straw	539	548	539	551	566	12.6	0.248
CM	300	225	150	75		-	-
MLM	-	86.6	173.1	259.7	346.2	-	-
TDM	839^{c}	859^{bc}	863^{bc}	886^{ab}	912^{a}	12.6	0.0002
Nutrients							
OM	776^{b}	787^{ab}	783^{ab}	798^{ab}	815^{a}	11.7	0.0282
CP	87.7	87.5	86.6	86.6	86.6	0.51	0.115
EE	28.5^{a}	26.8^{b}	24.9^{c}	23.3^{d}	21.7^{e}	0.16	<.0001
CF	350^{b}	358^{ab}	354^{ab}	364^{ab}	375^{a}	5.64	0.0131
NDF	529^{c}	542^{bc}	543^{bc}	558^{ab}	576^{a}	6.78	0.0001
ADF	328^{b}	336^{b}	336^{b}	347^{ab}	358^{a}	6.27	0.0014
ME (MJ/d)	8.51^{b}	8.77^{ab}	8.70^{ab}	8.97^{ab}	9.28^{a}	0.20	0.0099

$^{a-e}$Means with different superscript letters in a row differ significantly.
SEM: standard error of the mean; SL: significant level; DM: dry matter; TDM: total dry matter; CM: concentrate mix; MLM: mulberry leaf meal; OM: organic matter; CP: crude protein; CF: crude fiber; EE: Crude fat; NDF: neutral detergent fiber; ADF: acid detergent fiber; ME: Metabolisable energy;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

The organic matter intake was higher (p<0.05) for lambs supplemented with sole mulberry leaf meal than supplemented with concentrate mix alone. However, there were no differences (p> 0.05) in organic matter intake among T2, T3, T4 and T5 as well as among T1, T2, T3 and T4. The supplemented feeds were iso-nitrogenous, which was reflected in the similar total CP intake of the lambs across the different treatment diets. The NDF and ADF intake was higher (p<0.05) in the diets containing sole mulberry leaf meal (T5) than T1, T2 and T3. In general, except for CP intake that showed no differences across the different treatments, intakes of

other nutrients were higher (p<0.05) for sole mulberry leaf meal than for the whole concentrate mix.

4.2.5. Digestible nutrients intake

Digestible nutrient intake is presented in Table 39. The sole mulberry leaf meal supplemented group consumed significantly (p<0.05) higher digestible dry matter than the full concentrate mix supplemented group. Whereas, there were no significant differences in digestible dry matter intake among T1, T2 and T3. Digestible organic matter intake of the sole mulberry leaf meal supplemented group was significantly (p<0.05) higher than that of sole concentrate mix supplemented group. However, there were no significance differences in digestible organic matter intake among treatments when proportion of concentrate mixture decreased up to T4. Apart from the sole concentrate mix supplemented group, the DCP intake did not differ among the remaining treatment groups. Moreover, there were no significance differences between T1 and T2 in intake of DCP. The DNDF intake was significantly (p<0.05) higher in T4 and T5 than T1. There were no significant differences in digestible DADF intake among treatments, T1, T2, T3 and T4.

Table 39. Digestible nutrients intake

Digestible nutrients (g/d)	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
DDM	560.36^{c}	584.06^{bc}	584.14^{bc}	606.69^{ab}	634.09^{a}	13.32	0.0003
DOM	531.85^{b}	548.05^{ab}	543.56^{ab}	560.60^{ab}	579.71^{a}	12.24	0.0099
DCP	64.72^{a}	63.65^{ab}	62.44^{b}	62.43^{b}	62.83^{b}	0.63	0.0068
DNDF	289.55^{c}	304.25^{bc}	306.80^{bc}	324.48^{ab}	336.48^{a}	6.94	<.0001
DADF	261.75^{b}	273.57^{b}	267.27^{b}	279.16^{ab}	294.34^{a}	6.32	0.0006

[a-c]Means in the same row with different superscript differ significantly; SEM: standard error of the mean; SL: significant level; DDM: Digestible dry matter; DOM: Digestible organic matter; DCP: Digestible crude protein; DNDF: Digestible neutral detergent fiber; DADF: Digestible acid detergent fiber

T1: 300 g concentrate mix + *ad libitum* barley straw;

T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw

T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;

T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;

T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.6. Live weight change and feed conversion efficiency

The final body weight of lambs supplemented with T3 and T4 as well as T5 was higher ($p<0.05$) than those of lambs supplemented with T1 and T2 (Table 40). Lambs supplemented with T3 and T4 as well as T5 showed no difference in body weight change but lambs in T3 had significantly ($p<0.05$) higher body weight change than those of lambs supplemented with T1 and T2. The lambs fed with T3 showed higher ($P<0.05$) average daily weight gain than lambs fed with T1 but there were no differences with lambs in the remaining groups. Similarly, feed conversion efficiency was also significantly higher ($P<0.01$) for lambs fed with T3 than those fed with T1 and T2. In general, all the experimental lambs showed good growth performances throughout the experimental period.

Table 40. Growth performance parameters of lambs fed on partial or full substituted concentrate mix by mulberry leaf meal

Growth performance parameters	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Initial body weight (kg)	17.5	17.8	17.8	17.8	18.0	0.59	0.940
Final body weight (kg)	23.2^{b}	23.6^{b}	24.7^{a}	24.6^{a}	24.5^{a}	0.42	0.005
Body weight change (kg)	5.7^{b}	5.8^{b}	6.9^{a}	6.8^{ab}	6.5^{ab}	0.39	0.012
Average daily weight gain (g/day)	63.0^{b}	64.4^{b}	76.9^{a}	75.0^{ab}	72.2^{ab}	4.28	0.012
Feed conversion efficiency (g gain/g fed)	0.075^{b}	0.075^{b}	0.089^{a}	0.085^{ab}	0.079^{ab}	0.005	0.042

[a-b]Means in the same row with different superscript differ significantly; SEM: standard error of mean;
SL: significance level;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.7. Carcass characteristics

Carcass characteristics of Tigray highland lambs fed full or partially substituted concentrate mix by mulberry leaf meal were assessed for slaughter weight, empty body weight, hot

carcass weight, dressing percentage and rib-eye muscle area (Table 41). The slaughter weight, empty body weight and rib-eye muscle area were significantly ($p<0.05$) higher in T5, T4 and T3 than in T1 and T2. Moreover, dressed hot carcass weight was significantly ($p<0.05$) higher in T3 than T1 and T2. Nevertheless, there were no differences among T3, T4 and T5 for dressed hot carcass weight and rib-eye muscle area. Lambs in T3 had significantly ($p<0.05$) higher dressing percentage on slaughter weight base as well as empty body weight base than lambs in T1 and T2. However, lambs in T3 did no vary in dressing percentage on slaughter weight base as well as empty body weight base with lambs in T4 and T5. At higher proportion of mulberry, the carcass parameters were improved.

Table 41. Carcass characteristics of Tigray highland lambs supplemented with graded levels of mulberry leaf meal and concentrate mix

Parameter	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Slaughter weight, kg	23.0^{b}	23.5^{b}	24.5^{a}	24.4^{a}	24.3^{a}	0.39	<.0001
Empty body weight, kg	19.3^{b}	19.8^{b}	20.7^{a}	20.5^{a}	20.5^{a}	0.36	<.0001
Hot carcass weight, kg	10.6^{b}	10.9^{b}	11.8^{a}	11.5^{ab}	11.5^{ab}	0.32	0.0003
Dressing percentage on:							
Slaughter weight base	46.1^{b}	46.4^{b}	48.0^{a}	47.1^{ab}	47.4^{ab}	0.65	0.0087
Empty body weight base	54.8^{b}	55.1^{b}	56.8^{a}	56.1^{ab}	56.4^{ab}	0.65	0.0047
Rib eye muscle area, cm^2	9.0^{b}	9.3^{b}	9.9^{a}	9.8^{a}	9.6^{a}	0.18	<.0001

[a,b] Means with different superscript letters in a row differ significantly. SEM: standard error of the mean;
SL: significant level;
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.8. Edible offal components

The offal components were categorized in to edible and non edible offal components based on the eating habit of the people living around the area where the experiment was conducted.

Lambs in T3, T4 and T5 showed significantly (p<0.05) higher empty gut, heart, tail, total visceral fat and TEOW than lambs in T1 and T2 (Table 42). However, the above parameters did not vary between lambs in T1 and T2. Similarly, there were no differences observed among lambs in T3, T4 and T5 for the above mentioned parameters.

Table 42. Response to supplementation with partial or full substituted concentrate mix with mulberry leaves on edible offal of Tigray highland lambs

Parameter	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Empty gut, kg	1.57^{b}	1.58^{b}	1.66^{a}	1.68^{a}	1.67^{a}	0.029	0.0009
Head with tongue, kg	2.006	1.952	2.003	2.005	1.984	0.031	0.4307
Kidney, kg	0.070^{ab}	0.069^{b}	0.076^{a}	0.074^{ab}	0.074^{ab}	0.002	0.0219
Liver with bile, kg	0.340^{bc}	0.338^{c}	0.348^{abc}	0.353^{ab}	0.359^{a}	0.005	0.0013
Testis, kg	0.256	0.254	0.248	0.258	0.262	0.008	0.5489
Heart, kg	0.095^{b}	0.095^{b}	0.101^{a}	0.102^{a}	0.102^{a}	0.002	0.0005
Tail, kg	0.514^{b}	0.511^{b}	0.536^{a}	0.545^{a}	0.536^{a}	0.010	0.0086
Total visceral fat, kg	0.308^{b}	0.303^{b}	0.331^{a}	0.322^{a}	0.321^{a}	0.002	0.0007
TEOW, kg	5.15^{b}	5.10^{b}	5.30^{a}	5.31^{a}	5.31^{a}	0.041	0.0002

$^{a-c}$Means in the same row with different superscript differ significantly.
SEM: standard error of the mean; SL: significant level; TEOW: Total edible offal weight
T1: 300 g concentrate mix + *ad libitum* barley straw;
T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw
T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;
T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;
T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

4.2.9. Non-edible offal components

The values of gut content, skin and legs, esophagus and urinary bladder did not vary (p>0.05) between lambs supplemented with sole mulberry leaf meal and sole concentrate mix (Table 43). However, the values of spleen indicated T1=T2<T3=T4=T5.

Table 43. Response to supplementation with partial or full substituted concentrate mix with mulberry leaf meal on non edible offal components of Tigray highland lambs

Parameter	Treatment					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Gut content, kg	3.652^{b}	3.85^{ab}	3.805^{ab}	3.900^{a}	3.843^{ab}	0.084	0.0098
Skin and legs, kg	2.492^{b}	2.483^{b}	2.520^{ab}	2.555^{a}	2.507^{ab}	0.031	0.0257
Blood, kg	0.693	0.684	0.707	0.714	0.713	0.010	0.127
Penis, kg	0.054	0.055	0.057	0.060	0.056	0.002	0.115
Esophagus, kg	0.034^{ab}	0.032^{b}	0.036^{ab}	0.037^{a}	0.036^{ab}	0.001	0.0039
Lung with trachea, kg	0.261	0.245	0.270	0.269	0.255	0.021	0.231
Spleen, kg	0.027^{b}	0.027^{b}	0.030^{a}	0.031^{a}	0.031^{a}	0.001	<.0001
Urinary bladder, kg	0.025^{ab}	0.024^{b}	0.025^{ab}	0.027^{a}	0.026^{ab}	0.001	0.0346
TNEOW, kg	7.24^{b}	7.36^{b}	7.45^{ab}	7.59^{a}	7.47^{ab}	0.093	<.0001

[a-b]Means in the same row with different superscript differ significantly.

SEM: standard error of the mean; SL: significant level; TNEOW: Total non edible offal weight

T1: 300 g concentrate mix + *ad libitum* barley straw;

T2: 225 g concentrate mix + 86.6 g mulberry leaf meal+ *ad libitum* barley straw

T3: 150 g concentrate mix + 173.1 g mulberry leaf meal+ *ad libitum* barley straw;

T4: 75 g concentrate mix + 259.7 g mulberry leaf meal+ *ad libitum* barley straw;

T5: 346.2 g mulberry leaf meal + *ad libitum* barley straw

5. DISCUSSION

5.1. Survey

5.1.1. Socio-economic characteristics of the respondents

5.1.1.1. Sex, occupation and religion of the interviewed respondents

The higher proportion of male headed households was due to most of the respondents were married and in Ethiopian circumstances the husband is the head of the household. Hence, the female headed households might be either divorced or widow (a woman who has lost her husband by death and has not married again). Another reason may be attributed to societal customs and norms in the study area where males control most of the household's productive assets. In agreement with the current study, Tesfaye (2009) noted that the majority of the households in both cotton based and sesame based farming systems were headed by males which accounted for 97%. Similar results have been also reported across sub-sahara African countries (Baah *et al*., 2012; Ayalew *et al*., 2013). The large proportion of male farmers is very crucial for transferring and adoption of technologies since men are mostly the decision-makers in most African societies (Turkson and Naandam, 2006). In accordance with the current study, Aklilu (2007) indicated that majority of the respondents were Orthodox Christians, and religion influences livestock consumption and marketing through festivities and fasting periods.

5.1.1.2. Family size and land holding

The higher size of female children below eighteen years old in lowland might be due to most teenagers from the highland were thought to be migrated abroad to find their fortune and they might not be counted. In accordance with the current study, the average household size less than fifteen years observed in the three agro-ecological zones was close to a household size of 3.34 in Tigray region (Asfaw and Jabbar, 2008). The average family size obtained in the current study was larger than the values reported by Tesfaye (2009) from Metema woreda, Amhara region and Abraham *et al*. (2017) from Western Tigray, North Ethiopia who obtained

an average family size of 5.6 ± 2.45 and 4.85 ± 0.89, respectively. Additionally, the average family size obtained in the current study is larger than the values obtained in urban (5.44 ± 0.24) and in peri-urban (5.46 ± 0.25) areas of central zone of Tigray, Ethiopia (Gebrekidan *et al*., 2012) and for Tigray region (4.9) (CSA, 2008). However, unlike the result of the present study, Assen (2009) reported that average family size for adults above fifteen years of age was significantly ($p<0.05$) higher in midland than in the other agro-ecological zones of Tigray, Ethiopia.

In line with the present study, Yenesew *et al*. (2013) indicated that farmers in the lowland *kebele*s had more ($p<0.05$) land per household than those farmers found in the highland *kebeles*. The reason why households in lowland tended to have relatively larger land than households in highland and midland could be linked with the presence of relatively scarce human population/density in lowland agro-ecological zone. The mean landholding in the present study area was lower than the 1.42 ha reported in Amhara and Benishangul-Gumuz Regional States of north-western Ethiopia (Yeshambel *et al*., 2011) and the 1.55 ha reported for Bure district of the Amhara Regional State of Ethiopia (Shitahun, 2009).

5.1.1.3. Age category

The reasons why higher proportion of interviewed households were in the age category of 41-60 might be young people were less depended on sheep and goat keeping as they might find alternative formal as well as informal employments. It might be also lack of initial capital for flock establishment. However, for the household heads in 41-60 years of age, they mightn't want to go far from their family. Rather, they might prefer to look after/take care of and support their family with the available resources. In line with this study, higher proportion of households was obtained in Hawassa where 33.3% and 30% were in the age range of 41-50 and 51-60 years, respectively (Ike, 2002). For people between 41 and 60 years old, sheep and goat keeping seems to supplement other informal or formal employment. Moreover, for older people, sheep and goat keeping provide a coping strategy for retirement. In line with the present study, Abraham *et al*. (2017) also noted that the overall average age of the sampled

household heads was 50 ±10.44 years, implying that the respondents were adults with a good experience in sheep and goat farming.

5.1.1.4. Educational status of respondents

The proportion of illiterate respondents in the current study was much lower than the report of Endeshaw (2007) who noted that 75% of the interviewed households were illiterate in Dale district, Sidama zone. However, similar with the present study, Yilkal (2015) reported that 27.33% respondents neither write nor read in Chencha and Mirab Abaya Districts, Southern Ethiopia. Unlike the result obtained in the present study where majority of the respondents attended elementary school (less than eighth grade), Tesfaye (2009) reported that the majority (67.4%) of the household heads in Metema were illiterate and the remaining proportion (32.6%) were literate, who can read and write. A higher proportion of illiterate obviously has negative impact on adoption and transfer of improved technologies to the communities.

As most of the towns especially of the towns of the districts in the study areas are observed to be situated at higher elevation, the highland surveyed areas were relatively proximate to urban areas and had better access to basic educational infrastructure and had better literacy rates. This might reflect that farmers in the highland agro-ecology had better access to education that might have helped to improve the management of their animals and decreased constraints caused due to lack of awareness. Better literacy level means better livestock husbandry practices as literacy enhances societies to be aware of efficient utilization of natural resources and adopt new technologies in improving livestock productivity which agreed with findings of Abraham *et al*. (2017).

5.1.1.5. Income sources

The contribution of livestock as a source of family income obtained in the current study is in agreement with reports from other parts of Ethiopia (Mengistie *et al*., 2010; Yohannes *et al*., 2017). Additionally, the result of the current study agreed with the report of Lebbie *et al*. (1993) and Budisatria (2006) in that under traditional sheep and goat management systems, stock owners are usually crop farmers for whom sheep and goat keeping is of secondary

importance. The contribution of the off-farm employment (self and formal employment) also accounted for some portion of cash earned though ranked last.

5.1.2. Sheep and goat husbandry practices

5.1.2.1. Sheep and goats holding

The predominance of sheep and goats across the three studied agro-ecological zones might reflect their wide acceptability and ease of adaptation in diversified agro-ecological zones. The relatively higher proportion of goats obtained as compared to sheep in the lowland agro-ecological zone might be due to the fact that goats can thrive well under adverse and hot climate conditions. Moreover, the higher cattle and goats holding in the lowland than the highland agro-ecological zone might be due to larger natural grazing lands with relatively better coverage of bushes and shrubs in the lowlands which concurred with the report of Solomon *et al*. (2017). The higher sheep holding in the highland might be due to their adaptability to relatively cooler agro-ecological zones. In line with the current study, Solomon *et al*. (2007) noted that sheep are more dominant in the highland mixed crop-livestock production system than goats.

Generally, across all the three studied agro-ecological zones, households owned mixed species composition, and this might be to decreases competition for feed resources (different species tend to make use of different components), reduces risk by lessening the dependency on one species for meat and milk and increases the likelihood of meeting basic consumption needs. Various studies highlighted the importance of emphasizing sheep and goat production, (as opposed to large ruminant and non-ruminant production) not only for ensuring food security in rural regions, but also for helping to reduce poverty and overall household wellbeing (Lebbie, 2004; Peacock, 2005; Dossa *et al*., 2007). The emphasis is because sheep and goats are more efficient in converting non-grain feed into quality meat compared with beef, pork and poultry (Peacock, 2005) because they compete less for the human food. Less initial capital for flock establishment and relatively less capital investment in housing to attract farmers to own more sheep and goats than cattle. The smaller size of sheep and goats also makes them more suitable for home consumption among poor households, thereby

helping to improve the nutrition and animal protein requirements and food security situation of rural households (Oluwatayo and Oluwatayo, 2012).

5.1.2.2. Livestock species preference

Farmers across all the surveyed areas practiced mixed crop livestock farming system where crop production is the most important agricultural activity and the farmers' incomes mostly depend on it and sheep and goats are raised as an adjunct to crop farming. Hence, the reason why cattle are preferred most across all the surveyed areas might be due to their prominent importance in the mixed crop livestock farming system especially in the highland and midland agro-ecological zones. Cattle are the most important livestock species for cultivation, threshing, manure and milk which make them more preferred than sheep and goats. In the lowlands where crop production is less reliable, goat production has experienced success, with high households' preference (Tsegahun *et al*., 2000). The abundance of browse plants could favor goat keeping in the lowland than in the highland and midland agro-ecological zones and could be the major reason for keeping goats, the second most important livestock species (Assen and Aklilu, 2012).

The reason why farmers in the highland agro-ecological zone preferred chicken as compared to goats might be due to their proximity to the towns where there is relatively better access of market to sell chicken as well as eggs than the farmers in the lowland. Chicken or eggs could easily be produced and handled than goats to market whenever the farmers (women) want to visit the market during the regular market days. Additionally, chicken production is mainly the duty and business of the women in rural areas, who manage them freely and without any control, required of the husband and this provides the women to secure their unforeseen expenses in the house.

5.1.2.3. Purpose of keeping sheep and goats

The use of sheep and goats to satisfy an urgent need of cash such as settling unforeseen expenditures was the main reason in managing sheep and goats regardless of the differences

in agro-ecological zones. The income generated from sell of sheep and goats was spent on school fees, purchase of food & clothes, farm investment, medication, social activities and re-stocking. In agreement with the current study, sheep and goats are reared in many parts of the country mainly for income generation (Belete *et al*., 2010; Arse *et al*., 2013; Yenesew *et al*., 2013; Zergaw *et al*., 2016). Similar with the current finding especially of the highlands, Berihu *et al*. (2014) also noted that respondents in Ganta-Afeshush, northern Ethiopia ranked income source from sales of live animals and their products as a first purpose of keeping livestock followed by manure for farm use. Most of the surveyed areas were prone to drought and sometimes crop production becomes low and during these times, sheep and goats serve as a good additional source of income for the farmers. Crop production was the main agricultural practice across all the surveyed areas. However, in most cases, there is fluctuation of crop yield due to erratic rainfall so farmers keep sheep and goats as saving and insurance and hence, the second main reason for keeping sheep and goats in midland and lowland areas of the current study was for saving purpose.

Unlike the present study where meat and milk were the least ranked reasons of keeping sheep and goats across the study areas, Tesfaye (2009) and Hulunim (2014) reported the primary reason for keeping goats was to generate income followed by meat consumption, ceremony, and as means of saving in that order. In agreement with the results of the current study, Zewudu *et al*. (2012) and Urgessa *et al*. (2012) reported that production and consumption of milk from sheep was less common in mixed crop-livestock system where income generation was considered as the primary objective of keeping sheep. In the mixed crop-livestock system, income generation was the primary objective followed by meat production and wealth accumulation (Helen *et al*., 2013). Although the result of the present study showed the priority given by farmers for the purposes of keeping sheep and goats for immediate cash income, it is apparent that farmers keep sheep and goats not for a single purpose rather they keep for multiple purposes. Similarly, different authors (Getachew *et al*., 2010; Solomon *et al*., 2010; Jimmy *et al*., 2010) mentioned that multi-purpose sheep rearing is common in Ethiopia and linked to the need to maximize output from an animal that can survive on a low input of resources. Multiple functions are particularly important in low-to medium-input production environments (Zewudu *et al*., 2012). Given the diversified purposes that farmers have for

rearing sheep and goats, due attention is required in the choice of breeding objectives and breeding strategies as the function of the animals is closely linked to the traits desired by the producers (Jimmy *et al*., 2010). The differences in purposes for managing sheep and goats among the agro-ecological zones justify the numerous roles sheep and goats played in the livelihood of the farmers across the different agro-ecologyies. Hence, strategies to improve the traditional sheep and goat production system should not be concentrated on a single criterion. Multiple points should always be considered in designing and implementation of intervention strategies for different agro-ecological zones and production systems where sheep and goats used for dual purposes.

In rural areas of Ethiopia including the present study area, because of their subsistence and economic reasons, sheep and goats have been described as bank reserve which can be drawn upon when cash money is required. This confirms a study by Apori *et al*. (2011) and Abraham *et al*. (2017), who reported that keeping livestock, especially sheep and goats play a role as safety net that enables households to get quick income to settle urgent financial needs. Sheep and goats as well confer a certain degree of security in times of crop failure, as they are a "near-cash" capital stock. Furthermore, livestock provides farmyard manure that is commonly applied to improve soil fertility and also used as a source of energy (CSA, 2017).

5.1.2.4. Sources of foundation stock

The current finding would suggest the importance of market in establishing sheep and goat flocks compared to other sources of foundation stock in the high and midland areas and home born for the lowland areas. Nevertheless, gift (bride prize) in all agro-ecological zones and sharing in the highland and midland areas contributed less as a means of establishing sheep and goat flocks. Other sources of foundation stock include sharing and loan from the government and their contribution for establishing sheep and goats' foundation stock increased from lowland to highland areas. This practice often took place when the father of the household gave each of his children one breeding female to start generating an income for that child (Trevor, 2015). Likewise, purchase, gifts from different sources and inheritances from family were reported as important ways of building livestock including sheep and goats

(Tsedeke, 2007). In agreement to result obtained in the lowland of the present study, Yisehak *et al*. (2013) in south western Ethiopia, Helen *et al*. (2013) in Eastern Ethiopia and Abraham *et al*. (2017) in Western Tigray reported that home birth as the major form of sheep and goat acquisition.

5.1.2.5. Flock structure of sheep and goats

The proportion of female sheep of all age groups (72.2% in highland, 71.5% in midland and 74.6% in lowland) and male sheep of all age groups (27.8% in highland, 28.5% in midland and 25.4% in lowland) observed in the current study is close to the 72.14% and 27.86 female and male sheep reported in the country (CSA, 2017). The result obtained in the present study is also in harmony with Assen (2009) who reported that the proportion of female sheep of all age group was 71.1%, 70% and 69.3%, respective for highland, midland and lowland and male sheep of all age groups 28.9%, 30% and 30.7%, respective for highland, midland and lowland. The proportion of female to male sheep in lowland agro-ecology of the present study is comparable with 72.6 % female and 27.4% male of Abergelle sheep in Tanqua Abergelle. Moreover, the proportion of female to male sheep in highland is comparable with that of 71.1 % female and 28.9% male in highland sheep of Atsbi wemberta district reported by Seare (2007). With this ratio, rams could have maximum contacts with ewes and might mate them efficiently without missing any estrus.

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The reason why female sheep of all age group comprised the highest ratio might be males are either sold in the market or consumed at home while females are kept for breeding purpose and this conforms to the report of Asfaw and Jabbar (2008). The higher proportion of female stock across all the surveyed agro-ecology clearly indicated the higher importance of these stocks for breeding and production purposes and also objective allocation of considerable household incomes for building livestock asset. In line with the present study, adult females constitute 45% of the average flock, followed by young females (21%) (Workneh and Rowlands, 2004).

Respondents reported that rams were sold at an early age because of higher market demand whereas; ewes were sold if only there is an urgent need for cash income and the ewe has to be culled due to reasons. Similarly, Animut and Wamatu (2014) indicated that younger animals at finishing may have tender carcasses and greater market demand than fattened older animals and this needs to be determined through studies on consumer and market preferences in the Ethiopian context. The disposal/sale of ram lambs at an early age can have a negative effect on selection if preference is given to individuals that reach market weight faster than those which are not sold (Getachew *et al*., 2010). Hence, the issue of how to retain or obtain replacement stock, especially rams, needs urgent attention for sustainable utilization of available resources and to improve overall productivity (Helen *et al*., 2013). The higher sheep to goat ratio in the highland clearly implies the increased dominance of sheep as the altitude of the area increased. This might be due to sheep are more adaptive to the cold highland agro-ecology and are better suitable to this kind of climate and farmers prefer and own more sheep than goats.

The higher proportion of females than male goats is in a good agreement with previous findings in Ethiopia (Belete *et al*., 2010; Dhaba *et al*., 2012; Ahmed *et al*., 2015) and elsewhere in Africa (Dossa *et al*., 2015; Otieno *et al*., 2015). The higher proportion of adult female goats than other age groups suggests that adult females stay in a flock for breeding purposes and/or milk production. However, the less number of adult male goats as compared to adult females is because of marketing and slaughtering of the males at their younger ages. In agreement with the results obtained in the present study particularly in the lowland agro-ecological zone, Tesfaye (2009) noted that the breeding does made a major share of the goat population in Metema district followed by kids and weaned kids. Similarly, the percentage of kids less than 6 months of age across all the surveyed sites was lower than the finding of Markos (2000) who reported 48.9% in Sidama, Ethiopia. The percentage of bucks in the current study was considerably lower than 18.9% for Sidama goats (Markos, 2000) but greater than the values (3.6 – 6.9%) reported for Metema district (Tesfaye, 2009).

The proportion of female goats of all age groups (75.8% in highland, 73.4% in midland and 72.4% in lowland) and male goats of all age groups (24.2% in highland, 26.6% in midland

and 27.6% in lowland) observed in current study is close to the 70.61% and 29.39 female and male goats reported in the country (CSA, 2017). However, the proportion of female goats obtained in the current study is higher than that of Assen (2009) who reported that the percentage of female goats of all age groups was 69.8%, 70.5% and 68.3%, respectively for highland, midland and lowland and male goats of all age group was 30.2%, 29.5% and 31.7% respectively for highland, midland and lowland. The higher goats to sheep ratio in the lowland clearly imply the increased dominance of goats as the altitude goes down.

5.1.2.6. Feeds and feeding practices of small ruminants

5.1.2.6.1. Major feed resources of sheep and goats in wet season

Grazing on natural pasture and browses played paramount role as a major source of feed across all the surveyed agro-ecological zones. In agreement to the current study, Solomon *et al*. (2010) and Berihu *et al*. (2014) noted that the main feed resources are natural pasture and browse species. Similarly, assessment on the relative importance of feed resources during the dry and wet season indicated that, natural pasture followed by browses during the wet season and crop residues followed by cactus pear during the dry season are important livestock feed resources across the study districts (Gebremeskel, 2014). Despite the very crucial importance to the survival of livestock, grazing lands are being converted into cultivated lands at the expense of the natural grazing lands due to increased human as well as livestock population. So the communal grazing lands had decreased in size and resulted in more animals grazing on a limited area of grazing land. This further resulted in overgrazing and poor productivity of the grazing lands as well as the animals depending on it. In accordance with the current study, Yenesew *et al.* (2013) in Burie district, Amhara National Regional State, noted that buying agro-industrial by-products for sheep production is not common and farmers generally depend on the naturally available feed resources for their sheep and goat production.

Weeds were also other identified common feed sources for sheep and goats and this is in agreement with other reports (Yeshitila, 2007; Assen and Aklilu, 2012) who indicated that farmers use weeds during the wet season. Despite the fact that, these feed sources are limited to rainy seasons, some farmers have access to irrigation and weed their garden during other

times of the year too. During group discussion, it was noted in all of the three surveyed agro-ecological zones that some farmers practiced feed conservation mainly for dry season and they did this very rarely and gave the priority to cattle than sheep and goats which goes in harmony with the report of Assen and Aklilu (2012).

Cactus also played an important role in filling the gap when other feed resources become limited. During the wet season, the importance of the fruit peel became more significant than the cladode. This is clearly due to the ripening period of the cactus fruit and surplus amount of fruit peel available during this season. In line with the present study, the fruit peel was also reported as an excellent livestock feed in eastern and southern zones of Tigray (Gebremeskel *et al*., 2013). The same author also indicated that farmers considered it as a supplemental feed and usually offered to productive animals such as draught oxen, pregnant and milking animals. The seasonality of the fruit peel was reported as a problem, because its availability depends on the fruit, which is only available during the rainy season where most of the farming practice of farmers was rain fed. The higher proportions of interviewed respondents in the highland who use crop-residues, improved forages and the commercially purchased feeds as compared to respondents from the lowland might be due to the steady conversion of grazing lands in to cropping lands. Hence, crop residues are becoming more and more essential ruminant feed sources in highland and midland agro-ecological zones.

5.1.2.6.2. Major feed resources of sheep and goats in dry season

Unlike the present study where grazing took the leading source of feed, Gebremeskel (2014) indicated that crop residue is rated to be the primary feed resource in southern and eastern zone of Tigray during the dry season. The participants of the group discussion indicated that despite the fact that the magnitude and intensity of grazing differs from area to area, grazing lands are utilized throughout the year. This is in agreement with the findings of other previous studies (Teshome, 2006; Tsedeke, 2007; Tesfaye, 2008), who indicated that natural pasture is the main feed resource for sheep and goats and cattle in Ethiopia. The availability and quality of forages are not favorable and uniform in nutrient quality all year round, as a result, for animals that are not supplemented; the body gains made during the wet season is totally or

partially lost in the dry season (Alemayehu, 2003). Crop aftermath is an important source of sheep and goats feed from the start of the dry season to the start of the short rainy season after which its importance declines as farmers start ploughing their crop lands to prepare to the next season when the short rainy season begins. However, due to the seasonal availability of the crop aftermath across the three studied agro-ecological zones, its availability becomes very limited during rainy season.

In harmony with the current study, Solomon *et al*. (2017) indicated that stubble grazing is available right after crop harvest at the end of September and/or first week of October and continues until the aftermath is completely exhausted in January/February in Tigray. Other research works (Ahmed *et al*., 2010; Yayneshet, 2010) also noted that the contributions of crop residues during the dry season to be high and can reach up to 80%. Respondents however, indicated that crop residues are usually offered to productive animals with little or no attempt to improve their feeding value (Gebremeskel, 2014). Similarly, crop residues are particularly important during dry season when there is critical feed scarcity otherwise farmers let sheep and goats to forage by themselves and crop residues are given in priority for cattle (Assen and Aklilu, 2012).

The lower utilization of conserved feed resources across all the surveyed agro-ecologies justified the limited adoption and practice of feed conservation in the form of hay and silage across all the surveyed agro-ecological zones. The inefficient utilization of the available feed resources together with low management of sheep and goats might indicate small ruminant husbandry practice in the study area was not market oriented which contributed to the low performance of animals and less benefits from these animals. Moreover, poorly fed animals take longer to reach optimum slaughter weight and the meat produced by such animals might not satisfy the market demand (Gebremeskel, 2014). Both the spineless and spiny cactus cladodes are commonly grazed by livestock in all the surveyed agro-ecological zones. No cactus fruit peel was reported as feed source for sheep and goats during the dry season rather the importance of cladode become prominent during dry season. Similarly, Gebremeskel *et al*. (2013) reported that cladodes and fruit peel (skin) are the botanical parts of the cactus plant consumed by animals in eastern and southern zones of Tigray, Ethiopia.

The relatively better utilization of industrial by-products in the highland and midland during both wet and dry seasons might be due to the highlands are relatively proximate to towns and had better access to purchase these agro-industrial by-products. Additionally, the proportion of respondents who used industrial by-products in the current study was higher than 4%, 6% and 2%, respectively for highland, midland and lowland agro-ecological zones (Assen and Aklilu, 2012). Moreover, the information collected on feed usage experience of sheep and goat holders in the rural sedentary areas of Ethiopia shows, very small amount of by-products and improved feeds (only 0.78 and 0.15%) are used as animal feed (CSA, 2008). The variation on the utilization of industrial by-products observed in the current study and former studies might be due to increased awareness of farmers from time to time about the advantages of supplementing their animals.

Small trees and shrubs also contribute as a good source of feed for goats during the dry season where the availability of other feed resources becomes limited. The present study conforms to the report of Assen and Aklilu (2012) who indicated that only farmers who have wells and irrigation cultivate and use improved forages (mainly Susbania, Leucenea and Elephant grass). The utilization of indigenous browses by goats is also reported in Alaba district of southern Ethiopia (Yeshitila, 2007). The utilization of these indigenous browses as feed sources may be due to their high protein content so that they can keep animals in better body condition (Belete, 2009).

5.1.2.6.3. Cultivation of improved forage crops

Adoption and utilization of improved forages were reported to be low especially in the lowland agro-ecological zone. As a result, the proportion of respondents in highland who grown improved forages was about double to that of respondents in the lowland agro-ecology. Limited use of improved forages by the farmers is demonstrated by the existence of a small number of forage demonstration and multiplication sites and the limited awareness towards the use of improved forages at smallholder farms (Yayneshet, 2010). In accordance with the current study, Assen (2009) reported that limited land, water shortages and lack of access to

forage planting materials, were among the main problems hindering forage development in northern Ethiopia. Yayneshet (2010) indicated that one of the key factors that determine farmers' choice of crops to be planted in irrigated areas was the current commodity market value. The same author also noted that it is not surprising that most of the irrigable lands found across different districts in Tigray were covered with marketable crop commodities and the share of improved forage crops was generally lower than desired by the extension system.

The limited grown improved forages were reported to be provided in priority to dairy cows and draught oxen than sheep and goats. Additionally, broad use of such improved forage species in Tigray region was constrained by the absence of agro-ecologically suitable and diverse species, limited number of public and private forage genetic material multiplication sites, absence of a comprehensive improved forage management and utilization guidelines, and lack of feeding packages that incorporate improved forage species (Solomon *et al*., 2017). Similar with the personal observation during the survey time, Yayneshet (2010) also indicated that except in a few cases, the success rate of introducing improved forage crops into the farming community was generally not to one's expectation and a lot needs to be done to expand the adoption of different forage species by the farmers. These low contributions are despite the presence of evidences on the beneficial effects of forage crops and multi-purpose trees on dry matter intake and body weight gains (Melaku *et al*., 2004). Moreover, Fekadu *et al*. (2015) from their work in many parts of Ethiopia identified lack of market oriented specialized livestock production to catalyze forage development, crop-biased extension system, lack of reliable supply of forage seed/planting material and free livestock grazing system as the major factors limiting cultivated forage production and utilization.

5.1.2.6.4. Supplementary feeding of sheep and goats

The higher proportions of respondents from the highland and midland as compared to lowland who purchased supplementary feeds reflected their better awareness and access to the supplementary feeds. Similarly, Animut and Wamatu (2014), indicated that the type of concentrates used for sheep fattening vary depending on availability and cost of the ingredients. Hence, access to the by-products (oilseed cakes and cereal bran) varied across the

agro-ecological zones and hence affects its optimum utilization. Moreover, the result obtained in the current study (across all the surveyed agro-ecological zones) is better than the report of Assen and Aklilu (2012) who noted sample households of only 8% both in highland and midland and 4% in lowland agro-ecological zones indicated the use of purchased feeds to sheep and goats.

Similar with the current finding where farmers used different conventional as well as non-conventional feed resources to supplement their sheep and goats, Animut and Wamatu (2014) also reported that fatteners use a wide variety of supplemental feeds available in their localities including byproducts of local brewery (*atella* from *tella* or *areki*), household leftovers, milling by-products from the preparation of different pulses and cereals for human food which may contain some screenings that enhance feeding value. Farmers travel long distance (beyond 30km) to the zonal town (Adigrat) to purchase industrial by products where there is better access of animal feed shops. In agreement to this study, Animut and Wamatu (2014) reported that fatteners travel as far as 40 km to major towns like Bahir Dar to buy supplemental feeds such as noug seed cake, wheat bran and rice bran. The same authors also noted that traders also procure by-products from bigger towns and resell them to farmers in the smaller towns. This indicates there are smallholder farmers who can afford to buy supplemental feeds for their sheep and goats if the by-products are accessible.

Unlike the current result where less accessibility and high cost were the most important restraining factor that impedes farmers from using purchased feeds, Assen (2009) reported that the majority of the interviewed flock owners (40% in highland, 41.3% in midland and 58% in lowland) who did not practice supplementary feeding claim that sheep and goats do not require supplementary feeding as they can forage or scavenge effectively better than cattle do. Hence, sheep and goats usually obtain their feed from grazing and hence, they usually suffer from feed shortage and poor nutrition. Similarly, Zelealem *et al*. (2012) indicated that sheep and goats receive less priority than cattle and even the available feed to them has poor nutritive content, poor digestibility and unpalatable during major portion of a year. Moreover, the same authors noted sheep and goats are left to graze and browse alongside with large animals that even worsen the feed shortage since animals need to compete with each other.

The better proportion of respondents who supplement their sheep and goats in the current study than the previous studies might indicate the improved awareness of farmers on sheep and goat feeds and feeding. Small holder farmers showed promising improvement on sheep and goat supplementation from time to time. This could be due to the fact that farmers fetched better income by selling better conditioned sheep and goats at the high demand markets especially in the larger towns.

In line with the current study, Assen and Aklilu (2012) noted that whenever supplementary feeds are available priority is given for pregnant/lactating ewe and doe, sick and castrated sheep and goats. Available literature also supported that smallholder farmers who owns nearly all classes of livestock provide supplementary feed composed primarily of straw to lactating cows and work oxen only; supplemental feeding of other stock including sheep and goats is virtually unknown even though a few heads are fattened for special occasions or festivals (Ayen, 2004). This blows up the special ability of sheep and goats to thrive well using locally available feed resources better than cattle.

5.1.2.6.5. Grazing practices of sheep and goats

The higher proportion of respondents who practiced herded grazing was to prevent the animals mainly from damaging crops because most of the cultivated lands are covered with food crops especially during rainy season and this conforms to the reports of Belete (2010) and Assen and Aklilu (2012). In the lowlands, where goats were dominating and grazing lands were relatively larger, they were also protected to avoid damaging of cropland and to protect them from wild animals such as leopard, hyena and fox. The lower proportion of respondents who tethered their sheep and goat in highland and midland might be due to less availability of green pasture for practicing tethering; so, free grazing was more popular.

The lower tendency of keeping goats with large ruminants in the lowland might be due to difference in their feeding behavior. Goats have the ability of browsing many plant species within short period and less time is required to fill their gut than sheep which is in agreement to the report of Belete (2010). The larger proportion of respondents in the lowland who

herded their sheep and goats separate from other livestock might be due to respondents in the lowland rear larger proportion of goats with different feeding behavior than cattle. Unlike in the lowland, respondents in the highland herded their sheep and goats together with other types of livestock which justified the tendency of decreasing competition among the different species of animals during grazing and decrease the negative impact on the grazing land.

5.1.2.6.6. Feed shortage seasons and their mitigation strategies

Shortage of feed in quality and quantity was one of the limitations for sheep and goats production in the surveyed agro-ecological zones. In agreement with the current study, Assen *et al*. (2015) noted that feed shortage is quite common from February to June in Northern Ethiopia. The critical feed shortage during the dry season might be due to the majority of farmers use communal grazing lands which provide little forage due to overstocking. However, there were also respondents who mentioned feed shortage during summer which might be due to most of the arable lands are covered by crops and movement of animals might be limited to minimize trampling of the grown crops. Similarly, Alemu *et al*. (2013) also indicated that movement of livestock is restricted during rainy season due to the available land is occupied by crops. Decrease in size and productivity of grazing lands and increase in human as well as livestock population could be responsible for the prevailing feed shortage. Moreover, erratic nature of the rainfall was reported to be further aggravated the reduction in forage yields in the surveyed agro-ecological zones.

The higher proportion of respondents across the surveyed agro-ecological zones who utilize cactus pear (*Opuntia ficus indica*) during season of feed shortage as a coping mechanism could be due to the wider availability of cactus pear in the study area. The availability and potential value of cactus pear as food and fodder plant in Eastern zones compared to other zones of Tigray regional state was also reported by Gebremeskel *et al*. (2013). The higher proportion of respondents from the highland using purchased feeds next to cactus pear might be due to the better access of those respondents to purchased feed. However, destocking (reducing number through sale) was the second coping strategy of feed shortage mentioned by

the midland and lowland respondents. Similar coping mechanisms to feed shortage have been reported for different parts of Ethiopia (Alemu *et al*., 2013; Assefa *et al*., 2014).

5.1.2.7. Water sources and watering

The higher proportions of respondents who own bore hole in the highland might be due to the cultivation of marketable vegetables for sell to the nearby towns where there is better market access. Nevertheless, the use of river as main source of water in the midland and lowland might be due to their less proximity to the larger town where market places are located for their agricultural commodities to sell and hence might own less bore hole. In agreement with the result of the current study, Assen and Aklilu (2012) also noted that respondents who mentioned water source significantly varied among the three agro-ecological zones. Berihu *et al*. (2014) also noted that the major sources of water mentioned by farmers in Ganta-Afeshum district, Eastern Tigray were river (86.34%) followed by temporary wells, stream and natural ponds (13.66%). Similarly, Berihu (2016) indicated that major sources of water mentioned by the farmers were river (64%) followed by temporary wells, stream, and natural ponds (36%) in eastern zone of Tigray. In line with the current study, different authors (Seare, 2007; Tesfaye, 2009) were also noted that the majority of farmers obtained water from rivers for watering their animals and the remaining of the farmers used spring water and ponds, respectively as their major water source during wet and dry season.

5.1.2.7.1. Distance to water points

The higher proportion of respondents from highland and midland agro-ecological zones who accessed water at shorter distance than those respondents from the lowland agro-ecological zone during dry season might be due to the better availability of bore hole. Similarly, Tessema *et al*. (2003) from Belesa district of Amhara regional state reported that shortage of water was more common in lowland areas compared to highland and midland, as a result animals travel longer distance to watering points (5-10 km) per day and they waste their energy and time in search of drinking water during the dry season. Moreover, the amount of these water sources thought to be declined in dry season and hence the distances to watering points might increase during dry season and also vary with the intensity and length of rainy period during the

previous rainy season which is in agreement with Berihu (2016). The same author also indicated that majority of the respondents (74 %) trek their animals 1 to 5 km in search of water during the dry season, but during the wet season distance to the nearest water source that (85%) respondents trek their animals is reduced to less than 1 km.

In line with the result obtained in the present study, Adugna and Aster (2007) noted that there were shortage of water supply both for human and for livestock including sheep and goat consumption particularly during the dry season; as a result the people are forced to travel long distance (up to 5 hours walk) in search of water in Borena. Furthermore, Workneh and Rowlands (2004) also reported that during the dry season two-thirds of the sheep owned by households in pastoral areas have to travel to more than 5 km to reach to the nearest watering point, and about a half of these, to more than 10 km.

5.1.2.7.2. Frequency of watering

The better watering frequency in highland than midland and lowland might be due to the relatively better access to the proximate water sources (bore hole). Unlike the current study, Tesfaye (2009) noted almost all of the respondents allow their goats to drink water once per day at midday during dry season. Additionally, Adugna and Aster (2007) reported that during dry season and in drought years the pastoralists in Borena are forced to travel long distances in search of water and animals are also watered at longer watering intervals. The same author also noted that cattle and sheep are watered after an interval of 3 or 4 days while goats are reported to tolerate a longer interval of 5-6 days.

Due to the available moisture created by the rain during the wet season, animals accessed to water at shorter frequency. Similarly, Berihu *et al*. (2014) noted that during wet season, 5% of farmers watered their sheep and goats freely while 62.5% watered once a day and 24.16% once in two days. In dry season, however, only 13.33% of the respondents water once in two days and about 86.66% watered once a day (Berihu *et al*., 2014). Tesfaye (2009) also noted that during the wet season, more than 20% of farmers allowed their flock to drink water freely. Nevertheless, watering frequency was better in the current study than some other areas

like lowland of Afar area where once in two to three days watering was common (Tesfaye, 2008). The variation in watering frequency reported by different authors might be due to differences in water source availability, temperature and knowhow of the farmers about water requirement of their animals.

5.1.2.8. Housing of sheep and goats across the three agro-ecological zones

Respondents housed their sheep and goats in separate house from the main family house but adjacent to the main building which was in accordance with the report of Berihu (2016) who noted that most of the farmers in Ganta-Afeshum district, Eastern Tigray indicated that they housed their livestock (small ruminants, cattle and poultry) separately from their family whereas; other categories of all animal groups (females, males and young animals) were kept in the same house. The present study also goes in harmony with Mulata *et al*. (2013) who reported that sheep housing in Southern, Southeastern and Eastern part of Tigray region was not separated by sex and age of the animals.

In agreement with the current study, Assen and Aklilu (2012) noted that housing of sheep and goats by classes and species was virtually unknown in the three surveyed agro-ecological zones whereas, farmers' housed pregnant ewe or doe separately for the last few weeks of parturition. In addition, to prevent damaging by larger animals, farmers accommodate newly born lambs/kids separately in the family house or in a separate pen until the lamb/kid become strong enough. Moreover, Zelealem *et al*. (2012) reported that farmers keep all types of animals together and sometimes humans spend the night with their animals to guard their animals. Whenever all types and classes of livestock confined together in one common house, some animals get injured due to physical attack by dominant and larger animals. This might result abortion of pregnant ewes and does and dead of kids and lambs due to trembling. Additionally, Berihu (2016) had noted that good housing can determine productivity by reducing stress, disease hazards and making management easier.

Nevertheless, the type of housing of sheep and goats in the current study was inconsistent with Workneh and Rowlands (2004) in highland and midland agro-ecological zones of

Oromyia regional state and Tsedeke (2007) in Alaba, southern Ethiopia where sheep and goats were accommodated in the main houses together with the family members. Tsedeke (2007) also noted confining of flocks in separate barns (only 0.7% respondents) or adjoining structures (0.7% respondents) is uncommon because the local tradition is that 'sheep, goats and honey bees survive less in the absence of smoke from the house fire'. Similarly, Yenesew *et al*. (2013) in Burie district, North Western Ethiopia indicated sheltering sheep in the main house is predominant (58%) followed by sheep houses constructed attached to the main house (33%). Moreover, other previous study (Markos, 2000) also reported that housing of flocks in the main house is more common and confining of flocks together with family has zoonotic health implications, nevertheless, to reduce predator and theft losses household for long held the tradition of sharing the same roof with their flocks.

5.1.2.9. Breeding practices of sheep and goats

The predominance of uncontrolled mating obtained in the current study might be due to rams or bucks running together with the flock throughout the year while grazing on communal grazing lands. In agreement with the current study, Tesfaye (2009) and Dereje (2011) noted that majority of farmers practiced uncontrolled mating because the flocks consisted of goats of all ages except newly born kids and they were kept as a single flock and kids were born all year round. Similarly, other research works (Tassew *et al*., 2014; Zergaw *et al*., 2016) indicated mating was predominantly uncontrolled and the main reasons for lack of controlled mating in both areas were mixed flock herding and lack of awareness about the effect of inbreeding. In the traditional system of sheep and goat production, mating is uncontrolled with rams or bucks running together with the flock throughout the year which results in year round lambing/kidding with a peak in certain periods (Ayen, 2004). Uncontrolled breeding due to random mating, with the ram grazing together with the ewes, leads to early breeding of females resulting in low conception rate, low birth weight and poor survival rates (Zelealem *et al*., 2012).

This result implies lack of intentional mating system either to match mating with the available feed resources or without consideration of market demand. In agreement with the present

study, Berihu (2016) reported that there was no significant practice of controlled mating and hence the breeding practices were dominated by natural mating in which the male animals run with females throughout the year. In line with the present study, Helen *et al*. (2013) from Eastern Ethiopia also reported that mating was predominantly uncontrolled in most of the surveyed production systems; however, controlled mating was practiced to some extent to match lambing time with wet season and to avoid indiscriminate breeding in the pastoral production system.

In agreement with the current study, Zelealem *et al*. (2012) indicated that until crops are harvested, flocks are usually either controlled by herders or tethered whereas, immediately after the crop is harvested flocks freely graze on crop stubbles and aftermaths. Thus, adequate nutrition for reproductive process and access to breeding males might create favorable situation to the intensive flock breeding. This is also in agreement to findings of Mukasa-Mugerwa (2002) who observed peak conceptions of ewe in response to feed flushes or when crop residues are available. Moreover, Takele *et al.* (2006) reported availability of adequate feeds immediately following crop harvest allows free access to aftermath improve testicular sizes and semen characteristics in rams. Mukasa-Mugerwa *et al*. (2002) found that mating of ewes in the dry season lead to higher fertility than those mated in the wet season that ewes from the previous wet season came with enough body reserves. Adequate seasonal feed availability resulted superior reproductive performance of rams (Takele *et al*., 2006). This implies that major lambing and kidding during wet season is favorable to the new borne.

Own breeding ram accounted the main source of breeding male across all the study areas and is comparable with Workneh and Rowlands (2004) who have identified similar sources of breeding males in highland, midland and lowland agro-ecological zones of Oromiya regional state. Similarly, Helen *et al*. (2013) noted that out of the 90 respondents in each production system, 98%, 89% and 71% in the pastoral, agro-pastoral and mixed crop-livestock systems, respectively, kept their own indigenous breeding rams while those respondents with no breeding rams used those of neighbors. Similarly, Tesfaye (2009) reported that 72% of the farmers in Metema district kept their own breeding bucks whereas the remaining used neighbor's bucks.

It was observed that there is no deliberate practice of making selective breeding to avoid risks of the inbreeding depression in the flocks. It is of more concern that almost all breeding rams and bucks originated from their respective flocks might imply that the relationship of animals within a flock and even within a village is narrow and inbreeding is widespread and increasing. This is in agreement with the report of Berhanu (1998) and Jaitner *et al*. (2001). Similarly, Zelealem *et al*. (2012) also noted that mating within close relatives, especially sire daughter and ewe-offspring-could lead to inbreeding, which might have resulted in increased mortality. According to the focus group discussions conducted across all the study sites, participants indicated that grazing lands especially communal grazing lands are being shifted into area enclosures and cultivated lands, so farmers are forced to keep their sheep and goats near homestead. Hence, the level of inbreeding might become high where communal grazing is becoming less and less important.

5.1.2.9.1. Attributes of male sheep and goats for selecting breeding stock

Similar with the current study, Helen *et al*. (2013) reported that appearance of rams, which most of the owners associated with high carcass output and premium price across all the production systems includes wide chest, conformation and long body size was the top ranked criteria for selecting breeding ram. Solomon *et al*. (2010) has also shown that the overall appearance of sheep is an important economic trait that influences value, particularly in the traditional markets of Ethiopia. The majority of the respondents selected potential breeding rams from their own flocks, though selection of rams was more frequent than for ewes as has been recorded previously in other studies (Ferew, 2008). In agreement to the current study, previous reports indicated that black coat color is generally less preferred color in most parts of Ethiopia (Ferew, 2008; Zewdu *et al*., 2012; Selamawit and Matious, 2015). Traits like fast growth, body size, color and mating ability were all considered as important criteria used by sheep owners in other parts of the country in selecting breeding rams (Dejen, 2010; Getachew *et al*., 2010; Tassew *et al*., 2014). Additionally, farmers also select male animals based on the performance of their ancestors and based on the body conformation and growth rate they manifest in their course of development (Zelealem *et al*., 2012).

In line with the current study, different authors (Workneh and Rowlands, 2004; Assen and Akililu, 2012) noted that higher percentage of respondents in different agro-ecological zones indicated the use of body size followed by color as the main criteria during selection of breeding goats. Farmers in Meta-Robi had put more weight on body size, coat color as well as growth rate (Zergaw *et al*., 2016) and the preference of body size and growth rate might be due to the fact that larger animals in particular were preferred as they fetched better market prices, had better growth rate and reached market weight sooner. Therefore, it is very crucial to understand criteria to select and replace breeding bucks in order to improve the production and productivity of the flocks because the buck contributes fifty percent of the genetic makeup of every kid born and determines overall pregnancy rate of the flock. Moreover, bucks are selected from their contemporary group in a herd and kept for further evaluation. According to the respondents the bucks should be evaluated and re-evaluated based on their growth and development within their contemporaneous group. Only bucks that have achieved good growth, attractive coat color and are structurally sound are kept as replacement stock.

5.1.2.9.2. Castration

Unlike the current study where castration of ram in the highland was less commonly practiced, Workneh and Rowlands (2004) reported that there was practice of male sheep castration in all highland, midland and lowland agro-ecological zones of Oromiya regional state, Ethiopia. Additionally, Tassew *et al*. (2014) also noted that castration of lambs was a common practice and above half of the interviewed farmers in Northern Wollo (67.0% for Habru and 69.0% for Gubalafto) practice castration of lambs. Higher proportions of respondents across all the surveyed agro-ecologies castrate their buck aiming to fatten and fetch better market price. It is perceived that the demand for castrated and fattened buck is high particularly by the Irob community (one of the Ethnic groups in Eastern zone, Tigray). Contrary to the current study, Belete *et al*. (2015) in Bale zone reported that about 85.3% of the respondents were not practicing castrations because household in this area mainly depends on goat as source of cash and they sold male animals at younger ages. The same author also noted that there is cultural taboo regarding castration in the community; the society

considered castration as not to give birth and which they believe deviation from natural phenomena and not allowed by their cultures.

In harmony with the current study, Gebremeskel (2014) indicated that most of the respondents (88.2%) castrated their sheep and goat traditionally using local materials, such as stone, stick, hammer and knife, while 11.8% of the respondents take their animals to veterinary clinics and use Burdizzo. Similarly, Zergaw *et al*. (2016) in the Konso and Meta-Robi districts noted that majority of farmers use traditional castration method to castrate their buck while, some of the farmers took their goats to a nearby veterinary clinic to use burdizzo for castration. Unlike the results of the current study, commonly used method of castration was Burdizzo method which is accessible in animal health centers in Northern Wollo (Tassew *et al*., 2014). Traditional method of castration was also practiced in North West highlands (Mengistie *et al*., 2010) and Menz area (Tesfaye, 2008; Getachew *et al*., 2010).

In agreement with the current study where majority of respondents castrate their sheep and goats above one year, Tsedeke (2007) reported that average age of castration was 1.1 year for sheep and 1.6 year for goat and this is attributed to the households' interest to castrate and fatten sheep as early as possible to take advantage of the higher demand and prices at the present market. Moreover, Belete *et al*. (2015) also reported majority of the respondents castrate their male sheep and goats in the age range of one to two years. Contrary to the present study, Alemu (2008) suggested that lambs/kids should ideally be castrated as soon as the testicles descend into the scrotum (this can be from a few days of age to three weeks) and no sedation or pain killers are necessary if castration is done at this age. The same author also highlighted that to prevent unnecessary breeding; sheep need to be castrated at an age earlier than 3 weeks. Nevertheless, farmers recognize that castration at an early age results in stunted growth of the animal, thus recommend castration to be done for grown animals (Animut and Wamatu, 2014). Similarly, the reported average castration age was 17.9 months for Habru sheep and 20.4 months for Gubalafto sheep (Tassew *et al*., 2014). The same author indicated that farmers believed that castration at early age affect the growth of the sheep.

Reasons for castration

In agreement with the present study, Assen (2009) noted that getting better price was the main deriving factor for castration as reported by respondents of 90% in highland 84% in midland and 76% in lowland agro-ecological zones. Moreover, Belete *et al*. (2015) also reported that about 86.5% castrated their goats for the purpose of improve fattening and the castrated goats are mainly used for home consumption during ceremony or wedding rather than marketing since castrated goats are less attractive in markets. Similarly, Animut and Wamatu (2014) also indicated that in many places, castration is practiced with the intention of making the animals docile; make them grow faster and fatter. Castration was usually done for fattening a ram to get more incomes or used for home consumption but it has not been recognized as a method of preventing undesired breeding (Tassew *et al*., 2014). In agreement with the present study, Tsedeke (2007) also reported that several intact males in a household make noises and become restless and difficult to handle, thus 18.7% of the respondent castrate their animals to make them docile.

5.1.2.10. Sheep and goat fattening practices

The larger proportion of respondents in the highland and midland as compared to lowlands practicing sheep and goat fattening might be due to their proximity to the market potential towns and indicating their intent of fetching better benefit from sell of their well conditioned sheep and goats. Similarly, Animut and Wamatu (2014) noted that sheep fattening is common in almost all agro-ecologies, with a lower prevalence in the lowlands. The result obtained in the current study is better than that of Assen and Aklilu (2012) who noted that respondents of 11% in highland, 15% in midland and 8% in lowland practiced fattening of sheep and goats. On the other hand, in areas like Keffa zone, the highland areas are more geared towards sheep production and most of the fattening takes place in the lowland and midland areas (Animut and Wamatu, 2014). The same author further explained the perception that the fattening period is longer in highland areas due to slower body weight gain of fattening animals as a result of the relatively colder weather.

The information obtained in the current study is in accordance with Animut and Wamatu (2014) who indicated that smallholder farmers are the predominant category of sheep fatteners in Ethiopia and they are located mainly in rural areas. Unlike market-oriented commercial fatteners, subsistence livestock producers follow broad production objectives that are driven more by their immediate subsistence needs rather than market demands (Ayen, 2004). Similarly, Moti *et al*. (2009) also indicated the production decisions of subsistence farmers are based on production feasibility and subsistence requirements and selling only whatever surplus is left after household consumption requirements are met. Rams are mainly fattened because they grow faster, though culled females are also fattened (Animut and Wamatu, 2014).

Similar with the current study where stall-feeding followed by grazing plus supplementation with other purchased feeds were the feeds and the feeding practices during fattening in both highland and midland agro-ecological zones, Tassew *et al*. (2014) indicated that among the feed types used for fattening were natural pasture (grazing), crop residue, local brewery residue (*atella* of *katikalla* and *tella*), salt, leaf and root of sweet potato, concentrate and improved forage. Fattening usually practiced following the end of the main rainy season and in the beginning of dry season coinciding with the availability of good quality and quantity of natural pasture, better forage production and aim to specific markets (holiday markets).

The shorter fattening period in the highland agro-ecological zone might be due to higher demand of conditioned sheep and goats in the towns. Hence, this reflected their prompt to meet the higher demand in the proximate larger towns by supplying partially conditioned animals. Nevertheless, seasonality of feed supply and market demand could be the potential reasons for the relatively increased length of fattening period in the midland and lowlands. Moreover, lowland sheep and goat holding households do not want to dispose their animals through short term fattening because they consider their sheep and goats as a savings and capital building for socioeconomic and sociocultural benefits. This calls to the need for intensive and continued extension services and institutional commitment for improving input supply system, marketing system, credits and overall extension system. The seasonality of feeds, especially roughages and the associated rise in feed costs limit fattening in the critical

periods of feed supply (Animut and Wamatu, 2014). Participants during the group discussion mentioned that had the scarcity of feed been less and the demand is throughout the year, maximum annual fattening cycles could be achieved. Moreover, adopting feed conservation practices either own feed or bought when the availability of feed is better and less costly could be the way out to minimize seasonal feed availability. Similarly, Animut and Wamatu (2014) indicated that to overcome the seasonality in feed supply for fattening sheep, the strategy mentioned by fatteners was to buy sufficient feed and store during periods of plenty when the price is relatively low.

5.1.2.11. Events of slaughtering

In line with the current study, Easter, New Year and Christmas are the main occasions on which farmers slaughter sheep and goats in that order of importance (Yenesew *et al*., 2013). Moreover, previous researchers also (Tsedeke, 2007; Assen and Aklilu, 2012; Animut and Wamatu, 2014) indicated that sheep and goats are slaughtered for household consumption and major slaughter are made during festivals and various family and cultural events; whereas, slaughtering of sheep and goats for regular family consumption is virtually uncommon. The higher proportion of respondents who preferred male than female across all the agro-ecologies is in accordance with Assen and Aklilu (2012) who noted that vast majority of the flock owners in the three studied agro-ecological zones revealed the slaughtering of males than females. Younger and male sheep or goats were the most preferred animals slaughtered for consumption. On the other hand, whenever male sheep or goats are not available in the house, females are likely to be slaughtered or farmers purchase male sheep/goat from the market or from their neighbor. Apart from these reasons, female sheep and goats are usually kept essentially for breeding purpose. Similarly, Assen and Aklilu, (2012) noted that it is not usual to slaughter female sheep and goats unless they have physical abnormalities, health complications, over aged, injured/damaged, and die due to disease or other reasons. Additionally, Yenesew *et al*. (2013) from Burie district, North Western Ethiopia and Tassew *et al*. (2014) from North Wollo Zone, Ethiopia, also indicated that male sheep at young age were mostly slaughtered for home consumption.

5.1.3. Major constraints of sheep and goat production

5.1.3.1. Production constraints

Inadequate feed resources

Sheep and goat holding households in the three surveyed agro-ecological zones faced problems related with the year round availability of quality feeds. Due to change in land use as a result of population pressure, large proportion of respondents across all the surveyed agro-ecological zones indicated that grazing lands have been continuously converted to crop lands. This has led to shrinking of the grazing lands and overgrazing of the limited natural pastures and land degradation. For these reasons, feed shortage has become a serious problem for sheep and goats holding household and ranked the first constraint of sheep and goat production. Hence, it is obvious that there is a serious problem in exploiting the genetic potential of the animals due to the lack of good quality year round feed. The quantity and quality of feed resources available and offered to the animals was found to be below the requirement of animals, and these have been well recognized by sheep and goat holding households and reported as a severe problem hindering productivity of their animals. The increased cost of roughages and supplementary feed in the study area caused by the above problems resulted in insufficient nutrition, which was expected to decrease the productivity of sheep and goats across all the surveyed agro-ecological zones. Similarly, different previous authors (Seare, 2007; Assen and Aklilu, 2012) indicated that shortage of feed ranked the first most important constraint that afflicts sheep and goat production especially in highland and midland agro-ecological zones in Tigray, Ethiopia.

The present finding was also in agreement with different authors conducted their research in different parts of the country (Girma *et al*., 2013; Yenesew *et al*., 2013; Fikru and Gebeyew, 2015) who reported that feed shortage was one of the most important constraints that hinder productivity of livestock including sheep and goats. Feed shortage in both seasons (dry and wet) limits productivity of goats and it was further worsened due to the absence of awareness and practice of feed conservation techniques (Matawork, 2016). Moreover, Mesay *et al*. (2013) in Lemu-Bilibilo district in Arsi zone also reported that, shortage of feed at the end of

dry season when all crop residues have been consumed and pasture growth is poor was the major constraint for livestock including sheep and goat production.

Unlike the current study, Tesfaye (2009) indicated that disease, labor, and theft were the most pertinent constraints for goat production in that order of importance in both cotton based and sesame based farming systems whereas; feed shortage was ranked low in both production systems. The same author again mentioned that farmers did not stress lack of feed as a limiting factor for productivity of goats, and did not indicate the importance of improving their feeding regime as an essential step towards any improvement program. This might be due to the availability of enough feed or good range condition which was more likely good in Metema area. Nevertheless, in agreement with the current study Adugna (2007) indicated that among the major problems affecting livestock production and productivity in Ethiopia, feed shortage in terms of quantity and quality is the leading problem. Furthermore, of the major input costs incurred in any livestock production, feed cost accounts for over 50% of the total production and marketing costs (Solomon *et al*., 2017).

Inadequate land size

The inadequacy of land reported especially in both highland and midland agro-ecological zones might limit the farmers to grow improved forage in their backyard. These situations prohibited farmers from maximizing production possibilities through efficient use of low cost inputs. The total land area owned by the farmers was very small, less than a hectare. Therefore, land availability was the main limiting factor for livestock in general and small ruminants in particular across all the surveyed agro-ecological zones. Similarly, Selamawit and Matious (2015) indicated that limitation of land was the second important top prioritized constraint next to feed shortage in Walema area.

Water scarcity and drought

Shortage of water both in highland and midland agro-ecological zones ranked third prioritized problem in the current study. Additionally, participants during the group discussion revealed

that during dry season water in some of the rivers dries up and thus not only animals but even human beings spent much time searching water, particularly in the lowland agro-ecological zone. This agreed with earlier researchers **(**Tsedeke, 2007; Mesay *et al*., 2013). Mostly the lowland areas are drought prone areas, the occurrence of periodic drought and scarcity of water was the major problems that livestock in general and sheep and goats in particular faced with; as a result water scarcity and drought received higher rank in lowland than in the highland and midland agro-ecological zones (Assen and Aklilu, 2012).

Animal health aspects

Unlike the current study where animal health problem was not from the top four ranked production constraints, different authors (Tesfaye, 2009; Assen and Aklilu, 2012; Solomon *et al*., 2013; Yadeta, 2016) reported that disease ranked as first constraint for both sheep and goats in all the three agro ecologies and production systems. Additionally, Zemeda (2017) also noted that the majority of the sheep and goat holding households indicated that animal diseases and inadequate animal health services, shortage of feed, land, labor and predators as major constraints of sheep and goat production in Tahtay Adyabo, North Western Zone of Tigray.

Predators

The serious problem of predators reported by the respondents in the lowland is in accordance with the finding of Tsedeke (2007) in Alaba southern Ethiopia, Assen and Aklilu (2012) in different agro-ecological zones in Tigray and Solomon *et al*. (2014) in Amhara National Regional State of Ethiopia. Yadeta (2016) also noted that there were massive attacks of fox on young stock and hyena/other wild animals on adult flock in west Shoa. According to the respondents from the lowlands, due to the area enclosures for rehabilitation purposes, wild animals like leopard, hyena and fox are emerging. Despite the fact that it is good to see the degraded areas become rehabilitated and observing wild animals become increased in number, sheep and goat holding households are becoming victims by these wild animals. Kids and lambs are being attacked by fox whereas leopard is the most reported predator attacking

adult sheep or goats in the area and this could inflict immense loss to the small holder farmers in the current surveyed lowland agro-ecology.

5.1.3.2. Marketing constraints

Low price followed by seasonal fluctuation received the top priority of marketing problems in the highlands. Similarly, Gebremeskel (2014) reported that the major factors that affect the selling price of sheep and goats were seasonality inflow of animals (46.9%), market information (29.8%) and market locations (23.2%). Unlike the finding of the current study, Zemeda (2017) noted that lack of livestock market information, seasonality of sheep and goat demand, distance to livestock market and low market price are some of the constraints in Tahtay-Adyabo District of Tigray. Demand was high especially during cultural and religious holydays and hence, farmers are forced to sell their sheep and goats during none fasting periods to meet their cash needs and fetch better income. Similarly, Abraham *et al*. (2017) indicated that higher numbers of goats are sold and better price is fetched during holidays although farmers sell goats at any time of the year depending on their need for money.

In rural areas mostly marriage and other social activities take place right after crop harvest, hence at this time the price for sheep and goat increased (Assen, 2009; Zelealem *et al*., 2012). Additionally, demand and the selling price of small ruminants were reported to increase during the rainy season, as farmers are highly involved in other farming activities that would reduce the supply of animals to markets. Furthermore, availability of good grazing pasture during the rainy season may not encourage farmers to sale their animals, hoping to attain better conditioned and fetched better priced animals afterwards. However, in times of crop failure due to drought, farmers are forced to sell their sheep and goats at lesser prices to generate income for basic household needs. In agreement with the current study, Ayen (2004) indicated that seasonality in marketing is a common phenomenon with most agricultural products including livestock in general and sheep and goats in particular.

In agreement with the current finding where broker interference was less in sheep and goat transaction across all the surveyed agro-ecological zones, Assen (2009) also indicated

interference of brokers was not an issue of sheep and goat marketing problem in the highland, midland and lowland agro-ecological zones of northern Ethiopia. Therefore, selling or purchasing prices were fixed after a long bargaining between sellers and buyers. Farmers in the three market sites of the three agro-ecological zones found to reach in agreement mostly through direct and after long negotiation with traders, consumers and producers (Assen, 2009). Contrary to the current result, Tsedeke (2007) reported that interference of brokers as the number one problem in sheep and goat marketing in Alaba area.

5.1.4. Use of mulberry

The experience of respondents cultivating mulberry plant was not long across all the surveyed agro-ecological zones and this is in accordance with the report of Assen *et al*. (2015) who noted that mulberry cultivation is not only a recent activity but its scale of operation is also very limited in Northern Ethiopia. The same author indicated that the presence of low number of mulberry tree per household could be due to lack of awareness among farmers and livestock experts vis-à-vis its role as livestock feed. The plantation of different browse plants like mulberry at the back-yard and border lines of cultivated areas provides supplementary feeds for small ruminants and serves as a hedge and source of fuel wood as well. This could possibly increase the production and productivity of sheep and goats and producers could fetch better income from their animals. In accordance to the current observation, Zelealem *et al*. (2012) noted that the subsistence production systems are amenable to becoming intensive systems (market oriented) if farmers can receive information on how to produce good quality feed for their animals using locally available resources.

5.1.4.1. Initial sources of mulberry planting material and planting strategies

Larger proportion of respondents across the study agro-ecologies indicated that governmental organizations were disseminating the initial sources of mulberry plantation and this is in accordance with the report of Assen *et al*. (2015) who noted that, government organization namely Bureau of Agriculture and Rural Development was the major source of initial mulberry planting materials across visited study districts in the Northern Ethiopia. The contribution of nongovernmental organizations and other sources of mulberry plantation were

limited. Farmers used to plant mulberry at their back-yard, at cultivated land edges, in ridges of terrace land, along roadsides and along riversides. Mulberry plantation was also observed in school compounds and nursery sites. In line with the current study, Assen *et al*. (2015) in Northern Ethiopia and Shayo (1997) in Tanzania indicated that many farmers grew mulberry tree around their homestead, at border lines of cultivated areas and at borders of their irrigation fields. Additionally, respondents who had access to irrigation grew mulberry plant around their irrigation field in combination with other perennial fruit trees and no negative effect of growing mulberry plant in combination with other food crops was reported (Assen *et al*., 2015).

Experts during the focus group discussion forwarded that mulberry can be easily propagated through cuttings with minimum of time and expenditure and the cuttings should be prepared from one year old hard wood branches and cuttings should be with minimum of three buds. The ends of the cuttings should be clean cut with a sharp knife, without splits or bark peeling off. While planting, the cuttings should be planted with only a very slight tilt. Mulberry planted in June could be ready for first harvesting or pruning in June of the next year. Prior to that, two small harvests may be taken, once, sometime in October - November and again in April – May. The harvests should be light and made by picking only mature leaves, leaving major part of the growing branch intact covered with leaves. In accordance with the current results, different authors reported that though mulberry can be propagated artificially from seeds (seedlings) or cuttings (Sánchez, 2002; Singh and Makkar, 2002; Gezahegn *et al*., 2005; Assen *et al*., 2015), cutting is the most common method of propagation. Experts also indicated that inter-row distance of 1m, with 50 cm between plants, are recommended for mulberry planting.

5.1.4.2. Current purpose of growing mulberry in the study area

All respondents who know mulberry across the study areas indicated that the initial purpose of planting mulberry was for silk worm rearing. In agreement with the current result, Assen *et al*. (2015) reported that all respondents in northern Ethiopia noted that the purpose of introducing and growing mulberry tree was as feed for silkworm; whereas, majority of

mulberry owning households were not practicing silkworm rearing. According to the focus group discussion, participants indicated that most farmers did not benefit from silkworm rearing due to limited demand to the cocoons. Similarly, Assen *et al*. (2015) indicated that lack of attractive market for the silk produced, lack of the required skill for silkworm rearing, and awareness were among the constraints for silkworm rearing in northern Ethiopia. Additionally, JAICAF (2007) noted that the situation of silk worm production in east Africa including Ethiopia was just the dream of acquiring foreign currency and cash earnings through the export to foreign countries, without any clear thought of consumption needs or target consumers, and without considering the quality, price and design of the cocoons, raw silk and fabric that should be produced. Therefore, it has been noted that silk production appears to be not always profitable hence, alternative ways of using mulberry foliage, such as use of the plant for livestock feed would be welcomed by farmers when sericulture fails to bring encouraging results (Liu *et al*., 2001).

Currently respondents in highland and midland agro-ecological zones ranked the purposes of mulberry as animal feed followed by fuel wood. Animals were observed to browse the plant like the other browse plants and some farmers also practiced to picking the leaves and offered to their animals. Similarly, Sanchez (2002) indicated that farmers in Tanzania and Kenya use foliage from mulberry trees as part of the diet of ruminants. This is supported by Singh and Makkar (2002), who stated that the value and benefits of mulberry tree as high quality supplements to low quality roughages in ruminant feeding systems have not been widely known and fully exploited. On the other hand, although the nutritive value of mulberry is recognized in other countries like Tanzania and Kenya, there has not been much planting of mulberry for feeding ruminant livestock (Sanchez, 2002; Xu, 2004). Sánchez (2001) also reported that one of the main features of mulberry as forage is its high palatability. The same source further noted that small ruminants avidly consume the fresh leaves and the young stems of mulberry even if they have never been exposed to it before and cattle consume the whole biomass if it is finely chopped.

Assen *et al*. (2015) in their survey study indicated that respondents mentioned that mulberry grows fast, is highly palatable, has higher biomass production as compared to other improved

forage plants, and believe that it is even better than other improved forages in improving the performance of milking cows. The same author noted that farmers have been communicating the potential of mulberry to the livestock production experts in various meetings for mulberry to be seen and promoted as a valuable forage crop. Moreover, Lingaraj (2008) also indicated better animal preference for mulberry over other forages.

5.2. Experimental Study

5.2.1. Chemical composition

The declined trend of organic matter content as the proportion of concentrate mixture decreased might be due to the higher ash content of mulberry leaf meal. The NDF, ADF and ADL compositions of the treatment diets were not deviated largely from each other, justifying the comparable feeding value potential of mulberry foliage to that of concentrate mix. The CP content of mulberry leaf meal obtained in this study was within the range of values (18 to 25%) obtained by Ba *et al*. (2005), Kandylis *et al*. (2009) and Vu *et al*. (2011). The CP content of mulberry obtained in the current study could meet the CP requirement of lambs for maintenance and production which conformed to El-Shaatnawi and Mohawesh (2000) who reported that ewes require 7-9% and 10-12% CP for maintenance and lactation, respectively. The NDF content of sole mulberry leaf meal was to some extent higher than 31.1% and 26.4% reported by Vu *et al*. (2011) and Habib *et al*. (2016), respectively. Whereas, its ADF content was within the range of values (17.4 – 24.7 %) detected by Kabi and Bareeba (2008) as well as Habib *et al*. (2016). The ADL content of mulberry leaf meal in the present study is in accordance with that of the results of Kandylis *et al*. (2009) and Atiso *et al*. (2012) who reported 4.1% and 4.65%, respectively. In three clones of mulberry leaves, Schmidek *et al*. (2000) also reported comparable NDF (30.2–39.3%) and ADF (17.2–21.7%) results with the present finding.

Feeds with high ADF content could lower the availability of nutrients since there is a negative relationship between ADF and digestibility of feeds (McDonald *et al*., 2002). Moreover, Kabi and Bareeba (2008) also demonstrated that NDF, ADF and ADL contents increased with

increasing maturity. However, the fiber fractions values of mulberry leaf meal obtained in this study were low. This idea further corroborated the comparative supplementary feeding value of mulberry for ruminants. According to Lonsdale (1989) feeds that have <12%, 12-20% and >20% CP are classified as low, medium and high protein sources, respectively. Hence, mulberry leaf meal in the current study could be categorized among the medium upper limit protein source feed that can serve as a protein supplement for low quality crop residues particularly during the dry season. Similarly, Benavides (2000) also noted that mulberry leaves have a high potential as a protein-rich forage supplement to be used in feeds for ruminants, monogastrics and rabbits.

The ash content (15.4%) of mulberry reported by Habib *et al*. (2016) was comparable with the current finding. Similarly, Singh and Makkar (2002) stated that since mulberry leaves are rich in mineral matters like calcium, nitrogen, sulphur and other minerals they have the potential to be used as a supplementary feed for improving livestock productivity and this conforms to the current study. According to McDowell (1997), the recommended Ca to P ratio for ruminants is 2:1 to 4:1. Hence, the ratio obtained in the current study was within this range and the good mineral contents of mulberry foliage in this study further provoke its use as good alternative source of feed for ruminants. Ether extract obtained from the current study was higher than the value reported by Hurtado *et al*. (2012) (2.1%) whereas, it was comparable with 4.21% and 3.69% reported by Wang *et al*. (2012) and Doran *et al*. (2007), respectively. This suggests mulberry is not an energy deficient plant. Therefore, the leaf from this plant can be considered as a cheap and affordable supplement for ruminant animals particularly in herds of small scale rural farmers.

5.2.2. Dry matter and nutrient digestibility

The non significant ($p>0.05$) difference in apparent digestibility of CP among the treatments confirmed the comparable quality of mulberry leaf meal with that of concentrate mixture. The organic matter digestibility coefficient obtained in the current study conforms to that of Yulistiani *et al*. (2014) and Desta *et al*. (2017) who noted 0.70 and 0.71 organic matter digestibility coefficients for mature indigenous Malin rams and yearling intact male Abergelle

sheep, respectively. The CP digestibility coefficients obtained in the present study were within the range of values (68.18 - 76.5%) for dried mulberry leaves included at different levels in concentrate reported in different literatures (Atiso *et al*., 2012; Desta *et al*., 2017). Comparable values to the present study have been reported for dry matter digestibility coefficient of dried mulberry leaves partially substituted lucerne hay and concentrates in Karagouniko sheep breed (Kandylis *et al*., 2009). Apparent NDF digestibility appears to be positively ($p<0.05$) affected by the inclusion of higher proportion mulberry leaf meal. This result is in line with Kandylis *et al*. (2009) who noted it is the high digestibility and excellent level of crude protein make mulberry foliage to be comparable to commercial concentrates for ruminant feeding and production.

5.2.3. In vitro organic matter digestibility

The comparable *in vitro* organic matter digestibility of mulberry with the concentrate mixture makes it a good candidate substituting the costly and less accessible concentrate feeds to supplement the less quality crop residues in ruminant production. The *in vitro* organic matter digestibility results obtained in the current study were relatively higher than the results for *in vitro* digestibility of browse species during wet season (68%) and dry season (72%) reported by Solomon *et al*. (2010). Similarly, Bakshi and Wadhwa (2007) noted that *in vitro* digestibility of mulberry leaves was higher than other forage species. Moreover, Shayo (1997) reported that *in vitro* digestibility of mulberry leaves was 82.1% which is to some extent larger than the current study. The better digestibility of mulberry could be attributed to high CP level and increased concentration of ammonia nitrogen in rumen (Hristov *et al*., 2004). Higher ammonia nitrogen in rumen improves microbial activity and growth of fibrolytic bacteria resulting in more DM digestibility (Griswold *et al*., 2003). The narrow range of *in vitro* organic matter digestibility observed in the current study among the different treatment feeds might be a reflection of similarities in their chemical composition and potential of the mulberry to be comparable with that of concentrate mix.

The NDF content obtained in the current study was in accordance with the results reported by Schmidek *et al*. (2000) and Cheema *et al*. (2011) for multipurpose trees and shrub species.

The threshold level of NDF content in tropical plants beyond which feed intake of ruminants is affected is 60% (Meissner *et al*., 1991). Tree forages with a low NDF concentration (20–35%) are usually of great digestibility (Bakshi and Wadhwa, 2007). Therefore, the NDF (37.98%) value obtained in the present experiment could be regarded as a medium one. This attribute can induce even greater fermentation rate, therefore, improving its digestibility (Van Soest, 1994).

5.2.4. *In sacco dry matter degradability*

The higher washable materials in T1 than T5 might indicate relatively higher content of dusty and small particles which could easily pass or wash from the bags, rather than a greater solubility. Similarly, Promkot and Wanapat (2003) reported that the result of the rumen bag technique depends on the way the feed is prepared and the pore size of the material from which the bag is made. Unlike the washable materials, the opposite is true in the case of the potential degradation for non-water soluble materials (B). According to Belachew *et al*. (2013), multipurpose trees could be assigned to great (> 450 g/kg DM), medium (400‑450 g/kg DM), and low (< 400 g/kg DM) quality groups based on their ED values. Hence, all the experimental diets in the current study including the mulberry foliage belonged to great quality group. This further clarified the comparable nutritional potential of mulberry foliage with that of concentrate mix and justifies the nutritive potential of mulberry to supplement the less quality cereal crop residues in ruminant feed.

Six hours post incubation; the greatest DM disappearance was recorded for T1 and T2, which have higher proportion of concentrate mix in the diet. Even though DM disappearances of mulberry leaf meal were lower compared to concentrate mix, six hours post incubation; these results were comparable with other multipurpose trees. Belachew *et al*. (2013) noted that six hours post incubation, the greatest DM disappearance was recorded for the leaves of multipurpose trees like *E. capensis* (32.12%) and *M. lanceolata* (32.60%) and the least DM disappearance was determined for *F. sycomorus* (15.82%) and *R. glutinosa* (16.87%) leaves. In the present study, dry matter disappearance increased with rumen incubation time for all experimental feeds. This is in accordance with the findings of Tesema *et al*. (2003),

Lanyasunya *et al*. (2006), Vranic *et al*. (2009) and Lebopa *et al*. (2011) which confirmed that *in sacco* degradation of dry matter increase as incubation time advances.

The obtained results for potentially degradable and rate of degradation are higher than the results reported by Suchitra and Wanapat (2008) whereas, the washable (39.2), potential degradability (84.7), and effective degradability (64.2) values were higher than the values obtained in the current study. The rate of degradations obtained in the current study (0.084 to 0.090) was higher than most of the multipurpose trees reported by Belachew *et al*. (2013) and to some extent it is in accordance with that of Suchitra and Wanapat (2008). Belachew *et al*. (2013) reported that the rate of degradation for cassava hay (0.086) was highest compared to the other treatments resulting in low gut fill which could lead to higher intake and animal production. In short, the amount of dry matter found degraded in all tested feeds at 12 and 24 hours was more than 50 % and 66 %, respectively, which implied that they were all greatly degradable in the rumen.

5.2.5. Feed intake

The higher total dry matter intake observed when sole mulberry leaf meal was supplemented might be associated with improved rumen fermentation and rate of digestion without affecting cellulolytic rumen micro-organisms. This idea is consistent with the results reported by Van Soest (1994) who noted that improvement in dietary protein supplementation is due to an increase in nitrogen supply to the rumen microorganisms. This leads to an increase in microbial population and efficiency, thereby enhancing the rate of breakdown of the digesta which eventually leads to feed intake. Hence, the sole mulberry inclusion improved dry matter intake as compared to the whole concentrates mixture suggesting the potential of mulberry leaf meal in improving intake. In line with the current study, Atiso *et al*. (2012) also reported that increasing total DM intake with substitution of 50% of mulberry leaves for concentrate mix compared to sole concentrate mixture supplementation in dairy cows. The increased NDF and ADF intake as the proportion of mulberry leaf meal increases obtained in the current study suggests the relatively increased barley straw intake observed. Moreover, the sole mulberry leaf meal supplemented lambs gained significantly (p<0.05) higher metabolizable

energy than those with whole concentrate diet groups, reflecting higher digestible organic matter consumed by the lambs supplemented with sole mulberry leaf meal. According to Nguyen *et al*. (2005) and Doran *et al*. (2007), high nutritive value of mulberry forage has been recognized, and such attributes are sometimes comparable to conventional protein sources used in livestock feeding systems like soybean or alfalfa.

The high nutritive value of mulberry forage and the potential of this excellent alternative protein source forage for animal feeding in the tropics were largely discussed by González-García and Martín (2016). Mulberry forage banks respond to the objectives of looking for local animal production systems with self-sufficiency in forage production that align with whole-farm systems and address natural resource management issues such as organic matter recycling and other life cycle processes (González-García and Martín, 2016). The same author further noted positive animal responses have been obtained across different animal physiological or productive stages, both in meat (beef cattle, sheep and goats) and dairy (cattle, goats) production purposes.

5.2.6. Body weight gain and feed conversion efficiency

The improved final weight, body weight change and average daily gain when concentrate was partially or fully substituted by mulberry leaf meal were attributed to the differences in digestibility and intake of DM as well as OM observed. Rubanza *et al*. (2007) also indicated a better growth performance when meals of forage trees like *A. nilotica, A. polyacantha* and *L. leucocephala* were supplemented in combination with other concentrates for goats that is in support of the current finding. Similarly, Arece-García *et al*. (2017) reported that the differences found in dry matter intake could be the indirect resultant of the differences in the energy feed sources offered to each group, i.e. different energy pools coming from concentrate and/or mulberry. In line with the present finding, diet supplementation with mulberry leaves has been reported to lead in increased body weight gains in growing lambs (Benavides, 2000) and growing goats (Gonzalez and Milera., 2000). Moreover, Ba *et al*. (2005) also found that milk production increased with the levels of mulberry offered to goats. Benavides *et al*. (2000) also observed no difference in milk yield among groups of grazing

dairy cattle supplemented with either concentrate or mulberry leaves. Additionally, replacing the mulberry for soybean meal in diets for dairy cows did not affect milk yield or quality (Pham *et al*. 2007) and positive results including different levels of mulberry have been reported by others in the feeding of sheep (Pacheco *et al*. 2002).

5.2.7. Carcass characteristics

The higher slaughter weight and empty weight as a result of sole mulberry leaf meal as compared to the whole concentrate mix as well as the comparable dressing percentage on empty body weight base and dressed hot carcass weight across the different treatments might justify the potential of mulberry leaf meal to replace partially or fully the commercial concentrate mixture. Dressing percentage based on empty body weight (54.4-56.8 %) obtained in this study was comparable to 53-57% (Emebet, 2008), 53-56.3% (Abebe, 2011) and 55.7-56.4% (Hagos, 2011). However, Zemichael (2007) and Neamn (2011) reported lower results of dressing percentage based on empty body weight of 47-53% and 48.6-50%, respectively than the current study.

The dressing percentage based on slaughter weight obtained in the current study was similar with the values (47.3-48.6%) for Tigray highland sheep reported by Amare *et al*. (2009). Nevertheless, lower results of dressing percentages of 36-38.4%, 39.5-43.4%, 32-38% and 38-39.6% on slaughter weight basis than the current study were reported by Mulu (2005) for Wogera sheep, Zemichael (2007) for Arado sheep as well as Neamn (2011) and Gebretinsae (2011) for local sheep, respectively. Generally, the variations in carcass traits in this study and other results of previous studies might be due to variations in age and breed of sheep, and quantity and quality of basal and supplement feeds used during the experiment. In agreement with this, McDonald *et al*. (2010) noted that, nutrition, age, sex, genetics, season and other related factors affect the growth and carcass traits of animals.

Rib-eye muscle area is an indicator of muscling and amount of lean meat in the carcass. The rib-eye muscle area obtained in the current study was comparable with 8.2-10.4, 6.3-9.2 and 8.6-9.5cm^2 reported by Emebet (2008), Amare *et al*. (2009) and Abebe (2011) for

supplemented groups of Arsi-Bale sheep, Tigray Highland sheep and Black Head Ogaden sheep, respectively. Lower values of rib-eye muscle area than the present study were reported by Hagos (2011) (5.7-6.4 cm^2) and Desta *et al*. (2017) (8.43-8.98 cm^2) for Tigray Highland sheep and yearling intact male Abergelle sheep, respectively. The differences in rib-eye muscle area reported by various authors might be due to variations in the amount and quality of supplements and variations in sheep breeds used for the experiment. Rib-eye muscle area is affected by the weight and muscularity of the live animal (O'Rourke *et al*., 2004) and it is increased with carcass weight (Park *et al*., 2002), to which the results of the current finding agreed.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The study was conducted to assess the existing husbandry practices of sheep and goats in Eastern Tigray and evaluate effects of partial or full substitution of mulberry leaf meal for concentrate mix on chemical composition, dry matter and nutrient digestibility, *in sacco* dry matter degradability, dry matter and nutrient intake and body weight gain and carcass traits of Tigray highland lambs fed based on barley straw. Hence, thirty intact yearlings Tigray highland male lambs with average initial body weights of 17.8±0.95 kg were used for the experiment. Five dietary treatments with different proportions of mulberry leaf meal as a replacement to concentrate mix at iso-nitrogenous level were employed. The concentrate mix was prepared from noug seed cake and wheat bran at ratio of 1:2, respectively. Lambs had free access to salt and water. After the quarantine period and fifteen days of adaptation period digestibility trial and feeding trial were conducted for seven and ninety days, respectively with measurements of carcass parameters at the end. Chemical composition of feed and feces, and *in vitro* organic matter digestibility as well as *in sacco* dry matter degradability were also determined.

The survey result indicated that higher proportions of respondents were used crop-residues, improved forages and commercially purchased feeds in the highland as compared to respondents from the lowland. Cactus also played an important role in filling the gap when other feed resources become limited. The lower utilization of conserved feed resources across all the surveyed agro-ecologies indicated the limited adoption and practice of feed conservation in the form of hay and silage across all the surveyed agro-ecological zones. The study also showed the presence of different preferences for sheep and goats, livestock holdings and constraints of sheep and goat production in highland, midland and lowland agro-ecological zones. This implies that any development interventions aimed at improving the productivity of sheep and goats and thereby enhance the livelihood of smallholder farmers should be planned and implemented in relation to agro-ecological zones. Feed shortage both in quality and quantity throughout the year was the top ranked reason hindering productivity of sheep and goats in the study area. Respondents showed interest to supplement their sheep

and goats with concentrate supplements. However, less accessibility and high cost were the most important restraining factors that impede them from purchasing the concentrate supplements. Searching for other potential alternative feed resources which could be accessible to rural farmers is very crucial.

The results obtained from the experimental study indicated that substitution of concentrate mix (CM) with mulberry leaf meal significantly increased the intakes of total DM, OM, NDF and ADF. Similarly, the digestibility of DM, OM, NDF and ADF were also significantly increased in sole mulberry leaf meal (MLM) supplemented groups. Mulberry leaf meal by virtue of having high crude protein, good Ca to P ratio, promising digestibility and rate degradation as well as extent of degradation was as good as the concentrate mix. Comparable *IVOMD* as well as extent and rate of degradability results were also obtained between sole mulberry leaf meal and sole concentrate mix. Moreover, lambs showed high responses in growth performance parameters as well as carcass characteristics when supplemented with larger proportion of mulberry leaf meal. Similar growth performance and carcass characteristics were obtained among T3 (150 g CM: 173.1 g MLM), T4 (75 g CM: 259.7 g MLM) and T5 (sole MLM). Hence, farmers can use either of these proportions based on their access and price to the ingredients. It has been also observed during the survey period that, mulberry was planted as a hedge, at farm boundaries, in nurseries and planted on contour to curb soil erosion. So, it could easily be available in the vicinity of the farmers and provide large quantity of foliage to fill the feed scarcity gap particularly during the dry season. Therefore, the result of the present study indicated that, mulberry leaf meal could effectively be used as a supplement to poor quality roughage diets without affecting the performance of lambs that can be achieved by sole concentrate mixture supplementation and could potentially substitute the costly and not easily accessible protein concentrates by rural farmers in Ethiopia.

6.2. Recommendations

Based on the above conclusion, the following recommendations are forwarded:

- This study showed the differences existed in the motives of keeping small ruminants, land holding, level of education, major feed resources and watering. Therefore, the development intervention should tailor to the specific need of the farmers in each agro-ecology.
- Promoting and utilizing mulberry foliage could greatly enhance food security for communities owning small ruminants and would effectively substitute the introduced fodder trees, like *A. saligna* that have been observed encroaching the enclosure areas and that have been reported to be short lived and less palatable due to its high content in anti-nutritional factors.
- Considering the potential of mulberry in terms of its CP, mineral matter contents, palatability and digestibility, mulberry should be regarded as a suitable candidate for further development as feed resources.
- The effect of mulberry foliage feeding on meat quality (both sensory evaluation as well as detailed laboratory tests) should be undertaken on top of its potential to supplement the poor quality roughage feeds.
- Large scale on farm studies are needed to substantiate the controlled on station experiments.
- There is also a need to conduct detailed research to figure out the effect of integrating mulberry plant with other food crops.
- Availability, biomass production and farmers' perception on feeding value of mulberry foliage should be evaluated in Ethiopia at large and Tigray in particular.

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8. APPENDICES

Appendix 1. Questionnaire used

1. Background information

1.1. Name of the household head ----------

1.2. Sex of the respondent: 1. Male 2. Female

1.3. Age of respondent: -------

1.4. Education: 1. Illiterates 2. < 8^{th} grade 3. 10^{th} grade complete

4. 12^{th} grade complete

1.5. Occupation: 1. Farmer 2. Business man

3. Government employs 4. Retired person

1.6. Marital status: 1. Yes 2. No

1.6. Address 1.6.1. Woreda ---------- 1.6.2. Tabia ----------

1.7. Religion (circle one) 1= Muslim 2= Orthodox 3.Catholic

1.8. Agro-ecology (circle) 1. Highland 2. Midland 3. Lowland

1.9. Family size by age and sex (enter number in the boxes)

	Children (<18)	Adult (>18)
Males		
Females		

110. Indicate the major sources of income (Rnak in order of their importance)

Income sources	Rank
Crop	
Livestock	
Off farm activities	
If others, specify	

Land holding in Timad ----------

2. Management practices

2.1. Livestock composition

Fill the following table for the total number of different animals owned by family

(put number in the boxes)

Type of animal owned	Number	Type of animal owned	Number
Cattle		Chickens	
Sheep		Bee colony	
Goat		Equines	

2.2. Livestock species preference

Rank your preference for cattle, sheep and goat in order of their importance

Livestock species	Rank
Cattle	
Sheep	
Goat	

2.3. Purpose of keeping sheep and goats

For what purpose do you keep sheep and goats? (Rank them in order of their importance)

Purpose	Rank
Immediate source of Income/sell	
Saving as live animal	
Manure	
Home consumption	
Others (specify)	

2.4. Sources of sheep and goat for establishment

What were your Sources of sheep and goat for establishment? (Circle one)

1= Gift/Bride price 2 =market/purchase 3= Government 4=NGO/Project 5=others

_____

2.5. Sheep and goat flock structure

Fill the following table for age and sex structure of sheep and goats owned by the family

Flock category	Age category		
	Kids/lambs	Young	Adults

		0-4 months	4 months – 1 years	(above 1 year)
Sheep	Male			
	Female			
Goat	Male			
	Female			

2.6. Relative importance of keeping sheep and goats

What are the importance of rearing sheep and goat compared to other livestock (cattle)? (Rank them in order of their importance)

Variables	Rank
Consume less feed	
Fast reproduction rate	
Multiple births	
Low investment cost	
High resistance to disease	
High resistance to draught	
High market demand	
Others (specify)	

2.7. Feed Resources and Feeding

2.7.1. What are the main feed resources for sheep and goat during dry and wet season? (Tick one or more).

Source of feed	Wet season	Dry season
Grazing on natural grazing lands		
Aftermath		
Hay		
Straws		
wheat bran		
Improved Forage (sesbania, Lucenia, cowpea, pigeon)		

'*Atela*'		
Indigenous Plants(shrub , bushes , trees , pods)/		
Others (specify)		

2.7.2. Do you use purchased feeds for sheep and goat? (Circle one) 1= Yes 2= No

2.7.2.1. If yes for the above question, what type of purchased feeds do you use?

2.7.2.2. If no, what are the reasons? (Circle one) 1= unavailable 2= high cost 3= not aware 4= sheep and goat don't require purchased feeds 5=other (specify)

2.7.3. If you use supplemental feeding, is there any difference by type/classes of sheep and goat while offering supplemental feeds? (Circle one) 1=Yes 2= No

2.7.3.1. If your answer is yes for the above equation, for which type of sheep and goat do you give priority for supplemental feeding ----------

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2.7.4. Have you allocated farm land for growing forage crops? (Circle one) 1= Yes 2= No

2.7.4.1. If yes for the above question fill the following table

	Type of forage plant /crop grown	Unit (put in terms of number of plants or hectare)
1		
2		
3		
4		

2.7.4.2. If you are not growing improved forage plants/crops, what are your reasons? -----

1. Land problem 2. Lack of planting materials 3. Water shortage 4. Seed 5. Less awareness

2.7.5. Do you use communal grazing land? (Circle one) 1. Yes 2. No

2.7.6. Which grazing/feeding type do you practice during dry and wet season for sheep and goat? (Tick one or more)

Type of grazing	Herded	Un-herded	Tethering	Cut and carry/Zero grazing	Others (specify)

Dry season					
Wet season					

2.7.7. Are sheep and goat grazed/ fed with other animals (cattle, horse and donkey)? (Circle one) 1= Yes 2= No

2.7.8. Are kids and lambs graze/ fed with adult sheep and goat? (Circle one) 1. Yes 2= No

2.7.9. Do you practice fattening of small ruminants? 1. Yes 2. No

2.7.9. 1. If yes, which feeding practice you normally use when fattening sheep and goats? (Tick one or more)

No.	Feeding systems	Tick (√)
1	Stall feeding for the whole fattening period	
2	Grazing plus household wastes	
3	Grazing plus feeding supplements like industrial by products	
4	Others (Specify)	

2.7.9. 2.If your answer is no, for question no 2.2.1 what are the reasons? (Circle one or more)

1= lack of know-how 2= lack of market 3= lack of money

4 = lack of supplementary feeds for fattening 5 = other (specify)

2.7.9. 3.How long sheep and goats are fed during fattening? (Circle one)

1= two month 2=three month 3= four month 4= five or six month 5= other (specify)

2.7.9. 4.How do you manage fattened sheep and goats? (Circle one)

1= isolated from other herds 2= with other livestock

3= kept in and around homestead in the day times 4=other (specify) ----------

2.7.9. 5.What criteria do you use to select sheep and goat for fattening? ----------

2.7.9. 6. When are your critical feed shortage seasons? (Tick one or more)

No.	Critical feed shortage seasons	Tick (√)
1	Autumn (September - November)	
2	Winter (December - February)	
3	Spring (March - May)	
4	Summer (Jun - August)	

2.7.9. 7. What are the coping strategies to the critical feed shortage seasons? (Tick one or more)

No.	Coping strategies	Tick (√)
1	Destocking	
2	Purchasing feed	
3	Conserving feed	
4	Giving feed in small quantity	
5	Feeding cactus	

2.8. WATERING

2.8.1.What are the major water sources for your sheep and goat? (Tick one or more)

Season	Borehole	Dam/pond	River	Spring	Pipe wate	Rainwater
Dry						
Rainy						

2.8.2. How far is the watering point for sheep and goat from your home during dry and wet season? (Tick one)

Distance	Watered at home	<1km	1-5 km	6-10km	>10km
Dry					
Rainy					

2.8.3. What is the frequency of watering during dry season? (Tick one)

1. Freely available 2. Once a day 3. Once in 2 days 4. Once in 3 days 5.Other (specify) ----------

2.9. HOUSING

2.9.1. How do you house them? (Circle one)
1=they share the same house with the family house 2=they have separate house 3=with other animals 4= others (specify)

2.9.2. Do you give priority while housing sheep and goat by sex and age during dry and wet season? (Circle one) 1=Yes 2= No

2.9.3. If yes, which classes of sheep and goat get priority in housing during dry and wet season?

2.9.4. Are sheep and goats housed with other livestock species (cattle and equines)? (Circle one) 1=Yes 2= No

2.10. **Breeding management and castration practices**

2.10.1. What is your source of ram/buck for mating? (Tick one or more)

No.	Source	Ram	Buck
1	Own Breed		
2	Bought		
3	Donated		
4	Borrowed		
5	Neighboring		
6	Other(specify)		

2.10.2. What type of mating do you use? (Circle one) 1. Control 2. Uncontrolled

2.10.3. If you use controlled type of mating, what is your reason for using it? ----------

---

2.10.4. What criteria do you use to select breeding ram and buck? (Tick one or more)

No.	Criteria	Ram	Buck
1	Conformation		
2	Color		
3	Horns		
4	character/Temperament		
5	Availability		
6	Other(specify)		

2.10.5. At what season do you mostly breed your ewes/does? (Circle one)

1. Rain season 2. Dry season 3. Though out the year

2.10.6. Do you practice castration of sheep? (Circle one) 1. Yes 2. No

2.10.7. Do you practice castration of goat? Circle one) 1. Yes 2. No

2.10.8. Which methods of castration do you practiced? (Circle one)

No.	Method of castration	Reason for using it
	1=Traditional	
	2=Modern (specify the name of modern castration method)	
	3=both	

2.10.9. At what age do you castrate sheep and goat? (Tick one) age do you castrate sheep and goat? (Tick one)

	Age of castration			Other
	< 6 months	6-12 months	> 1 year	
Male sheep				
Male goat				

2.10.10. What are your reasons for castrating sheep and goat? (Rank them)

Reasons	Rank
Better Price	
Controlled Breeding	
Better Character /to tame them	
Others (Specify)	

3. MARKETING

3.1. What are sheep and goat selling outlets/channels? (Circle one or more)

1= Consumers 2= Neighbor 3= Trader 4= Butcher/restaurant 5= Institutions 6= other,

3.2. How do you sell sheep and goats in the market? (Circle one or more)

1=through negotiation 2=through brokers 3 =other (specify) ----

3.3. What is the market distance from your home?

No.	Market Area	Distance in hr/km	
		Km	Hours
1			
2			
3			

3.4. What grading criteria do you use during sheep and goat marketing? (Rank the best three grading criteria's)

No.	Criteria	Rank
1	Size	
2	Color	
3	Age	
4	Fatness	
5	Weight	
6	No grading	
7	Others (Specify)	

3.5. What are the major problems related to sheep and goat marketing? (Prioritize by their importance)

No.	Problems	Rank
1	Seasonal fluctuations	
2	Lack of market outlets /channels	
3	Low price	
4	Distance of markets	
5	Interference of broker	
6	Others (Specify)	

3.6. When do you usually slaughter sheep and goats for home consumption? Circle one or more)

1. Religious holidays 2. Religious festivities/rituals 3. Wedding 4. Births in family 5. For guests 6. others, specify

3.7. Which sex of sheep and goats you usually slaughter? 1. Male 2. Female

4. Sheep and goat production constraints

4.1. What are the major constraints/ problems that affect your sheep and goats production activity? *(Rank them by their importance)*

No.	Constraint/ problems	Rank
1	Shortage of feed	
2	Health problem	
3	Scarcity of labor	
4	Predator	
5	Water scarcity	
6	Market problem	
7	Lack of shelter	
8	Drought problem	
9	Poor Extension service	
10	Others (Specify)	

4.2. What do you suggest the solutions to the above top five problems of sheep and goat production?

Appendix 2. List of Appendix Tables

Table 1. Flock structure of sheep across the study agro-ecological zones (%)

	Highland		Midland		Lowland	
Variable	Male	Female	Male	Female	Male	Female
Lambs <6 month	8.6	11.0	8.6	7.5	8.7	15.9
Lambs 6 -1year	7.4	8.0	6.3	8.4	5.9	10.2
Adults 1 - 2 years	6	15	7	11	5	13
> 2 years old	5.7	38.2	6.6	44.6	5.8	35.5

Table 2. Flock structure of goats across the study agro-ecological zones (%)

Variable	Highland		Midland		Lowland	
	Male	Female	Male	Female	Male	Female
Kids <6 month	8.1	11.1	11.7	12.2	10.6	10.9
Kids 6-1year	6.1	10.1	5.4	5.4	6.7	6.1
Adults 1-2 years	5.1	11.1	5.0	10.4	4.8	10.9
> 2years old	5.1	43.4	4.5	45.5	5.5	44.5

Table 3. Educational status of respondents across the study agro-ecological zones (%)

Variable	Highland	Midland	Lowland
Illiterate	16.7	25.0	31.7
≤ 8^{th} grade	60.0	63.3	61.7
10^{th} grade complete	20.0	10.0	3.3
12^{th} grade complete	3.3	1.7	3.3

Table 4. Age structure of respondents across the study agro-ecological zones (%)

Variable	Highland	Midland	Lowland
20-30	3.3	5.0	6.7
31-40	5.0	8.3	16.7
41-50	48.3	46.7	41.7
51-60	35.0	33.3	26.7
>60	8.3	6.7	8.3

Table 5. *In sacco* dry matter degradability of the different treatment diets in different incubation times

Treatment	Incubation time (hr)						
	0	6	12	24	48	72	96
T1	26.2[a]	38.2[a]	61.3[a]	75.3[a]	76.2[a]	76.6	77.6
T2	26.1[a]	37.2[a]	60.9[a]	75.2[a]	76.4[a]	77.0	77.5
T3	24.1[b]	32.6[b]	61.4[a]	75.1[a]	76.0[a]	76.7	77.0
T4	22.7[c]	30.3[c]	57.0[b]	70.9[b]	72.9[b]	76.2	77.3
T5	22.2[c]	28.1[d]	55.1[b]	66.6[c]	73.9[b]	76.2	77.2

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Figure 1. Mulberry tree in one farmer farm around Adigrat town

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Figure 3. Drying the collected mulberry leaves

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Figure 5. Feeding trial

Figure 6. Hurnesing the lambs for the digestibilty trial

Figure 7. Weighing and feeding the experimental lambs

Figure 8. Collecting and weighing the refused barley straw

Figure 9. Weighing the experimental lambs

Figure 10. Grinding and taking samples of the experimental diets

Figure 11. Rumen fistulated Boran x Holstein Friesian steers used for *in sacco* DM degradability

Published Articles

- **Tesfay G, Tamir B, Berhane G**. (2018). Substitution of mulberry leaf meal on feed intake, body weight and carcass characteristics of Tigray highland lambs. *JITV,* **23** (1): 28-37. DOI: http://dx.doi.org/10.14334/jitv.v23i1.1634

- **Gebrekidan Tesfay, Berhan Tamir, Gebreyohannse Berhane**, (2017). Carcass and non-carcass characteristics of Tigray highland lambs fed mulberry (*Morus alba*) leaf meal at different supplementation levels. *Journal of Scientific and Innovative Research,* **6** (3): 104-109. www.jsirjournal.com

- **Gebrekidan Tesfay, Berhan Tamir, Gebreyohannse Berhane**, (2017). Feeding Value Potential of Mulberry (*Morus alba*) Leaf Meal to Replace Concentrate Mix. *Middle-East J. Sci. Res*., **25** (8): 1630-1637, 2017