CHARACTERIZATION OF PRODUCTION PRACTICES, ASSESSMENT OF VALUE CHAIN AND PERFORMANCE EVALUATION OF ARSI-BALE SHEEP SUPPLEMENTED WITH DIFFERENT PROTEIN SOURCES

PhD DISSERTATION

EYOB GEBREGZIABHEAR ZEMENFESKIDUS

December 2020

HARAMAYA UNIVERSITY, HARAMAYA

Characterization of Production Practices, Assessment of Value Chain and Performance Evaluation of Arsi-Bale Sheep Supplemented with Different Protein Sources

A Dissertation Submitted to the School of Animal and Range Sciences
(Postgraduate Program Directorate)
HARAMAYA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of
DOCTOR OF PHILOSOPHY IN TROPICAL ANIMAL PRODUCTION

EYOB GEBREGZIABHEAR ZEMENFESKIDUS

December 2020
Haramaya University, Haramaya

HARAMAYA UNIVERSITY
POSTGRADUATE PROGRAM DIRECTORATE

We hereby certify that we have read and evaluated this dissertation titled ***"Characterization of Production Practices, Assessment of Value Chain and Performance Evaluation of Arsi-Bale Sheep Supplemented with Different Protein Sources"*** prepared under our guidance by Eyob Gebregziabhear Zemenfeskidus. We recommend that it be submitted as fulfilling the dissertation requirement.

Mengistu Urge (Professor, PhD)		
Chairman, Advisory Committee	Signature	Date
Mengistu Ketema (Professor, PhD)		
Member, Advisory Committee	Signature	Date
Getachew Animut (PhD)		
Member, Advisory Committee	Signature	Date

As members of the Board of Examiners of the PhD Dissertation Open Defense Examination, we certify that we have read and evaluated the dissertation prepared by **Eyob Gebregziabhear** and examined the candidate. We recommend that the dissertation be accepted as fulfilling the dissertation requirements for the Degree of Doctor of Philosophy in Tropical Animal Production.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date

Final approval and acceptance of the dissertation is contingent upon the submission of its final copy to the Council of the Postgraduate Program (CPGP) through the candidate`s Department or School Graduate Committee (DGC or SGC).

DEDICATION

This dissertation is dedicated to my beloved mother W/ro Mulu Gebrehiwot and my sister who passed away before I joined Haramaya University for my PhD. My mother's love, proper guidance and support since my childhood contributed a lot in my career and day to day life.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this dissertation is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this dissertation. Any scholarly matter that is included in the dissertation has been given recognition through citation. This dissertation is submitted in partial fulfillment of the requirement for a PhD degree at Haramaya University. The dissertation is deposited in Haramaya University Library and is made available to borrowers under the rules of the Library. I solemnly declare that this dissertation has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Brief quotations from this dissertation may be made without special permission provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from, or reproduction of this dissertation in whole or in part may be granted by the Head of the School or Department when in his or her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the dissertation.

Name: Eyob Gebregziabhear Zemenfeskidus

Signature: _____

Date: December 2020

Place: Haramaya University, Haramaya

School: Animal and Range Sciences

BIOGRAPHICAL SKETCH

The author, Eyob Gebregziabhear, was born in 1976 in Addis Ababa. He completed his elementary and high school education in Dejazmach Bekele Weya Elementary School and Addis Ketema Senior Secondary High School, respectively in Addis Ababa. In 1996, he graduated in Animal Science from the then Alemaya Agricultural University. After graduation he worked in Ministry of Water Resources as a Livestock Expert in the Master Plan Project of Tekeze river basin for six months and in Ministry of Agriculture in Amhara Region (Antsokia-Gemeza, Shoa Robit and Ginager) Districts as a Livestock Expert, Animal Production and Forage Development Sub- team Leader and Animal Production and Health Desk Leader. Then he joined the Federal Agricultural Technical, Vocational, Educational Training (ATVET) and worked as Animal Science Senior Instructor in Bekoji, Agarfa and Assosa Colleges. After serving for nine years, he joined the School of Graduate Studies of Haramaya University in 2007 and graduated with Master of Sciences (MSc) in the field of Animal Production in 2010. Upon completion of his MSc study, the author was reinstated by Assosa and Alagie ATVET colleges and served as Senior Instructor until end of October 2011. He then employed as associate researcher in Ethiopian Institute of Agricultural Research (EIAR) in December 2011, from where he has given the opportunity to pursue his PhD study at Haramaya University, School of Animal and Range Sciences majoring in Tropical Animal Production (Meat stream) as of October, 2015.

ACKNOWLEDGEMENTS

"I know that thou canst do every [thing and [that] no thought can be withholden from thee". Job 42: 2.

I would like to thank the Almighty God with his mother Holy Saint Virgin Mary, the most Gracious and the most Beneficent, who enabled me to reach this point and for kind-hearted help in all aspects of my life.

My deep appreciation and special gratitude goes to my esteemed advisor Professor Mengistu Urge for his unlimited professional support all the way from the inception of the study through the writing up of this Dissertation. I am highly indebted for his encouragement, thoughtful evaluation and critical comments. My thanks and appreciation also goes to my co-advisors Dr. Getachew Animut and Professor, Dr. Mengistu Ketema who guided me during proposal write up and preparation of the dissertation. I am also grateful to Dr. Driba Geleti, Dr. Solomon Chanyalew, Dr Mekasha Chychaybelu, Worknesh Seid and Dr. Tekleab Serkebrhan for their exemplary help, which I can't express in words.

I would like to express my sincere gratitude to Ethiopia Institute Agricultural Research (EIAR) and Debre Zeiet Agricultural Research Center (DZARC) for supporting my study and providing me study leave. I must also thank AGP II and Haramaya University for supplementary fund and the latter one giving me the opportunity to join the postgraduate program and creating conducive environment and accommodation. Thanks to staff members of Debre ZeietAgricutural Research Center and laboratory technicians.

I am highly grateful for Digelu-Tijo and Meiso livestock production office experts, development agents and smallholder sheep producers in Digelu Tijo, and Meiso town study areas, who participated in facilitating, data gathering and providing information during the survey work. I would like to express my deepest thanks to my family. Words cannot express how grateful I am to my wife Kidest Solomon who filled the gaps I had and took all the responsibilities in managing our children (Nahom Eyob and Ananya Eyob) during my long absence of the study period. Without your love, patience and encouragement, this study wouldn't have been successful.

ACRONYMS AND ABBREVIATIONS

ADF	Acid Detergent Fiber
ADG	Average Daily Gain
AOAC	Association of Official Analytical Chemists
BW	Body Weight
CP	Crude Protein
CSC	Cottonseed Cake
DM	Dry Matter
DMI	Dry Matter Intake
DOM	Digestible Organic Matter
DP	Dressing Percentage
EBW	Empty Body Weight
FBW	Final Body Weight
FCE	Feed Conversion Efficiency
FWG	Final Weight Gain
GMMP	Gross Market Margin Products
HCW	Hot Carcass Weight
HHs	Households
IBW	Initial Body Weight
LDM	*Longissimus Dorsi Muscle*
LSC	Linseed Cake
LSP	Livestock Production
masl	Meters Above Sea Level
ME	Metabolizable Energy
NDF	Neutral Detergent Fiber
NI	Net Income
NSC	Noug Seed Cake
OM	Organic Matter
REM	Rib Eye-Muscle
SAS	Statistical Analysis System

SBC	Soybean cake
SBW	Slaughter Body Weight
SEM	Standard Error of Mean
SPSS	Statistical Package for Social Science
TDM	Total Dry Matter
TDN	Total Digestible Nutrient
TEO	Total Edible Offal
TMCC	Total Main Carcass Component
TNEO	Total Non-Edible Offal
TR	Total Return
TVC	Total Variable Cost
WB	Wheat Bran

Table of Contents

LIST OF MANUSCRIPTS IN THE APPENDICES

This PhD dissertation is based on the following three papers (Articles/manuscripts).

1. Characterization of Sheep Production Practices in mixed crop-livestock and Agro-pastoral systems of central and Eastern Ethiopia **(Published in East African Journal of Veterinary and Animal Sciences (EAJVAS), Vol. 3 (1).**

2. Analysis of Sheep Value Chain in Central and Eastern Ethiopia **(Accepted for publication in African Journal of Agricultural Research (AJAR)**.

3. Evaluation of different oilseed cakes on feed intake, digestibility, live weight changes and carcass characteristics of Arsi-Bale sheep. **(Accepted for publication in Scientific Research Publishing Ms. No. 3003049).**

Characterization of Production Practices, Assessment of Value Chain and Performance Evaluation of Arsi-Bale Sheep Supplemented with Different Protein Sources

GENERAL ABSTRACT

The study contains two surveys and one experimental activity. The surveys were conducted to generate baseline information on mixed crop-livestock and agro-pastoral sheep production management, fattening practices and sheep value chain analysis in Digelu-Tijo and Meiso districts of Central and eastern Oromia National Region State, respectively. A total of 150 households (75 mixed crop-livestock and 75 agro-pastorals) were interviewed using structured questionnaire. Focus group discussion, key informant interview and field observation were used to collect primary data. The on station experimental study was conducted in Debre Zeit Agricultural Research Center with the objective to evaluate the feedlot performance of Arsi-Bale sheep supplemented with compound ration based on different oilseed cakes. Twenty eight yearling sheep with initial body weight of 17.56±0.34 kg (mean ± SD) were used. A randomized complete block design was employed. Basal teff straw was fed ad libitum at a rate of 20% refusal. The study lasted for 90 days of feeding trial and 7 days of digestibility trial and all sheep were slaughtered for evaluation of carcass characteristics. The result of this study indicated the average number of sheep per household in mixed crop-livestock (12.5±0.99) was higher ($p<0.001$) than that of agro-pastoral production system (6.2±0.34). The purposes of keeping sheep in both production systems were to generate income followed by saving, meat, and manure. The age at first sexual maturity, age at first lambing, lambing interval (months), and liter size) were 6.52, 12.21, 12.17 and 1.2 for mixed crop-livestock, and 7.06, 13, 10.68, and 1.04 for agro-pastoral production systems, respectively. The major diseases of sheep in mixed crop-livestock production system were pasteurellosis, sheep pox, and blackleg while liver fluke and lung worm were the major prevalent parasites. Similarly, in agro pastorals pest des petit ruminants (PPR), Orf, pasteurellosis and foot and mouth disease (FMD) were reported as important diseases. Breeding practice in

mixed crop livestock production system was dominated by uncontrolled mating, but about 50% of the agro-pastoral employed variable practices of controlled mating. The sheep value chain analysis identified core functions of the sheep value chain (input supply, production, marketing, processing and consumption), market routes (Addis Ababa, Assela, Modjo, Adama and Methara), and market channels (Small traders, Big traders, Butchers and Hotels, and Consumers). About 75% and 72% share of the final price reach producers for hotel and butchers, respectively. Major market constraints include over tax, inconsistence supply of sheep, inhibition of live animal export due to disease and informal cross-border export. Dietary treatments for the 3rd study were formulated to be iso-nitrogenous. Treatments were ad libitum feeding of teff straw and supplemented with rations consisting of 36% noug seed cake + 22% maize +42% wheat bran (T1), 40% Linseed cake + 20% maize + 40% wheat bran (T2), 29% cotton seed cake (CSC)+ 24% maize + 47% wheat bran (T3) and 22% soybean cake+26% maize + 52% wheat bran (T4). The basal diet, total DM and OM intake and dressing percentage per metabolic body weight were higher ($p<0.001$) in T2 and T3 as compared to T4 and T1. NDF and ADF intake were declined ($p<0.001$) in the order of T3<T1<T2<T4. Crude protein intake was higher ($p<0.001$) in the order of T4>T2>T3>T1. There were no significant differences in final body weight (FBW), total weight gain (TWG) and average daily gain (ADG) among T2, T3 and T4 (Table 4), but T1 recorded lower values for all body weight traits. Sheep in T2 and T4 had higher ($P<0.05$) FCE than sheep in T1 and T3. Carcass characteristics measures showed that greater ($p<0.001$) slaughter, empty body, hot carcass weights and rib eye-muscle area and more ($p<0.001$) total non-edible offal components were recorded for T2, T3 and T4 than T1. In conclusion, the survey studies revealed the presence of diverse production and husbandry practices that are constrained by feed limitations, disease and parasite problems, recurrent drought, shortage of water and market, which need to be considered while designing and implementing sustainable sheep production improvement programs in both production systems. Results of the experimental study highlighted the need for supplementation of teff straw to Arsi-Bale sheep. The supplements considered in this study could be recommended in the order of: cotton seed cake > soybean cake >linseed cake > noug seed cake. Based on the results of the 3rd study the three protein sources (SBC, CSC and LSC) had a comparable nutritional

value. The 3rd study highlighted that CSC due to its effect of lowering production cost, to be a good input in buffering the increasing cost of production on relatively lower capital owning farmers. Therefore, CSC could be concluded that to serve as alternate supplement in teff straw based feeding of Arsi-Bale sheep.

Keywords: Carcass composition, feedlot, meat quality, partial budget, peri-urban, production constraints, sheep fattening.

1. GENERAL INTRODUCTION

Livestock is an integral component of the agricultural activities in Ethiopia. It contributes about 17% of the GDP, 39-49% of the agricultural GDP and 16–19% of the foreign exchange earnings of the country (Shapiro *et al*., 2017). Currently, livestock is one of the fastest growing agricultural subsectors in developing countries. From economic point of view, about 70 percent of the cost of animal production in Ethiopia is feed suggesting economic feasibility of animal agriculture is mainly a function of quantity and quality of nutrients and the science of feeding (Seyoum *et al*., 2018). As is the case for other growing economies, the demand for livestock commodities in Ethiopia is rapidly growing. Compared to the production base year of 2014/15 with estimated 167million liters of milk, 1.3 million tons of red meat and 419 million eggs, the projected demand is expected to be 1490 million liters of milk, 1.9 million tons of red meat and 3.9 billion eggs by 2020 (Shapiro *et al*., 2015). Thus, commercial feed sector in Ethiopia should take advantage of the global and the country's economic growth and the increased future for animal source food consumption.

Among the livestock species, sheep are the second most important species in Ethiopia (Solomon *et al*., 2013). Currently, Ethiopia is a home for about 33.02 million sheep (CSA, 2019) and harbors a huge and genetically diversified sheep population, which are considered as an important asset for the present and future livelihoods of the large rural poor farmers in terms of financial income, food and non-food products, and socio-economic and cultural functions (Asresu *et al*., 2013).

Livestock production system is defined as a group of farm operations with approximately the same characteristics of climatic conditions and farming practices (i.e. the combination of land/herd, labor and capital) (Shapiro *et al*., 2017). The same author reported that classification by production systems is critical, because interventions (i.e. improvements in animal health, feeding) are strongly livestock system specific. In Ethiopia, various categories of sheep production systems are practiced, namely highland sheep-barley system, mixed crop-livestock system, pastoral and agro-pastoral production system, ranching, and urban and peri-

urban (UPU) sheep production system (Solomon *et al.*, 2008). Although the sheep production systems in the country is well defined, the systems lack up-to-date and location specific information regarding production practices, constraints, and marketing strategy. Moreover, the vibrant nature of livelihood, agro-ecology, level of input, intensity of production, reliability of crop production, availability of land, and type of commodity produced require dynamic information. Therefore, understanding sheep production practices under the different production systems would enable to know the opportunities and constraints prevailing in the system and to design appropriate strategy to lessen the production bottlenecks.

The main idea of value chain is to highlight and map out specific physical commodity flows within a sector, including key stakeholders, through usually confining the analysis to domestic markets and ignoring dynamic adjustments to sector characteristics and relationships (Kaplinsky and Morris, 2001). Value chain approaches have been utilized by development practitioners and researchers alike to capture the interactions of increasingly dynamic markets in developing countries and to examine the inter-relationships between diverse actors involved in all stages of the marketing channel (Giulani *et al.,* 2005; Pietrobelli and Saliola, 2008). Indeed, many development interventions now utilize the value chain approach as an important entry point for engaging smallholder farmers, individually or collectively, in high value export markets (GTZ, 2007).

The present production level of sheep from the widely practiced subsistent type of production systems is far below their potential. Meat production is estimated at about 3.5 kg per sheep per year in the population and 10 kg per sheep slaughtered, which are very low when compared with those in neighboring countries having small ruminant population of 50-75% less than Ethiopia (Amha, 2008). One of the major constraints for such low productivity is lack of good quality and enough feed (CSA, 2018). Sheep responds very well to improved feeding (Gashu *et al*., 2017). Hence, the current production system demands interventions in feeding strategy to enhance animal productivity and meet the increasing demand both for domestic consumption and for the highly competitive export market.

High population growth and urbanization also resulted in reduction of grazing lands (Alemayehu *et al.*, 2017) which may necessitate farmers to consider additional feed options to their livestock. Although feeding and fattening sheep with single or couple of oilseed cakes for economic and social values in North-western Ethiopia is a very long traditional activity of the society (Mengistie *et al*., 2010; Yenesew *et al*., 2013), no comparative performance evaluation of oilseed cakes were done in Arsi-Bale sheep under different feeding regime and there is no information available to recommend for the extension programs and for the preference of consumers.

Therefore, taking the gap into consideration, the studies in this dissertation were designed with the general objective to generate baseline information on sheep production practices and value chain in mixed and agro-pastoral system in the study areas, and to evaluate the performances of Arsi-Bale sheep supplemented with ration based on different oilseed cakes.

Specific Objectives:

1. To assess sheep management practices, productive and reproductive performance and to identify production constraints of sheep.

2. To characterize sheep value chain by identifying major marketing routes, value chain actors, map sheep value chain and distribution of costs and margin of sheep value chain in central and eastern Ethiopia.

3. To investigate feed intake, digestibility, live weight change and carcass characteristics of Arsi-Bale sheep supplemented with ration based on different protein sources.

2. GENERAL BACKGROUND

2.1. Sheep Production Systems in Ethiopia

Various criteria have been used to classify livestock systems, which includes level of integration with crops (intensity of cropping, type and level of crop agriculture practiced, availability of resources, particularly land, water and climate), animal production in relation to land (land-based/grazing, mixed systems and landless/industrial, feedlot systems), contribution of the livestock sector to the total household revenue (income and food), agro-ecological zone and degree of market orientation or intensification and types of livestock species kept, mobility and duration of movement and socio-economic circumstances (awareness and skill, access to inputs and markets), government support (inputs services and policies) (Abegaz *et al*., 2008; Notenbaert *et al*. 2009; Solomon *et al*., 2010; Tolera *et al*., 2012; Solomon *et al.,* 2015). Six major sheep production systems are known to exist in Ethiopia. These include sub-alpine sheep cereal, highland cereal-livestock, highland perennial crop, lowland crop-livestock and pastoral systems.

Most of the small ruminant population of Ethiopia is kept by smallholder farmers and the production system is predominantly extensive and subsistence type that is based on cropping associated with livestock husbandry (Österle *et al*., 2012). Consequently, extensive systems of sheep production share the common characteristics, such as small flock sizes, limited communal and/or private grazing areas, uncontrolled mating, absence of record keeping, low productivity per animal, limited use of improved technology and use of on-farm by-products such as crop residue and stubble grazing as major feed resource rather than purchased inputs (Solomon, 2008). This system is generally found in areas where the altitude ranges between 1500 and 3000 m.a.s.l. (Birhan and Adugna, 2014). The area has adequate rainfall and moderate temperature and it is thus suitable for grain production. The integration of crops and livestock is high in most areas of such systems (Driba, 2014). The mixed crop-livestock system covers the whole region in the highlands of Ethiopia (Solomon *et al.,* 2015).

In Ethiopia, agro-pastoralism is the main mode of production in the sub-moist/moist lowlands or arid and semi-arid agro–ecological zones. Crop and livestock production are both important activities in the areas and the system is either transhumant or sedentary (Solomon *et al.,* 2010). Under this system, sheep are kept often in mixed flocks with goat, freely grazing or browsing in the rangelands. Agro-pastoral system is characterized by less integration with crop production as compared to the crop–livestock production systems. Crop failure is a common feature because of unreliable rainfall and frequent drought. Thus, livestock production remains to be the main means of livelihood. Hence, more emphasis should be given to improving livestock productivity and proper management of the rangelands (Adugna and Aster, 2007). The pastoral production system is based on extensive communal grazing production systems which is based largely on range, primarily using natural vegetation (Asfaw *et al.,* 2011)..

Unlike the other sheep production systems, ranching and urban-peri-urban (UPU) production systems are not currently practiced widely, but growing with a future market oriented production potential, mainly due to a relatively better management applied, with semi-intensive and intensive management approaches being virtually exercised and driven by the increased demand of livestock products, income growth and urban expansion in the country (Solomon *et al.,* 2008). According to Moti *et al.* (2009) subsistence agriculture may not be a viable activity to ensure sustainable household food security and welfare; rather commercialization of smallholder agriculture is an indispensable pathway towards economic growth and development for developing countries that are relying on the agricultural sector, implying that these sheep production system may increase in the future.

There are differences in the production objectives of sheep keepers in different production systems. The primary sheep production objectives of smallholder farmers in mixed crop-livestock production systems are as regular sources of income, meat and manure production (Tesfaye *et al.*, 2010), whereas Afar pastoralists primarily keep sheep for their milk followed by meat production and income generation (Solomon *et al.,* 2013).

2.2. Socio-Economic Importance of Sheep Production

Ethiopia has diversified and adapted indigenous sheep populations parallel to its diverse agro-ecology, ethnic communities and production systems. Hence, sheep production in the country depends on indigenous breeds of sheep except Awassi-Menz cross-breeds that contribute less than 1% of the population (Markos *et al.,* 2006). Currently, Ethiopia own an estimated 33.02 million sheep (CSA, 2019) and about 14 traditionally recognized sheep populations or types which habitat ranges from highland to lowland environments (Solomon, 2008).

In spite of the low level of productivity per animal due to several technical (genotype, feeding and animal health), institutional, environmental and infrastructural constraints, indigenous sheep breeds have great potential in contributing more to the livelihood of the people in low-input smallholder crop-livestock and pastoral production systems (Kosgey and Okeyo, 2007). Sheep significantly contributes towards the livelihood of the farm households in terms of financial income, food and non-food products, socio-economic and cultural functions and provides social security in the bad crop years as well (Asresu *et al.*, 2013). Comparatively, sheep production provides an opportunity for smallholder farmers since they require low initial capital and is able to use the marginal land as well as crop residues for feeding. In addition, care-taking of sheep can be carried out by any family members. Adane and Girma (2008) noted that small ruminants have a unique niche in smallholder agriculture from the fact that they require small investments, have shorter production cycles, faster growth rates and greater environmental adaptability as compared to large ruminants.

Besides their significant importance for the farm households in particular and the domestic demand in general, the increased international demand for Ethiopian sheep has established them as important sources of foreign currency for economic development of the country. As a result, sheep at a national level contribute 25% of the domestic meat consumption with a production surplus exported as a live animal and meet almost 50% of the domestic wool requirements; about 40% of fresh skin production and 92% of the value of semi processed skin export trade (EIAR, 2017). The annual meat production from small ruminant's, which

amounts to 154,000 tons is relatively small (Mourad *et al*., 2015). Sheep together with goats contributed 86% of the total value of meat exports (Legese and Fadiga, 2014).

2.3. Overview of Arsi-Bale Sheep habitat and Production Characteristics

Arsi-Bale sheep are fat-tailed and covered with course wool (wavy wool). They are widely distributed in the highlands of eastern and southern Ethiopia, in Arsi, Bale, Hararghe and eastern Showa zone of Oromia Region and in parts of the southern region (Kassahun and Solomon, 2008). The climate in this area varies from semi-arid to sub-humid. The production systems range from agro-pastoral to mixed agriculture and some urban and peri-urban production. Male Arsi-Bale sheep have minor wool growth in some parts of the body. Both males and females (about 52%) are horned and are large in size. The coat color is variable including brown (35.1%), brown with white patches (24.3%), black, white and combinations of these colors (Solomon *et al*., 2009).

Among the Ethiopian indigenous sheep breeds, Arsi-Bale sheep are identified as having mutton potential (Gizaw *et al*., 2013). Arsi-Bale lambs weigh 2.7 kg at birth and 14.2 kg at 120 days of weaning (Kassahun and Solomon, 2008). Cross breeding of local Arsi-Bale with exotic breeds such as Hampshire, Merino and Corriedale improved lamb weights and the total weight per ewe lambing. The birth weight and weaning weights for 50% exotic (kg) were 3.08 ± 0.03 and 18.41 ±0.17. It was also higher for 75% and 87.5% cross than for 50% crosses (Teferawork, 1989). In terms of carcass production potential, Tekelu (2016) noted that Arsi-Bale sheep appears to be more efficient and produces about an average of 15.7 kg carcass with dressing percentage (DP) of 42.6% to 46.5% under improved management condition. However, this incredible carcass production performance cannot be sustained and remained less averaging to about 10.6 kg/head and DP of 44.2% in grazing management condition with no supplementation.

2. Sheep Value Chain Analysis

Value chain is the sequence of activities required to make a product or provide a service (Vermeulen *et al.,* 2008). Value chain includes input suppliers, producers, traders (wholesaler and retailers), processors and consumers. Value chain analysis examines the full range of activities required to bring a product or service from its conception to its end use, actors that perform those activities in a vertical chain and final consumers for the product or service. It is used to identify how poor people, small enterprises or other target groups can play a larger and more active role in a particular value chain and how a value chain's structure or characteristics can be changed to enable it to grow in pro poor ways. It enables the poor to engage more productively in markets, the thinking goes and poverty be reduced through market engagement. Making markets work for the poor emphasizes the need to unblock access to profitable market opportunities. It is an original methodological tool that enables design teams in the product definition phase to comprehensively identify pertinent actors, their relationships with each other and their role in the product's life cycle (Donaldson *et al*., 2006). Specific targeting approach for small ruminant development, as well as a value chain approach, addressing constraints at critical leverage points across the small ruminant value chain and targeting appropriate producer groups (gender, literacy, etc.) for introducing technological interventions (Solomon *et al.,* 2015).

2.4.1. Value chain functions

The common functions include a) input supply (sheep, feed, veterinary drug, credit) b) production (feeding, herding, housing, and fattening) c) Marketing (collecting, transporting, buying, selling) and d) processing (slaughtering, butchering, cooking, chilling, packing) (Duguma *et al*., 2012; Beneberu *et al*., 2013). This approach involves all the basic marketing activities (functions) that have to be performed in the agricultural commodities and at the marketing of inputs in to agricultural production. Physical distribution (i.e. functions) and economic activity (i.e. buying, selling) are two dimensions of marketing carried out by institutions or people. An analysis of these two dimensions of agricultural marketing is

intimately linked to the institutions created by law or by corporate standards or simply by established procedure that have emerged as a result of the social and economic relation between the participants in the marketing process (middlemen, consumers and producers).

2.4.2. Value chain actors

According to GTZ (2007), the term “value chain actors” encompasses all individuals, enterprises and public agencies related to a value chain, in particular the value chain operators, providers of operational services and the providers of support services. In a wider sense, certain government agencies at the macro level can also be seen as value chain actors if they perform crucial functions in the business environment of the value chain in question. Getnet (2009) also defines value chain actors as those involved in supplying inputs, producing, processing, marketing and consuming agricultural products. Value chain actors includes input supplier, producers, traders, processors, consumers (Duguda *et al*., 2012)

2.4.3. Market channels

Marketing channel is a business structure of interdependent organizations that reach from the point of product origin to the consumer with the purpose of moving products to their final consumption destination (Kotler and Armstong, 2003). The analysis of marketing channels is intended to provide a systematic knowledge of the flow of goods and services from their origin (producer) to their final destination (consumer). This knowledge is acquired by studying the participants in the process, i.e. those who perform physical marketing functions in order to obtain economic benefits (Getachew, 2002).This channel may be short or long depending on the kind and quality of the product marketed, available marketing services and prevailing social and physical environment (Islam *et al*., 2001).

2.4.4. Marketing costs and margins

Marketing costs refers to those costs which are incurred to perform various marketing activities in the transportation of goods from producer to consumers. Marketing costs includes

feed, veterinary, labor, barn, handling (loading and unloading), collecting sheep, transporting, processing, packing, labelling costs and Taxes. Marketing margin is a commonly used measure of the performance of a marketing system (Abbott and Makeham, 1981). It is defined as the difference between the price the consumer pays and the price that is obtained by producers, or as the price of a collection of marketing services, which is the outcome of the demand for and supply of such services (William and Robinson, 1990; Holt, 1993; Cramers and Jensen, 1982). The size of market margins is largely dependent upon a combination of the quality and quantity of marketing services provided the cost of providing such services, and the efficiency with which they are undertaken and priced. For instance, a big margin may result in little or no profit or even a loss for the seller involved depending upon the marketing costs as well as on the selling and buying prices (Mendoza, 1991).

Under competitive market conditions, the size of market margins would be the outcome of the supply and demand for marketing services, and they would be equal to the minimum costs of service provision plus "normal" profit. Therefore, analyzing market margins is an important means of assessing the efficiency of price formation in and transmission through the system. Detailed analyses of the accounts of trading firms at each stage of the marketing channel (time lag method), computations of share of the consumer's price obtained by producers and traders at each stage of the marketing chain; and concurrent method are three methods generally used in estimating marketing margin. (Mendoza, 1991; Scarborough and Kydd, 1992).

2.5. Feed Resources for Sheep production in Ethiopia

Feed resources as reported by Adugna *et al*. (2012) can be classified as natural pasture, crop residue, improved pasture and forage and agro-industrial by-products of which the first two contribute the largest share. The fibrous agricultural residues contributes a major part of sheep feed especially in densely populated areas where land is prioritized for crop cultivation. The same authors reported that crop residues contribute about 50% of the total feed supply in Ethiopia. Similarly, the naturally occurring grasses, legumes, herbs, shrubs and tree foliage are used as animal feed (Adugna, 2008). The availability of feed resources in the highlands of Ethiopia depends on the mode and intensity of crop production as well as population pressure

(Seyoum *et al*., 2001). Crop residues represent a large proportion of feed resources in mixed crop-livestock systems (Malede and Takele, 2014). Reliance on crop residues for animal feed is increasing from time to time as more land is cropped to feed the fast growing human population.

In most production system of Ethiopia, extensive free grazing in communal lands and stubble grazing are the most common practices of sheep feeding (Solomon *et al*., 2010); whereas limited grazing areas and cultivation of pasture lands causes loss of palatable forage species due to high grazing pressure. Agro-industrial by-products are also other potential feed resources that can be used as supplements to crop residues and poor quality natural pasture based diets. These include the by-products from flour milling, oil processing, sugar and brewery factories (Alemayehu, 2006). Supplementation with agro-industrial by-products has been used in many developing countries for improving locally available nutrients of feed resources. Since feed cost accounts more to total cost in any livestock production, it is of paramount importance to incorporate locally available byproducts and raw materials into the feed of ruminant animals. The major feed resources in Ethiopia for sheep production are natural pasture, crop residues, aftermath, browse species and agro-industrial by-products and to a lesser extent improved pasture and forage crops (Seyoum and Zinash, 1989). In the dry season, the prominent feed used for livestock feeding is hay and crop residue, which are produced from farm. However, the quality and quantity of these feed resources are low.

2.5.1. Crop Residues

Crop residue is the main feed resource for livestock in most parts of Ethiopia (Gizaw *et al*., 2017). However, it has low quality, high fiber content and low digestibility, which reduce productivity of livestock, weaken disease resistance potential of animals (Malede and Takele, 2014). The major food crops produce large quantities of crop residues in addition to grain. These include cereal straws (e.g. Teff, wheat, barely, maize and sorghum) and grain legume halums (e.g. haricot beans, field peas, chickpeas, lentils and groundnut) (Adugna, 2008). Research reports showed that at national level, cereal and pulse crop residues contribute about 50% of the total feed supply followed by grazing (44%), whereas the balance is supplied by

other agricultural and agro-industrial by-products (Adugna, 2008). Straws consist of stems and leaves of plants after the removal of the ripe grain seeds by threshing. Chaff, which consists of the husk or glumes of the seed, which are separated from the grain during threshing, is also a byproduct of food crops that can be used for animal feed (McDonald *et al*., 2002).

Feeds with fiber content exceeding 55% (generally high cell wall content) may be low in CP (below 7%) or in other essential nutrients and induce intake limitation through deficiency (Van Soset, 1994) of nutrients, while a CP content of less than 6% will result in negative N balance due to protein malnutrition (Bondi, 1987). Cereal straws are mainly characterized by highly lignified cell wall material, which mostly constitute up to 80% of the dry matter (DM). These cell walls are mainly made up of the structural polysaccharides and lignin (Thendar, 1984). Therefore, they are low in CP (<60 g/kg DM), metabolizable energy (<7.5 MJ/DM) Vitamin A, D, E and poor in calcium, phosphorus and sulfur, high in fiber content, low in digestibility (rarely exceeding 50% due to close association of carbohydrate with lignin) and have low voluntary intake by animals (Devendera, 1988; Jackson, 1997). Straws contains almost nearly 80% that are completely fermentable, although the presence of lignin retards the bacterial fermentation process in the rumen (Jackson, 1997), and results in low organic matter digestibility (Devendera, 1988). These constraints are related to their specific cell wall structure, chemical composition and deficiencies of nutrients such as nitrogen, sulphur, phosphorus and cobalt, which are essential to rumen microorganisms. The cell wall fraction includes cellulose, hemicelluloses, lignin, cutin, lignified protein, silica and ash, which are present in most crop residues (FAO, 2002). Cellulose is the most abundant structural polysaccharide molecule made up of highly ordered glucose molecules linked by β-1-4 glycocidic bond. Hemicellulose is a polysaccharide molecule predominantly composed of xylans with a backbone of xylose, arabinose and glucouronic acid residues. The concentration of hemicellulose in grass species varies from 150-400 g/kg DM and is much lower amounting to between 80-150 g/kg DM in legumes. Hemicelluloses are partially soluble in dilute alkali (FAO, 2002). Lignin is a three-dimensional network of phenyl propane units consisting of 5-20 percent of DM of crop residues. It is physically and chemically linked with polysaccharides through glucocidic linkage and ester cross linkage, but only covalently

bonded with protein in wheat internodes. These lignin linkages prevent the cell wall components from enzymatic hydrolysis of rumen microorganisms and limit cell wall digestion (FAO, 2002).

The low nutritive value and digestibility of crop residues show the importance of supplementing animals fed with the residues as a major basal diet. Grain and other conventional supplements are too expensive for many resource poor farmers, thus there is a need to search for potential alternatives to conventional supplements (Odenyo *et al*., 1997). Upgrading of poor quality crop residues through supplementation of forage legumes or other cheaply available protein sources to fully or partially replace the costly concentrate feeds can reduce feed expenses and such practice is a break through to the traditional livestock feeding system (Lemma, 1993). The first type of supplement required for straw is one that provides adequate suppliers of nutrient such as nitrogen for the rumen micro-organisms and the second type of supplement required is the one that provides the animal with additional protein that is not degraded in the rumen (McDonald *et al.,* 1995). According to Snyman (1991) the utilization of crop residues and processing by-products has received much less attention because of unawareness of the potential benefits in improving the feeding value of such feeds. The usefulness and nutritive value of crop residues can also be variable depending on the species of livestock to which it is offered. Cattle, which retain fibrous matter in the rumen slightly longer than sheep have an advantage when fed with lower quality crop residues. *Bos indicus* cattle can digest more NDF in rumen and have longer ruminal retention time than *Bos taurus* (FAO, 2002).

Estimates about the availability of crop residues in Ethiopia indicate that around 14 million tons of crop residues are produced annually and teff straw is one of the leading and it accounts about 27% of the total straw production in the country (Seyoum and Dereje, 2000). Crop residue production in Ethiopia is 29,155,077. Teff has a wide agro-ecological adaptation and it is grown in 10 of the 18 agro-ecological zones in Ethiopia and cultivated in most parts of the country from mid to high altitudes (Adugna *et al*., 2012). This opportunity provides ample amount of teff straw that can be used as animal feed (Kebebew, 2003).

Among cereal straws, teff straw was found to have a better nutritional quality (Seyoum and Zinash, 1991). Seyoum and Dereje (2001) also reported that *in vitro* digestibility and the energy value of teff straw were higher as compared to wheat and barley straw and closer to native hay. However, different reports indicated that the nutritional value of teff straw varies widely according to variety, morphological fractions, planting date, seeding rate, harvesting date and storage time (Seyoum *et al.*, 1996). Furthermore, environmental factors such as location, climate, soil fertility and soil type have also been found to influence the nutritive values of a given crop residues. For instance, digestibility of roughage decreases with increase in temperature since high temperature increases the rate of enzymatic process associated with lignin biosynthesis promoting lignifications of cell wall and more rapid metabolic activity resulting in decreased pool of metabolites in the cell (Van Soest, 1988).

It was reported that nutrient supply from a sole teff straw is marginal to maintenance requirements of animals. The crude protein content of teff is reported to be between 2.5-7.5% (Seyoum and Zinash, 1998) and 4.9-8.3% (Debre Zeit Agricultural Research center, 1989). The NDF content varies from 72.6-77.8% (Seyoum and Zinash, 1998). Tikabo (2006) reported CP, NDF, ADF and soluble carbohydrate of 76, 705, 386 and 130 g/kg DM, respectively in the teff straw used in their experiment. Similarly, Solomon *et al*. (2003) reported the chemical composition of teff straw to be 912.3 DM, 913.5 OM, 42 CP, 735.9 NDF, 418.4 ADF and 45g/kg ADL. Zemicael (2007) reported that teff straw contains 881.4 g/kg DM, 94.75 OM, 30.6 CP, 825.8 NDF, 491.7 ADF, 53.2 ADL, 10.4 g/kg DM EE. The above results show that teff straw is low in nutrient content and high in fiber, which makes them to have low intake by the animals, low in the amount of readily available energy for rumen microorganisms that makes it less digestible. The low nitrogen and energy contents indicate that unless adequately supplemented, teff straw may provide no more than maintenance requirement of sheep.

The main sources of protein in the ruminant diet are microbial protein synthesized in the rumen and dietary protein that escapes fermentation in the rumen. The optimum rumen degradable nitrogen requirement is considered to be 3 g N/100 g of organic matter (OM) fermented in the rumen (ARC, 1980). Nutrient release of teff straw suggests that N release is

less than 1 g/100 g OM and it is below the level required for optimal fermentation and microbial protein synthesis (Seyoum and Dereje, 2000). Thus, it is important that a source of rumen degradable nitrogen should be included in teff straw based diets for optimal utilization.

Degradability of protein has practical importance to the response of the animal. In this aspect, the degradability of various oil seed cakes have been shown to be high and they can be used as good source of rumen degradable protein (Seyoum, 1995). Animal response to supplementation of teff straw using protein sources could give variable results depending on the extent of the supplements degradability in the rumen or whether it serves as a source of undegraded dietary protein. Higher animal performances were reported for slowly degrading protein sources with high undegradable dietary protein than for rapidly degrading ones with low undegradable protein (Lemma, 1991).

2.5. 2. Agro-Industrial By-Products

Agro-industrial by-products concentrates are feeds which have less fiber but higher content of soluble components. The major agro-industrial by-products commonly used as livestock feed include milling by-products, oilseed cakes, breweries and wineries by-products, molasses and other by-products of sugar factories, cereal grains and grains damaged during processing (Tolera *et al*., 2012). The traditional brewery residue (*Tela atella*) and traditional liquor residue (*Areke atella*) are also widely used (Mekasha *et al*., 2002) as livestock feed both at urban and rural areas of the country. The cereal grains are high in energy values but low in crude protein contents (Sarwar *et al*., 2013). Although grains are used as energy and/or protein supplements to low quality basal diet, it is a staple food for human and expensive for smallholder to afford. There is also stiff competition for use of agro-industrial by-products with monogastric animals and intensive dairy production systems.

Wheat Bran

Wheat bran is the major milling by-product used as livestock feed in Ethiopia with a 14-18% CP and ME content of 12 MJ/kg (Adugna, 2007). The CP in wheat bran has a relatively high digestibility of about 75%. Wheat bran is an excellent energy source with 65% total digestible nutrients and also contains about 10-14% digestible CP (Sindhu *et al*., 2002). It also has high phosphorus (1%) but low calcium (0.1%) content (Adugna, 2007). Wheat bran is one of the energy source concentrates containing easily digestible carbohydrates. Such feeds are readily digested in the rumen with high energy yielding potential. It is quite palatable and is well known for its laxative characteristics because of its swelling and water holding capacity. This is due to its high fiber and non-starch carbohydrates content. Wheat bran is a relatively good source of most of the water soluble vitamins except niacin (Adugna, 2007). Awet and Solomon (2009) reported that medium and higher level of wheat bran supplementation resulted in higher apparent digestibility and average daily weight gain. Another study by Hagos and Solomon (2017) indicated that heavier average daily weight was achieved in sheep supplemented with 100 g of wheat bran with 200g moringa leaf meal than 200 g of wheat bran with 100g moringa leaf meal and solely 300g wheat bran supplemented group. Similarly, Tagaynesh (2014) reported that supplementation of mixtures of safflower seed cake and WB to Hararghe Highland sheep fed teff straw basal diet improved DM, OM and CP digestibility.

Oil Seed Cakes

Oilseed cakes are the residues or cakes that are produced as by-products during extraction of oil from oilseeds. These include noug seed cake, cottonseed cake, groundnut cake, linseed cake, sesame cake, sunflower cake and others (Adugna, 2007; Yayneshet, 2010). In the predominantly subsistence livestock production systems in the tropics, by-products of oilseeds are commonly used as CP supplements to the low quality forage based diets of ruminants (Habib *et al*., 2013). Ethiopia produced about 8.4 million quintals of oil seeds among which noug and linseed comprise about 36 and 10.5% (CSA, 2017).The oilseed cakes are rich in protein and serve as sources of protein supplement in concentrate mixtures with 28-35% CP depending upon the type of oilseed and the method of extraction of oil (Yayneshet, 2010),

which may also affect its energy value (McDonald *et al*., 2002). Oilseed cakes are low in fiber contents (Adugna, 2007); cysteine, methionine and lysine content (McDonald *et al*., 2002).

Oilseed cakes contains high percentage of nitrogen as true protein (90%) that is usually highly digestible and moderate to good biological value; medium to high soluble fraction, fast degradation, high potential degradability and effective degradability of DM, OM and N disappearances (Seyoum, 1995). The energy content varies from 8.5-15.5 MJ/kg DM, depending on processing methods (McDonald *et al*., 2002). The calcium content is usually low, which varies from 0.17 to 0.72% and most meals are high in phosphorous content (0.75-1.31%), although half or more is present as phytase phosphorous (Church, 1986). Cotton seed cake and linseed cake are good sources of magnesium (McDonald *et al*., 2010). Cakes from Noug, cotton and linseed varied significantly in all chemical properties and IVOMD (Solomon, 1992). Seyoum (1995) reported lower IVOMD and higher cell wall content for cotton seed cake and lower CP and high IVOMD for linseed cake.

Noug seed cake

Noug seed cake (NSC) is one of the commonly used oil seed cake as a protein supplement in the diet of farm animals in Ethiopia. Annually about 84,802.34 tons of noug seed is produced, mostly in western part of Ethiopia, particularly western Oromia including West and South West Shewa zones and oil extraction is done almost entirely by mechanical press with predominantly old machines used in the milling industry. The amount of NSC produced is about 50% of the noug seed processed, making the amount of NSC produced per annum to be about 42,401.17 tons (Adugna, 2007).

The protein content of NSC varies from 28 to 38% with most values lying between 30 to 35% (Adugna, 2007). The fat content ranges 2.1 to 12.6% with mean of 8.4% and energy value of 2.37 Mcal ME/kg DM (Adugna, 2008). It has high fiber (34.4% NDF and 8.4% lignin) content and relatively low digestibility (61.7% *in vitro* DM digestibility) due to high cellulose and lignin content compared to most other Oil-seed cakes (Adugna, 2008; Heuzé, 2017a) with the fiber being largely available (Heuzé, 2017a).

Supplementation of animals with NSC improved live weight. Solomon *et al.* (1991) reported 94.89 -136.79 g/day body weight gain for grazing Begait sheep supplemented with graded level (200-500 g/day) of concentrate mixture of noug seed cake and maize. Lemma (1991) also reported body weight gain of 33 g/ day for Begait sheep fed teff straw and supplemented with noug seed cake and ground maize. Alemu Tarkegn (2016) indicated that increasing the level of NSC supplementation (0, 50, 67 and 75 %) improved digestibility of DM (43, 53, 58 and 71%), OM (40, 54, 58 and 71%) and CP (23, 65, 66and 78%).indicated that sheep supplemented with mixtures of noug seed cake (NSC) and wheat bran at the ratio of 3:1 and/or 2:1 gained more BW than the control and those supplemented with sole rice bran.

Cottonseed cake

Ethiopia produces an average of 38,000 metric tons of cotton in the year 2018. (USDA, 2018). Cottonseed cake is a by-product obtained after extraction of oil from cottonseed. It has high protein content, usually more than 36%, an excellent protein supplement for ruminants (Yayneshet, 2010). Cottonseed cake (CSC) can replace other oilseed cakes without affecting milk yield and composition dairy cows (Heuzé *et al.,* 2016). However, it is deficient in vitamin D, carotene and calcium, but rich in phosphorus. It may also contain a toxic substance known as gossypol, which could be more harmful to very young animals that do not yet have a functional rumen (Yayneshet, 2010).

Adugna (2008) noted the existence of big variation of protein and fiber content and digestibility of cottonseed cake depending upon whether the seeds were decorticated before extraction or not. The decortication of oilseeds before pressing for oil extraction removes the fiber contained on the seed coat and husks that removes the possible limitations that could be imposed by these components on feed intake and digestibility of the oilseed cake. Craig and Broderick (1981) reported true digestibility of CSC to be 91% and *in vitro* protein digestibility to be 80-85%. The rate of degradation for CSC was estimated at 7% h^{-1} (Sibanda *et al*., 1993). Based on a summary of ten trials, the average rumen escape protein for CSC was 46% (NRC, 1985). The digestibility of DM, CP and CF of mechanical extracted CSC fed to lambs was 70, 75 and 57%, respectively and nitrogen retention as percentage of nitrogen

intake was 19.3% (Khan *et al*., 2000). Slow rate of gas production with CSC suggests a slow release of N in the rumen (Egan, 1985).

Matiwos (2007) noted that feed intake, daily weight gain, apparent NDF digestibility and feed conversion efficiency were greater when sorghum stovers were supplemented with CSC than noug seed cake. Nitrogen retention (g/d) was also higher with CSC than with NSC supplementation suggesting that CSC has better biological value than the protein from NSC. The possible reason for the better utilization of N from CSC could be an attribute of less effective degradability in rumen and relatively more by-pass protein than NSC. Increasing levels of CSC is expected to increase the microbial N yield by providing additional readily fermentable energy (Ben-Ghedalia *et al*., 1978), peptides and amino acids (Wallace *et al*., 1999). Sibanda *et al*. (1992) also reported that supplementation of low quality roughages with slowly degradable protein significantly increased DM intake and live weight gain. Hayaz *et al* (2013) has confirmed that live weight gain and milk yield was increased with increasing CSC level in feed up to 35%. Preston (1986) reported that small inputs of by-pass protein, dramatically increased growth rate and feed efficiency of fattening cattle.

Despite its usefulness as a protein supplement, cottonseed may contain from 0.3 to 20 g/kg DM of yellow pigment known as gossypol (McDonald *et al*., 2002). In the presence of heat, gossypol reacts with proteins to produce “protein bound gossypol” mainly with the amino acid lysine (Cheeke, 1991) resulting in lowered lysine availability. Toxicity of CSC is associated with free gossypol (McDonald *et al*., 2002). The bound form gossypol is considered nontoxic to ruminants because it cannot be absorbed in the digestive tract (Mena *et al*., 2004). Although gossypol toxicity is uncommon when CSC is fed at conventional levels, such as 20 % in cattle (Lonsdale, 1989), toxicity has been observed when free gossypol intake was high (43 mg/kg BW/day) (Lindsey *et al*., 1980). Matiwos (2007) indicated presence of law in the UK that restricts use of CSC when its gossypol content exceeds 500 mg/kg for cattle, sheep and goats. Similarly, Pandey and Voskuil (2011) recommended that maximum feeding of cottonseed should not exceed more than 2.0 Kg/day/cow. However, McGregor (2000) and McDonald *et al*. (2002) revealed that ruminant animals and dairy cows can be fed cottonseed meal without adverse effects even when they consume large quantities of CSC.

Morgan (2015) also noted that ruminants such as cattle and sheep can tolerate higher levels of free gossypol, because gossypol binds to proteins in the rumen. Cotton seed meal inclusion rate for dairy cow, growing cattle, lactating ewe, growing lamb and dairy goats is 15, 20, 10, 10 and 15 kg/DM, respectively (EFSA *et al*., 2009).

Linseed cake

Linseed cake (LSC) is one of the most popular protein supplements because of its high protein content and palatability. Moreover, linseed cake has a slight laxative effect, which helps to keep the animals healthy. It has about 30% CP with its unique character among the oilseed cakes in that it contains about 3-10% mucilage (Adugna, 2007), which appears to have a conditioning effect on animals. It gives the animals a shiny coat and makes them more attractive. Jarczak *et al*. (2012) noted that LSC positively influence the functioning of the reproductive system and show anti-tumor activity. However, LSC contains anti-nutritional substance cyanogenic glucosides, although at low level. McDonald *et al*. (2010) stated that linseed cake has a very good reputation as ruminant animals feed, which is not easy to justify on the basis of its proximate analysis. The ability of the mucilage to absorb large amounts of water results in an increase in the bulk of the meal. This may increase retention time in the rumen and give a better opportunity for microbial digestion. The presence of polyunsaturated fatty acids in LSC is beneficial for the health quality of the milk (Heuzé *et al.*, 2017b). Because of the potent ability of these natural ingredients to inhibit adipogenic, diabetogenic, atherogenic, inflammatory, and carcinogenic diseases and their effects. Furthermore, high consumption of n3 LC-PUFA is typically associated with a lower incidence of depression, a decreased prevalence of age-related memory loss and a lower risk of developing Alzheimer's disease. This has led to a large number of studies aimed at increasing LC-PUFA content in dairy products for human consumption (Quang *et al*., 2018). The meal fed in large amounts is laxative, and excess amounts in rations have undesirable softening effects on butterfat and give milk a rancid taste. Ahemed *et al.* (2016) reported that significantly higher digestibility and ADG. Linseeds are now used 30–50% with other feeds such as bran, in order to obtain a product which is easy to handle and to incorporate in concentrates. (Michel and Anne, 2015).

Soybean meal

Soybean meal (SBM) is the material remaining after extraction of oil from soybean flakes, with 50% soy protein content (McDonald *et al*., 2002). The meal is 'toasted' and ground in a hammer mill. Whole soybean (*Glycine max*) contains 15 to 21% oil, which is removed by solvent extraction or by combination of mechanical procedures and solvent extraction (McDonald *et al*., 2002). Soybean protein is rich in lysine, methionine, valine, and isoleucine, constituting the first, second, third and fourth limiting amino acids in productive cows (Nowak *et al*., 2005). Processing of soybean is important in improving the biological value of its protein by destroying various inhibitors. Soybean meal is an excellent protein source, which can also contribute energy providing fat to the diet. Griffiths (2004) found that SBM, in addition to being an excellent source of lysine, is also a rapidly degradable protein source. As with most other oil seeds soybeans have a number of toxic stimulatory and inhibitory substances. For example a goitrogenic material is found in the meal and its long term use may result in goiter in some animal species. It may also contain antigen that are especially toxic to young pre- ruminants. However, the trypsin inhibitor factors present in soybean are irrelevant in ruminants, as they are mostly inactivated in the rumen (Caine *et al*., 1998). These toxic substances can be eliminated by heat during processing. Heating SBM above the optimum temperature might protect such meal against microbial degradation in the rumen, as well as making its protein content indigestible in the intestine, as a result of the Maillard reaction, which occurs between sugars and proteins (Loerch and Berger, 1981; Hadjipanayiotou, 1994; Nowak *et al*., 2005).

The whole soybean product is known in the feed trade as full fat soybean meal; it contains 38% CP, 18% fat and 5% CF (Wilson *et al.*, 1995). However, soybean meal has very high protein content (49.9% CP), and 89% DM, 84% TDN, 15% NDF and 10% ADF (NRC, 1981). Because soybeans contain a high quality protein with a good amino acid profile and are highly digestible in the small intestine, various processing methods and treatments have been used to increase its undegradable protein value. The most common methods for protecting soybean proteins from ruminal degradation are heat application, incorporating chemicals such as formaldehyde or a combination of heat and chemicals such as

lignosulfonate combined with xylose (McDonald *et al*., 2002). To achieve maximum productivity from high-producing or rapidly growing ruminants, better quality protein is required than that which is provided by rumen microorganisms (Loerch and Berger, 1981). Undegradable protein requirements tend to increase with improved performance of the animal. Such protein can be supplied by reducing the ruminal degradation, and by thus increasing the amount of protein that is digested post-ruminally. Although soybean meal protein is degraded relatively rapidly in the rumen, much of such a protein tends not to be digested in the rumen, thus making it available for enzymatic digestion in the small intestine (Khorasani *et al*., 1990). Lu *et al*. (1990) found that SBM tends to be less utilized than is meat and bone meal, despite the degradation in the rumen being higher for SBM. Loerch and Berger (1981) found higher gains among SBM fed steers than among those fed meat and bone meal.

Sheep on grass basal diet supplemented with protein concentrate such as SBM had greater dry matter intake and digestibility as a result of increased supply of protein to the rumen microbes (Jamie *et al.*, 2009). There were also greater ($P<0.01$) nitrogen intake, retention and apparent dry matter digestibility in growing lambs supplemented with SBM compared to browse legume hay supplementation when the lambs were fed with bahiagrass (*Paspalum notatum*) as a basal diet (Jamie *et al.*, 2009). In addition, kiflay *et al.* (2014) also reported that supplementation of soybean meal (SBM) has a positive effect on feed intake, FCE, average body weight gain, carcass parameters and economic feasibility. Akewake (2015) reported that soybean meal fed fish had increased apparent digestibility coefficient of DM and CP than nougseed and linseed meal supplemented groups fed on fish meal, wheat bran and corn grains as a basal diet.

2.6. Factors Affecting Production Performances of sheep

Growth, carcass yield and dressing percentage (DP) are the prominent performance parameters of meat animals (Payne and Wilson, 1999). Meat producing potential of animals is reflected mainly in the rate of gain, weight at slaughter and DP. Hence, growth is a dynamic process, which continues throughout the life of an individual animal and it refers to change in

size (height, length, girth or weight) and developmental changes associated with it (Hossner, 2005), whereas DP is expressed as the proportion of the carcass weight of an animal to the animal's live weight (Ford *et al.,* 2012). More specifically, DP is termed as the relationship between live weight and cold carcass weight (USDA, 2013). According to Amha (2008), carcass is defined as the major portion of a meat animal remaining after slaughter, but the head, the skin, internal organs and the shanks have been removed.

Apart from the big difference among different meat animal species, a number of factors affect growth and DP within the same species. Payne and Wilson (1999) noted that growth and DP are important performance traits of meat animals and are highly affected by age, gender and plain of nutrition; as a result, meat animals, either intact or castrated, should be adequately fed if high growth and DP are to be achieved.

2.6.1. Effect of Age on Growth and Carcass Parameters of Sheep

Younger growing animals utilize feed nutrients more efficiently than older and mature animals during fattening or finishing (Alemu, 2008). According to El Fadili *et al*. (2000), the decrease of ADG with the age of lambs could be due to a decrease of nursing and milk feeding of lambs by their mothers. Sultan (2010) reported that age differences had no significant ($P>0.05$) effects on the total digestibility of DM, CP and OM native sheep in Bangladesh, respectively. The same author indicated that, DMI, ADG an FCR decreased with increasing age. Furthermore, slaughter weight, hot carcass weight and dressing percentage of native sheep increased with advancement of age.

2.6.2. Effect of Sex on Growth and Carcass Parameters of Sheep

Petrović1m *et al.* (2015) noted that birth, weaning and yearling weight of lambs is greatly influenced by lamb sex. The same authors explained that type and measure of hormone secretion especially sexual hormones, lead to difference in animal growth. Similarly, estrogen hormone has a limited effect on the growth of long bones in females that could be one of the reasons for which females have smaller body and lighter weight compared to males *(*Baneh

and Hafezian, 2009*).*Feed intake, feed conversion and daily weight again performance of male lambs were better than the females lambs (Seyed and Mehadi, 2017)

2.6.3. Effect of Plain of Nutrition on Growth and Carcass Parameters of Sheep

The growth and meat production performances of sheep are highly affected by the type of the diets such as roughage and concentrate, diet management (dry and wet seasons). In many animal production systems, about two-thirds of improvements in livestock productivity can be attributed to improved nutrition; consequently, improving performance through better nutrition is determined by the availability of nutrients, type of feeding system (grazing, cut and carry, supplementary or combination of each other) and the level of feeding management (low, medium and maximum) (Alemu, 2008b).

In addition to the poor genetic makeup, the low performance of local sheep in terms of live weight gain and carcass yield in Ethiopia is mainly due to inadequate nutrition associated with reliance on natural pasture, crop residues and/or stubble grazing, which are inherently low in available nutrients being subjected to great seasonal variations (Solomon *et al.,* 2008). Apparently, small ruminant's productivity can be greatly improved by supplementing their diet while they are managed on long dry season grazing and on feedlot basal diets (Alemu, 2008b). Free-range diets are generally resulted in slower lamb growth rates compared to faster growth rates achieved with feedlot diets (Diaz *et al.*, 2002). In a comparative feeding system study, Getu *et al.* (2012) noted that feedlot lambs produced heavier final body weight (FBW), body weight gain (BWG) and feed conversion efficiency (FCE) in LSC and CSC supplemented animals than NSC supplemented ones. Similarly, Amare *et al*. (2009) reported that CSC supplemented animals had higher FBW, BWG and FCE than NSC. This is a consequence of type of diet that promotes earlier fattening or delayed growth and/or slower fattening process (Amha, 2008). Hence, to attain the high or low fat levels a particular market may demand, farmers can accordingly vary feeding regimes and husbandry methods.

The significance of nutrition on the growth and carcass production performance of different indigenous sheep breeds is highly pronounced in various research outputs. Performance

evaluation and feeding trial studies conducted on sheep revealed the positive effect of improved feeding and supplementation on sheep performance. A study by Negewo *et al.* (2018) on Arsi-Bale sheep fed urea treated maize cob basal diet indicated that total dry matter intake (DMI), daily weight gain (DWG), Final body weight (FBW), empty body weight (EBW) and dressing percentage (DP) were significantly improved with increasing levels of supplementation from 150-350 g/day. In another study conducted with the same breed of sheep managed on grass hay as a basal diet and with linseed cake and/or wheat bran supplementation, 21.8 kg vs.69.04g and 24.85 kg vs. 104.15 g average FBW and DWG, respectively were recorded (Abebe *et al.*, 2010). Similarly, LSC and CSC based oilseed cake meal supplemented cows attained greater daily gain than the group supplemented with NSC based concentrate (Mareshet *et al*., 2019 and Tekelab, 2019). Arsi-bale sheep fed natural pasture hay supplemented with 300 g DM concentrate mix had better average DWG and FBW (97.8 g and 24.3 kg) performance and produced higher mean DP of 45.3% and wider rib eye muscle area when compared to those fed natural pasture hay only, which could not attain even their maintenance requirements (Abebe *et al.*, 2009).These performance evaluation reports clearly noted that the better performance of animals on high proportion of concentrate supplementation could be attributed to the fact that the high level of available essential nutrients in the ration satisfied the animal's nutrient requirements for growth (Van Soest, 1994).

2.7. Feed Intake and Nutrient Requirements of Sheep

Domestic animals in general require nutrients primarily for maintenance of their body metabolism followed by growth, production and reproduction. Type of diet and provision of appropriate supplementary feed during critical periods of the year is important to enhance total DMI and productivity of the animals or at least avoid body-weight loss (Alemu, 2008b). This is especially true for livestock consuming poor quality pasture and crop-residue based diets containing less than 7% CP. It was confirmed that consumption of low quality roughages such as straw and poor grass hay can be increased markedly by the addition of non-protein and/or protein and energy supplements (Pond *et al.*, 1995). It is apparent that the nutrient requirement of sheep varies at different physiological state and daily body weight gain. Kearl (1982) recommended that the daily nutrient requirement of a 25 kg male lamb having 50-100g

DWG/day and 0.78-0.83 kg DM intake/day could be 75-85g CP/kg DM and 0.42-0.55 kg TDN/kg DM for both maintenance and growth. Similarly, the daily CP requirement for maintenance on DM basis for yearling sheep having body weight of 20 kg, 30 kg and 40 kg is 11.8 g/day, 10.9 g/day and 10.4 g/day, respectively (Ranjhan, 2004). Moreover, ARC (1980) recommended that a 20 kg sheep to gain daily body weight of 50 g and 100 g required 5.1 and 6.2 MJ/day Metabolizable energy and 50 g/day and 60 g/day protein, respectively.

Alemu (2008b) noted that the effect of nutrition on growth and production performance of meat animals is not a simple one as it involves the interactions among level of intake, the composition of the feed and nutrient needs of the animal. Meat production from sheep could significantly be improved in terms of higher body weight gains and better carcass composition by increasing energy levels in the diet (Mahgoub *et al.,* 2001) and feed energy was found to be a limiting factor for exploiting the maximum genetic potential for growth and carcass yield (Ranjhan, 2004). Ruminant diets are generally based on fibrous feeds that have low digestibility and are deficient in available nutrients such as energy, protein, minerals and vitamins, which result in low feed intake and productivity. Hence, small ruminants in the tropics are greatly affected by the less level of total digestible nutrient (TDN) in the diet as it can affect the feed intake of animals, unless proper supplementation has to be made. Whiteman (1980) revealed that feed resources containing less than 7% CP cannot support optimum rumen fermentation and affect the intake and digestibility of the feeds. Using poor quality forage having low protein (1-3% CP) and low energy (34-40% TDN) content without adequate supplementation in the dry season would results in loss of body weight in cattle (Topps, 1977).

The feed intake of animals varies based on animal factors (breed difference, metabolic body size, physiological status of the animals and degree of fatness) and feed factors (chemical composition and physical characteristics of feeds) (NRC, 2000). Regarding the feed factors, dry matter intake (DMI) is dependent on the type of concentrate since it can improve intake by supplying fermentable carbohydrates or proteins (Payne and Wilson, 1999). For instance, a study conducted by Getu *et al.* (2012) showed that Horro sheep fed natural pasture hay supplemented with different NSC (748.3 g/d) had lower total DMI than LSC (754 g/d) and CSC (934.3g/d). Similarly, Amare *et al.* (2009) showed that Horro sheep fed natural pasture

hay supplemented with different NSC (729.2 g/d) had lower total DMI than PNC (860.3 g/d) and CSC (909.4g/d). DMI of NSC supplemented cows was lower than that of LSC and CSC supplemented ones (Mareshet *et al*., 2018).

2.8. Dry Matter and Nutrient Digestibility

Digestibility is a measure of the degree of net absorption in the digestive tract of dietary nutrients i.e., the digestibility of a feedstuff is the proportion of the feed or of any single nutrient of the feed which is not recovered in feaces (McDonald *et al*., 2010). The digestibility coefficients of various nutrients from the same feedstuff is affected by species of the animal, breed, age of the animals, level of feeding, feed composition and ration composition (Ranjhan, 2004). Regarding the feed factor, the digestibility of a feed is closely related to its chemical composition, especially the quantity and quality of fiber fraction and the availability of degradable nutrients. Hence, different feed trial studies noted significant improvement in total dry matter and nutrient digestibility by local sheep due to concentrate supplementation. For instance, yearling Afar and Blackhead Ogaden lambs fed teff straw basal diet indicated a significant improvement in DM and CP digestibility with increasing levels of concentrate supplementation in the diet (Getahun, 2014).

In practice, apparent digestibility coefficients are used to determine organic constituents of feedstuffs than true digestibility coefficients. This is mainly due to the nutrient fractions found in the feces from the previously utilized food in the form of mucosal debris, unspent enzymes, undigested microorganisms, etc. are usually indistinguishable from one another (Ranjhan, 2004; McDonald *et al*., 2010). Digestibility measured directly from the difference between the intake and output in faeces of the nutrient is called the apparent digestibility. The apparent digestibility percentage, which can also be expressed as digestibility coefficient is used to determine the digestibility of dry matter (DMD), organic matter (OMD) and other nutrients as a difference of intake and fecal output divided by intake multiplied by 100.

3. GENERAL MATERIALS AND METHODS

This dissertation is based on three interrelated studies, which will be referred in the text as **Paper I, Paper II** and **Paper III**. **Paper I** and **Paper II** were survey studies, which generated basic information on mixed crop-livestock and agro pastoral sheep production systems and value chain performance evaluation. Whereas **Paper III** was undertaken to evaluate the effect of different oil seed cakes supplementation to teff straw on the performance of Arsi-Bale sheep on feed intake, digestibility, growth, carcass characteristics, main carcass component, edible and non-edible offal components and profitability.

3.1. Description of the Study Area

The survey **(Paper I and II)** studies were undertaken in Digelu Tijo district of Arsi zone and in Meiso district of West Hararghe zone of Oromia regional state. Digelu-Tijo district is located at 7^{O} 35" 0' and 7^{O} 52" 30' N latitude and 39° 0" 0' N and 39° 25" 0'E longitude. Its altitude ranges from 2000 to 3600 m.a.s.l. The annual rain fall was 900 to 1400mm and temperature is 10-22 ^{o}C, respectively. Mieso is one of the districts in the region where pastoral/agro-pastoral farming system prevails. The district is located between 40^{O} 9" 30.1' W and 40^{O} 56" 44' E and 9^{O}19" 52' N and 8^{O} 48" 12' N with an altitude range of 1107 to 3106 above sea level with most parts of the district situated at about 1700 m above sea level. It receives average annual rainfall within the range of 635-945 mm, while its mean annual temperature of 21^{o}C (MBPRD, 2014).

The experimental study **(Paper III)** was conducted at Debre Zeit Agricultural Research Center (DZARC). Its geographical location is 8° 44´ N latitude and 38° 58´ E longitudes. The area has an altitude of about 1900 m above sea level with maximum and minimum temperatures and average annual rainfall of 24.3 ^{o}C and 8.9 ^{o}C and 851mm, respectively. The climate of the area is mostly tepid to cool moist mid to high altitude (DZARC, 2015).

3.2. Sampling Procedure

Prior to the actual data collection, discussions were held with zonal and district livestock experts and development agents (DAs) to get actual information on the sheep population in the area, coverage and production potential of the rural kebeles in the districts. Arsi and West Haraghe zones were selected purposively based on sheep population, production system, and accessibility. Similarly, the districts also were selected purposively based on the same criteria **(Paper I and Paper II).** From each production systems, three rural kebeles were selected based on the sheep population and accessibility for transportation. Then after, the list of households with minimum number of two sheep and had prior experience in sheep production was collected. The sample size distributions in the study area were determined based on the distribution of sheep producing HHs after discussing with agricultural office experts and development agents (DAs). This was followed by random selection of 25 households from each rural kebele. The total numbers of randomly selected sampled households were 150 from the study area.

Focus group discussions were held with four groups of 48 sheep producers from two kebeles for each production systems. Nine men and three women were selected from each kebele. The groups were balanced regarding economic status, age and educational level. Each question was thoroughly discussed and the consensus reached by the group was taken as the best information **(Paper I and II).**

Key informant Interviews were conducted with livestock extension agents, collectors, abattoir managers, traders, hotels, butchers, livestock researchers, transporters and veterinarians. Sheep traders in the primary and secondary/intermediate markets of the district were also interviewed. A total of 30 key informants were interviewed during the field data collection **(Paper II).**

3.3. Methods of Data Collection

A structured questionnaire was used for the survey study, and data collection was administered through face-to-face interview of each respondent with the help of trained districts experts under close supervision by the researcher **(Paper I and II)**. Data collected through questionnaire was supported by the information obtained from field observations. Generally, data on socio-economic characteristics, production characteristics, like flock size, purpose of sheep keeping and management systems, feed resource, feeding and fattening practices, marketing practices, sheep production and fattening constraints were collected. Focus group discussions (FGD) and key informant interviews (KII) with knowledgeable individuals on the subject were conducted using a detailed checklist prepared for this purpose. Secondary data were also collected from the district offices. Relevant literature and documents were also reviewed to provide theoretical background.

3.4. Experimental Animals and Management

A total of 28 yearling male Arsi-Bale sheep were purchased from the Sagure market **(Paper III)**. The age of the animals were determined by dentition and body condition. The sheep were quarantined for 15 days and during that period all sheep were ear tagged for identification, injected Ivermectin against internal and external parasites and vaccinated for sheep pox and injected with 20% oxy-tetracycline for treatment of Pasteurellosis. The experimental sheep were blocked into seven groups of four treatments (seven animals per treatment) and each animal was kept in individual pens. The sheep were acclimated to the experimental conditions for about two weeks. This was followed by a digestibility trial consisting of 3 days of harness adaption followed by 7 days of data collection, and a feed trial of 90 days.

3.5. Experimental Design and Treatments

The experiment **(Paper III)** was conducted in a randomized complete block design (RCBD). Animals were categorized into seven blocks of four animals based on initial body weight of

the sheep. Animals from each block were randomly allocated to the four treatment groups, giving seven replications. Treatments were *ad libitum* feeding of teff straw at 20% refusal rate and 36% noug seed cake + 22% maize +42% wheat bran (T1), 40% Linseed cake + 20% maize + 40% wheat bran (T2), 29% cotton seed cake + 24% maize + 47% wheat bran (T3) and 22% soybean cake+ 26% maize + 52% wheat bran (T4). The treatments were formulated to the nearest iso-nitrogenous and iso-caloric. The concentrate diet was introduced gradually over the acclimation period until the total daily offer reached at the end of the acclimation. The concentrate was offered twice a day in two equal portions at 0800 and 1600 hours. Clean water and salt lick were available all the time.

3.6. Digestibility Trial

All animals were harnessed with faecal collection bags for three days of adaptation followed by 7 days of measurement and faeces collection **(Paper III)**. During faeces collection, feces voided were weighed and recorded for each animal separately, thoroughly mixed and a sub-sample of 10% was taken daily and bulked across the trial period and stored in a refrigerator at -20^{o}C until partially dried at 60^{o}C for 72 hours. Daily feed intake of each experimental animal was calculated on DM bases as the difference between the feeds DM offered and refused. Feed samples from the offer and refusals per animal were taken daily and pooled per feed type and treatments, respectively, thoroughly mixed and sub-sampled for chemical analysis. The apparent digestibility of DM and nutrients were determined as a difference of intake and fecal output divided by intake multiplied by 100.

$$\mathrm{DC}(\%) = \frac{(\text{Total amount of nutrients in feed} - \text{Total amount of nutrients in feaces}}{\text{Total amount of nutrients in feed}} X100$$

Intake was calculated as the difference between feed offered and refused corrected for DM content.

3.7. Growth Trial

The feeding trial **(Paper III)** lasted 90 days following the digestibility trial. When the growth trial commenced, the initial body weight (IBW) of each animal was taken after overnight fasting. The amount of teff straw offered and refused was recorded daily throughout the study period. Body weight of each animal was recorded at every 10 days interval after overnight feed withdrawal and before the daily feeding. Total weight gain (TWG) was calculated as the difference between final and initial body weights. Average daily gain (ADG) was determined by regressing body weight against time. Feed conversion efficiency (FCE) of the animal was determined as the proportion of ADG to the daily DM intake.

3.8. Profitability Analysis

Partial budget analysis **(Paper III)** was made to determine profitability differences of fattening intact Arsi-Bale sheep under different oil-seed cakes supplementation, considering total variable costs (TVC). The selling price of each animal was estimated by three experienced individuals involved in sheep trade in the area. The difference in average selling and purchase price of each animal was taken as total return (TR). Profitability was determined using net income (NI), calculated as NI = TR – TVC.

3.9. Feed and Feacal Sample Chemical Analysis

Representative samples of feeds and teff refusals and feces were dried at 60°C for 72 hours. The dried samples were ground using laboratory mill to pass through 1 mm screen and stored for subsequent analyses of dry matter (DM), crude protein (CP), ash (AOAC, 1990), acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) (Van Soest and Robertson, 1985). The CP was calculated as N*6.25.

3.10. Slaughter of Animals and Carcass Measurements

At the end of 90 days feeding trial, all animals were withdrawn from feed overnight with free access to water, and slaughtered after recording slaughter body weight (SBW) **(Paper III)**. The blood was drained into a bucket and weighed. After removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded including tail fat. Edible and non-edible offal components and all non-carcass fat depots were weighed and recorded. Weight of digestive tract was recorded while full and empty, and weight of gut-content was computed as the difference of the two. The empty body weight (EBW) was determined as SBW less gut contents. Dressing percentage (DP) was calculated as (HCW/SBW)*100 and (HCW/EBW)*100. Rib eye-muscle (REM) area and fat thickness (FT) were measured at the $12/13^{th}$ rib position of ***Longissimus dorsi*** muscle **(LD)** using transparent paper and plastic ruler, respectively.

3.11. Statistical Analysis

Survey data **(Paper I and II)** were analyzed using SPSS version 20 (SPSS, 2011) and thematic approach. Depending on the nature of the data, Chi-square test and ANOVA were employed to compare variables between both production systems presented as descriptive statistics such as mean and percentages. Pearson's Chi-square ($\chi 2$) test was used for categorical variables to assess a statistical significance of a particular comparison.

$$Y_{ij} = \mu + PS_i + \varepsilon_{ij}$$

Where: Y_{ij} = the observed production management in the i^{th} *production systems*

μ = overall mean

PS_i = the effect of i^{th} production systems (i = 1 and 2)

ε_{ij} = random residual error

$$\text{Rank index} = \frac{(R_n * C_1 + R_{n-1} * C_2 \ldots + R_1 * C_n)_{a-g}}{\sum_{a-g}(R_n * C_1 + R_{n-1} * C_2 \ldots + R_1 * C_n)}$$

Where,

R_n = Value of the least rank of constraint a (if the least rank is 7th, then $R_n = 4$, $R_{n-1} = 3$, $R_1 = 1$)

C_n = Counted value of the least ranked level (If the counts of the 4th rank=C_n, and C_1= the count of the 1st rank)

$(R_n * C_1 + R_{n-1} * C_2 \ldots + R_1 * C_n)_{a-g}$ = *W= weighted summation of each constraints (a,b,c...,g)

$\sum_{a-g}(R_n * C_1 + R_{n-1} * C_2 \ldots + R_1 * C_n)$ = Grand total weighted of summation of each constraint

Indices were calculated to provide overall ranking of a particular trait according to the formula: Index = sum of [4 for 1 + 3 for rank 2+2for rank 3 + 1 for rank 4] given for an individual trait divided by the sum of [4 for 1 + 3 for rank 2+2for rank 3 + 1 for rank 4] summed for overall traits (Kiflay *et al*., 2019).

Market margin determination surveys were conducted parallel to channel survey. To determine the channel, questions like “From whom did you buy?” and “To whom did you sell?” were asked. Scott (1995) pointed out that to obtain information concerning the margins, agents have to answer the question “what price did you pay?” and “what was the selling price?”

The cost and price information used to construct marketing cost and margin were gathered during the field work. Computing the total gross marketing margin (TGMM) is always related to the final price paid by the end buyer and is expressed as percentage (Mendoza 1995).

$$TGMM = \frac{End\ buyer\ price - First\ seller\ price}{End\ buyer\ price}\ X\ 100$$

Where, TGMM = Total gross marketing margin

It is useful to introduce the idea of 'farmer's portion', or 'producer's gross margin' (GMMp) which is the portion of the price paid by the consumer that goes to the producer. The producer's margin is calculated as:

$$GMMp = \frac{End\ buyer\ price - Marketing\ gross\ margin}{End\ buyer\ price}\ X\ 100$$

Where, GMM_p = the producer's share in consumer price

The net marketing margin (NMM) is the percentage of the final price earned by the intermediaries as their net income after their marketing costs are deducted. The percentages of net income that can be classified as pure profit (i.e. return on capital), depends on the extension to such factors as the middlemen's own (working capital) costs.

$$NMM = \frac{\text{Gross margin – Marketing costs}}{\text{End buyer price}} X100$$

Where, NMM = Net marketing margin

Experimental data **(Paper III)** were analyzed using the general linear model procedure of SAS (SAS, 2003). Adjusted Tukey test was used to locate the significant differences between means when F-test declare significance at $p<0.05$. The statistical model used was: $Y_{ij}= \mu + B_i + T_j + eij$. Where: Y_{ij} = the response variable; μ = overall mean; B_i = effect of block; T_j = effect of treatment; and e_{ij} = random error.

4. GENERAL RESULTS

4.1. Mixed and Agro-pastoral production systems

4.1.1. Household Socio-Economic Characteristics

Sheep had high importance in mixed crop livestock than agro-pastoral sheep production. The mean age of respondents was higher for mixed crop livestock than for agro-pastoral. Both production systems had similar family size. Higher proportion of respondents in mixed crop livestock were literate than those in agro-pastorals. Livestock is the primary source of income for agro-pastoral system and secondary for mixed crop-livestock system**. (Paper I)**

4.1.2. Livestock Species Kept, and Purpose of Sheep Keeping

Respondents in mixed-crop livestock production system had significantly higher number of cattle ($p < 0.05$), sheep ($p < 0.001$) and chicken ($p < 0.001$) than respondents in agro-pastoral. However, they had significantly lower ($p < 0.05$) number of goat as compared to agro-pastoral. Sheep was the largest livestock species possessed by the mixed-crop livestock production system. However, it is the second largest species in agro-pastoral. Regardless of production systems, proportion of breeding ewes was higher than other classes of sheep. Among ruminant livestock species, sheep was the second preference, next to cattle, for majority of producers in mixed-crop livestock production system where as in agro-pastoral less priority was given. The primary reason for keeping sheep in both production systems was income generation. Other reasons mentioned were saving, meat consumption, and manure in order of importance **(Paper I).**

4.1.3. Major Feed Resources and Management Systems

The quality and quantity of feed resources available for animals primarily depend upon the climatic and seasonal factors. The major feed resources for sheep during the wet season were

natural pasture, fallow land, crop residues and concentrate (wheat bran, maize, Linseed cake, mung bean (*masho*) and *brint* in both production systems. Similarly, during the dry season were crop stubble, natural pasture, crop residues and concentrate (wheat bran, maize, Linseed cake, mung bean (locally named as *masho*) and *brint*). Pasture was ranked first with overall average index of 0.42 and 0.40 for mixed and agro-pastoral production systems, respectively. **(Paper I).**

Majority of farmers in mixed crop livestock system use mainly own land (85.3 %), while those in the agro pastorals system use mainly communal land for grazing (80 %). In dry season, the majority of farmers and agro-pastoralists practice free grazing. In wet season, herding and tethering were the major practice in both production system with the main reason to prevent damage to crop. **(Paper I)**.

4.1.4. Watering, Housing, Breeding and Health Care Practices

The major sources of water for sheep in both production systems were rivers, springs, pond, and tap water. River water was ranked first with overall average index of 0.42 and 0.40 for mixed crop-livestock and agro-pastoral production systems in wet season, respectively. Similarly, in dry season, spring (0.36) and pond (0.44) were ranked first for mixed crop livestock and agro-pastoral production systems, respectively. The distances to watering points and frequency of watering varied with seasons and production systems. In the mixed crop-livestock system, animals mainly travel less than 1 km to get water. The majority of the respondents in agro-pastoral production system take animals up to 10 km in search of water during the dry season. The distance of water resource from home is very important consideration as it affects the application of improved management such as frequency of watering. Frequency of watering in the study areas is once per day in both production systems except during the dry season in agro-pastoral system when watering once in two days is practiced **(Paper I).**

There were significant differences ($P<0.001$) in housing system between production systems. The majority of households in both systems kept their sheep adjacent to their house. However,

it had no adequate space, feeding and watering trough, ventilation and cleanliness. Mud floors with no drainage systems and grass roof (not sloppy and leak). In agro-pastoral production system, sheep were kept in open kraal constructed from wood and branches of acacia.

About 97% of farmers in mixed crop-livestock and 49.3% of agro pastoralists practiced uncontrolled mating. Over 75% sheep owners in mixed crop-livestock had no their own breeding rams, whereas 36.7% of agro pastoralists had no breeding rams. It was found that 84% and 70% interviewed households in mixed crop livestock and ago-pastorals have access to veterinary services, respectively. The most commonly used veterinary services were government clinics (55.5% in mixed crop livestock and 69.8% agro pastorals). Veterinary service was available within 1-2 km distance for mixed crop livestock. However, 3-4 km service for agro pastoralists.

4.1.5. Major constraints of sheep production

Among the constraints, feed shortage, disease and water shortage were considered as the most important problem in both production systems with varying intensity. In Digelu-Tijo crop-livestock system feed shortage and disease ranked first and second with index of 0.38 and 0.36, respectively. However, feed shortage ranked first with higher index (0.36) and frequent drought ranked second with index of 0.24 in Meiso. **(Paper I).**

4.2. Sheep Value chain Analysis

The core functions in sheep value chain in the study area include input supply, production, marketing, processing and consumption. Input supply includes breeding stock, feed, drug, credit. Production includes feeding, watering, housing, breeding and health care. Marketing includes collecting, buying, selling, distributing, transporting and retailing. Processing includes slaughtering, cooking, chilling and packing. Sheep value chain actors are producers, traders, transporters, butchers, hotels, export abattoirs. Marketing routes in and out flow of sheep starts from gate, primary, secondary and tertiary market. Marketing channels include producers' sale to producers, small traders, big traders, butchers/ export abattoirs **(Paper II).**

4.2.1. Sheep value chain functions

The core functions in the sheep value chain in Digelu-Tijo and Meiso districts of Oromia region includes: input supply, production, marketing, processing and consumption, thus different activities were performed by the different functions.

4.2.1.1. Input supply

Value chain function starts from inputs use to produce sheep and value added products. Inputs such as land, feed, sheep, labor, credit, veterinary services among other obtained from different sources. Land is very important input in both production systems. About 88.2% and of farmers at Digelu-Tijo and 69% agro-pastoralist at Meiso, had a pasture land that ranges from 0.25-0.75 ha. The survey result revealed that most of the farmers were used purchased feeds such as linseed cake, wheat bran, scraps of faba bean and field peas and brint (by-product of areke; local alcohol drink) in mixed crop–livestock system, but agro-pastoralists use maize and wheat bran. In mixed crop livestock Arsi-Bale is dominant and niche to the area, whereas in agro pastoral, Afar, Black head Ogaden and Arsi Bale sheep breeds are found. It was found that 84% and 70% interviewed households in mixed crop livestock and ago-pastorals have veterinary services access, respectively. The most commonly used veterinary services were government clinics (55.5% in mixed crop livestock and 69.8% agro pastorals). Labor is also one of the key inputs in sheep production operations. Herding and feeding sheep were done primarily by boys (77.3 % and 60.7 %, respectively) in mixed crop livestock. Similarly, participation of boys in herding and fattening were 70.7 % and 48.3 %, respectively in agro pastoral production systems. Credit is widely regarded as an important instrument for improving the present and long term economic welfare of households. About 30.7% and 16 % had access to credit from private loan enterprise and NGO in the mixed crop livestock and agro-pastoral systems, respectively.

4.2.1. 2. Production

Farmers and agro-pastoralists sheep farming households are the main operators at this stage of the value chain. The mean number of sheep owned/household was high at Digelu Tijo (12.5) compared to Meiso (6.2). A significant difference in sheep flock size found in the current study might be due to the suitability of the environment for sheep production and the role of sheep for the livelihood of the owners. In mixed crop-livestock system, 30% of the farmers stated that they keep their sheep for breeding, 50% for sale and 20% for home consumption, in agro-pastoral production systems, 35%, 60% and 5%, respectively. About 74.7% and 65.3% of the respondents of mixed crop-livestock system and agro-pastoral production systems practice sheep fattening, respectively.

4.2.1. 3. Marketing/Trading

Sheep marketing involves collection, transportation and distribution to the end users. About 81.3 % and 66.7 % of respondents did not have any market plan in mixed crop-livestock and agro-pastorals, respectively. Majority (54.7%) of the farmers in Digelu-Tijo area sheep price determination was mainly based on body condition, 12% by market demand and 33.3% by both body condition and market demand. In Meiso, 34.7% of agro-pastoralists sheep price determination was mainly based on body condition, 21.3% by market demand and 44.0% by both body condition and market demand.

4.2.1. 2. Processing

Sheep from the study areas are mainly supplied/sold to hotels, butchers and export abattoirs. There are 22 hotels and restaurants that process sheep meat into different traditional dishes such as roasted meat, boiled meat (*kikil*), different stews (key or alicha wot) and *Dulet* (a chopped and spiced mixture of offals and *Longissimus dorsi* muscle). Hotels and butchers usually buy sheep either from producers, small traders in the market or they have suppliers (small traders) that supply on average about 10 animals a week.

4.2.1.2. Consumption

Consumers are the last link in the sheep value chain. Households often purchase sheep during cultural and religious festivals. They buy sheep from producers, collectors, small-scale traders and brokers at their nearest markets, selecting animals based on their individual preferences. About 20% and 5% of the respondents in mixed crop livestock and agro-pastorals were consuming sheep meat. There are considerable differences in consumption of mutton between study areas. Particularly in Meiso district, slaughtering sheep for mutton consumption by butchers and hotels is very little due to the high ambient temperature. Under such environment, mutton spoils quickly if not consumed in a short time after slaughtering. High ambient temperature will lead to dehydration in water deprived animals and this can affect meat quality by making it darker in color through shrinkage of the myofibres, and because of its dryness it has less weight loss during cooking. Besides, heat stress increase microbial burdens on carcasses and meat (Rana *et al*., 2014).

4.2.3. Marketing channels

Sheep market channels connect producers, traders, butchers/abattoirs, hotels/restaurants and consumers. Six types of market-outlets to sell sheep were identified in the study area and the starting point in the sheep market channels is producers and the final users of the products are the consumers. Generally, sheep is channeled either to export abattoirs, hotels/restaurants and live sheep export and then to consumers. Sheep marketing channels for both production systems have similar nature. Live sheep is channeled to Methara from both production systems to export market.

4.2.4. Distribution of costs and margins

The available marketing system links a number of different market actors as marketed animals move from producers to processors or end users. The number of links in the market chain

reflects the services that are required to deliver either live sheep or meat to various consumers or end users. In the current study, major sheep marketing costs starting from sheep producers to end users through different actors are estimated. The value of sheep increases from the lower end of the chain to the upper end (end users). As an indicator of the efficiency of the channel, net marketing margins of a particular marketing agent are estimated as a residual of the gross marketing margin after paying marketing costs. Distribution of costs and margins was calculated for the six marketing channels identified using information generated from the field study. The highest marketing cost is incurred by hotels (206.5 birr) followed by butcheries (127 birr) and export abattoirs (120). Both hotels and butchers incurred highest cost on spices followed by injera and labor.

Transportation followed by labour and feed costs is the major marketing costs for small traders. Processing costs are a major cost for hotels. In the study areas, almost all market actors have little or no access to market information and they depend on actual market day information for prices and selling decisions. In the study areas, both hotels and butchers sell '*tibs*' (roasted /fried meat), '*dulet*' and spiced boiled meat called '*kikil*' for consumption at their premises. In addition, hotels prepare hot stew made from the parts of meat unfit for frying. Butchers also sell raw meat on a kilogram basis in a take away form

.

4.3. Response of sheep to inclusion of different oilseed cakes in compound ration

4.3.1. Feed Intake and Digestibility

The CP, NDF and ADF content of teff straw used in this study were 3.6, 81.91 and 76.52%, respectively. Basal and supplement DM intakes were significantly affected ($P < 0.05$) by treatment. Total DM intake of T3 was higher ($P < 0.05$) than T1. Total dry matter intake increased by 19.4, 19.22 and 15% for T2, T3 and T4 as compared to T1. Sheep in T1 had a lower ($P < 0.05$) CP intake than T2, T3 and T4. As DM intake increased, CP intake also increased. Similarly, Intake of OM, NDF and ADF were higher ($P< 0.05$) for T2, T3 and T4 than T1. Digestibility of DM and nutrients were higher ($P< 0.001$) for T2, T3, and T4 than T1. **(Paper III)**.

4.3.2. Body Weight and Feed Conversion Efficiency.

Total weight gain (TWG), average daily gain (ADG) and feed conversion efficiency (FCE) were higher ($p< 0.01$) for T2, T3 and T4 than T1. In the present study, regardless of protein supplements, no significant difference was observed ($P >0.05$) on final live weight (FBW), whereas total weight gains (TWG), average daily gain (ADG) and feed conversion efficiency (FCE) differs. T2, T3 and T4 groups gained 3.2, 2.7 and 3.44 kg more weight, respectively than T1 **(Paper III)**.

4.3.3. Carcass Characteristics

Sheep in T2, T3 and T4 had higher SBW, EBW, HCW and REM area ($p<0.05$) than T1, with no difference ($P>0.05$) among T2, T3 and T4. There was significant difference in EBW ($P<0.05$) between treatments. Sheep in T4 had higher ($p<0.05$) dressing percentage on the basis of SBW than T1. DPEBW among treatments did not show significant difference ($P>0.05$). The rib eye muscle area which is an indicator of muscling was: 7.69, 9.58, 9.11 and 9.42 cm^2, respectively for T1, T2, T3 and T4. **(Paper III)**.

4.3.4. Edible and Non-Edible Offal Components

Among edible offal component, tongue ($P<0.001$), liver ($P<0.05$) kidney ($P<0.05$) and abdominal fat were higher for T2, T3 and T4 than T1. On the other hand, no significant difference was observed ($P>0.05$) among treatments in the weight of the following offals: blood, heart, kidney, Omasum-Abomasum, intestines, abdominal fat and the weight of total edible offals (TEO). However, there was an increasing tendency in the size of these offals in T2, T3 and T4 **(Paper III)**.

5. GENERAL DISCUSSION

5.1. Mixed and Agro-pastoral production systems

The study by Helen *et al*. (2015) in Ethiopia noted significant difference among production systems in most sheep production and reproduction parameters as well as in the major sources of income indicating the need for specific interventions with respect to the production systems. The number and type of livestock holding is affected by production systems, production objective, demand for meat, feed resources, and land availability (Zelealem *et al.,* 2012). According to Solomon *et al.* (2013) flock sizes of sheep and goat vary with the production system and the production environment in Ethiopia. Higher number of sheep was possessed by the mixed-crop livestock than agro-pastoral production system.

The quality and quantity of feed resources available for animals primarily depend upon the climatic and seasonal factors (Hezkiel *et al*., 2018). In the present study, the quality and quantity of feed resources available for animals primarily depend upon the climatic and seasonal factors. Pasture was ranked first in both production systems. In accordance with the present study, Kiflay *et al*. (2019) reported that Pasture was ranked first in sheep production and breeding practices in selected Zones of Tigray, Northern Ethiopia.

River water was the major source of water for sheep in wet season in both production systems. The findings of the current study was similar with that reported by Admasu *et al*. (2017) and Hezkiel *et al*. (2018) who reported river to be the major source of livestock drinking water in wet season in Woliyta Zone and Bensa district of southern Ethiopia. In the dry season, spring water in crop-livestock and pond water in agro-pastoral production systems are the major source of water. Zelalem (2018) noted that pond is the main source of water in dry season in different agro-ecologies of southern Ethiopia. Among the constraints of sheep production, feed shortage ranked first in both production systems followed by disease prevalence and water shortage. In this regard, Mengistu (2018) indicated that feed shortage and disease and sheep mortality problem were considered as crucial constraints to sheep

production. Moreover, Admasu *et al.* (2017) noted that feed and grazing land shortage, disease and drought were major constraints affecting sheep production.

5.2. Sheep Value chain Analysis

According to Sultan *et al*. (2012), value chain analysis is the process of breaking a chain into its constituent parts in order to better understand its structure and functioning. It consists of identifying value adding activities in the chain and assigning costs and added value to each of those activities. Mohamadou (2013) reported that sheep value chain includes all inputs and services that enable live sheep production through transporting, processing and marketing of outputs to creation of added value products such as meat through consumption of the animal source foods and related products. The core functions in sheep value chain include input supply, production, marketing, processing and consumption (Kassa *et al*., 2016; Usman *et al*., 2012).

5.2.1. Sheep value chain functions

In the present study, sheep value chain functions includes: input supply, production, marketing, processing and consumption. In agreement with this study, Kassa *et al.* (2016) reported that sheep value chain functions include input supply, production, marketing, processing and consumption. Similarly, Usman *et al.* (2012) also indicated that core functions in sheep value chain include input supply, production, marketing, processing and export or local consumption.

5.2.1.1. Input supply

Land is very important input for the production of fodder in both production systems. In line with this study, Driba *et al.* (2014) reported that land is very important input for the production of fodder. The majority of the respondents in both production systems owned

pasture land. This agreed with the report by Kedija (2007) who indicated that 10 % of households in agro-pastorals owned pastureland greater than 5 ha in Meiso district. The survey result revealed that most of the farmers were used purchased feeds particularly concentrate. From economic point of view, about 70 percent of the cost of animal production is feed and suggesting economic feasibility of animal agriculture is mainly a function of quantity or quality of nutrients and the science of feeding (Seyoum *et al*., 2018). Various management tasks which were undertaken mainly by the family members and involvement of individuals outside the family are exceptional across the study sites. The results are similar with the observation of Admasu *et al*. (2017) in Wolyieta Zone of Southern Ethiopia. This also agrees with the report of Negatu (2017) who indicated that 80% in the lowland and100% in the midland family members participate in goat husbandry and practices.

5.2.1. 2. Production

Sheep production is one part of livestock system that is integrated with crop production in both production systems. Sheep production is the core function of the sheep value chain, as it determines production of a quality product that will satisfy end-users (Ashenafi *et al*., 2013). Sheep was the largest livestock species possessed by mixed crop livestock, whereas in agro-pastorals second to goat. Major types of feed commonly used for sheep in the study area vary with seasons. Consistent with the current study, seasonality in availability of feed resources for livestock was also reported from Gamogofa Zone (Yadeta, 2016). Helen *et al*. (2015) also reported that most of the respondents (95.2%) in eastern Ethiopia reported seasonal fluctuation in feed availability. There is ample amount of grass in wet seasons while crop residue and aftermath in dry season. Some of the respondents reported that fatten sheep during religious holidays such as Ethiopian New Year, Christmas, Easter, Eid Al-Adha and Eid Al-Fetir. The report of Duguma *et al.* (2012) indicated that sheep fattening practice targets Ethiopian traditional festivals.

5.2.1. 3. Marketing/Trading

Majority of the sale of sheep is done by men when they were in need of cash to purchase inputs like fertilizer, improved seeds, for school fees and other expenses related to school. This result is similar to the report of Zahara et al (2014) who indicated that selling of animal in the market was the sole responsibility of men. Sheep marketing involves collection, transportation and distribution to the end users. Respondents sale their animals using 'eyeball' estimation. Ashenafi *et al* (2016) and Sultan *et al* (2014) reported that sheep sold /bought in eye ball based transaction and price is usually fixed by individual bargaining.

5.2.1. 4. Processing

Sheep from the study areas are mainly processed by hotels, butchers and export abattoirs. This agrees with the report of Ashenafi *et al*. (2013) who indicated that processing (slaughtering) in the area is mainly done in municipal slaughter houses. Gebregziabhear (2019) reported that hotels and butchers processed meat in to different retail food commodities in Adama district. Hotels and butchers usually buy sheep either from producers, small traders in the market or they have suppliers (small traders) that supply on average about 10 animals a week. In line with the current study, Hotels in Doyogena, Southern Ethiopia, slaughter 6–11 sheep per week (Ashenafi *et al*., 2013). The major processing work at export abattoirs is de-hiding, chilling the whole carcass, wrapping the carcass with white cotton fabric and transporting to the cargo plane. This fact is in line with the report by Sultan *et al*. (2014) who indicated that routine slaughter procedure followed by export abattoirs.

5.2.1.5. Consumption

Consumption is the last core functions in the value chain. 20% and 5% of respondents in mixed crop livestock and agro-pastorals were consuming sheep meat. Zahara *et al.* (2014) noted that 15% of farmers consumed sheep meat. There are considerable differences in consumption of mutton between study areas. Particularly in Meiso district, slaughtering sheep for mutton consumption by butchers and hotels is very little due to the high ambient

temperature. Under such environment, mutton spoils quickly if not consumed in a short period of time after slaughtering. No respondents produced sheep for the purpose of home consumption. Zahara *et al.* (2014) also noted that no respondents produced sheep for the purpose of consumption.

5.2. 2. Marketing channels

Marketing channel is a marketing process which performs several functions by bridging the gap between production and consumption (Kassa *et al*., 2016). Sheep market channels connect producers, traders, butchers/abattoirs, hotels/restaurants and consumers. Five types of market-outlets to sell sheep were identified in the study area and the starting point in the sheep market channels is producers and the final users of the products are the consumers. Duguma *et al*. (2012) and Ashenafi *et al*. (2013) reported that six types of market-outlets are available to sale. Generally, sheep is channeled either to export abattoirs, hotels/restaurants and export and then to consumers. Sheep marketing channels for both production systems are similar nature. Live sheep is channeled to Methara from both production systems to export market.

5.2.3. Distribution of costs and margins

The available marketing system links a number of different market actors as marketed animals move from producers to processors or end users. The number of links in the market chain reflects the services that are required to deliver either live sheep or meat to various consumers or end users. In the current study, major sheep marketing costs starting from sheep producers to end users through different actors are estimated. The value of sheep increases from the lower end of the chain to the upper end (end users). As an indicator of the efficiency of the channel, net marketing margins of a particular marketing agent are estimated as a residual of the gross marketing margin after paying marketing costs. Distribution of costs and margins was calculated for the six marketing channels identified using information generated from the field study. The highest marketing cost is incurred by hotels (206.5 Birr) followed by

butcheries (127 Birr) and export abattoirs (120 Birr). Both hotels and butchers incurred highest cost on spices followed by injera and labor. Transportation followed by labour and feed costs is the major marketing costs for small traders. Processing costs are a major cost for hotels. The same result was reported by Duguma *et al. (*2012) in Horro districts where the marketing cost is higher for hotels than butchers. In the study areas, almost all market actors have little or no access to market information and they depend on actual market day information for prices and selling decisions. Because of this, search costs or communication costs are very minimal and are omitted from the analysis. In the study areas, both hotels and butchers sell '*tibs*' (roasted /fried meat), '*dulet*' and spiced boiled meat called '*kikil*' for consumption at their premises. In addition, hotels prepare hot stew made from the parts of meat unfit for frying. Butchers also sell raw meat on a kilogram basis in a take away form.

5.3. Performance response of sheep to different oilseed cakes in a compound ratio

5.3.1. Feed Intake and Digestibility

The nutrient compositions of the experimental feeds used in the current study were within the range for Ethiopian feeds (Seyoum *et al*., 2007). The moderate level of CP of the native grass hay can satisfy the maintenance requirement and proper rumen function in ruminants (Van Soest, 1994). The CP content of the concentrate mix (22 % of DM) is in the range of the CP contents of quality feed for maximum growth (>15% CP) of sheep in warm climates (Salah et al., 2014). According to Ranjhan (2004) the average daily protein and energy requirement for maintenance of sheep weighing 30 kg are 36 g CP. The sheep used in the present study consumed 67-72.2 g/d CP, which are higher than the requirement for maintenance. Concentrate supplementation at high level provide opportunity for intake of more nutritionally dense and digestible feeds. In this regard, Van Soest (1994) noted that higher level of supplementation increases the supply of nitrogen to the rumen microbes thereby increasing microbial population and efficiency, the rate of fermentation of digesta and feed intake. In accordance with the present study, Getu *et al*. (2012) reported that higher feed intake for cotton and linseed cake supplemented Horo sheep than noug seed cake and Tagasaste forage legume.

According to David (2007) feed with DM digestibility of less than 55% is considered as poor quality and will not maintain body weight, whereas feed having digestibility exceeding 65% is categorized as high quality. This shows that both levels of supplements used could provide nutrients sufficient to allow growth of the animals. The higher DM and nutrient digestibility for T2, T3 and T4 in the present study could be a consequence of the higher CP intake. Supplementation of poor quality forage with good protein feed increases the availability of nitrogen in the rumen, thereby improving the rate of degradation and utilization of the feed (McDonald *et al*., 2010). The significant difference in digestibility of nutrients among treatments in the present study is due to high DM intake and CP intake.

5.3.2. Body Weight and Feed Conversion Efficiency

According to Getu *et al.* (2012) sheep supplemented with CSC had higher (P<0.001) final BW, BW change and daily BW gain than NSC supplemented ones. Moreover, Wondwosen *et al*. (2009) reported that Cottonseed cake and LSC supplemented goats had higher (P<0.05) mean daily BW gain and final BW as compared to the non-supplemented and NSC supplemented goats. In agreement with the present finding, the increased average daily gain in CSC and PNC supplemented animals than NSC supplemented ones (Amare *et al.*, 2009). This is in line with the fact that supplements result in improved animal performance possibly by providing essential nutrients for rumen microorganisms, enhancing the microbial activities in the rumen and through availing more nutrients for the animal (Van Soest, 1994). The higher weight gain observed for intact sheep than castrate at similar amounts of DM intake demonstrated difference in feed utilization efficiency among the groups. The higher FCE recorded for sheep on T2 and T4 than T1 and T3 could be due to the higher DM and CP intake and digestibility of the sheep in this treatment.

5.3.3. Carcass Characteristics

Slaughter body weight was higher (P<0.05) for sheep in T2, T3 and T4 than sheep in T1, whereas there was no significant (P<0.05) difference observed between T2, T3 and T4 T1. This might be due to high DM and CP intake. Dressing percentage on SBW was higher (P<0.05) for sheep in T4 as compared to sheep in T1, whereas dressing percentage on EBW did not vary (P>0.05) among the treatments. The dressing percentage of Arsi-Bale sheep in the current study was 40.13-44.04% and 49.18- 51.36% on slaughter and empty body weight basis, respectively. Sheep in T2, T3 and T4 had higher (P<0.05) rib-eye muscle area than sheep in T1, however, there was no significant (P>0.05) difference in T2, T3 and T4.

The higher SBW and the relatively better carcass yield of T2, T3 andT4 than T1 in the present study could be due to higher DM and CP intake and digestibility. Dressing percentage expressed as a proportion of the empty BW was higher than when expressed as a proportion of slaughter weight in this study indicating the influence of digesta (gut fill) on dressing

percentage. Rib eye area indicates the muscular development of the animal that will be increased through the live weight gain. The rib eye area (7.69-9.58 cm^2) for the present study was slightly higher than 7.3-8.3 cm^2 reported by Tekelu (2016) for the same breed of sheep fed different varieties of faba bean straws and supplemented with concentrate.

Regardless of the variations between supplement levels, the average DP value on SBW bases fall within the range of 40-50% recorded for many tropical sheep breeds (Payne and Wilson, 1999). However, the DP values calculated on SBW and EBW basis in the present study were higher than the values (32.7 and 48.2%) reported for the same breed in another study (Berhanu, 2014). The variations in DP of the same breed at different supplements clearly showed plain of nutrition to have a positive effect on carcass yield as described by Payne and Wilson (1999). The lack of significant difference in DP regardless of the variation in SBW and EBW between sex groups is because of the higher amount of total non-carcass components in intact sheep. In agreement with the current finding, Awet and Solomon (2009) noted increased non-carcass component for intact Afar sheep consumed high level of concentrate.

5.3.4. Edible and Non-Edible Offal Components

The increased weights of tongue, kidney fat, esophagus, bladder and TNEO of T2, T3 and T4 sheep might be explained by the higher total DM and CP intake. Results of the present study agree with that of Tekelu (2016) who reported that majority of offal components did not differ significantly among treatments. The increased weight of functional organs and TEO at high level of supplementation in the present study indicated that improving the nutritional status of the animal has a positive impact on the development of such organs and edible offal components (Archimede *et al*., 2008). In contrast to this, Kiflay *et al*. (2014) and Abebe *et al*. (2009), reported majority of offal components differ significantly among treatments. In different areas of the world, various offal components of meat animals including blood are edible and saleable, and fetch extra money that could add value to the carcass.

5.4. Partial Budget Analysis

Feed cost was the major cost of the feeding trial and selling price of sheep depend on body performance. In this study, it was realized that the economic return of the feeding trial mainly depends on feed cost, purchasing and selling price of the experimental sheep. Fattening sheep involves intensive feeding to attain slaughter weight with adequate finish in feedlots so as to improve carcass yield for domestic consumption/export and to directly increase producer's income (Alemu, 2008b). The higher net income for Arsi-Bale sheep in the present study is because of low feed cost, high growth, hot carcass yield and nutrient utilization efficiency. This agrees with the results of Getu *et al*. (2012) and Amare et al (2008) who reported Horro and Tigray highland sheep performed very well when they fed on CSC, respectively. Therefore, among the supplemented treatment groups, T3 was the best recommended oilseed cake based on economic point of view. Therefore, teff straw basal diet based feeding system for sheep should be supplemented with a good protein supplement like cotton seed meal to obtain good net income (profit) within a shorter duration.

6. GENERAL SUMMARY AND CONCLUSIONS

Sheep production is an important livestock production activity, which make a significant contribution to the mixed crop livestock and to a lesser extent in agro-pastoral economy and nutrition. In both production systems sheep are kept under traditional extensive systems with no or minimal inputs, and unimproved technologies, which leads to low production and productivity. A comprehensive description of the production environment is essential to make use of performance data.

Findings of the survey study showed that about 97% of the respondents in the mixed crop livestock and 64% of the respondents in the agro-pastoralists were headed by males. About 21.3% had basic and 72% formal education background in the mixed crop livestock, whereas in the agro-pastoralists 12% and 8%, respectively. Food crop is the primary and livestock is the secondary income sources in mixed crop-livestock system, while it was the reverse in the agro-pastoral system. the proportion of breeding ewes and rams made-up 30% and 36% of the total flock in mixed crop-livestock and agro-pastoral production systems, respectively.

The current study results showed that Pasteurellosis, sheep pox, Orf, liver fluke (fasciolosis), black leg, pest des petit ruminant (PPR), parasites and contagious caprine pluero pnemonia (CCPP) were affecting the health of sheep although their prvalence differs between the production systems and seasons. There was variation in index intensity in prioritizing constraints between the production systems. Feed shortage, disease and water shortage were the first three constraints in mixed crop-livestock system with index value of 0.38, 0.36 and 0.26, respectively. Recurrent drought, feed shortage and disease prevalence were also the most important constraints ranked by agro-pastoralists with index value of 0.36, 0.24 and 0.19, respectively.

The sheep value chain segments identified was: input supply, production, marketing, processing and consumption. Key inputs/services used in sheep husbandry were land, feed, breeding stock, credit service and labor. The study identified that extensive production system

was dominant in both production systems. Lack of land, breeding stock, credit service, low in quantity and quality of feed and its high price, inefficient veterinary and breeding services and low final producer's share and weak horizontal and vertical relationship was critical constraints between the value chain actors.

Total dry matter, organic matter and NDF intake were lower in NSC supplemented sheep compared to those supplemented with LSC, CSC and SBC. Total NDF and ADF intake was higher ($p<0.001$) in CSC supplemented sheep than those supplemented in T1. The apparent digestibility of dry matter was significantly impacted by treatments ($P<0.0001$) and was in the order of T4>T2>T3>T1. There were no significant difference ($P> 0.05$) in FBW, TWG and ADG among T2, T3 and T4. But there was significant difference ($P< 0.05$) between T_1 and other treatments (T2, T3 and T4).

Slaughter body weight was higher ($P<0.05$) for sheep in T2 and T4 as compared to sheep T1 and T3, whereas empty body weight showed significant ($P<0.05$) difference between T2, T3, T4 and T1. This might be due to the high DM and CP intake. Hot carcass weight was higher ($P<0.05$) for sheep in T4 as compared to sheep in T1 and there were no significant ($P>0.05$) difference among T2, T3 and T4. Dressing percentage on SBW was higher ($P<0.05$) for sheep in T4 as compared to sheep in T1, whereas dressing percentage on EBW did not vary ($P>0.05$) among the treatments. The dressing percentage of Arsi-Bale sheep in the current study was 40.13-44.04 % and 49.18- 51.36 % on slaughter and empty body weight basis, respectively. Sheep in T2, T3 and T4 had higher ($P<0.05$) rib-eye muscle area than sheep in T1, however, there was no significant ($P>0.05$) difference in T2, T3 and T4.

Sternum weight was greater ($P<0.01$) in T2 and T3 than T1 while T2 and T4 recorded heavier ($P<0.05$) vertebrae (Table 6). The TMCC was heavier in T4 ($P<0.05$) than the other treatments. Tail was heavier in T3 ($P<0.05$) than in T1. However, there were no difference ($P>0.05$) among treatments in forelegs, hind legs, neck, pelvic region and ribs.

The weight of most of the edible and non-edible offal's did not differ among the treatments. Greater weight of liver ($P<0.05$) and tongue ($P<0.001$) was observed in T4 than T1 and T2.

Lower (P>0.05) kidney fat was occurred in T1 and T3 as compared to T4. Except esophagus and bladder, non-edible offal components did not differ among treatments. The TNEO weight was lower in T1 than the other treatments (P<0.01). The partial budget analysis showed that cottonseed cake supplementation returned higher profit (net return) than other treatments because of the high growth, and hot carcass yield obtained from supplementing this diet.

The study revealed that the higher dependency of agro-pastoralists on livestock production than crop in the study area suggests introduction of carefully planned and pertinent sheep improvement strategy could result into successful sheep production. Besides, relatively better reproductive and productive performance of sheep under harsh environment would create an opportunity to improve the productivity of sheep through addressing the major constraints. Therefore, a coordinated effort is needed to address the constraints across different stages of sheep value chain. Besides, it is crucial to systematically describe the production systems in order to plan and design appropriate research and development interventions that are relevant to the specific systems. From the experimental result, it can be conclude that fattening of Arsi-Bale sheep with CSC supplementation is recommended to attain better animal performance and maximum profit. Such a system can be viewed as a better option for the production of more carcasses yield.

7. REFERENCES

Abebe Tafa & Solomon Melaku & Kurt J. Peters. 201Supplementation with linseed (Linum usitatissimum) cake and/or wheat bran on feed utilization and carcass characteristics of Arsi - Bale sheep. Tropical Animal Health Production 42:677–68.

Abegaz, S., Hegde, B.P. and Taye, M. (2011) Growth and Physical Body Characte-ristics of Gumuz Sheep under Traditional Management Systems in Amhara Region-al State, Ethiopia.

Admasu L., Aberra, M. and Banerjee, S. 2017. Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. *African Journal of Agricultural Research*, 12 (20): 1689-1701.

Adugna Tolera. 2008. Feed resources and feeding management: A manual for feedlot operators and development workers. Ethiopia Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM) Report. 38pp

Adugna Tolera. 2007. Feed Resources for Producing Export Quality Meat and Livestock in Ethiopia Examples from Selected Woredas in Oromia and SNNP Regional States. Ethiopia Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM) Report. 79pp

Adugna Tolera and Aster Abebe 2007. Livestock production in pastoral and agro-pastoral production systems of southern Ethiopia. *LRRD*. 19:12.

Adugna Tolera, Alemu Yami and Dawit Alemu. 2012. Livestock feed resources in Ethiopia: Challenges, Opportunities and the need for transformation. Ethiopia Animal Feed Industry Association, Addis Ababa, Ethiopia.

Ahmed Hassen, Abule Ebro, Mohammed Kurtu and AC. Treydte, 2010. Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. *Livestock Research for Rural Development*. 22 (229). *http://www.lrrd.org/lrrd22/ 12/hass22229.htm*

Alemayehu Mengistu, Gezahagn Kebede, Getnet Assefa and Fekede Feyissa, 2017. Overview of improved forage and forage seed production in Ethiopia: lessons from fourth livestock development project. *International Journal of Agriculture and Biosciences*, 6(4): 217-226.

Alemayehu Mengistu. 2006. Country pasture/forage resources profiles. In: Francias, J. M. Suttie and S.G. Reynolds (eds). FAO publications, Rome, Italy.

Alemu Yami. 2008a. Technical Bulletin No.18., on castration of sheep and goats. *In:* R.C. Merkel and L. Dawson (eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP).

Alemu Yami. 2008b. Nutrition and feeding of sheep and goats. pp.103-159. *In:* Alemu Yami and R.C. Merkel (eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP).

Amha Sebsibe. 2008. Sheep and goat meat characteristics and quality. pp. 325-340. *In:* Alemu Yami and R.C. Merkel (eds.), *Ethiopia sheep and goat productivity improvement program (ESGPIP)*. Branna Printing Interprise, Addis Ababa, Ethiopia.

AOAC. 1990. Official Methods of Analysis. Association of Official Analytical Chemists, *16th Edition.* Arlington, Virginia, USA

ARC (1980). The Nutrient Requirement of Ruminant Livestock. Common Wealth Agricultural Bureaux, ARC (Agricultural Research Council) Farnham Royal, England. Pp. 114 -151.

Asfaw Negassa, Shahidur Rashid and Berhanu Gebremedhin. 2011. Working Paper 26 on livestock production and marketing. ESSP II (Ethiopia Strategy Support Program II). Addis Ababa, Ethiopia.

Asresu Yitayew, Mengistie Taye, Agraw Amanie and Getenet Zeleke. 2013. Community based improvement scheme for washera sheep: Lessons from Yilmanadensa and Quarit districts in Western Amhara, Ethiopia. *African journal of Agricultural research*, 8(44): 5485-5491.

Baneh H., Hafezians S.H. (2009): Effects of environmental factors on growth traits in Ghezel sheep. *African Journal of Biotechnology*, 6(12) : 2903-2907.

Beneberu, T., Shenkute, G., Wamatu, J. & Solomon, G. 2013. *Analysis of Sheep Value Chains in Menz Gera District, North Shewa Zone, Ethiopia.* Addis Ababa.ICARDA.

Birhan M. and Adugna T., 2014. Livestock Feed Resources Assessment, Constraints and

Improvement Strategies in Ethiopia, *Middle-East Journal of Scientific Research*, 21, 616-622

Cheeke, P.R., 1999. Applied animal nutrition. Feeds and feeding. 2nd ed., Prentice Hall Inc. upper Saddle River, New Jersey. pp. 95-269.

CSA (Federal Democratic Republic of Ethiopia-Central Statistical Agency), 2017. Agricultural Sample Survey 2016/17 [2009 E.C.]Volume II, Report on Livestock and Livestock Characteristics (Private Peasant Holdings) Addis Ababa. Statistical Bulletin 585.

Degu, A. and Melaku, S. and Berhane, G. (2009): Supplementation of isonitrogenous oilseedcakes in cactus (Opuntia ficus-indica)–*tef* straw (*Eragrostistef*) based feeding of Tigray Highland sheep. *Animal-. Feed Science. Technology*, **148**:214-226.

Delgado C, 2005. Rising demand for meat and milk in developing countries: implications for

grasslands-based livestock production. Pp 29-39 in D A McGilloway (ed), Grassland: a

global resource. Wageningen Academic Publishers, The Netherlands.

Diaz, M.T., Velasco, S., Caneque, V., Lauzurica, S., Perez, C., Gonzalez, J. and Manzanares, C. 2002. The use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. *Small Ruminant Research*, 43: 257-268.

Deriba Geleti, Mekonnen Hailemariam, Ashenafi Mengistu and Adugna Tolera 2014 Analysis of Fluid Milk Value Chains at Two Peri-Urban Sites in Western Oromia, Ethiopia: Current Status and Suggestions on How They Might Evolve. Global Veterinarian 12 (1): 104-120, 2014 DOI: 10.5829/idosi.gv.2014.12.01.81164.

Duguma, G., Degefa, K., Jembere, T., Temesgen, W., Haile, A., Duncan, A.J. and Legese, G. 2012. Analysis of sheep value chains in Horro district, Oromia region, Ethiopia. Addis Ababa: ICARDA and ILRI.

Getahun, K. (2014) Effect of Concentrate Supplementation on Performances of Ethiopian Lowland Afar and Blackhead Ogaden Lambs. *Journal of Animal and Veterinary Sciences*, 2: 36-41. https://doi.org/10.11648/j.avs.20140202.14

Getahun L. 2008. Productive and economic performance of small ruminant production in production system of the highlands of Ethiopia. PhD dissertation. University of Hohenheim,Stuttgart, Hoheinheim, Germany.

Getu Kitaw, Mesfin Dejene, Aemiro Kehaliw and Getnet Asefa, 2012. Comparative evaluation of Tree Lucerne (*Chamaecytisus palmensis*) over conventional protein supplements in supporting growth of yearling Horro lambs. *Livestock Research for Rural Development.* 24(8). http://www.lrrd.org/lrrd24/1/getu24008.htm

Giuliani E, Pietrobelli C and Rabellotti R 2005 Upgrading in global value chains: Lessons from Latin American clusters, World Development 33(4):549-573.

Gizaw,S., Ebro, A., Tesfaye, Y., Mekuriaw, Z., Mekasha, Y., Hoekstra, D., Gebremedhin, B. and Tegegne, A. 2017. Feed resources in the highlands of Ethiopia: A value chain assessment and intervention options. LIVES Working Paper 27. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Gizaw, S., Abegaz, S., Rischkowsky, B., Haile, A., Mwai, A.O. and Dessie, T. (2013): Review of sheep research and development projects in Ethiopia. International Livestock Research Institute (ILRI). Nairobi, Kenya:

GTZ (Deutsche Gesellschaftfür Technische Zusammenarbeit GmbH). 2007. Value Links Manual: The Methodology of Value Chain Promotion, First Edition. http://www.valuelinks. de/manual/distributor.html.

Habib G., N.A. Khan, M. Ali, M. Bezabih, 2013. In situ ruminal crude protein degradability of by-products from cereals, oilseeds and animal origin. *Livestock Science* 153: 81–87

Hagos A. and Solomon M. 2017.Supplementation of Adilo Sheep with Sole or Mixtures of *Moringa stenopetala* Leaf Meal and Wheat Bran on Feed intake, Body Weight Gain and Digestibility. *The Journal of Agricultural Sciences,* 12 (3): 222-233

Hayaz Uddin, Abdur Rahman, Rajwali Khan, Bakht Daraz khan, Din Muhammad, Kamran Farid, Khrshaid Anwar, Sibghat Ullah and Zubair Ali 2013. Effect of Cotton Seed Cake on Cattle Milk Yield and Composition at Livestock Research and Development Station Surezai, Peshawar, Pakistan. *Pakistan Journal of Nutrition,* 12 (5): 468-475

Helen Nigussie, Yoseph Mekasha, Solomon Abegaz , Kefelegn Kebede, Sanjoy Kumar Pal. 2015. Indigenous sheep production system in eastern Ethiopia: Implications for genetic improvement and sustainable use. *American Scientific Research Journal for engineering, technology and Science,* 11: 136-152.

Heuzé V., Thiollet H., Tran G., Hassoun P., Bastianelli D., Lebas F., 2017a. Niger (Guizotia abyssinica). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO

Heuzé V., Tran G., Baumont R., Noblet J., Renaudeau D., Lessire M., and Lebas F. 2015. *Wheat bran*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/726

Heuzé V., Tran G., Hassoun P., Bastianelli D., and Lebas F., 2016. *Cottonseed meal.* Feedipedia, a programme by INRA, CIRAD, AFZ and FAO.

Heuzé V., Tran G., Nozière P., Lessire M., and Lebas F., 2017b. Linseed meal. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://feedipedia.org/node/735

Ingr, I. 1989. Meat quality: Defining the term by modern standards. Fleisch, 69:1268.

Kaplinsky R and Morris M 2001 A Handbook for Value Chain Research. Working Paper Prepared for the IDRC, Brighton, UK, Institute for Development Studies.

Kassa Tarekegn, Zelalem A. and Hailemariam G. 2016. Analysis of Sheep Value Chain in Kafa Zone, Southern Ethiopia. *International. Journal of.Scicences.* 4(2): 12–23 DOI: 10.22576/ijsf/SF-2016-59

Kassahun Awgichew and Solomon Abegaz. 2008. Breeds of Sheep and Goats. pp. 6-26. *In:* Alemu Yami and R.C. Merkel (eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP). Branna Printing Interprise. Addis Ababa, Ethiopia.

Kearl L C. 1982. Nutrient requirements of ruminants in developing countries. International Feed Staffs Institute, UTAH State University, Logan, 381pp.

Kosgey, I.S. and Okeyo, A.M. 2007. Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant. Research,* 70: 76-88.

Mahgoub, O., Horton, G.M.J. and Olvey, F.H. 1998. Effect of method and time of castration on growth and carcass characteristics of Omani sheep. *Australian Journal of Animal science,* 11(2):121-127. doi: https://doi.org/10.5713/ajas.1998.121.

Marishet T., Mengistu U., Getnet A., and Kassahun M. 2019. Effects of sources of dietary protein supplemented to oat-vetch hay mixture on milk yield and milk composition of crossbred dairy cows. *International Journal of Livestock Production,* 10(2): 56-61

McDonald P., Edwards R.A., Greenhalgh J.F.D., Morgan C.A., Sinclair L.A. and Wilkinson R.G., 2010. Animal Nutrition, 7th ed. Prentice Hall, London UK

McDonald P, Edwards R A, Greenhalgh J F D, Morgan, C A .2002 Animal Nutrition (6th edit.). Pearson Educational Ltd. Edinburgh, Great Britain. 544pp.

Mcdonald, P.; Edwards, R.A.; Greenhalgh, J.F.D. et al. 1995. Animal nutrition. 5.ed. London: Addison Wesley Longman Limited

Maleda Birhan and Takele Adugna. 2014. Livestock feed resources assessment, constraints and improvement strategies in Ethiopia. *Middle East Journal of Scientific Research,* 21(4): 618-704.

Melese Gashu, Berhan Tamir and Mengistu Urge. 2014. Effect of supplementation with non-conventional feeds on feed intake and body weight change of Washera sheep fed urea treated finger millet straw. *Greener Journal of Agricultural Sciences,* 4(2): 067-074.

MoA (Ministry of Agriculture). 2012. 2011/12 (2004 E.C) Performance assessment report on the growth and transformation agenda in the spheres of agriculture

Moran, J.B. and Wood, J.T. 1986. Comparative performance of five genotypes of Indonesian small ruminants on Growth and development of carcass tissues. *Australian journal of Agricultural research*, 37:435-447. https://doi.org/10.1071/AR9860435.

Morgan S.E., 2015. Gossypol Toxicity in Livestock. Oklahoma Cooperative Extension Service

Moti Jaleta, Berhanu Gebremedhin and Hoekstra, D. 2009. Discussion paper No.18 on Smallholder commercialization: Process, determinants and impact. *Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project.* Nairobi, Kenya.

Notenbaert, A., Herrero, M., Kruska, R., You, L., Wood, S., Thornton, P. and Omolo, A. 2009. Classifying livestock production systems for targeting agricultural research and development in a rapidly changing world. Discussion Paper No. 19. ILRI (International Livestock Research Institute), Nairobi, Kenya. 41 pp.

NRC (National Research Council), 1981. National Research of Goats. Academy Press, Washington, DC. PP.84.

NRC, 1985. Nutrient requirement of sheep 6th revised edition National Academy, Press Washington, DC (USA).

NRC, 2000. Nutrient requirements of beef cattle. 7th edition, National Academies Press, Washington D. C.

NRC, 2001. Nutrient Requirements of Dairy Cattle. 7th revised edition Natl. Acad. Sci., Washington, D.C.

Österle N., Angassa A., Tadesse A., Ebro A., Sauerborn J., and Anna C. T., 2012. Crop-Livestock Farming Systems Varying with Different Altitudes in Southern Ethiopia,

Science, Technology and Arts Research Journal, 1: 1-13

Pandey, G.S. and Voskuil, G.C.J., 2011. Manual on Improved Feeding of Dairy Cattle by Smallholder Farmers. Golden Valley Agricultural Research Trust. Lusaka, Zambia.

Payne WJ, Wilson RT (1999). An Introduction to animal husbandry in the tropics. *5th edition*. Blackwell Science Ltd, London, U. K. 815p.

Pietrobelli C and Saliola F 2008 Power relationships along the value chain: multinational firms, global buyers and performance of local suppliers, *Cambridge Journal of Economics*, 32(6): 947-962.

Pond, W.G., Church, D.C. and Pond, K.R. 1995. Basic animal nutrition and feeding, *4th Edition*. John Wiley and Sons, New York. 249-615p.

Rana MS , MA Hashem , S Akhter , M Habibullah , MH Islam , RC Biswas 2014.Effect of heat stress on carcass and meat quality of indigenous sheep of Bangladesh. Bangladesh Livestock Research Institute, Savar, Dhaka. *Bangladesh Journal of Animal Sciences*, 43 (2): 147-153

Teferawork Beyene. 1989. Performance of Arsi and crossbred sheep in the highland of Arsi Oromia Region, Ethiopia. MSc Thesis, Swedish University, Sweden.

Sanudo, C., Sanchez, A. and Alfonso, M. 1998. Small ruminant production systems and factors affecting lamb meat quality. Journal of Meat Science, 49(1): 29-64.

Seyed M.K and Mehdi B. 2017.The effect of Sex and Weaning Age on Growth Performance of First generation Lambs Derived from crossing ½ Romanov and Zel. Journal of Animal Research, 2(1): 1-4

Seyoum Bediye, Gemechu Nemi and Harinder Makkar, 2018. Ethiopian feed industry: current status, challenges and opportunities. Feedipedia, www.feedipedia.org.

Seyoum Bedeye, Getenet Assefa, Abate Tedla and Dereje Fikadu. 2001. Present status and future direction in feed resources and nutrition research targeted for wheat based crop livestock production system in Ethiopia: pp: 207-226. In P.C. Wall (ed.). Wheat and weed: food and feed. *Proceeding of two –stockholder workshop.* CIMMYT, Mexico City.

Seyoum Bediye, 1995. Evaluation of nutritive value of herbaceous legumes, browse species and oil seed cakes using chemical analysis, *In vitro* digestibility and nylon bag techniques. MSc. Thesis, Alemaya University of Agriculture, Ethiopia.

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset G. and Mechale. H. 2017. Ethiopia livestock sector analysis. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. and Mechal, H. 2015. *Ethiopia livestock master plan.* ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sibanda, S., Osuji P.O., Nsahlai, I.V., 1993. The degradation of oil seed cakes and their effects on the intake and rumen degradability of maize stover given to Ethiopian Menz sheep. *Animal production* 57: 421-428.

Sindhu A.A., Khan M.A., Mahr-Un-Nisa and Sarwar M. 2002. Agro-industrial by-products as a potential source of livestock feed. International Journal of Agriculture and Biology. 4: *307-310.*

Snezana Bogosavljevic-Boskovic, Sreten Mitrovic, Radojica Djokovic, Vladimir Doskovic and Vladan D.,2010. "Chemical composition of chicken meat produced in extensive indoor and free range rearing systems." African Journal of Biotechnology 9, no. 53 9069-9075.

Solomon G., Abegaz, S., Rischkowsky, B., Haile, A., Mwai, A.O. and Dessie, T., 2013. Review of sheep research and development projects in Ethiopia. International Livestock Research Institute (ILRI). Nairobi, Kenya:

Solomon Gizaw, Azage Tegene, Birhanu Gebremedhin and Hockstra, D. 2010. Sheep and goat production and marketing system in Ethiopia; characteristics and strategies for improvement. IPMS/ILRI, Addid Ababa, Ethiopia.

Solomon Gizaw, Hoekstra, D., Berhanu Gebremedhin and Azage Tegegne. 2015. LIVES Working Paper 5 on Classification of small ruminant production sub-systems in Ethiopia: Implications for designing development interventions. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Solomon Gizaw, Komen, H., Hanotte, O. and Van Arendonk, J.A.M. 2008. Indigenous sheep resources of Ethiopia: types, production systems and farmers preferences. Animal Genetic Resources Information, 43: 25-40. https://doi.org/10.1017/S1014233900002704

Sultan U., D. Abate, S. Belete, T. Wegi, G. Legese and A.J. Duncan. 2012. Analysis of the sheep value chain in Sinana district of Oromia Region, Ethiopia. Addis Ababa, Ethiopia: ICARDA and ILRI.

Tagaynesh Alemayoh (2014): Supplementation of sole wheat bran or its mixture with safflower seed cake on performance of Hararghe highland sheep fed grass hay basal diet. An MSc thesis, Haramaya University, Ethiopia.

Tekelu Wegi 2016. Effects of feeding different varieties of Faba Bean (*Vicia faba* L.) straws with concentrate on feed intake, digestibility, body weight gain and carcass characteristics of Arsi-Bale Sheep. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Tesfaye H. and, Solomon M, 2009. Feed intake, digestibility, body weight and carcass parameters of Afar rams fed tef (Eragrostis tef) straw supplemented with graded levels of concentrate mix. *Tropical Animal Health and Production*, 41: 599-606.

Tibbo, M., Anindo, D., Tembely, S., Mukasa-Mugerwa1, E., Baker, R.L., Strandberg, E., Schneider, M. del P., Philipsson, J., Ayalew, W. & Rege, J.E.O. 2006. Genetic parameter estimates of lamb survival using Linear Models and Survival Analysis in indigenous Ethiopian Menz and Horro sheep breeds.

Tolera, A., Yami, A., Mengistu, A., Alemu, D., Geleti, D., Assefa, G., Gizachew, L., Bediye, S. and Weldesemayat Y., 2012. Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation: Main issues, Conclusions and Recommendations; 1-135pp, Ethiopian Animal Feeds Industry Association, Addis Ababa, Ethiopia.

Topps, J.H. 1977. The relationship between reproduction and under nutrition in beef cattle. World Review of Animal Production, 13: 43-49.

Usman M., 2016. Analysis of Wheat Value Chain: The case of Sinana District, Bale Zone, Oromia Region, Ethiopia Msc thesis Haramaya University, Ethiopia.

Van Soest PJ, Robertson JB (1985). Analysis of forages and fibrous feeds. A laboratory manual for animal science, Vol. 613. Cornell University, Ithaca, New York.

Van Soest, P.J. 1994. Nutritional Ecology of Ruminants, *2nd edition*. Cornell University press, London.

Webb, E.C., Casey, N.H., Simela, L.,2005. Goat meat quality. Small Rumin.Res. 60, 153–166

Yayneshet Tesfay, 2010. Feed Resources Availability in Tigray Region, North Ethiopia, for Producing Export Quality Meat and Livestock. Ethiopia Sanitary and Phytosanitary Standards and Livestock and meat Marketing Program (SPS-LMM). USAID, Ethiopia.

Yenesew A, Solomon M, Azage T (2013). Sheep breeds, traditional breeding and flock structure in Burie District, North Western Ethiopia. *Global Advanced Research Journal of Agricultural Scicences* 2(12): 325-335. http://hdl.handle.net/10568/34333.

Zelealem T. G, Anal A. K. & Gebrezgiher G (2012). Assessment of the sheep production system of northern Ethiopia in relation to sustainable productivity and Sheep meat quality. *International Journal of Advanced Biological Research*. VOL. 2(2): 302-313. http://scienceandnature.org [February 1, 2019]

Zemicael Gebresilasie, 2007. Supplementation of Sesame seed (Sesame indicum) cake, wheat bran and their mixtures on feed intake, digestiblity, liveweight change and carcass charcterstics of Arado sheep fed basal diet of teff straw. An. Msc. Thesis prsented to the shool of graduate studies of Haramaya University of Agriculture, Haramaya, Ethiopia,57p.

8. APPENDICES

8.1. Paper I

Characterization of Sheep Production Practices in mixed crop-livestock and Agro-pastoral systems of Central and Eastern Ethiopia

Eyob Gebregziabhear[1*], Mengistu Urge, Getachew Animut[3] and Mengistu Ketema,

Published in East African Journal of Veterinary and Animal Sciences (2019) Volume 3 (1): 27-38

https://www.haramayajournals.org/index.php/EAJVAS/article/view/914

Characterization of Sheep Production Practices in Mixed Crop-livestock and Agro-pastoral Systems of Central and Eastern Ethiopia

Eyob Gebregziabhear[1*], Mengistu Urge[2], Getachew Animut[3], and Mengistu Ketema[4]

[1]Ethiopian Agricultural Research Institute, Debre Zeit Center, P.O. Box 32, Debre Zeit, Ethiopia
[2]School of Animal and Range Sciences, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia
[3]Agriculture Transformation Agency, P.O. Box 708, Addis Ababa, Ethiopia
[4]School of Agricultural Economics and Agribusiness Management, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

Abstract: The study was conducted in Digelu-Tijo and Meiso districts representing the mixed crop-livestock and agro-pastoral production systems, respectively with an objective of characterizing sheep production practices. A total of 150 households from six rural kebeles (75 households from each production system) were selected randomly based on sheep population and accessibility. Data were collected through structured questionnaire, focus group discussion and field observation. The average number of sheep per household in mixed crop-livestock (12.5±0.99) was higher ($p<0.001$) than that of agro-pastoral production system (6.2±0.34). The purposes of keeping sheep in both production systems were to generate income followed by saving, meat, and manure. Natural pasture and crop residues were the major feed resources in both production systems. Water sources were largely rivers, springs, ponds and pipe with different magnitude of use during wet and dry seasons. The major diseases and parasites of sheep during the dry season were pasteurellosis, sheep pox, orf, parasites, peste des petits ruminants (PPR), foot and mouth disease (FMD) and blackleg, while, liver flukes and lungworms were common across the production systems during the wet season. The survey revealed predominance of uncontrolled mating (97.7%) in mixed crop-livestock than the agro-pastoral (50.7%) production system ($p<0.05$). Despite diverse production management practices identified, overall sheep production systems were affected by constraints related to feed and water shortages and prevalence of infectious and parasitic diseases. Thus, to increase sheep productivity, designing and implementing sustainable sheep production improvement programs targeting at solving these constraints are crucial.

Keywords: *Breeding practices, Constraints, Feed sources, Production objectives, Sheep*

Introduction

Ethiopia is home for 9 breeds and 14 traditional sheep populations (Solomon *et al.*, 2007) with an estimated 33.02 million heads (CSA, 2019). In Ethiopia, sheep are the second numerous farm animals distributed across the different agro-ecologies ranging from cool alpine climate of the mountains to the arid pastoral areas of the lowlands (Solomon *et al.*, 2010). Sheep have multipurpose functions, which include provision of food, mainly meat in Ethiopia, manure, and source of income (Shigdaf *et al.*, 2013). They are also considered as a living bank against the various environmental calamities and have socio-cultural values for diverse traditional communities (Zewdu *et al.*, 2010). The prevailing sheep production systems have evolved in relation to the availability of land, the overall pattern of crop production and farming systems (the type of crop production practiced and the frequency or intensity of cropping), the area of uncultivated wasteland and the density of animal populations (Solomon *et al.*, 2010).

Mode of livestock production in Ethiopia is broadly classified into pastoral, agro-pastoral, mixed crop-livestock and the emerging peri-urban and urban production systems. Solomon *et al.* (2008) classified sheep production system in Ethiopia into five sub systems, which includes highland sheep-barely, mixed crop–livestock, pastoral and agro-pastoral, ranching and urban and peri-urban production systems. In pastoral systems, extensive livestock production is the main source of livelihood with little or no cropping. Livestock production is mostly a secondary enterprise in the highland mixed crop–livestock systems, although livestock assumes a major importance in areas, where crop production is unreliable.

Although the sheep production systems in the country is well defined, the systems lack up-to-date and location specific information regarding production practices, constraints and marketing strategy. Moreover, the vibrant nature of livelihood, agro-ecology, level of input, intensity of production, reliability of crop production, availability of land and type of commodity produced require dynamic information. Therefore, understanding sheep production practices under the different systems would enable to know the opportunities and constraints prevailing in the system and to design appropriate

*Corresponding Author. E-mail: eyobda21@gmail.com

Published by Haramaya University, 2019

ISSN: 2616-8804 (Print)

strategy to lessen the production bottlenecks. The objective of this study was, therefore, to characterize sheep production practices in agro-pastoral and mixed crop-livestock production systems to generate information that support the setting up of sustainable production improvement strategy within the specific system.

Materials and Methods

Description of the Study Areas

The study was conducted in Digelu-tijo and Meiso districts of Oromia National Regional State, located in the Central and Eastern Ethiopia, respectively. Digelu-tijo district is located between 7°5'0" and 7°52'30"N latitude and 39°0'0" and 39°25'0"E longitude. Its altitude ranges 1107 to 3106 meters above sea level (masl). The annual rainfall and temperature ranges 900 to 1400mm and 10-22°C, respectively. The sheep population of the district is estimated at 119,544 (DWOA, 2014). Mieso is a district where pastoral/agro-pastoral farming system prevails. The district is located between 40°9'30.1" and 40°56'44"E longitude and 9°19'52" and 8°48'12"N latitude, with an altitude ranging from 1107 to 3106 masl The most parts of the district are situated at about 1700 masl and it receives average annual rainfall of 635-945 mm, while its mean annual temperature is 21°C (MBPRD, 2014).

Sampling Procedure and Data Collection

Prior to the actual data collection, discussions were made with zonal and district livestock experts and development agents (DAs) to get actual information on the sheep population, production area coverage and production potential of the rural kebeles in the districts. Arsi and East Haraghe zones were selected purposively based on sheep population, difference in production system and accessibility. Similarly, the districts and three rural kebeles from each district were selected purposively based on the same criteria. Simple random sampling was used to select target households. The total number of households taken for the study was 150 (75 from each production system). A formal interview using structured questionnaire was employed to collect data from the selected households. The questionnaire was tested before the actual interview to ensure that all questions were of sufficient clarity to the interviewees. Data on general household information, purpose of keeping sheep, labor utilization, feeds and feeding, watering, housing, reproductive performance and major constraints of sheep rearing were collected.

Data Analysis

Data collected through questionnaire was organized and analyzed using SPSS version 20 (SPSS, 2011) and presented as descriptive statistics such as mean and percentages. Pearson's Chi-square ($\chi 2$) test was used for categorical variables to assess a statistical significance of a particular comparison. One-way ANOVA was applied for quantitative variables using the statistical model:

$$Y_{ij} = \mu + PS_i + \varepsilon_{ij}$$

Where:

Y_{ij} = the observed production management in the i^{th} *production systems*

μ = overall mean

PS_i = the effect of i^{th} production systems (i = 1 and 2)

ε_{ij} = random residual error

Indices were calculated to provide overall ranking of a particular trait according to the formula: Index = sum of [4 for 1 + 3 for rank 2+2 for rank 3 + 1 for rank 4] given for an individual trait divided by the sum of [4 for 1 + 3 for rank 2+2 for rank 3 + 1 for rank 4] summed for overall traits (Kiflay *et al.*, 2019).

Results and Discussion

Household Socio-economic Characteristics

The majority of the households in the study area were male headed ($p<0.001$) (Table 1). Female headed households represent only about 6.7% and 36% for mixed crop-livestock and agro-pastoral production system, respectively. Higher proportion of female headed household in agro-pastorals as compared to mixed crop-livestock might be due to polygamy (Helen *et al.*, 2015). Shewangzaw and Adis (2016), Admasu *et al.* (2017) and Hizkel *et al.* (2018) also reported 6%, 5.4% and 14.1% of female headed households, respectively in their studies. The high proportion of male headed household indicated that men play a dominant role in decision making over livestock production management and the utilization of benefits generated from live animal sale.

The average age of the household head was higher ($P<0.001$) in mixed crop-livestock than agro-pastoral production system implying that young people are more engaging in livestock rearing in agro-pastoral areas presumably due to inadequate and erratic rainfall and crop failure. It is well known that the family size has an implication on household labor force for sheep production related activities. There was no significant difference in family size between the production systems. About similar number of persons per household were also reported for Meiso (Kedija, 2007; Zelalem, 2007) and Alaba (Endeshaw, 2007) districts. About 93.3% of the head of the households in mixed crop-livestock system had education of different types and levels indicating that the majority can read and write. This could be considered as an opportunity since educated farmers are more receptive to adopt improved sheep management practices, technologies and newly disseminated innovations (Tassew and Seifu, 2009) and are easily trainable. On the other hand, majority of the respondents in agro-pastoral production system were illiterate (cannot read and write) mainly because, children are made to look after the livestock at early age rather than schooling. Moreover, there are few primary schools in the pastoral and agro-pastoral areas

(Zelalem, 2007) indicating that less opportunity exists to send children to school. This finding agrees with the result of Shiferaw (2006) who noted 90% illiteracy rate in pastoral and agro-pastoral areas of eastern Ethiopia. High rate of illiteracy has a negative effect on the acceptance and dissemination of new technologies and thus, agro-pastoralist need mainly a face to face training in order to acquaint them with improved sheep production technologies. Similarly, Hizkel *et al.* (2018) reported only 25.75% illteracy rate in southern Ethiopia indicating that access to education varies from area to area.

Table 1. Socio-economic characteristics of respondents by production system

Parameters		Production systems			
		Mixed crop-livestock (n=75)	Agro-pastoral (n=75)	Overall (n=150)	P-value
Sex (%)	Male	93.3	64	78.7	<0.001
	Female	6.7	36	21.3	<0.001
Age (year±SE)		43.3±1.38	36.2±0.82	39.8±0.86	<0.001
Family size		6.1±0.28	6.8±0.24	6.4±0.18	0.095
Educational level (%)	Illiterate	6.7	80	43.3	<0.001
	Read and write	21.3	12	16.7	<0.001
	Primary	48	5.3	26.7	<0.001
	Secondary	22.7	2.7	12.7	<0.001
	Higher education	1.3	0	0.7	<0.001

n= Number of respondents; SE= Standard error.

Income Source

There was variation in the contribution of income sources between the production systems (Table 2). Food crop is the primary and livestock is the secondary income sources in mixed crop-livestock system, while it was the reverse in the agro-pastoral system. This result showed that livestock production has given the highest priority than crop in agro-pastoral area due to frequent crop failure as a result of erratic and insufficient rainfall. The current result is in agreement with the finding of Arse *et al.* (2013) who illustrated that farmers in Adami Tulu and Arsi Negelle districts ranked income from crop production to be first compared to other sources.

Table 2. Ranking of income sources for households by production system

Variables	Mixed crop-livestock system (n=75)					Agro-pastoral system (n=75)				
	1	2	3	4	Index	1	2	3	4	Index
Food crop	65	3	7	0	0.36	26	15	34	0	0.28
Cash crop	6	0	55	14	0.19	21	21	32	1	0.28
Livestock	3	68	0	4	0.28	29	39	6	1	0.32
Manure	2	7	36	30	0.17	1	4	4	66	0.12

1, 2, 3 and 4= Ranks for traits; n= Number of respondents/ households.

Livestock Holding and Species Composition

Significant differences were observed in average number of livestock species kept between the production systems (Table 3). Except camel, which is not reared in mixed crop-livestock system, and goats, higher number of sheep, cattle, chicken and horses were recorded in mixed crop-livestock production system. This revealed that, the number and type of livestock holding is affected by production systems, production objective, demand for meat, type of feed resources and land availability (Zelealem *et al.*, 2012). The existence of a higher number of sheep per household in the present study is similar to the findings of Tesfaye (2008) who reported large proportion of sheep in mixed crop-livestock than pastoral areas.

Although livestock is ranked as a first source of income in agro-pastoral production system, the number of cattle and sheep are lower than those owned by mixed crop-livestock households, which could be due to low feed availability in the lowland as a result of erratic rainfall, high heat, and high prevalence of disease. According to Solomon (2011) the unpredictable rainfall and temperature variation induces a huge challenge to sorghum production and in turn to feed and food availability. Similarly, EPCC (2015) noted that 96%, 94.7% and 74.7% of the respondents perceive that climate change resulted in crop failure and feed and water shortage in Meiso district, respectively. In pastoral areas, climate change resulted in deterioration of the rangelands and its encroachment with woody browse. This has induced change in the species of livestock to be kept towards mixed herds of browsing animals (camels and goats) with smaller numbers of cattle and sheep (Kefyalew and Tegegn, 2012).

Sheep flock Structure

The breeding ewes and rams made-up about 30% and 36% of the total flock in mixed crop-livestock and agro-pastoral production systems, respectively (Table

4). Admasu *et al.* (2017) reported breeding ewes to represent 51.4% and 48.3% of the total flock of highland and midland agro-ecology, respectively. Other studies (Tesfaye *et al.*, 2010; Fsahatsion *et al.*, 2013; Hizkel *et al.*, 2018) from different locations in Ethiopia also recorded much greater proportion of breeding ewes in a flock than obtained in the present study. The proportion of different sheep categories appears to be generally similar between the two production systems.

Table 3. Average number of livestock holding (mean ± SE) by production system

Parameters	Production systems		
	Mixed crop-livestock (n=75)	Agro-pastoral (n=75)	P-value
Cattle	6.2±0.34	4.1±0.38	0.018
Sheep	12.5±0.99	6.2±0.34	<0.001
Goat	0.12±0.08	6.7±0.99	<0.001
Chicken	7.3±0.41	3.7±0.31	<0.001
Donkey	0.61±0.08	0.48±0.08	0.252
Mule	0.01±0.01	-	-
Camel	-	1±0.34	-
Horses	1.35±0.13	-	-

n= Number of respondents; SE= Standard error.

Table 4. Flock size and composition by production system

Sheep categories	Production systems							
	Mixed crop-livestock				Agro-pastoral			
	N	Mean±SE	Range	% of total flock	N	Mean±SE	Range	% of total flock
Lambs < 6m	244	3.25±0.03	0-20	21	104	1.79±0.11	0-4	16
Ram lambs	186	3.15±0.54	0-32	16	72	1.67±0.16	0-7	11
Ewe lambs	175	2.82±0.20	0-9	15	102	2.08±0.20	0-5	16
Breeding rams	170	3.33±0.48	0-21	15	135	2.25±0.23	0-10	20
Breeding ewes	344	4.57±0.27	0-23	30	240	3.12±0.35	0-16	36
Castrated	30	2.31±0.37	0-4	3	5	1.25±0.25	0-2	1

6m= Six months; N= Total number of animals.

Purpose of Keeping Sheep

The purpose of keeping sheep in the study area were primarily for income generation followed by saving, meat and manure production in order of importance with no significant difference (P>0.05) between production systems (Table 5). Studies from different parts of Ethiopia also noted primary utility of sheep to be source of income (Tesfaye *et al.*, 2010; Zelealem *et al.*, 2012; Fsahatsion *et al.*, 2013; Nigatu, 2017; Mengistu, 2018). None of the respondents mentioned keeping of sheep for milk production, which is associated with the tradition of not consuming sheep milk in the area.

Table 5. Ranking of purpose of keeping sheep by production system

Purposes	Mixed crop-livestock (n=75)					Agro-pastoral (n=75)				
	1	2	3	4	Index	1	2	3	4	Index
Income	48	10	12	5	0.37	41	12	11	0	0.38
Meat	5	25	3	2	0.22	10	20	2	2	0.25
Manure	1	5	12	1	0.15	6	4	3	0	0.09
Saving	22	13	10	2	0.26	18	11	10	1	0.29

1, 2, 3 and 4 = Ranks for traits; n= Number of respondents/households.

Labor Division in Sheep Husbandry and Decision Making

All members of the households were involved in sheep management operations (Table 6). However, women and children below 15 years shouldered greater responsibility for several important routine tasks. Boys were more responsible for flock herding and feeding, which is in agreement with that indicated by Admasu *et al.* (2017) who reported that the younger members of the family were mainly engaged in herding. Although children are engaged in agricultural activities to render labor needed by the family, intensive engagement of children may be one of the reasons for the high rates of school dropout, contributing to the high illiteracy rate in rural areas, implying that livestock husbandry practices may require changes that allow family to engage in schooling or there must be options for schooling of children. Most of the women and girls were engaged in barn cleaning and providing feed supplements to animals as they usually stay at home

while males are engaged in outside agricultural activities. In line with the present study, Kedija (2007) reported that 100% barn cleaning was done by girls.

Sheep marketing is primarily done by men in mixed crop-livestock, whereas women play the primary role in agro-pastorals system. In line with the current study, Fsahatsion *et al.* (2013) reported that purchasing and selling of sheep in most part of Ethiopia was the responsibility of husbands and they possess more power in deciding on the expenditure of incomes generated from sale of animals. Similarly, Zewdu *et al.* (2012) reported that 95.6% of purchasing and 97% of selling of sheep were mainly performed by males above 15 years of age, particularly by the head of the household, in mixed crop-livestock as opposed to the corresponding 38.3% and 60.7% by females above 15 years of age in pastoral/agro-pastoral areas.

Table 6. Proportion (%) of the family members involved in sheep husbandry practices by production system

Responsible members		**Production systems**		P-value
		Mixed crop-livestock (n=75)	Agro-pastoral (n=75)	
Herding				0.054
	CMF	77.3	70.7	
	CMHI	6.7	2.7	
	CFF	4[b]	17.3[a]	
	AMF	6.7	8	
	AMHI	4	0	
	AFF	1.3	1.3	
Feeding				0.001
	CMF	60	48	
	CMHI	6.7[a]	0[b]	
	CFF	6.7	16.7	
	AMF	18.7[a]	6.7[b]	
	AMHI	4	0	
	AFF	4[b]	29.3[a]	
Barn cleaning				0.049
	CMF	6.7	9.3	
	CMHI	0	1.3	
	CFF	52[a]	28[b]	
	AMF	4	6.7	
	AMHI	1.3	0	
	AFF	36[b]	54.7[a]	
Marketing				0.001
	CMF	0.0[b]	6.7[a]	
	CMHI	0.0[b]	8[a]	
	CFF	0.0	0.0	
	AMF	93.3[a]	18.7[b]	
	AMHI	1.3	2.6	
	AFF	5.4[b]	64[a]	

[a,b]Values among production systems are significantly different (P<0.001); CMF= Children male family< 15 years; CMHI= Children male hired< 15 years; CFF= Children female family < 15 years; AMF= Adult male family > 15 years; AMHI= Adult male hired> 15 years; AFF= Adult female family > 15 years; n= Number of respondents.

Feed Resources and Grazing Management

The main feed resources in the study areas were pasture and crop residues in the wet season and pasture and crop stubble in the dry season in both production systems (Table 7). However, natural pasture was the major feed resource for sheep during dry and wet seasons and ranked first in both production systems. The quality and quantity of feed resources available for animals primarily depend upon seasonal factors such as temperature and rainfall. According to Zewdu *et al.* (2012), the major feed resources for sheep during the wet season were natural pasture followed by crop residues across the production systems, while crop residues followed by natural pasture are the main dry season feeds. In general, feed resources are adequate during the rainy season, but become depleted during the dry season (Adugna and Aster, 2007). The grasses also over mature in dry season and become very low in nutritive value being rich in fiber content, but low digestibility and low voluntary intake by animals (Adugna and Aster, 2007) and the situation is more aggravated when the dry season is prolonged.

Management with respect to grazing, tethering and herding was significantly ($p<0.05$) different between production systems (Table 8). In dry season, the majority of mixed crop-livestock farmers and agro-pastoralists practice free grazing. In wet season, herding and tethering were the major practice in both

production systems with the main reason to prevent crop damage. The farmers in mixed crop-livestock system use mainly their own land, while those in the agro-pastoral system use mainly communal land for grazing.

Table 7. Ranking of feed resources for sheep by production system

Seasons	Feeds	Mixed crop-livestock (n=75)					Agro-pastoral (n=75)				
		1	2	3	4	Index	1	2	3	4	Index
Wet	Pasture	58	13	2	1	0.42	67	5	3	0	0.40
	Fallow land	3	15	27	21	0.15	0	-	-	-	-
	CRs	9	39	17	7	0.23	6	46	21	2	0.29
	Browse	-	-	-	-	-	-	14	36	11	0.18
	Concentrate	5	5	23	29	0.20	-	4	5	53	0.13
Dry	CS	47	27	1	0	0.36	19	52	0	4	0.21
	CRs	28	45	2	0	0.23	55	20	0	0	0.12
	Pasture	0	0	42	32	0.26	0	0	14	58	0.44
	Concentrate	0	3	30	42	0.15	0	0	61	13	0.23

1, 2, 3 and 4 = Ranks for traits; n= Number of respondents/households; CRs= Crop residues; CS= Crop stubble.

Table 8. Grazing management and grazing land type by production system

Variables	Mixed crop-livestock (n=75) %	Agro-pastoral (n=75) %	P-value
Grazing management in dry season			0.035
Free grazing	68	80	
Herding	21.3	6.7	
Tethering	10.7	13.3	
Grazing management in wet season			0.032
Free grazing	10.7	14.7	
Herding	60	38.7	
Tethering	29.3	47.6	
Grazing land type			0.000
Own	85.3	20	
Rented	6.7	0	
Communal	8	80	

n= Number of respondents.

Water Source and Watering

River water was the major source of water for sheep in wet season in both production systems (Table 9). The findings of the current study are similar with those reported by Admasu *et al.* (2017) and Hizkel *et al.* (2018) who reported river to be the major source of livestock drinking water in wet season in Woliyta Zone and Bensa district of southern Ethiopia. In dry season, spring water in crop-livestock and pond water in agro-pastoral production systems are the major source of water. Zelalem (2018) noted that pond is the main source of water in dry season in different agro-ecologies of southern Ethiopia.

Table 9. Ranked water sources for livestock drinking by production system

Seasons	Variables	**Production systems**									
		Mixed crop-livestock (n=75)					Agro-pastoral (n=75)				
		1	2	3	4	index	1	2	3	4	Index
Wet	River	58	14	0	0	0.43	58	13	0	0	0.40
	Spring	15	52	0	0	0.34	13	54	0	0	0.32
	Pond	1	0	0	26	0.05	1	0	13	15	0.07
	CTW	1	2	57	0	0.18	2	4	52	12	0.21
	Total	**75**	**68**	**57**	**26**	**1.0**	**74**	**71**	**65**	**27**	**1.0**
Dry	River	17	7	0	27	0.19	1	1	2	35	0.07
	Spring	26	20	12	0	0.30	13	0	23	0	0.16
	Pond	14	29	6	5	0.26	59	13	0	0	0.44
	CTW	15	14	26	6	0.25	2	58	13	0	0.33
	Total	**72**	**70**	**44**	**38**	**1.0**	**75**	**72**	**38**	**35**	**1.0**

1, 2, 3 and 4= Ranks for traits; n= Number of respondents/households.

The distances to watering points and frequency of watering varied with seasons and production systems (Table 10). In the mixed crop-livestock system, animals mainly travel less than 1 km to get water. The majority of the respondents in agro-pastoral production system take animals up to 10 km to find water sources during the dry season. Zelealem (2007) noted that the mean time taken to reach at watering points by agro-pastoralist in Meiso district were 2.73 and 2.89 hours by small ruminant fattening package adopters and non-adopters, respectively. The distance of water resource from home is very important consideration as it affects the application of improved management such as frequency of watering. Frequency of watering in the study areas is once per day in both production systems except during the dry season when watering of animals is once per two days in agro-pastoral system due to less accessibility to water sources.

Table 10. Proportion (%) of watering frequency and distance travelled during dry and wet seasons by production system

Descriptors	Mixed crop-livestock (n=75)		Agro-pastoral (n=75)	
	Dry %	Wet %	Dry %	Wet %
Distance				
At home	10.7	14.7	4	8.3
<1km	61.3	85.3	4	34.7
<5km	28	0	12	21.3
6-10km	0	0	80	32
Frequency				
Available free	0	8	1.3	5.3
Once in a day	100	88	12	82.7
Twice in a day	-	4	-	-
Once in two days	-	-	86.7	12

n= Number of respondents.

Sheep Housing and Breeding Practices

Type of housing used for sheep significantly (P<0.001) varies between production systems (Table 11). Majority of the households in mixed crop-livestock and agro-pastoral production systems keep sheep in adjoining family houses followed by keeping within the family house. Moreover, agro-pastoral households also use kraals to keep their animals. In line with the present study, Helen *et al.* (2015) reported practice of keeping sheep in the family leaving house during the night. According to Admasu *et al.* (2017) keeping the animals within the family house is thought to be a safe way to protect the animals from predators and theft. However, zoonotic diseases transmission risk and poor sanitary conditions due to poor ventilation are expected to affect both household members and animals. In this regard, Animut and Wamatu (2014) noted that the practice of sharing family house for animals is common among smallholder farmers across the rural areas of Ethiopia; may be because of low awareness and lack of understanding of the risk and space requirement of animals.

Table 11. Type of sheep housing and breeding practices of households by production system

		Mixed crop-livestock (n=75) %	Agro-pastoral (n=75) %	Overall	P-value
Housing type					
	WFH	40	32	36	0.001
	AFH	60	41.3	50.7	
	KWR	0	26.7	13.3	
Breeding practice					
	Controlled	1.3	50.7	26	0.001
	Uncontrolled	97.7	49.3	74	
Ram ownership and utilization					
	HOBR	28	56	42	0.01
	HNBR	72	44	58	
	Use of ram from:				0.001
	Near neighbors	79.6	42.4	65.5	
	Far neighbors	20.4	57.6	34.5	

n= Number of respondents; WFH= Within the family house; AFH= Adjacent to the family house; KWR= Keraal without roof; HOBR= Having own breeding ram; HNBR= Having no breeding ram.

The result of sheep breeding practice of households showed that indiscriminate breeding (uncontrolled mating) is prevalent in the area as rams and ewes are run together throughout the year sharing common grazing land and watering point (Table 11). However, a significant proportion of the agro-pastoralist in Meiso practiced controlled mating. The majority of sheep owners in Meiso reported that they try to avoid dry season lambing and indiscriminate mating, through methods like ram isolation and castration.

Majority of the crop livestock farmers as opposed to the agro-pastoralists also use rams from near neighbors in addition to their rams (Table 11). Solomon *et al.* (2010) stated that 100% of the respondents used their own breeding rams in Mieso district. Helen *et al.* (2015) reported that 70% and 45.5% of the pastoral and agro-pastoral respondent's herded sheep flock alone without mixing with other flocks, indicating that agro-pastoralists to have better understanding about the benefit of controlled breeding. Pastoralists, using long tradition of animal breeding practices select better quality herds by using different traditional management practices such as castration, culling, offspring testing and pedigree keeping with social restrictions on the sales of genetically valuable breeding animals that lead to closed gene pool with varieties of selection objectives (FAO, 2003).

Reproductive Performance

Reproductive performance of indigenous sheep in both production systems are summarized in Table 12. Sexual maturity of sheep for both sexes was higher ($P<0.05$) in agro-pastoral production system than mixed crop-livestock, but it is lower than reported by Hizkel *et al.* (2018), which were 7±0.12 and 7.15±0.2, and 7.68±0.23 and 7.8±0.12 months for male and female in high and mid altitude of Bensa district, respectively. Age at first lambing was also higher ($P<0.001$) in agro-pastoral production than mixed crop-livestock system. Lambing interval and litter size are greater in mixed crop-livestock than agro-pastoral production system. The value for lambing interval obtained in the current study were higher than the previous report of Helen *et al.* (2015), which were 6.63±0.13,8.81±0.24, 10.2±0.19 months for mixed crop-livestock, agro-pastoral and pastoral production systems, respectively. The average litter size observed in the current study was similar to Hizkel *et al.* (2018) who reported 1.3±0.34 for high land and 1.2±0.15 for mid land of Bensa district of Southern Ethiopia.

Table 12. Average reproductive performance (Mean ± SE) of sheep by production systems

Particulars	Mixed crop-livestock (n=75)	Agro-pastorals (n=75)	Overall (n=150)	P-value
Age at puberty for male (months)	6.24±0.63	6.49±0.58	6.36±0.05	0.12
Age at puberty for female (months)	6.52±0.66	7.06±0.72	6.8 ±0.61	0.001
Age at first lambing (months)	12.21±0.07	13±0.06	12.61±0.06	0.001
Lambing interval	12.17±0.06	10.68±0.11	11.43±0.09	0.001
Average litter size	1.2±0.05	1.04±0.02	1.12±0.03	0.002

n= Number of respondents; SE= Standard Error.

Table 13. Major sheep diseases and parasites by production systems

Seasons	Variables	**Production systems**										
		Mixed crop-livestock (n=75)					Agro-pastoral (n=75)					
		1	2	3	4	Index	Variables	1	2	3	4	Index
Wet	IP	44	10	10	1	0.31	Orf	49	15	10	1	0.35
	Pasteurellosis	16	30	20	9	0.28	FMD	16	20	15	15	0.23
	Sheep pox	5	15	30	30	0.21	IP	5	25	40	35	0.28
	Lungworm	10	15	15	35	0.20	CCPP	5	15	10	19	0.14
	Total	**75**	**70**	**75**	**75**	**1.00**	**Total**	**75**	**75**	**75**	**70**	**1**
Dry	IP	44	20	10	1	0.34	PPR	55	12	5	3	0.37
	Pasteurellosis	16	30	20	9	0.27	Pasteurellosis	5	25	45	9	0.27
	Sheep pox	5	10	30	30	0.19	EP	10	21	10	28	0.21
	Lungworm	10	15	15	35	0.2	CCPP	5	7	15	35	0.15
	Total	**75**	**75**	**75**	**75**	**1.00**	**Total**	**75**	**65**	**75**	**75**	**1**

1, 2, 3 and 4= Ranks for traits; IP= Internal parasite; FMD= Foot and mouth disease; CCPP= Contagious caprine pleuropneumonia; PPR= Peste des petits ruminants; EP= External parasite; n = Number of respondents.

Diseases and Parasites

The result showed that pasteurellosis, sheep pox, orf, liver fluke (fasciolosis), blackleg, peste des petits ruminants (PPR), parasites and contagious caprine pleuropneumonia (CCPP) were affecting the health of sheep although their prvalence differs between the production systems and seasons (Table 13). It is well known that diseases have numerous negative impacts on livestock herds and flocks. It causes death of animals, loss of weight, slow down growth, results in poor fertility, and decreases physical power (CSA, 2019). Similar types of diseases were reported across different part of the country to occur in any of the seasons (Zelealem *et al.,* 2012; Fsahatsion *et al.,* 2013;

Hizkel *et al.*, 2018). However, the occurrence and severity of the effect posed by the diseases vary across the agro-ecology and season indicating the need for season and area specific animal health intervention strategy (Homann *et al.*, 2007).

According to the focus group discussants and key informant interviewees, the veterinarians assigned are not sufficient to reach all rural kebeles. As a result, the housholds in the study area use their own indigeneous knowledge to treat diseases and parasites. Improper use of drugs by livestock owners was also reported, which they said caused serious problems and adverse effects. Animal health services delivery in the country is characterized by lack of drugs, inadequacy of service, and lack of skilled personnel (Hulunim, 2014). Zelealem *et al.* (2012) also noted that most of the respondents encountered serious problems and adverse effects as a result of improper use of medicines. Hence, provision of better health service that suit the production system would be recommended as a strategy to enhance livestock productivity (Hulunim, 2014). According to Tsedeke (2007), women had higher responsibility in managing different mix of species of livestock like cattle, sheep, goats and equines and the care they provide to animals is thought to be better.

Table 14. Sheep production constraints by production system

Constraints	Production systems									
	Mixed crop-livestock					Agro-pastoral				
	Rank					Rank				
	1st	2nd	3rd	4th	Index	1st	2nd	3rd	4th	Index
Feed shortage	55	13	0	0	0.38	24	34	9	1	0.36
Water shortage	0	0	19	0	0.26	0	0	10	5	0.15
Disease prevalence	17	29	1	0	0.36	4	3	14	3	0.19
Drought	0	0	0	0	0	45	26	2	0	0.24

Sheep Production Constraints

Among the constraints of sheep production, feed shortage ranked first in both production systems followed by disease prevalence and water shortage (Table 14). The current finding is similar with previous studies (Kedija, 2007; Helen *et al.*, 2015; Admasu *et al.*, 2017; Mengistu, 2018; Shgute and Anja, 2018). Recurrent drought and crop failures, which are directly related to feed availability, appear to be major problems in agro-pastoral system (EPCC, 2015). Hence, designing intervention and implementation strategies to solve the feed shortage should be given priority in the effort to improve sheep productivity across the study area.

Conclusion

The average flock size of sheep per household was relatively larger for crop-livestock than agro-pastoral production systems. The purpose of sheep keeping was mainly for cash income, saving, meat and manure in order of importance. Selection and controlled mating were less practiced. Feed shortage, high disease and parasite prevalence, water shortage and drought were the major constraints in mixed crop-livestock and agro-pastoral production systems. As a result, productivity of sheep in both production systems is very low. Therefore, designing strategies that improve sheep management practices and addressing the prevailing challenges is necessary in order to enhance sheep productivity and thereby producers income.

Acknowledgements

The authors would like to acknowledge Ethiopian Institute of Agricultural Research, AGP II and Haramaya University for financial support. The supports given by local experts, farmers and agro-pastoralists during data collection are highly appreciated.

Conflict of Interests

The authors declare that they have no competing interests.

References

Admasu, Lakew, Aberra, Melesse & Sandip Banerjee (2017). Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. *African Journal of Agricultural Research*, 12 (20): 1689-1701.

Adugna Tolera & Aster Abebe (2007). Livestock production in pastoral and agro-pastoral production systems of southern Ethiopia. *Livestock Research for Rural Development,* 19 (12).

Animut, G. & Wamatu, J. (2014). Prospects to improve the productivity of sheep fattening in Ethiopia: Status, challenges and opportunities. Addis Ababa: ICARDA.

Arse Gebeyehu, Feyisa Hundessa, Gurmessa Umeta, Merga Muleta & Girma Debele (2013). Assessment on challenges and opportunities of goat farming system in Adami Tulu, Arsi Negelle and Fantale districts of Oromia Regional State, Ethiopia. *African Journal of Agricultural Research*, 8 (1): 26-31.

CSA (Ethiopia Central Statistical Agency) (2019). Agricultural Sample Survey 2018/19: Volume II Report on Livestock and Livestock Characteristics (Private Peasant Holdings), Central Statistical Agency, Addis Ababa, p: 38.

DWOA (Digelu-tijoWoreda Office of Agriculture) (2014). Annual report for livestock production.

Endeshaw Assefa (2007). Assessment on production system and marketing of goats at Dale district, Sidama Zone, MSc Thesis, Hawassa University, Ethiopia.

EPCC (Ethiopian Panel on Climate Change) (2015). First Assessment Report, Working Group II Agriculture and Food Security, Published by the Ethiopian Academy of Sciences.

FAO /GTZ/ (2003). Proceedings of the Workshop "Community-Based Management of Animal Genetic Resources – A Tool for Rural Development", held in Mbabane, Swaziland.

Fsahatsion Hailemariam, Aberra Melesse & Sandip Banerjee (2013). Traditional sheep production and breeding practice in Gamogofa Zone, Southern Ethiopia. *International Journal of Livestock Production Research,* 1 (3): 26-43.

Helen Nigussie, Yoseph Mekasha, Solomon Abegaz, Kefelegn Kebede & Sanjoy Kumar Pal (2015). Indigenous sheep production system in eastern Ethiopia: Implications for genetic improvement and sustainable use. *American Scientific Research Journal for engineering, technology, and Sciences (ASRJETS),* 11: 136-152.

Hizkel Kenfo, Yoseph Mekasha & Yosef Tadesse (2018). A study on sheep farming practices in relation to future production strtegies in Bensa district of southern Ethiopia. *Tropical Animal Health and Production*, 50 (4): 865-874.

Homann, S, Van Rooyen, A., Moyo, T. & Nengomasha, Z. (2007). Goat production and marketing: Baseline information for semi-arid Zimbabwe. Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics, p: 84.

Hulunim Gatew (2014). On-farm phenotypic characterization and performance evaluation of Bati, Borena and short eared Somali goat populations of Ethiopia. MSc Thesis, Haramaya University, Ethiopia.

Kedija Hussen (2007). Characterization of milk production system and opportunity for market orientation: A case study of Mieso district, Oromia region, Ethiopia. MSc Thesis, Alemaya University, Ethiopia.

Kefyalew Alemayehu & Tegegn Fantahun (2012). The effect of climate change on ruminant livestock population dynamics in Ethiopia. *Livestock Research for Rural Development*, 24 (10).

Kiflay Welday, Mengistu Urge & Solomon Abegaz (2019). Sheep Production Systems and Breeding Practices for Selected Zones of Tigray, Northern Ethiopia. *Open Journal of Animal Sciences*, 9: 135-140

MBPRD (2014). Meiso office of Pastoralists and Rural development Annual Report. Meiso Wereda.

Mengistu Regassa (2018). Performances of Highland Sheep under Community-based Breeding Program in Atsbi Wenberta District, Tigray, Ethiopia, MSc Thesis, Bahir Dar University, Ethiopia.

Nigatu Dejene (2017). Assessment of production and marketing systems and on-farm evaluation of the effect of supplementing the leaves of *Balanites aegyptiaca* and maize grain on growth performance and economic return of indigenous goats in Gamo Gofa Zone. MSc Thesis, University of Hawassa, Awassa, Ethiopia.

Shewangzaw Addisu & Adis Kassahune (2016). Sheep Production and Marketing System in North Gondar Zone of Amhara Region, Ethiopia. *Advances in Biological Research*, 10 (5): 304-308.

Shiferaw Gomaz (2006). *In-situ* phenotypic characterization of Kereyu cattle type in Fentalle District of Oromia Region, Ethiopia, MSc Thesis, Haramaya University, Ethiopia.

Shigdaf, M., Zeleke, M., Mengistie, T., Hailu, M., Getnet, M. & Aynalem, H. (2013). Reproductive performance and survival rate of Washera and Farta sheep breeds under traditional management systems in Farta and Lay Gayint Districts of Amhara Regional state, Ethiopia. *Ethiopian Journal of Animal Production,* 13: 65- 82.

Shigute Etalema & Anja Abera (2018). Small ruminant production and constraints in Misha Woreda, Hadiya Zone, Southern Ethiopia. *International Journal of Livestock Production*, 9 (8): 192-197.

Solomon Abegaz, Girma Abebe & Kassahun Awugichew (2008). Sheep and Goat Production Systems in Ethiopia. In: Alemu Yami and R.C. Merkel (Eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP), Branna Printing Interprise. Addis Ababa, Ethiopia, pp: 27-32.

Solomon Gizaw, Azage Tegegne, Berhanu Gebremedhin & Dirk Hoekstra (2010). Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 23. ILRI (International Livestock Research Institute), Nairobi, Kenya, pp: 58.

Solomon Gizaw, Van Arendonk, J.A.M., Komen, H., Windig, J. J. & Hanotte, O. (2007). Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Animal Genetics*, 38: 621–628.

Solomon T. Wodajo (2011). Assessing the Effect of climate variability and change on production on and productivity of Sorghum (Sorghum bicolar) in Meiso area Eastern Ethiopia, MSc Thesis Haramaya University, Ethiopia.

SPSS (2011). Statistical Package for Social Sciences Study. Version 20, Chicago, Illinois, USA.

Tassew, A. & Seifu, E. (2009). Smallholder Dairy Production System and Emergence of Dairy Cooperatives in Bahir Dar Zuria and MechaWoredas, Northwestern Ethiopia. *World Journal of Dairy Food Sciences,* 4 (2): 185-192.

Tesfaye Getachew, Aynalem Haile, Markos Tibbo, Sharma, A. K., Sölkner, J. & Wurzinger, M. (2010). Herd management and breeding practices of sheep owners in a mixed crop livestock and a pastoral system of Ethiopia. *African Journal of Agricultural Research*, 5 (8): 685-691.

Tesfaye, G. (2008). Characterization of Menze and Afar Indigenous Sheep Breeds of Smallholders and Pastoralist for Designing Community Based Breeding Strategies in Ethiopia, MSc Thesis, Haramaya University, Ethiopia.

Tsedeke Kocho (2007). Production and marketing system of sheep and goat at Alaba district. MSc Thesis, University of Hawassa, Ethiopia.

Zelalem Abate (2018). Performance evaluation of Bonga Rams and their Progenies in different Agro-ecologies of Southern Ethiopia, MSc Thesis, Jimma University, Ethiopia.

Zelalem Tamerat (2007). Adoption of Small Ruminants' Fattening Package in Agro pastoral areas, MeisoWereda, Eastern Oromia. An MSc Thesis presented to the School of Graduate Studies of Alemaya University.

Zelealem Tesfay Gebretsadik, Anal, A. K. & Gebrezgiher Gebreyohanis (2012). Assessment of the sheep production system of northern Ethiopia in relation to sustainable productivity and Sheep meat quality. *International Journal of Advanced Biological Research*, 2 (2): 302-313.

Zewdu Edea, Aynalem Haile, Markos Tibbo, Sharma, A. K, Dejene Assefa, Johann Sölkner & Maria Wurzinger (2012). Sheep production systems and breeding practices of smallholders in western and south-western Ethiopia: Implications for designing community-based breeding strategies. *Livestock Research for Rural Development,* 24 (7).

Zewdu, E., Haile, A., Tibbo, M., Sharma, A. K., Assefa, D., Sölkner, J. & Wurzinger, M. (2010). Morphological characterization of Bonga and Horro indigenous sheep breeds under smallholder conditions in Ethiopia. *Ethiopian Journal of Animal Production,* 1: 117-133.

8.2. Paper II

Analysis of Sheep Value Chain in Central and Eastern Ethiopia

(Accepted in African Journal of Agricultural Research (AJAR))

Analysis of Sheep Value Chain in Central and Eastern Ethiopia

Eyob Gebregziabhear[1*], Mengistu Urge[2], Getachew Animut[3] and Mengistu Ketema[4]

[1]Debre Zeiet Agricultural Research Center, P.O. Box 32, Debre Zeiet, Ethiopia

[2]School of Animal and Range Sciences, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

[3]Agriculture transformation Agency, P.O. Box 708, Addis Ababa, Ethiopia

[4]School of Agricultural Economics and Agribusiness, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

**Corresponding author e-mail: eyobda21@gmail.com; mobile: 251-912127285;*

Abstract

The study was conducted to analyze sheep value chain in central and eastern Ethiopia. The objectives were to identify core functions, major market routes and to assess distribution of costs and margins. Purposive and simple random sampling was employed as a sampling technique to select150 (75 mixed crop-livestock producers and 75 agro-pastoralists) respondents. Focus group discussions were held with four groups of 48 sheep producers from two kebeles from each production systems. The groups were balanced regarding economic status, age and educational level. Each question was thoroughly discussed and the consensus reached by the group was taken as the best information (Paper I and II). Key informant Interviews were conducted with livestock extension agents, livestock marketers, abattoir managers, traders, hotels, butchers, livestock researchers, transporters and veterinarians. Sheep traders in the primary and secondary/intermediate markets of the district were also interviewed. A total of 30 key informants were interviewed during the field data collection (Paper II). The data collected through structured questionnaire and analyzed by using statistical package for social sciences (SPSS) Software. Core value chain functions were used to show both qualitative and quantitative data collected during the field study period. Agro-pastoralists on the other hand supplement wheat bran and corn. About 84% and 70% of the interviewed households in mixed-crop livestock and ago-pastoralists, respectively

have access to veterinary services.. Majority of the respondents in mixed crop livestock (85.6%) and agro-pastorals (67.9%) got veterinary services within 4km distance. About 69.3% of mixed crop-livestock farmers and 84% of the agro-pastoralists had no access to credit service. Sheep fattening is not market oriented. The analysis of costs and margins along the different sheep market channels shows that the proportion of final sheep price that reaches producers from hotels and export abattoirs were 75% and 72%, respectively. Hotels were benefited more in the value chain actors. The value chain is constrained by low genetic potential, shortage of feed in quality and quantity, disease, lack of technology, simultaneous operation of both legal and illegal livestock marketing, lack of market information and lack of integration among value chain actors. It is recommended that to increase final share, bargaining power of farmers/agro-pastoralists, encourage horizontal linkage and marketing cooperatives should be established.

Key words: Market route, Value chain, Production system, Sheep.

INTRODUCTION

There are about 33.02 million heads of sheep (CSA, 2019) in Ethiopia, classed into nine known breeds characterized through phenotypic and molecular methods (Gizaw *et al.,* 2007). These breeds are distributed across the different agro-ecologies ranging from cool alpine climate of the mountains to the arid pastoral areas of the lowlands (Gizaw *et al.,* 2007). Sheep in Ethiopia play important role in contributing to food security, domestic meat consumption, generating cash income and foreign currency, and in the overall livelihood of smallholder farmers (Shigedaf *et al*., 2013).

Sheep in Ethiopia is mainly managed by resource poor smallholder farmers and agro/pastoralists under traditional extensive production system, with the level of production and productivity being generally low (Solomon *et al*., 2011). Sheep production is generally of subsistence nature with no or minimal inputs and improved technologies. On the other hand, there is huge demand for live sheep and sheep meat in the Gulf countries. The demand and prices for sheep are also increasing locally (Shapiro *et al.,* 2017), due to increased urbanization and income of consumers. However, sheep production in Ethiopia is not market oriented and supply remains inconsistent. Moreover, there is a lack of well-functioning marketing systems that effectively link the many smallholder producers with domestic and international markets (Zahra *et al.,* 2014). Multi-stakeholder platforms that could serve as forums to strengthen market linkages (Beneberu *et al*., 2013) happen to be lacking as well. Apparently there is limited information on the sheep value chain of Ethiopia, which is crucial to understand the overall benefits out of sheep production and to respond to supply and demand changes (Kaplinsky and Morris, 2001). Value chain analysis is a tool used to comprehensively identify pertinent actors, their relationships with each other and their role in the product's life cycle (Donaldson et al., 2006). Value chain approach provides the basic understanding for designing and implementing appropriate development programs and policies (Duguma *et al*., 2012).Indeed, many development interventions now utilize the value chain approach as an important entry point for engaging smallholder farmers, individually or collectively, in high value export markets (GTZ, 2007). This study characterized sheep value chain and identified major marketing routes, value chain actors,

distribution of costs and margin of sheep value chain, and map sheep value chain in central and eastern Ethiopia.

MATERIALS AND METHODS

Study Area

The study was conducted in Digelu Tijo and Meiso districts of Oromia region, central and Eastern Ethiopia. Digelu-Tijo district is located at 7^{O} 35" 0' and 7^{O} 52" 30' N latitude and 39° 0" 0' N and 39° 25" 0'E longitude. The altitude ranges 2000-3600 meters above sea level (masl), annual rainfall ranges 900-1400 mm, and temperature is between 10-22 ^{o}C (DWOA, 2014). Mieso is a district where pastoral/agro-pastoral farming system exists. The district is located between 40^{O} 9" 30.1' W and 40^{O} 56" 44' E longitude and 9^{O}19" 52' N and 8^{O} 48" 12' N latitude, with an altitude range of 1107-3106 masl. It receives average annual rainfall within the range of 635-945 mm, while its mean annual temperature of 21^{o}C (MBPRD, 2014).

Data collection

Both primary and secondary data were gathered through key informant interview, focused group discussion, personal farm visits and discussion with farmers using structured questionnaires. Digelu Tijo (Crop livestock mixed) and Meiso (Agro-pastoral) districts were selected purposively based on production systems, production potential, market and accessibility. Before deciding on the target kebeles, a preliminary survey discussion were held with district experts, development agents, elders, farmers/agro-pastoralists representatives about the local sheep types and the current production systems of the area. In the second stage, three kebeles from each district were selected purposively. From each production systems, three rural kebeles were selected based on the sheep population and transport accessibility. Then after, the list of households with a minimum number of two sheep and had prior experience in sheep production was collected. This was followed by random selection of 25 households from each rural kebele. A total of 150 households (75 from each production system) were selected randomly from the kebeles. Major value chain actors operating at zonal

level and district levels input suppler, producers, traders, processors and consumers were identified in consultation with zonal and district Livestock Development Office. Rapid market appraisal technique was conducted with sheep traders at five primary (Sagure, Assela, Modjo, Bishoftu and Asebot, three secondary (Meiso, Adama and Methara) and two terminal in Addis Ababa (Kalti and Shogolle) livestock market centers. Focus group discussions (FGD) were held with four groups of 48 sheep producers and key informant interviews (KII) with knowledgeable individuals on the subject were conducted using a detailed checklist prepared for this purpose. Secondary data were also collected from the district offices. Experts of livestock extension, veterinarians, traders, transporters, butchers, abattoirs and hotels managers and animal exporters were used as key informants of the study. A total of 30 key informants were interviewed during the field data collection.

Data Analysis

Data collected through questionnaire were organized and summarized for analysis using SPSS software version 20 (SPSS, 2011) and presented as descriptive statistics such as mean and percentages. Depending on the nature of the data, Chi-square test and ANOVA were employed to compare variables between production systems. Pearson's Chi-square (χ^2) test was used for categorical variables to assess a statistical significance of a particular comparison. Data collected through FGD and KII were analyzed using thematic analysis approach. Market actors' marketing margin was estimated following Mendoza (1995) as:

Gross Marketing Margin = Selling price – buying price.

Net Marketing Margin = Gross Marketing – Total Cost.

Total cost= Standard Marketing Cost +Transaction Cost.

Market cost include transportation, loading and unloading, barn costs, processing cost, capital cost (interest on loan), market fees, commission and unofficial payments (Heltberg and Tarp, 2001). Share received by producers was computed as:

$$Ps = \frac{Px}{Pr} = 1 - \frac{MM}{Pr}$$

$$NMM = \frac{\text{Gross Margin - Marketing costs}}{\text{End buyer price}} \times 100$$

Where: PS = Producer's share, P_x = Producer's price, Pr = Retail price, MM = Marketing margin NMM = Net Marketing Margin

RESULTS AND DISCUSSION

Sheep Value Chain Functions

The core functions in the sheep value chain in Digelu-Tijo and Meiso districts of Oromia region includes: input supply, production, marketing, processing and consumption, thus different activities were performed by the different functions.

Input supply

The average crop land holding per household in the study area was in the range of 0.5- 0.75 ha (Table 1). The result was less than that reported in Meiso district previously (1-1.5 ha) (Kedija, 2007). The reason for small land size in Meiso district is due to increasing population pressure, severe drought, land degradation and depletion of soil nutrients. In addition, the rural kebeles included in this study are relatively peaceful than other rural kebeles in the district and this has resulted in migration of more people to these rural kebeles due to tribal conflict. This has created serious shortage of cropland as well as grazing land.

About 88 % and 69 % households have pasture land in the range of 0.25-0.75 ha in mixed crop-livestock and agro-pastorals, respectively. This indicates that majority of respondents in mixed crop livestock own private grazing land while half of respondents in agro-pastorals own communal grazing land. The majority of the respondents in both production systems owned pasture land 31 % of households in agro-pastorals owned pastureland in the range of 1-

2 ha. This is less than with the report by kedja (2007) who indicated that 10 % of households in agro-pastorals owned pastureland greater than 5 ha in Meiso district.

Table 1. Crop and forage land size (per household) distribution in the study districts

		Mixed crop livestock		Agro-pastoralists	
Land		N	%	N	%
Crop	0.5-0.75	34	45	42	57
	1-2	19	25	15	20
	2.5-3	16	22	8	10
	>3	6	8	10	13
Pasture	0.25-0.75	66	88	52	69
	1-2	9	12	23	31

Sheep value chain include all inputs and services that enable live sheep production through transporting, processing and marketing of outputs to creation of added value products such as meat through consumption of the animal source foods and related products (Mohamadou, 2013). Value chains also include the institutional and governance arrangements that enable these systems to function. The study on sheep value chains have identified the core functions, actors, market routes, market channels, constraints and existing opportunities recommendations on interventions at each node of the value chain. In both production systems, natural pasture and crop residue were the major feed resources across different seasons. In dry season crop stubble and natural pasture are used in the mixed crop livestock system and natural pasture and concentrate are used in the agro-pastoral production system. The survey result revealed that most of the farmers were used purchased feeds such as linseed cake, wheat bran, scraps of faba bean and field peas and brint (by-product of areke (local alcohol drink). Similarly, agro-pastoralists maize and wheat bran. Earlier reports similarly indicated that natural pastures, crop residues, improved forage and agro-industrial by-products are the available livestock feed resources (Adugna *et al*., 2012) and generally feed is the major factor limiting livestock productivity (Kidanu *et al*., 2011).

Mating was generally uncontrolled in both production systems. The primary reason for uncontrolled mating was lack of awareness and the use of communal grazing area whereby animals from various households graze together. 72% and 44% of the respondents in mixed

crop livestock and agro-pastoralist had no breeding rams, respectively. According to focus group discussants, no breeding center or other responsible body to supply breeding sheep in the study areas. In Ethiopia, except where there is community based sheep breeding program, ram supply organization or firm is not available (Legesse *et al*., 2014; Duguma *et al*., 2012). Hence, both mixed crop-livestock farmers and agro-pastoralists use local rams for breeding and fattening from their own flock and breeding is through natural mating. There are 26 private drug vendors and 10 veterinary clinics operating in Digelu Tijo district. Similarly, 2 private drug vendors and 11 veterinary clinics are available in Meiso district (Table 1).

Table 2. Access, sources and distances of veterinary services in the study areas.

Veterinary service		Mixed crop livestock		Agro-pastoralists		χ^2	P-value
		N	%	N	%		
Access	Yes	63	84	53	70.3	3.80	0.051
	No	12	16	22	29.3		
Source	OaARDA	14	22.2	10	18.9	4.761	0.190
	DA offices	21	33.3	27	50.9		
	Private	15	23.8	11	20.8		
	Open market	13	20.7	5	9.4		
Distance	< 1 km	8	12.7	9	17	18.925	0.001
	1-2 km	28	44.4[a]	10	18.8[b]		
	2-3 km	12	19[a]	3	5.7[b]		
	3-4 km	6	9.5[b]	14	26.4[a]		
	>4 km	9	14.4[b]	17	32.1[a]		

OaARDA=Oromia agriculture and rural development Agency; DA=development agent

Key informants from district veterinary clinics revealed that Sheep pox, pasteurellosis, lung worm, brucella, liver fluke and ecto-parasites are the important sheep diseases in the district. Similarly, agro-pastoralists identified Pestes de Petitis, Orf, pasteurellosis, internal and external parasites, FMD, and CCPP as the major diseases and parasites affecting sheep productivity in that order.

About 84% and 70% of the households in mixed crop livestock and ago-pastoralists have access to veterinary services, respectively. The most commonly used veterinary services were government clinics (55.5% in mixed crop livestock and 69.8% agro-pastoralists). Besides, private clinics did not provide veterinary services except selling drugs.

Majority of the respondents in mixed crop livestock (85.6%) and agro-pastoralists (67.9%) got veterinary services within a distance of 4 km while 14.4% and 23.1% should walk over 4 km. The results obtained in this study were in agreement with the findings of Hulunim (2014) who indicated that about 69.79, 55.17 and 69.61% of the interviewed households in Bati, Borena and Siti areas of Ethiopia, respectively have veterinary service access within 5 km distance and 30.21, 44.83 and 30.39% of the households in that order should walk over 6 km to find veterinary service. However, contrary to the present result in Uganda there was no shortage of qualified veterinarians rather absenteeism by government veterinarians, limited opportunities for career progress, weak veterinary structures, and inadequate and unpredictable budgetary allocations were found to affect their ability to deliver veterinary services (John, 2017).

In both production systems, one veterinary health post is built to support 2-3 rural kebeles (Rk). Usman *et al.* (2014) reported that one veterinary health post was built to serve three rural kebeles. The public veterinary service provided at Rk level is simple diagnosis, drug prescription and vaccination. Similarly, Kedeja (2007) reported shortage of experts, accessibility of veterinary services and lack of adequate transport facility were the major problems in Meiso district of Oromia region. Wude (2017) also reported poor accessibility and resource limitations are causes of low veterinary services in urban and peri-urban of Debre Birhan and Dessie zones of Amhara region. Contrary to the present result, Melese (2014) reported no complain were reported in veterinary services in urban and peri-urban of Awi, East and West Gojam zones of Amhara region.

The service delivery is limited and the demand of the farmers/agro-pastoralists could not be met due to shortage of animal health technicians, distance from clinics and shortage of budget to supply adequate veterinary drugs. Benberu *et al*. (2013) reported that farmers trekked

animals' long distance (5-7 km) to get to the veterinary services site. Public sector mentions poor supply of drugs during some seasons as a problem, while private shops complained about illegal traders, lack of credit, taxation and unbalanced supply and demand (Legesse *et al*., 2014).

The survey result revealed that important sheep farm operations are herding, feeding, barn cleaning, breeding and marketing. The main source of labor for these operations was family. The results are similar with the observation of Admasu *et al*. (2017) in Wolyieta Zone of Southern Ethiopia. Herding (77.3%) and feeding (60.7%) of sheep were done primarily by boys in mixed crop livestock. Similarly, participation of boys in fattening was high in both production systems. Animut and Wamatu (2014) and Admasu *et al* (2017) reported that various management tasks were undertaken by family members. Admasu *et al.* (2017) reported that younger members of the family engage in herding the animals besides assisting their parents in the day to day livestock husbandry activities. Similar results were also reported by Solomon et al (2010) children and women provide the bulk of labor in sheep and goat management. Contrary to this study, Kedija (2007) reported that 11.7 %, 60.8 % and 22.7 % of goat, cattle and goat and cattle goat, and camel were herded and watered by females The contribution of girls is also appreciated in herding sheep (4% in mixed crop and 17.7% in agro-pastoralists). 52 % of farmers and 54.7 % agro-pastoralists girls and women were engaged in barn cleaning, this may because most of the women were home makers and stayed at home while the male members had other activities to perform. Zahara *et al*. (2014) reported that women performed most tasks related to sheep and goat production. They carried out activities such as feeding, cleaning, caring for the sick and young animals, and other duties around the house. Similarly, Women and Young girls contribute to small ruminant production by carrying out a number of tasks, such as milking, cleaning animal shade, harvesting fodder and other dairy related activities (FAO, 2013). This finding also have similarity with the finding Tesfaye (2009) who reported wives (66.0%) and girls (33.1%) were responsible for cleaning flock barns. Contrary to this study, Deriba *et al*. (2014) reported dairy barn cleaning is mainly carried out by hired labor (54%), followed by women and children (33%) in Nekemet and Bako peri-urban sites of Western Oromia.

Credit is widely regarded as an important instrument for improving the present and long term economic welfare of households (Shambel, 2013). The same author also indicated that access to credit would enhance the financial capacity of the cattle keeper to purchase necessary inputs for the production of cattle. Credit access, sources and purpose of credit in the study area are described in Table 2.

Table 3. Sample households' access to credit

Credit		Mixed crop livestock		Agro-pastoral			
		N	%	N	%	χ^2	P-value
Access	Yes	23	30.7[a]	12	16[b]	4.509	0.034
	No	52	69.3[b]	63	84[a]		
Source	Micro finance	4	17.4	0	0	8.567	0.073
	Private banks	5	21.7	0	0		
	Government	8	34.8	7	58.3		
	NGO	4	17.4	5	41.7		
	Cooperative	2	8.7	0	0		
Purpose	Purchase fertilizer	11	47.8	7	58.3	2.37	0.308
	Ruminant fattening	8	34.8	5	41.7		
	Pay Tax	4	17.4	0	0		

The majority of mixed crop-livestock farmers and agro-pastoralists had no access to credit service. This agreed with thee report by Ashenafi *et al*. (2013) who indicated that no or little access to credit service. However, contrary to the present result, in Bonke district of Gamo Gofa Zone, 97.5%, 97.5%, and 100% of the respondents of highland, midland and lowland in Ethiopia did not receive credit for cattle fattening (Guyo, 2016)

Credit sources for purchase of livestock in general and sheep in particular are not satisfactory. Because microfinance institutions taught that livestock is a risk full activity and borrowers cannot return credit taken (Legesse *et al*., 2014). Moreover, the credit services provided by the micro-finance institutions are group based, which makes individual farmers accountable for the group members who are unable to pay their loan and this makes individuals to shy away of taking loan. Yet, Oromiya Credit and Saving Share Company (OCSSCO) was the only credit supplier to agro-pastoralists (Tihtena, 2011). It was also indicated that mixed crop-

livestock farmers had better access to get credit from government, cooperative and private banks than pastoralists (Kedeja, 2007). The scenario is not similar across the country and there are reports that show about 91.1% of cattle market participants had access to credit service for cattle keeping in Wolyita Zone (Shambel, 2013). Getu *et al*. (2012) reported that Oromia Credit and Saving Share Company and special savings and credit associations provide credit to 35% of livestock producers in Wolemera district. In agro-pastoral area, CARE-West Hararge program assist agro-pastoralists by distributing goats in selected kebeles that are highly vulnerable to crop failures and recurrent droughts. From the response obtained, it seems that less attention was given to credit access while competitive financial market is crucial to get the maximum benefit out of sheep production. Therefore, it is imperative for the government and private banks and other financial institution to revise loan policies and packages so as to support sheep keepers to enhance production performance.

Production

Farmers and agro-pastoralists sheep farming households are the main operators at this stage of the value chain. The mean number of sheep owned/household was high at Digelu Tijo (12.5) compared to Meiso (6.2). Sheep was the largest livestock species possessed by mixed crop livestock. The possible reasons can be sheep is easy to manage and the area is cereal crop producing area which is conducive for grazers. The number of sheep owned (24.3) per household in dega was greater than weyna-dega (13.1) reported for Gamogofa Zone. Contrary to this study, Helen et al. (2015) reported that sheep owned per household were 97, 72 and 7 for Pastorals, agro-pastorals and mixed crop livestock production systems, respectively.

A significant difference in sheep flock size found in the current study might be due to the suitability of the environment for sheep production and the role of sheep for the livelihood of the owners. According to Solomon *et al.* (2013) flock size of sheep and goat vary with the production systems and the production environment in Ethiopia. In mixed crop-livestock system, 30% of the farmers stated that they keep their sheep for breeding, 50% for sale and 20% for home consumption. In agro-pastoral production systems, 35%, 60% and 5%, respectively.

In both production systems, ewes, ewe lambs and breeding rams are obtained from farmers/agro-pastoralists, market or from other farmers. No breeding center or other responsible body was found to supply breeding sheep. Producers buy sheep from known locations for breeding purposes. Producers usually buy breeding stock on their own criteria. Agro-pastoralists face recurrent drought that usually wipes out their livestock and NGOs provide replacement stock from nearby markets. The results pertaining to sheep fattening in the study area are presented in Table 3. The results indicate that majority of respondents practice sheep fattening.

Table 4. Practice and frequency of fattening.

Fattening		Mixed crop livestock		Agro pastoral		χ^2	P-value
		N	%	N	%		
Practice	Yes	56	74.7	49	65.3	1.56	0.212
	No	19	25.3	26	34.7		
	Total	75	100	75	100		
Cycle per year	Once	8	14.3	10	20.4	5.691	0.051
	Twice	24	42.9	28	57.1		
	Three times	18	32.1	11	22.5		
	Four times	6	10.7	0	0		
	Total	56	100	49	100		
Duration (month)	Two	5	8.9	11	22.4	5.87	0.053
	Three	46	82.2	30	61.2		
	Four	5	8.9	9	16.3		
	Total	56	100	49	100		

Two times fattening cycle and three months of fattening period is common in both production systems. Smallholder rural mixed crop-livestock farmers /agro-pastoralists fatten an average of 2-3 sheep per cycle (Melese *et al*., 2017; Animut and Wamatu, 2014). Numbers of sheep per fattening cycle are determined by capital, quantity and quality of feed available and availability of market. Most sheep fattener in the study area fattens 1-3 sheep per production cycle.

Marketing/Trading

Sheep marketing involves collection, transportation and distribution to the end users. About 81.3 % and 66.7 % of respondents did not have any market plan in mixed crop-livestock and agro-pastorals, respectively. This was in agreement with Ramesh *et al*. (2012) who found that majority of respondents did not have any market plan. 52 % of farmers and 54.7 % agro-pastoralists girls and women were engaged in barn cleaning, this may because most of the women were home makers and stayed at home while the male members had other activities to perform.

Majority (54.7%) of the farmers in Digelu-Tijo area sheep price determination was mainly based on body condition, 12% by market demand and 33.3% by both body condition and market demand. In Meiso, 34.7% of agro-pastoralists sheep price determination was mainly based on body condition, 21.3% by market demand and 44.0% by both body condition and market demand. Benberu *et al* (2013) and Duguma *et al.* (2012) reported that majority of the respondents sale/purchase sheep based on body condition. Sheep sourced from the study area are transported to export abattoirs in Modjo, Bishoftu and Addis Ababa market.

Processing

Sheep from the study areas are mainly processed by hotels, butchers and export abattoirs. There are 22 hotels and restaurants that process sheep meat into different traditional dishes such as roasted meat, boiled meat (*kikil*), different stews (key or alicha wot) and *Dulet* (a chopped and spiced mixture of offals and *Longissimus dorsi muscle*. Hotels and butchers usually buy sheep either from producers, small traders in the market or they have suppliers (small traders) that supply on average about 10 animals a week. The major processing work at export abattoirs is de-hiding, chilling the whole carcass, wrapping the carcass with white cotton fabric and transporting to the cargo plane. They buy sheep from small and big traders that supply a minimum of 100 sheep at a time.

Consumption

About 20% and 5% of respondents in mixed crop livestock and agro-pastorals were consuming sheep meat. There are considerable differences in consumption of mutton between study areas. Particularly in Meiso district, slaughtering sheep for mutton consumption by butchers and hotels is very little due to the high ambient temperature. Under such environment, mutton spoils quickly if not consumed in a short time after slaughtering. Duguma *et al*. (2012) indicated that sheep are consumed both by domestic and foreign consumers. Domestic consumers buy processed raw meat from supermarkets at large cities such as Nazreth and Addis Ababa, from butchers at small towns such as Sagure, consume different dishes made up of sheep meat at hotels or buy live sheep and slaughter at home. The export markets need live sheep and sheep carcasses of different sizes.

Marketing routes

Small ruminants are trekked and supplied to Sagure and Meiso towns from different surrounding towns in the districts. Figure 1 indicates sheep flow in two major routes. The central route of live sheep and mutton export and major routes for sheep marketing identified during value chain analysis depict Sagure to be the major sheep market.

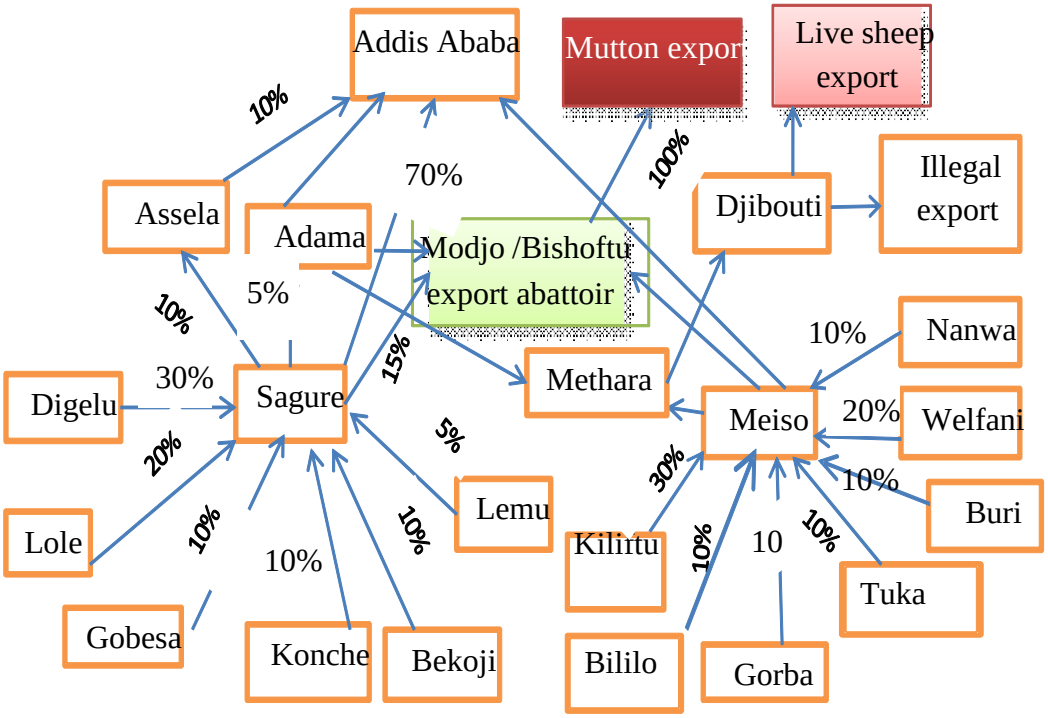

Figure 1. Sheep marketing routes and estimated volume of flow

Analysis of end Market for Sheep Value Chain

End market buyers have a powerful voice and generate change. They are important sources of demand information, transmit learning and in some cases are willing to invest in firms across the chain. End markets for sheep can be broadly classified as domestic and export. In the present study, the domestic end markets comprises individual consumers, butchers, hotels and supermarkets located in Sagure, Meiso, Adama, Bishoftu and Addis Ababa, while the export markets are in Debre Zeiet, Modjo and Methara.

Domestic markets

Sheep and goat butcheries and retail sheep and goat meat in supermarkets were found in the major towns at all targets sites. A recent development is that even the sheep and goat butcheries in major towns in the highlands were serving goat meat while they used to serve mutton only. This trend is expanding to smaller towns too. The butcheries mostly slaughter fattened male sheep. They slaughter male sheep which have large body size and sometimes sterile female sheep. The price of sheep meat (240 birr /kg), was greater than that of beef (220 birr /kg) in Sagure town, whereas in Meiso, mutton was not sold neither in the hotels nor in the butchers due to high spoilage and bad flavor. The price of mutton in Addis Ababa during the survey time was up to birr 280/kg. This is because of the service cost and the freedom of selecting the parts to be cut when buying from butchers. Domestic individual consumers are the major final consumers for sheep meat. Demand for mutton is quite seasonal as it follows the religious calendar of fasting periods and festivities such as New Year, Meskel, Christmas, Easter, ED-Al adaha (Arafa) and ED-Al fetir. Coat colour, tail type, health status and origin of the animals are some of the criteria used by individual consumers in selecting sheep. A black coat is not preferred by most buyers wanting to use animals for sacrifice. Terfa et al. (2012) indicated that black color sheep received a price discount of 15% compared to red coat color sheep and the group discussants revealed that color preference is largely seasonal or related with certain occasions.

Export markets

The most important destination markets for Ethiopian meat are Saudi Arabia, Dubai and Kuwait, Qatar and Congo. Offals such as liver, kidney, tongue, brain and heart has been exported to Saudi Arabia (Gebregziabhear, 2018). Recently, sheep weighing from 24 – 30kg were needed for slaughter and the carcass was exported. However, sheep heavier and lighter than 30 kg were a loss to the traders because heavier animals are needed large cargo space and labor cost to load the animals. Moreover, domestic consumers pay them a higher price for heavier and well-conditioned animals as compared to the export abattoirs (Shapiro *et al*., 1991). This agreed with the report by Sintayehu *et al*. (2010) who indicated that domestic market sheep price is higher than export.

Smaller animals usually have less fat coverage and their carcasses discolor easily. Sheep older than 2 years of age are not also accepted by export market since different countries have their specific carcass weight requirements indicating that sheep having different sizes (live weight) are needed to satisfy the different market requirements. According to Legese and Hordofa (2011) the United Arab Emirates needs carcass weighing 5 – 10 kg, which needs slaughtering of sheep weighing 13 – 25 kg. On the other hand, 8- 12 kg sheep carcass is needed for Saudi Arabia market, which in turn needs slaughtering of sheep weighing 20 – 30 kg. It was also reported that inconsistent supply of quality animals, cargo space shortage and technical problems such as body conditioning and chilling environment are some of the major problems mentioned by export abattoirs (Dugma *et al.*, 2012).

Marketing Channels

According to key informant interview, there are six major sheep marketing channels. Actors in the sheep value chain have specific criteria to buy sheep. Hotels prefer mature ewes due to high carcass quantity and low price, export market depend on specific importer requirement from light to heavy weight and smallholder farmers/agro-pastoralists buy ewe lambs for breeding and ram lambs for fattening. Dugma *et al*. (2012) reported that market channels depend on the consumers demand.

Distribution of costs and margins

Cost of production is total costs for production of a yearling sheep. A producer may use different inputs to rear sheep. For example, inputs needed to grow yearling sheep may include labor, feed, housing and medication. As can be seen from Table 7, the highest cost for growing yearling sheep is feed cost followed by labor cost. Feed cost accounts for 60% of the total costs of sheep production. According to Getu *et al*. (2012) feed account for 70% of the cost of livestock farm.

In order to calculate marketing margins and net margins, two important sheep marketing channels were selected. The first important channel is hotels from which the largest margin is gained. The share of final price that reach producers in this channel is higher (75 percent) relative to the channel for export abattoirs implying that it is more efficient channel (Table 4). Though the export abattoirs do not enter into further processing apart from slaughtering, removing the skin, chilling, wrapping the chilled carcass with white cotton fabric and transportation of the carcass to the airport, the proportion of value added is lower (72 percent) than hotels (Table 5).

Table 5. Costs and margins of sheep market actors involved in hotels' channel (Birr/head)

	Producers	Collectors	Small traders	Hotels
Production cost (Birr/head)	526	-	-	-
Selling price	1500	1550	1650	2000
Marketing cost	-	33.5	15.5	206.5
Marketing margin	-	50	100	300
Net margin	-	16.5	84.5	93.5
Producers share of final Price (%)	-	-	-	75
Value added (Birr/head)	974	80	140	780
Proportion of value added (%)	49	4	7	40

The other selected channel for comparison of costs and margins is channel to butchers. In this channel the highest net margin goes to butchers/hotels. This is mainly because they enter into

further processing of the meat into different dishes and add value to the product. Thus, the proportion of value addition is highest for hotels/restaurants as compared to other value chain actors in this channel. Hotels in Sagure town sell one Kg of the sheep meat for 240 birr for take away and one dish Tibs for 60 birr. One kg of sheep meat is used to prepare four Tibs dishes and this could be sold for 240 birr. However, in Meiso town mutton was not sold in the hotel or in the butchers' or prepared as a dish. Because of the high environmental temperature and fat oxidation, mutton develops unpleasant smell and flavor quickly and processors do not engage in mutton trade in this area. Sheep slaughtered at hotels/butcheries and market actors are producers, collectors and small traders (Table 5). In this marketing channel, producers' share of final price is 75 percent which is higher than that of export abattoirs.

Table 6 .Costs and margins of actors involved in selling sheep to export abattoirs channel (Birr/head).

.

	Producer	Small trader	Big trader	Export abattoir
Production cost (Birr/head)	526	-	-	-
Selling price	900	1020	1144	1250
Marketing cost	0	77.5	77	120
Marketing margin	-	120	144	110
Net margin	-	42.5	67	10
Producers share of final price	-	-	-	72
Value added	374	42.5	67	10
Proportion of value added (%)	74	8	13	2

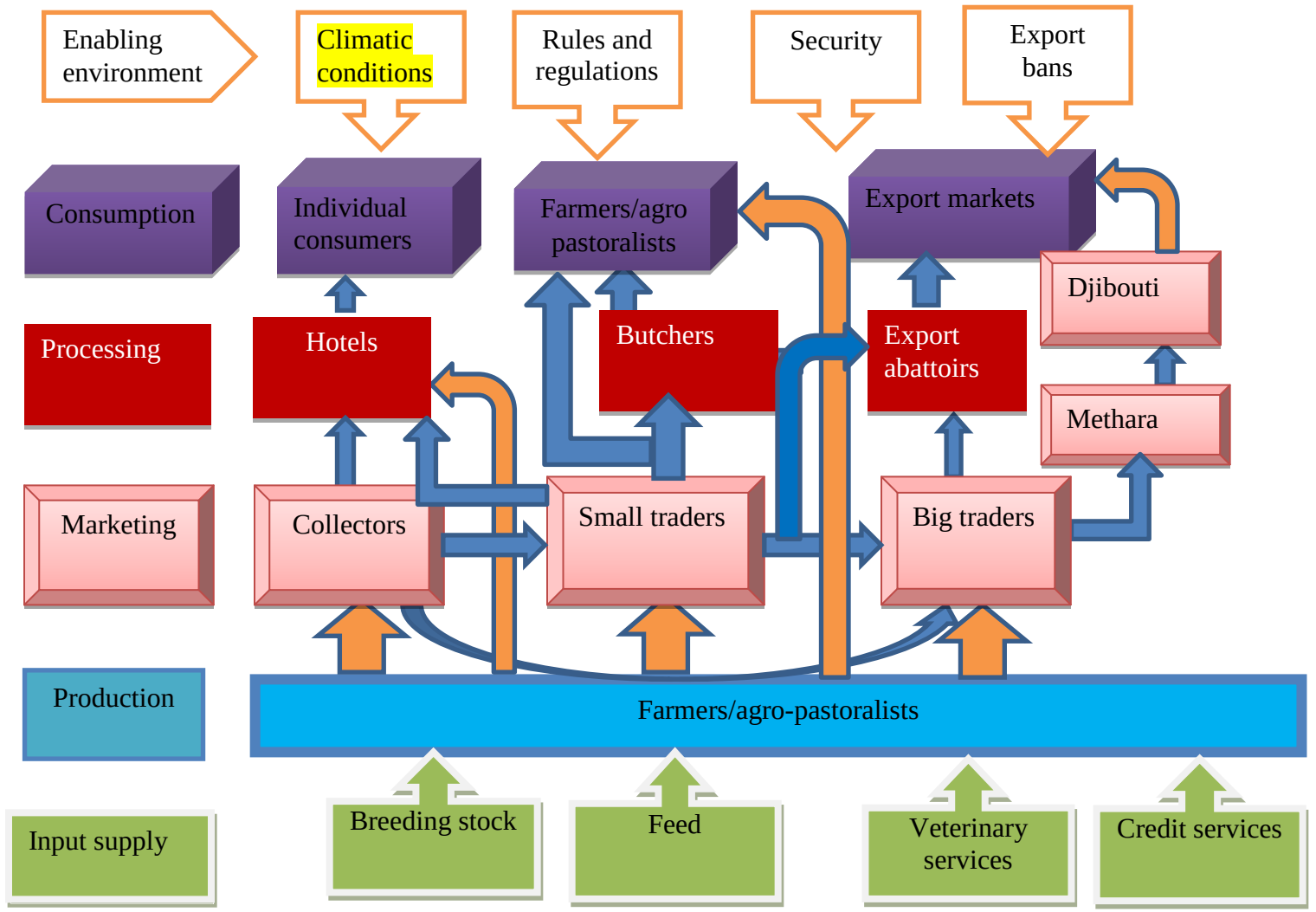

Figure 2. Map of sheep value chain in the study area.

Marketing costs

Marketing costs are those variable costs involved in product marketing by every actor. Sheep producers marketing cost is considered as zero since they are trekking their animals to the nearby markets by themselves or using family labor. Distribution of costs and margins was calculated for the seven marketing channels identified using information generated from the field study (Table 6). The highest marketing cost is incurred by hotels (ETB 206.5) followed by butchers (ETB 127.5) and export abattoirs (ETB 120). Both hotels and butchers incurred highest cost on spices followed by injera, bread and labor. Transportation followed by labor and feed costs is the major marketing costs for small traders. Processing costs are a major cost for hotels. The highest marketing cost is incurred by hotels followed by butchers and 'big traders.' The two market actors need relatively skilled labor for slaughtering and splitting the different carcass parts. Thus labor cost is estimated at 24% for hotels and 31% for butchers. In a competitive and efficient market, marketing costs determine the size of returns to farmers and all marketing actors in a value chain (Beneberu *et al.*, 2013).

Feed costs and margins

The major feeds marketed in the study area are crop residue and concentrate (Table 6). The proportion of crop residue price that reaches producers was 10.66% of the final price of the product when it is sold to urban users. Farmers sell crop residues to traders and traders bring concentrate from Adama and sell to the users. In this market chain, very small numbers of actors were involved and only the margin of feed traders was calculated. The present findings were less than that reported by Beneberu *et al.* (2013) which is 34.4 %.

Table 7.Costs and margin of actors in selling crop residue and concentrate to users

Particulars	Crop residue		Concentrate	
	Producers	Small traders	Particulars	Traders
Selling price (birr/sack)	60	80	Selling price (birr/Qt)	880
Marketing cost (birr/sack)	-	10	Purchasing cost (birr/Qt)	820
Marketing Margin (birr/sack)	-	20	Gross margin (birr/Qt)	60
Net margin (birr/sack)	-	10	Marketing cost (birr/Qt)	35
Producer's share of final price (%)	-	16.66	Net margin (birr/Qt)	25

Constraints of sheep value chain

The major constraints limiting sheep production and marketing were mostly similar, their importance, however, varied across the production systems. The present study generally revealed that in both sites, various sheep value chain constraints prevail; productivity of sheep was generally poor, induced by both technical and non-technical constraints. According to focus group discussants, among the major constraints most of the farmers pinpointed feed shortage, disease and water shortage, while agro-pastoralist ranked feed shortage, drought, disease and water shortage. The identification of problems at all stages of the chain helps to upgrade sheep value chain sector that exist across the value chain from input supply to marketing of the final product.

Table 8. Sheep marketing cost (birr) per head of sheep for different market participants

Cost category	Channels to export abattoirs			Channels to hotels in Sagure town			
	Small traders	Big traders	Export abattoir	Rural collector	Small traders	Hotels	Butchers
Feed cost	5.00	0.00	0.00	5.5	4.5	9.5	9.5
Veterinary cost	2.5	0.00	0.00	2.5	0.00	0.00	0.00
Barn cost	0.00	0.00	0.00	8.50	0.00	5	6
Labor cost	0.00	0.00	0.00	2.00	1.00	50	40
Search cost	0.00	20	0.00	0.00	0.00	0.00	0.00
Processing and packing	0.00	0.00	120	0.00	0.00	120	50
Transportation cost	54	54	0.00	5.00	0.00	10	10
Total tax payment	7	0.00	0.00	7	7	7	7
Loading/unloading	3.00	3.00	0.00	0.00	0.00	0.00	0.00
Others	5	0.00	0.00	3	3	5	5
Total	77.5	77	120	33.5	15.5	206.5	127.5

CONCLUSION AND RECOMMENDATIONS

From the field study conducted, sheep value chain in two production systems, central and western Oromia, were analyzed. The study was conceived with the objective of identifying core functions, major market routes, value chain actors and their roles and to assess distribution of costs and margins. The sheep value chain segments identified includes input supply, production, marketing, processing and consumption. Key inputs/services used in sheep husbandry are land, feed, breeding stock, credit and labor. The study identified that extensive production system was dominant in both production systems. Lack of land, breeding stock, credit, low quantity and quality feed and high feed price, inefficient veterinary breeding services and low final producer's share and horizontal and vertical relationship was critical constraints. Overall, developing efficient input delivery systems, designing economically efficient, intensive and extensive market oriented production systems.

Forming and upgrading cooperative union and strengthening linkages between sheep producers and other value chain actors and institutional, regulatory and policy support are important aspect of enhancing the livelihood and source of income for producers.

Conflict of interest

The authors have not declared any conflict of interests.

REFERENCES

Admasu L., Aberra M. and Banerjee S (2017). Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. African Journal of Agricultural Research. Vol.12 (20), pp1689-1701

Adugna Tolera (2012). Potential for Development of Alternative Feed Resources in Ethiopia. Report prepared for ACDI/VOCA. Addis Ababa Ethiopia, pp. 20.

Animut, G. and J. Wamatu (2014). Prospects to improve the productivity of sheep fattening in Ethiopia: Status, challenges and opportunities. Addis Ababa: ICARDA.

Ashenafi, M., Addisu, J., Shimelis, M., Hassen, H. and Legese, G. 2013. Analysis of sheep value chains in Doyogena, southern Ethiopia. Addis Ababa: ICARDA.

Beneberu, T., Shenkute, G., Wamatu, J. and Solomon, G. (2013). Analysis of sheep value chains in Menz Gera district, North Shewa zone, Ethiopia. Addis Ababa: ICARDA.

CSA (Central Statistical Authority). 2019. Agricultural Sample Survey 2018/19 Volume II: Report on Livestock and livestock characteristics (Private peasant holdings). Statistical Bulletin 588. Federal Democratic Republic of Ethiopia, Addis Ababa.

CSA (Federal Democratic Republic of Ethiopia-Central Statistical Agency), 2017. Agricultural Sample Survey 2016/17 [2009 E.C.]Volume II, Report on Livestock and Livestock Characteristics (Private Peasant Holdings) Addis Ababa. Statistical Bulletin 585.

Deriba Geleti, Mekonnen Hailemariam, Ashenafi Mengistu and Adugna Tolera 2014 Analysis of Fluid Milk Value Chains at Two Peri-Urban Sites in Western Oromia, Ethiopia: Current Status and Suggestions on How They Might Evolve. Global Veterinarian 12 (1): 104-120, 2014 DOI: 10.5829/idosi.gv.2014.12.01.81164.

Donaldson, K.M., K. Ishii and S.D. Sheppard (2006). Customer value chain analysis. Springer-Verlag London Limited 2006. Research in Engineering Design (2006) 16: 174–183.

Duguma, G., Degefa, K., Jembere, T., Temesgen, W., Haile, A., Duncan, A.J. and Legese, G (2012). Analysis of sheep value chains in Horro district, Oromia region, Ethiopia. Addis Ababa: ICARDA and ILRI.

DWOA (Digelu-tijo Woreda Office of Agriculture) (2014).Annual report for livestock production.

FAO (2013). Understanding and integrating Gender Issues into Livestock Projects and Programs: A checklist for practitioners. Rome, Italy: FAO.

Gebregziabhear E. (2018). Analysis of Sheep Value Chain: The case of Adama district, East Shoa Zone of Oromia Regional State, Ethiopia. Acad. Res. J. Agri. Sci. Res. 6(3): 148-162

Getu K, Mesfin D, Aemiro K and Getnet A. (2012). Comparative evaluation of Tree Lucerne (*Chamaecytisus palmensis*) over conventional protein supplements in supporting growth of yearling Horro lambs. *Livestock Research for Rural Development. Volume 24, Article #8.*

Gizaw S., Van Arendonk JAM, Komen H, Windig JJ, Hanotte O (2007)."Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia". Animal Genetics. Vol. 38: pp. 621–628.

Hulunim Gatew 2014. On-farm phenotypic characterization and performance evaluation of Bati, Borena and short eared Somali goat populations of Ethiopia. An MSc Thesis presented to the School of Graduate Studies of Haremaya University.

Heltberg R. and Tarp F.(2001). Agricultural supply response and poverty in Mozambique. Paper presented at the conference on "Growth and Poverty". University of Copenhagen, Copenhagen. 25-26 May 2001. Institute of Economics.

GTZ (Deutsche Gesellschaftfür Technische Zusammenarbeit GmbH) (2007). Value Links Manual: The Methodology of Value Chain Promotion, First Edition. http://www.valuelinks. de/manual/distributor.html.

Guyo D. (2016). Assessment of Fattening and Marketing system, and effect of Concentrate supplementation with locally available feeds on fattening performance of indigenous Cattle in Bonke Woreda of Gamo Gofa Zone of SNNPRS, Ethiopia. M.Sc.thesis, Hawasa University. Hawasa, Ethiopia.

John L 2017. Improving the delivery of veterinary services in Africa: insights from the empirical application of transaction costs theory in Uganda and Kenya. Consultative Group on International Agricultural Research (CGIAR) Independent Science and Partnership Council's Standing Panel on Impact Assessment, Rome, Italy. Rev. Sci. Tech. Off. Int. Epiz. 36 (1), 279-289

Kaplinsky R and Morris M (2001). A Handbook for Value Chain Research. Working Paper Prepared for the IDRC, Brighton, UK, Institute for Development Studies.

Kedeja Hussien, 2007. Characterization of milk production system and opportunity for market orientation: A case study of Mieso district, Oromia region, Ethiopia. An MSc Thesis presented to the School of Graduate Studies of Alemaya University.

Kidanu, E., Gebremedhin, B. and Hoeckstra, D (2011). Supply chain 'from gate to plate' analysis of butter supply chain the case of Atsbi Wonberta and Alamata woredas Tigray, Ethiopia. Lambert, Germany.

Legese, G. and Hordofa, D (2011). Value chain analysis of small ruminant sub-sector in Oromia and Southern Nation Nationalities Regional States (SNNP) Addis Ababa, Ethiopia: Berhan and Associates Consultancy PLC.

Legese, G., Haile, A., Duncan, A.J., Dessie, T., Gizaw, S. and Rischkowsky, B (2014). Sheep and goat value chains in Ethiopia: A synthesis of opportunities and constraints. ICARDA/ILRI Project Report. Nairobi, Kenya: International Center for Agricultural Research in the Dry Areas/International Livestock Research Institute.

MBPRD (2009). Meiso office of Pastoralists and Rural development Annual Report. Meiso Wereda

Mendoza, G (1995). A primer on marketing channels and margins. In G.J.Scott (eds.). Prices, products, and people: Analyzing agricultural markets in developing countries. Lynne Reinner Publishers, Boulder, London. Access

Mohamadou, F (2013). Situation Analysis of Small Ruminants Value Chain in Ethiopia: Draft report. Nairobi: International Livestock Research Institute.

Shambel Bekele (2013). Analysis of Cattle Value Chain: the case of Wolaita Zone of SNNPRS, Ethiopia. An M.Sc. Thesis Presented to School of Graduate Studies of Haramaya University. 58p.

Shapiro B., Getachew G., Solomon D., Asfaw N., Kidus N., Gezahegn A. and Henok M (2017). Ethiopia livestock sector analysis. ILRI, Addis Ababa, Ethiopia.

Shapiro, K (1991). Assessment of animal agriculture in Africa: Economic issues. Morrilton, Arkansas, USA: Winrock International Institute for Agricultural Research.

Shigdaf Mekuriaw, Zeleke Mekuriaw, Mengiste Taye Hailu Mazengia, Getnet Assefa and Aynalem H (2013). Reproductive performance and survival rate of Washera and Farta sheep breeds under traditional management systems in Farta and Lay Gayint Districts of Amhara Regional state, Ethiopia. J. Anim. Prod. 13: 65- 82.

Sintayehu G., Samuel A., Derek B., Ayele S 2010. Diagnostic study of live cattle and beef production and marketing constraints and opportunities for enhancing the system Bill & Melinda Gates Foundation pp 40

Solomon Abegaz, Girma Abebe and Kassahun Awgichew. 2011. Sheep and Goat Production Systems in Ethiopia. Addis Ababa, Ethiopia: Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP).

Solomon G., S. Abegaz, B. Rischkowsky, A. Haile, A. O. Mwai, and T. Dessie. *Review of sheep research and development projects in Ethiopia*. Nairobi: International Livestock Research Institute (ILRI), 2013 pp.2-10.

Solomon Gizaw, Azage Tegegne, Berhanu Gebremedhin and Dirk Hoekstra. 2010. *Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvemen*t. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 23. ILRI (International Livestock Research Institute), Nairobi, Kenya. 58 pp.

SPSS. 2011. Statistical Package for Social Sciences Study. Version 20, Chicago, Illinois, USA.

Terfa, Z.G., Haile, A., Baker, D. and Kassie, G.T.(2012). Sheep market participation of rural households in Western Ethiopia. *African Journal of Agricultural Research*, 7(10):1504 – 1511. ing in white linen and transportation to a range of different countries.

Tesfaye, G., Aynalam, H., Markos, T., Sharama, A.K. and Solkner, J.M. (2010) Herd Management and Breeding Practices of Sheep Owners in a Mixed Crop-Livestock and a Pastoral System of Ethiopia. African Journal of Agricultural Research, 5, 685-691.

Tesfaye T 2009. Characterization of goat production systems and on- farm evaluation of the growth performance of grazing goats supplemented with different protein sources in Metema Woreda, Amhara Region, Ethiopia. MSc. Thesis submitted to School of Graduate Studies of Alemaya University, Ethiopia. 51p.

Usman S. D. Abate, S. Belete, T. Wegi, G. Legese and A.J. Duncan 2012. Analysis of sheep value chains in Sinanna district, Oromia region, Ethiopia. Addis Ababa: ICARDA and ILRI.

Wude Tsega, Berhan Tamir, Girma Abebe and Zaralis, K. 2014. Characteristics of urban and peri-urban sheep production systems and economic contribution in highlands of Ethiopia. *Iranian Journal of Applied Animal Science*, 4(2): 341-349.

Zahra, A., Mulema, A., Colverson, K., Odongo, D., and Rischkowsky, B (2014). A review of Ethiopia small ruminant value chains from a gender perspective. Nairobi: ILRI and ICARDA

8.3. Paper III

Evaluation of different oilseed cakes on feed intake, digestibility, live weight changes and carcass characteristics of Arsi-Bale sheep

(Accepted in Scientific Research Publishing, ID: 3003049)

Effects of different oilseed cakes in a concentrate mixture on feed intake, digestibility, live weight gain and carcass characteristics of Arsi-Bale sheep

Eyob Gebregziabhear[1*], Mengistu Urge[2], Getachew Animut[3] and Mengistu Ketema[4]

[1]Ethiopian Agricultural Research Institute, DebreZeit Center, P.O.Box 32, DebreZeiet, Ethiopia

[2]School of Animal and Rangeland Sciences, Haramaya University, P.O.Box 138, Dire Dawa, Ethiopia

[3]Agriculture Transformation Agency, P.O.Box 708, Addis Ababa, Ethiopia

[4]School of Agricultural Economics and Agribusiness Management, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

Abstract

A study was conducted to investigate the effect of feeding different oil seed cakes in concentrate mixture on feed intake, digestibility, total weight gain and carcass characteristics of Arsi-Bale sheep (mean body weight 17.56±0.34kg) consumed a basal diet of teff straw. The experiment sheep were blocked in to seven blocks of four animals based on initial body weight and within a block randomly assigned to one of the treatments. Treatments were ad libitum feeding of teff straw and 36% noug seed cake + 22% maize +42% wheat bran (T1), 40% Linseed cake + 20% maize + 40% wheat bran (T2), 29% cotton seed cake (CSC)+ 24% maize + 47% wheat bran (T3) and 22% soybean cake+26% maize + 52% wheat bran (T4) supplements. Significant difference was observed (P<0.0001) among treatments on total daily DM intake as a percentage of body weight (BW) and total daily DM intake per metabolic body weight (MBW). Crude protein intake was lower (P<0.0001) in T1 than T2, T3 and T4. T1 has lower (P<0.001) apparent digestibility of CP and daily body weight gain than T2, T3 and T4. Empty BW was higher (P<0.05) for T2, T3 and T4 compared to T1. Dressing percentage on slaughter weight base tended to be higher (P=0.0582) for T4 than T1. Hot carcass weight was lower (P<0.01) for sheep in T1 than in T2, T3 and T4. The oilseed cakes considered in this study could be recommended in the order of cotton seed cake > soybean cake > linseed cake >

noug seed cake. *Economic analysis showed that CSC based supplementation was feasible than the remaining oilseed cakes.*

Keywords: *Body weight, feed intake, iso-caloric, iso-nitrogenous, oil seed cakes, wheat bran* .

Introduction

There are about 33.02 million heads of sheep (CSA, 2019) in Ethiopia, playing an important role in the livelihood of resource poor farmers. This number is projected to increase in the near feature, because sheep have higher survival rates and can restore stocks very rapidly under drought conditions compared to cattle. Moreover, prolific nature and high rate of multiple births enable to have higher annual off take than cattle. In fact, in some areas of the country, small ruminants have been described as the “village bank”. Small ruminants represent only 7% of the average total capital invested in livestock in mixed crop livestock production system; but they account on average for 40% of the cash income and 19% of the total value of subsistence food derived from all livestock production (Adane and Girma, 2008). It is also noted that sheep and goat contribute to a quarter of the domestic meat consumption; about half of the domestic wool requirement; 40% of fresh skin and 92% of the value of semi-processed skin and hide export trade (Adane and Girma, 2008). There is also a growing export market for sheep and goat meat in the Middle East Gulf States and African countries. Ethiopia exported 306, 310 sheep and goat by the year 2018, which covers 91.6 % of total live animal export. From this export the country earned 16.650 million USD (52.6 % of the total live animal export) (EMDDI 2018). The current annual off take rates of sheep and goats is, however, only 33% and 35%, respectively. The average carcass weight of Ethiopian sheep and goat is only 10kg, which is the second lowest in sub-Saharan Africa.

Although many factors constrained sheep production and reproduction in Ethiopia, feed shortage both in terms of quantity and quality constituted the lion's share. There is an estimated 40% of deficit in the national feed balance where also sheep and goat are disposed to such scarcity. In economic terms, feed cost accounts for about 70% of the cost of livestock production under Ethiopian condition (Seyoum *et al*. 2018). The feasibility of livestock

enterprise is, therefore, a function of the type of feed and feeding system. The feed shortage is aggravated by seasonal availability of forage, increasing demand for land for crop production and recurrent droughts particularly in the low land areas. The major feed resources for sheep such as straw and mature grasses have low crude protein (CP) contents. Feeds with fiber content exceeding 55% are low in CP (below 7%) or in other essential nutrients and induce intake limitation through deficiency (Van Soset, 1994) of nutrients, while a CP content of less than 6% will result in negative N balance due to protein malnutrition (Bondi 1987). Under the prevailing economic circumstances of smallholder farmers in the tropics, increasing efficient utilization of poor quality crop residues through supplementation with oil seed cakes, rather than the more costly cereal concentrate feeds is proved to be a feasible alternative and such efforts can make a breakthrough to the traditional animal feeding practices. Therefore, the objective of this experiment was to study the effect of supplementation with isocaloric and isonitrogenous levels of concentrate mixture based on major crude protein sources of noug seedcake (NSC), linseed cake (LSC), cotton seed cake (CSC), or soybean cake (SBC) on feed intake, digestibility, body weight gain and carcass parameters of Arsi-Bale sheep consumed teff straw based diet.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Debre Zeit Research Center (DZARC). It is situated at 9^{o}N latitude and 40^{o}E longitude at an altitude of 1850 m.a.s.l. The center receives an annual rain fall of 866 mm of which 84% falls during the long rainy season (June to September) and the remaining in the short rainy season (March to May). The mean annual minimum and maximum temperature of the area are 10.9^{o}C and 28.3 ^{o}C, respectively with mean relative humidity of 61.3%. Mixed farming system with extensive crop and livestock production is the common agricultural practice in the area (NMSA, 2010).

Feeds and Feeding

Teff straw was purchased from Ude kebele and transported to the research center where the experiment is executed. Sheep was fed teff straw as a basal feed at the rate of 20% refusal of the previous few days offer to ensure *ad libitum* consumption. The supplements were based on different oil seed cakes as a major crude protein source consisting of 36% noug seed cake + 22% maize +42% wheat bran (T1), 40% Linseed cake + 20% maize + 40% wheat bran (T2), 29% cotton seed cake (CSC) + 24% maize + 47% wheat bran (T3) and 22% soybean cake+ 26% maize + 52% wheat bran (T4) . The supplements were formulated to be closely iso-nitrogenous. Water and mineral salt block were offered without any restrictions. The supplements were offered in a separate trough in two equal portions at 0800 h and 1600 h.

Experimental Animals Management and Design

Tewenty eight Arsi-Bale sheep with 17.56±0.34 kg initial body weight were purchased from Sagure where the local breed "Arsi-Bale sheep" predominantly exists. The age of the animals was estimated by dentition and asking the owner. The sheep were transported to Debrezeit Agricultural Research Center where the experiment was executed. The sheep were quarantined for 15 days to adapt them to the experimental site. During adaptation period, all sheep were ear-tagged for identification. The animals were injected with ivermectin (Kelamectin 1%) for treatment against gastro-intestinal and ecto-parasites. The sheep were placed in to individual pen and adapted to the experimental diets and pens for 15 days prior to the commencement of data collection. The sheep were put in to seven group of four lambs each based on initial live weight and randomly assigned to one of the four dietary treatments in a completely randomized block design.

Body weight and Feed Conversion Efficiency

The feeding trial lasted for 90 days following the acclimatization period of 15 days. The amount of feed offered and refused for each sheep was recorded daily. Body weight of each animal was measured at the beginning of the feeding trial and at an interval of 10 days after

overnight fasting. Total weight gain (TWG) was calculated as the difference between final and initial weights. Average daily weight gain (ADG) was calculated as the difference between final body weight and initial weight divided by number of feeding days. Feed conversion efficiency (FCE) of the animal was determined as the proportion of daily weight gain to the daily DM intake.

Digestibility

All animals were harnessed with fecal collection bags for three days of adaptation followed by 7 days of total feces collection period. Feces voided into the bags were emptied into a container, weighed and recorded for each animal separately, thoroughly mixed and a sub-sample of 10% was taken daily and bulked across the experimental period and stored in a refrigerator at -20^{o}C. At the end of the experiment, the bulk samples from each animal were thawed, thoroughly mixed, and sufficient amount of sub-sample from each were taken and partially dried at 60^{o}C for 72 hours, ground to pass 1 mm screen and stored at room temperature pending chemical analysis. The apparent digestibility coefficient (DC) of nutrients was determined by the following equation:

$$\text{Apparent Nutrient Digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient excreted in faeces}}{\text{Nutrient intake}} \text{X } 100$$

Carcass characteristics

At the end of the experiment, all sheep were fasted overnight for carcass analysis. Sheep were killed by severing the jugular vein and the carotid artery. The esophagus was tied off close to the head to prevent flow of digesta before it is weighed and the body was suspended head down for complete bleeding. Flaying was done carefully and the skin was weighed with legs below the hock joints. The entire alimentary tract was removed and weighed with and without contents. Blood, head, tongue, hot carcass, liver with gall bladder, heart, kidneys, lung with trachea, tail, testis, penis, spleen, fat, gut fill total and empty gut were recorded during the slaughter process. Hot carcass weight was computed by excluding offal. Rib eye area of each

animal was determined by tracing the cross sectional area between 12^{th} and 13^{th} ribs after cutting perpendicular to the backbone. Percentage of total edible offal components (TEOC) were taken as the sum total weight of blood, heart, liver with gall bladder, empty gut, kidney, tongue, tail, testis and fat.

Chemical analysis

Chemical analysis of samples was done in DebreZeiet Agricultural Research Center Animal nutrition laboratory. Representative samples of feeds (teff straw and concentrates), teff straw refusals and feces were dried at 60°C for 72 hours. The dried samples were ground using laboratory mill to pass through 1 mm screen and stored for subsequent analyses of dry matter (DM), crude protein (CP), ash (AOAC, 1990), acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) (Van Soest and Robertson, 1985). The CP was calculated as N*6.25.

Statistical Analysis

Data was analyzed using the general linear model GLM procedure of SAS (SAS, 2003). Adjusted Tukey test was used to locate the significant differences between means when F-test declare significance at $p<0.05$. The statistical model used was:

$$Yij = \mu + Bi + Tj + eij$$

Where: Y_{ij} = the response variable;
μ = overall mean;
B_i = effect of block;
T_j = effect of treatment;
e_{ij} = random error.

Partial Budget Analysis

Partial budget analysis was made to determine profitability differences of fattening yearling Arsi-Bale sheep under different oilseed cakes based concentrate mixtures supplementation, considering total variable costs (TVC) (Purchase price of sheep, total feed cost and labor cost). The selling price of each animal was estimated by experienced sheep dealers in the area. The difference in average selling and purchase price of each animal was taken as total return (TR). Profitability was determined using net income (NI), calculated as NI = TR – TVC.

Results

Chemical Composition of the Experimental Feeds

Low CP and high NDF and ADF contents of teff straw categorized it as low quality feed (Table 1). The CP content of basal diet observed in the present study was not sufficient to meet maintenance requirement of ruminants (Van Soest, 1994). Therefore, supplementation of teff straw with feeds that contain better nutrients is important to catalyze more efficient utilization of poor-quality roughages (Alemu 2008). The higher CP and OM, and the lower fiber fraction contents of the concentrate mixture used make it appropriate supplement to the teff straw basal diet.

Table 1.Chemical composition (% for DM and % DM for others) of teff straw, concentrate ingredients and concentrate mixture

Teff straw and concentrate ingredients	DM	OM	Ash	CP	NDF	ADF	ADL
Teff straw	93.31	88.55	11.45	3.62	81.91	76.52	9.82
Maize	89.46	98.15	1.85	9	8.86	4.79	3.64
Wheat bran	90.79	94.69	5.31	13.5	44.77	11.43	4.81
Noug seed cake	91.51	92.4	7.6	30.01	44.2	30.94	12.32
Lin seed cake	92.5	93.86	6.14	27.9	37.88	23.61	5.8
Cotton seed cake	91.67	91.75	8.25	33.6	60.59	29.74	11.97
Soybean cake	92.07	93.16	6.84	36.4	19.03	10.71	4.74
Treatments							
T1	91.1	95.03	4.97	18.49	40.4	17.2	11.11
T2	90.3	94.15	5.85	18.36	30.6	12.4	7.57
T3	90.69	95.59	4.41	18.25	43.7	19.8	11.7
T4	90.37	95.58	4.42	18.79	27.6	10.2	7.36

DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF= Neutral detergent fibre; ADF = Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).

Feed Intake

The concentrate was consumed without refusal and teff straw dry matter intake was statistically different among oilseed meals (Table 2), as a result the daily Basal, total DM and OM intake were higher ($p<0.0001$) in T2 and T3 as compared to T4 and T1 (Table 2). NDF and ADF intake were declined ($p<0.0001$) in the order of T3, T1, T2 and T1, respectively. CP intake was higher ($p<0.0001$) in the order of T4, T2, T3 and T1, respectively.

Table 2.Feed intake (g/d) of Arsi-Bale sheep fed teff straw basal diet supplemented with concentrate based on different oil seed meals

Parameter	**T1**	**T2**	**T3**	**T4**	***P-value***	**SEM**
Teff Straw basal diet	287.15[c]	401.12[a]	400.02[a]	375.02[b]	0.0001	1.99
Concentrate	300	300	300	300	-	-
Total	587.15[c]	701.12[a]	700.02[a]	675.02[b]	0.0001	2.04
DM (% BW)	3.02[c]	3.41[a]	3.46[a]	3.23[b]	0.0001	0.011
DM (g/kg $W^{0.75}$)	62.66[c]	72.59[b]	73.33[a]	68.93[b]	0.0001	0.21
OM	554.6[c]	661.77[a]	661.78[a]	636.16[b]	0.0001	1.9
CP	66.97[d]	71.26[b]	70.3[c]	72.20[a]	0.0001	0.08
NDF	353.33[d]	423.58[b]	457.97[a]	384.70[c]	0.0001	1.67
ADF	197.05[d]	245.8[b]	263.41[a]	223.94[c]	0.0001	1.05

[a,b,c]*Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).*

Apparent Digestibility

Dry matter digestibility was significantly impacted by treatments (Table 3) and was in the order of T4>T2>T3>T1. Organic matter digestibility was higher in T4 group than the other treatments and T2 has greater OM digestibility than T1 and T3 (P<0.0001). The digestion coefficient of CP was higher (P<0.0001) for T4 compared to the other treatments. Similarly, T4 had higher (P< 0.0001) NDF digestibility than T1 and T3 while ADF digestibility was greater in T4 than the other treatments.

Table 3. Apparent digestibility (%) of dry matter and nutrient content of Arsi-Bale sheep fed a basal diet of teff straw supplemented with concentrate mixture based on different oil seed meals.

Parameters	T1	T2	T3	T4	*P-value*	SEM
DM	0.57^{d}	0.67^{b}	0.63^{c}	0.72^{a}	0.0001	0.009
OM	0.65^{c}	0.69^{b}	0.66^{c}	0.74^{a}	0.0001	0.007
CP	0.86^{d}	0.92^{b}	0.91^{c}	0.95^{a}	0.0001	0.003
NDF	0.43^{c}	0.61^{ab}	0.46^{bc}	0.64^{a}	0.0001	0.009
ADF	0.39^{c}	0.49^{b}	0.51^{b}	0.62^{a}	0.0001	0.013

^{a,b,c}*Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).*

Body Weight and Feed Conversion Efficiency

Final body weight (FBW), total weight gain (TWG) and average daily gain (ADG) were significantly affected by oilseed meals (p<0.01; Table 4). There were higher significant difference in final body weight (FBW), total weight gain (TWG) and average daily gain (ADG) in T2, T3 and T4 than in T1. Sheep in T2 and T4 had higher (P<0.05) FCE than sheep in T1 and T3.

Table 4. Body weight traits and feed conversion efficiency of Arsi-Bale sheep fed a basal diet of teff straw supplemented with concentrate based on different oil seed cakes

Parameters	T1	T2	T3	T4	*P-value*	SEM
IBW(Kg)	17.94	17.41	17.57	17.28	0.9342	0.34
FBW(Kg)	21.18^{b}	24^{a}	23.49^{a}	24^{a}	0.0246	0.47
TWG (Kg)	3.27^{b}	6.59^{a}	5.91^{a}	6.71^{a}	0.0032	0.39
ADG (g/day)	36.35^{b}	73.11^{a}	65.71^{a}	74.6^{a}	0.0032	4.36
FCE	0.066^{b}	0.106^{a}	0.094^{b}	0.11^{a}	0.0104	0.005

^{a,b,c}*Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; IBW= Initial body weight; FBW = Final body weight; TWG= Total*

weight gain; ADG= Average daily gain; FCR =Feed Conversion Ratio; SEM = Standard error of mean; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).

Carcass characteristics

SBW, EBW, HCW and REMA ($P<0.05$) for sheep consumed T2, T3 and T4 supplements were higher than sheep in T1 (Table 5). Dressing percentage as a proportion of SBW was higher ($P<0.05$) for sheep in T4 as compared to sheep in T1, whereas dressing percentage on EBW did not vary ($P>0.05$) among the treatments.

Table 5. Carcass characteristics of Arsi-Bale sheep fed teff straw basal diet supplemented with concentrate mixture based on different oil seed cakes

Traits	Treatments					
	T1	T2	T3	T4	*P-value*	SEM
SBW (kg)	21.19[b]	24.00[a]	23.49[a]	24.00[a]	0.0465	0.34
EBW (kg)	17.31[b]	19.66[a]	19.34[a]	20.01[a]	0.0396	0.44
HCW (kg)	8.49[b]	9.88[a]	9.62[a]	10.26[a]	0.0037	0.21
Dressing percentage						
SBW basis	40.13[b]	43.22[ab]	40.96[ab]	44.04[a]	0.0582	0.57
EBW basis	49.18	50.85	49.79	51.36	0.5397	0.01
REMA (cm^2)	7.69[b]	9.58[a]	9.11[a]	9.42[a]	0.0114	0.01

[a,b,c]Means with different superscripts within a row are significantly different ($P<0.05$); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).

Sternum weight was greater ($P<0.01$) in T2 and T3 than T1 while T2 and T4 recorded heavier ($P<0.05$) vertebrae (Table 6). TMCC was heavier in T4 ($P<0.05$) than the other treatments. Tail was heavier in T3 ($P<0.05$) than in T1. However, there were no difference ($P>0.05$) among treatments in forelegs, hind legs, neck, pelvic region and ribs.

Table 6. Main carcass yield and carcass compositions of Arsi-Bale sheep fed teff straw basal diet supplemented with concentrate mixture based on different oilseed cakes.

Traits (Kg)	T1	T2	T3	T4	*P-value*	SEM
Forelegs	1.78	1.97	2.01	2.10	0.109	0.048
Hind legs	2.24	2.55	2.53	2.40	0.173	0.056
Neck	0.75	0.89	0.82	1.02	0.075	0.038
Sternum	0.35^{b}	0.49^{a}	0.47^{a}	0.45^{ab}	0.007	0.015
Vertebrae	1.15^{b}	1.39^{a}	1.27^{ab}	1.42^{a}	0.015	0.034
Pelvic region	0.51	0.56	0.56	0.61	0.149	0.014
Tail	0.22^{b}	0.32^{ab}	0.39^{a}	0.31^{ab}	0.040	0.020
Ribs	1.29	1.4	1.34	1.44	0.4178	0.032
TMCC	8.31^{b}	9.63^{ab}	9.21^{ab}	9.87^{a}	0.0202	0.199

[a,b,c]Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC); TMCC=total main carcass component.

Edible and non-edible offal components

The weight of most of the edible and non-edible offal's did not differ among the treatments. Greater weight of liver (P<0.05) and tongue (P<0.001) was observed in T4 than T1 and T2 (Table 7). Lower (P>0.05) kidney fat was occurred in T1 and T3 as compared to T4.

Table 7. Edible offal components of Arsi-Bale sheep fed teff straw basal diet supplemented with concentrate mixture based on different oilseed cakes

Edible offal (g)	Treatments					
	T1	T2	T3	T4	*P-value*	SEM
Blood	876.23	879.40	897.91	819.19	0.0512	28.85
Heart	116.34	111.94	115.83	117.03	0.271	3.18
Kidney	63.46	64.33	64.53	66.73	0.057	3.58
Liver	304.77^{b}	300.09^{b}	316.17^{ab}	346.97^{a}	0.046	6.95
Tongue	57.9^{c}	60.2^{bc}	62.61^{ab}	65.79^{a}	0.0002	1.15
Reticulo-Rumen	449.59	500.14	471.53	468.89	0.222	8.89
Omasum-Abomasum	178.1	173.63	173.49	168.67	0.625	2.95
Intestines	1042.56	1025.79	973.83	866. 9	0.318	31.68
Kidney fat	43.31^{bc}	58.19^{ab}	36.23^{c}	61.37^{a}	0.012	3.59
Abdominal fat	79.26	99.03	86.80	114.34	0.689	10.59
TEO	3.21	3.28	3.20	3.09	0.741	0.056

[a,b,c]Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).

Except esophagus and bladder, non-edible offal components did not differ among treatments. The TNEO weight was lower in T1 than the other treatments (P<0.01).

Table 8. Non-edible offal components of Arsi-Bale sheep fed teff straw basal diet supplemented with concentrate mixture based on different oilseed cakes

Non edible offal's (Kg)	Treatments					
	T1	T2	T3	T4	*P-value*	SEM
Skin and feet (Kg)	2.00	2.23	2.09	2.33	0.077	0.049
Head without tongue (g)	1519.3	1656.5	1669.1	1721.3	0.078	37.07
Penis (g)	51.74	58.24	49.9	58.26	0.49	2.37
Testicles (g)	254.69	272.23	284.40	311.97	0.359	11.44
Lung with trachea (g)	238.43	281.91	267.89	273.79	0.079	6.41
Esophagus (g)	33.14^{b}	35.44^{ab}	32.8^{b}	44.69^{a}	0.01	1.98
Spleen (g)	28.27	39.66	44.43	40.52	0.155	2.68
Bladder (g)	18.87^{a}	7.71^{b}	17.47^{a}	14.03^{ab}	0.050	1.59
Gut fill (Kg)	3.88	3.36	3.27	4.14	0.2128	25.53
TNEO (kg)	8021.5^{b}	8658.8^{a}	8594.6^{a}	8641.5^{a}	0.0042	78.98

[a,b,c]Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF=

Neutral detergent fibre; ADF =Acid detergent fibre; T1= Teff straw ad libitum + Concentrate (66g maize+126g WB+ 108g NSC); T2= Teff straw ad libitum + Concentrate (60g maize+120g WB+ 108g LSC); T3= Teff straw ad libitum + Concentrate (72g maize+141g WB+ 108g CSC); T4= Teff straw ad libitum + Concentrate (78g maize+156g WB+ 66g SBC).

Partial Budget Analysis

Sheep in T3 returned higher net income (171.16 birr/sheep) as compared to the other supplemented groups (Table 9)

Table 9. Profitability of Arsi-Bale sheep fed teff straw basal diet supplemented with different oilseed cakes

Parameters	T1	T2	T3	T4
Purchase price of sheep (birr /sheep)	850	850	850	850
Teff straw consumed (kg/sheep)	25.8	36.1	36	33.8
Concentrate consumed (kg/sheep)	27	27	27	27
Total feed consumed (kg/sheep)	52.8	63.10	63	60.8
Cost of tef straw (birr /sheep)	77.40	108.30	108	101.40
Cost of concentrate (birr /sheep)	162.87	214.81	136.84	178.74
Total feed cost (birr /sheep) (TVC)	240.77	323.11	244.84	279.55
Cost for feed preparation (birr /sheep)	100.5	100.5	100.5	100.5
Medication cost(birr /sheep)	13.50	13.50	13.50	13.50
Total variable cost (birr /sheep)	354.77	437.11	358.84	393.55
Gross income (R) (birr /sheep)	1300	1400	1380	1400
Total return (TR) (birr /sheep)	450	550	530	550
Net return (NR) (birr /sheep)	95.23	112.89	171.16	156.45

Birr =Ethiopian currency ; TR = Total Return; TVC = Total Variable Cost; NR = Net Return; T1= Teff straw ad libitum + concentrate (36% noug seed cake + 22% maize + 42% wheat bran);T2=Teff straw ad libitum + concentrate (40% Linseed cake + 20% maize + 40% wheat bran); T3=Teff straw ad libitum + concentrate (29% cotton seed cake + 24% maize + 47% wheat bran); T4=Teff straw ad libitum + concentrate (22% soybean cake + 26% maize + 52% wheat bran).

Discussion

Chemical Composition of Feeds

Generally, the nutrient compositions of the experimental feeds were within the range for Ethiopian feeds (Seyoum et al 2007). The CP content of teff straw cannot satisfy the

maintenance requirement and proper rumen function (Van Soset 1994). On the other hand CP content of the concentrate mix (18.25- 18.79 % of DM) is within the range of the CP contents of quality feed for greater growth (>15% CP) of sheep in warm climates (Salah *et al*., 2014). The oilseed cakes are rich in protein and serve as sources of protein in concentrate mixtures. The protein content may vary from 20-50% depending upon the type of oilseed and the method of extraction of oil (mechanical vs solvent). In general, the high CP content of the feed supplements suggests the potential of these agro-industrial by-products to improve animal performance.

Feed Intake

Dry matter intake expressed on percent body weight basis was consistent with that recorded in other sheep breeds of Ethiopia (Getu *et al.,* 2012) and recommended by ARC (1980). The CP (67-72g/day) consumption by the sheep were higher than the requirement for maintenance Ranjhan (2004) showing the concentrate supplementation provide opportunity for intake of more nutritionally dense and digestible feeds. In this regard, Van Soest (1994) noted that higher level of supplementation increases the supply of nitrogen to the rumen microbes thereby increasing microbial population and efficiency, the rate of fermentation of digesta and feed intake.

In the present study, supplement based on NSC depressed intake as compared to the other oil seed cakes as also noted in previous studies (Amare *et al* 2009; Getu *et al.* (2012). This reflects that NSC is rumen degradable protein, whereas LSC, CSC and SBC are by-pass protein which are digested in the lower gut and increase total feed intake. Getu *et al.* (2012) also reported slower rate of degradation of cotton and linseed cakes can be used as sources of escape nitrogen, while nougseed cake is very good sources of fermentable nitrogen and easily degraded in the rumen. The increase in the basal feed or total feed intake with cotton, linseed and soybean cake agree with the finding of Wondwosen *et al.* (2009) who observed in Sidama goat that cotton seed meal provide animals with by-pass protein resulting in increased total feed intake. Bonsi *et al.* (1996) also observed in Menz sheep that finely ground cotton seed meal provide animals with by-pass protein resulting in increased total feed intake.

Improved intake after supplementation with linseed, cotton and soybean cake from the present trial clearly suggests the importance of availability of source of nitrogen for effective utilization of the basal diet which is again in agreement with previous reports that dietary CP levels and quality of protein in the feed supplement influence DM intake in sheep positively (Badamana and Sutton 1992).

Body Weight and Feed Conversion Efficiency

The increase in total feed intake with linseed, cotton andsoybean cake agree with the finding of Getu *et al*., (2012) who observed in Horro sheep that cotton seed and linseed meal provide animals with by-pass protein resulting in increased total feed intake. The higher TWG, ADG and FBW observed in T2, T3 and T4 than T1 supplemented group is due to the differences in intake. Marishet *et al*. (2019) and Tekelab (2019) noted lower body weight change when noug seed cake was supplemented to cross bred cows fed oat-vtech hay than LSC and CSC Noug seed meal is rumen degradable protein and it is more useful for microbes than the animals. The comparison of leguminous hay and oil seed cakes supplementation to growing sheep fed a basal diet of teff straw also demonstrated that equal intake of CP from different sources does not support the same live weight gain (Lemma 1991) and suggested that higher animal performance is attained when slowly degrading protein sources with high undegradable dietary protein is fed than for rapidly degrading protein sources. According to Brown et al *(*2001), animals that have high feed conversion efficiency are considered efficient users of feed. Therefore, among sheep in T2, T3 and T4 were best feed converters than T1. Similarly, Getu *et al*. (2012) noted that LSC and CSC supplemented sheep had higher feed conversion ratio than NSC supplemented sheep.

Slaughter and carcass characteristics

The higher slaughter performance of T4 than T1 in the present study could be related to high CP intake and digestibility of SBC than NSC. Previous studies also observed higher slaughter

performance in sheep supplemented with CSC and LSC than NSC (Amare *et al*., 2009; Wondwosen *et al.,* 2009). Higher REM area recorded from sheep consumed LSC and SBC supplement reflected the positive relationship between the amount of nutrients availability and the degree of fat deposition and muscle development. In agreement with the results of this study, Tigray highland sheep fed on a basal diet of teff straw and cactus pear and supplemented with CSC, NSC and PNC recorded rib-eye muscle area of 7.4-9.2 cm^2 (Amare *et al*., 2014).

Edible and non-edible offal's

In general, various studies showed that supplementation had significant and positive effect on TEO (Melese *et al*., 2017; Getahun 2019). In the present study, the source of protein did not differently impacted TEO indicating that they have similar potential for proper development of organs. This agrees with the results of Asefu (2012) who reported TEO components lack significant difference among treatments. However, the significant difference that existed in TNEO components among treatments can be ascribed to the fact that non-carcass tissues also grows faster in younger animals. Consistent to the present study, Prescott (1979) reported that as the lamb gets older and heavier, its body composition changes, the viscera (internal offals), skin, head, and feet grows relatively slower than the carcass tissue so that the ratio of carcass weight to total live weight increases as the lamb matures.

Profitability

Fattening sheep involves intensive feeding to attain slaughter weight with adequate finish in feedlots so as to improve carcass yield for domestic consumption/export and to directly increase producer's income (Alemu, 2008b). The higher net income for CSC sheep in the present study is mainly due to low price cost, high body weight gain and feed utilization efficiency which improved performance and their sale values than LSC, NSC and SBC. From the present result, it can be suggested that supplementing Arsi Bale sheep with cottonseed mean is potentially more profitable than other oil seeds meals because of the high growth, and hot carcass yield obtained from supplementing this diet and low price of CSC.

Conclusion

The present study highlighted that LSC, CSC and SBC supplemented sheep had higher FBW, TWG, ADG, EBW, HCW and REMA than NSC presumably due to higher CP intake and digestibility. The supplements considered in this study could be recommended in the order of: T3>T4>T2>T1. Partial budget analysis showed that fattening Arsi-Bale sheep by supplementing CSC resulted in higher net income because of low price than other oilseed cakes.

Acknowledgements

The Authors would like to acknowledge Ethiopian Institute of Agricultural Research for the financial support and research facilities including laboratory and Haramaya University for the provision of supplementary budget.

References

Adane H. and Girma A. 2008 Economic Significance of Sheep and Goats. In: AlemuYami& R.C. Merkel (eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP). Branna Printing Interprise, Addis Ababa, Ethiopia.

Alemu Yami 2008. Short term intensive fattening of sheep and goats before slaughter for rapid improvement in weight and condition and also producer incomes. In: R.C. Merkel (ed.), Ethiopia sheep and goat productivity improvement program (ESGPIP). *Technical Bulletin No.11*.

Amare D., Solomon M.,Gebreyohannes B 2009 Supplementation of isonitrogenous oilseed-cakes in cactus (Opuntiaficus-indica)–*tef*straw (*Eragrostistef*) based feeding of Tigray Highland sheep. *Anim. Feed Sci. Tech*, 148:214-226.

Amha S. 2008 Sheep and goat meat characteristics and quality. In: AlemuYami and R.C. Merkel (eds.), Ethiopia sheep and goat productivity improvement program (ESGPIP). Branna Printing Interprise, Addis Ababa, Ethiopia.

AOAC 1990. Official Methods of Analysis. Association of Official Analytical Chemists, 16th Edition. Arlington, Virginia, USA.

ARC 1980. The Nutrient Requirement of Ruminant Livestock. Agricultural Research council

Assefu G., 2012. Comparative feedlot performance of Washera and Horro sheep fed different roughage to concentrate ratio. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Awet, E. and Solomon, M. (2009) Supplementation of Graded Levels of Wheat Bran to Intact and Castrated Afar Sheep Fed Urea Treated Tef Straw: Effects on Feed In-take, Digestibility, Body Weight and Carcass Characteristics. East African Journal of Sciences, 3, 29-36.

Badamana M S and Sutton J D 1992 Hay intake, milk production and rumen fermentation in British Saanen goat given concentrates varying widely in protein concentration. Anim. Prod., 54:395-403.

Bonsi M L K, Tuah A K, Osuji P O, Nsahlai I V and Umunna N N 1996 The effect of protein supplement source or supply pattern on the intake, digestibility, rumen kinetics,

nitrogen utilization and growth of Ethiopian Menz sheep fed Tef straw. Anim. feed Sci. and Technol., 64:11-25.

Brown, D .L, M. R. Dally, M. R. Schwartz, and G. E. Bradford. 2001. Feed efficiency, growth rates, body composition, milk production and milk composition of Targhee sheep selected for increased weaning weight. *J. Anim. Sci*. 65: 692 - 698.

CSA (Central Statistical Authority) 2019 Agricultural Sample Survey 2018/19 Volume II: Report on Livestock and livestock characteristics (Private peasant holdings). *Statistical Bulletin 678*. Federal Democratic Republic of Ethiopia, Addis Ababa.

Ethiopian Meat & Dairy Industry Development Institute (EMDIDI) 2018. Annual Report, Debre Zeiet, Ethiopia.

Ensminger, M.E., E.J Oldfield and W.W. Hernemann, 1990. Feed and feeding. 2nd ed. Ensminger publishing company, United State, California. pp. 925-926.

FAO (Food and Agricultural Organization) 2004 FAO production year book, http://faostat.fao.org

Geremew A., Getahun A, Rana K 2015 Digestibility of Soybean Cake, Niger Seed Cake and Linseed Cake in Juvenile Nile Tilapia, *Oreochromis niloticus* L. J Aquac Res Development 6: 333. doi:10.4172/2155-9546.1000333

Getahun K 2014 Effect of Concentrate Supplementation on Performances of Ethiopian Lowland Afar and Blackhead Ogaden Lambs. *Animal and Veterinary Sciences*, 2(2), 36-41. doi: 10.11648/j.avs.20140202.14.

Getahun Kebede 2019 Sugarcane byproducts as feed resources and performance of sheep fed on sugarcane tops based diets. PhD dissertation submitted to Addis Ababa University, Addis Ababa.

Getu K, Mesfin D, Aemiro K and Getnet A 2012: Comparative evaluation of Tree Lucerne (*Chamaecytisuspalmensis*) over conventional protein supplements in supporting growth of yearling Horro lambs. *Livestock Research for Rural Development. Volume 24, Article #8.* http://www.lrrd.org/lrrd24/1/getu24008.htm

Kearl, L. C. 1982 Nutrient requirements of ruminants in developing countries. International Feedstuffs Institute, USA.

Kiflay, W., Getachew, A. and Mengistu, U. (2014) Effect of Different Levels of Soy-bean/Glycine Max/Meal Supplementation on Feed Intake, Digestibility, Live Weight Changes, and Carcass Characteristics of Black Head Ogaden Sheep. *East African Journal of Sciences*, 8, 135-146.

Lemma Gizachew 1993. Comparison of legume hay, urea and noug cake as protein supplements to Horro sheep fed on Tef straw. 4th NLIC (National Livestock Improvement Conference), 13-15 November, 1991. Addis Ababa, Ethiopia.

Lemma G., 1991. Comparison of legume hay, urea and noug cake as protein supplements for sheep fed teff straw. pp. 211- 215. In: Proceedings of the Fourth National Livestock Improvement Conference. 13-15 November, 1991. IAR, Addis Ababa, Ethiopia.

McDonald, P., Edward, R. A., Greenhalgh, J. F. D. & Morgan, G. A. 2002. Animal Nutrition, *6th Edition*. Pearson Educational Limited. Edinburgh, Great Britain.

McDonald, P., Edwards. R. A., Greenhalgh, J. F., Morgan, G. A., Sinclair, L. A. & Wilkinson, R. G. 2010 Evaluation of foods: digestibility, Animal nutrition, *7th Edition*. Pearson Educational Limited. Edinburgh, Great Britain.

Marishet T., Mengistu U., Getnet A., and Kassahun M. 2019. Effects of sources of dietary protein supplemented to oat-vetch hay mixture on milk yield and milk composition of crossbred dairy cows. *International Journal of Livestock Production*,10(2):. 56-61

Melese G., Mengistu U., Getachew A. and Dereje T 2017. Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition. African Journal of Agricultural Research, 12(41) : 3072-3080.

McDonald, P., Edward, R. A., Greenhalgh, J. F. D. & Morgan, G. A. 2002. Animal Nutrition, *6th Edition*. Pearson Educational Limited. Edinburgh, Great Britain.

McDonald, P., Edwards. R. A., Greenhalgh, J. F., Morgan, G. A., Sinclair, L. A. & Wilkinson, R. G. 2010 Evaluation of foods: digestibility, Animal nutrition, *7th Edition*. Pearson Educational Limited. Edinburgh, Great Britain.

MengistieT., GirmaAbebe, Solomon Gizaw, Sisay Lemma, Abebe Mekoya & Markos Tibbo 2010 Traditional management systems and linear body measurements of Washera sheep in the western highlands of the Amhara National Regional State, Ethiopia. *Livestock Research for Rural Development*, 22(9). http://www.lrrd.org/lrrd22/9/taye22169.htm.

NMSA 2010 National Meteorological Services Agency, Addis Ababa, Ethiopia.

Payne WJ, Wilson RT 1999. An Introduction to animal husbandry in the tropics. *5th edition*. Blackwell Science Ltd, London, U. K. 815p.

Prescot, H.J.D., 1979. Growth and development of lambs. pp. 358-376. In: The Management and Diseases of Sheep. Commonwealth Agricultural Bureaux, Farnham Royal,Slough, U.K.

Ranjhan, S. K. 2004 Animal Nutrition in the Tropics, 6th *Edition*. Vikas publishing house Pvt. Ltd., New Delhi, India. 672p.

Salah, N., Sauvant, D. and Archimède, H. 2014. Nutritional requirements of sheep, goats and cattle in warm climates: a meta-analysis, 8 (9), 1439-1447. Dol: 10.1017/ S1751731114001153.

SAS 2003. The Statistical Analysis System. Version 9.1, SAS Institute Inc., Cary, North Carolina, USA.

Seyoum Bediye 1995. Evaluation of nutritive value of herbaceous legumes, browse species and oil seed cakes using chemical analysis, *In vitro* digestibility and nylon bag techniques. MSc. Thesis, Alemaya University of Agriculture, Ethiopia. 209p

Seyoum, Bediye, Gemechu Nemi and Harinder Makkar, 2018. Ethiopian feed industry: current status, challenges and opportunities. Feedipedia, www.feedipedia.org.

Seyoum Bedye, Zinash Sileshi & Dereje Fekadu 2007 Research Report 73 on Chemical composition and nutritive value of Ethiopian feeds. Ethiopian Institute of Agricultural Research (EIAR).

SSGWG (Sheep Standards and Guidelines Writing Group) 2013 Sheep Castration Standards and Guidelines. *Sheep castration discussion paper*, public consultation version 1.3.13, Australia. http://www.animalwelfarestandards.net.au/.

Tekleab S., 2019. Perception and utilization of improved forage and evaluation of natural pasture hay supplemented with vetch (*vicia dasycarpa*) or oil seedcakes as an alternative feeding regime for lactating Jersey Cows. PhD Thesis Haramaya University, Haramaya, Ethiopia.

Van Soest, P. J. & Robertson, J. B. 1985. Analysis of forages and fibrous feeds. A laboratory manual for animal science, Vol. 613. Cornell University, Ithaca, New York.

Van Soest, P. J. 1994 Nutritional Ecology of Ruminants, *2nd edition*. Cornell University press, London.

Wondwosen A., Solomon M. and Adugna T. 2009. Supplementation of cottonseed, linseed, and noug seed cakes on feed intake, digestibility, body weight, and carcass parameters of Sidama goats. *Trop Anim. Health Prod*., 42:623–631 DOI 10.1007/s11250-009-9466-9 .

8.4. SURVEY QUESTIONNIARE

Sheep production and marketing systems in Eastern Ethiopia

CODE_____

This questionnaire is intended to obtain primary data to assess the current Sheep production and marketing systems.

Date of interview_____ Enumerator's name_____

Woreda _____Kebele/PA _____
Location_____

Respondent's Name_____ Sex_____ Age_____
Tel_____

I. HOUSEHOLD CHARCTERSTICS

1. Head of household a= Male b= Female

2. Marital status a= Married b= Single c=Widowed d=Divorced

3. Religion a=Orthodox b=Catholic c= Muslim d=Protestant e=Traditional f=Other__

4. Education level a= Illiterate b= Read and write c=Primary d= Secondary e= Higher education

5. Major occupation a= Farmer b= Business man c= Employed d=Retired e=Other-----

6. Family size Male_____ Female_____ Total_____

7. Farmer's ethnic origin a=Oromo b=Amhara c= Tigre d= Gurage 5=other(specify)_____

8. Household annual revenue from different source (Rank 1, 2, 3…in descending order)

No	Source of income	Rank
1	Non cash crop	
2	Cash crop	
3	Sale of livestock	
4	Manure	
5	Trading	
6	Sale of charcoal/fire wood	
7	Causal works (working for others)	
8	Remittance	
9	Others	

9. How many years of experience do you have on sheep fattening? _____

10. How much is your land allocated for the followings?

No	Type of Crops	Hectare			
		Own	Rented-in	Shared-in	Total
1	Barely				
2	Wheat				
3	Teff				
4	Maize				
5	Sorghum				
6	Fababean				
7	Peas				
8	Lentil				
9	Grasspea(Guaya)				
10	Linseed				
11	Chat				
12	Coffee				
13	Others				

11. Land holding (in ha)

	Own	Rented
a. Crops (including fallow land)	_____	_____
b. Fallow land	_____	_____
c. Grazing	_____	_____

d. Others (specify) _____

12. Type of grazing land and ownership

	Own		Rent		Communal		
a. Open grassland							* *(Tick one or more boxes in the first half of the box in each column. Then rank top three in second half of box, according to their importance; 1 for most important , etc.)*
b. Tree covered grassland							
c. Bush/shrub grassland							
d. Stone covered grassland							
e. Swampy grassland							

13. What is your major farming activity?

a. Livestock production b.Crop production c. Both

1 ⌊4 umbers of livestock kept

	Number		Number
a. Cattle		f. Donkeys	
b. Sheep		g. Mules	
c. Goats		h. Camels	
d. Chickens		i. Horses	

15. Population trend in major livestock species

	Increasing	Decreasing	Stable	Reason
a. Sheep				
b. Cattle				
c. Goat				
d.Equines				
e. Camel				

11. Purpose of keeping Sheep (Rank them)

No	purpose	Rank
1	Income generation	
2	Milk consumption	
3	Meat consumption	
4	Sacrifices/rituals	
5	Manure production	
6	Social prestige	
7	Saving (Insurance)	
8	Risk/benefit distribution with other animals	
9	Hair/wool production	
10	Other	

12. How many of the following animals you keep in past 12 months?

SN	Structure	Number Owned	Ownership		
			Own	Share	Ribi
1	Lambs <6 months				
2	Males 6-12 months				
3	Females 6-12 months				
4	Males > 12 months				
5	Females > 12 months				
6	Ewes				
7	Rams (intact)				
8	Castrated male				

III. USE OF LABOR

Activity	Children (< 15 years)				Adult (≥ years)			
	Male		Female		Male		Female	
	F	Hi	F	Hi	F	Hi	F	Hi
Herding								
Feeding								
Breeding								
Watering								
Barn Cleaning								

Feed collection								
Caring for sick animals								
Milking								
Making dairy products								
Selling dairy products								
Purchasing sheep								
Selling sheep								
Others								

F=Family labor Hi=Hired labour

Feeding, grazing and watering

1.Feed source (Tick one or more boxes in each column and rank the top 3 in 2nd column

	Dry Season	Rank	Wet season	Rank
a.Natural pasture				
b.Established				pasture
c. Hay				
d.Crop residues				
e.Fallow land				
f.Concentrate				
g.Others				

2. Grazing method

	Dry Season	Rank	Wet season	Rank
a.Free grazing				
b.Herded				
c. Paddock				
d.Tethered				
e.Zero grazing				
f.Others				

3. Length of grazing time during dry seasons (in hours):

Morning from_____ to_____ hours
Afternoon from_____ to_____ hours

4. Length of grazing time during wet seasons (in hours):
Morning from _____ to_____ hours
Afternoon from_____ to_____ hours

5. How sheep graze? 1= Sheep alone 2= Sheep + Goat 3=Together with other livestock

6. Do you usually provide your sheep with supplementary feeds in addition to grazing?
a=Yes b=No

7. If yes, what type of feed and others?

No	Feed types	Sheep			
		Lambs	Ewe	Ram	Castrated
1	Wheat bran				
2	Maize grain				
3	Oil cakes/meals				
4	Chat leftover				
5	Food leftovers				
6	Homemade brewers recipes(atela)				
7	Salt/local mineral				
8	Cultivate Fodder Leaves				

8. When do you offer your sheep with supplements?
a=Dry season b=Wet season c=Both d= during pregnancy e= others_____
9. How often do you offer supplements to your sheep ?
a=Daily b=Twice a day c=whenever available d=others, specify_____
10. If you do not provide with supplements, why?
a=Not accessible b=Expensive c=Not feasible d=others, specify_____

11. What types of feeds you use for fattening ?_____
_____

12. Mention the name of feeds you mostly use for fattening purpose

	Crop residues	Concentrate (grain, bran, cake, etc.)	Non- conventional feeds (attella, brint, household by product	Mineral/ vitamin supplements	Any other feeds
1.					
2.					
3.					
4.					

13. Do you have experience of purchasing feed for your sheep? A) Yes B) No
14. Mention the type of feed purchased over a typical 12 month period?

Feeds purchased	Price/ local unit	Local unit name	1 kg = how many local units	Quantity purchased each time you purchase feed (local unit)	Number times amount purchased throughout the year

15. What kind of feeding practice you mostly use when fattening sheep? _____
why?_____
_____
_____
16. Do you conserve feed? 1=Yes 2=No
17. If yes in what form? 1=Hay 2=Silage 3=Others_____
18. If not why? a=Not skilled and experienced b=Shortage of grasses/fodder 3=Labor shortage 4=others_____
19. Do you practice tether feeding of sheep a=Yes b=No
20. If yes, why? a=To avoid crop and vegetation damages b=Save labor c=Protect from predators d=Utilize marginal land and hillsides e= control breeding f=Others, specify
21. Is there feed shortage or constraint for your sheep ? 1=Yes 2=No
22. If yes, when? a=Dry season b=Wet season c=Both
23. If feed shortage in your locality, why? (Rank)
a=Shrinking and decline in productivity of grazing lands 2=Increase of animal population 3=Cultivation, settlement and protection on grazing lands 4=Drought 5=Increase of human population 6=Others,_____
24. What are the common water sources of sheep ?

No	Sources of water	Dry season	Wet season	Distance to the nearest water point		Key A=watered at home B= < 1km C=1-5 km D=6-10km E= > 10 km
				Dry season	Wet season	
1	River					
2	Dam/Pond					
3	Spring					
4	Bore hole/Deep well					
5	Pipe water					
6	Rain water					
7	Any other sources					

25. In what intervals you offer sheep with water?

No	Frequency	Seasons	
		Dry season	Wet season
1	Any time required		
2	Once a day		
3	Twice a day		
4	Every other day		
5	Every three day		
6	Others, specify		

26. Is there any water shortage or problem to sheep ? 1=Yes 2=No
27. If yes, when? 1=Dry season 2=Wet season 3=Both
28. Why shortage of water? 1=Drying of water sources 2=Far distant from water sources
3=Not allowed to use sources 4=Priorities to other livestock 5=others, specify_____

3. Housing

1. Housing/enclosure for adult sheep (*Tick one or more boxes)*
a. In family house b. Separate house c. Veranda d.Yard e.Other_____

2. Type of housing materials

	Iron sheets	Grass/Bushes	Wood	Stone/bricks	Earth/mud	Others
Roof						
Wall						
Floor						

3. Are lambs housed with adults? 1=Yes 2= No
4. If no, specify_____
5.If yes, with which animal ? a= Cattle b=Goat c=Equines d= Camel e) others,_____

4.Health

1.What are the common diseases and parasites that affect health and production of sheep ?

Type of disease and parasite	Symptoms	Susceptible age group	Months of occurrence	Rank	Treatment	
					Modern	Traditional

2. What would you do when your sheep sick?

a=Treat with ethno veterinary practices b=Sales immediately c=Slaughters immediately d=Takes to veterinary center e=Take to or treat with treatments of local traders 6=Others _____

3. Are you accessible to veterinary services in your locality/near distance? 1=Yes 2=No
4. If yes, how far? _____Km
5. From where you obtain veterinary services?
a=OoARD b=DA offices c=NGOs 4=Private institutions 5=Open markets 6=other_____
6. How do you obtain services in these institutions?
1=Free of charge 2=Payment d=Credit e=others, specify
7. Do your sheep get vaccination? 1=Yes 2=No
8. If yes, how? a=After report of disease cases b=After some animals died c=Others, specify_____
9. Do you uses medicines and drugs from open markets for sheep ? 1=Yes 2=No
10. If yes, yes why? a=Cheap b=Not access to veterinary center c=Not want to use veterinary center e=Others__
11. If not use, why? 1=Not cures 2= Because of advised not to use 3=Expensive 4=Not accessible 5=Others____
12. Do you brand with hot iron your sheep ? 1=Yes 2=No
13. If yes, why? 1= Ethno veterinary treatment to sick animals 2=Identify/tag the animals 3=others, specify
14. If not, why? 1=Learnt that it affects quality of skin 2= Reduce price of skin 3=others_____ 15.Has there been any death of sheep over the last 12 months? 1=yes 2=No
16. If yes, (specify the number)

No	**Sheep**	
	Structure	Died
1	< 3months	
2	3-6 months	
3	Ewes	
4	Rams	
5	Castrates/fattening	

17. What are the common problems of sheep health management in this area?
1=Widespread of diseases and parasites 2=Shortage of feeds and water in the area
3=Lack/shortage of veterinary institutions 4=Lack of animal health professions
5=Lack/shortage of drugs and medicines 5=Unaffordable prices for services 6=Drought in the area 6=others, specify_____

5. Breeding

1. Do you select your male animals for breeding purpose? 1=Yes 2=No
2. What are the criteria for sire (Ram) selection?

Criteria	Color	Body conformation	Lamb survival	Growth	Character	Age	Pedigree	Others
Rank								

3. What are the criteria for Ewe selection?

Criteria	Color	Body conformation	Lamb survival	Growth	Character	Age	Lambing Interval	Others
Rank								

4. What type of mating do you practice? a= Controlled b= Uncontrolled

5. If uncontrolled, what is the reason? a=sheep graze together b=Lack of awareness c=Lack of Ram d=other__

6. Do you have your own breeding male animals (ram & buck)? a=Yes b=No

7. What are common sources of breeding males for your flocks?

No	Sources of breeding males	Ram
1	Own	
2	Far Neighbors	
3	Near Neighbors	
4	Others, Specify	

8. When (season/months) during the year you observe high lambing rate? (Rank 1...4

Intense breeding and conception seasons			
Summer(July-Sep)	Autumn(Oct-Dec)	Spring(Jan-Mar)	Winter(Ap-June)

9. How is the reproductive performance of sheep in your farm?

SN	PARTICULARS	SHEEP		Remark
		Male	Female	
1	Age at first puberty(months)			
2	Age at first parturition (months)			For female
3	Parturition interval (months)			For female
4	Average litter sizes(single, twin, triplets)			For female
5	Infertility			
6	Slaughter age /marketing age (months)			

10. Do you provide lambs any feed in addition to their dam's milk until they begin grazing? a=Yes b=No

11. If yes, what types of feed resources and feeding? _____

12. Do you practice weaning lambs ? 1=Yes 2=No

13. If yes, when? Lambs_____ months

14. Do you practice castration of sheep? a=Yes b=No

15. If yes, why?

a=To fetch more price (by fattening) b=To control unwanted mating c=Better temperament d= Others ___

16. At what age do you castrate? a= < 3months b= 3 -6 months c= >6 months d=Specify_____

17. How do you select sheep for castration and fattening?(rank)

a=Conformation (height, length and appearance) _____b=Breed (known local ecotypes)_____

c=Physical characteristics (color, horn, tail length and width, ear etc)_____d=Age _____e=Others ___

18. If you practice selecting with physical characteristics, rank each
a=Color b=Horn c=Ear d=Tail e=body Length and height f=Others_____

19. Do you offer specific feeding and other management practices for castrated sheep ?
1=Yes 2=No

20. If yes, what feed types ?_____ _____

21. What is the common ways of castrating your sheep?
1=Local methods (stone, stick, metal, others) 2= Burdizo (OoARD)
3=others_____

22. Do you practice fattening of sheep for target market seasons and market places? 1=Yes 2=No

23. If yes, which season/months and rank?
1=New Year 2=Ester 3=Christmas 4=Meskel 5=Ed al Fetir 6=Ed alada 6.others _____

24. How many fattening cycles per year do you practice on average and Why?
_____
_____
_____

25. Which duration is the best and the most profitable staying period?_____

Season	Fattening duration	Reason
1. _____	_____	_____
2. _____	_____	_____
3. _____	_____	_____

26. Is there emerging opportunity of increased demand and incentive price for fattened sheep ?
1=Yes 2=No

27. Do you practice culling of sheep from your flock ? 1=Yes 2=No

28. If yes, why (rank)?

No	Culling reason	Rank
1	Oldage	
2	Sickness	
3	Lambing problems	
4	Physical defect	
5	Unwanted physical characteristics	
6	Increased price of feed	
7	Absence of market	
8	Shortage of land	
9	Other	

29. How do sheep left from your flock over the last 12 months?
a=Sale b=Death c=Slaughter for home consumption d=Theft e=Predator f=Gift g=Share out h=Others____

30. How do you replace/own sheep left the household flock in various ways?
a=home born b=share arrangements c=gift d=purchase e=Not replace f=others, specify

31. If you sale sheep for urgent income needs, which do you prefer to sale?

a=Lambs b=Rams 3=Ewes 4=Castrates 5=others, specify___

32. How you sale young male sheep? a=Sale all when reach to marketing age b=Sale holding some for breeding c=Sale holding some to castrate and fattening d=others, _____

33. Do you cut tail of /dock female sheep/ewe? a=Yes b=No

34. If yes, why and when (age, months)?_____

35. If you slaughter sheep for home consumption, usually when? a=For festivals b=weeding c=Whenever slaughter age animals available d=Births in a family e=for guests f=circumcise g=At funeral ends h=specify____

36. Which sex of sheep do you usually slaughter? 1=Male 2=Female 3= Both

37. Is milking and use of milk and milk products from sheep common in your area? 1=Yes 2=No

38. If no, why? a=Cultural taboo b=Religious taboo c=Not common in the area d=Others, specify

39.If yes, Milk production per day per ewe ? Average _____ Minimum_____ Maximum_____

40. Frequency of milking? a=Once a day b=Twice a day c=Three times a day

41. What is average weaning age of lambs? a= < 3 months b=3-4 months c= 5-6 months d= >6 months

42. For what purposes you usually use the milk?

a=Children consumption b=Adult consumption c=Processing d=Medicine e=others, specify _____

43. Who in the family is given priority for consuming milk?

a=children b=sick people c=old people d=Females e=Other_____

6. Marketing

1. Have you sold sheep in the past 12 months? 1=Yes 2=No

2. If yes, why? (rank)

S/N	Reasons	Rank
1	Purchase input (fertilizer, seed...)	
2	Children school fee	
3	Health care	
4	Purchase food	
5	Payback credit	
6	Others	

3. Where do you sell your animals? a. At the farm gate b. At local market c District market d. Out of the district market 5=Primary livestock market center 6= Secondary livestock market center 7=Others_____

4. Have you purchased sheep in the last 12 months? 1= Yes 2= No

5. If yes, why did you purchase sheep? a=slaughter for festivals b=slaughter for ceremonies/rituals c=Breeding d=fattening e=others

6. If yes, from where did you purchase? 1. At the farm gate 2. At local market 3. District market 4. Out of the district market 5=Primary livestock market center 6= Secondary livestock market center 7=Others_____

7. How many sheep have you sold and purchased in the past 12 months and how much?

SN	CLASSES OF ANIMALS	SOLD				PURCHASED			
		Number	When/ Months	Unit Price	Total Price	Number	When/ months	Unit Price	Total price
1	Sheep								
2	Ewe								
3	Ram								
4	Male lamb								
5	Female lamb								
6	Castrate								

8. When in the year you prefers to sale or purchase sheep ?

Purchase_____
why_____
Sale_____
why_____

9. Which class of sheep do you sell first in case of cash needed?

	Class of animals	Rank
A	male lambs less than 6 months	
B	Female lambs less than 6 months	
C	Ram lambs between 6 months and one year	
D	Ewe lambs between 6 months and one year	
E	Breeding ewes	
F	Breeding rams	
G	Castrated	
H	Old ewes	
I	Old rams	

9. How you sales or purchases your animals? 1= Live weight basis 2= visual judgment 3=Both
10. Give reason for your choice? 1= Incentive prices 2= Traders make mischief with weighing scale 3= Purchasers like this it 4= Reliable and saves my time 5= Other, specify_____
11.How do you transport your animals ? a= Trucking b=Trekking c= Both
12.How long it will take to reach the nearest livestock market ?
a=0 km b= < 1km C=1-5 km d=6-10km e= > 10 km
13. Did you ever get animal price and market information? 1= Yes 2= No
14. If yes, from where? a= DAs b= Governmental organizations 3= NGOs 4= Others_____
15. Do you face any problem in marketing of your animals? 1= Yes 2= No

16. If yes, what? 1= Tax burden 2= Unwanted broker disorder and high commission fees 3= Seasonality of market demand and prices 4= Lack of market accessibility 5= Lack of market and price information 6= others, ____

17. Do your family sales milk products from sheep ? a= Yes b= No

18. If yes, what is the price per your local unit (approximated in kg?)_____ Birr
Milk _____ Butter_____ Cheese_____

19. If you do not market your products, why not? a= Not produce at all b= Produce but consume at home c= Not fetches reasonable price d= Don't have any market demand in my locality 5= Others, specify_____

20. What did you do with the skin(s)?
1= Sales 2= Used for making household materials (seat, bed materials, containers) 3= Used for ride horse/mule seat 4= others, specify_____

21. If sold, how much was the average prices? a= Sheepskins _____ Birr

20. Do you preserve/process skins at home immediately after flaying? 1= Yes 2= No

21. If yes, what? a= Apply salts b= Dry c= Others, specify_____

22. After how many days (usually) you take the skins to the traders or collectors____days

23. Where and to whom you usually sales skins?
a=Sub-agents in my locality b= In nearby town for any traders c=Others, specify _____

24. Did any of your customers have complained on quality of the skins you sold? a= Yes b= No

25. If yes, what were the defects they complained? a= Cut during flay b= Cut during trimmings c= Spoiled with bacteria and dirt d= Too much dried on the sun e= others, specify? _____

26. What are the common problems you encounter in skin production and marketing?
a= Lack of market information and markets b= Lack of capacity building on skin production, preservations and marketing c= Lack of local organization (farmers' coops) in preservation, storage and marketing d= Animals produce poor quality skins 5= Others, specify_____

27. What are major constraints hinder production of sheep in this area?

No	Constraints	Rank
1	Disease and parasites	
2	Feed and grazing land shortages	
3	Water shortage	
4	Labor shortage	
5	Drought	
6	Predators	
7	Marketing problems	
8	Inadequate/lack of inputs	
9	Inadequate/lack of extension and support	
10	Inadequate/lack of technologies and innovations	
11	Lack of credits	
12	Others, specify	

28. Do you want to expand sheep flock sizes and production in the future? a=Yes b=No

29. If yes,

No	Reasons for expansion	Rank

1	High market demand	
2	Incentive market price	
3	Easy to manage and keep	
4	Distribute benefits and losses	
5	Immediate returns	
6	Appropriate for slaughter and home consumption	
7	Others, specify	

30. If no, why? a=Shortage of grazing lands and feeds b=Shortage of labor c=Prefer another animal species d=Marketing problem e=Lack of capital to purchase animals and inputs f=Others, specify_____

35. Is there any cultural, traditional and religious taboo in the area that prohibits use of sheep products and by-products in your areas? 1=Yes 2=No

36. Is there any tradition that exceptionally prefer/requires certain sheep color in the area.1=Yes 2= No

37. Do you sacrifices sheep for any religious or traditional occasions 1=Yes 2=No

38. Did you receive credit in recent years? 1=Yes 2=No

39. If yes in what form? a=Cash b=Kind c=Both

40. If you received what is the source 1=micro-finances 2=Private banks 3=Credit Institutions 4=Governmental offices (OoARD, etc) 5=NGOs 6=Cooperatives 7=Others _____

41. What do you do with it? a=for crop production b=cattle and small ruminant fattening c=trading d=other

42. Who receive credit in your family? a=Husband b=Wife c=young boys d=young girls e=others_____

43. Are you satisfied with the lending regulations and terms to repay the credit? 1=Yes 2=No

44. Did you receive sheep from any source a=Yes b=No

45. If yes, from which sources? a=Credit b=Gift from NGOs c=Gift from GOs (safety net, credit, revolving funds) d=Share arrangements e=Exchange (crop, other livestock, inputs, etc)

46. If you received sheep for share arrangements, why? a=To keep or allocate labor b=To House c=To Fatten d=To Breed e=Others, specify _____

47. How share agreements made? a=Share incomes from sale of animals received b=Share new born animals c=Share the original animals after certain years (___ years) d=others, specify___

48. Is there any cooperative in your area? a=Yes b=No

49. If yes, in what sector a=Crop production (storage, marketing, deliver inputs to members, etc) b=Livestock (Marketing, deliver inputs, assemble products, etc) c=Inputs (deliver different inputs, credits, insurance, etc) d=others, species_____

50. Have you received training on sheep production? 1= Yes 2=No

51. If yes, mention the title_____and duration_____

52. Do you need training in the future? 1=Yes 2=No

53. If yes, mention the area_____-

54. Do you keep farm record? 1=Yes 2=No

55. If, no why? a= no time b= It is difficult c= No routine work d=I don't know

56. If, yes which record? a= Financial b= Production c= Health d=others_____