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INFLUENCE OF TRANSPORTATION AND USE OF EFFECTIVE MICROORGANISMS TREATED FEEDS ON GROWTH, CARCASS YIELD AND MEAT QUALITY OF *ARSI-BALE* AND *AFAR* SHEEP

PhD DISSERTATION

BY

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

PhD Program in Animal Production

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Bishoftu

INFLUENCE OF TRANSPORTATION AND USE OF EFFECTIVE MICROORGANISMS TREATED FEEDS ON GROWTH, CARCASS YIELD AND MEAT QUALITY OF *ARSI-BALE* AND *AFAR* SHEEP

A PHD DISSERTATION SUBMITTED TO THE COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE OF ADDIS ABABA UNIVERSITY FOR THE REQUIREMENTS OF THE DEGREE OF PHILOSOPHY IN ANIMAL PRODUCTION

BY

TIBEBU MANAYE

APRIL2019

BISHOFTU

SIGNATURE SHEET OF DISSERTATION

INFLUENCE OF TRANSPORTATION AND USE OF EFFECTIVE MICROORGANISMS TREATED FEEDS ON GROWTH, CARCASS YIELD AND MEAT QUALITY OF *ARSI-BALE* AND *AFAR* SHEEP

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Entitled: **INFLUENCE OF TRANSPORTATION AND USE OF EFFECTIVE MICROORGANISMS TREATED FEEDS ON GROWTH, CARCASS YIELD AND MEAT QUALITY OF *ARSI-BALE* AND *AFAR*SHEEP** and recommend that it be accepted as fulfilling the Dissertation requirement for the degree of Philosophy in Animal Production

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DEDICATION

I dedicated this thesis manuscript to my sisters W/roMekidesManaye and W/ro Tsige Manaye who had sacrificed their happiness for my well-being since my childhood and contributed to the highest degree for what I am today.

STATEMENT OF AUTHOR

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

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BIOGRAPHICAL SKETCH

The author was born on November 7, 1971 in Oromya Region, East Harrarghe Zone Harawacha town. He attended his elementary and junior secondary school at Harawacha Primary and Junior Secondary School, Harew Primary School, Diredawa Addis Ketema Primary School and Legehare Primary and Junior Secondary School and his Secondary School at Dedder Senior Secondary School. He joined the then Alemaya University of Agriculture and graduated with BSc degree in Animal Sciences in August 1993. He then worked at the former Agarfa Multipurpose Development Agents Training Center, which is now Agarfa Agricultural Technical Vocational Education Training College from June 1995 to September 2003 as Instructor (Trainer) and Acting Head of Livestock Production Department.

He joined Haramaya University in October 2003 and acquired his Master of Science degree in July 2006 in the field of Animal Production whose thesis research was in Animal Nutrition. He was reinstated in October 2005 to the Agarfa Agricultural Technical Vocational Education Training College before he graduated and worked as Head of Animal Feed Development and Processing, and Acting Head of Research and Publication until July 2006. He has been working at Haramaya University since August 2006 where he served as Lecturer, Associate Dean for Administration of College of Agriculture and Director of Consultancy and Short-Term Training Enterprise. Further, he also served Haramaya University in designing the working process of Learning-teaching, Research and Community Engagement core processes being member of the Business Process Re-engineering team. He has also served as chairperson of the re-designed processes implementation team.

Lastly, he has been studying for his PhD in Animal Production at Addis Ababa University since October 2013.

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LIST OF ABBREVIATION AND ACRONYMS

AB	*Arsi-Bale* Sheep
ABC	Anterior Buttock Circumference
ADF	Acid Detergent Fiber
ADFD	Acid Detergent Fiber Digestibility
ADFI	Acid Detergent Fiber Intake
ADL	Acid Detergent Lignin
ADLI	Acid Detergent Lignin Intake
ADWG	Average Daily Weight Gain
AF	*Afar* Sheep
AGP-LMD	Agricultural Growth Program-Livestock Market Development
AMSA	American Meat Science Association
AR	Application Rate
BDL	Bag Drip Loss
BHO	Black Head *Ogaden*
BW	Buttock Width
BWB	Body Weight After Bleeding
CC	Carcass Compactness
CCDP	Cold Carcass Dressing Percentage onSBW Basis
CCW	Cold Carcass Weight
CL	Carcass Length
CP	Crude Protein
CPD	Crude protein digestibility
CPI	Crude Protein Intake
CS	Chilling Shrinkage
CSA	Central Statistics Agency
CW	Chest Width
DFD	Dark, Firm and Dry
DM	Dry Matter
DMD	Dry Matter Digestibility
DMI	Dry Matter Intake
DP	Dressing Percentage
DPEB	Cold Carcass Dressing Percentage on EBW Basis
DPEB	Cold Carcass Dressing Percentage on EBW Basis
EBW	Empty Body Weight
EC	Ethiopian Calendar;
EE	Ether Extract
EED	Ether Extract Digestibility
EEI	Ether Extract Intake
EI	Empty Intestine
EM	Effective Microorganisms
EP	Ensiling Period
ES	Empty Stomach
FAO	Food and Agriculture Organization of the United Nations
FBW	Final Body Weight
FE	Feed Efficiency
GB	Gall Bladder
GC	Gregorian Calendar
GF	Genital Fat

LIST OF ABBREVIATION AND … (Continued)

HCDP	Hot Carcass Dressing Percentage
HCW	Hot Carcass Weight
HF	Heart Fat
IBW	Initial Body Weight
IMF	Intra Muscular Fat
IVDMD	*In Vitro* Dry Matter Digestibility
IVDOMD	*In Vitro* Digestible Organic Matter in Dry Matter
IVOMD	*In Vitro* Organic Matter Digestibility
KF	Kidney Fat
LC	Leg Compactness
LL	Leg Length
ME	Metabolizable Energy
MF	Mesenteric Fat
MUFA	Monounsaturated Fatty Acid
NDF	Neutral Detergent Fiber
NDFD	Neutral Detergent Fiber Digestibility
NDFI	Neutral Detergent Fiber Intake
NSC	*Noug* Seed Cake
NT	Not Transported
Oeso	Oesophagus
OF	Omental Fat
OM	Organic Matter
OMD	Organic matter digestibility
OMI	Organic Matter Intake
PBC	Posterior Buttock Circumference
PSE	Pale, Soft and Exudative
PUFA	Polyunsaturated Fatty Acid
REA	Ribeye Area
SBW	Slaughter Body Weight
SEM	Standard Error of Mean
SFA	Saturated Fatty Acid
SR	Substitution Rate
SW	Shoulder Width
TC	Thorax Circumference
TENCF	Total Edible Non-Carcass Fat
TEO	Total Edible Offal
TEP	Total Edible Proportion
TF	Tail Fat
TL	Transportation Loss
TNEO	Total Inedible Offal
TS	*Tef* Straw
TSS	*Tef* Straw Silage
TWG	Total weight gain
UB	Urinary Bladder
WBB	Wheat Bran Bokashi
WBSF	Warner–Bratzler Shear Force

INFLUENCE OF TRANSPORTATION AND USE OF EFFECTIVE MICROORGANISMS TREATED FEEDS ON GROWTH, CARCASS YIELD AND MEAT QUALITY OF *ARSI-BALE* AND *AFAR* SHEEP

TIBEBU MANAYE (MSc, Animal Production)
PhD DISSERTATION
ADDIS ABABA UNIVERSITY (2019)

ABSTRACT

The present study was conducted with the objectives of assessing the level of deployment of sheep for carcass export and effect of transportation of sheep and goats on body weight, mortality and carcass condemnation; studying the effect of trekking or trucking on body weight, carcass and meat quality of Arsi-Bale and Afar lambs; assessing the effect of Effective Microorganisms (EM) application rate and duration of ensiling on tef straw silage quality; evaluating the effect of genotype and concentrate supplementation of tef straw silage on growth performance, carcass and meat quality of Afar and Arsi-Bale lambs. A retrospective abattoir survey was conducted in export abattoirs in Bishoftu and Modjo towns. The experimental design of the experiments was factorial arrangement incompletely randomized design. In the transportation experiment two lamb groups were transported 25 km from Bishofti to Modjoby either trekking or trucking and the third was kept at abattoir for five days before the other two. The silage was made from tef straw inoculated with EM and packed in plastic bags. It was then, subjected to physical and chemical analysis. During feeding and digestibility trials each lamb was fed tef straw silage alone, or supplemented with bokashi alone or mixed with noug seed cake. The survey result indicated that, 3,904,338 sheep and goats were slaughtered for export in 2012/13-2014/15*. Mortality and weight loss caused by transportation, respectively were 0.01% and 6.49% for sheep and 0.10% and 6.58% for goats. There were 0.09% full and 0.12%, partial carcass condemnations.The physical appraisal of tef straw silage showed that it was of good quality. The water socked tef straw ensiled for 21 days inoculated with EM at a rate of 500ml/kg was found to have better nutritional quality. Content and* *digestibility of crude protein and digestibility of organic matter appeared better for 21 days ensiling period. The transportation experiment revealed that Arsi-Bale lambs were better than Afar for most carcass traits. All ultimate pH, color and sensory eating quality of meat samples from both transportation and feeding trials were in the range of good quality meat. The intake of most nutrients of Afar was higher than the Arsi-Balewhile it was lower for control lambs except the fibers. The Arsi-Bale lambs performed better than Afar lambs in live weight, feed efficiency and all the carcass traits. Most of the carcass linear measurements were influenced only by diet for which the supplemented lambs were better. The L* value and fat content were higher for meat from Afar lambs while other physicochemical characteristics were similar for bothbreeds. Mode of Transportation did not affect most of carcass traits, but meat pH.However, there was significant breed effect with Arsi-Bale lambs showing higher growth performance and better predictability with better lean meat yield having acceptable quality that makes it more suitable to be used for export meat production.*

Key words

Carcass condemnation, Effective microorganisms, Meat quality, Sensory evaluation, *tef* straw silage, Transportation

1. INTRODUCTION

Ethiopia has over 25.5 million heads of sheep of which 75% are found in the highlands, where mixed crop-livestock production system dominates, while the remaining 25% of the population is in the lowlands (CSA, 2013). The country has high sheep genetic diversity that has been developed by natural selection (Galal, 1983). *Washera*, *Bonga*, *Horro*, *Arsi-Bale* and *Adilo* are among Ethiopian sheep breeds that are good mutton producers in good environmental conditions while Black Head *Ogaden* (BHO)are good mutton producers even if availability of feed and water is constrained (Gizaw, 2008). Meat production is the most important function of these breeds (Zelealem*et al.*, 2012).

Ethiopia's commercial red meat industry of small ruminants has shown remarkable progress (AGP-LMD,2013) with considerable growth potential for the future (Export.gov, 2018). Nonetheless, the overall meat export market share, among other export items of Ethiopia, remained as low as not more than 2%. Its global market share is also so lower, accounting for less than 1% of which most is chilled goat meat followed by sheep meat in 2011(Tekeba*et al.*,2018). Consequently, the Ethiopian government has planned transforming the livestock sector and there by enhance production and exports of meat (Export.gov, 2018).

Generally, animal production in Ethiopia has been on a very low production level due to chronic shortage of feed and under nutrition. The major feed resources in mixed farming areas are crop residues (including *tef* straw) which may not fulfill even the maintenance requirement of the animals (Adugna*et al.*, 2012; Malede and Takele, 2014). In pastoral areas, animals obtain their feed mainly from degraded range grazing and in some cases standing hay that provide nutrients below the requirement of the animals (Alemayehu *et al.*, 2017; Mekuanint and Girma, 2017).

In addition, the ever-increasing human population has caused conversion of range/pasture lands into croplands, leading to diminishing land available for grazing and fodder production. Besides, while the quality and quantity of forage available from natural pasture is declining due to excessive grazing pressure, populationof cattle has been increasing to meet the demand for power required to the increased crop production activities, (Adugna*et al.*, 2012;Malede and Takele, 2014). As all the livestock spices graze together, the increased population usually put sheep under high competition pressure for feed exerted by cattle. Being unable to compete sufficiently, sheep are forced to collect poor quality feed left over by cattle (Gebretsadik*et al.*, 2012). Hence, focusing on options other than increasing the size of grazing land, to address the feed availability and quality challenges that sheep are facing needs due attention.

Improving the nutritive value of the poor-quality feed resources is one option of enhancing feed quality and supply. Biological treatment of low-quality roughage is among the effective feed treatments technologies available (Mahesh and Mohini, 2013; Abdel-Aziz *et al*, 2015). In this regard, the use of Effective Microorganisms (EM) is widely advocated for improving nutritional qualities (Wondmeneh*et al.*, 2011; Samsudin*et al.*, 2013; Yonatan *et al.*, 2013).

Effective microorganisms are mixture of aerobic and anaerobic microorganisms, specifically, lactic acid bacteria, yeast, photosynthetic bacteria, fermenting fungi and actinomycetes. These microorganisms survive together synergistically and prevent growth of pathogens as well as rotting microorganisms (Higa and Wididana, 1991, Talaat*et al.*, 2015). The growth of pathogenic microorganisms is checked by the inhibiting effect of lactic acid as a result of reduced pH, while the yeast feed the other microbes by producing many food substances like amino acids and polysaccharides. The phototrophic bacteria also play important role in nitrogen and carbon cycles metabolic systems (Higa and Wididana, 1991, Talaat*et al.*, 2015). Therefore, the symbiosis existing among EM microbes can avoid the putrefactive and pathogenic effect of spoilage microorganisms and assure good quality silage production from inferior quality feed resources. Thus, fermentation of plant materials with EM improves fiber digestibility and nutrient content of feed (Kannahi and Dhivya, 2014).

This positive effect of EM application for feed quality improvement was reported by Lemma and Endalew (2017) who studied *Fogera* cows fed EM treated rice straw. The cows scored higher dry matter intake, higher weight gain, and higher milk yield.Getu*et al.* (2013) also noted that cows receiving EM in the form of *Bokashi* displayed unusually superior daily growth over those cows that have been dosed with EM through the sprayed natural pasture hay. However, there are no studies done on *tef* straw (TS) to evaluate the application rate of EM as well as ensiling period and sheep response in feeding and digestibility trials.

Another important factor that may reduce market acceptability of Ethiopian live animals and their meat is believed to be the mode and duration of transportation of live animals (Zelealem*et al.*, 2012). Among the problems, which could be the result of pre-slaughter transportationis a problem of highland sheep and goats meat darkening (Abebe *et al.*, 2010) which had restricted the meat export to only the lowland originated animals (Akililu*et al.*, 2005).

In this regard, there were merely few meat quality studies undertaken which were evaluated pH and color of meat, while other meat traits are also strongly demanded to classify the mutton/lamb according to international market quality specifications. The studies undertaken so far were done on limited sheep genotypes to investigate the causes and possible remedies for the dark cut meat (Girma*et al.*, 2010; Merera*et al.*, 2010; Merera*et al.*, 2013;Merera*et al.*, 2015). All of these studies focused only on length of rest and feeding after transportation as quality factors. Yet, the type of road (Lama *et al.*, 2011), transportation systems (Miranda-de la Lama *et al.*, 2012), mode of transportation (Ponnampalam*et al.*, 2017) among others, also affect meat quality. In Ethiopia, animals are transported from farm to the primary and secondary markets by trekking and to abattoirs and/or terminal markets by trucking (Getachew *et al.*, 2008; Zelealem*et al.*, 2012).

Sariözkan*et al.* (2009) studied the effects of road transport on yearling lambs and found significant weight losses in transported lambs with an increase in journey duration. A survey of livestock production system and marketing in the Tigray region of Ethiopia showed that trekking of animals to market reduces the quality of meat and market price of live animals (Zelealem*et al.*, 2012).

Hence, the present study was conducted with the following objectives.

- to assess the level of deployment of sheep for carcass export and effect of pre-slaughter transportation of sheep and goats on body weight, mortality and carcass condemnation in export abattoirs;
- to study the carcass characteristics and meat quality of *Arsi-Bale* and *Afar* lambs transported either by trekking or trucking;
- to assess the effect of application rate and ensiling period of *tef* straw with Effective Microorganisms on silage quality, nutrient composition and *in vitro* digestibility and;
- to assess the effect of genotype and concentrate supplementation of *tef* straw ensiled with Effective Microorganismsondigestibility ofnutrients, growth performances,carcass characteristics and meat quality of *Afar* and *Arsi-Balelambs* under stall feeding condition.

2. REVIEW OF THE LITERATURE

A review of literatures on the importance of Ethiopian sheep breeds and their meat production, feed availability and quality improvement, factors affecting carcass characteristics and meat quality and their analysis are presented in details here under.

2.1. The Ethiopian Sheep Breeds

Ethiopia has about 14 recognized sheep breeds (Gizaw*et al.*, 2007) that have been studied for identification, classification, and description since the 1970s with the classification of the sheep populations into broad categories of tail and fibre types. Characterization of performance identified small (*Menz, Wollo*, *Tikur* sheep), medium (*Sekota*and *Simien* sheep), large (Black Head *Ogaden* (BHO), *Adilo*, *Farta* and *Arsi-Bale* sheep) and very large (*Gumz, Afar, Washera, Horro*and *Bonga*) sheep breeds. The very large breeds are more prolific than the smaller, with litter sizes varying from 1.0 to 1.09 in the small breeds and 1.28 to 1.55 in the very large breeds (Gizaw*et al.*, 2013).

There is a substantial variation in the Ethiopian sheep population that arises from variations within and between breeds, and across the agro-ecologies, indicating the possibility of performance enhancement through genetic as well as management improvements (Gizaw, 2009). The adaptation and merits of the Ethiopian sheep breeds are summarized in Table 1.

Generally, Ethiopian indigenous sheep are characterized by slow growth, late maturity and low production performances with high mortality of lambs (Tibbo, 2006; Mengesha and Tsega, 2012). The mean carcass weight of such sheep is estimated to be around 10 kg (FAO, 2009), which is low as compared to the average of sub-Saharan African countries.

Table 1: Adaptation and merits of the Ethiopian sheep breeds

Breed	Adaptation	Merit
Menz	Cold stress; surviving and producing in marginal areas	Tasty meat; coarse wool
Farta	Feed shortage	Coarse wool
Sekota	Feed shortage	
Semien	Cold stress, high altitude and feed shortage;	Coarse wool
Tikur	Feed shortage	Coarse wool
Wollo	Feed shortage	Coarse wool
Adilo	Produce in good environment	Good mutton production
Arsi-Bale	Cold stress, produce in good environment	
Horro	Produce in good environment	Good mutton producers
Bonga	Produce in good environment	Good mutton producers
Gumz	Heat stress	Unique genetic make-up
Afar	Heat stress, feed and water shortage, long trekking	Good meat yield; fatty meat
Washera	Produce in good environment	Good meat yield
Black Head *Ogaden*	Heat stress, feed and water shortage, long trekking	Good meat yield; fatty meat

Source: Gizaw, 2008

This low productivity of indigenous flocks can be attributed to the low management standards of the traditional production systems, which can be improved by enhancing the management practices. Supporting this, Getachew *et al.* (2011) reported an average daily weight gain and carcass weight as around 126 g and 16 kg, respectively for feedlot growth and carcass performance of *Washera*, while Taye (2009) reported 76.40g average daily weight gain for the same breed when grazing is supplemented with concentrate.

In line with these studies, Tibebu *et al.* (2009) reported 103 g/day average daily weight gain of hair type southern Ethiopian local sheep when fed on green Napier grass supplemented with 300 g/kg sesbania foliage. Similarly, Gemiyu (2009) reported an average daily weight gain of 89.2g from local sheep reared by farmers in a mixed farming system in Alaba, Southern Ethiopia.

Among the Ethiopian indigenous sheep breeds, the *Afar*and*Arsi-Bale*sheep are identified as mutton potential (Gizaw*et al.*, 2013). The*Afar*sheep is a fat-tailed breed with mature weight ranging 30–35kg. The natural habitat of the breed is the Middle Awash Valley in eastern Ethiopia, extending as far as Dire Dawa in the east and the town of Bati in the north. Rainfall in the area is erratic and annual precipitation ranges from 300 to 700mm. The vegetation is mainly of sub-desert range types consisting of a sparse cover of low shrubs and bush. They are adapted to tolerate periods of drought, which made them suitable for pastoral production system. The *Afar* sheep have small ears and usually have a dewlap and thick layers of fat on the brisket. The fat tail has a wide base and reaches below the hocks. Hair is short and coarse, the predominant color being solid blond with other colors ranging from shaded white to light brown. The average observed wither height for adult rams is 66cm while it is 61cm for adult ewes. *Afar* sheep weigh about 2.5kg, 13kg and 25.8kg at birth, weaning, and one year of age, respectively. Ewe mature weight is about 31.6 kg while the rams attain average mature bodyweights of approximately 40kg with post-weaning growth rates of around 100g/day with supplementary feeding (Kassahun and Solomon, 2009).

Arsi-Bale sheep are fat-tailed and covered with coarse wavy wool. They are widely distributed in the highlands of eastern and south-central Ethiopia, in Arsi, Bale, Hararghe and East Shoa zones of Oromia Region and in many parts of the southern region. The climate in these areas varies from semi-arid to sub-humid. The production systems range from agro-pastoral to agricultural and urban. *Arsi-Bale* lambs weigh 2.7 kg and 14.2 kg at birth and at weaning, respectively (Kassahun and Solomon, 2009).

2.2. The Roles of Sheepand Goatsand Their Meat in Ethiopia

The role of sheep in this context includes their economic importance, market opportunity that the sheep have and the constraint faced from production up to marketing. Literatures reviewed for the roles of Ethiopian sheep breeds are presented under the following sub-titles in detail.

2.2.1. The economic role of sheep and goats in Ethiopia

Small ruminants are kept by smallholders as an integral part of the livestock sub-sector. Sheep and goats contribute significantly to the subsistence, economic and social livelihoods of a large human population in low-input, smallholder production systems in developing countries in general and Ethiopia in particular (Workneh, 2000; Tibbo, 2006). They are important to the socioeconomic wellbeing of people in developing countries in the tropics in terms of nutrition, income and intangible benefits such as savings and insurance against emergencies as they are regarded as a quick source of cash (Gemiyu, 2009). They also serve as an insurance against crop failure and death of large ruminants (Getahun, 2008) playing a considerable role in the livelihoods of rural farms serving as a living bank for many farmers, and closely linked to the social and cultural resource of life for poor farmers (Tibbo, 2006).

There is a strong complementary relationship between small ruminant keeping and cropping, since the staple foods for farmers in mixed farming systems of Ethiopia are either cereals like *tef*, barley, wheat, maize or horticultural crops like *enset*, sweet potato and potato (Gemiyu, 2009). The integration of these commodities is common as the income from crops can be used to buy small ruminants while the sale of sheep and goats can be used for financing cropping inputs like fertilizers and improved seeds. There is also a linkage through manure, since the manure of small ruminants is commonly used to fertilize home gardens and crop lands (Tesfay*et al.*, 2012).

The small ruminants' contribution to food production in the form of meat, milk and other livestock products takes a remarkable position in the livestock outputs. According to Gemiyu (2009), net cash income from small ruminants for households in Alaba during the year 2008 was estimated to be 24.2% of the net total agricultural cash income which is equivalent to that of cattle. Cattle are sold very rarely while the sale of small ruminants was frequent throughout the year to generate immediate cash income. Moreover, the cash obtained was used for purchasing critical inputs for crop production, making sheep and goats an important link in the crop-livestock system in Alaba.

The other valuable product of sheep is the skin, which is produced jointly with meat but generally accounts for less than 5% of the value of the animal. The leather footwear sector in Ethiopia, resulting from hide and skin processing, has great potential to enhance manufacturing and export production, and thereby to increase employment opportunities and reduce poverty (van der Loop, 2003). In particular, Ethiopian highland sheep skins (cabretta), retain a high reputation in international markets for clarity, thickness, flexibility, strength and compact texture which make them especially suitable for high quality gloves, sports equipment and garments (Bini, 2002; Arend, 2006).

In 1995 sheepskins (mainly in pickles) accounted for 66% of the total of US $ 61.3 million foreign earnings by the leather sector, while this percentage was 18% for goat skins and 16% for hides and other skins (Muchie, 2000). As stated in the annual national report of NBE (2014), the contribution of hides and skin for the Ethiopian export market is grown as they all exported after tanning in the form of leather and leather products. The total income generated from the leather sector was 103.8 million USD in 2010/11;

109.9 million USD in 2011/12 and 120.6 million USD in 2012/13; for which the small ruminant's role is so imperative.

2.2.2. Market opportunities and constraints of live sheep and their meat

It is observed that there are significant off-takes of cattle, sheep and goats for national consumption. For example, the off-take rate for cattle, sheep and goats for national consumption in 2005/06 was 3, 13 and 10%, respectively. Thus, national consumption absorbs a large share of the already overall low net commercial off-take rates or market supply from smallholder farmers and pastoralists leaving a small share of marketed supply for the live animal and meat export activities (AGP-LMD, 2013). Significant livestock transaction takes place among the livestock producers themselves for breeding and replacement.

In the short run, there might be some degree of market segmentation regarding the demand for live animals for domestic and export markets due to different quality requirements. However, in the long run, with growing domestic supermarkets and increased demand for high quality meat, as a result of increasing human population, urbanization and incomes, coupled with changing consumer preferences, the demand for high quality live animals for domestic consumption is expected to increase, which augments the competitive pressure on export abattoirs (Asfaw and Jabbar, 2008; AGP-LMD, 2013).

The market price of sheep in the local market depends mainly on body weight and condition, which is dependent on availability of feed and judged based on bare observation (Gebretsadik*et al.,* 2012; AGP-LMD, 2013). Factors such as availability of feed, festivals, occurrence of disease and natural calamities, household requirements for expenditure such as purchase of grains and house consumables, consumer's income and preference affect the price of sheep (Ehui*et al.*, 2000; Gebretsadik*et al.*, 2012).

Gebretsadik*et al.*, (2012) further reported that animals trek by foot from the starting point at farmers' compounds up to the terminal markets with little feed and water provision; although animals are allowed to rest in the evening and roam around for grazing and drink water. Only few intermediate traders and large merchants transport their animals by truck from the tertiary market to the terminal market. Yet, the vehicles used are not appropriate as they are not designed for animal transportation. This trekking and mixing of animals from different farms, villages and localities has consequences for the health of the animals and subsequently on the quality of meat.

Despite considerable constraints checking livestock development, there are quite favorable opportunities to increase sheep and goat productivity in Ethiopia. The country owns large and diverse livestock resources with genetically diverse potential that are not yet adequately exploited. Some of the breeds have special merits (Gizaw, 2009) that meet the requirements of certain markets and fetch premium prices. For instance, lowland breeds are in high demand in the Middle East; Menz sheep produce delectable meat; long-fat-tailed sheep breeds are highly prolific; and the highland sheep produce branded 'cabretta' leather (Bini, 2002; Arend, 2006).

Though not to the level it is supposed to be, the country has started to see some progress in the volumes as well as diversity of meat and live animal export. The meat export increased from 7,717metric ton in 2005 to 17,800 metric ton in 2013 (Aklilu and Catly, 2014). As part of overall economic development plan, and in line with a need to improve foreign exchange earnings, the government planned to increase meat exports (World Bank, 2006). Because of these promising conditions, many private investors are now engaged in meat as well as live animal export trade. In addition, export-oriented meat-processing facilities have started to emerge around the country and revenue from meat export trade, primarily sheep and goats carcasses, is on rise (Rich *et al.*, 2008).

Conversely to the considerable opportunities, inadequate feed and nutrition; diseases prevalence; poor breeding stock; lack of upto-standared livestock production policies with respect to credit, extension and marketing and the high incidence of informal cross border trade have been stated as the major constraints affecting livestock performance in Ethiopia (Gizaw*et al.,* 2013). Lack and low adoption rate of improved technologies, unavailability and/or inaccessibility of inputs, inappropriate delivery methods of extension messages are further problems constraining livestock production (Gizaw*et al.*, 2010).

A study held in the Tigray region (Zelealem*et al.*, 2012) disclosed that the market structure and infrastructure itself has a considerable negative effect on sheep marketing and quality of production. Problems such as seasonality of market demand, rough roads, long distance trekking before slaughter and lack of feeding, watering and resting structures through the course of trekking contribute to poor body condition and poor meat quality. In conclusion, these and other constraints burdened on livestock sector in Ethiopia pulled down its profitability and marketability in particular and its contribution for the national economy in general.

2.3. Improvement of Nutritional Quality of Crop Residue and the Use of Effective Microorganisms in Ruminant Feeding

Crop residues, principally the straws of cereals like tef, wheat and barley are becoming increasingly important as sources of roughage feeds for ruminants in Ethiopia (Adugna *et al.,* 2012). Good quality straw can be regarded as a good roughage source for feedlots next to native grass hay (Adugna *et al.,* 2012). However, most straws are bulky and of low nutrient density with low digestibility. Cereal straws are generally characterized by relatively low nutrient content, high fiber content, low digestibility and low voluntary intake by animals (Adugna, 2007). Traditional livestock production system mainly depends on these crop residues, which are usually inadequate to support reasonable livestock production because of their low nutritional quality (Tsige, 2000).

Thus, the national quality, specifically digestibility of straws should be enhanced if they are to be used as major feed resources. The digestibility of crop residues can be improved by physical treatment like chopping and socking in water; chemical treatment like ensiling with sodium hydroxide, potassium hydroxide, or urea (ammonia) (McDonald*et al.*, 2010) and biological treatment like the use of yeast, white and brown-rot fungi, soft-rot fungi (Mahesh and Mohini, 2013)and effective microorganisms (Syomiti, 2009).

For improving animal productivity and product quality, solutionof effective microorganisms can be administered orally via drinking water or spraying over roughage feed or mixing with concentrates as feed additives or used for making fermented feed (Balogun *etal*., 2016). Above all, its application in improving the quality of animal feed has received great attention in many regions of the world. Two consecutive studies conducted in Kenya indicated that EM treated dry maize stovers ensiled with spent brewers' grains has good silage stability and increased in CP content (Syomiti, 2009).

Results from DM *In Sacco* degradability conducted by using steers inoculated with EM through drinking water have shown improvement in nutritive values and utilization of high fibre diets except lignin (Syomiti*et al.*, 2010). In Malaysia, fungal-treated rice straw inoculated with EM has shown good quality silage and improvement in nutritive values. A digestibility study on this feed sample using an *In-Sacco* approach showed an increased degradation of the lignocellulosic contents, thus improving the rumen DM degradability, which would affect the performance of the animal (Samsudin*et al.*, 2013). By further degrading the lignocellulosic contents of rice straw, more nutrients are made available for ruminal microflora, which in turn will sustain the longevity of the microbes. More importantly, harmful microorganisms such as toxin-producing fungi that contaminate the straw could be suppressed by application of EM (Maqbool *et al.*, 1997).

Effective microorganisms inoculated coffee husk ensiled with chopped grass hay has successfully reduced anti-nutritional factors (lignin, caffeine and condensed tannin) and substantially improved the nutritive quality of coffee husk and thus, both coffee husk and wet pulp, when treated with EM, could be considered as possible feed ingredients for ruminant animals (Yonatan *et al.*, 2011; Yonatan *et al.*, 2013). However, Syomiti*et al*. (2010) did not report the effect of EM treatment on lignin.

Yeasts and bacterial species isolated from the EM have shown a positive effect on feed degradability in the effective microorganisms treated samples (Syomiti, 2009). This can explain the higher degradability of EM-treated roughage feed, which may have stimulated the activity of beneficial microbes, especially the cellulolytic organisms and their associated enzymes in ruminants (Maurya, 1993; Yoon and Stern, 1995).

In Ethiopia, result from dairy cows feed supplemented with EM *Bokashi* made from pasture hay, have shown an increased daily weight gain as compared to EM treated natural pasture hay(Getu*et al.*, 2013).According to these authors, silage produced from EM inoculated pasture has shown to contain a higher crude protein content, a lower sugar content and a higher ammonia value, which is an indication for more protein degradation.

Generally, the application of EM in low quality animal feed treatment had been proved to result in remarkable improvement in the utilization of the poor-quality feed, which is reflected, by higher feed conversion efficiencies and increased product yielding. Yet, no studies had been conducted on improvement of *tef* straw.

2.4. Overview of Meat Quality Parameters

Meat quality can be assessed from meat traders ‘perspective, which is its suitability for fabrication, packaging, storage and transportation. It can also be seen from consumers perspectives, which are its nutritional value, food safety and palatability among others. Literatures are reviewed formeat quality parameters in some details under the following sections.

2.4.1. The concept of meat quality

Meat is a major food source and a staple ingredient in many food products for which overall types of quality can be distinguished, i.e functional quality and conformance quality, which both have various aspects.

Functional quality refers to desirable attributes in a product. For example, we might want red meat to be tender and chicken to have good flavor. **Conformanc**e quality is producing a product that meets the consumer’s specification exactly. An example of this type of quality might be that we want pork chops to be trimmed so there is exactly 5mm of fat overlying the lean, or we want ‘portion sized’ chicken breasts to weigh exactly a certain amount. When most people talk about quality, they tend to mean functional quality, but quality management often focuses on conformance quality. However, both types are important because no one really wants chicken breasts that are exactly the right weight but have poor flavor or texture (Warriss, 2000; Kerry and Ledward, 2009).The major components of meat quality are in Table 2.

Table 2: The major components of meat quality

Yield and gross composition	• Quantity of saleable product • Ratio of fat to lean • Muscle size and shape
Appearance and technological characteristics	• Fat texture and color • Amount of marbling in lean (intramuscular fat) • Color and water holding capacity of lean • Chemical composition of lean
Palatability	• Texture and tenderness • Juiciness • Flavour
Wholesomeness	• Nutritional quality • Chemical safety • Microbiological safety
Ethical quality	• Acceptable husbandry of animals

Source:Warriss, 1996; as cited by Warriss (2000)

Different people mean different things when they talk of functional quality depending on their cultural background, personal experience and where they stand in the production chain. In other words, quality has a number of different components. While certain of these are of interest to everyone, others are only immediately important to some sectors. Meat yield, mainly concerns the farmer and wholesaler, technological characteristics mainly the processor and palatability – what the meat is like to eat – the final consumer (Warriss, 2000).

2.4.2. Meat quality parameters

A literature review regarding meat quality parameters is presented under the following sub-titles in detail.

2.4.2.1. *Appearance and technological characteristics (physical parameters)*

The appearance of lean meat and its technological characteristics are often related. This is because factors that influence the microstructure of the muscle post mortem affect both aspects of color and also water holding capacity (WHC). Color is a major determinant of appearance while WHC is determinant of technological value. Appearance is important because it is practically the only criterion, the consumer can use to judge the acceptability of most meat at purchase. The lean has a characteristic color appropriate for each species and muscle. But in general, it should be bright in color, and red or pink rather than brown, purple or grey. Moreover, this color should be stable to give the product a long shelf life (Warriss, 2000; Damez and Clerjon, 2012; Lorenzo, 2012).

Water holding capacity is the ability of meat to retain its constituent water when an extraneous force or treatment is applied to it. This property affects the retention of vitamins, minerals and salts, as well as the volume of water retained. Muscles that lose water easily are drier and lose more weight during refrigeration, storage, transport and marketing (Beriain*et al.*, 2000). Hence, there are three main reasons why WHC is important. First, the drip or exudate that results from poor WHC detracts from the appearance of the meat. This is especially so in modern retail packs where drip tends to collect, rather than draining away, and despite the frequent inclusion of absorbent pads in the bottom of trays to soak up the liquid. Second, loss of drip leads to weight loss in fresh meat, and in processed meats, poor WHC may reduce water retention and therefore yield of product. Third, WHC is thought to influence the perceived juiciness of fresh meat after cooking. Meat with low WHC loses a lot of fluid in cooking and may taste dry and lack succulence (Warriss, 2000; Jense*et al.*, 2004).

Meat color is related to the concentration of pigments, mainly myoglobin, the chemical state of the myoglobin on the surface of the meat, the structure and physical state of muscle proteins and the proportion of intramuscular fat. Values of pH above the isoelectric point of proteins of 5.5 results in an open structured muscle and a greater diffusion of light between the myofibrils of the muscle, which make the cut face of the meat darker (Beriain*et al.*, 2000). The fat tissues are a natural occurring part of the meat carcass and the color of the fat in meat cuts also contributes to influence the choice of the consumers. The yellow color is caused by carotenes derived from green plants. It is therefore commoner in older animals and those that are grass-fed. The pigments are fat-soluble and the propensity to lay them down in the fat is genetically determined (Warriss, 2000; Lorenzo, 2012).

2.4.2.2. *Eating quality (palatability) parameters*

As well as the appearance of raw meat, mainly determined by its color, the important sensory (or organoleptic) characteristics are texture, juiciness, flavor and odor of the cooked product. Meat texture is perceived as a combination of tactile sensations resulting from the interaction of the senses with physical and chemical properties, such as toughness, moisture and elasticity. Toughness can be defined as the ease with which meat can be cut and masticated, and is principally related to the muscle proteins. However, it is also affected by intramuscular fat, the structure of the connective tissue, the size of the muscle bundles, rigidity, and water retention capacity. In lamb meat, there is little variation in toughness if the management of cooling after slaughter is correct (Beriain*et al.*, 2000; Cockett*et al.*, 2005; Margawati*et al.*, 2010). The juiciness of meat is perceived in two ways, first the sensation of moisture in the first moments of mastication produced by the rapid release of juices, followed by the stimulating effect of fat on the secretion of saliva.

Flavor is one of the most important factors in determining consumer acceptability of meat. The basic flavor of meat is related to water soluble compounds in the muscle, such as sugars, amino acids and nucleotides, which are common to different species. The characteristic flavor of meat of a particular species is determined, however, by the proportions of different fatty acids in the fat, and, in particular, by the unsaturated fatty acids, which are more susceptible to oxidation to volatile compounds of low molecular weight, such as aldehydes, ketones, hydrocarbons and alcohols, which contribute to the aroma of meat. Phospholipids, which are rich in polyunsaturated fatty acids, also play a fundamental role in the flavor of meat (Rousset-Akrim*et al.*, 1997; Young *et al.*, 1997; Beriain*et al.*, 2000). Small amounts of intramuscular fat, affect the flavor and juiciness of cooked meat. The predisposition to oxidation of free fatty acids (linoleic, and arachidonic) from the different meat lipid fractions, especially phospholipids in the cell membranes of the muscles and the adipocytes (Christie, 1981) contribute to the appearance of volatile compounds, responsible also for aroma of the meat (Rhee, 1992).

2.4.2.3. *Wholesomeness*

The wholesomeness of meat has two components. First, meat should be positively beneficial to consumers' health in contributing minerals, vitamins and high value protein, and possibly essential fatty acids. However, it should be remembered that the energy value of meat varies somewhat with variation in its fat content. Second, meat should be safe to eat, both in terms of freedom from parasites that may infect humans and microbiological pathogens and hazardous chemicals (Heitzman, 1996;Warriss, 2000).

The potentially dangerous elements that may contaminate meat may be endogenous (such as bone shards) or exogenous, being unintentionally introduced during handling (such as shards of glass, metal, plastics or wood) (McFarlane *et al.*, 2003). Another group of contaminants are the heterocyclic amines (HCAs), from the heating of meat and meat products. Fraudulously added products, which the industry terms “adulterants” (such as liver, tripe, heart, or kidney), are also among materials that may negatively affect wholesomeness of meat (Damez and Clerjon, 2012)

2.5. Some Factors Affecting the Growth Performance, Carcass Characteristics and Meat Quality of Sheep

As to the factors that would affect the growth performance, meat and carcass quality, the animal breed, animal age, nutrition and feeding practices are identified as critical factors worth looking into.

2.5.1. Breed (genotype) and sex of the sheep

Momoh *et al.* (2013) reported that breed and sex significantly affected body weights at all ages. This is also evidenced from early findings (Figueiredo*et al.*, 1982) that reported large breed and gender variation in weight at birth, 86^{th} day, 112^{th} day and 6 months after birth of Brazilian Somali, Morada Nova and Santa Inêssheep breeds in Brazilian tropics. Shaker *et al.* (2010) indicated that genotype of lambs and litter size significantly affected average daily gain, live weight at birth, 15, 30, 45 and 60 days of age. The same study further investigated the effect of sex on live weight of lambs at birth and at 60 days and found differences between males and females. In an experiment that compared bodyweight from birth to yearling age, pre-weaning and post-weaning growth rate of purebred Menz, Corriedale × Menz F_1 cross and Awassi × Menz F_1 cross breed sheep, both crossbreds exceeded the purebred Menz lambs in all weights recorded from birth to yearling age (Demeke*et al.*, 2004).

When pH and color are considered, various scholars reported different results. Beriain*et al.* (2000) reported that the male animals showed slightly higher pH values than females.

In contrary, Dransfield *et al.* (1990) and Horcada*et al.* (1998) reported no differences in ultimate pH between intact males, castrated male and female lambs. Further, Dransfield *et al.* (1990) found no significant differences in color parameters between intact males, castrate males and females. Similarly, Horcada*et al.* (1998), found no differences in color parameters and water holding capacity between Rasa Aragonesa and Lacha males and females, fed in the same way and slaughtered at the same age.

Breed is a clear source of variation in carcass morphology related to fat quantity or meat quality, although its influence varies a lot and depends on which factor is being studied or compared (Guerrero *et al.*, 2013). According to Sañudo*et al.* (1997), breed effect was found to be significant for various carcass characteristics. Tsegay*et al.* (2012) indicated that there were significant differences among genotypes.

Significant breed effects were also reported by Sañudo*et al.* (1997) for some instrumental measurements of meat quality and some sensorial attributes. Martínez-Cerezo*et al.* (2005a and b) carried out a sensory analysis on three different Spanish lamb breeds, with various slaughter weights and age. Results showed that sensory attributes were different for different breeds, although other factors studied had a higher significance.

There are research findings that indicate the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight (Guerrero *et al.*, 2013). However, other scholars argue that there are clear variations which are probably explained by differences in precocity or in muscularity levels of the experimental breed of animals (Ramírez-Retamal and Morales, 2014).

In their review aimed on consolidating animal factors affecting the meat quality of Australian lambs, Jacob and Pethick (2014) concluded that animal factors have a significant and large effect on meat quality that calls up on the need to consider animal breeding objectives as a vital component of overall improvement strategy.

2.5.2. Husbandry practice and nutrition

Feeding systems for lambs can be based on grazing or concentrates (Ponnampalam*et al.*, 2010). There are also mixed systems that combine the two (Jacques *et al.*, 2011) and systems based on mother's milk or milk substitutes (Pérez *et al.*, 2002). The feeding system can affect the composition of the carcass (Lewis *et al.*, 2002) and the degree of fattening.

Grazing animals generally deposit less fat than animals fed on concentrate with generally less carcass weight when slaughtered at the same age (Priolo*et al.*, 2002). Hence, animals fed mainly on concentrates require less time to be prepared for slaughtering (Mustafa *et al.*, 2008; Ramírez-Retamal and Morales, 2014).

Animal growth and animal nutrition are inherently linked, in the sense that one can influence the other. The growth pattern of an animal determines its nutrient requirements. Conversely, by altering its nutrition, an animal's growth pattern can be modified. Another aspect of this interaction is that the growth pattern of an animal determines the composition of the product of growth (i.e. meat), and so affects the consumer of meat (McDonald, 2010).

According to Mustafa *et al.* (2008) who compared Suffolk×Mule lambs with Scottish Blackface fed concentrate or silage, diet type and the interaction between breed and diet affected feed conversion ratio. They also found that the effect of breed and diet on daily live weight gain was significant with a significant effect of interaction between breed and diet. Intheir study that analyzed the performance of two Ethiopian sheep breeds and their crosses with Dorper sheep breed when fed on native grass hay supplemented with concentrate, Tsegay*et al.* (2012) reported that leaner carcasses were harvested from lambs fed on low level of concentrate supplement.

It is an established fact that a low plane of feeding results in chronic nutritional stress, characterized by low reserves of muscle glycogen and increased final pH values in the meat (Bray *et al.*, 1989). The plane of feeding and the type of feed are closely related to the effect of the period of pre-slaughter fasting and stress before slaughter on final pH values of the meat (Beriain*et al.*, 2000).

In an experiment conducted to evaluate carcass traits and meat quality by feeding lambs on rations containing different level of Leucaena hay, Abd El-aal (2008) found significant differences on carcass components like hindquarter, shoulder, sets weight; and meat quality traits like water holding capacity and pH. Furthermore, the lambs on different feed treatment were different on tenderness, juiciness, flavor and over all acceptability of their meat.

2.5.3. Pre-, peri- and post-slaughter handling

The pre-slaughter phase includes the conditions and practices that apply during the period when the animal is moved or mustered on-farm to entry into the knocking box or restrainer at the abattoir. During this period, animals can be exposed to a range of challenging stimuli including handling and increased human contact; transport; unfamiliar environments; food and water deprivation; changes in social structure and changes in climatic conditions. These challenges disturb the animal's homeostasis and an adaptive response is activated in an attempt to restore balance (Hemsworth and Barnett, 2001; Moberg, 2001).

Because of these pre-slaughter challenges, an animal may experience fear, dehydration and hunger, increased physical activity, fatigue and physical injury. Moreover, the inability to adequately resolve some of these states (e.g. dehydration or fatigue) may invoke further psychological distress (Ferguson and Warner, 2008).

Stress factors through their effect on the physiological and physical activity of animals, causes depletion of glycogen reserve in the muscle rendering meat to have a higher ultimate pH, resulting in a dark-cutting meat (Gregory, 2007). Table 3 indicates the effect of acute pre-slaughter stress on plasma lactate and meat quality measurement.

Table 3: Effect of acute pre-slaughter stress on plasma lactate and meat quality measurement

Trait	Count electric prodder (not stressed)	Electric prodder (stressed)	Significance
Plasma lactate at slaughter (mmol/l)	4.29	7.12	P<0.005
pH 1h	6.33	6.29	ns
pH_u(ultimate pH)	5.46	5.38	ns
Shear force (2 day)	91.1	89.2	ns
Shear force (21 day)	47.0	51.0	ns

Source: Warner *et al.*, 2007

The main factor determining the quality of meat is its pH, which is related to biochemical processes during the transformation of muscle to meat. Consequently, changes in the pH during the post-mortem period influence the eating quality of the meat. Stress before slaughter in lambs can produce a high level of pH, which affects meat color more than other pre-slaughter factors. The normal release of juices during mastication is also reduced and the meat gets very dry, due to the strong binding of water to proteins, (Berian*et al.*, 2000). Devine *et al.* (1993) observed a significant increase in final muscle pH in lambs, which was directly related to the level of stress to which they were exposed.
After slaughter, there is a series of physico-chemical and biochemical changes in the skeletal muscles, which include the establishment of rigor mortis and a phase of aging. These changes, to a great extent, determine the organoleptic quality (which is assessed by sensory characteristics related to color, texture, smell, flavor and juiciness) of lamb meat

and its suitability for packaging (Berian*et al.*, 2000; Greaser and Guo, 2012). Aging results in a progressive softening of the muscle, a slight increase in water retention capacity and the development of a characteristic smell.

Table 4 present sensory scores of some meat quality traits as influenced by aging.Consumer acceptability and the subjective quality of lamb meat is also affected by the method of butchering, preparation for sale, marketing and cooking methods (Berian*et al.*, 2000; Damez and Clerjon, 2012).

Table 4: Range of sensory scores (on seven points hedonic scale) of some quality characteristics of meat aged for two and 21 days as reported in literature (Muchenje*et al.*, 2009)

Meat sensory characteristics	Range of values	Sources
Aroma at 2 days	5.21-5.70	Monsón*et al.* (2005), Muchenje*et al.* (2008)
Aroma at 21 days	5.02-5.70	Monsón*et al.* (2005), Muchenje*et al.* (2008)
Juiciness at 2 days	3.33-6.6	Byrne *et al.* (2000), Muchenje*et al.* (2008)
Juiciness at 21 days	4.38-5.60	Monsón*et al.* (2005), Muchenje*et al.* (2008)
Flavor at 2 days	3.1-5.89	Byrne *et al.* (2000), Monsón*et al.* (2005), Muchenje*et al.* (2008)
Flavor at 21 days	5.39-5.93	Monsón*et al.* (2005), Muchenje*et al.* (2008)
Tenderness at 2 days	2.1-6.4	Byrne *et al.* (2000), Maher*et al.* (2005), Monsón*et al.* (2005), Muchenje*et al.* (2008)
Tenderness at 21 days	5.50-6.47	Monsón*et al.* (2005), Muchenje*et al.* (2008)
Overall acceptance at 2 days	1.8-5.65	Byrne *et al.* (2000), Monsón*et al.* (2005)
Overall acceptance at 21 days	4.26-4.94	Monsón*et al.* (2005)

Aging lamb meat for 2-5 days increases the acceptability of the flavor, tenderness and general palatability. The rapid cooling of muscle can cause the phenomenon called **"cold shortening**", which results in a considerable increase in the toughness of the meat. Other processes, such as packing in a modified atmosphere, the use of lactic acid bacteria and/or bacteriocins and irradiation, in addition to refrigeration; can improve the shelf life of the meat (Berian*et al.*, 2000; Damez and Clerjon, 2012).

2.6. Methods of Meat Quality Analysis

Meat quality can be assessed subjectively using panels of sensory assessors and objectively using instruments developed for a particular purpose. Literature review on these methods of meat quality analysis is presented under the following sub-titles in detail.

2.6.1. Instrumental (objective) methods

The meat industry needs reliable meat quality information throughout the production process in order to guarantee high-quality meat products for consumers. Damez and Clerjon (2008, 2012) summarized almost all available biophysical methods of meat analysis related to meat structure. Reliable meat quality information (tenderness, flavor, juiciness, color) can be provided by a number of different meat structure assessment either by means of mechanical (i.e., Warner–Bratzler shear force), optical (color measurements, fluorescence), electrical probing, or using ultrasonic measurements, electromagnetic waves and so on.

Quality traits related to mechanical properties are often better assessed by methods that take into account the natural **anisotropy** of meat due to its relatively linear myofibrillar structure. Biophysical methods of assessment can either measure meat component properties directly, or calculate them indirectly by using obvious correlations between one or several biophysical measurements and meat component properties (Clerjon, 2008& 2012).

2.6.2. Use of Panelists (subjective methods)

Instrumental assessments of the components of eating quality of meat can only be approximations to the true measure of particular attributes. This is because no machine can measure the range of interacting characteristics that contribute to eating quality and palatability. We do not perceive tenderness in isolation; we perceive it in relation to juiciness and 'mouth feel' and perhaps even apparently unrelated attributes such as flavor and odor. For some assessments, therefore, there is no real alternative to the use of a test panel that evaluates the sensory attribute of meat (Warriss, 2000).

Sensory analysis is a method for analyzing and interpreting reactions to characteristics of foods and materials perceived by the senses of sight, smell, taste, touch and sound. The sensations experienced by consumers are not an intrinsic characteristic of the food, but result from an interaction between the food and the person. Analysis of the chemical and physical properties of a food provides information on the nature of the stimulus perceived by the consumer, but not on the sensation the consumer experiences (Beriain*et al.*, 2000). Untrained consumer panelists express subjective reactions, indicating whether they like or dislike a food, or prefer one to another. Trained panelists discriminate between two or more samples. They may also further describe and define the sensory properties of the food and evaluate it as objectively as possible. Although the descriptive test gives more information on the food than the other two, it is more difficult to carry out. The training of the panelists is more intense and, monitoring and interpretation of the results is more laborious (Smulders,*etal*., 1986).

2.6.3. Instrumental versus panelists methods

Although one would obviously expect a relationship between the results obtained from instrumental texture measurements and sensory assessment scores from teste panels, the closeness of the correlation varies and may indeed be quite small. For example, a correlation coefficient of about 0.4 (Warriss, 2000). There are several potential reasons for the low correlation. The first is that considerably less precision is attached to the results from test panels because of the nature of the measurement and the fact that different individuals have different perceptions of the tender-to-tough scale. Their scoring may also vary from day to day. Secondly there is the confounding effect of juiciness on texture. Thirdly, the relationship may vary depending on cooking method, and particularly cooking temperature. At different temperatures various components making up overall meat texture, such as the myofibrillar and connective tissue elements, will differ in the extent to which they have been broken down or changed (Warriss, 2000; Young *et al.*, 2012).

What therefore should be the strategy for any assessment of meat quality, and particularly eating quality? An ideal is obviously to measure quality in all possible ways to get a complete picture. However, this may be too expensive both in time and sample requirements. Choosing options will then depend on the actual questions to be answered by the study (Warriss, 2000; Young *et al.*, 2012).Instrumental texture and chemical assessment are objective, reasonably precise ways of detecting actual or potential effects on meat quality. Trained test panels enable us to put instrumental results into perspective. They will tell us whether statistically significant differences in instrumentally determined texture are detectable by the human tester in practice. In other words, they give us a feel for the size of shear force difference which is important. Hence, the different instrumental and sensory methods for measuring meat quality are useful and complementary for understanding the criteria of quality used by consumers, and each method has advantages and disadvantages. However, it must be stressed, that the correlations between sensory and instrumental methods are very variable, because of the large number of factors that influence quality (Berian*et al.*, 2000; Warriss, 2000)

3. MATERIALS AND METHODS

The dissertation research involveda survey assessing the level of deployment of sheep for carcass export and the effect of pre-slaughter transportation on body weight, mortality and carcass condemnation of export sheep and goats. Carcass yield and quality analysis of meat produced from *Arsi-Bale* and *Afar* lambs under traditional management system before and after transportation was the other study undertalent*ed* straw silage making experiment was run to determine application rate of EM solution and ensiling period used in thesubsequentfeeding and digestibility trials. Feeding and digestibilityrailswere conducted using the results obtained from the silage making experiments.

The methods of executing the survey and the experiments are presented in details under the following sub-titles separately.

3.1. Description of the Study Area

Six export abettors in and around Modjo and Bishoftu towns were used for the survey. The*tef* straw silage making, feeding and digestibility trials were done at Addis Ababa University, College of Veterinary Medicine and Agriculture at Bishoftu (Debre Zeit) Campus, Ethiopia. Bishoftu is located 45 km South East of Addis Ababa, at an altitude of 1900 meter above sea level at coordinates of 8°45′N and 38°59′E. The 2018 meteorological data showed that the area has an average temperature ranging from 9 to 28°C and average annual rainfall of 851mm (Data source: Meteorology station at Ethiopian Institute of Agricultural Research, Debre ZeitResearch Center).

3.2. Impact of Transportation on Body Weight, Mortality and Carcass Condemnations in Export Abattoirs

A retrospective abattoir survey was conducted for duration of three years (2012/13-2014/15) in six export abattoirs found in and around Bishoftu and Modjo towns. Data ontotal slaughter; mortality rate, weight loss and carcass condemnations due to transportation were taken from the abattoirs daily records. However, it was not possible to get information on the exact age and sex of sheep and goats slaughtered in each abattoir.

3.3. Mode of TransportationExperiment

Mode of transportation in this context refers to the means of moving live animals from place to place. In the present study, the mode of transportation used were on hoof walking of the animals (Trekking) and moving the animals by using vehicle (Trucking). Accordingly, trekking or trucking mode of animal transportations were taken as treatment and the sheep breeds as the second factor.

For the transportation trial, yearlingintact male*Afar (Af)* and *Arsi-Bale (AB)* sheep, twenty-five from each breed, were purchased from the respective local markets. Dentition for age determination and physical judgment for health evaluation were the main criteria used for selection during purchase of the sheep. The purchased sheep were then transported to the study site and quarantined for fifteen days. During this time, they were treated against internal parasites andecto-parasites, and vaccinated against anthrax and ovine pasteurellosis.

Thereafter, they were allowed to graze on natural pasture in the compound for a fifteen-day adaptation period. Twenty-one lambs selected for the study were then divided into seven weight groups based on standard deviation of their weight. Then, one lamb from each weight group wasassigned at random to either trekking or trucking or non-transported groups. Two lamb groups were transported 25 km from Bishoftu to Modjoeither by trekking or trucking in such a way that both groups arrive at the abattoir at the same time. The third group was transported to the abattoir five days ahead of the other two groups.Hence the experimental design used was factorial arrangement incompletely randomized design with seven replications per treatment and two 2 x 3 factors, namely,two breeds and tree modes of transportation.

3.4. *Tef* Straw Silage Making, Feeding and Digestion Trials

The EM stock solution was purchased from Woljjejji private limited company and used after activation and subsequent extension.

3.4.1. Activation and extension of effective microorganism solution

Activated EM solution, as per the manual of the company, was prepared by mixing (thoroughly stirred until uniform solution is obtained) EM stock solution, molasses, mango juice and chlorine free water in the ratio of 1:1:1:17 and then storing in an airtight container for 21 days. The resulting solution is now activated EM solution which can be used for one month.

The EM solution was used for making *tef* straw silage (TSS) and Wheat Bran *Bokashi* (WBB) after it was diluted by mixing (thorough stirring until uniform solution is obtained) activated EM solution, molasses and chlorine free water in the ratio of 1:1:18 and then storing it in an airtight container for one day. Molasses was added into the EM solution in order to initiate the microbial metabolism and proliferation (Fekadu, 2007).

3.4.2. Preparation of tef straw silage

The *tef* straw (TS) was purchased from local vicinity around Bishoftu town. The preparation of *Tef* Straw Silage (TSS) was started 21 days before the commencement of the feed adaptation period of the feeding trial and performed daily so that the feeding of the animals with TS fermented for 21 days was maintained throughout the experimental periods of both feeding and digestion trials. A one-day ration of TSSwas prepared by uniform spraying of 20 litter of water over 40kg of TS mass in an earth silo lined with thick plastic sheath. Then the wetted TS was fully covered with the plastic sheath and left overnight being pressed by heavy weight distributed uniformly over its top so that the water is fully and uniformly absorbed. The next morning, the diluted activated EM solution was uniformly sprinkled over the socked TS at a rate of 500ml EM into one kilogram TS on dry (as feed) basis with thorough mixing. Then, the EM treated TS was packed tightly in an air tight plastic bag and stored under shade for 21days before it was fed to the experimental lambs.

3.4.3. Preparation of wheat bran bokashi

Wheat bran *bokashi* is EM fortified wheat bran, which was prepared by wetting 50 kg wheat bran with 20 litter diluted EM solution and allowed to ferment under shade for 21 days in airtight plastic bag. The *bokashi* was then dried on earth floor covered by a plastic sheath under shade and then stored in a large plastic barrel until offered to the experimental lambs.

3.4.4. Tef Straw Silage Making Experiment

Method of ensiling *tef* straw and data collection on the assessments on physical and chemical characteristics of the resulting silage are presented in detail under the following sub-titles.

3.4.4.1.Experimental design and treatments

The experimental design used was factorial arrangement incompletely randomized design with three replications per treatment and two 3 x 3 factors (Table 5), namely, three EM application rates (250, 500 and 750ml EM/1kg dry TS (AR_{250}, AR_{500} and AR_{750}, respectively)) and three durations of ensiling period (14, 21and 28days (EP_{14}, EP_{21} and EP_{28}, respectively)).

At the end ofan ensiling period, the bags meant for the period were withdrawn and samples of the *Tef* straw silage were taken from each bag and stored frozen (-18^{o}C) until prepared for chemical analysis while the sensory analysis and pH measurement were performed just during withdrawal of the bags.

Table 5: Experimental treatments for*tef* straw silage making

Pre-treatment action[a]	EM application rate (AR[b], ml EM/kg dry TS)	Ensiling period (EP[b], days)		
		EP_{14}	EP_{21}	EP_{28}
Overnight water socked	250	14	21	28
Overnight water socked	500	14	21	28
Overnight water socked	750	14	21	28

[a]*tef* straw was socked with cold water at a rate of one litter water to two kilograms of dry (as feed basis)*tef* straw

[b]AR= application rate; EM=effective micro-organisms; EP= Ensiling period

3.4.4.2.pH measurementand sensory evaluation of tef straw silage

The pH measurement was done using portable digital pH meter (HI99163, HANNA instruments) while the sensory (color, odor, texture and fungal prevalence)evaluation was performed subjectively by a test panel of eight people which were given a sort of training for silage sensory appraisal.

A sample from each ensiling bag was collected by untying and making tiny opening through which the sample was taken from the top, middle and bottom using forceps. The pH of samples was measured according to Playne and McDonald (1996). Consequently, 20g of samples were put in plastic containers having firm cap into which 100ml of distilled water was poured. Then, the container was firmly fitted with the cap and stored for 24hrs. Next day, each container was shacked thoroughly and extracts were filtered and collected in three equal plastic cups from which the pH was measured.

The odor, color, texture and fungal prevalence of samples were assessed just after opening the silage bags.During the sensory evaluation, the panelists (assessors) were offered color chart to which they compared the color of the samples and assigned a color name. The assessors also named the odor of the samples by relating it to the usual odor of alcohol, yogurt, fresh cheese, hot bread, vinegar, burnt tobacco, fishy or deviating from these odors(Kaiser and Piltz, 2004). For the prevalence of fungus, they simply see for the presence of mold. The texture of the silage was assessed with touch feeling, rubbing samples between fingers. The assessors had a look at the ensiling bags by walking around in random order with no opportunity to see each other's judgment(Kaiser and Piltz, 2004). They were provided with record sheet for scoring their assessment and the highest frequently scored judgment of the assessors was taken as the value of the assessment for each sensory parameter.

3.4.4.3.Silage sample preparation and chemical analysis

To prepare the silage samples for chemical analysis, they were thawed to room temperature overnight after which they were oven dried at 60^{o}C for 48 hours upon which partial dry matter was determined. The oven dried samples were then ground through one milli meter sieve and stored in airtight polyethylene containers until analyzed. Finally, the samples were subjected to proximate (AOAC, 1990), detergent fibers (van Soest*et* *al*.,1991 and van Soest and Robertson, 1985) and *in vitro* digestibility (Tilley and Terry, 1963) analysis.

3.4.5. Feeding Trial

The feeding trial was conducted for 90 days and examined the feed intake, growth performance, feed conversion efficiency, and carcass and meat qualities. The detail is presented down under.

3.4.5.1.Experimental design and management ofanimals

Yearlingintact male*Afar (Af)* and *Arsi-Bale (AB)* sheep, twenty-five from each breed, were purchased from their respective local markets. Dentition for age determination and physical judgment for health evaluation were the main criteria used for selection during purchase of the sheep. The sheep were then transported to College of Veterinary Medicine and Agriculture at Bishoftu and acclimatized for fifteen days for conditioning as the *Af* lambs were under heavy drought stress before they join the experiment. During this time, they were treated against internal parasites andecto-parasites and vaccinated against anthrax and ovine pasturolosis. Twenty-one lambs selected for the study were then divided into seven weight groups based on standard deviation of their weight. Then, one lamb from each weight group was assigned at random to either of the tree experimental diets.Hence the experimental design used was factorial arrangement incompletely randomized design with seven replications per treatment and two 2 x 3 factors, namely,two breeds and tree experimental diets.

Thereafter, they were provided with the treatment diets for fifteen days adaptation period. During the experiment, the lambs were housed in individual pens equipped with feeding and watering troughs. The pens and troughs were cleaned every day before offering feed. All animals had free access to water and Rursal RQ mineral blocks (Tecnozoo, https://tecnozoo.it/en/product, Italy).

3.4.5.2.Treatment diets and feeding

The treatment diets as shown in Table 6 were TSS alone offered *ad libitum* (D_1, control); TSS offered *ad libitum* and supplemented with wheat bran *Bokashi* (WBB) only (D_2); and TSS offered *ad libitum* and supplemented with a concentrate mix made from WBB and *Noug*Seed Cake (NSC, D_3).

Table 6: Composition of the experimental diet

Diet representation	Composition
D_1(control)	*Ad libitum* EM treated *tef* straw only
D_2	*Ad libitum* EM treated *tef* straw + wheat bran *Bokashi*
D_3	*Ad libitum*EM treated *tef* straw + wheat bran *Bokashi* + *noug* seed cake

The formulation and offer of the concentrate was done to fulfill the minimum Crude Protein (CP) requirement of the lambs on D_2 and D_3 based on NRC (1985) using the chemical composition of the feed ingredients indicated in Table 7.

At the beginning of the experiment D_3 was prepared by mixing 67% wheat bran *Bokashi*with 33% *noug* seed cake; and the lambs on D_2 were offered 500g of wheat bran *Bokashi* while those on D_3 were given 464g of the mix until changed.In order to maintain fulfilling the requirement of the lambs, the feed formulation and offer amount were adjusted fortnightly following their weight change. The concentrates were offered in a separate trough being divided into two equal portions and provided at 08:00 and 18:00 hours before the offer of the TSS basal diet.

Table 7: Dry matter, nutrient and metabolizable energy content and *in vitro* organic matter digestibility of *tef* straw silage and the supplements

Parameter[a]	Experimental Feed[b]			
	TSS	WBB	NSC	Concentrate mix
DM (%)	28.26	84.90	90.77	87.48
Ash (g kg^{-1}DM)	87.56	68.31	195.34	124.21
OM (g kg^{-1}DM)	912.44	931.69	804.66	875.79
CP (g kg^{-1}DM)	58.10	173.10	322.10	238.66
EE (g kg^{-1}DM)	9.62	31.58	42.33	36.31
NDF (g kg^{-1}DM)	795.36	413.35	418.47	415.60
ADF (g kg^{-1}DM)	438.77	243.88	337.48	243.88
ADL (g kg^{-1}DM)	140.14	111.76	145.03	126.40
IVDOMD (g kg^{-1}DM)	353.95	650.62	355.89	468.00
IVOMD (%)	38.79	69.83	44.23	-
ME (MJ kg^{-1} DM)	5.66	9.23	5.27	7.49

[a]ADF=Acid detergent fiber; ADL=Acid detergent lignin; CP=Crude protein; DM=Dry matter; EE=Ether extract; IVOMD=In-vitro OM digestibility; IVDOMD=*in vitro* digestible organic matter in dry matter; OM=Organic matter; NDF=Neutral detergent fiber; ME=Metabolizable energy.

[b]TSS=*Tef* Straw silage; NSC=*Noug* seed cake; TS=*tef* straw; WBB=Wheat bran *bokashi*;

3.4.5.3.Growth and feed efficiency measurements

Daily record of feed intake was maintained throughout the experiment. The treatment animals were weighed on the first day of the feeding trial and subsequently every fourteen days intervals before offering the morning feed after withholding feed and water overnight, until completion of the trial. Regression was run for each individual animal weight collected and the slope was used as weight gain measurements. Feed efficiency of the animals were computed from the same data as a proportion of Average Daily Gain (ADG) to daily Dry Matter (DM) intake.

3.4.6. Digestion Trial

After completion of the 90 days feeding trial, four animals per treatment with similar live weight were selected and fitted with feces collection harness for *in vivo* digestibility experiment done in factorial arrangement incompletely randomized design with four replications per treatment and two 2 x 3 factors, namely,two breeds and tree experimental diets. The lambs were assigned to the same treatment diet they were offered in the feeding trial.

After allowing harness adjustment period of three days, feces was collected for seven consecutive days. The fecal output of each day was weighed and 25% was frozen (-18 ^{o}C) and the seven days collection were pooled for each lamb. The same was done for the feed offer and refusal samples. Composite samples of feed, refusal and feces were thawed to room temperature, oven dried at 60°C for 48 hours, ground through one milli meter sieve and stored in airtight polyethylene containers until analyzed. Nutrient digestibility (%) was calculated as difference between nutrient intake and nutrients in feces divided by nutrient intake and multiplied by 100.

3.4.7. Chemical Analysis of Feed Offer, Refusals and Feces

Dry matter and nutrient composition except detergent fibers were determined in the nutrition laboratory of national veterinary institute. The IVOMD was determined in Holeta agricultural research center while the detergent fibers were analyzed in Haramaya University animal nutrition laboratories. DM was determined by drying samples overnight at 105^{o}C in a forced draft oven. Ash was determined by combusting sample at 550^{o}C for 6 hours and organic matter (OM) was determined by difference as 100-ash%. Cruide protein was computed from the respective N contents as determined by the Kjeldahl method employing the equation CP = N x 6.25 (AOAC, 1990). Neutral detergent fiber (NDF) was analyzed using the procedures of van Soest*et al.* (1991)

whereas acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to van Soest and Robertson (1985). Ether extract was determined by extracting the ether soluble components through continuous evaporation and condensation. The extracted material was then dried and weighed.

Metabolizable energy (ME) was estimated according to McDonald *et al.* (2010) from the *In-Vitro*digestible organic matter in DM (IVDOMD, g kg^{-1} DM) which is the product of the OM content (g kg^{-1} DM) and IVOMD coefficient of the feed as: [ME (MJ kg^{-1} DM) = $0.016 \times$ IVDOMD].

3.4.8. Slaughter of Animals and Carcass Measurements

Followingcompletion of the experiments (transportation, feeding, and digestibility trials), all the lambs were slaughteredafter withdrawing from feed overnight with free access to water.

In transportation experiment, the lambs were transported to Luna Export Slaughter House PLC where they were slaughtered on the same day immediately after arrival to the abattoir while the lambs used for feeding and digestibility trials were slaughtered in the slaughterhouse found in the College of Veterinary Medicine and Agriculture. During the slaughter, one lamb from each of the treatment groups, which are in the same initial weight block were taken to insure equal chance across treatment and replications.

All the lambs were slaughtered after measuring body weight (Slaughter Body weight, SBW). The blood weight was determined by deducing weight after bleeding from SBW. Edible and inedible offal components and all non-carcass fat depots (kidney, omental and mesenteric fats) were weighed and recorded. The weight of the digestive tract was recorded while full and empty. Thus, weight of gut-content was computed as the difference between full and empty weights of digestive tract. After the removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded before the tail fat is removed. Empty body weight (EBW) was determined as SBW less gut contents.

The carcasses with the tailfats were stored in a chilling room (4 to 5°C) for 24h after which evaluation of carcass characteristics was done. The tailfats were removed from the chilled carcasses and weighed before carcass evaluation. During carcass evaluation, samples of *longissimus dorsi* muscle were collected from the chilled carcasses for meat quality analyses. Water loss during chilling was considered as carcass chilling shrink (CS) and expressed as percent of HCW. Hot carcass dressing percentage on SBW basis (HCDP), cold carcass dressing percentage on SBW basis (CCDP) and cold carcass dressing percentage on EBW basis (DPEB) were calculated as (HCW/SBW) *100; (CCW/SBW) *100 and (CCW/EBW) *100, respectively. Rib eye area (REA) was measured on cold carcass at the 12/13th rib position using transparent paper. The left and right REA were traced onto a square paper which was placed on the transparency, and the area of the squares (0.25 cm^2 each) that fell within the traced area were counted and those partially outside were estimated and average of the two sides was taken as the REA.

All morphometric measurements, i.e., anterior and posterior buttock circumference (ABC, PBC), buttock width (BW), carcass length (CL), chest width (CW), leg length (LL), shoulder width (SW) and thorax circumference (TC) were also measured on chilled carcass (Figure 1). Leg compactness (LC) and carcass compactness (CC) were calculated as (BW)/LL and CCW/CL, respectively.

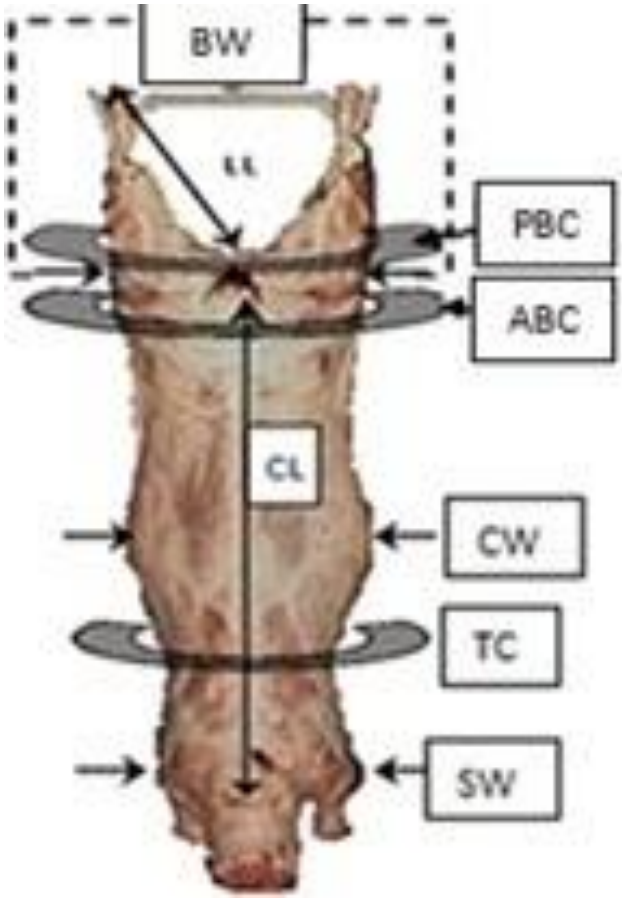

Figure 1 Schematic representation of carcass linear measurement locations: ABC=Anterior buttock circumference; BW=Buttock width; CL=Carcass length; CW=Chest width; LL=Leg length; PBC=Posterior buttock circumference; SW=Shoulder width;TC= Thorax circumference (Source: Teixeira *et al.*, 2004)

3.4.9. Meat Sample Preparation

On both sides of the chilled carcass, a cut was made on the back between the 8^{th} and 12^{th} rib bone to obtain the *Longissimus dorsi* muscle on which the physicochemical, chemical and sensory eating quality analyses were performed. A total of four samples, two from left and two from right sides, with a weight ranging30g (from the smaller) to 63g (from the bigger lamb) were collected. The left side samples were used for determination of color, pH and chemical composition while the right-side samples were used for sensory analysis. After taking the color and pH, the left side samples were vacuum packaged and stored frozen (<-20^{0}C). The right-side samples were aged for five days in chilling temperature (4 to 5°C) and stored frozen until evaluated.

3.4.10. Determination of Physicochemical Characteristics and Chemical Composition of Meat

The bag drip loss of the meat samples was determined by deducting the weight of the samples after ageing and freezing from the weight of the sample before packing (Pérez-Munuera*et al.*, 2009). The pH measurements were made 45minutes postmortem (pH_{45}) on the carcass at *Longissimus dorsi* muscle before chilling and on samples taken from carcass chilled for 24hours chilling (pH_u) using a portable meat pH-meter (HI99163, HANNA instruments) having a sharp penetrating blade over the electrode. The probe was cleaned with distilled water and calibrated with pH 4.1 and 7.1 buffer solutions between each measurement.

For color measurements, the cut surface of chilled samples was freshly exposed on flat surface of white background in the measuring room, and allowed to bloom for about 30 to 45 minutes at ambient temperature. Then, meat color parameters [CIE-values, lightness (L*), redness (a*) and yellowness (b*)] were obtained using a digital colorimeter (HunterLabMiniScan EZ, Serial number MsEZ1547, 45/00 illumination/viewing system, D65 light source, and 10° observer angle) calibrated with black and white standardized plates between each measurements (AMSA, 2012). For both pH and color three readings at different locations per sample were taken and averaged.The determination of moisture, crude protein (CP), fat and ash were performed according to the methods described by the Association of Official Analytical Chemists (AOAC, 1995)

3.4.11. Sensory Evaluation for Eating Quality of Meat

The frozen samples were thawed overnight in a refrigerator at 4°C, wrapped individually in aluminum foil and oven roasted at 125°C for 45min (Griffin*et al.*, 1985).

Immediately after roasting, the samples were cut into uniform size pieces and held in food warmer until served to the panelists. Before the analysis was made, the order of service was decided by drawing the code of a sample from its group among the six breed by mode of transportation groups and the six breed by diet groups, randomly. The same was repeated for the other groups ensuring equal chance for every sample. Then the pieces of a sample were served to the panelists at a time and only once so that every panelist evaluates samples from all lambs at a random order.

The samples were evaluated for tenderness, juiciness, flavor and overall acceptability using 7 points hedonic scale. They were randomly assigned for sensory evaluation to eight semi-trained panelists according to AMSA (1995). The assessors were teaching staff members, laboratory technicians and postgraduate students of the Food Science and Technology Program of Haramaya University.

The analysis was done by the same panelists in two consecutive days (21 samples each) at the same time in the afternoon. The test results were reported by the assessors filling a prepared format. The data were pooled over the panelists for individual lamb and the average of the eight assessors for an attribute was taken as an observation for the specific lamb.

3.5. Statistical Data Analyses

The survey data were analyzed with descriptive statistics using SPSS statistical software version 16 (SPSS, 2007). Data on transportation, silage making, feeding and digestibility experiments were analyzed using JMP™, The Statistical Discovery Software™ Version 5 and mean differences were tested using LSMean Tukey HSD mean separation tool (SAS, 2002) and considered significant at $p<0.05$.

The models used were: -

$Y_{ij} = \mu + b_i + t_j + (bt)_{ij} + e_{ij}$ fortransportation experiment;

$Y_{ij} = \mu + b_i + d_j + (bd)_{ij} + e_{ij}$ for feed intake and digestibilitytrials and

$Y_{ij} = \mu + AR_i + EP_j + (AREP)_{ij} + e_{ij}$ for *tef* straw silage making experiment

Where:

Y_{ij} = Response variable; μ = the overall mean; b_i = the i^{th} breed effect; t_j = j^{th} mode of transportationeffect;$(bt)_{ij}$ = the effect of interaction between i^{th} breed and j^{th} mode of transportation; d_j = j^{th} diet effect; $(bd)_{ij}$ = the effect of interaction between i^{th} breed and j^{th} diet; AR_i = the i^{th} EM application rate effect; EP_j = j^{th} ensiling period effect; $(AREP)_{ij}$ = the effect of interaction between i^{th} EM application rate and j^{th} ensiling period; e_{ij} = random error

4. RESULTS

The thesis research generated considerable data from the survey and the four experiments. The detailed results of the studies are presentedin the following sub-sections.

4.1. Impact of Transportation on Body Weight, Mortality and Carcass Condemnation in Export Abattoirs in Bishoftu and Modjo

The survey investigated the total slaughter, mortality rate of transported animals and carcass condemnation due to transportation of sheep and goats in six export abattoirs.

4.1.1. Total number of sheep and goats slaughter in six export abattoirs found in Bishoftu and Modjo

As seen in Table 8, a total of more than 3.9 million sheep and goats were slaughtered for export markets during the three years period (September 2012 to August 2015) in the studied abattoirs. Out of the total slaughter, around 743 thousand (19%) were sheep and around 3.2 million (81%) were goats.

Table 8: Total number of slaughters in ***six*** export abattoirs found in Bishoftu and Modjo

Species	Year	Total slaughter (Count)
Sheep	2012/13	78139
	2013/14	602659
	2014/15	62159
	Sub-Total	742957
Goat	2012/13	113260
	2013/14	1129507
	2014/15	899267
	Sub-Total	3161381
Grand Total		3904338

According to key informants in the abattoirs and personal observation, almost all slaughtered sheep and goats were transported to the abattoirs by trucking using ordinary trucks while trekking was practiced for transporting animals to primary and secondary, rarely to tertiary markets. No records were found about the age of the animals slaughtered, distance and duration of transportation.

Figure 2 summarises the contributions of different sheep and goat breeds to carcass export in the three years period. The most used breed was the *Somali* goats (66.23% of total slaughter) in which the *Woito-Guji* goats were also included, as the abbatoirsrecorded the two breeds by the name of Somali. Among the sheep breeds, the BHO was the most slaughtered sheep although it covered only 3.28% of the total slaughter while the contribution of the *Arsi-Bale* (0.04% of total slaughter) was the lowest. The same was true for the *Arsi-Bale* goats (3.32%), compared to theothergoat breeds.

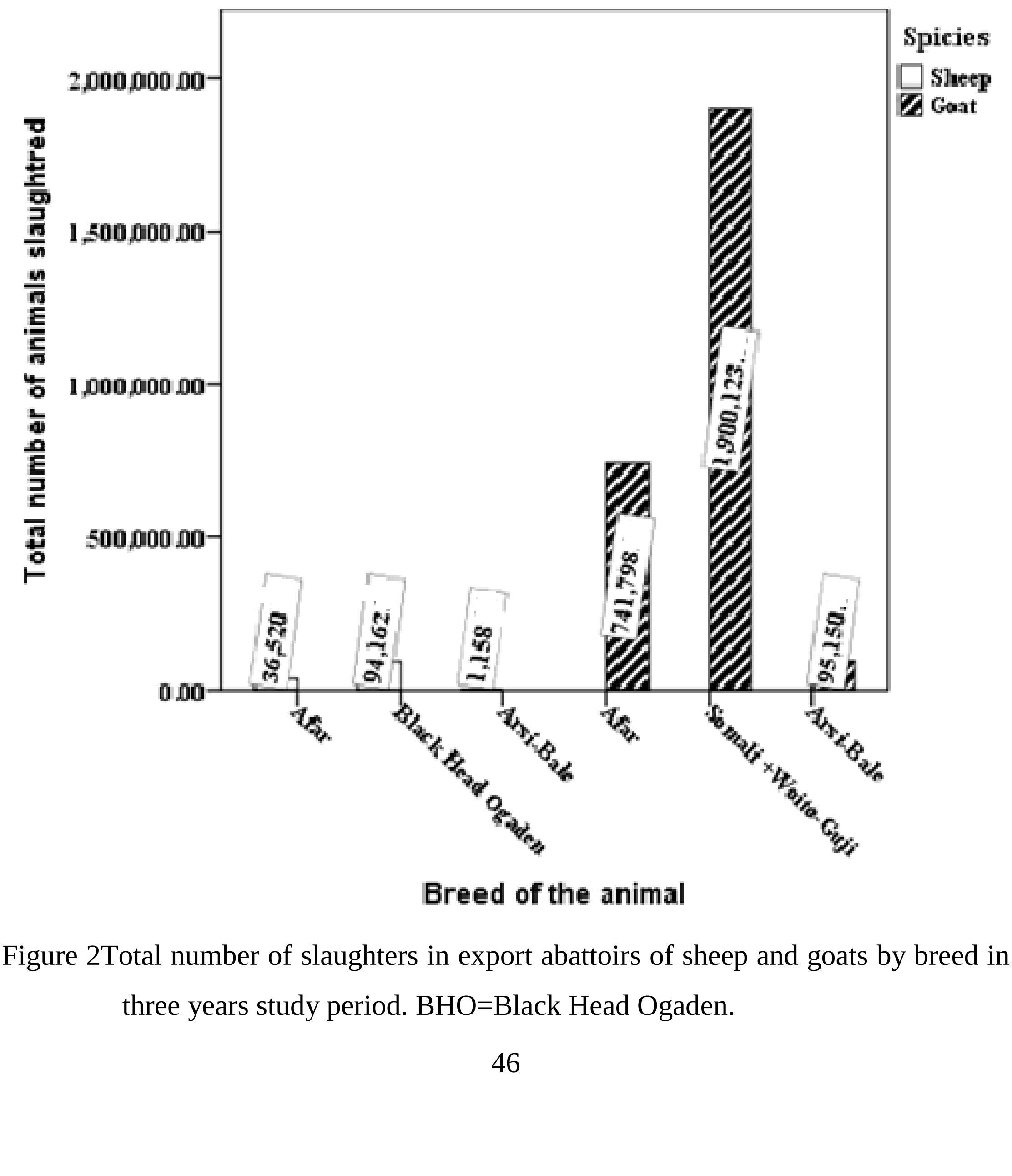

Figure 2Total number of slaughters in export abattoirs of sheep and goats by breed in three years study period. BHO=Black Head Ogaden.

4.1.2. Mortality and weight loss of transported sheep and goats

Concerning the effect of transportation on mortality and weight loss in the three years period, the record of the abattoirs indicated that out of totalsheep and goats transported,0.14% sheep and 1,0.10% goats were died (Table 9).

Table 9: Mean weight loss and mortality of transported sheep and goats

	Sheep	Goat
Transported animals (Count)	528,359	1,721,129
Mortality (Count)	716	1,802
Mortality (% transported animals)	0.14	0.11
Weight loss (kg/head)	1.30	1.21
Weight loss (%)	6.49	6.58

Furthermore, it was seen that weight loss of 6.49% and 6.58% of body weight on sheep and goats, respectively (Table 9 and Figure 3).

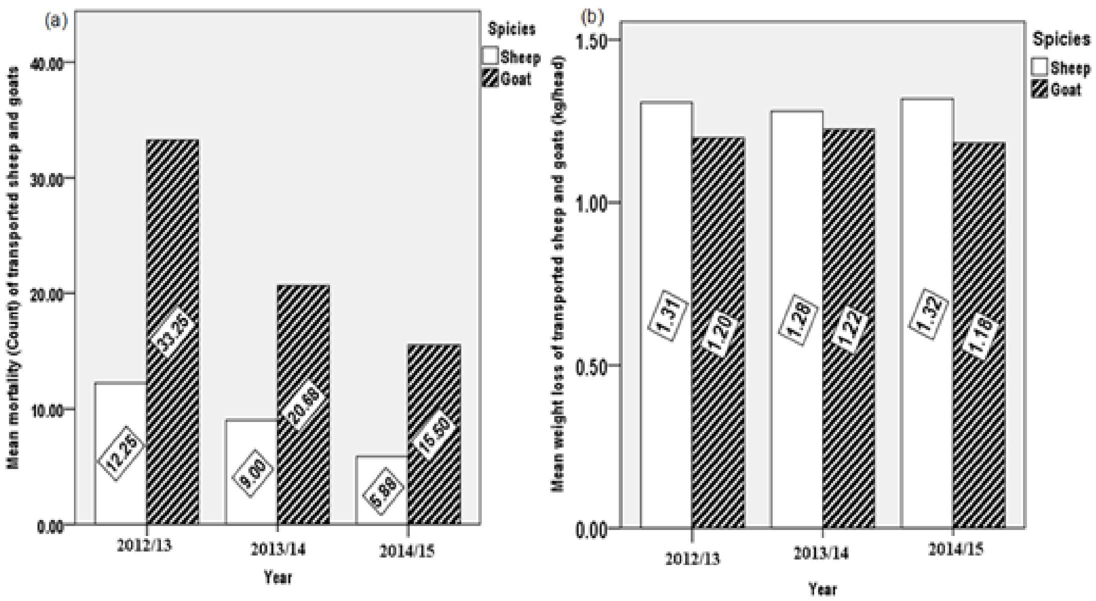

Figure 3(a) Mean mortality (Count) and (b) mean weight loss (kg/head) of transported sheep and goats by year

4.1.3. Carcass condemnation due to transportation of live sheep and goats

As presented in Table 10, the data on effect of transportation on carcass condemnation were classified neither by breed nor by species. In the three years study period, as obtained from records of the studied abattoirs, 0.09% carcasses of sheep and/or goats were fully condemned, while0.12% of carcasses of sheep and/or goats were partially condemned due to defects related to transportation problems. As per the information obtained from key informants, the partially condemned carcasses were sold in domestic markets after trimming off the unfit parts.

Table 10: Carcass condemnation by year in six export abattoirs found in *Bishoftu* and *Modjo* towns due to transportation problems

Year	Full carcass condemned		Partial carcass condemned	
	Total piece (Count)	% of total slaughter	Total piece (Count)	% of total slaughter
2012/13	1729	0.14	1474	0.12
2013/14	886	0.05	3896	0.12
2014/15	838	0.09	2112	0.22
Total	3453	0.09	7482	0.12

4.2. Impact of Mode of Transportation on Carcass Characteristics and Meat Quality of Arsi-Bale and Afar lambs

The influence of trekking or trucking on carcass characteristics and meat quality of *Arsi-Bale* and *Afar* lambs are presented under the following sub-sections.

4.2.1. Carcass characteristics andmeat yieldof Arsi-Bale and Afar lambs transported by trekking or trucking

Table 11 presents the carcass characteristics and yield attributes of *AB* and *Af* lambs trekked or trucked. The *AB* lambs showed significantly higher ($p < 0.05$) Slaughter Body Weight (SBW), Empty Body Weight (EBW), Hot Carcass Weight (HCW), Cold

Table 11: Carcass characteristics[f] and yield of *Arsi-Bale* and *Afar* lambs trekked or trucked

Treatment (T)	Not transported		trekking		Trucking		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
TL (%)	0.00[b]	0.00[b]	2.39[a]	4.69[a]	3.98[a]	2.43[a]	0.967	0.001	0.751	0.154
SBW (kg)	17.29[y]	20.29[x]	16.71[y]	19.83[x]	16.86[y]	20.00[x]	0.738	0.778	<0.0001	0.995
EBW (kg)	12.60[by]	14.27[bx]	13.36[ay]	16.29[ax]	13.21[ay]	16.78[ax]	0.617	0.029	<0.0001	0.290
HCW (kg)	6.68[y]	8.49[x]	6.48[y]	8.93[x]	7.12[y]	8.34[x]	0.385	0.918	<0.0001	0.298
CCW (kg)	6.51[y]	8.39[x]	6.29[y]	8.72[x]	6.95[y]	8.38[x]	0.375	0.841	<0.0001	0.428
CS (%)	2.48[y]	1.52[x]	2.86[y]	2.33[x]	2.38[y]	2.00[x]	0.237	0.052	0.003	0.450
HCDP (%)	38.67[y]	42.03[x]	38.77[y]	45.10[x]	42.10[y]	42.84[x]	1.377	0.282	0.004	0.147
CCDP (%)	37.72 [y]	41.39[x]	37.66[y]	44.04[x]	41.08[y]	42.00[x]	1.347	0.329	0.002	0.146
DPEB(%)	53.3[qr]	59.74[q]	48.66[r]	54.9[qr]	53.71[r]	51.12[qr]	1.906	0.035	0.038	0.035
REA (cm^2)	5.69[b]	6.08[b]	6.87[a]	7.70[a]	5.91[b]	6.43[b]	0.356	0.001	0.054	0.818

[e]*AB* = *Arsi-Bale* lambs; *Af*=*Afar* lambs; SEM=Standard error of mean

[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area; TL= Transportation loss

[a,b,c] Mean effects of mode of transportation in a row superscribed by different letters are significantly different; [q,r,s]Mean breed x mode of transportation interaction effects in a row superscribed by different letters are significantly different;[x,y] Mean breed effects in a row superscribed by different letters are significantly different;

Carcass Weight (CCW), Chilling Shrinkage (CS), Hot Carcass Dressing Percentage on SBW Basis (HCDP), Cold Carcass Dressing Percentage on SBW Basis (CCDP) and Cold Carcass Dressing Percentage on EBW Basis (DPEB)than the *Af*lambs while breed did not affect (p>0.05) Transportation Loss (TL) and Rib eye area (REA).

The effect of mode of transportation was significant (p<0.05) for TL, EBW, DPEB and REA while it did not affect SBW, HCW, CCW, HCDP and CCDP. Accordingly, there were no statistical difference(p>0.05) observed between trekked and truckedlambs for TL and EBW, but they were significantly higher than the non-transported (NT) lambs. The DPEB of NT groups were significantly higher (p<0.05) than trucked groups while the trekked were not different(p>0.05) from both NT and trucked lambs. The REA of the trekked lambs was significantly higher (p<0.05) than the other two groups which were not different from each other. The breed x mode of transportation interaction effect was significant (p<0.05) only for DPEB. Accordingly, the highest was scored for NT *AB* lambs and the lower was scored for transported *Af* lambs whereas NT *Af* and the transported *AB* lambs were statistically similar to each other and to both high and low scoring lambs as well.

4.2.2. Carcass linear measurementsof Arsi-Bale and Afar lambs transported by trekking or trucking

Table 12 summarized morphometric carcass measurements of trekked or trucked *AB* and *Af* lambs. All of the measurements were affected (p>0.05) by breed except Shoulder Width (SW), Thorax Circumference (TC) and Leg Compactness (LC). The Carcass Length (CL), Leg Length (LL), Buttock Width (BW), Chest Width (CW), Anterior Buttock Circumference (ABC), Posterior Buttock Circumference (PBC) and Carcass Compactness (CC) were significantly (p< 0.05) higher in *AB* than in *Af*lambs.

The effect of mode of transportation was not significant (P>0.05) except for CW and PBC. Accordingly, CW was significantly higher (P<0.05) for NT compared to trekked lambs while trucked lambs were not significantly (P>0.05) different from both NT and trekked groups. The PBC of NT and trekked lambswere significantly (P<0.05) higher than those of trucked lambs.

Table 12: Morphometric carcass measurements of *Arsi-Bale* and *Afar* lambs trekked or trucked

Variable[f]	Treatment (T)[e]				Breed (B)[e]			p-value		
	NT	Trek	Truk	SEM	*Af*	*AB*	SEM	T	B	T x B
CL (cm)	39.43	37.85	38.75	0.644	36.38[y]	41.13[x]	0.526	0.327	<0.0001	0.467
LL (cm)	30.79	30.69	30.60	0.667	29.33[y]	32.12[x]	0.545	0.960	0.001	0.154
BW (cm)	25.43	22.31	21.83	1.290	21.52[y]	24.99[x]	1.053	0.113	0.031	0.16
CW (cm)	29.07[a]	26.61[b]	27.52[ab]	0.565	26.76[y]	28.82[x]	0.461	0.018	0.004	0.91
SW (cm)	28.50	29.85	26.23	1.430	26.43	28.82	29.31	0.338	0.076	0.41
TC (cm)	57.14	56.35	56.56	1.156	56.43	56.94	0.944	0.881	0.706	0.96
ABC (cm)	43.50	42.38	42.05	0.993	40.62[y]	44.78[x]	0.811	0.577	0.0008	0.72
PBC (cm)	44.71[a]	44.23[a]	39.51[b]	0.996	41.33[y]	44.31[x]	0.813	0.001	0.0108	0.47
LC	0.82	0.75	0.72	0.045	0.75	0.79	0.037	0.219	0.460	0.07
CC (kg/cm)	0.19	0.20	0.19	0.006	0.18[y]	0.21[x]	0.005	0.504	0.0001	0.61

[e]*AB*=*Arsi-Bale* lambs; *Af*=*Afar* lambs; NT=Not transported; Trek=trekking; Truk=Trucking; SEM=standard error of mean

[f]ABC=Anterior Buttock Circumference; BW=Buttock Width; CC=Carcass compactness; CL=Carcass Length; CW=Chest Width; LC=Leg compactness; LL=Leg Length; SW=Shoulder Width; TC=Thorax Circumference; PBC=Posterior Buttock Circumference

[a,b,c]Mean effect of mode of transportation in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.2.3. Proportionsof non-carcass componentsof Arsi-Bale and Afar lambs transported by trekking or trucking

The proportion to empty body weight of edible and non-edible components as influenced by mode of transportation and breed are presented here under.

4.2.3.1.Proportionsedible offal of Arsi-Bale and Afar lambs transported by trekking or trucking

Table 13 shows the proportions of edible offal components to empty body weight of trekked or trucked*AB*and *Af* lambs. The proportions of liver, Empty Intestine (EI), tongue, Tail Fat (TF) and Heart Fat (HF) were not affected($p>0.05$) by breedand by mode of transportation neither.

The breed effect was not significant ($p>0.05$) forall except the Empty Stomach (ES). The NT lambs were seen to have significantly higher ($p<0.05$) proportions of head,Total Edible Non-Carcass Fat (TENCF) and Total Edible Offal (TEO) compared to those of the transported groups which were also not different from each other. The proportions of heart, kidney and Mesenteric Fat (MF) of NT lambs were similar ($p>0.05$) to trucked and higher ($p<0.05$) than those of the trekked lambs.

The breed x mode of transportation interaction affected ($p<0.05$) only the ES and Ommental Fat (OF).The proportion of ES of NT and trekked *Af* were significantly ($p<0.05$) higher than those of NT and trekked*AB*, and trucked *Af* lambs while the trucked *AB* lambs were statistically ($p>0.05$) not different from all the rest. Similarly, the proportions of OFof NT lambs of both breeds were significantly ($p<0.05$) higher than those of trekked lambs while the trucked lambs of both breeds were statistically ($p>0.05$) not different from NT and trekked lambs.

Table 13: Proportion (g kg^{-1}) of edible offal[f] components to empty body weight of trekked or trucked *Arsi-Bale* and *Afar* lambs

Treatment (T)[e]	NT		Trek		Truk		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
Blood	21.74^{b}	25.64^{b}	31.69^{a}	34.81^{a}	21.90^{b}	25.91^{b}	2.72	0.002	0.12	0.99
Heart	5.55^{a}	6.02^{a}	4.36^{b}	5.32^{b}	5.01^{ab}	5.23^{ab}	0.35	0.03	0.07	0.58
Kidney	5.16^{a}	4.72^{a}	4.28^{b}	4.03^{b}	4.75^{ab}	4.13^{ab}	0.29	0.03	0.07	0.82
Liver	21.01	26.01	22.86	23.10	23.36	21.56	1.41	0.75	0.33	0.06
ES	49.14^{q}	36.97^{r}	51.04^{q}	37.62^{r}	38.77^{r}	41.62^{qr}	2.24	0.18	0.0002	0.001
EI	37.79	35.26	41.13	32.07	32.98	37.80	3.09	0.91	0.38	0.10
Head	79.32^{a}	71.57^{a}	47.77^{b}	52.01^{b}	51.35^{b}	55.44^{b}	7.43	<0.0001	0.89	0.51
Tongue	3.67	3.72	3.39	3.26	3.66	3.21	0.16	0.06	0.17	0.27
TF	33.53	26.29	28.62	21.14	26.36	18.80	4.60	0.27	0.06	1.00
HF	1.44	1.55	1.50	1.21	1.44	1.32	0.17	0.69	0.48	0.50
OF	2.57^{r}	3.52^{q}	1.96^{r}	1.70^{r}	3.46^{q}	1.58^{r}	0.32	0.003	0.14	0.0004
MF	2.77^{a}	2.37^{a}	1.79^{b}	1.74^{b}	1.31^{ab}	2.43^{ab}	0.32	0.04	0.41	0.06
TENCF	18.72^{a}	19.08^{a}	13.85^{b}	13.92^{b}	14.6^{b}	13.30^{b}	0.98	<0.0001	0.70	0.64
TEO	284.97^{a}	261.16^{a}	235.14^{b}	213.34^{b}	208.13^{b}	213.69^{b}	11.77	<0.0001	0.17	0.38

[e]*AB*=*Arsi-B*ale lambs; *Af*=*Afar* lambs; NT=Not transported; Trek=trekking; Truk=Trucking; SEM=standard error of mean

[f]EI= Empty Intestine; ES=Empty Stomach; HF=Heart Fat; MF= Mesenteric Fat; OF=Omental Fat; TENCF= Total Edible Non-Carcass Fat; TEO=Total Edible Offal; TF=Tail Fat

[a,b,c]Mean mode of transportation effects in a row superscribed by different letters are significantly different; [q,r,s] Mean breed x mode of transportation interaction effects in a row superscribed by different letters are significantly different;[x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.2.3.2. Proportion of non-edible offalof Arsi-Bale and Afar lambs transported by trekking or trucking

The proportion to empty body weight of inedible offal components of *AB* and *Af* lambs transported by either trekking or trucking is presented in Table 14. The lungs, trachea, testis, GF, feet and skin were affected by none ($p>0.05$) of the factors. Breed effect was significant ($p<0.05$) for proportion of oesophagus and penis for which *AB* lambs were significantly higher than the *Af* lambs.

Mode of transportation significantly ($p<0.05$) affected the proportions of pancreas, gall bladder and kidney fat. The NT lambs of both breed were significantly higher than the trucked lambs but the trekked lambs were not significantly ($p>0.05$) different from both NT and trucked lambs for the proportion of pancreas and gall bladder.The proportion of kidney fat of NT lambs of both breeds were significantly ($p<0.05$) higher than the trekked lambs and similar to the trucked lambs which were also not different from the Trekked lambs.

The effect of the interaction between mode of transportation and breed was significant ($P<0.05$) for proportion of spleen, urinary bladder and total non-edible offal (TNEO). Accordingly, the proportion of spleen of NT *Af* lambs was significantly higher than all trekked and trucked lambsbut not different from NT *AB* lambs which were also similar with the other lambs. The proportion of urinary bladder of trekked*Af* lambs was statistically ($P<0.05$) higher than their corresponding lambs but not different from the rest groups which were also not significantly ($P>0.05$) different from each other. The proportion ofTNEO of the NT lambs of both breeds was significantly ($P>0.05$) higher than of all the transported lambs.

Table 14: Proportion (g kg^{-1}) of non-edible offalf components to empty body weight of *Arsi-Bale* and *Afar* lambs trekked or trucked

Treatment (T)[e]	NT		Trek		Truk		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
Lungs	15.02	14.76	14.08	12.12	14.12	12.69	0.96	0.15	0.13	0.67
Trachea	1.69	1.93	1.73	1.87	1.98	1.99	0.14	0.35	0.28	0.74
Oeso	1.47^{y}	2.10^{x}	1.06^{y}	1.50^{x}	1.30^{y}	1.96^{x}	0.20	0.05	0.001	0.84
Spleen	4.97^{q}	3.79^{qr}	3.16^{r}	3.12^{r}	3.47^{r}	2.52^{r}	0.26	0.004	<0.0001	0.001
Panc	2.16^{a}	2.54^{a}	2.11^{ab}	1. 89^{ab}	1.71^{b}	1.79^{b}	0.19	0.03	0.79	0.07
UB	1.20^{qr}	1.34^{qr}	1.72^{q}	1.12^{s}	1.56^{qr}	1.44^{qr}	0.13	0.21	0.07	0.02
GB	0.81^{a}	0.68^{a}	0.58^{ab}	0.65^{ab}	0.53^{b}	0.33^{b}	0.10	0.03	0.09	0.17
Penis	3.08^{y}	3.15^{x}	2.72^{y}	3.65^{x}	2.70^{y}	3.71^{x}	0.22	0.91	0.001	0.07
Testis	16.66	17.21	14.10	15.52	13.52	16.56	1. 46	0.29	0.17	0.68
GF	9.92	10.63	7.92	7.37	6.68	7.41	0.89	0.002	0.69	0.72
KF	4.72^{a}	5.16^{a}	4.03^{b}	4.28^{b}	4.13^{ab}	4.75^{ab}	0.29	0.03	0.07	0.82
Feet	38.99	35.78	34.86	34.88	33.45	38.40	2.08	0.49	0.73	0.15
Skin	154. 40	131.47	128.26	144.20	145.17	155.84	9.98	0.38	0.88	0.12
TNEO	615.38^{qr}	678.48^{q}	488.68^{s}	532.49^{s}	425.39^{rs}	436.19^{s}	29.46	<0.0001	0.19	0.02
Gut content	380.75^{a}	421.12^{a}	254.55^{b}	217.88^{b}	279.63^{b}	193.23^{b}	14.899	<0.0001	0.20	0.06

[e]*AB*=*Arsi-Bale*d lambs; *Af*=*Afar* Breed lambs; NT= Not transported; Trek=trekking; Truk=Trucking; SEM=standard error of mean

[f]GB=Gall Bladder; GF=Genital Fat; KF=Kidney Fat; Oeso=Oesophagus; TNEO=Total None-edible offal; UB=Urinary Bladder;

[a,b,c]Mean mode of transportation effects in a row superscribed by different letters are significantly different; [q,r,s] Mean breed x mode of transportation interaction effects in a row superscribed by different letters are significantly different;[x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.2.3.3.Physicochemical characteristics and chemical composition of meat of Arsi-Bale and Afar lambs transported by trekking or trucking

The physicochemical characteristics and chemical composition of meatof *AB* and *Af*lambs trekked or trucked is presented in Table 15. The breed effect was significant (P<0.05) for bag drip los (BDL) and meat color (Lightness (L*) and redness (a*)) coordinates. The meat BDL and L* were significantly (P<0.05) higher for the *Af*lambs than *AB* lambs while the a*was higher (P<0.05) in *AB* lambs.

Table 15: Physicochemical characteristics and chemical composition of meat of*Arsi-Bale* and *Afar* lambs trekked or trucked

Variable[f]	Treatment (T) [e]				Breed (B)[e]			p-value		
	NT	Trek	Truk	SEM	*Af*	*AB*	SEM	T	B	T x B
BDL (%)	15.61[a]	14.11[ab]	13.90[b]	1.08	15.02[x]	14.06[y]	0.59	0.003	0.027	0.053
pH										
pH_{45}	6.28[a]	5.88[b]	5.93[ab]	0.11	6.00	5.97	0.09	0.02	0.27	0.49
pH_u	5.38[b]	5.78[a]	5.83[a]	0.11	5.73	5.59	0.09	0.007	0.27	0.58
Color										
L*	37.42	39.08	40.77	1.46	41.24[x]	36.83[y]	1.19	0.27	0.01	0.77
a*	14.31	13.15	13.14	0.92	12.42[y]	14.71[x]	0.75	0.60	0.04	0.57
b*	11.11	11.78	11.81	0.42	11.86	11.25	0.35	0.43	0.24	0.43
Moisture (%) and chemical composition (%DM)										
Moisture	72.74	72.07	73.91	1.01	73.19	72.65	0.82	0.40	0.59	0.14
CP	23.28	23.72	22.25	0.96	22.46	23.70	0.79	0.52	0.26	0.74
Ash	4.48	4.65	4.67	0.11	4.48	4.73	0.09	0.36	0.05	0.48
Fat	4.64	4.06	3.49	0.43	4.29	3.83	0.35	0.18	0.84	0.37

[e]*AB*=*Arsi-Bale* lambs; *Af*=*Afar* lambs; NT= Not transported; Trek=trekking; Truk=Trucking; SEM=standard error of mean

[f]BDL = Bag drip loss**;** L* Measure Lightness and varies from 100 for perfect white to zero for black, a* measure redness when +ve, grey when zero, green when -ve, b* measure yellowness when +ve, grey when zero, blue when -ve ; pH_{45} = pH measure taken 45 minutes after flaying; pH_u = pH measure taken after 24 hours chilling; CP = Crude protein;

[a,b,c]Mean mode of transportation effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

Mode of transportation significantly ($p<0.05$) affected meat BDL and pH. Accordingly, significantly ($p<0.05$) higher BDL and pH_{45} were observed on the meat samples of NT lambs. The lowest BDL and pH_{45} values were recorded on meat samples of trucked and trekked lambs, respectively. The pH_u of meat samples of transported lambs was significantly ($p<0.05$) higher than the NT lambs. The moisture and chemical composition of meat samples were affected by none of the effects.

4.2.3.4. **Sensory eating quality of meat *of Arsi-Bale and Afar lambs transported by trekking or trucking***

The sensory quality ratings of meat of *Arsi-Bale* and *Afar* lambs trekked or trucked are summarized in Table 16. The breed of the lambs affected the juiciness, flavor and general acceptability of meat samples for which the *AB* lambs were significantly ($P<0.05$) higher than the *Af* lambs. The mode of transportation and their interaction with breed did not affect any attribute of the sensory eating qualities.

Table 16: Mean rating of sensory eating quality of meat of *Arsi-Bale* and *Afar* lambs trekked or trucked

Variable[f]	Treatment (T)[e]				Breed (B)[e]			p-value		
	NT	Trek	Truk	SEM	*Af*	*AB*	SEM	T	B	T x B
Tenderness	5.50	5.44	5.59	0.19	5.34	5.69	0.160	0.890	0.120	0.630
Juiciness	5.51	5.46	5.76	0.16	5.35[b]	5.82[a]	0.130	0.400	0.014	0.550
Flavor	5.01	5.13	5.48	0.15	5.03[b]	5.40[a]	0.125	0.096	0.038	0.230
GenrAccep[f]	5.23	5.27	5.56	0.18	5.14[b]	5.58[a]	0.149	0.390	0.045	0.810

[e]*AB*=*Arsi-Bale* lambs; *Af*=*Afar* lambs; NT= Not transported; Trek=trekking; Truk=Trucking; SEM=standard error of mean

[f]GenrAccep= General Acceptability

[a,b,c]Mean mode of transportation effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.3. Tef Straw Silage Making Experiment

The*tef* straw silage making experiment evaluated the sensory quality, nutrient composition and *in vitro* digestibility of the silage. Results are presented in detail in the following sections.

4.3.1. Sensory evaluation of samples of tef straw silage

The sensory appraisal of *tef* straw silage treated with EM at different application rate and ensiled for varying duration is presented in Table 17. All the TSsilage did not show any sign of mold development.

The color of the silage ranges from banana (light yellow) of TS ensiled for 14 day with 250 ml EM application to mustard (dark yellow) of TS ensiled for 28 day with 500 and 750ml EM application. This confirmed that the color of the silage tended to change from light to dark with increasing rate of EM application and ensiling duration.

It was also observed that all the silages tended to get darker upon exposure to air with no change in odor. There was no foul smell felt, but pleasant acid smell varying from very weak yogurt smell of TS ensiled for 14 days with 250 ml/kg EM application rate to weak cheese for TS ensiled for 28 days with 500 and 750 ml/kg EM application rate.

The silage of TS ensiled for 21 days at the EM application rate of 500ml/kg situated in between the two extremes for both color and odor as it has shown darker yellow (tuscan sun) color and good yogurt odor.

The odor of the silage as the case of their color also showed clear gentle linear pattern of change from very weak yogurt to weak cheese with increasing rate of EM application and ensiling duration. The texture of all the TSsilage was found to have soft stems, which were non-slimy and separable upon chafing between fingers.

Table 17: Sensory appraisal of tef straw silage treated with effective microorganisms at three application rates and three ensiled durations

Ensiling period (EP)	EP_{14}			EP_{21}			EP_{28}		
EM application rate (AR)	AR_{250}	AR_{500}	AR_{750}	AR_{250}	AR_{500}	AR_{750}	AR_{250}	AR_{500}	AR_{750}
Color	banana	blonde	tuscan sun	blond	tuscan sun	mustard	blonde	tuscan sun	mustard
Odor	very weak yogurt	weak yogurt	weak yogurt	weak yogurt	good yogurt	sour yogurt	good yogurt	sour yogurt	weak cheese
Texture	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems	flexible & non-sticky stems
Mould	none	none	none	None	none	none	none	none	none

AR=application rate; AR_{250}=250mL EM:1kg *tef* straw; AR_{500}=$_{500}$mL EM:1kg *tef* straw; AR_{750}=750ml EM: 1kg *tef* straw; EM=Effective microorganism; EP=ensiling period; EP_{14}=14 days ensiling period; EP_{21}=21 days ensiling period; EP_{28}=28 days ensiling period.

4.3.2. Nutrient composition, in-vitro digestibility and pH of tef straw silage

The data on nutrient composition and estimated ME content, in *vitro* DM and OM digestibility and pH of TSS are summarized in Table 18. Duration of the ensiling period did not affect the pH, nutrients composition and ME content, except IVOMD, OM and CP contents.

The OM and CP contents of TSS under EP_{21} were similar to those under EP_{14} and higher ($p<0.05$) than that of under EP_{28}.Whereas, the IVOMD of TSS under EP_{21} was higher ($p<0.05$) than that of under EP_{14} and comparable with that of under EP_{28}. Similarly, the effect of EM application rate was significant ($p<0.05$) only for pH value, ash content and OM content of TSS.

The ash content was higher ($p<0.05$) in the TSSunder AR_{750} than TSSunder the other two ARs, which were not statistically different from each other. The OM contents of the TSSunder AR_{250} and AR_{500} were not different to each other but, higher ($p<0.05$) than that of under AR_{750}.

The pH of the TSSunder AR_{750} was more acidic than under AR_{250} but that of under AR_{500} was not different from both under AR_{250} and AR_{750}.

Table 18: Dry matter (%), nutrient (g kg^{-1}DM), estimated metabolizable energy (MJ kg^{-1} DM) composition, *in vitro*organic matter digestibility (%) and pH of treated *tef* straw silage making experiment

Variable[e]	Ensiling period (EP)[f]			SEM[f]	Application rate (AR)[f]			SEM[f]	p-value		
	EP_{14}	EP_{21}	EP_{28}		AR_{250}	AR_{500}	AR_{750}		EP	AR	EP x AR
DM	33.97	32.95	34.39	1.49	36.16	33.10	32.04	1.49	0.78	0.16	0.68
Ash	78.95^{ab}	77.46^{b}	80.72^{a}	0.74	76.78^{y}	78.11^{y}	82.23^{x}	0.74	0.02	0.0002	0.14
OM	921.07^{ab}	922.54^{a}	919.27^{b}	0.75	923.22^{x}	921.90^{x}	917.78^{y}	0.75	0.02	0.0002	0.14
CP	54.65^{ab}	58.02^{a}	51.58^{b}	2.70	54.81	55.52	53.92	1.60	0.01	0.24	0.09
EE	11.41	10.13	9.45	0.69	10.59	10.32	10.09	0.69	0.15	0.88	0.47
NDF	281.93	269.49	276.63	12.83	296.56	268.29	263.19	12.83	0.79	0.17	0.78
ADF	150.22	135.03	154.77	6.53	154.89	143.25	141.87	6.53	0.11	0.32	0.83
ADL	56.79	46.61	64.88	5.75	56.65	60.25	51.38	5.75	0.11	0.56	0.07
IVDMD	43.29	41.86	41.21	0.80	42.82	42.48	41.07	0.80	0.20	0.29	0.64
IVOMD	37.43^{b}	40.02^{a}	38.28^{ab}	0.68	37.95	38.97	38.80	0.68	0.04	0.56	0.63
IVDOMD	344.78^{b}	369.13^{a}	351.82^{ab}	6.81	350.33	359.26	356.14	6.12	0.04	0.54	0.64
ME	5.52	5.90	5.63	0.10	5.60	5.75	5.70	0.10	0.22	0.41	0.65
pH	4.76	5.22	4.91	0.24	5.67^{x}	4.99^{xy}	4.24^{y}	0.24	0.41	0.002	0.08

[e]ADF=Acid detergent fiber; ADL=Acid detergent lignin; CP=Crude protein; DM=Dry matter; EE=Ether Extract; IVDMD= in vitro DM digestibility; IVOMD=in vitro OM Digestibility; IVDOMD (g kg^{-1}DM) =in vitro digestible OM in DM; OM=Organic matter; ME=Metabolizable energy; NDF=Neutral detergent fiber.

[f]AR_{250}=250mL EM:1kg *tef* straw; AR_{500}=500mL EM:1kg *tef* straw; AR_{750}=750ml EM: 1kg *tef* straw; EM=Effective microorganism; EP_{14}=14 days ensiling period; EP_{21}=21 days ensiling period; EP_{28}=28 days ensiling period; SEM=standard error of mean; Values in a row superscribed by different letters are significantly different, letters [a,b,c] standing for EP and [x,y,z] standing for AR.

4.4 Feeding and Digestibility Trials

4.4.1. Nutrient Intake and Digestibility of Experimental Lambs

Results of DM and nutrients intake and substitution rate of basal by supplemental feed of *Af* and *AB* lambs are given in Table 19. The *Af* lambs were superior ($p<0.05$) over *AB* lambs for DM and nutrients intake except the NDF and ADF intakes for which no significant($p>0.05$) effect of breed was observed

The lambs offered control diet consumed lower ($p<0.5$) DM, ash, OM, CP and EE while they scored higher ($p<0.05$) intake of ADF and ADL than the supplemented groups, which were not different from each other for ADL. The lambs on D_3 exhibited higher ($p<0.05$) ADF intake than those on D_2 whereas the reverse was true for OM intake. Conversely, all the diet groups did not show significant difference on NDF intake. Though statistical evaluation is not applicable due to its nature, there was strong evidence observed that the TSS basal feed was substituted by the supplements. The tendency of substitution effect was stronger for *Af* compared to the *AB* lambs (Table 19).

The digestibility of DM, OM, CP, NDF and ADF is presented in Table 20. The breed effect on digestibility of DM, OM, NDF and ADF of *Af* lambs were higher ($p<0.05$) than *AB* lambs while no breed effect was observed on CP digestibility (CPD) and ash digestibility. The DM digestibility (DMD) and OM digestibility (OMD) of control diet were lower ($p<0.05$) than both supplemented diets which were not different from each other. The ash digestibility in D_3 groups were higher ($p<0.05$) than in D_1 and D_2 groups. The NDF digestibility (NDFD) was higher ($p<0.05$) for the control groups compared to the D_2, while the D_3 groups were not different from both other groups. Conversely, the diet effect was not significant for CPD and ADF digestibility (ADFD).

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Table 19: Daily mean dry matter and nutrients intake (g $kg^{-1}W^{0.75}day^{-1}$) and substitution rate of basal diet by the supplements of *Afar* and *Arsi-Bale* lambs fed on sole or supplemented *tef*straw silage

Variablee	Treatment (T)[f]				Breed (B)[f]			p-value		
	D_1	D_2	D_3	SEM[f]	*Af*	*AB*	SEM[f]	T	B	T x B
DMI	46.77[b]	64.53[a]	60.90[a]	1.07	59.73[x]	55.68[y]	0.87	<0.0001	0.0080	0.3900
Ash I	4.55[c]	5. 45[b]	6.95[a]	0.11	5.95[x]	5.38[y]	0.09	<0.0001	0.0002	0.2000
OMI	40.94[c]	57.50[a]	53.09[b]	0.93	51.92[x]	49.09[y]	0.58	<0.0001	0.0126	0.5809
CPI	1.01[c]	7.81[b]	8.87[a]	0.15	6.64[x]	5.42[y]	0.15	<0.0001	<0.0001	0.0703
EEI	0.63[b]	1.83[a]	1.95[a]	0. 04	1.56[x]	1. 42[y]	0.03	<0.0001	0.0251	0.5704
NDFI	34.93	33.97	33.74	0.70	34.92	33.51	0.57	0.4067	0.0789	0.6576
ADFI	18.75[a]	14.20[c]	15.77[b]	0.38	16.21	16.1`2	0.31	<0.0001	0.5690	0.8956
ADLI	6.08[a]	5.66[b]	5.57[b]	0.12	5.90[x]	5.64[y]	0.09	0.0085	0.0485	0.7166
SR	-	0.28	0.23	-	0.30	0.22	-	-	-	-

[e]ADFI=acid detergent fiber intake; ADLI=Acid detergent lignin intake; Ash I=Ash intake; CPI=Crude protein intake; DMI=Dry matter intake; EEI=Ether Extract intake; NDFI=Neutral detergent fiber intake; OMI=Organic matter intake; SR=Substitution rate

[f]*Af*=*Afar* Breed; *AB*=*Arsi-Bale* Breed; D_1=Sole fermented TS; D_2 =TS silage supplemented with WBB alone; D_3=TS silage supplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=*Tef* straw; Values in a row superscribed by different letters are significantly different, letters [a,b,c] standing for diet and [x,y,] standing for breed.

Table 20: Least square mean of dry matter and nutrient digestibility (%) of the experimental diets

Treatment (T)[f]	D_1		D_2		D_3		SEM[f]	p-value		
Breed (B)f	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
DMD	19.38[bx]	13.57[by]	55.54[ax]	42.18[ay]	58.55[ax]	50.96[ay]	2.43	<0.0001	0.0003	0.292
Ash D	32.11[b]	22.56[b]	25.26[b]	17.27[b]	17.38[a]	43.26[a]	6.43	0.0040	0.1813	0.906
OMD	43.26[bx]	35.86[by]	62.72[ax]	48.13[ay]	64.51[ax]	57.36[ay]	4.41	0.0005	0.0153	0.631
CPD	78.08	61.87	74.25	69.10	75.86	73.88	4.73	0.5884	0.0603	0.328
EED	47.59[qr]	41.38[qr]	69. 40[q]	40.83[r]	71.65[q]	69.64[q]	8.26	<0.0072	0.0122	0.019
NDFD	55.67[ax]	49.81[ay]	48.12[bx]	28.95[by]	50.68[abx]	40.19[aby]	5.08	0.0430	0.0110	0.433
ADFD	67.57[x]	58.06[y]	72.16[x]	66.69[y]	71.23[x]	62.98[y]	3.19	0.1509	0.0086	0.812

[e]ADFD=Acid detergent fiber digestibility; Ash D=Ash digestibility; CPD=Crude protein digestibility; DMD=Dry matter digestibility; EED=Ether Extract digestibility; OMD=Organic matter digestibility; NDFD=Neutral detergent fiber digestibility;

[f]*Af*=*Afar* Breed; *AB*=*Arsi-Bale* Breed; D_1=Sole TSS; D_2=TS silage supplemented with WBB alone; D_3=TSS supplemented with mix of WBB and NSC; SEM=standard error of mean; TS=*Tef* straw; Values in a row superscribed by different letters are significantly different, letters [a,b,c] standing for diet and [x,y,z] standing for breed and [q,r,s] for diet x breed interaction.

4.4.2. Growth Performance of Experimental Lambs

Initial body weight, final body weight, total weight gain and average daily weight gain and Feed Efficiency (FE) of *Afar* and *Arsi-Bale* lambs fed on supplemented *Tef* Straw Silage (TSS) are presented in Table 21. The *AB* lambs are higher ($p<0.05$) than *Af* lambs in all aspects of live weight and FE performance. The FBW and TWG of both supplemented lamb groups were higher ($p<0.05$) than the control lamb groups. The ADWG and FE of the D_3 lambs were statistically ($p<0.05$) higher followed by the D_2 lambs and that of the D_1 lambs appeared to be the lowest. Conversely, the supplemented groups were continuously growing (Figure 4) with significant ($p<0.05$) regression over growth period having positive coefficients (Table 22). This confirms that both supplements satisfied the nutrient requirement of the lambs. The predictabilities of weight as a function of growth period were varied ($p<0.05$) among the effect of interactions between breed and diet.

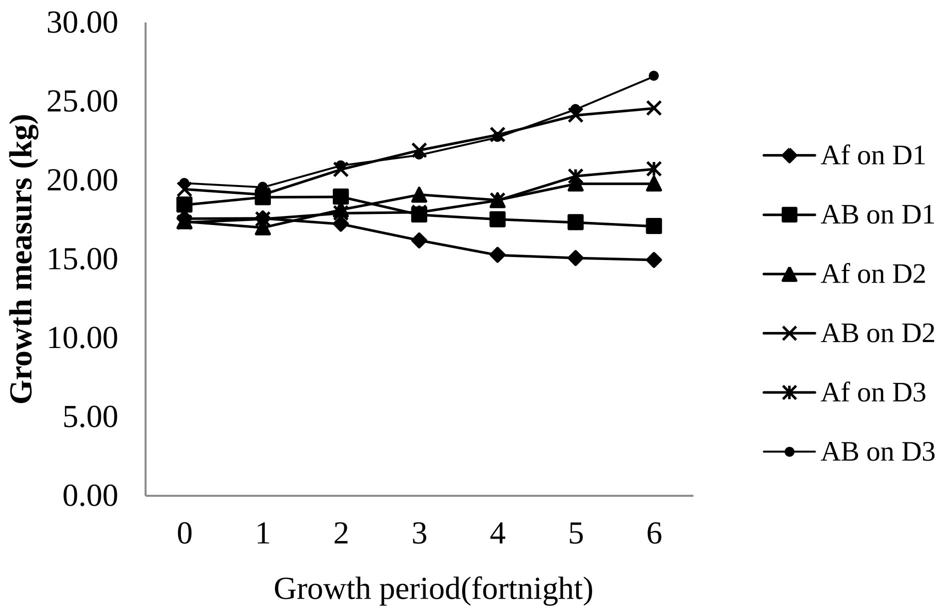

Figure 4.Mean growth (kg) measured on *Afar* and *Arsi- Bale* lambs fed *tef* straw silage alone (control, D_1) or supplemented with wheat bran *bokashi* alone (D_2) or concentrate mix (D_3) in feeding trial

Table 21: Mean growth performances and feed efficiency of *Afar* and *Arsi-Bale* lambs in feeding trial

Variable[e]	Treatment (T)[f]				Breed (B)f			p-value		
	D_1	D_2	D_3	SEM[f]	*Af*	*AB*	SEM[f]	T	B	T x B
IBW (kg)	18.01	18.41	18.57	0.56	17.49[y]	19.23[x]	0.46	0.9659	0.0082	0.5617
FBW(kg)	16.01[b]	22.18[a]	23.66[a]	0.70	18.48[y]	22.75[x]	0.57	<0.0001	<0.0001	0.1540
TWG(kg)	-1.99[b]	3.77[a]	5.09[a]	0.41	1.05[y]	3.52[x]	0.33	<0.0001	<0.0001	0.1325
ADWG($gday^{-1}$)	-26.34[c]	43.58[b]	59.853[a]	4.66	13.57[y]	39.73[x]	3.80	<0.0001	<0.0001	0.1313
FE	-0.07[c]	0.06[b]	0.09[a]	0.007	0.01[y]	0.05[x]	0.01	0.006	<0.0001	0.8208

[e]ADWG=Average daily weight gain; FBW=final body weight; IBW=Initial body weight; TWG=Total weight gain; FE=Feed efficiency; Means in columns in each effect categories superscribed by different letters are significantly different

[f]*Af*=*Afar* Breed; *AB*=*Arsi-Bale* Breed; D_1=Sole fermented TS; D_2= TS silage supplemented with WBB alone; D_3= TS silage supplemented with mix of WBB and NSC; SEM=standard error of mean; TS=*Tef* straw; Values in a row superscribed by different letters are significantly different, letters [a,b,c]standing for diet and [x,y,z] standing for breed.

Table 22: Regression of Growth (kg) performance of *Afar* and *Arsi-Bale* on Growth period influenced by breed, diet and their interaction

Treatment[f]	D_1		D_2		D_3	
Breed[f]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*
n	49	49	49	49	49	49
Equation	Wt=17.86-0.53GP	Wt=18.94-0.31GP	Wt =17.13+0.48GP	Wt =18.84+0.99GP	Wt =16.88+0.59GP	Wt =18.82+1.14 GP
R^2	0.49	0.09	0.27	0.35	0.46	0.49
p-value.	< 0.0001	< 0.0338	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[f]*Af* =*Afar*; AB=Arsi-Bale; D_1=Sole fermented *tef* straw; D_2=TS silage supplemented with wheat bran bokashi alone; D_3= TS silage supplemented with mix of wheat bran *bokashi*and*noug* seed cake; Wt=Weight; GP=Growth period (fortnight); n=number of observation; R^2=root square (Coefficient of determination).

The coefficient of determination (R^2) of *Af* lambs on D_1 and D_3 were higher than their corresponding *AB* lambs while the reverse was true for the lambs supplemented with WBB (D_2). This indicates that the growth performance of *Af* lambs fed sole TSS or supplemented with concentrate mix was more predictable than that of *AB* lambs supplemented with WBB. Furthermore, very low proportion (9.2%) of observations of *AB* lambs fed on the sole TSS followed by the *Af* lambs supplemented by WBB (27.1%) were explained by the best fit line. However, the proportion of observations explained by the best fit line of *AB* lambs were improved to 34.8% on D_2 and49% on D_3.

This indicates that the supplementation of TSS by WBB and its mix with NSC improved the predictability of live weight performance. Generally, the lambs on the supplemented diet showed higher growth and FE performance although the *AB* lambs are better than *Af* lambs.

4.4.3. Carcass Characteristics and Meat Yield

Table 23 presents the carcass characteristics and yield attribute of *AB* and *Af* lambs. The *AB* lambs showed higher ($p< 0.05$) SBW, EBW, HCW, CCW and REA than the *Af* lambs while breed did not affect ($p>0.05$) the CS, HCDP, CCDP and DPEB. Whereas, diet affected all parameters except DPEB.

The supplemented lambs were similar to each other except for REA, but improved ($p<0.05$) performance had been observed over the control lambs. Chilling shrinkage was higher ($p<0.05$) in lambs fed control diet, the lowest being for D_3 implying the positive impact of supplementation. The REA was also improved ($p<0.05$) by supplementation, the higher being for lambs on D_3 followed in the order of D_2 and D_1 groups.

Table 23: Carcass characteristics and yield of *Arsi-Bale* and *Afar* lambs fed on sole *tef* straw silageor supplemented with wheat bran *bokashi* or concentrate mix

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
SBW (kg)	16.41[b]	22.59[a]	24.11[a]	0.67	18.68[y]	23.20[x]	0.55	0.00	0.00	0.49
EBW (kg)	11.65[b]	18.27[a]	19.73[a]	0.56	14.89[y]	18.05[x]	0.45	0.00	0.00	0.36
HCW (kg)	5.46[b]	9.01[a]	10.16[a]	0.42	7.44[y]	8.91[x]	0.34	0.00	0.01	0.33
CCW (kg)	5.15[b]	8.51[a]	9.76[a]	0.41	7.12[y]	8. 43[x]	0.33	0.00	0.01	0.33
CS (%)	5.80[a]	5.56[ab]	3.81[b]	0.57	4.36	5.70	0.47	0.038	>0.05	0.92
HCDP (%)	33.31[b]	40.12[a]	41.97[a]	1.07	39.00	37.90	0.87	0.00	0.33	0.58
CCDP (%)	31.41[b]	37.91[a]	40.37[a]	1.08	37.32	35.78	0.88	0.00	0.19	0.57
DPEB (%)	46.92	49.51	51.28[a]	1.40	49.49	49.00	1.14	0.09	0.73	0.05
REA (cm^2)	3.71[c]	5.34[b]	6.75[a]	0.31	4.81[y]	5.71[x]	0.26	0.00	0.00	0.49

[e]*AB* =*Arsi-Bale* lambs; *Af*=*Afar* lambs; D_1=Sole *tef* straw silage; D_2= *tef* straw silage supplemented with WBB alone; D_3= *tef* straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean

[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area;

[a,b,c] Mean diet effects in a row superscribed by different letters are significantly different; [x,y]Mean breed effects in a row superscribed by different letters are significantly different

4.4.4. Carcass Linear Measurements

Table 24 summarizes morphometric carcass measurements. None of the measurements were affected ($p>0.05$) by breed, except LL BWandPBC, which were higher ($p<0.05$) for *AB* lambs.

Diet did not affect LL, while the supplemented groups were higher ($p<0.05$) than the control and similar to each other for BW, CW, SW, ABC, PBC, LC and CC. Yet, TC of D_2 and CL of D_3 lambs were higher ($p<0.05$) than the control lambs but similar to the other supplemented groups which were also not different ($p>0.05$) from the control groups. The breed x diet interaction effect was none ($p>0.05$) for all linear carcass measurements, except CC, for which all supplemented were similar to each other and higher ($p<0.05$) than the control lambs. However, the control *Af* lambs were not different ($p>0.05$) from *Af* lambs on D_2.

Table 24: Morphmetric carcass measurements of *Arsi-Bale* and *Afar* lambs fed on sole *tef*straw silage or supplemented with wheat brane *bokashi*or concentrate mix

Variable[f]	Treatment (T)[e]			SEMe	Breed (B)[e]		SEMe	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
CL (cm)	36.53[b]	41.39[ab]	41.94[a]	1.57	39.28	40.53	1.28	0.04	0.51	0.87
LL (cm)	27.36	27.86	27.74	0.42	26.23[y]	29.01[x]	0.35	0.74	<0.00	0.99
BW (cm)	25.12[b]	29.52[a]	29.84[a]	0.92	26.11[y]	30.05[x]	0.75	0.00	0.00	0.80
CW (cm)	10.36[b]	15.27[a]	15.50[a]	1.07	14.37	13.00	0.87	0.00	0.23	0.08
SW (cm)	16.89[b]	20.23[a]	21.34[a]	0.96	19.24	19.68	0.78	0.01	0.72	0.69
TC (cm)	51.34[b]	62.76[a]	60.04[ab]	2.80	55.32	60.42	2.29	0.02	0.14	0.84
ABC (cm)	37.6[b]	50.7[a]	49.0[a]	1.69	44.2	47.0	1.38	0.00	0.22	0.53
PBC (cm)	44.26[b]	53.34[a]	53.91[a]	0.95	48.16[y]	52.58[x]	0.78	0.00	0.00	0.79
LC	0.92[b]	1.06[a]	1.08[a]	0.04	1.00	1.04	0.03	0.01	0.46	0.74
CC (kg/cm)	0.14[b]	0.21[a]	0.23[a]	0.01	0.18	0.20	0.008	0.00	0.10	0.92

[e]AB =Arsi-Bale lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean

[f]ABC=Anterior Buttock Circumference; BW=Buttock Width; CC=Carcass compactness; CL=Carcass Length; CW=Chest Width; LC=Leg compactness; LL=Leg Length; SW=Shoulder Width; TC=Thorax Circumference; PBC=Posterior Buttock Circumference

[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.4.5. Proportion of Non-Carcass Components

The proportion to the empty body weight of non-carcass components as influenced by feeding regime and breed are elaborate here under.

4.4.5.1.Proportion of edible offal

Table 25 presents the proportion (g kg^{-1}) of edible offal components to empty body weight of *Arsi-Bale* and *Afar* lambs. The effect of interaction between breed and diet was not seen ($p>0.05$) for any of the components. Breed affected ($p<0.05$) only empty intestine (EI), tail fat (TF), heart fat (HF), total edible non-carcass fat (TENCF) and total edible offal (TEO) for which the *Af* lambs were higher ($p<0.05$) than *AB* lambs except for the EI.

The proportion to EBW of blood, heart, kidney, liver and ES were affected by neither($p>0.05$) breed nor diet. The diet effect was found ($p<0.05$) only on EI, head, tongue, mesenteric fat (MF) and TENCF. Proportion of empty stomach (ES) was higher ($p<0.05$) in D_2 lambs compared to that of D_3 while D_1 lamb were similar ($p>0.05$) to both groups. The proportion of head in the control lambs was higher ($p<0.05$) than the supplemented lambs which were not different ($p>0.05$) from each other. The control labs had higher ($p>0.05$) proportion of tongue than lambs on D_3 while that of D_2 were not statistically ($p>0.05$) different from both diet groups. The MF and TENCF were found in higher ($p>0.05$) proportion in the D_3 lambs compared to the control lambs while that of D_2 lambs was similar ($p>0.05$) to both groups.

Table 25: Proportion (g kg^{-1}) of edible offal components to empty body weight of *Arsi-Bale* and *Afar* lambs fed on sole *tef* straw silageor supplemented with wheat bran *bokashi*or concentrate mix

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Blood	72.52	60.29	65.07	8.67	60.09	71.82	7.081	0. 60	0.24	0. 90
Heart	5.49	4.88	4.93	0.20	5.06	5.15	0.16	0.06	0.69	0.98
Kidney	3.80	3.53	3.47	0.13	3.60	3.60	0.10	0.14	0.92	0.18
Liver	15.13	17.34	16.00	0.73	15.94	16.31	0.59	0.12	0.71	0.77
ES	39.61	36.87	37.24	2.28	39.40	36.53	1.86	0.65	0.30	0.78
EI	40.32[ab]	43.72[a]	38.47[b]	1.47	37.53[y]	44.13[x]	1.20	0.05	0.0004	0.11
Head	97.77[a]	73.73[b]	67.77[b]	2.30	79.69	80.10	1.88	<0.0001	0.75	0.26
Tongue	4.84[a]	4.65[ab]	3.72[b]	0.33	4.59	4.21	0.27	0.04	0.30	0.14
TF	23.63	34.20	38.44	5.30	42.17[x]	22.38[y]	4.33	0.126	0.002	0.80
HF	1.12	1.84	1.82	0.28	1.95[x]	1.24[y]	0.23	0.12	0.03	0.50
OF	5.55	5.09	6.88	0.75	6.03	5.64	0.61	0.23	0.65	0.84
MF	2.62[b]	4.74[ab]	6.79[a]	0.71	5.00	4.43	0.58	0.001	0.49	0.29
TENCF	9.29[b]	11.63[ab]	15.48[a]	1.11	13.02	11.31	0.91	0.001	0.20	0.93
TEO	239.96	231.04	225.59	5.93	241.07[x]	223.79[y]	4.84	0.23	0.02	0.56

[e]*AB* =*Arsi-Bale* lambs; *Af*=*Afar* lambs; D_1=Sole *tef* straw silage; D_2= *tef* straw silage supplemented with wheat bran *bokashi* alone; D_3= *tef* straw silage supplemented with mix of wheat bran *bokashi* and *noug* seed cake; SEM=Standard error of mean

[f]EI= Empty intestine; ES=Empty stomach; HF=Heart fat; MF= mesenteric fat; OF= Omental fat; TENCF= Total non edible carcass fat; TEO=Total Edible offal

[a,b,c] Mean diet effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

4.4.5.2.Proportion of non-edible offal

The proportion (g kg^{-1}) of inedible offal components to empty body weight of *AB* and *Af* lambs is presented in Table 26.The proportions to the EBW of lungs, oesophagus (Oeso), penis and genital fat (GF) were affected by breed for which *Af* lambs were higher ($p<0.05$) than the *AB* lambs.

Table 26: Proportion (g kg^{-1}) of inedible offal components to empty body weight of *Arsi-Bale* and *Afar* lambs fed on sole *tef* straw silageor supplemented with wheat bran *bokashi*or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Lungs	13.68[a]	11.68[b]	10.89[b]	0.45	11.38[y]	12.77[x]	0.37	0.0003	0.01	0.13
Trachea	3.67	3.37	3.63	0.28	3.58	3.54	0.23	0.79	0.87	0.07
Oeso	2.63[a]	2.10[b]	1.98[b]	0.11	2.41[x]	2.07[y]	0.09	0.0003	0.01	0. 90
Spleen	1.94	3.15	2.69	0.23	2.79	2.38	0.19	0.002	0.09	0.33
Panc	1.77	1.35	1.50	0.13	1.58	1.51	0.11	0.09	0.71	0.51
UB	1.48	1.91	2.23	0.28	1.91	1.84	0.23	0.17	0.80	0.09
GB	0.55	0.91	0.97	0.18	0.96	0.67	0.15	0.22	0.18	0.96
Penis	2.85[a]	2.40[b]	2.31[b]	0.11	2.75[x]	2.30[y]	0.09	0.004	0.002	0.66
Testis	13.62	14.17	12.50	3.38	15.86	11.06	2.76	0.94	0.23	0.26
GF	1.77[b]	3.35[a]	3.17[a]	0.31	3.54[x]	1.99[y]	0.25	0.001	<0.0001	0.06
KF	1.77[b]	2.24[b]	3.17[a]	0.23	2.45	2.34	0.18	0.0002	0.68	0.35
Feet	35.89[a]	29.22[b]	26.92[b]	0.86	31.38	30.05	0.70	<0.0001	0.22	0.84
Skin	134.93	137.77	129.73	6.87	132.89	135.16	5.61	0.71	0.801	0.45
TNEO	628.26[a]	448.15[b]	423.09[b]	20.81	485.95	516.02	17.00	<0.0001	0.19	0.72

[e]*AB* =*Arsi-bale* lambs; *Af*=*Afar* lambs; D_1=Sole *tef* straw silage; D_2= *tef* straw silage supplemented with WBB alone; D_3= *tef* straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean

[f]GB=Gall bladder; GF=Genital fat; KF=kidney fat; Oeso=Oesophagus; Panc=Pancreas UB=Urinary bladder; TNEO=Total inedible offal

[a,b,c] Mean diet effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

Trachea, spleen, pancreas, urinary bladder (UB), gall bladder (GB), testis, kidney fat (KF), feet, skin and total non-edible offal (TNEO) were not affected ($p>0.05$) by breed.The proportion to the EBW of trachea, spleen, pancreas, UB, GB, testis and skin were not affected ($p>0.05$) by diet. The proportion of lungs, oesophagus, penis, feet and TNEO were higher ($p<0.05$) for the control diet lambs than both supplemented groups which were not different ($p>0.05$) from each other. The supplemented lambs scored similar ($p>0.05$) to each other but higher ($p<0.05$) proportion of genital fat (GF) over the control groups while proportion of kidney fat (KF) of lambs on D_3 was higher ($p<0.05$) than the control and D_2 groups which were not different ($p>0.05$) from each other.

4.4.6. Physicochemical characteristics and chemical composition of meat

The physicochemical characteristics and chemical composition of the meat is presented in Table 27. The BDL, the pH_{45} and a* color measure were not ($p>0.05$) affected by breed or diet. Breed affected only the b*color measure and fat content being higher ($p<0.05$) for *Af* than for *AB* lambs.

Regarding diet effects, the pH_u was found higher ($p<0.05$) for control diet compared to D_3, while D_2 was not different ($p<0.05$) from both control and D_3. The lightness (L*) was lower ($p<0.05$) in control diet than in D_3 while D_2 was not different ($p<0.05$) from both control and D_3. Chemical composition was not affected by breed except fat content, which was also affected by diet and the interaction as well, while moisture and ash contents were affected by diet only.

Table 27: Least square mean physicochemical characteristics and chemical composition of meat of *Arsi-Bale* and *Afar* lambs fed on sole *tef* straw silage or supplemented with wheat bran *bokashi*or concentrate mix

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
BDL (%) [f]	13.45	12.66	11.42	8.81	11.28	11.04	1.25	0.07	0.25	0.63
pH[f]										
pH_{45}	6.30	6.34	6.40	6.13	6.34	6.29	1.13	0.91	0.36	0.49
pH_u	5.66[a]	6.19[a]	5.65[ab]	5.55[ab]	5.20[b]	5.46[b]	0.22	0.00	0.33	0.79
Color[f]										
L*	32.86[b]	28.76[b]	32.28[ab]	34.98[ab]	37.03[a]	34.00[a]	1.54	0.01	0.25	0.08
a*	12.77	14.08	15.89	13.72	14.18	14.80	0.75	0.17	0.90	0.07
b*	14.80	13.86	14.81	14.33	14.92	14.28	0.41	0.76	0.047	0.85
Moisture (%) and proximate chemical composition (%DM) [f]										
Moisture	72.81[a]	73.50[a]	72.20[ab]	72.75[ab]	71.72[b]	71.28[b]	0.50	0.01	0.52	0.47
CP	20.65	21.65	21.01	20.01	20.12	20.40	0.44	0.12	0.78	0.09
Ash	4.89[a]	4.84[a]	4.44[ab]	4.53[ab]	4.33[b]	4.19[b]	0.18	0.01	0.83	0.84
Fat	6.35[s]	3.66[t]	9.19[r]	8.97[r]	11.83[q]	9.97[qr]	0.48	0.00	0.00	0.02

[e]*AB*=*Arsi-Bale* Breed; *Af*=*Afar* Breed; D_1=Sole TSS; D_2=TSS supplemented with WBB alone; D_3=TSSsupplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=*Tef* straw;

[f]BDL = Bag drip loss; L* Measure Lightness and varies from 100 for perfect white to zero for black, a* measure redness when +ve, grey when zero, green when -ve, b* measure yellowness when +ve, grey when zero, blue when -ve ; pH_{45} = pH measure taken 45 minutes after flaying; pH_u= pH measure taken after 24 hours chilling; CP = Crude protein;

[a,b,c] Mean diet effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different; [r,r,s,t] Mean diet x breed interaction effects in a row superscribed by different letters are significantly different

The CP content was not influenced by either of the effects. The moisture and ash contents of the meat from lambs fed the control diet were higher ($p>0.05$) than those of lambs on D_3 while lambs on D_2 were in between with no variation from both.

In contrary, the fat content was higher ($p<0.05$) in meat from the lambs fed supplemented diets than those on control, *Af* lambs on D_3 being the highest ($p< 0.05$) followed by *AB* lambs on D_3 which in turn was not different from *Af* lambs on D_2. The fat content of samples from *Af* lambs on the control diet was also higher ($p< 0.05$) than that of *AB* lambs given the same diet. This may lead to the generalization that *Af* lambs were more fatty than the *AB* lambs.

4.4.7. The sensory eating quality of meat

The sensory eating quality of meat of *AB* and *Af* lambs is summarized in Table 28. As opposed to diet, breed did not affect any attribute of the sensory eating qualities.

Table 28: Least square mean rating of sensory eating quality of meat of *Arsi-Bale* and *Afar* lambs fed on sole *tef* straw silageor supplemented with weat bran *bokashi* or concentrate mix

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
Tenderness	4.07^b	3.97^b	5.69^a	5.25^a	6.18^a	5.50^a	0.32	0.00	0.13	0.66
Juiciness	3.63^b	4.17^b	5.13^a	4.98^a	5.04^a	5.25^a	0.26	0.00	0.35	0.45
Flavor	3.90^b	4.38^b	5.57^a	5.02^a	5.66^a	5.41^a	0.24	0.00	0.59	0.09
GenrAccep[f]	3.48^s	4.20^{rs}	5.79^q	5.13^{qr}	5.93^q	5.54^q	0.23	0.00	0.54	0.01

[e]*AB*=*Arsi-Bale*Breed; *Af*=*Afar* Breed; D_1=Sole fermented TS; D_2=TSS supplemented with weat bran *bokashi*alone; D_3=*Tef* straw silage supplemented with mix of weat bran *bokashi*and*noug* seed cake; SEM.=standard error of mean;

[f]GenrAccep= General Acceptability

[a,b,c] Mean diet effects in a row superscribed by different letters are significantly different; q,r,s Mean breed x diet interaction effects in a row superscribed by different letters are significantly different; [x,y] Mean breed effects in a row superscribed by different letters are significantly different

All the eating quality attributes were higher ($p<0.05$) for meat from the supplemented over the control lambs, though they were not different from each other. The control lambs of both breeds were also not different ($p>0.05$) from each other for all attributes of meat sensory eating quality evaluated. Nevertheless, the meat samples from *Af* lambs on D_1 were less ($p>0.05$) tender than that of supplemented *Af* lambs but not different from the other lambs. The juiciness, flavor and general acceptability were all higher ($p>0.05$) for the supplemented lambs of both breeds compared to the control *Af* lambs but not different from the control *AB* lambs.

5. DISCUSSION

The results of a survey and four experiments are discussed under the following sub-sections.

5.1. Impact of Transportation on Body Weight, Mortality and Carcass Condemnation in Export Abattoirs in Bishoftu and Modjo

Results of a survey investigated the total sheep and goats slaughtered in six export abattoirs, and the mortality rate and carcass condemnation are discussed here under.

5.1.1. Total number of slaughter of sheep and goats in the export abattoirs

Similar to the result obtained in the present study earlier authors reported the mode of transportation of animals in Ethiopia from production area via primary to secondary market is trekking while trucking with ordinary trucks is used from secondary and tertiary market to terminal market or abattoirs (Berhanu*et al.*, 2007; Dugasa and Belachew, 2009; Jerlström, 2013).

Most used breed of both sheep and goat found recorded are originated in the low land areas. This could be due to the darkening problem of highland sheep muttons and goat meat (Girma*et al.*, 2010). In support of this, Akililu*et al.* (2005) have also reported that the export of sheep and goat carcass had been limited only to the animal breeds originated in the lowland areas of Ethiopia.

5.1.2. Mortality and weight loss of transported sheep and goats

As seen in the present study, Padalino*et al.* (2018) reported an average mortality rate of 0.038% of transported sheep and goats across European countries to Italy with especially designed truck for animal transportation. Similarly, Makin *et al.* (2009) studied the mortality rate during road transportation of sheep in Australia and found an overall incidence of mortality of 6.54 deaths per 10,000 (0.06%mortality). Despite the use of inappropriate transportation truck and uncomfortable road infrastructure (Berhanu*et al.*, 2007; Hailemariam *et al.*, 2008), the result of the present study on the mortality rate of the sheep and goats transported to the abattoirs appeared to be similar to the reports of other studies that used trucks designed for livestock transportation and derived over relatively better comfortable roads. This could be because the live animal traders supply the animals to the abattoirs after keeping them for conditioning and avoiding the dead animals, as a result of which the abattoirs had no or limited record of mortality of the transported animals (Hailemariam *et al.*, 2008, Duguma*et al.*, 2012).

Factors affecting the safety of livestock during road transport by trucking were reported to be truck design, stocking density, ventilation in the vehicle, the driver's skill and road quality (Fazio and Ferlazzo, 2003). Hence, it is so obvious that transporting livestock using ordinary vehicles usually results injuries, stress and suffering that may end up with weight loss (shrinkage) or mortality (Javis and Cockram, 1994; Ayo and Oladele, 1996). Vignesh *et al.* (2018) studied effect of trucking on sheep and goat whose age was 6-10 months and found a very low weight loss (0.97% and 3.1 % for short (20km) and long distance (150km) transport, respectively) compared to the result of the present study. The variability in the weight loss between the two studies might have been attributed to the fact that the temperature and relative humidity of the transport environment in their study were within the comfort zone of the animals while the animals in the present study were transported across varying climatic conditions. Yet, Zhong *et al.* (2011) reported figures a bit higher than the present study with weight losses of 7.18%, 9.04%, and 9.57% of 6, 12 and 24-month old sheep, respectively after an 8-hour journey. Fisher *et al.* (2010) also reported that 4–5-year-old sheep trucked for 12, 30 and 48hours decreased live weight by 4.9%, 9.8% and 12.1%, respectively which is the range in which the result of the present study is found.

5.1.3. Carcass condemnation due to transportation of live sheep and goats

Aynalem*et al.* (2015), from their study held for seven months in an export abattoir in Bishoftutown, reported a 3% full carcass condemnation due to bruise and discoloration, which are most probably the result of transportation of live animals (Mitchell and Slough, 1980; Ishmael, 2014). In another study conducted in another export abattoir in Bishoftu, Sisay*et al.* (2013) reported a 4.71% full carcass condemnation due to bruise and discoloration. The findings of these studies were far higher than the present study, which could be the reflection of the differences in year of study, duration and abattoir coverage between them and the present study. The former studies were conducted in a single abattoir for less than one-year duration while the present study was conducted in six abattoirs for duration of three years.

Yesihak and Webb (2015) studied rate and causes of cattle carcass condemnation in three abattoirs in Ethiopia for four years of duration. They found 0.014% full carcass condemnation caused by bruising and pneumonia that could possibly attributed to pre-slaughter transportation fatigue. This result is nearly similar to the present study though their studied species of slaughtered animals were different. Conversely, the partial carcass condemnation they reported was 34.11%, which is far higher than the 0.12% in the present study. The large difference in partial carcass condemnation could be due to the difference between the two studies in species of animals slaughtered, locations of abattoirs studied, and the location where the animals were transported which might have been different in road quality and climatic conditions.

5.2. Impact of Mode of Transportation on Carcass Characteristics and Meat Quality of *Arsi-Bale* and *Afar lambs*

The result of the experiment that evaluate the effect of pre-slaughter trekking or trucking of *Arsi-Bale* and *Afar* sheep breeds on carcass characteristics and meat quality are discussed here under.

*5.2.1. Carcass characteristics and meat yield***of** *Arsi-Bale and Afar lambstransported by trekking or tracking*

Ramírez-Retamal and Morales (2014), from theirreview, found that breed has effect on carcass quality and characteristics. Confirming the result of the present study, Shashie*et al.* (2018), from their study that compared three Ethiopian sheep breeds, reported significant breed effect on all the carcass traits considered in this study. Other authors also revealed similar result of effect of breed significantly affecting different carcass traits in sheep (Peraza-Mercado *et al*., 2010; Cloete *et al*., 2012).

The lower EBW of the NT lambs seen could best be explained by the lower gut content of the transported lambs (Table14) owing to dehydration and elevated feces dropping resulted from transportation stress (Knowles *et al*., 1994; Hogan *et al*., 2007; Kadim*et al*., 2007). In agreement to the present study, Kadim*et al.* (2007) observed significant live weight loss due to transportation and non-significant difference on HCW and CCW between lambs of road transported and non-transported groups. In disagreement with the present study Zhong*et al.* (2011) reported significant difference between lambs of road transported and non-transported groups on HCW and HCDP.

The disparity seen among and between the prior and the present study could be attributed to the difference in the breed of the lambs, the type of vehicle used, the type of the road, distance and duration of the transport (Knowles, 1998). The lack of statistical difference between transported and non-transported and among the mode of transportation in the HCW and CCW could be explained by the fact that the transportation loss could be due to their difference in gut content. This is evidenced by Knowles*et al*. (1996) who reported that the body weight loss of sheep during transport is mainly attributed to feed and water deprivation than the other stress conditions incurred by transportation.

5.2.2. *Carcass linear measurements of Arsi-Bale and Afar lambs transported by trekking or trucking*

As summarized by Guerrero *et al.* (2013) difference among breeds were seen in morphology and tissue composition. de Lima *et al*. (2016) had also indicated on their review that breed has a large effect on carcass morphology. In support of the present study,Shashie*etal*. (2018) reported significant difference between three Ethiopian breeds on CL, hind leg length and CC. Tsegay*et al.* (2012) also reported significant differences between black head *Ogaden*, *Hararghe* highland, and their F_1 cross with Dorper sheep for morphometric measurements of their carcass except CC thatdisagree with the result of the present study.

The carcass compactness in the present study was within the range of 185.1 to 240.2 g/cm reported by Tsegay*et al.* (2012) for black head *Ogaden, Hararghe* highland, and their F_1 cross with Dorper sheep and comparable with the reported ofShashie*et al.*(2018) for BHO, *Washera* and *Horo* sheep breeds and higher than the values (133 to 159 g/cm) reported for Red Maasai sheep (Safari *et al*., 2011). The variation in CC between the breeds in the present study seems attributed to the difference in CCW and carcass length (Camacho *et al*., 2015). This is further supported by the report of Cañeque*et al*. (2004) and Safari *et al*. (2011) that declared significant correlation of CC with slaughter body weight, HCW and LC. Because of the higher leg and the carcass compactness values, the *AB* lambs have preferred conformations indicating theirhigher flesh yield (Fozooni and Zamiri, 2007). As animals with good conformation are supposed to have carcasses with more lean meat, the *AB* lambs were proved to have higher lean meat yield compared to *Af* lambs (Nsoso*et al*., 2000).

Though literature is lacking on lambs' morphometriccarcass measurements affected by transportation and mode of transportation, Ekiz*et al*. (2012) reported no effect of transportation on carcass linear measurements. This confirms the result of the present study.

5.2.3. Proportion of non-carcass components of Arsi-Bale and Afar lambs transported by trekking or trucking

There is no literature that reported the effect of mode of transportation comparing trekking and trucking. The studies done to evaluate issues related to effect of transportation were dedicated to factor other than trekking and trucking like stocking rate on trucks, partitioning of trucks, time of rest during and/or after transporting, deprivation of feed and water during and/or after transportation (Knowles *et al*., 1996; Knowles, 1998; Knowles and Warriss, 2000; Hogan *et al*., 2007;Kadim*et al.*, 2007;Fisher *et al.*,2010;Kadim*et al*., 2010;Adzitey, 2011;Miranda-de la Lama*et al*., 2014; Teke*et al*., 2014;Vergara *et al*., 2017).Furthermore, the same studies did not provide data on non-carcass components (offal).

5.2.3.1. Impact of mode of transportation on proportion of edible offal

Influenced by the culture of the community in concern, the non-carcass components can be considered as inedible waste or as most liked dishes among which liver, kidney, intestines, tongue and stomach are most preferred by Ethiopian consumers (Ermias*et al.*, 2000).

The higher proportion of omental, mesenteric and total edible non-carcass fat in NT lambs than the transported groups could be attributed to the relatively comfortable housing and management under which NT groups were kept during their five days stay at the abattoir. The lack of effect of both transportation, breed and their interaction on the proportion of EI, tongue, TF and HF could be due to short duration of the transport to affect the metabolic activity of the organs and their fat tissues (Kirton*et al.*, 1972; Joy *et al.* 2008) as well as the similarity between the breeds in the relative weight of the organs and their fat tissues (Kirton*et al.*, 1972). However, as opposed to the present study authors reported significant breed effect on the same and other organs (Peraza-Mercado *et al.*, 2010;Boujenane, 2015).

Confirming the result of the present study, Shashie*et al.* (2018) observed no significant difference among three Ethiopian sheep breeds on proportion to EBW of heart, kidney, tongue and stomach. Macit*et al.* (2002) also reported a confirming result of three Turkish sheep breeds showing no statistical difference in the proportion of non-carcass components. In disagreement with the present study, Ekiz*et al*. (2012) did not observe significant variation between transported and non-transported lambs on edible offal.

5.2.3.2. Impact of mode of transportation on proportion of non-edible offal

Shashie*et al.* (2018) found significantly different proportion of oesophagus, gut content and penis among three Ethiopian sheep breeds, which confirmed the result of the present study. Divergent from the present study, the same authors also reported significant difference between the breeds on proportion of pancreas, skin, legs and testis. Similar to the present study Macit*et al.* (2002) found no significant difference between three sheep breeds on feet, skin, testis and lungs. In dissimilarity with the present study, Ekiz*et al*. (2012) did not observe significant variation between transported and non-transported lambs on inedible offal except gut content, which made it similar with the present study.

5.2.4. Physicochemical characteristics and chemical composition of meat of Arsi-Bale and Afar lambs transported by trekking or trucking

As thereview of Ponnampalam*et al.* (2017) indicated most research reported evidence of variability among different sheep breeds on pH and color of meat.However, Teixeira*et al.* (2005) showed a confirming result to the present study of no breed effect on ultimate pH and a* color coordinate. Yet, they also found a disagreed result of significant difference on b* color coordinate and no difference on L* color coordinate between two sheep breeds.

According to the review of Ramírez-Retamal and Morales (2014),despite the importance that breed can have on meat quality, some authors attach more importance to other factors, like the age of the animal and the type of feed.Associated with breed, however, these differences may also be influenced by factors like the place of origin of the animal (Girma*et al*., 2010; Merera*et al.*, 2010; Merera*et al*., 2013;Merera*et al*., 2015;).

de Lima*et al.* (2016) reviewed the effect of breed and reported that literature describes variations in color scores, juiciness and water holding capacity between breeds which seems that the result of the present study is confirmed with the exception of the pH and b*color value which deviates from the general conclusion of the review.

Validating the result of the present study, there are reports for which breed effect is non-significant for b* color coordinate (Esenbuga*etal*., 2009) and significant for drip los (Peraza-Mercado *etal*., 2010), L* (Peraza-Mercado *etal*., 2010; Yucca, 2012) and a* color coordinates (Peraza-Mercado *etal*., 2010) of sheep meat. There are also works that reported results contrasting to the present study that breed effect was seen significant on ultimate pH (Yucca, 2012), b* color coordinate (Peraza-Mercado *etal*., 2010; Yucca, 2012) andnon-significant L* (Esenbuga*etal*., 2009) and a*(Esenbuga*etal*., 2009; Yucca, 2012) color coordinates of sheep meat.

Similar to the present study, Kadim*et al*. (2007 &2010) found effect of transportation being non-significant for color (L*, a* and b*) coordinates and significant for ultimate pH, the meat from transported being higher than the meat from non-transported sheep. Likewise, other reports also indicate muscles from stressed sheep had significantly higher ultimate pH values than non-stressed counterparts (Apple *et al*., 1995). Although several authors (Geesink*et al.*, 2001; Kannan *et. al.*, 2003; Honikel, 2004; Kadimet *al.,* 2006; Zhong*et al*., 2011) agreed that transportation elevates ultimate pH of meat as a result of glycogen depletion due to pre-slaughter stress,Ekiz*et al*. (2012) reported that the rise in pH of sheep is more aggravated by short than long duration of transportation. On the other hand, as opposed to early reports that indicated sheep are more tolerant to stress (Fisher *et al*., 2010; Cockram*et al*., 2012;Ponnampalamet *al*., 2017), it has been observed in the present study that meat pH was significantly different between transported and non-transported lambs. This could be attributed to the short journey covered and no rest and no feed was given to the lambs before slaughter in the present study.It is fact that sheep are more prone to stress caused by short and early stage of journey (Kadim*et al*., 2009; Ekiz*et al*., 2012) and the effect remains longer if not rested and fed (Merera*et al.*,2013). This is probably the reason why the ultimate pHs of the transported lambs were significantly higher than the non-transported lambs as the duration of the trucking in the present study was short.

The present study revealed that the meat harvested from all transport groups can be considered as good quality (Table 15) as their color value fall in the range L* ≥34 and a* ≥ 9.5 (Khliji*etal*., 2010) and the ultimate pH fall in the range 5.4 to 5.8 (MSA, 2015) which are readily acceptable by consumers.

5.2.5. *Sensory eating quality of meat of Arsi-Bale and Afar lambs transported by trekking or trucking*

From their review on factors affecting meat quality traits,Guerrero *et al.* (2013) found disagreement among various research works on effect of genotypes on sensory eating quality as some found no effect and others reported considerable variability between breeds. Yet, they drew a generalization stated as a rule that the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight, most differences being probably justified by differences in precocity or in muscularity levels.

There is a serious shortage of literature that report effect of transportation and/or mode of transportation on sensory attribute of meat-eating quality. The available reports concentrate on effects like transport duration (María*et al.*, 2003; Villarroel*et al.*, 2003), road type (Lama *et al.*, 2011), feed and water deprivation before and during transport (Hogan *et al*., 2007), logistic stopover during transport (Miranda-de la Lama *et al*., 2012) and others.

From the available literatures, the reports appeared to have a contrasting result to the present study with significant effect of transportation. Kadim*et al.* (2010) found that muscles from non-transported sheep had a significantly lower shear force value compared to transported sheep. Likewise, Kadim*et al.* (2006) and Apple *et al.* (1995) found that meat from non-transported sheep was significantly tenderer than that from transported ones. Yet, Chrystall*et al.* (1982) found a contrasting result to the formerly stated works that the muscle from sheep chased to exhaustion by dogs was tenderer than those from their non-transported counterparts.

5.3. *Tef* Straw Silage Making Experiment

Results of *tef* straw silage making are discussed in detail under the following sub-titles

5.3.1. Sensory evaluation of samples of tef straw silage

There is shortage of literature on *tef* straw silage treated with EM or other microbial inoculums. But, from general straw silage characteristics it can be observed that, regardless of the EM application rate and the ensiling duration, the TS silage in the present study was of good quality category as it has maintained the color of the dry straw with minimum change (Kaiser and Piltz, 2004). This is confirmed by its good yogurt smell indicating that lactic acid was sufficiently produced by the fermentative action of lactic acid bacteria in the EM solution (Higa and Wididana, 1991; Kim *et al.*, 2017; Zhang *et al.*, 2017). Furthermore, the absence of mould, ill color and bad smell might have been attributed to the dominance of the desirable over undesirable microorganisms (Kaiser and Piltz, 2004; Oladosu*et al*, 2016).

5.3.2. Nutrient composition, in-vitro digestibility and pH of tef straw silage

Daniel *et al* (2016) obtained 4.17 pH in EM fermented chopped sorghum stover at a rate of 950ml/kg DM and ensiled for 21 days which is relatively similar to the 4.24 pH value of the TSSensiled for 28 days with EM application rate of 750ml/kg in this study. The slight difference seen between the two studies could be attributed to the difference in the substrate (TS vs sorghum stover), the EM application rate and ensiling duration.

There is general agreement that a silage pH below 4.5 is an indicator for the occurrence of adequate anaerobic fermentation that increases hydrolysis of fiber fractions of the feed (FAO, 1999). Accordingly, the results of the current study indicate that the TS ensiled with the EM application rate of 750ml/kg could be categorized as good silage as its pH values was less than 4.5.

In support of the present study, Samsudin*et al.* (2013) reported significant effect of EM inoculation of fungal-treated rice straw on CP and OM content. Conversely, they also found a significant effect on NDFand ADF contents, which could be attributed to the fungal treatment in contrast to water socking of the TS in the present study. Furthermore, the same authors reported significant effect of duration of fermentation on composition of some nutrient and DM digestibility with a decreasing trend of fibers with increasing fermentation period, confirming further degradation. Their result had certain similarity with the result of the present study for which the OM and CP contents and IVOMD of the TSSwere higher at EP_{21} than EP_{14}, though they were lower at EP_{28}. The lower content of these nutrients at the higher EP and AR suggests that DM might have been lost (Kung, 2013) due to increased solubilization (Mulugeta, 2015). In support of this, Higa and Wididana (1991) stated that the action of the microorganisms in the EM liberates various low-molecular weight organic compounds by decomposition of complex compound that can either be used up by the microbes (Widjaja*et al.*, 2016) or released as gaseous los.

5.4. Feeding and Digestibility Trials

The results of the feeding and digestibility trials from the feed and the animal point of view are discussed as follows.

5.4.1. Nutrient intake of experimental lambs

Supporting the present study, Tsegay*et al.* (2012) and Ayele*et al.* (2017) revealed that different sheep breeds were noted showing different nutrient intake. Moreover, in agreement with this study, Getahun (2014) showed significant breed effect that *Af* lambs had higher total DM intake than BHO lambs in which TS basal feed was supplemented with concentrates. Tesfay and Solomon (2009) also reported that *Af* lambs fed on sole untreated TS exhibiting lower intakes of DM and CP compared to the supplemented ones.

In agreement with the present study, improvement in DM and nutrient intakes due to supplementation is usually observed in various studies. As a case in point, Washera lambs fed on supplemented urea treated rice straw were noted to have higher DMI compared to the non-supplemented lambs (Melese*et al.*, 2014). Takele and Getachew (2011) also reported that feed intake of Horro lambs fed vetch haulm was improved because of supplementation with wheat bran, acacia albida leaf meal or their mixtures. However, similar with the present study, Mulugeta and Gebrehiwot (2013) also reported DM and OM intakes of untreated TS basal feed was increased with decreasing level of supplementation. The possible explanation for this could be the low CP content of the feed used in the control group (Table 7) obliged the lambs to seek to meet their nutrient requirement only by consuming more TSS basal feed. This is an indication of substitution effect of supplements at the expense of TSS basal diet. Several prior works done on various Ethiopian sheep breeds also revealed confirmation of substitution effect of supplementation of low-quality basal feed (Dawit and Solomon, 2008;Degu *et al.*, 2009; Hagos and Melaku, 2009; Mulugeta and Gebrehiwot, 2013) and higher substitution tendency of *Af* sheep (Getahun, 2014).

This indicates that the *Af* lambs have more tendency of depending on concentrate feed which may categories them as a breed of more suitability for intensive management. On the contrary, Ayele*et al.* (2017) and Gelgelo*et al.* (2017) reported that daily hay DMI was not affected by supplementation. The researchers explained that the possible reason for the lack of substitution effect probably is a complementary effect of the supplements on the basal diet which was not the case in this study.

5.4.2. Dry matter and nutrient digestibility

In his study that compared two breeds fed on supplemented TS, Getahun (2014) found *Af* lambs with superior digestibility of DM, CP, NDF and ADF over BHO lambs. His report confirmed the result of the present study for which the *Af* lambs performed better than the *AB* lambs except for CPD. The present study is in agreement with the result of Tesfaye and Solomon (2009) and Gelgelo*et al.* (2017) for DMD and OMD; and in contrast for CPD. In disparity with result of the present study that found no significant difference among diet groups, supplementation of low-quality diet with oil seed cakes were reported (Degu *et al.*, 2009) improving apparent digestibility of CP.

The lack of supplementation effect on CPD in the present study could be best explained by the decomposing ability of the microbes in the EM that might have exhaustively solubilized the complex nitrogenous compounds in TSS into low-molecular weight organic compounds that can readily be absorbed (Higa and Wididana, 1991), leaving no or little for rumen microbial fermentation as well as digestion by the enzymes of the lambs. Hence, the proportion of the digestible nitrogen in the experimental diets and the corresponding feces appeared to be statistically similar among the diet groups. This is further evidenced by improved CPI (Table 19) and growth performance of the supplemented lambs (Table 21) indicating availability for absorption of CP without further degrading the nitrogenous compounds in the TSS.

Partly in-line with this study Ayele*et al.* (2017) observed no interaction between breed and diet for digestibility of DM and nutrients. However, Getahun (2014) found significant effect of breed with diet interaction on DM and nutrient apparent digestibility in *Af* and BHO sheep fed on sole or supplemented untreated TS. This variability could be attributed to the difference in the breeds of sheep and the experimental deists used.

5.4.3. Growth performance of experimental lambs

As opposed to this study, the result of an experiment that compared *Af* with BHO lambs (Getahun, 2014) indicated that FBW of lambs increased ($p<0.0001$) with increased concentrate level, the *Af* lambs showing higher performance. The inferiority of *Af* lambs in the present study could be attributed to the difference in the sheep breeds compared with the *Af* sheep (*AB* vs *BHO*), the mean initial body weight of the *Af* and the corresponding breeds (17.49 and 19.23 vs 18.26 and 17.41 kg *Af* and *AB* vs *Af* and BHO sheep in the present study vs in the Getahun (2014) study, respectively) and season of the study periods (wet vs dry season). Furthermore, the *Af* lambs used in this experiment were under heavy drought stress before they join the experiment which might have reduced their responsiveness for the feeding regime of the study.

Confirming the result of the present study several earlier findings (Degu *et al.*, 2009; Hagos and Melaku, 2009; Mulugeta and Gebrehiwot, 2013; Getahun, 2014; Melese*et al.*, 2014; Gelgelo*et al.*, 2017) indicated that the ADWG, FBW and the FE were higher for supplemented sheep. The increased ADWG and FE of the supplemented lambs could be attributed to the higher intake of nutrients (Table 19) that might have provided nutrients available for absorption. It can also be the result of enhanced protein availability due to microbial protein synthesis by the EM from non-protein nitrogen that otherwise can be lost (Higa and Wididana, 1991).

The inferior growth performance and FE of *Af* lambs may be because they had higher metabolic loss or use for hair growth (Graham and Searle, 1982) of nutrients than their corresponding *AB* lambs. This is confirmed by their better performance in nutrients intake (Table 19) and digestibility (Table 20), while their growth performance was lower than the *AB* lambs fed the same diet (Table 21 and Figure 4).

5.4.4. Carcass characteristics and yield

Similar to the present study, others studies reported that breed affects the carcass characteristics and yield traits (Macit*et al.*, 2002; Kashan *et al.*, 2005; Flakemore*et al.*, 2015). From his study used supplemented untreated TS basal diet, Getahun (2014) reported result that indicated superiority of *Af* over black head Ogaden (BHO) lambs in SBW, HCW and HCDP.

The lower CS and higher REA of the D_3 group may show the betterment of WBB and NSC mix than sole WBB supplementation for higher meat yield with minimum storage loss. Similarly, Tesfay and Solomon (2009) found improvement in SBW, EBW, HCW and REA on *Af* rams fed supplemented untreated TS. In his study that compare straws of five faba bean varieties supplemented with concentrate mix of untreated wheat bran and NSC fed to *AB* sheep *ad libitum*, Teklu (2016) found no difference incarcass characteristics, dressing percentage and REA except SBW and EBW. His report confirmed the lack of difference in carcass characteristics of this study, but opposed the REA result which could be due to the difference in the basal diets.

In another study used supplemented urea treated barley straw (Abebe and Yoseph, 2015)*AB* sheep scored increasingly higher SBW, EBW, HCW and REA with increasing level of supplementation. Their results support the findings of the present study as all supplemented lambs were higher than the control on these parameters. Melese*et al.* (2017) also confirmed the same trend of carcass traits improvement on *Washera* sheep due to supplementation of hay by concentrates. According to Lloyd *et al.* (1981) and Žgur*et al.* (2003), higher values of carcass traits are apparent for heavier lambs. This is directly in support of the findings of the present study as all higher traits except CS (higher value implies lower quality) were of heavier lambs.

5.4.5. Carcass linear measurements

In agreement with this study, other studies (Macit*et al.*, 2002; Popova and Marinova 2013) found no effect of breed on CL. They also found no difference between breeds on LL, as opposed to the present study. Concurring with the present study, two Ethiopian local sheep breeds and their cross with Dorper were found to be different for measurements of LL, BW and PBC (Tsegay*et al.*, 2012). The same authors also reported contrary result to the present study of different CL, ABC, TC, SW and CW measurements and similar CC measurements. These differences in result might be attributed to the difference in the breeds and diets used in the experiments.

Supporting the results of the present study Majdoub-Mathlouthi*et al.* (2013) who fed oat hay basal diet supplemented with concentrate to weaned Barbarine lambs, reported that diet affected LC and CC, and did not affect LL and rump circumference. The same authors also found contradictory result of a no diet effect on CL. Likewise, Ahmed *et al.* (2012) reported no effect of diet on LL of *Af* sheep fed on Rhodes grass hay basal diet supplemented by *Prosopisjuliflora* pods or/and leaves. In contrast, Tsegay*et al.* (2012) reported diet affected LL and did not affect CL, TC and SW. They also found similar results with the present study that diet effect was seen on PBC, ABC, BW, CW and CC. Similar to the present, previous studies also observed no breed and diet interaction effects (Tsegay*et al.*, 2012; Getahun, 2014).

5.4.6. Proportion of non-carcass components

Based on the culture of the target community the non-carcass components can be either edible or non-edible. These are discussed under the following sub-headings.

5.4.6.1.Proportion of edible offal

In agreement to the present study, Singh *et al.* (2003) reported breed effect on percentage of TEO. Further, Macit*et al.* (2002) reported no effect of breed on percentage of head, liver and heart which confirmed the result of the present study. In another study that compared hair and wool type breeds of Mexican sheep, no differences were found on proportion of head, blood and gastro-intestinal viscera (Hernández-Cruz *et al.*, 2009). Their result is inline with the present study except that EI and ES were reported in combination as gastro-intestinal viscera.

However, a contrary result of genotype affecting percentage of liver, heart and head was found by Cividini*et al.* (2012). In their study aimed to evaluate effect of days of rest before slaughter, Abebe *et al.* (2010) found no difference between *AB* and BHO sheep on percentage of head, heart and liver which is similar to the present study. Conversely, genotype was found affecting the same components in an experiment done on the same breeds with the aim of evaluating effect of length of feeding period before slaughter (Merera, 2010).

Confirming the present study, Majdoub-Mathlouthi*et al.* (2013) reported diet affecting proportion of empty gut and not affecting proportion of heart. The same authors also reported a contradictory result to the present study that they found effect of diet on proportion of liver and kidney. However, similar to this study, none diet effect on percentage of TEO was reported (Singh *et al.*, 2003).

5.4.6.2.Proportion of non-edible offal

Supporting the result of this study, genotype was reported to have effect on percentage of lungs (Cividini*et al.*, 2012). In contrast to the present study, the same authors found that genotype affected percentage of spleen and skin. However, Singh *et al.* (2003) reported no effect of breed on percentage of TNEO that confirm the results of the present study. Hair and wool type sheep comparison revealed effect on skin and no effect on feet percentage (Hernández-Cruz *et al.*, 2009), which is in disagreement with the present study. Similar to the present study, Macit*et al.* (2002) found no differences between three sheep breeds on proportion of spleen, testis, feet and skin. However, in contrast to this study, they also found no difference on the proportion of lungs.

Contrasting the present study, in an experiment investigating the effect of days of rest before slaughter, *AB* and BHO sheep were reported as different on percentage of spleen and skin (Abebe *et al.*, 2010). As the same time, in support of this study, they also found testis not affected by breed. On the other hand, Merera*et al.* (2010), in their study examining the impact of length of feeding period before slaughter, revealed a contrasting result of difference between the two sheep breeds on percentage of skin and similar result of no variation on feet and testis percentages.

In contrary, Singh *et al.* (2003) found similar percentage of TNEO among lambs fed different rations. Majdoub-Mathlouthi*et al.* (2013) also reported a contradicting result of percentage of testis affected by diet.

5.4.7. Physicochemical characteristics and chemical composition of meat

Hopkins and Fogarty (1998) found no effect of genotype on pH and color of six genotypes they studied except a pH difference seen amongst ewes only. Hernández-Cruz *et al.*, (2009) also reported a similar lack of effect of genotype on loin meat color of hair and wool type sheep while Çelik and Yilmaz (2010) reported no difference between Awassi and their cross with Turkish Merino on meat pH_{45}&pH_u. Their results confirmed the results of the present study with the exception of yellowness, for which meat from *Af* lambs were more ($p<0.05$) yellow. Contradicting the result of the present study, Blackhead Persian, Dorper and South African mutton Merino were noted with different meat pH_u and color (except the a*) values (Chulayo and Muchenje, 2013) while Martínez-Cerezo*et al.* (2005a) found differences in color values between three breeds.

Abebe *et al.* (2010) also reported $pH_u$and color (except lightness) variability between *AB* and BHO lambs. This result divergence could be attributed to the differences in the breeds and management of the experimental animals and different experimental treatments applied. Though there is considerable variation in findings regarding the effects of breed, there is also a general agreement that the effect of genotype of sheep on meat pH (Martínez-Cerezo*et al.*, 2005a), color and eating quality is limited as long as the animals are on good nutrition and stress prior to slaughter is maintained at minimum (MSA, 2015).

As was observed in the present study, Color and pH taken at 1 and 24hr post mortem of *Longismus dorsi* meat of *Washera* sheep were found not influenced by level of supplementation (Melese*et al.*, 2017). Likewise, Sheridan *et al.* (2003) reported no effect of diet on color of 8-9-10-rib cut meat of mutton Merino lambs. Similarly, *Af* lambs fed different diets found having no difference in color of the *longismussdorsi* meat (Ahmed *et al.*, 2012). The result of the present study is in agreement with their result, but pH_u and L* color value.

With the exception of *AB* lambs on the control diet and *Af* lambs on D_3, the physicochemical values generally fall in the ranges (5.4-5.8 pH_u, ≥34 L* and ≥ 9.5 a* values) considered as normal (Dragomir, 2005, as cited by Majdoub-Mathlouthi*et al.*, 2013; Khlijі*et al.*, 2010; Chulayo and Muchenje 2013; MSA, 2015). Generally, lambs with heavier SBW exhibited lower pH_u and lighter (L*) color (Table 21 and Table 27) confirming the result reported by Majdoub-Mathlouthi*et al.* (2013).

Lambs of Pelibuey and Polypay x Rambouillet were compared and found not different on proximate chemical composition of the *Longissimus dorsi* muscle (Peraza-Mercado *et al.*, 2010). This finding is inline with the present study except for fat which was influenced by breed. Substantiating the result of the present study, Abd El-aal and Suliman (2008) reported differences between diet groups on proximate chemical composition of meat from *Longissimus dorsi* muscle of sheep. The lower fat concentration of meat produced from lambs on the control diet could be associated with their higher moisture content. This is best explained by the inverse relationship that exists between fat and moisture concentrations of carcasses (Stankov *et al.*, 2002).

5.4.8. The sensory eating quality of meat

Confirming the present finding, Hoffman *et al.*, (2003) reported no effect of genotype on the sensory quality characteristics of semimembranous muscle. From their review on factors affecting meat quality traits, Guerrero *et al.,* (2013) found inconsistency among various research works on effect of genotypes on sensory eating quality as some found no effect and others reported large variability between breeds. Yet, they drew a generalization stating that the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight, most differences being probably due to differences in maturity or in muscularity levels.

Contrasting the present study, Panea*et al.* (2011) reported that feed type did not affect sensory characteristics of lamb. Similarly, Sheridan *et al.*, (2003) also did not get any impact of diet on eating quality of meat from Mutton Merino lambs supplemented by either low or high energy concentrates. According to Beriain*et al.*, (2000), there is little variation in toughness in lamb meat, if the management of cooling after slaughter is correct. Nevertheless, there are also other works that reported diet affecting the sensory attributes of meat (Mavimbela*et al.*, 2000; Abd El-aal and Suliman, 2008).

Regardless of the statistical variability, all the supplemented lambs were distinguished as very good meat producers as all evaluated eating quality traits were rated above five on seven-point hedonic scale, the *Af* lambs scoring better value.

6. CONCLUSION AND RECOMMENDATION

The summary of methods followed to carry out the studies, the major findings of the studies and recommendations drawn are presented here under.

6.1. Conclusion

In this study, one survey and four experiments were undertaken. The survey was a retrospective study conducted using data collected over three years (2012/13-2014/15) in six export abattoirs. The experimental design of all experiments wasfactorial arrangement incompletely randomizeddesign. The silage was made from *tef* straw soaked in cold water overnight, inoculated with EM, packed in plastic bags and then subjected to physical and chemical analysis. During feeding and digestibility trials, each lamb was fed *tef* straw silage alone or supplemented with either wheat bran *bokashi*alone or mixed with *noug* seed cake. In the transportation experiment two lamb groups were transported 25 km by either trekking or trucking and the third was trucked to the abattoir five days ahead of the other two groups.

Result of the survey indicated that, a total of3.9million sheep and goats were slaughtered in the three years study period, out of which 19% were sheep and 81% were goats. The most used breeds werethe Somali and Woito-Guji goats, which together accounted for 66.23%. TheBlack Head *Ogaden* sheep were the most slaughtered among the sheep breeds, but contributed only 3.28% of the total slaughter. The *Arsi-Bale* sheep and *Arsi-Bale*goats were found contributing only 0.04% and 3.32%, respectively.

Mortality and weight loss caused by transportation, respectively, were 0.14% and 6.49% for sheep and 0.10% and 6.58% for goats, whereas the full and partial carcass condemnations were 0.09% and 0.12%, respectively. These levels of loss and carcass rejection may not have affected the performance of the abattoirs as it is commonly seen in many commercial abattoirs.

Results of the *tef* straw silage making experiment indicated that cold water socked *tef* straw, ensiled for 21 days with EM solution at a rate of 500ml/kg *tef* straw, had better OM and CP content with higher OM digestibility than those ensiled for 14 and 28 days at application rates of 250 and 750ml EM/kg *tef* straw. However, the pH of the silages was not as low as expected and color change was seen when exposed to air. This indicates that the silage may lack stability during feed-out.

Results of the transportation and feeding trials show that the *Arsi-Bale* lambs were better than the *Afar* lambs in most of the carcass characteristics and carcass linear measurements, which were also improved by supplementation. Most of the carcass linear measurements were influenced by diet for which the supplemented lambs performed similar to each other. The 25km trekking or trucking mode of transportation did not affect most of the carcass characteristics,whereas, breed in the transportation trial did not affect most of proportion of edible offal. The total non-edible offal was significantly higher for the non-transported lambs. The affected proportion to empty body weight of non-carcass components were higher for *Afar* lambs and found lower for supplemented lambs. The drip loss was not affected by breed in feeding trial while it was higher for *Afar* lambs in the transportation experiment.

In the transportation trial, the meat pH and color were affected by mode of transportation and breed, respectively, while chemical composition was not affected at all. In the feeding trial the physicochemical characteristics and chemical composition of meat were similar for both breeds except L*color value and fat content which were higher for *Afar* lambs. As influenced by diet, control lambs scored higher ultimate pH, moisture and ash; and lower L*and fat. Most of the evaluated sensory quality traits of meat were affected by breed for which the *Arsi-Bale* lambs were better than that of *Afar*. However, all the meat samples can be considered as good quality, looking at all the eating quality attributes, which were in the range of a good quality meat. In the feeding and digestibility trials, the *Afar* lambs were found superior over the *Arsi-Bale* lambs in nutrient intakes and digestibility, however they were inferior by growth performance and feed efficiency. There were substitution effects of the supplements at the expense of *tef* straw silage. It was observed that the highest weight gain with better predictability and feed conversion efficiency was achieved by*Arsi-Bale* lambs fed *tef* straw ensiled with effective micro-organisms basal diet supplemented by the mix of wheat bran *bokashi* and *Noug* seed cake.

In generally, the *Arsi-Bale* lambs were found to produce similar quality but better lean meat yield than their *Afar* counter under the conditions of the present studies.

6.2. Recommendation

Based on the outputs of the current research, the following are forwarded as recommendations:

- further survey is needed to undertake a follow-up study incorporating live animal value chain actors as key informants to obtain actual data on live weight loss, mortality, injury, bone fracture and other stressor conditions that may reveal rejection rate at the abattoirs;
- further studies are needed to investigate means of boosting deployment of sheep for carcass export.
- future *tef* straw silage making studies should emphasize on application of effective microorganisms, incorporating other additives that have fermentation stimulation and/or inhibition role aiming to tackle feed-out stability problem.
- Other carcass yield and quality parameters not covered by this study such as length of feedlot time required for fulfilling export weight, meat fatty acid profile, stability of physicochemical characteristics and technological meat quality need to be addressed in future studies.
- future similar studies on the same feed with *Afar* sheep need to consider nutrient balances, as the *Afar* lambs showed inferior growth and feed efficiency performance though they were better on nutrient intake and digestibility,
- future studies that aim to evaluate effect of live animal transportation should consider different distances of travel as a factor.

- future studies should focus on investigation of the actual length of rest time needed from end of transportation to slaughtering and appropriate feeding regime during the rest time for the highland sheep breeds, as the *Arsi-Bale* sheep which are highland originated showed less tolerance to transportation stress than their *Afar* counter.
- the export abattoirs' management and personals should get continuous training to maximize the use of the *Arsi-Bale* sheep for carcass export and further wider promotion is also highly recommended for exploitation of the potential of the *Arsi-Bale* sheep of producing better carcass yield with meat quality comparable to *Afar* sheep.
- the commercial sheep finishers and fattenersare advised to use EM treated at a rate of 500ml/kg *tef* straw as major basal feed supplemented with mixture of wheat brane *bokashi* and *noug* seed cake.

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8. APPENDICES

Appendix 1 Questionnaire Used for Survey of Export Abattoirs

I. The Questionnaire to be filled by the top official of the abattoir

Introduction

The aim of this questionnaire is to collect data for a PhD thesis research project whose objective is to ***assess the effect of mode of live animal transportation and feeding regimes on meat yield and quality of export lambs.*** This study will assess the constraints in lamb yield and export meat quality attributed to transportation of the live animals and the feed they were offered in husbandry practices. Among the direct beneficiaries of the study, export abattoirs are the major ones for improving the quantity and quality of their export commodity sustainably. As a result, the reliability of the data has a due importance for the abattoirs and the researchers as well. ***The confidentiality of the information is strictly maintained and the outcome of the study is expressed only as average of various abattoirs and reviles the generalsituation only***. By no means may it refer to a specific abattoir, its organization or persons who provide the data. Hence, we earnestly request you to respond for every question carefully and genuinely.

Eventually, we would like to thank you in advance for your unreserved cooperation.

1. General information of the abattoir.

1.1. Address:-

i) City:____

ii) Specific location:____________________________________

1.2. Tel:

i) Office:____

ii) Mobile:____

iii) Fax:____

1.3. When was the abattoir established?____________________________

2. What was(were)the objective(s) of the abattoir:

2.1. During its establishment______________________________

2.2. At the present __________________________________

3. If the objective(s) is/are changed at the present, pleas list the reason(s) for the change.____

4. What speciesof animals does the abattoir slaughter? (Tick √ in the box)

- Cattle------------ ☐
- Goats------------------------- ☐
- Sheep----------- ☐
- Camel------------------------ ☐
- If there is variation in number of slaughter between years and/or months of a year, please give reason for the peak slaughter.

____

5. If the abattoir uses more than one breed of sheep, please explain the reason for the variation in the level of utilization of the sheep breeds through the three years time.

____

6. What is the maximum capacity [Number of animals (cattle, sheep or camel) slaughtered per day] of the abattoir?____________________________

7. What is/are the reason(s) for condemning and/or selling in the local market of full

carcass or part of
carcass?____

8. Purchase of slaughter animals:

a. From where (Market place) does the abattoir get sheep and/or goats? ____

b. How the sheep/goats are collected from the market? (Tick √ in the box)

- By marketing firms---------------------- ☐
- By brokers-------------------------------- ☐
- By live animal traders ------------------ ☐
- By purchasing officers of the abattoir- ☐
- Other(s)____
____

9. What are the constraints and opportunities of the abattoir with respect to achieving its objectives?

a. Constraints:____

b. Oportunities:____

10. Can you list any additional source of information(data) please?

____

____

Thank you in deed

II. Questionnaire to be filled by meat inspector of the Abattoir

Introduction

The aim of this questionnaire is to collect data for a PhD thesis research project whose objective is to ***assess the effect of mode of live animal transportation and feeding regimes on meat yield and quality of export lambs.*** This study will assess the constraints in lamb yield and export meat quality attributed to transportation of the live animals and the feed they were offered in husbandry practices. Among the direct beneficiaries of the study, export abattoirs are the major ones for improving the quantity and quality of their export commodity sustainably. As a result, the reliability of the data has a due importance for the abattoirs and the researchers as well. ***The confidentiality of the information is strictly maintained and the outcome of the study is expressed only as average of various abattoirs and reviles the general situation only***. By no means may it refer to a specific abattoir, its organization or persons who provide the data. Hence, we earnestly request you to respond for every question carefully and genuinely.

Eventually, we would like to thank you in advance for your unreserved cooperation.

Note that:

- ***If the space provided are not enough you may use the back page and/or additional paper indicating the question number.***
- ***All the information you provide are specific for this abattoir***

1. General information of the abattoir.

1.1. Address:-

i) City:____

ii) Specific location:____

1.2. Tel:

iv) Office:____

v) Mobile:____

vi) Fax:____

2. Purchase of slaughter animals:

- From where (Market place) does the abattoir get the sheep?_________________________
- Transportation of the sheep:

2.1.1.How the animals are transported? (Tick √ in the box)

- By Trucking-☐ ♦ By Trekking-- ☐ ♦ By Both---☐

2.1.2.If both mode of transportation are used:

2.1.2.1. For how long and what distance the animals are transported?

2.1.2.1.1. By trucking:____

2.1.2.1.2. By trekking:____

3. What problems are observed on the sheep in the holding yard and/or lairage? (Tick √ in the box)

- Death---------------☐ ♦ Sickness------------☐

- Weight loss----------☐
- Physical injury (fracture)------- ☐
- Other(s):____

  ____

3.1. What are the causes (recorded) for each of the problems observed?

3.1.1. For the death:____

3.1.2. For the sickness:____

3.1.3. For weight loss:____

3.1.4. For Physical injury (fracture): ______________________________________

3.1.5. For other(s):____

3.2. What problems are observed on the sheep just pre-mortem and post-mortem? (Tick √ in the box)

- Unfitness of the live sheep for the slaughter ☐
- Carcass discoloration----------------------------- ☐
- Bruise--- ☐
- Other(s):____

3.3. What are the consequences of the above problem(s)? (Tick √ in the box)

- Culling of live animal from slaughtering-----☐
- Full carcass condemnation --------------------☐
- Partial carcass condemnation -----------------☐
- Other(s)____

3.4. Please provide document/data that quantify the consequences in relation to mode of transportation in the last two years? (Pleas list the documents)

3.4.1. When trekked:____

3.4.2. When trucked:____

3.4.3. When transported by alternating trekking and trucking:______________________

3.5. How much carcass or part of carcass is condemned or sold in the local market due to **bruise, bone fracture, carcass discoloration, transportation fever or other defects caused by transportation of live animals**in the last three Ethiopian calendar years? (Please fill the following table)

Ethiopian Calendar year	**Month**	**Condemned**		**Carcass or part of carcass sold in the local market (kg or piece)**	**Comments**
		Full (kg or piece)	**Partial (kg or piece)**		
2005	Meskerem				
	Tikimit				
	Hidar				
	Tahisas				

	Tir				
	Yekatit				
	Megabit				
	Miyaziya				
	Ginbot				
	Sene				
	Hamile				
	Nehase				
2006	Meskerem				
	Tikimit				
	Hidar				
	Tahisas				
	Tir				
	Yekatit				
	Megabit				
	Miyaziya				
	Ginbot				
	Sene				
	Hamile				
	Nehase				
2007	Meskerem				
	Tikimit				
	Hidar				
	Tahisas				
	Tir				
	Yekatit				

	Megabit				
	Miyaziya				
	Ginbot				
	Sene				
	Hamile				
	Nehase				

4. How many heads of which breed of sheep/ goat does the abattoir slaughter? (pleas fill the following table)

Breed	**Year (EC)**	**Spices**	Number of sheep/goat slaughtered in a month (1=Meskerem;….;12=Nehase)											
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Afar/ *Kereyu*	2005	Sheep												
		Goat												
	2006	Sheep												
		Goat												
	2007	Sheep												
		Goat												
Arsi-Bale	2005	Sheep												
		Goat												
	2006	Sheep												
		Goat												
	2007	Sheep												
		Goat												
Black Head *Ogaden* (Somali)	2005	Sheep												
	2006	Sheep												
	2007	Sheep												
Somali	2005	Goat												

(Borena/*Guji*) goats	2006	Goat												
	2007	Goat												
Adilo Sheep	2005	Sheep												
	2006	Sheep												
	2007	Sheep												
Bonga Sheep	2005	Sheep												
	2006	Sheep												
	2007	Sheep												
Washera Sheep	2005	Sheep												
	2006	Sheep												
	2007	Sheep												
Horo Sheep	2005	Sheep												
	2006	Sheep												
	2007	Sheep												
Menz Sheep	2005	Sheep												
	2006	Sheep												
	2007	Sheep												

- ❖ If the abattoir use other breed, pleas list them at the back of this page forming the same table.

5. Any additional information or comments:

____

____

6. Can you list any additional source of information (data)?

____

____

Thank you in deed

III. The Questionnaire to be filled by <u>production supervisor and/or animal purchaser</u> of the abattoir

<u>Introduction</u>

The aim of this questionnaire is to collect data for a PhD thesis research project whose objective is to assess the effect of mode of live animal transportation and feeding regimes on meat yield and quality of export lambs. This study will assess the constraints in lamb yield and export meat quality attributed to transportation of the live animals and the feed they were offered in husbandry practices. Among the direct beneficiaries of the study, export abattoirs are the major ones for improving the quantity and quality of their export commodity sustainably. As a result, the reliability of the data has a due importance for the abattoirs and the researchers as well. The confidentiality of the information is strictly maintained and the outcome of the study is expressed only as average of various abattoirs and reviles the general situation only. By no means may it refer to a specific abattoir, its organization or persons who provide the data. Hence, we earnestly request you to respond for every question carefully and genuinely.

Eventually, we would like to thank you in advance for your unreserved cooperation.

<u>Note that</u>: If the space provided are not enough you may use the back page and/or additional paper indicating the question number.

1. General information of the abattoir.

1.1. Address:-

i) City:____

ii) Specificlocation:______________________________________

1.2. Tel:

vii) Office:____

viii) Mobile:____

ix) Fax:____

2. What is the age of the sheep the abattoir slaughters? ____________________

3. How the age of the animal is determined in the market and at the lairage of the abattoir?

- ♦ By dentition----------☐
- ♦ By asking the seller--☐
- ♦ Other(s):____

4. Transportation of the sheep:

4.1.1. How the animals are transported?(Tick √ in the box)

a. By Trucking--☐

b. By Trekking--☐

c. By Both-------☐

4.1.2. If both mode of transportation are used:

4.1.2.1. For how long and what distance the animals are transported?

A. By trucking:____

B. By trekking:____

4.1.2.2. From which area to which area?

A. By trucking:

1. ____
2. ____
3. ____
4. ____

B. By trekking:

1. ____
2. ____
3. ____
4. ____

4.1.2.3. How do you care to the animal during transportation? (Tick √ in the box)

A. By trucking:

a) Bedding the floor of the truck------------- ☐
b) Watering at certain distance -------------- ☐
c) Feeding at certain distance -------------- ☐
d) Feeding and watering at certain distance ☐
e) Resting at certain distance ---------------- ☐
f) None --------------------------------------- ☐
g) Other(s):____

B. By trekking:

a) Feeding at certain distance --------------- ☐
b) Feeding and watering at certain distance ☐
c) Resting at certain distance --------------- ☐
d) None --------------------------------------- ☐
e) Other(s):____

4.1.2.4. When trucking is the preferred mode of transportation:

A. What is the type of track usually used?__________________________

B. How do you restrain the animals during trucking?__________________

C. What is the number of sheep per truck (pleas identify type of the truck)?

1. ____
2. ____
3. ____
4. ____

5. What problems are observed on the sheep just after transportation in the holding yard? (Tick √ in the box)
   - Death---------------------------[ ]
   - Sickness-----------------------[ ]
   - Weight loss-------------------[ ]
   - Physical injury (fracture)----[ ]
   - Other(s):____

6. Holding yard and Lairage conditions:

6.1.1. What is the duration of holdingand/or lairage before slaughtering the sheep?____

6.1.2. What cares are given to the sheep in the holding yard? (Tick √ in the box)

a) Bedding the floor ------------[ ]
b) Watering only-----------------[ ]
c) Feeding only------------------[ ]
d) Feeding and watering ---------[ ]
e) Sheltering----------------------[ ]
f) No care at all-------------------[ ]
g) Other(s):____

6.1.3. What cares are given to the sheep in the lairage? (Tick √ in the box)

a) Bedding the floor ------------[ ]
b) Watering ----------------------[ ]
c) Sheltering----------------------[ ]
d) No care at all-------------------[ ]
e) Other(s):____

7. Pleas fill the following table for weight of the sheep/goats at the market and in the collection yard just at their arrival for the last three years.

NB. You will be provided with separate table

Date	Number of animals		Total Weight		Number of animals died	Duration of travel (Hours)
			At the market (MW)	At arrival to the abattoir (HW)		
	Sheep					
	Goat					
	Sheep					
	Goat					
	Sheep					
	Goat					

8. Any additional information or comments:

9. Can you list any additional source of information (data)?

Thank you in deed

Appendix 2. Formatsused for data collection

Parameters	ID----	ID---	ID-----	ID----	BW

Parameters	ID--------	ID--------	ID--------	ID--------	ID--------
Slaughter Body Weight (SBW)					
Body Weight After Bleeding (BWB) / Blood					
Hot carcass wt					
Head wt(**ጭንቅላት**)					
Tongue (wt) (**ምላስ**)					
Feetwt (**እግሮች**)					
Skinwt (**ቆ□**)					
Liver wt(**ጉበት**)					
Gall bladderwt(**የሀሞት ከረጢት**)					
Heartwt(**ልብ**)					
Heart fatwt (**□ልብ ስብ**)					
Kidneywt(**ኩላሊት**)					
Kidney fatwt(**የኩላሊት ስብ**)					
Urinary bladder wt(**□ኛ**)					
Full stomach and intestine wt(**ሖ □ራና አንጀትከነፈርሱ**)					
Empty stomachwt(**ባ□ ሖ □ራ**)					
Mesenteric fat wt(**□ሖ □ራ ስብ**)					
EmptyIntestinewt(**ባዶአንጀት**)					
Ommental (intestine) fat wt(**የአንጀትስብ**)					
Spleen wt(□□□)					
Pancreas wt					
Lungwt(**ሳንባ**)					
Tracheawt(**የአየር ቱቦ**)					
Oesophaguswt(**□ሮሮ**)					
Penis wt(**የወንድብልት**)					
Testes wt (**ቆለ□**)					
Genital fat wt(**ብልት አቃፊስብ**)					
Tail fat wt (**የላት ስብ**)					

Appendix Table 21.Carcass and Non-carcass Data sheet

Appendix Table 22. Morphometric Carcass Measurement data sheet

CCW(Kg)					
Carcass length(cm) (CL)					
Leg length (LL)					
Buttocks Width (BW)					
Anterior circumference of buttocks (ACB)					
Posterior circumference of buttocks (PCB)					
Chest Width (CW)					
ShouldersWidth (SW)					
Thorax Circumference (TC)					
Rib eye area (12/13 rib position)					

Appendix Table 23 Color and p^Hdatarecord sheet

Parameters		ID___________			ID___________			ID___________			ID___________			ID___________		
		Measurement replication			Measurement replication			Measurement replication			Measurement replication			Measurement replication		
		1^{st}	**2^{nd}**	**3^{rd}**	**1^{st}**	**2^{nd}**	**3^{rd}**	**1^{st}**	**2^{nd}**	**3^{rd}**	**1^{st}**	**2^{nd}**	**3^{rd}**	**1^{st}**	**2^{nd}**	**3^{rd}**
pH	At 45 minute															
	At 24hrs															
Color	**L***															
	a*															
	b*															

Appendix 3Analyses of Variance

Appendix Table 31. Analyses of variance of carcass characteristics and meat qualityof experimental lambs in transportation trial

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Slaughter Body Weight (SBW, kg)	Model	5	100.21893	20.0438	5.3974
	Error	35	129.97619	3.7136	Prob > F
	C. Total	40	230.19512		0.0009
Transportation Loss (TL, %)	Model	5	5.137631	1.02753	4.1611
	Error	35	8.642857	0.24694	Prob > F
	C. Total	40	13.780488		0.0045
Empty Body weight (EBW, kg)	Model	5	101.39753	20.2795	7.8233
	Error	35	90.72691	2.5922	Prob > F
	C. Total	40	192.12444		<.0001
Hot Carcass Weight (HCW, kg)	Model	5	36.153175	7.23063	7.1728
	Error	35	35.282264	1.00806	Prob > F
	C. Total	40	71.435439		0.0001
Cold carcass weight (CCW, kg)	Model	5	38.961111	7.79222	8.1118
	Error	35	33.621133	0.96060	Prob > F
	C. Total	40	72.582244		<.0001
Chilling shrinkage (CS, %)	Model	5	7.288181	1.45764	3.8057
	Error	35	13.405419	0.38301	Prob > F
	C. Total	40	20.693600		0.0074
Hot carcass dressing percentage (HCDP, %)	Model	5	203.05201	40.6104	3.1437
	Error	35	452.13188	12.9181	Prob > F
	C. Total	40	655.18390		0.0190
Cold carcass dressing percentage on SBW basis (CCDP, %)	Model	5	209.36163	41.8723	3.3830
	Error	35	433.19876	12.3771	Prob > F
	C. Total	40	642.56040		0.0135
Cold carcass dressing percentage on EBW basis (DPEB, %)	Model	5	488.6439	97.7288	3.9464
	Error	35	866.7362	24.7639	Prob > F
	C. Total	40	1355.3801		0.0061
Ribeye area (REA, cm^2)	Model	5	17.546119	3.50922	4.0702
	Error	35	30.176086	0.86217	Prob > F
	C. Total	40	47.722205		0.0051
Carcass length (CL, cm)	Model	5	252.58188	50.5164	8.9361
	Error	35	197.85714	5.6531	Prob > F
	C. Total	40	450.43902		<.0001
Leg Length (LL, cm)	Model	5	103.66308	20.7326	3.4198
	Error	35	212.19049	6.0626	Prob > F
	C. Total	40	315.85356		0.0128
Buttock Width (BW, cm)	Model	5	311.9660	62.3932	2.7527
	Error	35	793.3095	22.6660	Prob > F
	C. Total	40	1105.2755		0.0337

Appendix Table 31. Analyses of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Chest Width (CW, cm)	Model	5	83.66152	16.7323	3.8486
	Error	35	152.16668	4.3476	Prob > F
	C. Total	40	235.82820		0.0070
Shoulder Width (SW, cm)	Model	5	194.4559	38.8912	1.3960
	Error	35	975.0952	27.8599	Prob > F
	C. Total	40	1169.5511		0.2498
Thorax Circumference (TC, cm)	Model	5	9.13176	1.8264	0.1002
	Error	35	637.66668	18.2190	Prob > F
	C. Total	40	646.79844		0.9914
Anterior buttock circumference (ABC, cm)	Model	5	201.77371	40.3547	3.0009
	Error	35	470.66668	13.4476	Prob > F
	C. Total	40	672.44039		0.0234
Posterior buttock circumference (PBC, cm)	Model	5	345.29769	69.0595	5.1122
	Error	35	472.80953	13.5088	Prob > F
	C. Total	40	818.10722		0.0013
Leg compactness (LC)	Model	5	0.2716144	0.054323	1.9613
	Error	35	0.9693905	0.027697	Prob > F
	C. Total	40	1.2410049		0.1090
Carcass compactness (CC, kg/cm)	Model	5	0.00962625	0.001925	4.1915
	Error	35	0.01607619	0.000459	Prob > F
	C. Total	40	0.02570244		0.0043
Proportion of Blood (g kg^{-1})	Model	5	914.0430	182.809	3.6139
	Error	35	1770.4854	50.585	Prob > F
	C. Total	40	2684.5284		0.0097
Proportion of Heart (g kg^{-1})	Model	5	10.729777	2.14596	2.5411
	Error	35	29.557048	0.84449	Prob > F
	C. Total	40	40.286824		0.0460
Proportion of Kidney (g kg^{-1})	Model	5	6.473378	1.29468	2.3117
	Error	35	19.601579	0.56005	Prob > F
	C. Total	40	26.074956		0.0647
Proportion of Liver (g kg^{-1})	Model	5	106.95355	21.3907	1.5754
	Error	35	475.22836	13.5780	Prob > F
	C. Total	40	582.18191		0.1926
Proportion of Empty Stomach (g kg^{-1})	Model	5	1278.5579	255.712	7.4602
	Error	35	1199.6817	34.277	Prob > F
	C. Total	40	2478.2395		<.0001
Proportion of Empty Intestine (g kg^{-1})	Model	5	386.6525	77.3305	1.1914
	Error	35	2271.8305	64.9094	Prob > F
	C. Total	40	2658.4830		0.3334

Appendix Table 31. Analyses of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Proportion of Head (g kg^{-1})	Model	5	5645.957	1129.19	3.1105
	Error	35	12705.882	363.03	Prob > F
	C. Total	40	18351.839		0.0200
Proportion of Tongue (g kg^{-1})	Model	5	1.7624972	0.352499	2.1149
	Error	35	5.8336833	0.166677	Prob > F
	C. Total	40	7.5961805		0.0867
Proportion of Tail Fat (g kg^{-1})	Model	5	950.9676	190.194	1.3176
	Error	35	5052.2863	144.351	Prob > F
	C. Total	40	6003.2539		0.2793
Proportion of Heart Fat (g kg^{-1})	Model	5	10.729777	2.14596	2.5411
	Error	35	29.557048	0.84449	Prob > F
	C. Total	40	40.286824		0.0460
Proportion of Omental Fat (g kg^{-1})	Model	5	25.606261	5.12125	7.2075
	Error	35	24.869114	0.71055	Prob > F
	C. Total	40	50.475376		<.0001
Proportion of Mesenteric Fat (g kg^{-1})	Model	5	10.204012	2.04080	2.8489
	Error	35	25.072007	0.71634	Prob > F
	C. Total	40	35.276020		0.0292
Proportion of Total Edible None Carcass Fat (g kg^{-1})	Model	5	4.3297851	0.865957	5.8911
	Error	35	5.1447905	0.146994	Prob > F
	C. Total	40	9.4745756		0.0005
Proportion of Total Edible Offal (g kg^{-1})	Model	5	44.550017	8.91000	9.5267
	Error	35	32.734486	0.93527	Prob > F
	C. Total	40	77.284502		<.0001
Proportion of Lungs (g kg^{-1})	Model	5	46.43070	9.28614	1.4798
	Error	35	219.63549	6.27530	Prob > F
	C. Total	40	266.06619		0.2213
Proportion of Trachea (g kg^{-1})	Model	5	0.5560973	0.111219	0.7773
	Error	35	5.0079905	0.143085	Prob > F
	C. Total	40	5.5640878		0.5728
Proportion of Oesophagus(g kg^{-1})	Model	5	5.230528	1.04611	3.7976
	Error	35	9.641248	0.27546	Prob > F
	C. Total	40	14.871776		0.0075
Proportion of Head(g kg^{-1})	Model	5	5645.957	1129.19	3.1105
	Error	35	12705.882	363.03	Prob > F
	C. Total	40	18351.839		0.0200
Proportion of Spleen (g kg^{-1})	Model	5	25.977274	5.19545	10.9560
	Error	35	16.597429	0.47421	Prob > F
	C. Total	40	42.574702		<.0001
Proportion of Pancreas (g kg^{-1})	Model	5	3.231132	0.646226	2.7043
	Error	35	8.363629	0.238961	Prob > F
	C. Total	40	11.594761		0.0362

Appendix Table 31. Analyses of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Proportion of Urinary Bladder (g kg^{-1})	Model	5	1.6802304	0.336046	2.9224
	Error	35	4.0246476	0.114990	Prob > F
	C. Total	40	5.7048780		0.0262
Proportion of Gall Bladder (g kg^{-1})	Model	5	0.9115693	0.182314	2.9167
	Error	35	2.1877429	0.062507	Prob > F
	C. Total	40	3.0993122		0.0265
Proportion of Penis (g kg^{-1})	Model	5	6.462715	1.29254	3.9599
	Error	35	11.424398	0.32641	Prob > F
	C. Total	40	17.887112		0.0060
Proportion of Testis (g kg^{-1})	Model	5	76.33342	15.2667	1.0470
	Error	35	510.32793	14.5808	Prob > F
	C. Total	40	586.66136		0.4059
Proportion of Genital fat (g kg^{-1})	Model	5	87.36953	17.4739	3.2321
	Error	35	189.22197	5.4063	Prob > F
	C. Total	40	276.59150		0.0167
Proportion of Kidney fat (g kg^{-1})	Model	5	6.473378	1.29468	2.3117
	Error	35	19.601579	0.56005	Prob > F
	C. Total	40	26.074956		0.0647
Proportion of Feet (g kg^{-1})	Model	5	165.0072	33.0014	1.1211
	Error	35	1030.2774	29.4365	Prob > F
	C. Total	40	1195.2846		0.3672
Proportion of Skin (g kg^{-1})	Model	5	4325.634	865.127	1.2743
	Error	35	23761.993	678.914	Prob > F
	C. Total	40	28087.627		0.2969
Proportion of Total None-edible offal(g kg^{-1})	Model	5	33210.382	6642.08	7.0280
	Error	35	33077.881	945.08	Prob > F
	C. Total	40	66288.264		0.0001
Proportion of Gut content (g kg^{-1})	Model	5	283942.87	56788.6	12.5184
	Error	35	158773.80	4536.4	Prob > F
	C. Total	40	442716.67		<.0001
Bag drip loss (%)	Model	5	45.26701	9.05340	5.0927
	Error	35	62.21980	1.77771	Prob > F
	C. Total	40	107.48681		0.0013
pH_{45}	Model	5	1.6916832	0.338337	2.2371
	Error	35	5.2933119	0.151237	Prob > F
	C. Total	40	6.9849951		0.0723
pH_u	Model	5	2.1490491	0.429810	2.8420
	Error	35	5.2933119	0.151237	Prob > F
	C. Total	40	7.4423610		0.0295
L* color value	Model	5	293.0995	58.6199	2.0238
	Error	35	1013.7921	28.9655	Prob > F
	C. Total	40	1306.8917		0.0993

Appendix Table 31. Analyses of variance… (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
a* color value	Model	5	78.17364	15.6347	1.3714
	Error	35	399.02584	11.4007	Prob > F
	C. Total	40	477.19948		0.2587
b* color value	Model	5	12.110895	2.42218	0.9883
	Error	35	85.776407	2.45075	Prob > F
	C. Total	40	97.887302		0.4388
Moisture content (%)	Model	5	83.87958	16.7759	1.2072
	Error	35	486.36203	13.8961	Prob > F
	C. Total	40	570.24161		0.3261
CP (% DM)	Model	5	39.85415	7.9708	0.6312
	Error	35	441.97925	12.6280	Prob > F
	C. Total	40	481.83341		0.6771
Ash (% DM)	Model	5	1.1792776	0.235856	1.5531
	Error	35	5.3152833	0.151865	Prob > F
	C. Total	40	6.4945610		0.1990
Fat (% DM)	Model	5	12.37985	2.47597	0.9642
	Error	35	89.87714	2.56792	Prob > F
	C. Total	40	102.25700		0.4529
Tenderness	Model	5	1.859049	0.371810	0.7367
	Error	35	17.664029	0.504687	Prob > F
	C. Total	40	19.523078		0.6010
Juiciness	Model	5	3.344173	0.668835	1.9923
	Error	35	11.750105	0.335717	Prob > F
	C. Total	40	15.094278		0.1041
Flavor	Model	5	4.105050	0.821010	2.5333
	Error	35	11.342950	0.324084	Prob > F
	C. Total	40	15.448000		0.0466
General Acceptability	Model	5	3.048723	0.609745	1.3398
	Error	35	15.928429	0.455098	Prob > F
	C. Total	40	18.977151		0.2706

Appendex Table 32. Analyses of variance of Nutrient content and digestibility *Tef* straw silage in fermentation experiment

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
DM Content (%)	Model	8	138.27947	17.2849	0.8633
	Error	18	360.39147	20.0217	Prob > F
	C. Total	26	498.67094		0.5633
Ash Content (g kg^{-1}DM DM)	Model	8	233.47843	29.1848	5.8504
	Error	18	89.79347	4.9885	Prob > F
	C. Total	26	323.27190		0.0009
OM Content (g kg^{-1}DM DM)	Model	8	233.47843	29.1848	5.8504
	Error	18	89.79347	4.9885	Prob > F
	C. Total	26	323.27190		0.0009
CP Content (g kg^{-}DM DM)	Model	8	299.43196	37.4290	1.6354
	Error	18	411.95413	22.8863	Prob > F
	C. Total	26	711.38610		0.1836
EE Content (g kg^{-1}DM DM)	Model	8	34.72007	4.34001	1.0174
	Error	18	76.78087	4.26560	Prob > F
	C. Total	26	111.50094		0.4577
NDF Content (g kg^{-1}DM DM)	Model	8	9148.656	1143.58	0.7716
	Error	18	26676.018	1482.00	Prob > F
	C. Total	26	35824.674		0.6321
ADF Content (g kg^{-1}DM DM)	Model	8	3405.065	425.633	1.1102
	Error	18	6900.677	383.371	Prob > F
	C. Total	26	10305.742		0.4015
ADL Content (g kg-1DM DM)	Model	8	4945.239	618.155	2.0793
	Error	18	5351.237	297.291	Prob > F
	C. Total	26	10296.477		0.0940
IVDMD (%)	Model	8	50.48274	6.31034	1.0830
	Error	18	104.88040	5.82669	Prob > F
	C. Total	26	155.36314		0.4174
IVOMD (%)	Model	8	47.28221	5.91028	1.4151
	Error	18	75.17867	4.17659	Prob > F
	C. Total	26	122.46087		0.2561
IVDOMD (%)	Model	8	4740.666	592.583	1.4210
	Error	18	7506.313	417.017	Prob > F
	C. Total	26	12246.979		0.2538
ME content (MJ kg^{-1} DM)	Model	8	0.6504667	0.081308	0.9620
	Error	18	1.5213333	0.084519	Prob > F
	C. Total	26	2.1718000		0.4940
pH	Model	8	15.565933	1.94574	3.6424
	Error	18	9.615333	0.53419	Prob > F
	C. Total	26	25.181267		0.0108

Appendix Table 33. Analyses of variance of growth, nutrient digestibility, carcass characteristics and meat quality performance of *Afar* and *Arsi-Bale* lambsin Feeding and digestibility trials

Parameter	**Source**	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Dry matter intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	2481.9377	496.388	31.7266
	Error	35	547.6029	15.646	Prob > F
	C. Total	40	3029.5407		<.0001
Ash intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	43.909506	8.78190	55.5100
	Error	35	5.537133	0.15820	Prob > F
	C. Total	40	49.446639		<.0001
Organic matter intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	2081.8895	416.378	35.1868
	Error	35	414.1671	11.833	Prob > F
	C. Total	40	2496.0566		<.0001
Crude protein intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	496.49877	99.2998	222.5016
	Error	35	15.62008	0.4463	Prob > F
	C. Total	40	512.11885		<.0001
Ether extract intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	14.419610	2.88392	158.3844
	Error	35	0.637293	0.01821	Prob > F
	C. Total	40	15.056902		<.0001
Neutral detergent fiber intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	37.67404	7.53481	1.1369
	Error	35	231.96185	6.62748	Prob > F
	C. Total	40	269.63590		0.3594
Acid detergent fiber intake(g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	144.32464	28.8649	14.4441
	Error	35	69.94360	1.9984	Prob > F
	C. Total	40	214.26824		<.0001
Acid detergent lignin intake (g $kg^{-1}W^{0.75}day^{-1}$)	Model	5	2.8251858	0.565037	3.0853
	Error	35	6.4098190	0.183138	Prob > F
	C. Total	40	9.2350049		0.0207
Dry matter digestibility (%)	Model	5	6892.4748	1378.49	61.5137
	Error	17	380.9625	22.41	Prob > F
	C. Total	22	7273.4373		<.0001
Ash digestibility (%)	Model	5	2829.9444	565.989	3.6014
	Error	17	2671.6701	157.157	Prob > F
	C. Total	22	5501.6145		0.0210
Organic matter digestibility (%)	Model	5	2829.9444	565.989	3.6014
	Error	17	2671.6701	157.157	Prob > F
	C. Total	22	5501.6145		0.0210
Crude protein digestibility (%)	Model	5	649.2323	129.846	1.5281
	Error	17	1444.5375	84.973	Prob > F
	C. Total	22	2093.7698		0.2334

Appendix Table 33. Analyses of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Ether extract digestibility(%)	Model	5	8334.672	1666.93	6.4222
	Error	17	4412.499	259.56	Prob > F
	C. Total	22	12747.171		0.0016
Neutral detergent fiber digestibility(NDFD, %)	Model	5	1724.1590	344.832	3.5221
	Error	17	1664.4036	97.906	Prob > F
	C. Total	22	3388.5626		0.0229
Acid detergent fiber digestibility(NDFD, %)	Model	5	555.4790	111.096	2.8698
	Error	17	658.1024	38.712	Prob > F
	C. Total	22	1213.5815		0.0467
Average daily weight gain (ADWG, g/day)	Model	5	65702.143	13140.4	44.4144
	Error	35	10355.087	295.9	Prob > F
	C. Total	40	76057.230		<.0001
Feed efficiency (FE)	Model	5	739.9891	147.998	2.2364
	Error	35	2316.1947	66.177	Prob > F
	C. Total	40	3056.1839		0.0724
Slaughter body weight (kg)	Model	5	675.40636	135.081	21.8406
	Error	35	216.47025	6.185	Prob > F
	C. Total	40	891.87660		<.0001
Empty body weight (kg)	Model	5	621.64251	124.329	30.6341
	Error	35	142.04753	4.059	Prob > F
	C. Total	40	763.69004		<.0001
Hot Carcass Weight (HCW, kg)	Model	5	193.68708	38.7374	16.0359
	Error	35	84.54849	2.4157	Prob > F
	C. Total	40	278.23556		<.0001
Cold carcass weight (CCW, kg)	Model	5	180.49908	36.0998	15.8957
	Error	35	79.48649	2.2710	Prob > F
	C. Total	40	259.98556		<.0001
Chilling shrinkage (CS, %)	Model	5	51.20815	10.2416	2.2985
	Error	35	155.95044	4.4557	Prob > F
	C. Total	40	207.15860		0.0660
Hot carcass dressing percentage (HCDP, %)	Model	5	610.5742	122.115	7.8719
	Error	35	542.9438	15.513	Prob > F
	C. Total	40	1153.5181		<.0001
Cold carcass dressing percentage on SBW basis (CCDP, %)	Model	5	642.1393	128.428	8.1523
	Error	35	551.3723	15.753	Prob > F
	C. Total	40	1193.5116		<.0001
Ribeye area (REA, cm^2)	Model	5	74.98060	14.9961	11.1829
	Error	35	46.93450	1.3410	Prob > F
	C. Total	40	121.91510		<.0001
Carcass length (CL, cm)	Model	5	269.1817	53.8363	1.6015
	Error	35	1176.5505	33.6157	Prob > F
	C. Total	40	1445.7322		0.1854

Appendix Table 33. Analyses of variance … (Continued)

Parameter	**Source**	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Leg compactness (LL, cm)	Model	5	81.43368	16.2867	6.6544
	Error	35	85.66320	2.4475	Prob > F
	C. Total	40	167.09688		0.0002
Buttock Width (BW, cm)	Model	5	351.47621	70.2952	6.0449
	Error	35	407.01082	11.6289	Prob > F
	C. Total	40	758.48702		0.0004
Chest width (CW, cm)	Model	5	339.41956	67.8839	4.3713
	Error	35	543.52853	15.5294	Prob > F
	C. Total	40	882.94810		0.0034
Shoulder width (SW, cm)	Model	5	160.90904	32.1818	2.5719
	Error	35	437.94491	12.5127	Prob > F
	C. Total	40	598.85395		0.0440
Thorax circumference (TC, cm)	Model	5	1253.2617	250.652	2.3365
	Error	35	3754.6905	107.277	Prob > F
	C. Total	40	5007.9522		0.0624
Anterior buttock circumference (ABC, cm)	Model	5	1495.6888	299.138	7.6565
	Error	35	1367.4474	39.070	Prob > F
	C. Total	40	2863.1362		<.0001
Posterior buttock circumference (PBC, cm)	Model	5	1002.7157	200.543	16.2702
	Error	35	431.4022	12.326	Prob > F
	C. Total	40	1434.1180		<.0001
Leg compactness (LC)	Model	5	0.23483043	0.046966	2.4673
	Error	35	0.66624762	0.019036	Prob > F
	C. Total	40	0.90107805		0.0513
Carcass compactness (CC, kg/cm)	Model	5	0.06136074	0.012272	9.3802
	Error	35	0.04579048	0.001308	Prob > F
	C. Total	40	0.10715122		<.0001
Proportion of blood (g kg^{-1})	Model	5	2733.891	546.78	0.5336
	Error	35	35866.726	1024.76	Prob > F
	C. Total	40	38600.617		0.7494
Proportion of tongue (g kg^{-1})	Model	5	17.584476	3.51690	2.4122
	Error	35	51.027626	1.45793	Prob > F
	C. Total	40	68.612102		0.0557
Proportion of tail fat (TF, g kg^{-1})	Model	5	5855.597	1171.12	3.0622
	Error	35	13385.354	382.44	Prob > F
	C. Total	40	19240.951		0.0214
Proportion of heart (g kg^{-1})	Model	5	3.333720	0.666744	1.2421
	Error	35	18.788305	0.536809	Prob > F
	C. Total	40	22.122024		0.3107
Proportion of kidney (g kg^{-1})	Model	5	15.703210	3.14064	4.9777
	Error	35	22.083200	0.63095	Prob > F
	C. Total	40	37.786410		0.0015

Appendix Table 33. Analyses of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Proportion of liver (g kg^{-1})	Model	5	37.83229	7.56646	1.0527
	Error	35	251.56683	7.18762	Prob > F
	C. Total	40	289.39911		0.4029
Proportion of empty stomach (g kg^{-1})	Model	5	179.0158	35.8032	0.5070
	Error	35	2471.7865	70.6225	Prob > F
	C. Total	40	2650.8023		0.7690
Proportion of empty intestine (EI, g kg^{-1})	Model	5	789.3882	157.878	5.3748
	Error	35	1028.0746	29.374	Prob > F
	C. Total	40	1817.4628		0.0009
Proportion of head (g kg^{-1})	Model	5	7229.1552	1445.83	20.0934
	Error	35	2518.4456	71.96	Prob > F
	C. Total	40	9747.6008		<.0001
Proportion of Heart Fat (HF, g kg^{-1})	Model	5	3.333720	0.666744	1.2421
	Error	35	18.788305	0.536809	Prob > F
	C. Total	40	22.122024		0.3107
Proportion of omental fat (OF, g kg^{-1})	Model	5	28.25099	5.65020	0.7394
	Error	35	267.44831	7.64138	Prob > F
	C. Total	40	295.69930		0.5991
Proportion of mesenteric fat (MF, g kg^{-1})	Model	5	142.58153	28.5163	4.1770
	Error	35	238.94198	6.8269	Prob > F
	C. Total	40	381.52351		0.0044
Proportion of Total Edible None Carcass Fat (TENCF, g kg^{-1})	Model	5	305.35998	61.0720	3.6184
	Error	35	590.74063	16.8783	Prob > F
	C. Total	40	896.10061		0.0096
Proportion of Total Edible Offal (TEO, g kg^{-1})	Model	5	5082.697	1016.54	2.1244
	Error	35	16747.345	478.50	Prob > F
	C. Total	40	21830.042		0.0855
Proportion of Lungs (g kg^{-1})	Model	5	89.63215	17.9264	6.4444
	Error	35	97.35934	2.7817	Prob > F
	C. Total	40	186.99149		0.0002
Proportion of trachea (g kg^{-1})	Model	5	6.684297	1.33686	1.2532
	Error	35	37.335893	1.06674	Prob > F
	C. Total	40	44.020190		0.3058
Proportion of Oesophagus(g kg^{-1})	Model	5	4.4465998	0.889320	5.6270
	Error	35	5.5315905	0.158045	Prob > F
	C. Total	40	9.9781902		0.0007
Proportion of spleen (g kg^{-1})	Model	5	13.666775	2.73335	3.8929
	Error	35	24.574664	0.70213	Prob > F
	C. Total	40	38.241439		0.0065

Appendix Table 33. Analysis of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
Proportion of pancreas (g kg^{-1})	Model	5	1.633296	0.326659	1.3518
	Error	35	8.457626	0.241646	Prob > F
	C. Total	40	10.090922		0.2660
Proportion of urinary bladder (g kg^{-1})	Model	5	9.414116	1.88282	1.7804
	Error	35	37.013571	1.05753	Prob > F
	C. Total	40	46.427688		0.1425
Proportion of gall bladder (g kg^{-1})	Model	5	2.327162	0.465432	1.0206
	Error	35	15.960740	0.456021	Prob > F
	C. Total	40	18.287902		0.4205
Proportion of penis (g kg^{-1})	Model	5	4.544233	0.908847	5.1233
	Error	35	6.208771	0.177393	Prob > F
	C. Total	40	10.753005		0.0013
Proportion of testis (g kg^{-1})	Model	5	692.7852	138.557	0.8877
	Error	35	5463.0846	156.088	Prob > F
	C. Total	40	6155.8698		0.4998
Proportion of genital fat (g kg^{-1})	Model	5	53.91227	10.7825	8.1534
	Error	35	46.28578	1.3225	Prob > F
	C. Total	40	100.19805		<.0001
Proportion of kidney fat (g kg^{-1})	Model	5	15.703210	3.14064	4.9777
	Error	35	22.083200	0.63095	Prob > F
	C. Total	40	37.786410		0.0015
Proportion of feet (g kg^{-1})	Model	5	627.99865	125.600	12.4008
	Error	35	354.49159	10.128	Prob > F
	C. Total	40	982.49024		<.0001
Proportion of skin (g kg^{-1})	Model	5	0.00149576	0.000299	0.4587
	Error	35	0.02282619	0.000652	Prob > F
	C. Total	40	0.02432195		0.8041
Proportion of Total None-Edible Offal (TNEO, g kg^{-1})	Model	5	361803.85	72360.8	12.2575
	Error	35	206619.22	5903.4	Prob > F
	C. Total	40	568423.07		<.0001
Proportion of gut content (g kg^{-1})	Model	5	3295.5612	659.112	16.3305
	Error	35	1412.6276	40.361	Prob > F
	C. Total	40	4708.1888		<.0001
pH_{45}	Model	5	0.5035094	0.100702	0.3882
	Error	35	9.0780857	0.259374	Prob > F
	C. Total	40	9.5815951		0.8535
pH_u	Model	5	3.501703	0.700341	2.0115
	Error	35	12.185819	0.348166	Prob > F
	C. Total	40	15.687522		0.1011
L* color value	Model	5	461.0017	92.2003	5.2897
	Error	35	610.0558	17.4302	Prob > F
	C. Total	40	1071.0574		0.0010

Appendix Table 33. Analysis of variance … (Continued)

Parameter	Source	DF	Sum of Squares	Mean Square	F Ratio
a* color value	Model	5	35.69565	7.13913	1.8624
	Error	35	134.16474	3.83328	Prob > F
	C. Total	40	169.86039		0.1262
b* color value	Model	5	5.819650	1.16393	1.0321
	Error	35	39.469150	1.12769	Prob > F
	C. Total	40	45.288800		0.4141
Moisture content (%)	Model	5	22.831640	4.56633	2.6973
	Error	35	59.252648	1.69293	Prob > F
	C. Total	40	82.084288		0.0365
CP (% DM)	Model	5	25.127696	5.02554	3.5918
	Error	35	48.970655	1.39916	Prob > F
	C. Total	40	74.098351		0.0100
Ash (% DM)	Model	5	2.718581	0.543716	2.4747
	Error	35	7.689819	0.219709	Prob > F
	C. Total	40	10.408400		0.0508
Fat (% DM)	Model	5	311.99172	62.3983	7.3188
	Error	35	298.40189	8.5258	Prob > F
	C. Total	40	610.39360		<.0001
Tenderness	Model	5	27.941119	5.58822	8.0161
	Error	35	24.399286	0.69712	Prob > F
	C. Total	40	52.340405		<.0001
Juiciness	Model	5	14.684257	2.93685	6.2322
	Error	35	16.493255	0.47124	Prob > F
	C. Total	40	31.177512		0.0003
Flavor	Model	5	17.421505	3.48430	9.2253
	Error	35	13.219105	0.37769	Prob > F
	C. Total	40	30.640610		<.0001
General Acceptability	Model	5	32.617554	6.52351	18.1798
	Error	35	12.559133	0.35883	Prob > F
	C. Total	40	45.176688		<.0001