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ON-FARM PRODUCTIVE, AND FEEDLOT PERFORMANCE EVALUATION OF WOLLO HIGHLAND SHEEP BREED AND THEIR F_1 CROSSBREDS OF AWASSI AND WASHERA SHEEP IN ETHIOPIA

PhD DISSERTATION

BY

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

By

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Addis Ababa University
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As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the dissertation prepared by Tadesse Amare Sisay entitled With "**On-Farm Productive, and Feedlot Performance Evaluation of Wollo Highland Sheep Breed and Their F_1 Crossbreds of Awassi and Washera Sheep in Ethiopia".** This recommend accepted as fulfilling the Dissertation requirement for the degree of Philosophy in Animal Production.

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STATEMENT OF THE AUTHOR

I reiterate and declare that this dissertation is my original work and that all sources of material used for this have been duly acknowledged. The dissertation submitted in partial fulfillment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine, and Agriculture and deposited in the University/College library to make available to borrowers under the rules of the Library. I critically declare that this dissertation is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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DEDICATION

This work dedicated to my beloved pleasurable mother Asselef Zewode but unfortunately, she passed away when I was so kid.

BIOGRAPHICAL SKETCH

The author of this dissertation was born in April 1984 G.C in Kutaber District found near Dessie town of South Wollo Zone in Amhara Regional State. He attended his Elementary, Junior Secondary, and High School at Bambasi District between 1991 to 2003 G.C and he joined Preparatory and High school at Assosa Town in Benishangul Gumuz Regional State.

In September 2006 G.C, he joined Haramaya University and he graduated with a BSc. Degree program of Animal Production in 2008. After he had boasted two years of work experiences in Ministry of Agriculture Office of Benishangul Gumuz Region and then he admitted for his MSc. study in Animal Production and Technology program at Bahir Dar University Poli-Technique Compass in September 2010 and graduated in January 2011.

After graduation, the author employed by the Ethiopian Ministry of Higher Education in Wollo University, lecturer position since June, 2011. The author served for two consecutive years from June, 2011 to September, 2013, in the department of animal science by teaching, community service, research, teachers' association coordinator and other committee member. Then, he joined Addis Ababa University, College of Veterinary Medicine, and Agriculture and Department of Animal Production Studies in September 2013 for PhD programme by Animal Production Study.

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ABBREVIATIONS AND ACRONYMS

AAU	Addis Ababa University
ADF	Acid Detergent Fiber
ADG	Average Daily Gain
AGBU	Animal Genetics and Breeding Unit
ANOVA	Analysis of Variance
ARC	Agricultural Research Council
ASB	Animal Science, Biotechnology
BWC	Body Weight Change
CCW	Cold Carcass Weight
CGC	Collage Graduate Committee
CP	Crude Protein
CSA	Central Statistics Authority
SD	Standard devation
CVMA	College of Veterinary Medicine and Agriculture
DAGRIS	Domestic Animals Generic Resources Information System
DAPS	Department of Animal Production Study
DM	Dry Matter
EARI	Ethiopian Agricultural Research Institute
EBW	Empty Body Weight
ESGPIP	Sheep and Goats Productivity Improvement Program
FBW	Final Body Weight
GLM	General Linear Model
HCW	Hot Carcass Weight
IBW	Initial Body Weight
ILCA	International Livestock Center for Africa
ILRI	International Livestock Research Institute

Abbreviations and Acronyms (Continued)

IVDMD	In Vitro Dry Matter Digestibility
LSD	Least Significant Difference
ME	Metabolizable Energy
NDF	Neutral Detergent Fiber
NSPC	Number of Service Per Conception
OM	Organic Matter
PA	Peasant Association
PPI	Pair of Permanent Incisor
REA	Rib Eye Area
SAS	Statistical Analysis System
SBW	Slaughter Body Weight
SEM	Standard Error of the Mean
SRR	Small Ruminant Research
USA	United State of America

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Tadesse Amare Sisay
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ABSTRACT

The study was done, at on-farm productivity, and feedlot performance evaluation of Wollo highland sheep breed and their F_1 crossbreds of Awassi and Washera sheep in Ethiopia. The main objectives of the research was identify flocks size and composition, reproductive performance, breeding objective, and strategies, on-farm lamb growth rate and on-station productive performance evaluation. Data collection conducted via questionnaire survey, focus group discussions, flock monitoring, on-station feeding trial, and carcass yield evaluation. The three genotypes used, based on their locations, available ram breed type and breeding strategies, agro-ecological similarity and their sheep production system. The main smallholder sheep producers' traits of interest were growth rate, body size, and weaning rate in the order of their importance. The higher random mating breeding strategies were characterised in Wollo highland genotype flocks (38.6%). Whereas, village community based control breeding strategy was higher in Awassi and Washera genotype flocks with 35.8 and 35.3%, respectively.The private controlled breeding strategies (43.7%) higher in Wollo highland genotype flocks. Washera F_1 crosses designated for fast weaning rate, good body size, marketing age, age at first lambing, good temperament, and large litter size traits. The mean number of lambs, ewes, matted and pregnant ewes per flock comprised significant variation between the three genotypes ($P<0.05$) and higher with Wollo highland breed flocks. The number of services per conception has significant variation between genotypes' flock($P<0.05$) and higher in the Wollo highland breed flocks (1.4±0.2). Age at first mating, age at first lambing, single birth, twin birth, weaning rate and lambing interval significantly different ($P<0.001$) between genotypes. Comparatively higher fertility rate recorded in the Awassi genotypes (89.8%) and lower mortality rate recorded in Wollo highland breed flocks. Lamb mortality due to disease and drought was higher in the Washera genotype flocks (32.2%) and lower in Wollo highland breed flocks (26.0%). Yearling lamb growth rate performance was the linear function with the age of lambs . Awassi F_1 crosses had significantly havier ($P<0.001$) birth and 6^{th} month of weight gain than Washera crossbreds. On-farm average body weight at 3^{rd}, 9^{th} and 12^{th} months and effect of birth type between Awassi and Washera crosses were comparable each other. However, significant difference with Wollo highland breed lambs ($P<0.001$). The effect of parity, sex and their interaction also does not *have significant effect on on-farm lamb growth performance. The males pre-weaning average daily weight gain greater than females for entire genotypes. However, the female post-weaning average daily weight gains greater than males for Awassi and Washera crossbreds. Body weight, body length, chest girth, back width, chest width, height at withers and rump height, hip width and hip length measurement traits had positive and significant (P<0.05) correlation with age and body weight gain of lambs. The average daily weight gain (ADG), total body weight change and final body weights of the supplemented group of each genotypes were significantly higher than (P<0.05) non-supplemented group. Hence, the supplemented and non-supplemented Awassi crossbreds had higher average daily weight gain followed by supplemented Wollo highland breed. Between genotypes there is significant difference (P<0.05) was observed for rib-eye area, empty body weight, hot and cold carcass weight and cold carcass dressing percentage. Wollo highland breed showed compensatory growth pattern daily weight gain at experimental period. This indicated, without nutritional requirement restriction, Wollo highland breed breed can increase a comparable weight gain with their* F_1 *crossbred lambs. Whatever resource is available more economically, it will be advantageous to identify those breeds of which are more efficient meat producers and efficiency to produce saleable products. Therefore, the effect of genotype and feeding type had profound factors to enhance weight gain response in lamb growth performance. Washera genotype might have better nutrient utilization and conversion rate and resulted better carcass and non-carcass fat content. The quality and accessibility to the better grazing management system of natural pasture in wet season can satisfy the maintenance and weight gain requirement of lambs.*

Keywords: Reproductive, productive, breeding objective, monitoring, supplementation, Wollo *highland.*

1. INTRODUCTION

Sheep production is a major component of the livestock sector in Ethiopia, owing to the large population of 30.70 million sheep are estimated to be found in the country, out of which about 72.14% are females, and about 27.86% are males (CSA, 2017). Ethiopia is not only rich in sheep population, but also rich in sheep genetic diversity which developed by natural selection and potential genetic resources of sheep breeds (Gizaw, 2008). In the highlands of the country, about 75% of sheep population are found, while the remaining 25% are distributed in the lowlands (Mukasa-Mugerwa and Lahlou-Kassi, 1995). However, Aklilu (2005) reported that there is an even distribution of sheep population in the highland and lowland areas. The small ruminants account for 40% of cash income earned by farm households, 19% of the total value of subsistence food derived from all livestock production, and 25% of total domestic meat consumption (Hirpa and Abebe, 2008). Smallholder sheep production is the major source of food security serving a diverse function, including cash income, savings, fertilizer, socio-cultural functions and fiber production. Sheep are particularly important for farmers in subalpine highlands and pastoralist/agropastoralist where crop production is unreliable. Moreover, despites its socio-cultural importance, sheep resources significantly contributed for foreign currency earning accounting for the live animal exports (Gizaw, 2008).

The cool highland sheep production systems in most highland areas are characterized by erratic and unevenly distributed rainfall, recurrent drought, and scarcity in livestock feeds and feed that is poor in quality (Bogale *et al*., 2008). In those production environments, the role of sheep in supporting the livelihood of smallholder farmers is increasing due to recurrent crop failure (Yeheyis *et al*., 2004 and Tibo, 2006). However, the sheep flocks are managed under traditional extensive systems with no or minimal inputs and improved technologies, which results in low productivity. They depend on natural pasture and fibrous crop residues for their survival, growth and reproduction. The available natural pasture lands are overloaded with livestock beyond optimum carrying capacity that has resulted in overgrazing and land degradation (Dejene, 2003). This indicated, the critical need of supplemental feed during the feed deficient period. Sheep get their energy, protein, vitamins, and minerals from the pasture or through supplemental feed. A limited supply of nutrients in the sheep's diet can lead to weight loss, low fertility, high mortality, increased risk of disease and poor wool growth. Sheep need a balanced diet containing energy (fat and carbohydrates), protein, vitamins, minerals, and water. Sheep and goat production in Ethiopia suffers feed shortages at all levels with an estimated 40% deficit in the national feed balance. This is aggravated by seasonal availability of forage and crop residues in the highlands and by recurrent and prolonged drought in the lowlands.

Conversely, reproductive performance is prerequisite for any successful sheep production program (Kosgey, 2004). Where farm resources severely limited, reproductive failure was first sign of decreased productivity and reproductive traits are difficult to measure and are strongly influenced by management decisions.

Reproductive performances of sheep together with, survival and growth traits are important determinants of productivity of sheep in a meat livestock farming systems (Wilson *et al.,* 1985). Sheep traits need to be recorded for genetic and management improvement. However, no detailed analyses of environment and management factors affecting the reproductive and growth performance of local breed have been documented in the study area. Moreover, the flock reproductive rate affects the selection intensity and consequently the rate of genetic improvement in all traits and a little or no research has been done on the performance of local breeds (Kosgey, 2004). Hence, assessment of existing reproductive performance of the local breeds and their crossbreds are vital for sheep genetic performance improvement practice.

Therefore, the genetic improvement program requires comprehensive both reproductive and productive performance evaluation of the existed breed and the breeding objectives of sheep producers'and their traits of interest. Hence, breeding objective is an important part of breeding practices in the smallholder sheep production and productivity improvement programme. According to Fewson (1993) a breeding objective is defined as developing vital animals which will ensure that a profit is as high as possible under future commercial conditions of production. However, in most cases it has been missing while designing breeding programs (Sölkner *et al*., 1998). Animal breeding is largely concerned with selection of animals based on well-defined breeding goal, which should fit the future farm production and market requirement.

More over, the major problems of sheep crossbreeding practice as indicated by Workneh (2000) and Tibbo (2006) were lack of clear vision where to bring impact on smallholder sheep producers' interest, lack of reproductive performance recording of existing indigenous breed at smallholder level, exclusive nature of sheep producers' interest and incompatibility of the genotype with the existing environment. Smallholder farmers are keeping multi-purpose animals based on their selection criteria which produce meat, milk, wool, hide beside their transport and draught service. Furthermore, assessment of the breeding objectives of the farmers, identification of the existing flock characteristics and their breeding practice, reproductive and productive performance are the first steps to establish sustainable breeding programs (Sölkner *et al*., 1998; Kosgey and Okeyo, 2007). Hence, evaluation of local sheep breed current genetics improvement practice might lead to a reconsideration of the breeding goal for the next round of selection.

Currently Awassi breed in the highland is being used for crossbreeding by farmers to improve the performance of local sheep breeds. In addition to Awassi sheep, local breed from western Gojjam were being introduced to South Wollo smallholder farming condition. According to rural development and agricultural office report (2015), Washera rams were introduced in north eastern highland area of the counrty before 1999. To be done genetic improvement in production and reproduction performance of ewes and information on possible genetic improvement effects of crossbreeding on farmer's and their livelihood and the national economy at large is limited or none. The major downside in the crossbreeding programs in Ethiopia has been the lack of a clear and documented evidence of productive and reproductive performance and survival rate of the crossbred progenies and the existing local breed at their prevailing environment. Moreover, previous studies have not or little, if any, addressed on-farm and on-station growth performances and morphometric characteristics of Wollo highland indigenous sheep and their crossbred progenies. Therefore, to design sustainable breeding program and to select appropriate breeds to the local environment, reproductive and productive performance assesment of the existing breed and their crosses is the profounding factor.

Therefore, the present study was accomplished on smallholders' sheep farm circumstance assessment of flock size and their composition, identification of farmers' trait of interest and their selection criteria, reproductive and productive performance assessment, on-farm growth rate and on-station feedlot weight gain performance and carcass characteristics evaluation of Wollo highland sheep and their F_1 crosses with Awassi and Washera sheep breeds.

The specific objectives of the study were:

1. To evaluate smallholders' sheep farm flock characteristic, breeding strategies, and their breeding objectives, identification of trait selection criteria and traits of interest.
2. On-farm evaluation of ewes' reproductive and lamb growth performance of Wollo highland sheep and their F_1 crossbreds with Awassi and Washera breeds.
3. On-station feedlot weight gain and carcass yield characteristics evaluation of Wollo highland sheep breed and its Awassi and Washera F_1 crossbreds.

2. LITERATURE REVIEW

2.1. Genetic Diversity of Ethiopian Sheep Breeds

Different work were done to characterize indigenous sheep breeds (types) in Ethiopia. Gizaw (2008b) has been classified Ethiopian sheep breeds based on their morphological characteristics and geographic distribution. There are about 14 traditionally recognized sheep populations in Ethiopia, and sheep populations are classified in to nine genetically distinct breeds and 6 breed groups which are well explained in Table1. Identification of the breed is the base for different sheep breed improvement strategies and sheep productivity scheme. They are found in different ecological zones of the country: sub-alpine, arid lowland, sub-humid lowland and wet highlands. The short fat tailed sheep, Washera breed, thin tailed sheep, long fat tailed sheep, Bonga sheep and fat rumped sheep were characterised by both phenotypic and molecular genetics distance parameters evaluation of Gizaw (2008b).

Table 1.Classifications summary of Ethiopian sheep breeds and breed groups.

Breed group	Breed	Population	Tail type/shape	Fiber type
Short fat tailed	Simien	Simien	Fatty and short	Fleece
	Short fat tailed	Sekota, Farta, Tikur, Wollo, Menz	Fatty and short	Fleece
Washera	Washera	Washera	Fatty and short	Hair
Thin-tailed	Gumz	Gumz	Thin and long	Hair
Long fattailed	Horro, Arsi	Horro, Arsi-Bale, Adilo	Fatty and long	Hair
Bonga	Bonga	Bonga	Fatty and long	Hair
Fat rumped sheep	Afar and BHS	Afar and BHS	Fat rump/fat tail Fat rump/fat tiny	Hair Hair

Source: (Gizaw, 2008); BHS, Black Head Somali

The geographical distribution of sheep breeds of Ethiopia is presented in Figure 1 and its important distinguishing physical characteristics also showed in Table 1. This location map of the breeds/types can also indicate how the indigenous sheep population in Ethiopia are highly adapted to their broad range of environment and different physical characteristics of sheep type are found in the country also presented in Figure 1.

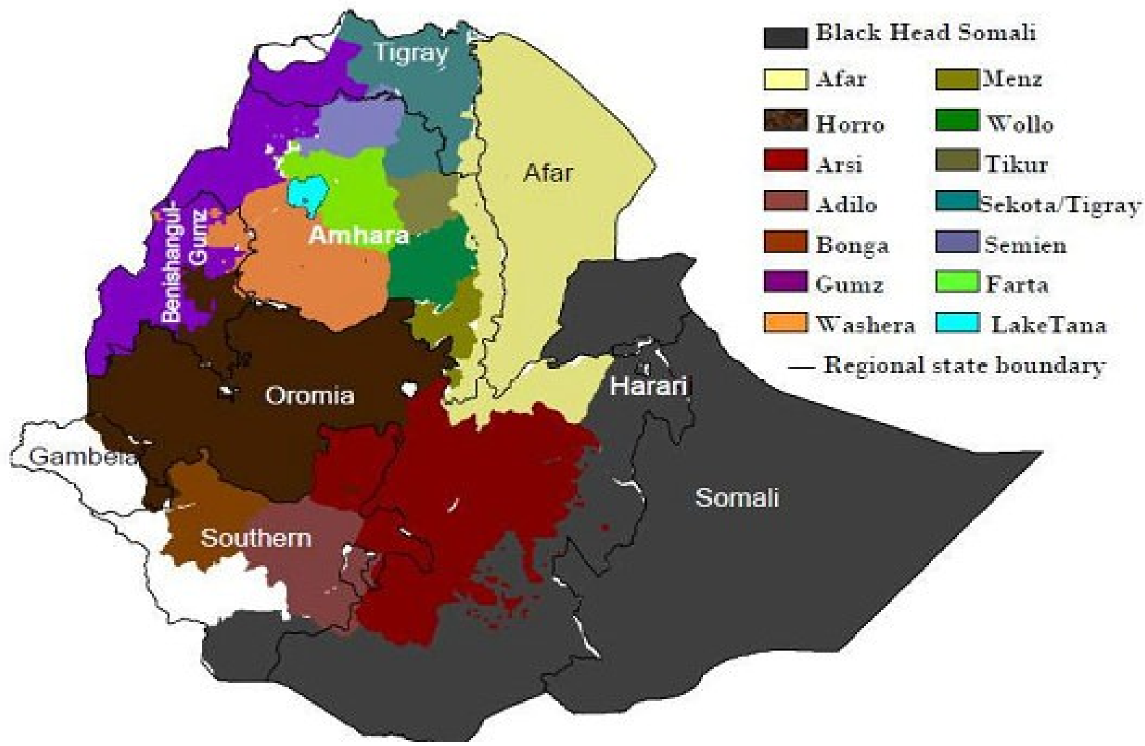


Figure 1. Geographic distribution of sheep populations in Ethiopia

The degree of local Wollo highland sheep adaptation was measured by their reproductive and productive activities were remain stable during strong sever drought and disease prevalency period and providing optimal out put to the local sheep producers for long years ago.

2.2. Flock Size and Composition

The characteristic feature of a particular flock size is the reflection of communities' sheep production strategies. Large flock sizes usually indicate extensive sheep breeding and production of a large number of lambs for sale. The strategy largely based on the sale of non-fattened yearling lambs because of the high dependence on sheep production for food security (Gizaw *et al.*, 2010a). Communities practicing such production are rich in indigenous breeding knowledge and more likely to participate in genetic improvement programs. The large flock sizes in the subalpine sheep-barley and pastoral systems characterize the extensive mode of production, whereas the strategy in high potential cropping areas (particularly in Bonga) is maintenance of small flocks and production of lambs for fattening (Gizaw *et al.*, 2010a).

Smallholder sheep producers' flock size in developing countries is small, however varied and extremely complex. Zelalem and Fletcher (1991) revealed that in the central highlands of Ethiopia sheep flock size increased as the altitude increases. For the reason that cool highlands above 3000 m.a.s.l. are not suitable for crop production as the land is degraded due to continuous cultivation and frost problem. Higher average sheep flock size of 24 sheep per head has been reported by Abebe (1999) for Menz sheep in Lalo-Mama woreda. While in the lower altitude, smaller flock size of 2.9 (Takele, 2005) and 6.97 (Aden, 2003) in the humid Bench Maji zone and around Dire Dawa, respectively were reported. In most of the traditional systems, both breeding ram and ewe graze together throughout the year with all age classes of sheep and in most cases with other species of livestock (Abebe, 1999 and Aden, 2003). Report on male to female ratio of different studies range from 1:6.7 to 1:29 (Niftalem, 1990; Abebe, 1999; Aden, 2003; Abegaz, 2007).

Correspondingly, flock structures reflect production objectives and breeding practices. For this occasion, the maintenance of castrates and a larger number of intact males (particularly in Menz) related to the objective of meat production. The higher proportion of males in the given flocks of traditional systems indicates the objectives of wool, hair, or meat production (Wilson, 1986). The lower proportion of ram lambs in Menz compared to other locations in the crop–livestock system indicates the tradition of marketing young ram lambs because of the greater dependence on sheep production.

The study of flock characteristics helps in the design of tailor-made breeding programs. The genetic improvement activities predisposed and hindered by unbalanced flock structures and small flock sizes. This demonstrated with the practice of maintaining limited numbers of breeding ewes in Bonga and Horro results in a small number of lambs being produced (selection candidates) thus limiting the effectiveness of selective breeding because of the low selection intensity (Wilson, 1986). Maintaining multiple breeding rams is another traditional practice, which is a challenge to the effectiveness of selective breeding at the village level, including those rams that need to cull because of their inferior genetic merits. Flock characteristics need to address in the design of genetic improvement programs. Farmers and pastoralists have their own indigenous/traditional breeding strategies when adopting a given flock size and structure/means of reproduction. Thus, the approach should be to design breeding programs that suit their strategies and practices, which do not impose an exotic practice in an attempt to introduce exotic breeding strategies.

When designing breeding programs, flock ownership patterns and traditional exchange of animals between flocks considered. Decisions made regarding breeding management affected by multiple ownership flocks and movement of animals between flocks. Multiple ownerships are common in traditional communities and there are several arrangements between farmers in this regard (Edea, 2008). In Bonga, 31.8% of the flocks are owned by one person, 37.7% by two, 20.2% by three, and 13.2% by four or more. Similar patterns observed in Horro (23.6, 44.1, 28.3, and 20.5%) and Menz (48.9, 45.27, 4.73, and 1.12%) (Abebe, 1999). The exchange of animals between farmers is more common in Bonga, accounting for 1.4% of flock entries and 2.1% of flock exits (Gizaw *et al.*, 2013a).

2.3. Sheep Genetic Resources Improvement

Sheep are found in different ecological zones of the country and that encompasses sub-alpine, arid lowland, sub-humid lowland, dry highland and wet highlands. The common type of sheep production in Ethiopia is based on indigenous breeds, however, Awassi crossbreds, Dorper crossbred and indigenous Washera crossbreds also existing in the different part of the country as reported by (Tibbo, 2006; Mekuriaw *et al.*, 2013;Lakew *et al.*, 2014), respectively.

Within a long period of time, indigenous sheep breeds have become adapted to various stress condition such as heat, cold, humidity, water scarcity, seasonal fluctuations in feed availability in terms of quality and quantity, and various diseases. They thrive on marginal and marshy lands unsuitable for cultivation, and on roadsides also convert leftover and by-products into animal protein, manure, wool and skin. Unfortunately, a large number of these genetic resources have been lost and many more are threatened due to uncontrolled crossbreeding and replacement with exotic breeds (Tibbo, 2006; Gizaw *et al*., 2013). Despite large sheep genetic resource endowment, so far efforts have been less to identify and characterize the genotypes and morphometric of local sheep breeds and their crosses existing in Ethiopia. Furthermore, doesn't have breeding program genetic improvement programs are still lacking. Results from fragmented studies indicated that there are 18 indigenous sheep populations in Ethiopia. The diverse groups of sheep populations in the central and western highlands above 2000 m.a.s.l. Include the Menz, Legagora, Tikur also called Lasta, Arsi-Bale, and Dangila also called Washera and Agew. These are collectively referred by Wilson (1991) as Abyssinian sheep or Ethiopian Highland sheep.

Lemma (2002) made the first comprehensive phenotypic characterization of sheep in the Amhara Regional State of Ethiopia and classified sheep groups of the state into four major groups. Namely Central Highland sheep (Menze breed, Wollo highland breed, Washera breed, Tikur, Semen and Farta), Northwestern Highland sheep (Gumuz sheep breed), Northwestern Lowland sheep (Begiet sheep breed) and Rift Valley sheep types (Afar sheep breed and their crosses with Menz and Horro sheep breeds).

2.3.1. Crossbreeding practices

The first introduction of exotic sheep breeds in Ethiopia traced back to 1944 when Merino sheep introduced from Italy by an American aid organization and maintained at Entoto near Addis Ababa sheep breeding station (DBSBMC, 2007). Research and development on sheep crossbreeding started at Chilalo Agricultural Development Unit (CADU) and the introduction of several exotic Wool sheep of Blue De Maine, Merino, Corriedale and Hampshire breeds in the late 1960s. The Menz crossbreeding program started in 1967 using Corriedale, Hampshire and Romney Marsh as sire breeds. The primary objective of the programs was to improve wool and meat production in local breeds. The program terminated and none of the exotic breeds traced back except for a few.

The two common perspectives condemned with sheep crossbreeding: First, crossbreeding considered a threat to survival of adapted indigenous breeds. Secondly, the crossbreeding is failed strategy to sustain genetic improvement in village flocks owing exotic genotypes being maladapted to local environment. Crossbreeding can be considered "a necessary tool in livestock improvement,'' however, its negative impacts on indigenous breeds can be ameliorated through rational crossbreeding strategies. The failure of crossbreeding programs cannot be attributed solely to poor adaptation of exotic genotypes, but the failure to design village crossbreeding programs are in line with farmers' aspirations and village breeding practices (Gizaw *et al*., 2013a).

2.3.2. Crossbreeding performance using exotic and indigenous sires

Tesfaye *et al*. (2013) revealed, commencing from the year 1969 to 1974, a total of 99 crossbred (ewe and ram lambs) lambs distributed to farmers. DBSBMC (2007), stated, the breeds' growth performance were performing well under on-station and farmer situation except Romney breed. Nevertheless, they were not preferred by farmers due to their physical characteristics (face covered with hair, absence of horn in males and thin tail), fatty nature of wool making it difficult to spin wool in the traditional way, and the suspected poor skin quality. Thus, during the imperial era, the crossbreeding was mainly limited to on-station to supply fattened sheep for the king palaces and occasions. Following the downfall of the monarchy (1974), crossbreeding efforts were directed to produce and disseminate crossbred rams to smallholder farmers. DBSBMC (Debre Berhan Sheep Breeding and Multiplication Center) distributed more than 4000 crossbred rams of different breeds (Awassi, Corriedale, and Hampshire) to smallholder farmers at subsidized prices between the year 1974 and 2001 (DBSBMC, 2007). Hampshire and

Corriedale breeds were initially used while these breeds were gradually replaced by Awassi following the introduction of Awassi in 1980. Awassi breed has been well accepted by Ethiopian farmers due to its similar physical appearance to that of local breeds. In the first four years of Awassi ram distribution, individual smallholder farmers were targeted.

Later on, from 1979 to 1989, the focus shifted to farmers organized in cooperatives. However, no performance evaluation was performed in the cooperatives and animals were looted during the government change in 1991 (Tesfaye *et al.*, 2013). Consequently, the cooperatives were abolished and dismantled, so the focus was again changed to disseminate rams to individual smallholder farmers. The target has been on disseminating rams with 75% Awassi inheritance to farmers for crossbreeding with their local ewes aimed at replacing the local sheep breed through repeated backcrosses (DBSBMC, 2007).

The Awassi × Tikur sheep crossbreeding started in two villages of Northern Wollo by Sirinka Agricultural Research Center in 2007 (Tesfaye *et al.*, 2013). The same author also roported, the ESGPIP project was implemented in collaboration with local universities and research centers at two nucleus and 10 breeding evaluation and distribution (BED) sites, established in the different parts of the country since 2007. Their nucleus sites were used to multiply the imported purebred Dorper sheep and provide a continuous supply of pure Dorper sheep to BED sites, private, commercial or cooperative farms and to those individuals who wished to establish their own pure breed producing farms. At BED sites, purebred sires were crossed with indigenous dams to obtain F_1 sires for dissemination to farmers. The funding of ESGPIP terminated in 2011 and the activities handed over to local universities and research centers for further implementation of the crossbreeding program (Tesfaye *et al.*, 2013).

Crossbreeding among indigenous breeds has also been practiced at DBARC as an alternative to the use of exotic genotypes for crossbreeding. Indigenous Washera rams were distributed in the highlands of North Shewa, South Wollo, North Wollo, and Gondar areas. In 2005, a village-based Farta×Washera sheep crossbreeding program has been started (Mekuriaw *et al.*, 2013) with the aim of increasing productivity of medium sized indigenous Farta (Gizaw *et al.*, 2008a) by crossing or introducing male and females of indigenous Washera sheep.

2.4. Indigenous Wollo Highland Sheep Breed

The indigenous sheep are year round breeders and mating is not controlled (Tibbo, 2006; Tesfaye, 2008). Wollo highland sheep breed is one of the indigenous sheep populations in Ethiopia and found in the North Eastern highland part of the country and accounts 1,991,087 heads of sheep and has the highest population found in the Amhara region (CSA, 2017). It is small in body size with a short-fat-tail (Gizaw *et al.*, 2007b) and they dominated in the highland areas are the main habitat. This sheep breed is well adapted high altitude precipitous topography and scarcity of feed with limited production of crop due to extreme low temperatures (Lemma, 2002; Gizaw, 2009). Smallholder farmers are keeping this breed as an important component of their livelihood income source (Gizaw, 2008b).

Wollo highland sheep are kept in a traditional, low input and subsistence-oriented production system. The production system characterized as a subalpine sheep cereal system (Gizaw *et al.*, 2008a) and in the extreme altitudes above 3000 m.a.s.l climatic conditions (recurrent droughts and cold temperature) are limiting crop production to sheep productivity (Tibbo, 2006). In such a production system, sheep are the main source of cash, manure, meat, skin and coarse wool (Gizaw, 2008) in addition to the socio-cultural role. Natural pasture is the main source of feed during all seasons and sheep are supplemented with crop residue during the critical dry season. However, feed shortage is the main challenge since productive pasture lands are gradually turning into crop fields and communal pasture lands are shrinking. Introduction of improved forage production is lacking and not adopted with the environment and lack of continuous developmental effort (Gebretsadik *et al.*, 2012). As a result, feed shortage in supply and quality is considered to be a challenge to increase livestock productive potential in highland areas of the country (Tibbo, 2006; Mengesha and Tsega, 2012).

2.5. Sheep Breeding Systems

The genetic improvement programs produced no significant effects on sheep productivity or on farmers' and pastoralists' livelihoods and national economy at large. The major downside of livestock crossbreeding programs in Ethiopia has been the lack of a clear and documented breeding and distribution strategy. Together with this, there has been very little consideration of the needs of the farmers and pastoralists, their perceptions, and indigenous practices (FAO, 2009). Additionally, they have limited or no participation in the design and implementation of the breeding programs. Further more, the breeding programs lacked breeding schemes to sustain crossbreeding at the nucleus centers and at the village level. The distribution of the improved genotypes of these programs was indiscriminate and unplanned, resulting in failure of breeding programs and threatened to dilute sheep genetic diversity in the country (Gizaw *et al*., 2013) and farmers in the highlands of Ethiopia, however, declined to accept the crossbreds due to their phenotypic unlikeness to the indigenous sheep.

2.5.1. Conventional hierarchical breeding schemes

A conventional hierarchical breeding scheme (top to downward breeding strategy) is a major determinant of success of breeding programs in smallholder livestock production systems. Designing a suitable breeding scheme for smallholder livestock production systems has remained a challenge hitherto. Until now, the sheep breeding programs in Ethiopia had adopted exclusively the conventional hierarchical breeding schemes. All the crossbreeding programs and the earlier Afar and Horro sheep breeding programs were hierarchically structured. Crossbreeding programs inherently require a hierarchical structure as improver breed needs to be imported, maintained, and multiplied at nucleus centers. However, livestock selection programs could be designed with hierarchical structure involving two or three tiers or with only a single tier combining the breeding and production activities together.

The conventional hierarchical sheep breeding schemes have several drawbacks (Gizaw and Tesfaye, 2009). The major shortcoming is they do not address fully the farmers' preferences under low-input systems (Gizaw *et al.*, 2011a). The conventional approaches also fail to consider different intangible, socioeconomic, and cultural roles that livestock play in each situation. This usually leads to wrong breeding objectives (Kosgey, 2004). As a result, most conventional breeding programs have failed. Kosgey *et al.* (2006) cited that, due to the absence of any distribution of improved genotype to farmers' flocks and inappropriate selection objectives, the failure of D'man sheep breed improvement in Morocco observed. Insufficient involvement of farmers and the shortage of financial and logistical resources for sustaining Peul, Touabire, and Djallonké sheep breed program in Senegal are additional reasons for the lack of success.

The major advantage of hierarchical breeding schemes is that they yield faster genetic progress as genetic improvement is carried out in a controlled environment at nucleus centers with advanced selection tools. These selection tools include selection on the basis of best linear unbiased prediction (BLUP) of the breeding values of selected candidates. In order to hierarchical programs to be successful, need to accommodate breeding objectives and have a design based on the indigenous breeding strategies of the farmers and pastoralists. Attempts have been made to design breeding schemes to transform the conventional nucleus breeding approach into a sustainable participatory breeding scheme (Mueller, 2006; Gizaw *et al.*, 2011a ; Haile *et al.*, 2011).

2.5.2. Participatory community based breeding schemes

The failure of the conventional hierarchical breeding system lead to community-based breeding schemes being suggested as viable options for genetic improvement programs of small ruminants in low-input, smallholder production systems (Kosgey and Okeyo, 2007; Gizaw and Tesfaye, 2009). Some success stories of community based breeding programs have been reported. These include significant involvement of a women's group in Northern Togo, involvement of farmers in the selection and control of inbreeding in

South and Southeast Asia and the use of indigenous selection criteria in southern Mexico (Kosgey *et al.*, 2006 and Castro-Gámez *et al.,* 2008).

A community-based breeding program refers to village-based breeding activities planned, designed, and implemented by smallholder farmers, individually or cooperatively to bring effect in genetic improvement in their flocks and conserve indigenous genetic resources. The process basically facilitated, coordinated, and assisted by outsiders of development agents, researchers, experts, governmental and non-governmental organizations. Unlike the conventional top to down breeding approach, community-based breeding strategies need a detailed understanding of the community's indigenous knowledge of farm animals regarding breeding practices and breeding objectives. The community-based breeding strategies, also consider production system holistically and involves the local community at every stage, from planning to operation of the breeding program (Baker and Gray, 2004). The breeding structure of such a program is commonly single-tiered with no distinction between breeding and production tiers, i.e. farmers and pastoralists are both breeders and producers.

Community-based breeding programs have recently been initiated in Ethiopia by research institutes. Community-based breeding programs are designing suitable breeding schemes that enable communities to implement breed improvement activities under uncontrolled village breeding practice. This includes procedures for selection and use of superior breeding stock and prediction of genetic progress under village conditions. However, the most genetically efficient and operationally feasible schemes need to be adopted.

2.5.3. The basis for designing community based breeding strategies

The basis for designing community-based breeding programs are the farmers' indigenous breeding strategies and resultant mode of livestock production. Farmers' and pastoralists' strategies arise from their indigenous knowledge of animal breeding and management system. Farmers' indigenous knowledge are expressed in their breeding and management practices, breeding/production objectives, marketing strategies. The indigenous strategies of the farmers and pastoralists take in to account for the production environment, long-standing tradition of livestock production practices, management skills, socioeconomic and cultural factors, and the availability of inputs and services (Kosgey *et al*., 2006).

The mode of livestock production practiced by a farming community has a direct bearing on the design of livestock development strategies. Thus, the production system in a target area have to characterized and understood in order to design a suitable breeding program. Community-based sheep breeding requires a full description of the existing environment, the current level of productivity, breeding objectives, and the selection criteria of sheep herder, available indigenous knowledge and breeding practices, and the full participation from the beginning of the farmers and pastoralists (Kosgey *et al*., 2006). The approach to designing breeding programs should attempt to fit new breeding strategies in to the indigenous breeding strategies of the target farmers and pastoralists, rather than forcing exotic methods and products assist the case with the conventional top to down design of breeding programs (Gizaw *et al*., 2011a).

2.6. Growth and Reproductive Performance

2.6.1. Growth performance

Growth in animals is defined by an increase in body size by differentiation of body cells (Bathaei and Leroy, 1996). Growth-rate and body size in company with changes in body composition are of great economic importance for efficient production of meat animals. The growth rate of lambs, particularly during the early stages of growth, is strongly influenced by breed (genotype), milk yield of the ewe, the environment under which the animals are maintained, including the availability of adequate feed supply in terms of both quantity and quality (Bathaei and Leroy, 1996). In another study (Laes-Fettback and Peters, 1995) it has been reported that pre-weaning growth performance is influenced by birth weight. As stated by Gizaw (2008) growth rate of lambs increases until the point of inflection which is attained when the animals are between one and five months of age.

After this point is reached, the animals continue to increase in weight, but at a declining growth rate as they approach maturity.

In tropical and sub-tropical regions, extensive grazing systems are practiced, the growth rate of animals fluctuates because of the seasonality of forage available. Forage based sheep production systems like those mostly found in the tropics and sub-tropics usually associated with slower weight gains, but total cost of gain may be less than those in the more intensive systems. To alleviate poor productivity performance or minimize the impact of fluctuations in seasonal forage growth patterns and feed availability, careful management practices are required. In such environments, lambs in their growing stages pass through weight gain and weight loss phases (Ehoche *et al.*, 1992).

Average daily weight gain and weaning weight are known to be significantly affected by the mothering ability of the dam. This is particularly important during the growth stages of lambs where there is more dependent on the milk production of the ewe rather than on forage.

Table 2. Growth performance of some breeds and their crosses in Ethiopia

Breed type	Management Type	BirthWeight (kg)	Weaning Weight (kg)	Yearling Weight (kg)	Source
Adilo	Traditional	2.3	11.2	-	Getahun (2008)
Afar	On station)	2.7	11.5	26.6	Yacob (2008)
Arsi-bale	Traditional	2.9	12.2	-	Getahun (2008)
BHS	On- station	2.6	11.4	23.7	Yibrah (2008)
Dorper	Extensive	4.1	30.0	64.4	Snyman and Olivier (2002)
Gumuz	On farm	2.8	12.6	–	Abegaz (2007)
Horro	On station	2.3	9.9	17.1	Tibbo (2006)
Horro	On station	2.6	12.1	23.8	Abegaz *et al.* (2002)
Menz	On station	2.1	9.1	17.3	Tibbo (2006)
Menz	On farm	2.4	8.3	16.4	Dibissa (2000)
Washera	On farm	2.7	12.4	23.5	Taye *et al.*(2009)

A similar trend was observed (Laes-Fettback and Peters, 1995) on Egyptian goats where breed and mothering ability of the doe have significantly influenced both the pre-weaning daily weight gain and the weight at 14 days of age.

The post-weaning growth rate of lambs has been just as important as the pre-weaning growth performance. This should be particularly looked into if the main objective of the sheep industry is producing meat through lamb production. In general, it is considered (Gatenby, 1986) that if the sheep did not reach their mature live weight, they will grow faster if provided with a better diet (compensatory growth). In practice, however, since the feed supply, particularly in the tropics is not constant throughout the year, a growth rate of animals shows seasonal variation. This is more evident in the dry tropics, where the growth curve for lambs is typically irregular due to losing and gaining of body weight. In regions where nutrition is poor, a rapid growth potential of larger breeds will have no advantage since smaller breeds could grow as well or even better than lambs from large breeds (Gatenby, 1986).

2.6.2. Reproductive performances

Reproductive performances like litter size, lambing interval and age at first lambing are economically important traits in sheep production enterprises (Gizaw, 2002). Both biological and economic efficiency of sheep production enterprises is improved with high levels of flock reproduction rate. Increased reproduction rate spread the high fixed energy input cost of maintaining the breeding ewe flock and replacements over more sales of offspring.

Conception and lambing rates in Horro ewes were found to increase with ewe parity and ewe weight at mating to a certain limit (extremely high ewe weights at mating and advanced age ewes have shown adecline in conception rates). Very low weight of ewes at mating affected conception negatively. Conception rate also declined with advanced age (Gizaw, 2002). Low heritability for litter size, which indicates there would be a low genetic improvement from direct selection of this trait.

Studies reported age at first lambing for Menz breed is 16.5 months (Gautsch, 1987), 17.06 months (Niftalem, 1990) and 15-22 months (Abebe, 1999). Furthermore, Tesfaye and Zewdu (2008) recently reported age at first lambing of 15.7 and 13.3 months, respectively for Menz and Horro sheep. Niftalem (1990) and Abebe (1999) reported on-farm and on-station lambing interval for Menz sheep shown that 12.7-13.6 months and 7.6-9.1 months, respectively. According to Tesfaye and Zewdu (2008) on-farm study lambing interval for Menz and Horro sheep is 8.5 and 7.8 months, respectively. Litter size for Menz breed 1.14 (Agyemang *et al*., 2011), 1.08 (Gautsch, 1987), 1.02 (Niftalem, 1990) as well as for Horro breed 1.34 (Abegaz and Gemeda, 2000a) reported. Litter size of Ethiopian sheep breeds like Menz sheep breeds is low which is almost close to one lamb per lambing while breeds like Horro is more prolific with litter size of 1.35 and 1.34 (Gizaw, 2002). Furthermore, Zewdu (2008) reported twinning rate of 39.8% for Horro sheep.

Table 3. Rproductive trait performances of selected indigenous breeds

Breed	LS	AFL	LI	Management	Source
Menz	1.0	512.0	395.0	On-farm	Niftalem (1990)
Menz	1.1	450.0	252.0	On-station	Mukasa-Mugerwa and Lahlou-Kassi (1995)
Menz Local	Na	522.3	260.0	Traditional	Tesfaye *et al.*(2013)
Menz Awassi cross	Na	630.7	329.4	Traditional	Tesfaye *et al.* (2013)
Menz	1.1	450.0	255.0	Traditional	Dibissa (2000)
Washara	1.1	464.0	285.0	Traditional	Taye (2008)
Washera	1.1	464.0	271.0	On-farm	Taye (2008)
Adilo	1.4	438.0	na	Traditional	Getahun (2008)
Arsi-bale	1.2	381.0	234.0	Traditional	Tsedeke (2007); Getahun, (2008)
Bonga	1.4	390.0	240.0	Traditional	Belete (2009)
Wollo Local	Na	434.1	227.1	Traditional	Tesfaye *et al.* (2013)
Wollo Awassi cross	Na	489.1	249.7	Traditional	Tesfaye *et al.* (2013)
Wollo Corriedale crosses	Na	469.4	224.9	Traditional	Tesfaye *et al.* (2013)

Na, not available; AFL, age at first lambing; LS, litter size and LI, lambing interval

Overall, Berhan and Van-Arendonk (2006) concluded that, Menz ewes have more acceptable reproductive performance compared to Horro ewes under controlled breeding. Though, the authors recommended for better characterization of those sheep breeds to do the same experiment in the area where Horro breed originated. Awgichew (2000) revealed that, sex, birth type, and dam parity also influence lamb birth weight. Lambs born at the end of the rainy season tend to be heavier at birth compared to those born at the beginning of the rainy season. Furthermore, Awgichew (2000) attributed higher birth weight to the provision of qualitatively better forage for the ewes during the wet season which covers the latter part of the gestation period.

Awgichew (2000) also reported, survival rate between birth and weaning (90 days) for Menz lambs with 89%. This was significantly higher than that for the Horro with 76%. The study also indicated that, Menz lambs had much better post-weaning survival rate from birth to 180, 270 and 365 days of age (81, 71 and 62%) compared to Horro (51, 39 and 37%), respectively. Tibbo (2006) reported a pre-weaning mortality of 33.1% for Horro and 19.2% of Menz sheep. This difference in pre-weaning mortality could be attributed to breed differences.

The reproductive performance of indigenous breeds in the different parts of the country was presented Table 4. Berhan and Van-Arendonk (2006) found an overall mortality rate in Menz and Horro breed of 13.5% and 27%, respectively in an on-station experiment. Tibbo (2006) reported that there is adequate within and between breed genetic variation for growth and survival, which can be exploited through selective breeding for permanent improvement of the breeds. In addition to this, Gizaw *et al.* (2007b) show that there is substantial additive genetic variation in the population of Menz breed which can lead to significant genetic improvement through selective breeding.

2.6.3. Lamb survival performance

Lamb survival rate is the major economic importance to sheep producers' world-wide since most lambs are sold primarily for mutton. Literature reviews indicated geographical variation in lamb mortality is considerable (Dalton *et al.*, 1980; Yapi *et al.*, 1990).

In South Africa, management inputs even with intensive care failed to reduce 'core' level of lamb losses below 15% (Brand *et al.*, 1985). It is generally accepted that, during the first few days of life the majority of weak lambs will die and the mortality declines as survivors grew older (Yapi *et al.*, 1990).

Table 4. Different breeds comparison of lamb mortality rate

Genotype	N	Mortality rate (%)				
		≤ weaning	≤ 6 months	≤ yearling	Overall	References
Local	848	3.8	6.8	11.4	7.3	Gizaw *et al.* (2012b)
Awassi *x* local crossbred	782	2.0	5.6	10.1	5.9	Gizaw *et al.* (2012b)
Corriedale *x* local crossbred	359	1.4	3.3	9.4	4.7	Gizaw *et al.* (2012b)
Dorper crosses	9	-	-	-	6.6	Lakew *et al.* (2014)
Local	158	-	-	-	4.6	Lakew *et al.* (2014)

N, number of sheep

2.6.4. Carcass characteristics and composition

Ahead of attempting to optimize approaches to lean lamb production, essential to understand environmental and genetic factors affecting carcass characteristics. Characterization of breeds for carcass composition is one such method through which potential genetic resources for lean lamb production could be identified. This will lead to a better understanding of management alternatives required for different genotypes.

The proportion of muscle, fat and bone in carcasses change as animals grows. Relative to empty body weight, bone tissue matures early followed by muscle (lean) and the fat tissue maturing late (Afonso and Thompson, 1996). The review by Anous (1991) shows, the ratio between weight of muscle (lean) and bone tissues is the most critical determinant of the value of carcasses. Tissue proportions of various sheep breed sand their crosses are differing each other. Most reports state a lean content of between 54 % and 58 %. Higher values are reported for Texel of 60% and Baluchi and Karakul of 75–77% (Colomer-Rocher *et al.*, 1992). Colomer-Rocher *et al.* (1992) have reported, the mean muscle content of male New Zealand Saanen goats was about 60% and stated that this was higher than that normally found in sheep. Ruvuna *et al*. (1992) have reported a lean: fat: bone ratio of 73:9:18 for 14 ½month old goats.

In meat production enterprises, lean is the most important economic component of the carcass yield characterestics traits. Producing and marketing of lean lamb to meet the consumer demand for less fat has become a challenge for livestock industry particularly in developed countries. The relative merit of different sheep breeds for meat production is determined by a high proportion of lean with low proportion of fat and bone in the carcass. While the tendency in developed countries is to produce meat animals with a decrease in fatness at the appropriate market weight and an increase in growth-rate and mature size, animals with a higher degree of fatness regardless of size and weight fetch a higher premium in most tropical countries. This is particularly true in Ethiopia where during festivities, lambs with higher fat cover are also priced higher.

2.7. Breeding Objectives and Breeding Practices

Breeding objectives and description of the production system and environment is the basis for designing tailor-made management and breeding interventions. These review invariably identified, farmers' primary breeding objective is to increase meat production.

Defining the production objectives identifies tangible and intangible uses of the sheep breeds reared by a community. The uses are equivalent to 'gross trait categories' which form the basis for identifying specific breeding objective traits. Some of the sheep production objectives of farmers and pastoralists in the mixed crop–livestock and pastoral systems presented in Table 5. The results show that, sheep play multifunctional roles in all production systems and reasons for keeping sheep are rational and related to the farmers and pastoralists' needs in the long or short-term.

The particular importance of multiple varieties of indigenous livestock breeds in low-input traditional systems has been widely established in Ethiopia (Gizaw *et al*., 2010a) and elsewhere (Kosgey, 2004). The primary sheep production objectives of smallholder farmers in mixed crop-livestock production systems are regular sources of income, meat, and manure. However, the Afar pastoralists primarily keep sheep for their milk followed by their meat and for income generation (Gizaw *et al*., 2013a).

Table 5. Farmers' breeding objective and traits selection criteria

Selection criteria	Rank Indexes of traits for farmers' breeding objective			
	Menz	Bonga	Horro	Afar
a. Breeding ram selection criteria				
Appearance/conformation/size	0.290	0.349	0.412	0.350
Colour	0.200	0.282	0.216	0.150
Horn	0.030	0.009	0.007	0.006
Ear	0.020	-	-	0.005
Growth rate	0.240	0.052	0.014	0.170
Fleece yield	0.004			
Mating ability	0.040	0.027	0.002	0.110
Tail size and shape	0.180	0.273	0.280	0.210
Temperament	-	0.005	0.002	-
b. Breeding ewes selection criteria				
Appearance/size	0.080	0.279	0.403	0.150
Coat colour	0.120	0.238	0.233	0.100
Mothering ability	0.220	0.075	0.046	0.160
Age at first lambing	0.030	0.020	0.101	0.030
Lambing interval	0.310	0.076	0.006	0.120
Twining	0.160	0.124	0.024	0.090
Tail size and type	0.050	0.137	0.089	0.090
Milk yield for family				0.220
Ear size	0.010			0.000
Longevity	0.020	0.003	0.0	0.040

Source, Gizaw *et al*. (2013a).

Different research adopted to understand farmers' traditional breeding practices have recently gained momentum. The farmers' traditional knowledge has been used to design village-based selection and breeding programs. Results showed that farmers do select their breeding stock (93% select rams in Menz region) using subjective selection criteria (Gizaw *et al*., 2011a). Research conducted to validate farmers' subjective selection criteria shown, there is a high congruence between selection based on subjective criteria and that on estimated breeding values. However, there is also limited research effort to evaluate the effectiveness of farmers' traditional breeding practices.

2.8. Indigenous Sheep and Their Crossbred Performance

2.8.1.Indigenous sheep breed performance

On-farm productivity of small ruminants in subsistence oriented smallholder production systems in Ethiopia is low and the estimated off-take rate (the percentage of animals slaughtered of all the population) for sheep is below 40% (FAO, 2009). With an average carcass yield about 10 kg per animal, the low off-take rate indicate that low productivity at farm and national level. Accordingly, FAO (2009) stated that the annual off-take rate for sheep is estimated to be 40 % with an average carcass weight of about 10 kg which is the second lowest among the Sub-Saharan African countries. Carcass quality is poorly defined in Ethiopia, while the proportion of fat in the carcass and lean to bone ratio are of major importance if animals sold to more affluent urban and export markets. Dressing percentage could be also an important tool to evaluate carcass merit and estimate of dressing percentage for Menz and Horro lambs were 49.1% and 48.0 %, respectively (Awgichew, 2000).

According to Awgichew (2000) reported, on-station Menz and Horro lambs did not have significant difference both pre-weaning and post-weaning average daily gain. However, between birth and 180 days of age group, Horro and Menz lambs gained 26.2 and 26.3g, respectively. Furthermore, lambs born in the wet season had a slightly better pre-weaning growth rate compared with dry season which indicates the seasonal influence on growth performance. Moreover, the fixed effect of birth type, dam parity and season of birth significantly influenced pre-weaning average daily weight gain (Awgichew, 2000).

However, Aklilu (2005) reported that sheep export from the highland area is limited due to darkening of the meat after slaughter. The favorable proportion of carcass fat, higher carcass lean yield and lean to bone ratio in Horro and Menz breed as well as the lowest non-carcass components in the Menz breed indicate sustainability for export of mutton.

Moreover, Negussie *et al*. (2004) stated, growth and carcass composition in Horro and Menz breed are significantly affected by genotype, growth phase and season of birth. The growth rate in indigenous Ethiopian sheep breeds is slow and this result in limiting the profitability. However, growth in lambs is influenced by breed, sex of lamb, litter size and season of birth as a reflection of seasonal fluctuation in feed availability and milk yield of the dam. Because of seasonal fluctuation in feed availability, animals lose weight during dry season and gain weight during the wet season, deposit fat during the later season and mobilizes during the unfavorable season (Negussie *et al*., 2004; Ermias *et al*., 2002). According to Awgichew (2000) birth weight of Horro and Menz lambs, 2.43kg and 2.17 kg, respectively. Furthermore, Horro sheep had significantly larger live body weight at all ages than the Menz by as much as 6 to 18%. In both breeds, lambs born single were significantly heavier than those born as twins or triplets. In all age categories and both breeds, males were consistently heavier and larger in size than females (Tibbo *et al*., 2004).

2.8.2.Crossbred sheep performance

On-farm evaluation of the performance of Awassi x local crossbred sheep under farmers' management were launch by DBARC in three villages in the highlands of Ethiopia in 1997. Details of the breeding program followed by DBARC are indicated (Gizaw and Tesfaye, 2009; Tesfaye *et al*., 2013a). Similarly, the Awassi x Tikur sheep crossbreeding started in two villages of North Wollo by Sirinka Agricultural Research Center in 2007. The better growth performance of Awassi crossbreds (Hassen *et al*., 2004; Gizaw and Tesfaye, 2009) and comparable reproductive performances of Awassi and Corriedale crossbreds (Tesfaye *et al*., 2013) compared to their local counterparts were reported from the on-station and on-farm evaluation of sheep crossbreeding. Longer age at first lambing and lambing interval, higher ewe post-partum weight of Awassi crossbred ewes reported (Tesfaye *et al*., 2013a: Gizaw *et al.,* 2014). The positive association of ewe postpartum weight with lamb birth weight has been reported (Hassen *et al*. 2002) and resulted in better lamb growth and survival rate from crossbred ewes (Tibbo, 2006; Tesfaye *et al*., 2015b). The inferiority of Awassi crossbred ewes in age at first lambing and lambing interval are offset by their ability to raise their lambs to weaning age, which resulted in comparable (Tesfaye *et al.*, 2013a) and better lambs weaned/ewe/year under farmers and on-station management condition, respectively.

2.8.3. Linear body measurement

Body measurement is considered as quantitative growth indicator of growth performance, which reflects the conformational changes occurring during the life span of animals. Although live body weight is an important growth and economic trait, it is not always possible to measure it due to mainly the lack of weighing scales, particularly in rural areas. However, the body weight can be reasonably estimated from some linear body measurements (Mayaka *et al.,* 1995). According to these authors, body weight of West African Dwarf (WAD) goats has been satisfactorily predicted by using heart girth as the only regressor variable.

Linear body measurements have been also used to give information on differences in body proportion as well as short- term fluctuation of body proportion mainly due to weight loss and gut fill. Indices using body measurements have been used to estimate shape which is usually difficult to quantify due to its subjectivity in comparison with the size. Body dimension measurements will be particularly useful when it is not possible to take direct measurements of the main meat production traits such as body weight and carcass traits.

2.8.4. Phenotypic ranking of group of live animals

Phenotype ranking of animals has been recently employed to capture information about breeding animal selection criteria of owners. For aphenotypic ranking of live animals, identifying/marking and randomly assigning of animals of similar age, size and condition into different sub-groups for ranking are crucial. It would also be interesting if animals of different colors can be included to elicit their preferences for the different colors and attach a value to each color type. Involving relevant stakeholders other than livestock owners, like local traders, can also help to attach values to animals of different age, color and size. Randomly regrouping or reshuffling of animals at certain interval is necessary during the course of the ranking process to minimize biases. Then each interviewee is asked by a well-trained enumerator to rank animals of the different groups according to his/her own preferences and to provide reasons why she/he ranked the animals in that order (Pares *et al*., 2014). The ranking can be conducted first based on phenotype alone where after the interviewee is provided with additional information on each animals life history provid, including production and reproduction performances; then to investigate decision changes to be made by the respondents (Gemeda *et al*., 2010).

2.9. Feed Shortage and Nutritional Stress

One of the limiting factors for increasing production and productivity of small ruminant in most of the agro-ecological zones of Ethiopia, particularly in highland area is a feed shortage and quality (Gebremedhin *et al*., 2007; Bogale *et al*., 2008). The ruminants in the smallholder sector depends on natural pasture and fibrous crop residues for survival, growth and reproduction. The available natural pasture land overloaded with livestock beyond optimum carrying capacity resulting overgrazing and land degradation, leading to low agricultural productivity. Since the quality and quantity of the natural pasture vary with season (Kitaba and Tamir, 2007; Bogale *et al*., 2008), animals that depend on it are subject to nutritional stress in the dry season when feed resources are sensed and in short supply. Many authors described the seasonal feed shortages, both in quality and quantity, and the associated reduction in livestock productivity in different parts of the country (Tibbo, 2006; Tsedeke, 2007; Getahun, 2008). The feed shortage problem is similar throughout the country, being serious in high human population areas where land size is diminishing due to intensive crop cultivation and soil degradation. The better use of available feed and non-conventional feeds for supplementation is growing (Yishitila, 2008; Belete, 2009).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The current research was conducted in the two selected area of Dessie Zuria and Kutaber Districts in South Wollo Zone of Amhara Region, Ethiopia. The geographical location of South Wollo Zone is delimited with North Shewa and Oromia region in the Southern part, East Gojjam in the West, South Gondar in the Northwest, North Wollo in the North, Afar Region in the Northeast and Argobba district of the Oromia Zone in the Eastern part.

Dessie Zuria district is located at a distance of 401 km from Addis Ababa at the Northern part and bordered at the Southern part with Albuko and Were-Illu, in the Southwest with Leghambo, in Northwest with Tenta and Kutaber, in the Northeast with Tehuledere and with East at Kalu districts. The geographic feature of the area was dominated by cool highland topographical structure with some areas peak close to 4,000 m.a.s.l. While the widespread areas situated above 2500 m.a.s.l and located at latitude and longitude of 11°8′N 39°38′E and the remaining part has a range from 1500 m.a.s.l up to 2500 m.a.s.l. This district had a total human population of 157, 679 out of this 47.7% are men 52.3% women. The total area coverage of the district is 937.32 km^2 and with a population density of 168.22 persons/ household per km^2 and a total of 35, 437 households with an average family size of 4.45 (CSA, 2015).

Kutaber is the second district of the study area; which is located at a distance of 421 km from Addis Ababa and 20 km from the main highway road in the northwestern part of Dessie town. It is delimited with North Eastern direction by Dessie Zuria and Tehuledere, Southern part with Ajibar and Tenta, the Northern part with Ambassel, and the western direction with Wogel Tena Districts. The geographical feature of the district consists of 26.4% mountainous, 48% undulating, 13.3% plain and 12.3% lowland. It is characterized by an average altitude ranging from 1400-2900 m.a.s.l. Therefore, the agro-ecology comprised of Dega (highland), Woina Dega (mid-highland) and Kolla (lowland).

According to CSA (2015), the total population of Kutaber District was 95,410,and of which 47,341 were men and 48,069 women and 5.18% are urban dwellers. The population density of the area was 132.53 per km^2, which was less than the Zonal average of 147.58 persons per square kilometer.

Figure 2. Map of the study areas in South Wollo Zone, Amhara Region, Ethiopia.

3.1.1. Sheep production of the study area

Dessie Zuria and Kutaber Districts have a populous sheep population from other districts of the administrative Zone and the region. Even though, the livelihood economy depends on the crop production, it's strongly supported by livestock production and mainly with sheep, cattle, goat and chicken production. The districts historically chronic food insecure area for long years ago because of shortage of rainfall and drought, however, strongly supported by sheep production. Sheep were sold to get immediate cash income through petty trading, including buying, fattening and selling practices. Nowadays composite crossbred sheep common and familiarized in the market and in farmers’ flock with the introduction of exotic Awassi and indigenous Washera rams for local sheep breed genetic improvement practice.

3.1.2. On-farm flock management practice

The smallholder farmers' flock management practice was characterized by mixed crop-livestock production system. Smallholder farmers' sheep flocks allowed in a communal and private grazing land during daytime and depart during night time and housed together with other livestock separated by woodlot. Some farmers who own only small flock does tied by a peg. The main feed source for sheep is grazing on private and communal natural pastures, improved forage like, oat grass (*Jerry Oats) and* vetch (*Vicia sativa*) and non-conventional and conventional feed supplementation were very common practice. The other very common practice is, during crop harvesting times, sheep have access to fed crop aftermath. Some farmers give supplementary feeds (wheat bran, milling by-products and local brewery by-product, grain and grain by-product, home by-product and salt) for the pregnant and nursing ewes, suckling lambs and castrated and fatten rams. Their flock is characterized by small, medium and large flock size of 1-13, 14-26 and 27 or more ewes/flock, respectively based on number of ewes per flock (Agyemang *et al.*, 2011).

Figure 3. Communal grazing area sheep production system in the study area

The breeding practice is usually year-round under smallholder management systems and breeding rams are selected by the objectives of smallholder farmers' traits of interest. The phenotype attributes of ram and ewes are used as the major selection criteria. Breeding rams run with the group of flock to mate with any ewe in heat during the day. Ram lambs born in the flock and not needed for breeding would be sold or castrated before reaching breeding age. The sheep flocks were de-wormed against internal parasites three times a year (at the end of rainy season, at mid-dry season and the onset of rainy season) and external parasites when needed. They were vaccinated against pasteurellosis, anthrax and black leg with irregular intervals.

3.2. Description of the Study Genotypes

3.2.1. Local Wollo highland sheep breed

Wollo highland sheep breed is one of the indigenous sheep breed found in the highland part of North Eastern Ethiopia. This breed is characterized by short fat tail and twisted/ coiled end, occasionally turned up at end, small size, well-developed wooly undercoat, predominantly black, white or brown, either plain or patches of white, black or brown, long hair with wooly undercoat and horned males. Wollo highland sheep breed is mostly recognized by adaptation of feed shortage, lamb survival rate and wool production. Sheep are important source of cash income and manure, social and cultural functions, a means of insurance against drought, and other adversities for landless small and marginal farmers because of their lower capital cost and easy management of women and children.

Figure 4. Local Wollo highland sheep breed on private natural pasture grazing area

3.2.2. Washera × Wollo highland sheep crossbreed progenies

Washera sheep breed is one of the indigenous sheep breeds reared by the rural farmers in the mixed crop-livestock farming systems of the northwestern highlands of Ethiopia (Lemma, 2002). The pure Washera sheep breed is found in the West and East Gojam and Agew Awi zones of Amhara regional state. Its characteristic features are; short, fat tailed, large body size, short-haired, predominantly brown, both males and females are polled. These breed has an important source of income, manure, social and cultural functions, a means of insurance against drought and other adversity. Lemma (2002) reported, the Washera breed has an important genetic potential for growth and adaptation to a wide range of agro-climatic conditions. Chipman (2003) has been reported, relatively fast growth rate under harsh circumstances with potentials to support farmers and the national economy. Because of the accessibility and adaptation problems of exotic breeds for the genetic improvement practice, the smallholder farmers are increasingly interested in using Washera rams for breed improvement practices through crssbreeding.

Figure 5. Washera rams and their crossbreds on village based breeding scheme

3.2.3. Awassi × Wollo Highland sheep crossbreed progenies

The Awassi crossbreeding projects were operated by the Debre Berhan and Amed Guya Sheep Multiplication center in Amhara region since 1974. The multiplication center has been closed from 2004 to 2007 due to an outbreak of a respiratory disease (Maedi-visna). The Awassi ram cross with Wollo highland breed ewes crossbreeding scheme involves, introduced improved Awassi rams in sheep breed multiplication center, for production of 3/4 Awassi×Wollo highland sheep crossbred progenies, distribution of 6-month-old ¾ Awassi crossbred ram lambs for villagers and upgrading of the village flocks to 75% Awassi with back crossing. Bureau of Agriculture and Rural Development is responsible for the dissemination of crossbred rams to the villagers. The characteristic features of the crossbred progenies are large body size, wooly hair, well-developed coarse and wooly undercoat, predominantly white or brown, either plain or with patches of white, horned males, short and medium fat tailed, long and convex face, short type of ear.

Figure 6. Awassi × Wollo Highland crossbreds on private controlled breeding scheme

3.3. Farmers' Sheep Breeding Practices

Currently, smallholder farms are using participatory based sheep genetic improvement approach through crossbreeding with producers involvement through designing common breeding objectives. Therefore, the smallholder farms are participating through planning, designing individually and cooperatively to achieve genetic improvement objectives of local sheep breed and conserve indigenous genetic resources. The whole processes were facilitated, coordinated and assisted by outsiders of the development agents, researchers, both governmental and non-governmental institute professional. Unlike conventional top down breeding approach, community based breeding strategies basically need a detailed understanding of local communitys' indigenous knowledge regarding breeding practices and objectives.

Figure 7.Washera F_1 crossbred sheep on private controlled breeding scheme

Genetic improvement practices done through introduction of indigenous pure Washera sheep breed and 3/4 % Awassi rams at farmers' management condition with participation of sheep producers. The genetic improvement objectives of local communities were to improve the productive and reproductive performance of local Wollo highland sheep breed.

Genetic improvement strategies of farmers take into account of production environment, livestock production practices, management skills, socioeconomic and cultural factors with the availability of inputs and services.

Figure 8. Awassi F_1 crossbreds on village community based breeding scheme.

3.4. Research Design

The study areas were clustered into three genotypes, based on availability of local Wollo highland sheep breed and their F_1 crossbreds of 75% Awassi and pure Washera rams with Wollo highland ewes. The genotype based cluster formation considered the availability of comparable sheep population, agro-ecology similarity, comparable flock management practice, farmers' breeding strategies and objectives. Data collection conducted through questionnaire survey, participatory oriented group discussion, smallholder farmers' flock monitoring and feeding trial experiment.

Table 6. The genotypes and number of flocks in each clustered area.

Districts	PA/ Kebeles	Genotypes	No of flocks
Dessie Zuria	Guguftu (Village 35)	Awassi F_1 crosses	23
	Guguftu (Village 36)	Awassi F_1 crosses	23
	Tebasit (Village 37)	Washera F_1 crosses	37
	Gelsha (Village 38)	Washera F_1 crosses	37
Kutaber	Alasha (Village12)	Local Wollo highland breed	67
	Borumeda (Village13)	Local Wollo highland breed	68
Total	Six	Three	255

PA, Peasant association (adiministrative kebele)

3.5. Sample Size and Sampling Procedure

3.5.1. Purposive sampling method

Dessie-zuria and Kutaber Districts and six peasant association areas of four from Dessie-Zuria and two from Kutaber district were purposefully selected. The selection procedures were based on infrastructure accessibility, sheep population, availability of Awassi and Washera rams and their F_1 crossbred lambs, crossbreeding practices and comparative uniformity of existing agro-ecology. The number of sampling frame flocks selected by purposive sampling method based on smallholder sheep producers who have appropriate genotype, flock size, breeding strategies and crossbreeding experience. Subsequent to the decision making on the number of flocks as sample size, from each selected sampling frames, each individual sampling units were selected by purposive sampling techniques.

3.5.2. Stratified proportional to size sampling method

The study areas were clustered into three genotypes of Awassi F_1 crossbreds, Washera F_1 crossbreds and Wollo highland breed. Thus, each sampling frames were drawn from each genotypes according to their population size. Hence, Awassi F_1 crossbreds, Washera F_1 crossbreds and Wollo highland breed consisted of 230, 370 and 675 sampling frame household flocks, respectively by the purposive sampling. Then the sampling fraction of each of the three genotypes synthesized and sampled elements were drawn from each individual genotypes. First select and decided the smallest size genotype and then divided the size of each genotype by the smallest one (ILCA, 1990 and Wayne, 1995).

$$\text{Proportional size of the three genotypes were} = \frac{675}{230}:\frac{370}{230}:\frac{230}{230} \approx 3:2:1$$

Thus, these proportions mean that; when 3 households drawn from Wollo highland sheep breed owners, at the same time there should be 2 and 1 households draw from Washera and Awassi rams F_1 crossbred owners, respectively. In such a way that, the total sample size drawn as proportional to size method from the three genotypes. According to the sampling ratio was calculated using the addition of proportions (3+2+1), that gave as 6 as value of total proportion. Finally, it was divided the smallest proportion which equals to 1 by the total sum of proportions of 6 and the sampling ratio was calculated to get the correction factor: 1/6=0.17 and used the nearest value of 0.2 as correction factor.

Then sample elements drawn from each genotypes were = 0.2*675=135 household flocks selected from Wollo highland sheep breed, 0.2*370 = 74 flocks from Washera rams F_1 crossbreds and 0.2*230=46 flocks from Awassi rams F_1 crossbreds. Therefore, a total of 255 household flocks selected from three genotypes according to Wilson *et al.*(1985b), ILCA (1990) Wayne (1995) procedures. Consequently, 4-5 months of pregnant ewes were also selected through purposive sampling method from the three genotypes for on-farm flock monitoring.

3.6. Data Collection Methods

3.6.1. Questionnaire survey, focus group discussion and on spot observation

Single-visit, multiple-subject survey approach of semi-structured questionnaire and oral interviews were held on three genotypes flock owners, development agents and experts. The questionnaire survey initially pre-tested on key informants and re-adjusted before administrated for actual respondents. Smallholder sheep producers' flock characteristics data, including flock size and composition, breeding ewes, breeding rams, pre-weaning ewe and ram lambs, post-weaning ewe and ram lambs, unproductive ewes, castrated, fattened rams and annual off-take rate (slaughtered+sold) gathered through questionnaire survey. While, participatory based recall focus group discussion delivered on breeding objectives, breeding strategies, farmers' traits of interest and trait trait selection criteria identification.

On-spot observation with group discussion data collection applied to gather information on phenotype characteristic of live animals' surveillance of their body size, color type, horn type, hair type, body conformation, temperament and tail type of Wollo highland breed, Awassi and Washera F_1 crossbreds. Farmers' breeding ewes and rams selection criteria were based on the interest of lamb survival rate, mothering ability, temperament, lamb growth rate, parental history, drought tolerance, tail type, breed type, horn type and body conformation data were gathered through group discussion and on-spot observation of live animals.

3.6.2. On-farm flock monitoring

3.6.2.1. Reproductive performance monitoring

Annual flock reproductive and lamb growth performance data were gathered through smallholder farmers' flocks monitoring throughout 365 days. Through proportional to size sampling method, 846 total sampled candidate ewes were selected and monitored from the three genotypes. Consequently, 142 ewes from Awassie F_1 crossbreds, 259 ewes from Washera F_1 crossbreds and 445 ewes from Wollo highland breed used for flock reproductive and lamb growth performance study. Through continuous recall multiple visit, multiple subject survey method, appropriate informations of lambing rate, number of breeding ewes and rams, number of parturition/year/ewes, number of services/ conception, age at first mating and lambing, number of single and twin birth/flock/ewes, weaning rate, lambing interval, lamb mortality and survival rate informations were collected. The major ewes reproductive performance information like, fertility rate (ewes lambed/ewes mated), prolificacy rate (number of lambs born/ number of ewes lambing), lambing rate (lambs born/ewes mated), weaning rate (number of lambs weaned/ number of ewes lambed) and mortality rate (number of lambs died prior to weaning/ number of lambs born) were calculated.

3.6.2.2. Lamb growth performance

The total of 360 ewes with 4-5 months pregnancy period selected from 846 candidate ewes from the three genotypes to gather growth performance information. In general 85 ewes from Awass F_1 crossbreds, 120 ewes from Washera F_1 crossbreds and 155 ewes from Wollo highland breed used for ewes reproductive and lamb growth perofrmance study. Consequetively, 132, 218 and 322 lambs were produced from Awass F_1 crossbreds flocks, Washera F_1 crossbreds flocks and Wollo highland breed flocks of pregnant ewes, respectively. Consecutively, data collection measurment conducted through body weight gain, survival rate, mortality rate and weaning rate directly from the measurment value and indirectly from calculated values. Lambs growth performance measured by birth weight, average daily weight gain between 3, 6, 9, 12 months of body weight gain and linear body measurement values. The data collection conducted through multiple visit and multiple subject surveillance record with the help of field book and observational notes.

The data recording and collection done throughout birth to 365 days of monitoring period and both pre-weaning and post-weaning growth performance also calculated. Therefore, every 15 days interval body weight gain measurement taken from birth to 365 days using a mobile system of weighing scale and at 0.1 kg precision scale. The average daily weight gain was computed by dividing the total body weight gain at a given period of time by the total number of days monitored. In addition to, body weight gain recording data, growth performance also computed by linear body measurement traits at 3, 6, 9 and 12 months of age groups (Wilson *et al.,* 1985b).

$$Average\ daily\ Weight\ gain = \frac{Weight\ at\ a\ period\ (t+1) - Weight\ at\ period\ (t)}{Numbers\ of\ days\ between\ t, t+1}$$

$$Weaning\ rates\ (\%) = \frac{Number\ of\ offspring\ weaned\ per\ flock}{Number\ of\ females\ given\ birth} x100$$

3.6.2.3. Linear body measurements

Linear body measurements were taken together at 3 months of interval measurement of body conformation change up to 1 year monitoring period. All body measurement traits were taken with a measuring tape in centimeter and measured to the nearest 0.5 cm. The following linear body measurements were taken as lamb growth performance indicator traits of heart girth (the circumference of the chest posterior to the forelegs at right angles to the body axis), withers height (the highest point measured as the vertical distance from the top of the shoulder to the ground), body length (the distance between the crown and the sacrococcygeal joint) and f) tail circumference (directly behind the tuber iced).

3.6.3. On-station body weight gain and carcass yield characterestics

3.6.3.1. Experimental animal management

The experiment was conducted at Borumeda peasant association area which is located at peri-urban area of Dessie Town, Farmers' Training Center (FTC). The farmers' training center well constructed concrete floor house and 3 hectares of controlled natural pasture grazing area. In the FTC center, local farmers' have an opportunities to observe different genotypes body weight gain performance and management practices of experimental activities through periodical evaluation.

On-station feed supplementation experiment designed to confirm on-farm lamb growth performance variation of the three genotypes with controlled management situation and to quantify the reliable genotype effect. Therefore, experimental animals purposefully selected from on-farm survived lambs throughout growth performance monitoring period. A total of 36 ram lambs (12 from each genotypes) were selected for on-station growth performance and carcass yield characteristics evaluation. Experimental animals were selected from on-farm monitored lambs based on the assumption of their age, body and health condition, physical appearance, sex and birth type and on-farm recorded data. They were selected from Awassi F_1 crosses, Washera F_1 crosses and local Wollo highland breed lambs. Experimental animals purchased from farmers' with appreciable price to encourage farmers' participation in data collection. They were quarantined for a period of three weeks and vaccinated against diseases like ovine pasteurellosis, sheep pox and anthrax before the actual trial started. They were injected with Ivermectin and dewormed with Al-bendazole, and sprayed with acaricide against parasites. After 21 days of quarantine and acclimatization time, each animals were kept in $1.5 \times 1m^2$ dimensions individual pen with concrete cemented floor.

3.6.3.2. Experimental design

A 3×2 factorial experimental design arrangement of three genotype and two feeding type factors with six treatment levels (three genotypes by two feeding type's combinations) and 6 replications were used. The three genotypes belonging to 50% Awassi F_1 crosses, 50% Washera F_1 crosses and 100% local Wollo highland lambs were grouped in to three by their genotypes and in to two by their feeding types of supplemented and non-supplemented groups for each genotypes. The supplemented and non-supplemented feeding types randomly assigned for each 36 experimental animals.

Both supplemented and non-supplemented groups grazed for 8 hours/day as a basal diet with rotational grazing system and animal holding of 36 sheep/0.5 hectare paddock/day. The supplemented group fed at the rate of 1% of their body weight/day of concentrate mix diet. Whereas, the non-supplemented group fed only natural pasture grazing area for 8 hours/day from 8:00 AM to 5:30 PM with a 1 hour rest from 12:30 AM to 1:30 PM and had free access of drinking water.

3.6.3.3. Experimental animals grazing management

The grazing land characterised by both annual and perennial grass such as *Cyperus rotundus, Dactylis glomerata Cynodon nlemfuensis, Cynodon dactylon, Cyperus polystachyos and Urochloa brizantha* (Table 7). The size of natural pasture grazing area was 2.5 hectares of land and that, sub-divided into 5 paddocks with each individual paddock size was 0.5 hectare.

Figure 9. Natural pasture rotational grazing management of experimental animals

Table 7. Grass species composition of natural pasture grazing area

Local name	Scientific name	Growth form
Akirma	*Cynodon nlemfuensis*	Grass-perennial
Tult	*Asarum canadense*	Herb-annual
Sindedo	*Urochloa brizantha*	Grass-perennial
Serdo	*Cynodon dactylon*	Grass-annual
Gicha	*Cyperus rotundus*	Grass-annual
Gazia	*Dactylis glomerata L.*	Grass-perennial
Arintata	*Trifolium repens*	Herb-annual
Muja	*Snowdenia polystachya*	Grass-annual
Gudign	*Dichondra repens*	Herb-annual
Ketema	*Cyperus polystachyos*	Grass-perennial

3.6.3.4. Experimental feed preparation and chemical analysis

The concentrate feed formulated from local available industrial by product which composed of wheat bran, linseed cake and mixture of pea middling and husk. These by-products were the most commonly available industrial by-prduct feed in the lacal market and familiar with local livestock producers' flock. Hence, experimental diet purchased from Dessie town wheat flour milling factory, oil processing industry, small scale milling house and these are the common type of supplementation diet for sheep fattening. The concentrate mixture was comprised of 51.3% of wheat bran, 30.6% of linseed cake, 17.1% mixture of pea middling and husk and 1% of salt. The different feed ingredients formulated to have CP and energy level to meet the optimum recommendation of supplementary feed requirement of growing lambs (18 % of CP and 10 MJ ME/kg DM) (Flint, 2005). The supplemented feed thoroughly mixed at the given proportion rate.

Natural pasture grazing land of 2.5 hectares used as a basal diet. The grazing area fenced and free from animal contact during spring and summer season and it has abundant with annual and perannual grass. It was formerly used as production and conservation of hay making to generate income for the office of agricultural developmental agents through minimum cost sale for local livestock producers during drought time.

Samples of feed were dried at 65 ^{0}C for 48 hours. The dried samples were ground (1 mm screen) for subsequent analyses of Dry Matter (DM), Crude Protein (CP), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). N and total ash determined according to official methods of AOAC (1990) (Association of Official Analytical Chemistry) and NDF and ADF according to Van Soest *et al.* (1991).

Table 8. Chemical analysis and its nutritional contents of experimental diet

Ingredient (%)	DM	CP	NDF	ADF	CF	P	Ca	Ash	IVDMD	MJ ME /kg DM
Linseed cake	93.6	31.8	40.3	21.2	9.7	0.9	0.1	7.0	84.5	13.0
Pea middling and husk	92.9	5.9	55.3	47.8	1.8	0.1	1.7	5.0	59.5	9.3
Wheat bran	90.8	16.4	49.2	16.5	4.7	1.1	0.2	7.0	60.0	9.4
Total mixture	91.8	18.2	48.3	28.5	5.4	0.7	0.6	6.7	68.0	10.7
Basal diet hay	90.1	8.8	64.7	45.2	0.9	0.3	0.3	8.0	51.3	8.1

DM, Dry matter; CP, Crude protein; NDF, Neutral detergent fiber; ADF, Acid detergent fiber; CF, Crude fat; P, Phosphorous; IVDMD, Invitro dry-matter digestiblity; MJ ME, Mega-Jule metabolizable energy and Ca, Calcium.

The dry matter content of the feed determined by drying the samples in an oven at 105 °C overnight while ash content was determined by burning the samples at 550 °C for 5 hours in a muffle furnace. Nitrogen (N) was determined by Kjeldahl method (CP = N × 6.25). Ccalcium (Ca) determined by a wet digestion method using an Atomic Absorption Spectrophotometer and phosphorus (P) using a continuous flow auto-analyzer.

3.6.3.5. Body weight measurement

Experimental animals weighed every 10 days interval for the experimental period (90 days) before morning feeding. When ram lambs body weight change occurred via treatment period the amount of feed offered readjusted every body weight measurement. Initial weight (IW) and final weight (FW) recorded twice in two consecutive days and the average taken. Average daily weight gain (ADG) was determined by regressing the body weight against time of 90 days feeding trial experimental periods. The final weight gain and total body weight change recorded on final experimental period and every weight measurement time, respectively.

Linear body measurements such as body length (length from point of shoulder to pin bone), height at withers (measured from the base of the hoof to the highest point of wither) and heart girth (body circumference immediately behind the forelegs) taken at the end of the feeding trial using measuring tape as described by Tadesse *et al.* (2016).

3.6.3.6. Slaughter and carcass yield measurements

A total of 18 ram lambs (50% per each treatment groups) from each genotype was randomly selected at the end of the experiment period for carcass and non-carcass yield characterestics evaluation. Lambs were weighed in the day before slaughter (24 h) to obtain their live weight (LW) and then transported to Dessie municipal slaughter house. Then lambs were slaughtered by severing of carotid arteries and skinned and eviscerated to obtain their hot carcass weight (HCW) according to Kadim *et al.* (2003) procedure. The carcass weight is the weight after removing both edible and non-edible non carcass components (skin, weights of blood, head, forefeet (at the carpal-metacarpal joint), hind feet (at the tarsal-metatarsal joint) viscera and fat depot). Internal organs fat depots such as scrotal fat, kidney, renal pelvis fat and mesentery fat were removed and recorded. Hot carcass weight (HCW) and the internal organs, testicles, fat depots and full and empty gastrointestinal tracts recorded. An empty body weight (EBW) is excluded of the gastrointestinal tract contents also recorded. Dressing percentage (DP) is the hot and cold carcass weight expressed as a percentage of slaughter and empty body weight bases. The total edible proportion (TEP) was the SBW minus the total non-edible carcass and non-carcass components. Subsequently, carcasses were kept for 24 h in cold storage at 4±2 °C and cold carcass weight (CCW) recorded. Chilling losses calculated as the difference between HCW and CCW. Yields of hot (HCY) and cold carcasses (CCY) calculated using respective carcass weight in relation to live weight. All carcass and non-carcass measurment taken by weighing scale and sensetive balance, respectively with precision scale of 1mg readability. To maintain the performance of the balance and calibrations was performed after any adjustment procedure made for the balance.

Carcass linear measurements such as carcass length (measured from caudal edge of the last vertebrae to the dorso-cranial edge of the atlas), leg width (widest measurement of the hind leg), chest depth (maximum distance between the sternum and the back of the carcass at the sixth thoracic vertebra) and shoulder width (maximum width of the shoulder measured at the level of the scapula from one lateral surface to the other) were taken following the method of De Boer *et al*. (1974) procedure.

The rib section (11-12th) from the left half of each carcass was dissected and the tissues separated to estimate the total fat and tissu value of fat thickness and total tissue depths were measured at the 12 rib, 11 cm from the spinal cord on the left side of the carcass (Ponnampalam *et al*., 2003). Rib eye-muscle (Longissimus dorsi area) was measured after tracing the eye-muscle at the 12/13th rib position. The left and right rib-eye muscle area was traced on to a grid paper and the area of the squares that fell within the traced squared area was counted and those partially fell outside was estimated and the average of the two sides was taken as the rib-eye muscle area.

3.7. Data Analysis

3.7.1. Descrptive statistics analysis

Descriptive statistics of average and percentage analysis procedures were computed to average flock size and their composition, average number of breeding ewes, breeding rams, pre-weaning, and post-weaning ewe and ram lambs, and unproductive ewes flock reproductive performance parameters. Graphical representation used to present farmers' culling reason and methods. Breeding strategies and methods in each the three genotypes were analyzed by the percentage and its frequency value of descriptive statistics. Ewe's reproductive performance parameters such as, fertility rate, prolificacy rate, lamb survival and weaning rate, were analyzed by descriptive explanatory statistics methods:

$$Fertility\,rate\,(\%) = \frac{Nubber\ of\ females\ that\ give\ birth}{Totnumber\ of\ ewes\ exposed\ to\ mating\ in\ the\ flock} x100$$

$$Prolificacy(\%) = \frac{Total\ Number\ of\ offspring\ produced}{Number\ of\ ewes\ that\ given\ birth} x100$$

$$Weaning\ rates\ (\%) = \frac{Number\ of\ offspring\ weaned\ per\ flock}{Number\ of\ ewes\ given\ birth} x100$$

$$Lamb\ Survival\ Rate = \frac{Number\ of\ offspring\ weaned}{number\ offspring\ produced} x100$$

Source: (Wilson *et al*., 1985b; ILCA, 1990)

Both on-farm and on-station lamb growth performance evaluation was conducted through their Average Daily Gain (ADG) calculated for the following stages of growth (Wilson *et al*., 1985b; Awgichew, 200).

a) Pre-weaning average daily weight gain (PrADG) = Birth to 90 days of age

b) Yearling post-weaning average daily weight gain (PoADG) = 90 to 365 days of age

c) Weaning weight = Average body weight gain at 90 days of age.

$$ADG = \frac{FWT\ Kg - IWT Kg}{D} * 1000$$

Where: ADG=Average daily gain, FWT = Final body weight, IWT = Initial body weight and D = number of treatment given/growing period in days.

3.7.2. Ranking analysis

Smallholder sheep producers' trait selection criteria of live animals for their breeding objectives such as, body conformation, hair type, color type, drought resistance, disease resistance, marketing value, horn type, growth rate, temperament, prolificacy rat, meat character, tail type, body size, age at first lambing, lambing rate and weaning rate analyzed using index method ranking analysis (Musa et al., 2006). Breeding rams and ewes selection criteria analyzed using index method of ranking analyses. Ranking index is important to manage multiple trait selection probability has the same rank by different individuals and to differentiate those traits having the same number of respondents.

$$Ranking\ Index = \frac{Rn * C1 + Rn - 1 * C2 \ldots + R1 * Cn}{\sum Rn * C1 + Rn - 1 * C2 \ldots + R1 * Cn}$$

Where, Rn = value given for the least ranked level (example, if the least rank is 9th, then Rn= 9, Rn-1=8, R1=1). Cn = Counts of the least ranked level (in the above example, the count of the 9th rank = Cn, and the count of the 1st rank = C1) Musa *et al.* (2006).

3.7.3. Analysis of variance determination of the response variable

According to a 3 x 2 factorial statistical designs of the breed and diet as main effects and the PROC GLM of multivariate analysis package of the SAS Windows 9.0-2004 system was used. The data fitted with the main factors of breed, feeding type, sex, birth type and parity effects on body weight gain response variable in the model. Birth weight used as a covarate factor for on-farm lambs' growth performance comparison of their average daily gain at pre-weaning, weaning and postweaning age of the three genotypes. Similarly, initial body weight used as a covarate factor in the model to control the residual effects of initial body weight on consequetive body weight gain. The dependent variables including totale body weight, average daily weight gain, survival rates, linear body measurements, reproductive traits and carcass yield characteristic parameters were considered in the GLM multivarate analysis of variance. The stepwise procedure of Pearson Correlation of the SAS system was used to see the effects of association between body weight and linear body measurement traits. Tukey's standardised range significancy test used to compare the different groups of mean.

Models fitted for lamb growth performance analysis

The following statistical models used to analyze on-farm and on-station average body weight gain through birth, pre and post weaning age as response variable. The effect of explanatory variables on weight gain and linear body measurement traits also designed.

Model 1. On-farm lamb growth performance

$Y_{ijkln} = \mu + A_i + B_j + P_k + S_l + (A \times B)_{ij} + b(Bwt_{ijkln} - Bwt) + e_{ijkln}$

Where:

Y_{ijkln} = Body weight gain (ADG at pre-weaning and post-weaning age groups)

μ = Overall Mean

A_i = fixed effect of the i^{th} breed type (i = Awassi crosses, Washera crosses and Wollo highland breed)

B_j = fixed effect of the j^{th} birth type (j = single, twin)

P_k = fixed effect of the k^{th} parity (k = 1, 2, 3, 4, ≥5)

S_l= fixed effect of the l^{th} sex types (l= male, female)

$(A \times B)_{ij}$ = breed by birth type interaction effect

$b(Bwt_{ijkln}-Bwt)$ = Covariates appearing in the model at the values of: Birth weight = 2.145±0.2.

E_{ijkln} = Effect of the n^{th} random error.

Model 2. On-station growth performance (Body weight gain)of ram lambs:

$Y_{ijm} = \mu + B_i + T_j + (BxT)_{ij} + b\,(Bwt_{ij}-Bwt) + e_{ijm}$

Where :

Y_{ijm} = Body weight gain at aperiod of 90 days, ADG, final weight and total weight change

μ = Overall Mean

B_i = fixed effect of the i^{th} breed type (i =Awassi cross,Washera cross, Wollo highland breed)

T_j = effect of the j^{th} feeding type (j= supplemented, non-supplemented)

b= Covariates appearing in the model evaluated at the values of: Initial body weight = 26.56).

E_{ijm} = Effect of the m^{th} random error.

Model 3. Carcass and non carcass parameters:

$Y_{ijk} = \mu + B_i + F_j + e_{ijk}$

Where:

Y_{ijk} = Carcass and non carcass yield parameters

μ = Mean

Bi = effect of the i^{th} breed (i = Awassi cross, Washera cross, Wollo highland breed)

F_j = the fixed effect of the j^{th} feeding type (j = supplemented, non-supplemented)

E_{ijk} = effect of the k^{th} random error

4. RESULTS

4.1. Smallholder Sheep Producers' Flock Size and Compositions

Smallholder sheep producers' flock composition presented by the asumption of sex, age and sheep production objectives in the flock. Therefore, the flock composition comprised of breeding ewe and rams, pre-weaned ewe and ram lambs, unproductive ewes, castrated and fattened rams and annual off-take rate were presented in Table 9. The overall average flock size was 22.6 heads per flock, however, the three genotypes of average flock sizes were different one to the other. Washera genotype nominated area average flock size greater than both Awassi and Wollo highland genotypes. The average number of ewes, rams, pre-weaned ewe and ram lambs, unproductive ewes, castrated and fattened rams and annual off-take rate different between each genotypes. Except average number of ewes and rams, Washera genotype has higher in number than both Awassi and Wollo highland genotypes. However, Wollo highland genotype number of ewes and rams larger than Awassi and Washera genotypes.

Table 9. Average flock composition percentage analysis of the three genotypes

Genotypes	Awassi F_1 crosses (N= 46)		Washera F_1 crosses (N= 74)		Wollo highland (N= 135)		Overall (N= 255)
Number of sheep/flock	n	%	n	%	n	%	n (%)
Average flock size	19.2	100.0	26.7	100.0	21.9	100.0	22.6 (100)
Average number of ewes	5.2	27.1	6.8	25.5	8.0	36.5	6.6 (29.2)
Average number of rams	2.2	11.5	3.3	12.4	3.5	16.0	3.0 (13.3)
Pre-weaned ewe lambs	3.1	16.1	4.2	15.7	3.2	14.6	3.5 (15.5)
Pre-weaned ram lambs	3.7	19.3	4.7	17.6	2.4	11.0	3.5 (16.5)
Unproductive ewes	2.2	11.5	3.6	13.5	2.3	10.5	2.7 (12.4)
Castrated and fattened	2.8	14.6	3.9	14.6	2.5	11.4	2.7 (12.5)
Off-take rate	4.2	21.9	3.2	12.0	3.8	17.4	3.7 (16.4)

N, total number of flocks and n, number of sheep.

The highest percentage holding of flock compositions were number of ewes followed by pre-weaned ram lambs, pre-weaned ewe lambs, number of rams, castrated and fattened rams and unproductive ewes in their order of importances. An annual off-take rate was composed of number of sheep sold and slaughtered per annum per flocks (Table 9). The average annual offtake rate in Washera genotype flocks was lower than Awassi and Wollo highland breed flocks. Similarly, Wollo highland breed flocks' annual offtake rate lower than Awassi genotype flocks. However, the overall average annual offtake rate was lower than Awassi genotype and Wollo highland breed flocks but higher than Washera genotype flocks.

4.2. Producers' Culling Rationale

Smallholder sheep producers had their own providential flock size management practices and consisted of their own sheep rearing momentary objectives. The main objective of sheep producers' culling practices were, to control flock size, increase income generation and home meat consumption purpose. The common culling reasons of sheep producers' were, when animals become old age, disease, reproductive problems, physical defect, unwanted physical appearances, negative selection, drought and predators presented in Figure 9. Therefore, sale removal for immediate cash, slaughtering for meat consumption and condemnation were the most common culling practice. However, the highest value of culling rational represented by negative selection. It is the process of smallholder sheep producers selecting best performance sheep form the flock for immediate cash income through market sale. Conversely, for the reason of unwanted physical appearance, the largest number of sheep were slaughtered for meat consumption. However, the highest number of sheep attacked by predators were culled throgh condemnation. Condemnation culling practice does not applied when animals marking out as old age, physical defects and feed shortage occasion of culling reason. However, flock owners either used for meat consumption or sold in local markets for direct cash income (Figure 9).

Among sick animals, the highest numbers were culled through local market sale. As a result, owners not interested to avoid sick animal selling practice because of frustration of income loss due to animal death. In addition to sick animals sold, producers also used for home meat consumption (Figure 9). Because of a reproductive problem the largest number of sheep were sold for direct cash income and used for fattening purpose. On the other hand, followed by negative selection, reproductive problems and old age culling rational had the largest portion of sheep exposed to the local market (Figure 10).

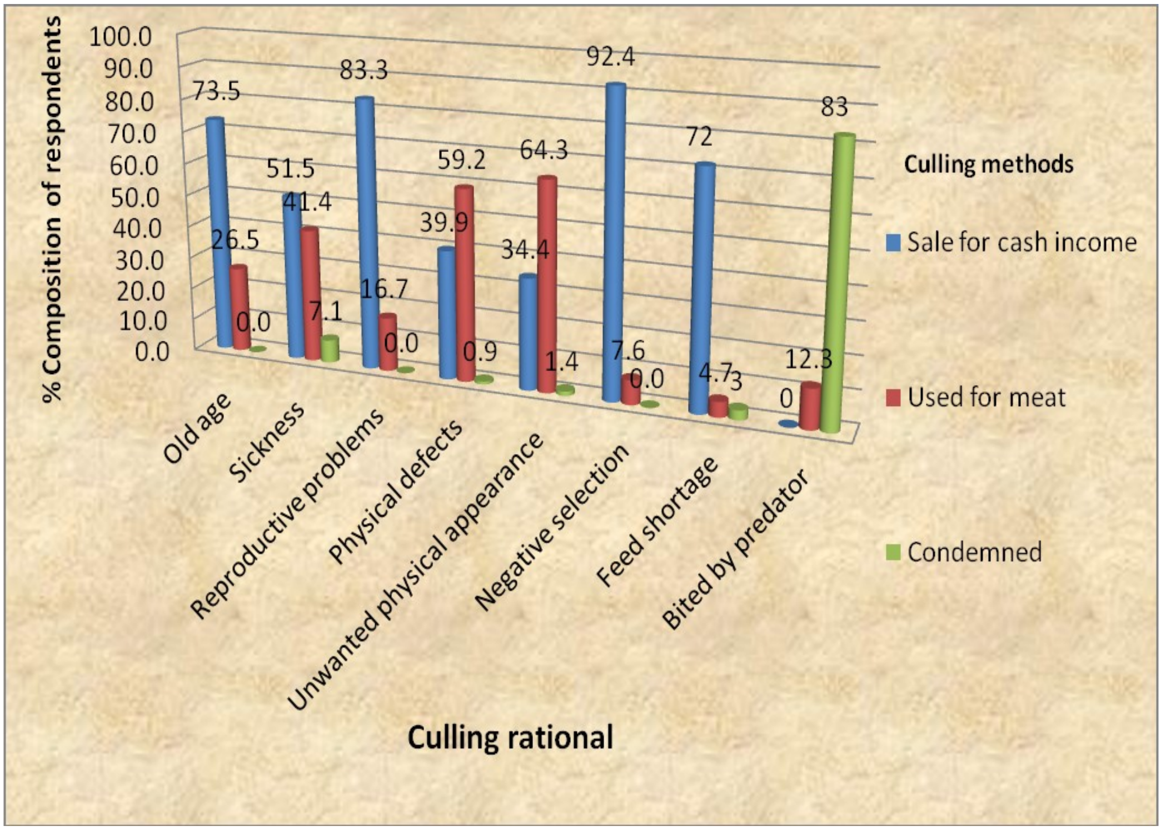


Figure 10. On-farm sheep producers' culling rationale and flock management practice

4.3. Breeding Strategies and Ram Breed Source

In the current study, village community based controlled sheep crossbreeding practices being adopted approach of genetic improvement practices. This strategies, mostly applied in Washera and Awassi genotype flocks dominated area than Wollo highland breed flocks (Table 10). Village communities selected their own interested ram breed type for genetic improvement of their local breed through controlled communal ram use method and their own common interest. The producers' common interests were governed by their established rules and agreements accordingly shared rule of breeding objective of village communities. On the other hand, private owned controlled breeding practice beneficiaries had the largest coverage in Wollo highland breed flock, Washera and Awassi genotypes in their order of importance. While, traditional way of random mating breeding practice prominent in the Wollo highland breed flocks. However, all breeding strategies were mixed together and presented in all genotypes with various extent of occurrence. Hence, mixed type of breeding practices most commonly applied in Washera and Awassi genotypes than Wollo highland breed flock (Table 10).

Table 10. Smallholder sheep producers' breeding strategies and ram breed source

			Village control breeding		Private control breeding		Random mating		Mixed type	
Strata	Ram source	N	n	%	n	%	n	%	n	%
Awassi genotype	Own flocks	56	9.0	16.1	16.0	28.6	9.0	16.0	22.0	39.3
	Project	61	21.0	34.4	19.0	31.1	4.0	6.6	17.0	27.9
	Market	79	35.0	44.3	22.0	27.8			22.0	27.8
	Government	16	11.0	68.8					5.0	31.3
	Total	212	76.0	35.8	57.0	26.9	13.0	6.1	66.0	31.1
Washera genotype	Own flocks	65	10.0	15.4	17.0	26.2	16.0	24.6	22.0	33.8
	Project	68	23.0	33.8	21.0	30.9	7.0	10.3	17.0	25.0
	Market	85	38.0	44.7	25.0	29.4			22.0	25.9
	Government	17	12.0	70.6					5.0	29.4
	Total	235	83.0	35.3	63.0	26.8	23.0	9.8	66.0	28.1
Wollo highland breed	Own flocks	91	3.0	3.3	26.0	28.6	58.0	63.7	4.0	4.4
	Project	66	7.0	10.6	31.0	47.0	25.0	37.9	3.0	4.5
	Market	53	12.0	22.6	37.0	69.8			4.0	7.5
	Government	5	4.0	80.0					1.0	20.0
	Total	215	26.0	12.1	94.0	43.7	83.0	38.6	12.0	5.6

N, total number of flock owners and n, frequency of ram source in each breeding strategies.

All breeding strategies in each genotypes had their own source of ram. Smallholder sheep producers' were obtained their own ram breed type from their own flock, donor project, purchased from markets and government supply. In village comminities based breeding practices the major ram source were market, project and government in their order of importance in the three genotypes. While in the private controlled breeding strategy, project source of ram was higher in the Awassi and Washera genotypes flocks and market source in for Wollo highland breed flocks were the most common. Likewise, in random mating breeding practice the prominant ram source was own flock in Wollo highland genotype flocks. Whereas, mixed type of breeding strategy had the main source of ram were both market and own flock in Awassi and Washera genotype flocks and government source in Wollo highland genotypes.

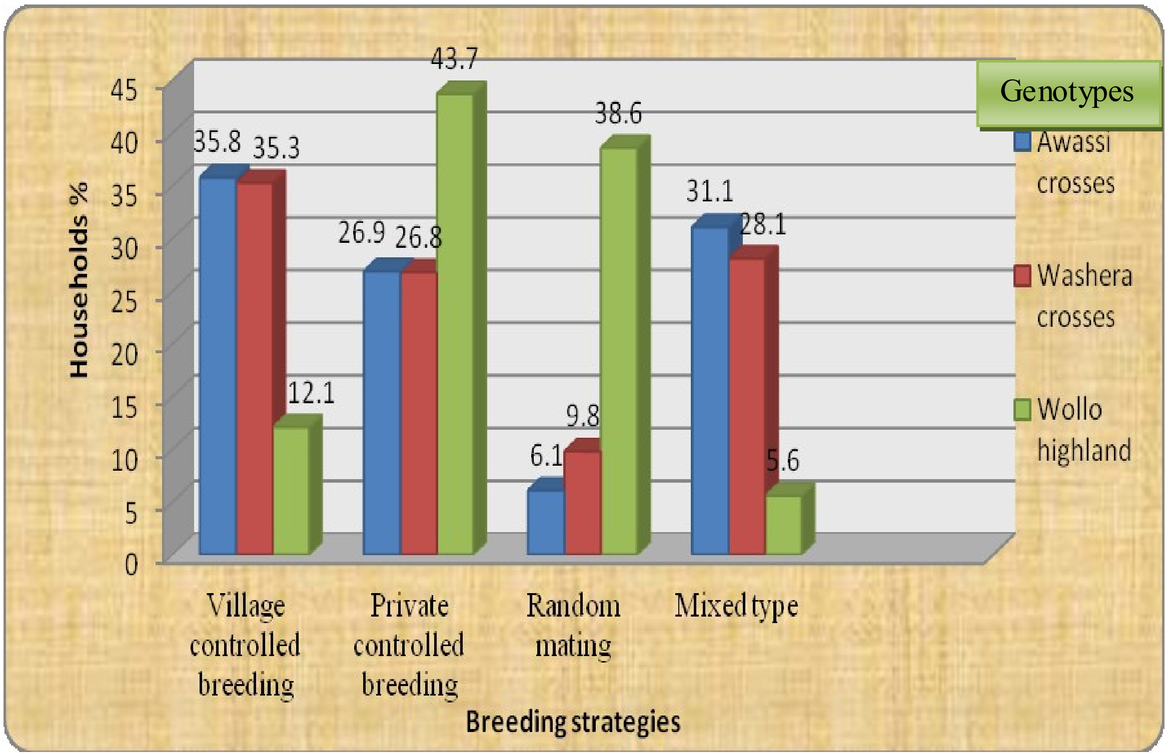


Figure 11. On-farm sheep producers' breeding strategies and available genotypes.

Generally, private controlled breeding strategies followed by random mating were the most common breeding strategies in Wollo highland genotype flocks. Similarly, village controlled, mixed type, private controlled breeding strategies were common in Awassi genotype flocks in the order of their importance. Likewise, in Washera genotype flocks village controlled, mixed type and private controlled breeding strategies were common according to their order of importance. The current study indicated, random mating breeding strategy being reduced and replacing by private controlling breeding practices (Figure 10) in the smallholder sheep production condition of Wollo highland genotype flocks.

4.4. Breeding Objectives and Trait Selection Criteria

On-farm smallholder sheep producers comprised of their own breeding objectives and their traits of interest. In the current study, farmers were listed their interested type of traits and then each trait was ranked accordingly. Both productive and reproductive traits improvement were major crossbreeding objective of the smallholder farming conditions. Accordingly, producers' trait selection criteria, growth rate, body size, weaning rate, body conformation, age at first lambing, lambing rate, drought resistance, color type, disease resistance, marketing value**,** twin birth, horn type, tail type and temperament traits were prioritized in order of their importance (Table 11). Therefore, the most frequently used traits for reproductive and productive purposes were growth rate, body size, weaning rate, body conformation, age at first lambing and lambing rate accordingly their order of importance.

Table 11. Ranking of phenotypic traits according to producers' interest

Traits of interest	Index	Rank
Growth rate (fast)	0.191	1
Body conformation (large frame)	0.186	2
Weaning rate (fast)	0.090	3
Age at first lambing (short)	0.086	4
Lambing rate (fast)	0.075	5
Drought resistance (resistant one)	0.068	6
Color type (without black and white)	0.060	7
Disease resistance (resistant one)	0.055	8
Hair type (wooly type)	0.055	9
Prolificacy rate (twin)	0.050	10
Horn type (medium and upward twisted)	0.044	11
Tail type (long and fat tailed)	0.040	12

N= number of respondents

Temperament, disease and drought resistance attributes were evaluated and ranked by means of the animal response towards behavioral change and the incidence of disease and drought in the smallholder sheep production environment, respectively.

Growth rate, body conformation and weaning rate traits were selected for productive performance improvement objective. Therefore, farmers evaluated their live animals' productivity on the bases of their conceptual perception of fast growth performance, large body frame and the rate of lambs weaning from their dam (Table 11).

Together with the productive trait improvements, hair, color, tail and horn type traits selected for marketing value addition purpose based on their previous conventional marketing knowledge. Hence, wooly type of hair, colors without black and white, upward twisted horn and long fatty tailed type of trait performance were selected for marketing value addition.

Drought and disease resistance performance considered as the potential capacity of animals were resistant and recover from disease and drought occurrence. Prolificacy rate, age at first lambing, lambing and weaning rate attributes were preferred as reproductive performance improvement traits of interest. Thus, twin birth, fast age at first lambing, short lambing interval and fast weaning breed type of ewes and rams particular attributes of farmers' breeding objectives for reproduction purpose. Generally, smallholder sheep producers selected their interested traits of interest with impression of producing, marketing and reproductive performance improvement practice of their animals.

4.4.1. Breeding ewes selection criteria and farmers' traits of interest

Smallholder sheep producers were subjectively evaluated their own ewe's reproductive performance by means of lamb survival rate/ewes, twinning rate, temperament, growth rate, lambing interval, parental history, tail type and body conformation ranked as owner's traits of interest and used as breeding ewes' selection critera in the order of their importances. The index method of ranking analysis supported by weighted average to prioritize producers' attribute of interest which obtainable from their breeding ewes. Therefore, the sequential index values of each parameter were presented in Table 12 according to their order of importance.

On the bases of producers' traits of interest, lamb survival rate is the first interested reproductive trait. Twins rate, parental history and lambing interval ranked as 2nd, 3rd and 4th considerable reproductive performance parameters. Therefore, producers' attributes of interest were used as measurable parameter for selecting parents of the next generation and to improve productive and reproductive performance. Temperament was selected for behavioral related desire to keep large number of sheep at different age groups together in the flock and for easy of flock management (Table 12).

Table 12. Ranking of breeding ewes' attributes accordingly producers' traits of interest.

Ewes' selection criterion	Weighted Average (*W)	Index	Rank
Lamb survival rate per ewes	656	0.190	1
Twin rate	649	0.154	2
Parental history	630	0.127	3
Lambing interval	606	0.126	4
Temperament	545	0.125	5
Lamb growth rate	528	0.124	6
Tail type	505	0.082	7
Body conformation	488	0.081	8

N= number of respondents

Lamb growth rate was used to make their lambs early weaned and to reduce age at first marketing, increase body size and oftake rate. Currently producers' exploit lambs as an immediate cash crop for their various urgent household consumption needs. Tail type and body condition traits preferred for physical conformation and attractiveness for market value addition objective. Currently, smallholder sheep producers' were selective for their traits of interest from both ewes and rams side by considering their socio-economics and cultural value.

4.4.2. Breeding rams selection criteria and farmers traits of interest

Smallholder sheep producers ranked their breeding rams' attributes accordingly their traits of interest to meet the productive and reproductive performance improvement objectives. The most important rams' attributes were body size, growth rate and market value were the first, second and third traits of interest, respectively (Table 13). Body conformation, coat color and tail type were the fourth, fifth and sixth traits of interest, respectively. Horn orientation, hair type and meat characterestics were ranked in their order of importance and used for ram selection criteria.

Table 13. Ranking of breeding rams' attributes accordingly producers' traits of interest.

Study parameters	Weighted Average (*W)	Index	Rank
Body size	1497	0.175	1
Growth rate	1354	0.159	2
Marketing value	1094	0.135	3
Body conformation	1058	0.103	4
Coat color	1045	0.102	5
Tail type	1044	0.089	6
Horn orientation	1018	0.085	7
Hair type	1011	0.083	8
Meat characterestics	942	0.071	9

Currently on-farm sheep producers have enhanced their understanding for trait selection and preference of productive and reproductive performance improvement practices of the existing breed type and crossbred progenies.

At on-farm producers' situation ram selection process was different between individuals with type of breeding strategies and their objectives. This indicated that within village community based breeding strategies ram selection process done through the group of common interest and governed by village leaders. However, privately owned controlled breeding strategy breeding rams selection process was decided by the owner themselves. Whereas, mixed type of breeding strategies had partly ram selection criteria, breeding objectives and partly breeding system was undertaken through random mating and didn't have selection criteria and breeding objectives. Whereas, in traditional type of breeding strategies no ram selection criteria and breeding objectives and the mating system were undertaken randomly.

4.5. On-Farm Annual Flock Reproductive Performance

4.5.1. Annual flock reproductive performance evaluation

Yearling flock reproductive performance was presented in Table 14. The mean number of breeding ewes, lambs/ewes, mated ewes, abortion/flock, age at first mating and lambing, numbers of single and twin birth/flock, and number of pregnant ewes/ flock were significantly ($P<0.05$) higher in Washera genotype flocks than in Awassi genotype flocks. Therefore, the reproductive performance of Washera genotype flocks indicated eye-catching than Awassi genotype flocks. Similarly, the mean number of lambs/flock, age at first mating and lambing were significantly ($P<0.05$) higher in Wollo highland genotype flocks than Washera genotype flocks. Hence, local Wollo highland sheep breed indicated delayed age at first mating and lambing than Washera F_1 crossbred progenies (Table 14). However, the number of lambs/flock, pregnancies/flock and parturation/flock were significantly ($p<0.05$) higher in Wollo highland breed flocks than the Awassi genotype flocks. This implied that, local Wollo highland breed had superior reproductive trait performance than Awassi sire F_1 crossbred progenies (Table 14). However, Awassi F_1 crossbred progenies had significantly ($p<0.05$) lower mean number of abortion rate than Washera F_1 crossbred progenies and local Wollo highland breed lambs and more lambs per flock weaned.

Lambing interval significantly ($p<0.05$) shorter in Washera genotype flocks than Awassi genotype flocks and Wollo highland breed flocks. Generally, Washera genotype flocks had significantly ($p<0.05$) shortest age at first mating and lambing, fastest age at first marketing, and shortest weaning age than Awassi genotype and Wollo highland breed flocks (Table 14).

Table 14. Reproductive performance analysis of variablity between flocks

Rroductive performance	Awassi F_1 crosses (n=46)	Washera F_1 crosses (n=74)	Wollo highland (n=135)	Overall (N=255)	
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	P-value
Breeding ewes/flock (number)	3.2±0.6^{a}	3.5±1.0^{b}	3.3±0.8^{a}	3.3±0.9	**
Breeding rams/flock (number)	0.4±0.0	1.1±0.0	1.4±0.2	0.9±0.0	Ns
Lambs /flock (number)	6.2±2.0^{a}	8.3±2.7^{b}	7.7±2.8^{c}	7.4± 2.3	**
Lambs/ewes (number)	1.9±0.6^{a}	2.4±0.0^{b}	2.3±1.0^{b}	2.2±0.8	**
Pregnancies/flock (number)	5.6±2.9^{a}	7.3±1.0^{b}	7.1±2.1^{b}	6.3±2.7	**
Parturition/flock (number)	4.5±2.0^{a}	5.7±1.0^{b}	5.4±1.6^{b}	5.2±1.5	**
Abortion rate/flock (number)	1.2±0.7^{a}	1.6±0.0^{b}	1.7±0.7^{b}	1.4± 0.5	**
Service/conception (number)	1.3±0.1	1.1±0.0	1.4±0.2	1.3±0.1	Ns
Age at first mating (months)	7.0±0.7^{a}	5.0±0.6^{b}	6.3±0.8^{c}	6.1±2.5	***
Age at first lambing (months)	12.3±0.7^{a}	11.1±3.0^{b}	11.9±0.1^{a}	11.8±3.6	***
Single birth/flock (number)	2.6±1.3^{a}	3.1±1.0^{b}	3.1±4.0^{b}	2.9±1.1	***
Twin birth/flock (number)	1.8±0.8^{a}	2.6±0.0^{b}	2.3±2.8^{c}	2.2±0.9	***
Lambing rate (number)	1.4±0.2	1.6±0.2	1.6±0.2	1.5±0.6	Ns
Lambing interval (months)	6.3±2.7^{a}	5.8±1.6^{b}	6.1±3.0^{a}	6.1±2.1	**
Age at weaning (months)	5.8±0.6^{a}	4.6±1.0^{b}	6.3±1.0^{a}	5.6±1.9	*

N, number of flocks/genotype; superscript with the same letter is not significant and different letter has significant difference; *, $p<0.05$; **, $p<0.01$ and ***, $p<0.001$. First stratum, Awassi F_1 crosses; second stratum, Washera F_1 crosses; third stratum, local Wollo highland sheep.

The number of ewes/flock, number of lambs/flock, number of pregnancy ewes/flock, number of parturation/flock, lambing rate, number of twin birth, lambing interval and age at first mating were significantly ($p<0.05$) lower in the Awassi genotype flocks (Table 14) than Washera genotype and Wollo highland genotype flocks. Nevertheless, twins birth, lambing interval, weaning age, age at first mating and lambing were higher in Washera genotype flocks. Therefore, reproductive performance variation was recorded between genotypes.

4.5.2. Ewes' reproductive performance attributes

The overall percentage of fertility rate, prolificacy rate, weaning rate, lamb survival rate at birth-90, 91-180, 181-270 and 271-365 days, overall annual survival rate, mortality because of disease and drought, mortality because of predator and overall annual mortality rate were presented in Table 15. Fertility rate indicated, the number of females that give birth per total number of females exposed to mating per flock and higher in the Awassi genotype ews, Wollo highland genotype ewes and Washera genotype ewes, respectively. Whereas, prolificacy rate indicated the total number of offspring produced per flock per total number of ewes that give birth and higher in the Washera genotype ewes than Awassi genotype ews and Wollo highland genotype ewes.

Weaning rate indicated, the total number of offspring weaned per flock per total number of females that given birth and higher in Wollo highland genotype, Awassi genotype and Washera genotype. It shows, the potential of ewes enable to weaned their lambs/flock. Lamb survival rate is the total number of offspring weaned/flock/the total number of offspring produced and higher in the Wollo highland genotype.

Table 15. Percentage analysis of ewe's reproductive performance attributes

Reproductive traits (%)	Awassi F_1 crosses	Washera F_1 crosses	Wollo highland	Overall
Fertility rate	89.8	84.3	86.3	86.8
Prolificacy rate	134.4	150.0	143.8	142.7
Weaning rate	132.7	128.1	155.4	138.7
Survival rate Birth-90 days	86. 8	88.1	88	87.6
91-180 days	85.1	76.6	81.2	80.9
181-270 days	76.2	69.9	76.3	74.1
271-365 days	68.9	65.5	71.2	68.4
Overall annual lambs survival rate	68.5	65.5	71.2	68.4
Mortality because of disease and drought	27.9	32.2	26.0	28.7
Mortality because of predator	3.6	2. 8	2. 3	2.9
Overall annual mortality rate	31.5	34.5	28. 3	31.6

%, percentage composition.

Generally, fertility rates and lamb survival rate at 90-180 days were higher in the Awassi genotype ewes. Whereas, prolificacy rate and survival rate at 270-365 days was higher in the Washera genotypes. Weaning rate was shorter in the Washera genotype than Awassi genotype and Wollo highland breed.

Survival rate from 91-270 days shown increasing trend in Wollo highland breed and Washera genotype, but decreasing in Awassi genotype ewes. Whereas from 271-365 days indicated increasing trend with Awassi genotype ewes and Washera genotype, but no change in the Wollo highland breed. However, the overall survival rate was higher with the Wollo highland breed ewes than Awassi genotype and Washera genotype ewes and higher mortality rate were observed in Washera genotype lambs (Table 15). Mortality because of disease and drought and overall annual mortality was higher in Washera genotype lambs. While, mortality because of predator was higher in Awassi genotype than Washera genotype lambs and Wollo highland breed lambs. Nevertheless, the overall annual mortality rate was higher in the Wollo highland breed than others.

4.6. On-Farm Lamb Growth Performance and Effect of Genotypes

4.6.1. Yearling lamb growth performance characterestics

In the present study, yearling growth performance were the simple linear function of age and their body weight association. Awassi and Washera F_1 crossbreed progenies had better growth rate than Wollo highland breed lambs at birth to 365 days of age (Figure 12). On the other hand, at the age of 30 to 90 days, Washera F_1 crossbreed progenies showed superior growth rate than both Awassi F_1 crossbreds and Wollo highland genotypes. However, from the age of 120 to 365 days, Awassi F_1 crosses has showed the fastest growth performance than both Washera F_1 crosses and Wollo highland genotypes. Whereas, Washera F_1 crossbred lambs showed higher growth rate than Wollo highland genotype. The comparative evaluation between local Wollo highland breed, and their crossbreds of Awassi and Washera rams was considerably lower growth rate. The rate of body weight change across increasing rate of age was higher in Awassi F_1 crosses followed by Washera F_1 crosses and Wollo highland breed, in the order of their importance (Figure 12).

The simple linear association of growth rate of lambs with their age of Awassi and Wshera F_1 crossbreed progenies had comparable performance but, higher rate of body weight gain than local wollo highland breed. The rate of body weight gain for each individual genotypes were different with the same age groups. This comparison of growth rate as linear function of age with the assumption of keeping constant for the other factors to indicate the genetic potential variation in growth performance of the three genotypes at farmers' production situation.

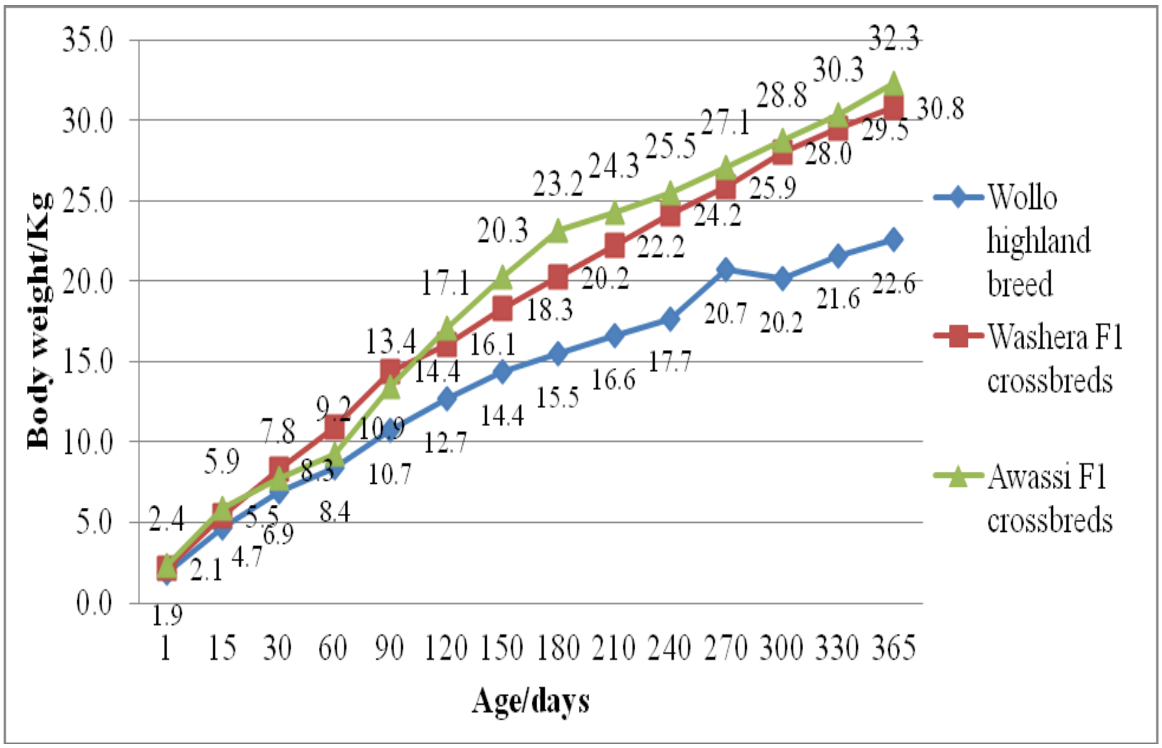


Figure 13. On-farm lamb growth performance characterestics

4.6.2. Effect of genotype, sex, birth type and parity at on-farm lamb growth rate

The birth weight of Awassi, and Washera crosses and local Wollo highland breed were significantly different ($p<0.001$) each other. As a result, Awassi F_1 crossbreed progenies had higher birth weight than both Washera and local Wollo highland breed and followed by Washera F_1 crossbred progenies (Table 16). The birth weights of local Wollo highland breed lambs were lower than the overall average value. Birth type didn't have significant effecte ($p>0.05$) on the birth weight of lambs and comparatively similar weight at birth for single and twin birth type. Parity and sex type didn't have a significant effect on birth weight of lambs for each genotypes, but numerical variations of both parity and sex type was observed. Birth type effect on average body Weight at 3, 6 and 9 months age had significant ($p<0.05$) difference between each genotypes. It also significantly affected pre and post-weaning body weight gain of lambs. For all cases single birth type had higher average body weight and average daily gain at 3, 6, 9 months and pre and post-weaning age.

The average body weight at 3, 6, 9 12 months of age and average daily gain at pre-and post-weaning time observed significant ($p<0.001$) variation between the three genotypes. However, weaning and 12 months of age, Awassi and Washera F_1 crossbreed progenies had comparable body weight gain. Nevertheless, both Awassi and Washera F_1 crossbred lambs' average body weight significantly ($p<0.001$) greater than local Wollo highland breed lambs. At birth and yearling age, between single and twins births of the three genotypes did not have significant variation.

On the other hand, at 6 months of age, all genotypes had a significant variation ($p<0.005$) of average body weight gain. Hence, at this age group, Awassi F_1 crossbred lambs had higher body weight gain than both Washera and local Wollo highland breeds. Sex type did not have a significant effect on average body weight at birth, and 3months of age and their average daily gain at pre-weaning period for Wollo highland genotype.

Table 16. The effect of breed, sex, birth type and parity on body weight gain variablity

	Birth (kg)		3 months (kg)		6 months (kg)		9 months (kg)		12 months (kg)		PrWADG (g)		PoWADG (g)	
Source	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	136	2.145±0.2	136	12.9±0.3	136	18.8±0.3	136	23.1±0.4	136	27.3±0.5	136	69.9±1.0	136	127.8±1.7
Breed type		***		***		***		***		***		***		***
A	46	2.4±0.04^{a}	46	13.8±0.5^{a}	46	22.7±0.6^{a}	46	26.0±0.7^{a}	46	30.4±1.0^{a}	46	77.0±2.1^{a}	46	145.6±3.4^{a}
L	40	1.9±0.04^{b}	40	10.7±0.6^{b}	40	15.7±0.6^{b}	40	19.0±0.7^{b}	40	21.6±1.0^{b}	40	60.1±2.1^{b}	40	103.3±3.4^{b}
W	50	2.2±0.04^{c}	50	14.0±0.4^{a}	50	19.5±0.5^{c}	50	24.7±0.5^{a}	50	30.2±0.8^{a}	50	73.8±1.6^{a}	50	137.8±2.6^{a}
Birth type		ns		*		**		*		ns		**		**
Single	109	2.1±0.3c	109	13.3±0.3^{a}	109	19.5±0.3^{a}	109	23.6±0.4^{a}	109	27.5±0.6	109	72.0±1.2^{a}	109	130.4±1.9^{a}
Twins	27	2.2±0.5c	27	12.0±0.5^{b}	27	17.2±0.6^{b}	27	21.8±0.7^{b}	27	26.9±1.1	27	64.8±2.1^{b}	27	121.6±3.4^{b}
Sex type		ns		ns		ns		ns		ns		ns		ns
Female	67	2.2±0.4	67	13.1±0.4	67	18.5±0.5	67	22.9±0.5	67	28.0±0.8	67	69.6±1.5	67	128.0±2.4
Male	69	2.1±0.3	69	12.8±0.4	69	19.2±0.4	69	23.1±0.5	69	26.8±0.7	69	70.1±1.4	69	127.7±2.3
Parity		ns		ns		ns		ns		ns		ns		ns
1	26	2.1±0.1	26	13.2±0.5	26	19.1±0.6	26	23.6±0.7	26	28.7±1.1	26	70.7±2.0	26	131.6±3.3
2	27	2.1±0.1	27	13.6±0.6	27	20.7±0.6	27	24.0±0.7	27	27.2±1.1	27	75.2±2.1	27	132.7±3.4
3	37	2.2±0.0	37	12.2±0.5	37	20.1±0.5	37	23.6±0.6	37	26.7±1.0	37	70.5±1.9	37	131.3±3.0
4	17	2.2±0.1	17	13.2±0.7	17	19.0±0.8	17	23.4±0.9	17	26.7±1.4	17	70.3±2.6	17	126.9±4.2
≥ 5	29	2.0±0.1	29	13.0±0.8	29	19.0±0.9	29	24.1±1.0	29	29.9±1.6	29	70.8±3.0	29	134.5±4.8
Breed*Sex		*		*		*		**		**		*		***
A	F	2.4±0.1^{a}	23	14.0±0.7^{a}	23	26.3±0.9^{a}	23	22.7±0.8^{a}	23	30.7±1.4^{a}	23	76.5±2.7^{a}	23	147.3±4.4^{a}
	M	2.4±0.1^{a}	19	13.7±0.7^{a}	19	26.0±1.0^{a}	19	22.7±0.8^{a}	19	30.1±1.5^{a}	19	77.4±2.8^{a}	19	143.9±4.6^{a}
L	F	1.9±0.1^{b}	18	11.2±0.8^{b}	18	19.9±1.0^{b}	18	16.1±0.9^{b}	18	23.9±1.6^{b}	18	62.6±3.0^{b}	18	109.5±4.8^{b}
	M	2.0±0.1^{b}	14	10.3±0.7^{b}	14	18.2±0.9^{b}	14	15.4±0.8^{b}	14	19.5±1.4^{c}	14	57.9±2.6^{b}	14	97.8±4.2^{b}
W	F	2.2±0.1^{c}	15	14.0±0.6^{a}	15	23.7±0.8^{c}	15	18.3±0.7^{b}	15	29.8±1.2^{a}	15	71.5±2.3^{a}	15	132.7±3.7^{c}
	M	2.1±0.1^{c}	20	14.0±0.6^{a}	20	25.5±0.8^{a}	20	20.4±0.6^{a}	20	30.5±1.1^{a}	20	75.7±2.2^{a}	20	142.1±3.6^{a}

*, $P<0.05$; **, $P<0.01$; ***, $P<0.001$; A, Awassi F_1 crosses; W, Washera F_1 crosses; L, Wollo highland lambs; BW, Birth weight; ADG, Average daily weight gain; ABW, Average body weight gain; PrWADG, Pre-weaning average daily gain; PoWADG, Post-weaning average daily gain; superscript with the same letter is not significant and different letter has significant difference.

In all age groups, parity does not have a significant effect on average weight gain of lambs and their average daily gain. However, average daily weight gain at pre and post-weaning age has a significant variation ($p<0.001$) between the three genotypes. The higher average daily gain was recorded for Awassi, Washera F_1 crossbred lambs, and the lower average daily gain was observed for local Wollo highland breed lambs (Table 16).

The interaction effect of breed and sex type had significant effect on average body weight gain at 6, 9, 12 months of age and pre and post-weaning average daily weight gain. Hence, between male and female Awassi and Male Washera F_1 crossbred lambs at 6 and 9 months had non significant difference of average body weight gain. However, Wollo highland breed lambs significantly lower average body weight gain than others. The within breed interaction effect has significant variation between male and female Washera F_1 crossbred lambs and non significant for both Awassi F_1 crossbred and Wollo highland breed lambs.

Washera F_1 crossbred lambs at the age of birth, 3, 9, 12 months and pre-weaning period doesn't have significant difference on breed and sex interaction effect between male and female lambs average body weight gain. Similarly, the interaction effect of breed and sex on average body weight gain between female and male lambs of Awassi F_1 crossbreds didn't have significant difference at all age groups. While, at yearling age, interaction of breed and sex type have significant difference between male and female Wollo highland breed lams.

4.6.3. Effects of genotype and sex on birth weight and average daily weight gain

The effect of breed and sex on birth weight and average daily weight gain presented in Figure 11. Average birth weight of female Awassi crosses were slightly less than that of the males. On the other hand, its greater than both local Wollo highland and Washera F_1 crossbred females. However, slightly comparable with local Wollo highland and Washera F_1 crossbred male progenies (Figure 11). Male Awassi F_1 crossbred lambs' birth weight were significantly greater than Wollo highland and Washera F_1 crossbred lambs (Table

16). Nevertheless of that, male birth weight of Wollo highland and Washera F_1 crossbred progenies had more or less comparable value.

The female and male Awassi F_1 crossbred progenies at pre-weaning average daily weight gain were strongly greater than Local Wollo highland and slightly more than Washera F_1 crossbred progenies (Figure 11). Likewise, both male and female pre-weaning average daily weight gain of Washera F_1 crossbred was greater than local Wollo highland breed lambs.

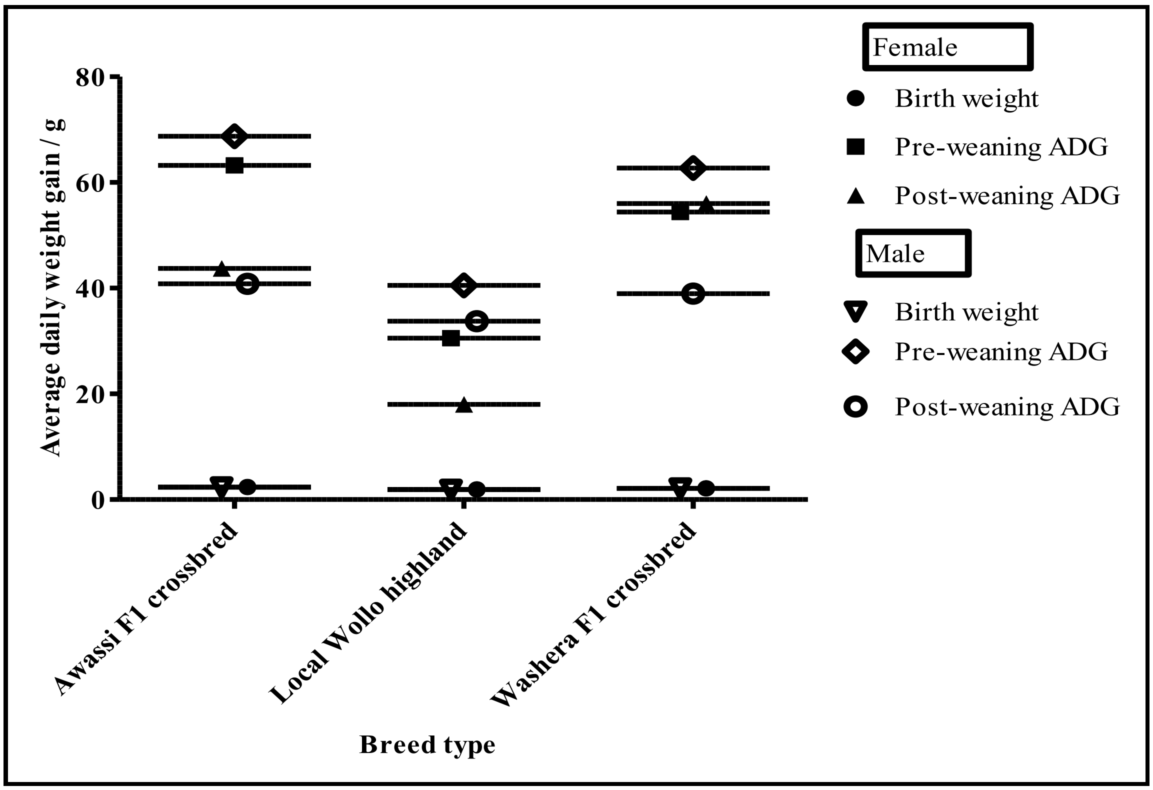


Figure 14. Graph pad prism method analysis of breed and sex effect on lamb weight gain.

Female post-weaning average daily weight gain of Washera crosses were strongly greater than female Wollo highland and Awassi crosses (Appendix 1: Table 1). Similarly, female Awassi F_1 crossbreds at post-weaning age, average daily weight gain greater than female Wollo highland lambs. Furthermore, female post-weaning average daily weight gain of Washera F_1 crossbreds greater than the males. The female Awassi F_1 crossbreds slightly more than males. However, in the case of Wollo highland breed lambs the effect of sex type on post-weaning average daily weight gain of males were greater than the females (Figure 11).

4.6.4. On-farm lamb growth performances and their linear body measurements

In addition to body weight gain, linear body measurement of lambs indicated the growth performance characterestics of lambs (Table 17). The current study, involved the major linear body measurement traits of body weight, body length, chest girth, back width, chest width, height at withers and rump height, hip width and hip length used to evaluate the growth performance of three genotypes at farmers production condition. This mean that, when age of lambs increasing, posetive and strongly correlated linear measurment traits also increased simultaneously.

Table 17. Pearson correlation coefficient of linear body measurement traits

Pearson Correlation	Age	Body weight	Body length	Chest girth	Back width	Chest width	Height at withers	Rump height	Hip length
Body weight	.792**								
Body length	.752**	.799**							
Chest girth	.941**	.829**	.840**						
Back width	.828**	.783**	.880**	.845**					
Chest width	.895**	.674*	.624*	.791**	.738**				
Height at wither	.903**	.815**	.848**	.962**	.843**	.754**			
Rump height	.878**	.844**	.852**	.933**	.834**	.746**	.955**		
Hip length	.680*	.711**	.656*	.736**	.697*	.520*	.723**	.714**	
Testicular size	.833**	.705**	.747**	.798**	.826**	.721**	.747**	.756**	.668*

*P<0.05; **P<0.01; ***P<0.001.

The age of lambs have posetive and significant (p<0.05) correlation with chest girth, height at withers and rump height and which were the three top positively correlated traits in the order of their importances (Table 17). Body weight had significant (p<0.05) and positive correlation with rump height, chest girth, height at wither, body length, back width, hip length and testicular size with decreasing order of correlation coefficient. Similarly, body length has significant and positive correlation with back width, rump height, height at withers, chest girth and testicular size in decreasing order of their importance. At the same time as, chest girth have significant and positive correlation with height at withers, rump height, back width, and moderately correlated with testicular size, chest width and hip length body measurement traits.

The back width of lambs strongly correlated with height at withers, rump height and testicular size and moderately correlated with chest width. However, slight and posetively correlated with hip length. Likewise, chest width moderately correlated with height at withers, rump height and testicular size and poorly correlated with hip length. Height at wither of lambs strongly correlated with rump height and moderately correlated with hip length and testicular size. The rump height of lambs have significant positive correlation with hip length and testicular size traits. The hip length of lambs poorly correlated with testicular size (Table 17).

4.6.5. Withn and between genotypes variablity of linear body measurement traits

Awassi F_1 crossbreds had the maximum within and between breed variablity observed for chest width linear body measurement trait. Whereas, Washera crosses had higher value of variablity recorded for height at wither compared with Awassi crosses and local Wollo highland breed lambs. Except testicular size all linear body measurement traits observed poor variablity between Washera genotype and local Wollo highland lambs. This means testicular size recorded higher variablity value of Wollo highland lambs compared with Washera crosses (Table 18). Within breed variablity of the chest width trait had highest numerical value for Awassi ram F_1 crossbred progenies than other traits. Testicular size also had the highest numerical value of within breed variation for Wollo highland breed lambs than other traits.

Table 18. The Mean and standard deviation of linear body measurement traits.

	Awassi F_1 crossbreds	Wollo highland breed	Washera F_1 crossbreds
Linear body traits	Mean±SD	Mean±SD	Mean±SD
Body weight (kg)	29.6±1.4	26.5 ±2.1	27.4 ±1.9
Body length (cms)	57.7±0.7	43.4±3.2	47.2±3.4
Heart girth (cms)	83.9±2.3	73.5±3.1	76.7±1.5
Back width (cms)	19.6±0.5	15.8±0.9	18.4±1.1
Chest width (cms)	12.0±5.1	12.7±0.7	13.5±0.9
Height at wither (cms)	72.0±3.3	66.9±2.1	67.7±1.5
Rump height (cms)	77.3±2.8	67.8±3.0	70.9±2.8
Hip width (cms)	10.0±0.7	8.6±0.6	8.7±1.0
Hip length (cms)	36.5±1.4	30.5±2.1	34.5±2.3
Testicular size (cms)	28.2±3.1	25.1±5.3	26.2±1.6

SD, standard deviation; F_1, first produced offspring by crossbreeding

Washera F_1 crosses has the highest within and between genotype variablity observed in height at withers trait. However, between genotypes the highest variablity observed in chest width trait and higher in Awassi crosses followed by testicular size trait for Wollo highland breed lambs than the other traits.

4.7. Genotype and Supplementation Diet Effects on Ram Lambs' Growth Rate

4.7.1. Effects of genotype and supplementation feed on ram lambs growth rate

Genotype and supplementation diet effect on ram lambs' average body weight and their daily weight gain is presented in Table 19. Initial body weight had significant ($p<0.05$) difference between genotypes and used in the covarate analysis model to avoid its residual effect on consecutive body weight gain and to quantify the genotype effect. However, it had non significant difference within genotypes. The between and within genotype variations were continued throughout 10, 20 and 30 days experimental period except supplemented Washera F_1 crossbreds and Wollo highland breed lambs and which were significantly higher than their non supplemented group at 10 and 20 days treatment period, respectively. Despite the fact that, at 30, 40, 50 and 60 days of feed treatment period the supplemented group of Wollo highland lambs had non significant differences with both supplemented and non supplemented Washera crossbred lambs and between breed variation eliminated. At 40 and 50 days, treatment period, ecxcept Wollo highland lambs the other genotypes have insignificant differences between supplemented and non supplemented groups. Conversely, at 60 days of treatment period supplemented Wollo highland breed lambs had non-significant variation with both supplemented and non-supplemented Washera F_1 crossbred lambs and vis-versa. Awassi F_1 crossbred lambs significantly ($p<0.05$) higher average weight gain than both Wollo highland and Washera F_1 cross ram lambs throughout the experimental period (Table 19).

The supplemented diet effects on 50, 60, 70 to 90 days, total body weight change and average daily weight gain of supplemented Awassi F_1 crossbred and Wollo highland breed lambs had significantly higher than their non supplemented groups. However, both supplemented and non-supplemented Awassi F_1 crossbred lambs significantly higher ($p<0.001$) average weight gain than other genotypes throughout experimental period. The supplemented Wollo highland breed lambs non significant differences with supplemented Washera F_1 crossbred lambs at 60, 70 and 80 days of treatement period, but significant ($p<0.05$) differences observed with non supplemented Wollo highland breed lambs. In general, between 50, 90 days of the treatment period average body weight, total body weight change and average daily weight gain of the supplemented Wollo highland breed and supplemented Washera F_1 crossbred ram lambs had significantly ($p<0.05$) higher than their non supplemented groups. The supplemented group of Washera F_1 crossbred ram lambs significantly higher weight gain than non-supplemented group (Table 19). While, the total body weight change and average daily weight gain of supplemented and non-supplemented Washera F_1 crossbred lambs had non-significant ($p>0.05$) variation. The total body weight gain, total weight change and average daily gain had significant ($p<0.05$) difference between supplemented and non supplemented groups of Awassi F_1 crossbred lambs. Hence this genotype had significantly higher average final body weight gain, total body weight change and average dialy weight gain than Wollo highland and Washera F_1 crossbred lambs.

The rate of body weight change, throughout the experimental period significantly higher with supplemented and non supplemented Awassi F_1 crossbreds than Wollo highland and Washera crossbred lambs. Correspondingly, significant difference both between and within group were observed in total body weight change.

Table 19. Genotype and supplemented diet effect on ram lambs body weight gain

	Awassi genotype		Wollo genotype		Washera genotype		
ABW/kg	T 1	T2	T 1	T2	T 1	T2	Sig.L
IBW	31.6 ± 1.0^{a}	31.5 ± 0.8^{a}	21.9 ± 0.7^{b}	21.4 ± 0.5^{b}	26.4 ± 0.7^{c}	26.6 ± 0.7^{c}	***
10days	33.4 ± 0.9^{a}	34.0 ± 0.9^{a}	26.9 ± 0.9^{b}	24.5 ± 0.9^{b}	29.0 ± 0.5^{c}	27.5 ± 0.5^{d}	*
20 days	33.3 ± 1.1^{a}	34.1 ± 1.1^{a}	26.6 ± 1.1^{c}	24.2 ± 1.1^{b}	28.8 ± 0.6^{c}	26.9 ± 0.6^{c}	*
30 days	36.7 ± 1.3^{a}	36.9 ± 1.3^{a}	28.4 ± 1.3^{bc}	26.3 ± 1.3^{b}	30.3 ± 0.7^{c}	29.0 ± 0.7^{c}	*
40 days	37.8 ± 1.3^{a}	37.7 ± 1.3^{a}	29.3 ± 1.3^{b}	27.0 ± 1.3^{d}	30.6 ± 0.7^{c}	29.2 ± 0.7^{c}	*
50 days	38.3 ± 1.7^{a}	36.1 ± 1.7^{b}	30.8 ± 1.7^{ce}	28.4 ± 1.7^{d}	31.1 ± 0.9^{e}	29.4 ± 0.9^{cd}	*
60 days	38.8 ± 1.8^{a}	35.8 ± 1.8^{b}	32.4 ± 1.7^{c}	29.8 ± 1.8^{d}	32.1 ± 1.0^{c}	29.9 ± 1.0^{d}	**
70 days	39.9 ± 1.8^{a}	37.3 ± 1.8^{b}	33.3 ± 1.8^{d}	30.4 ± 1.8^{c}	32.2 ± 1.0^{cd}	30.6 ± 1.0^{ec}	**
80 days	41.4 ± 1.8^{a}	38.2 ± 1.8^{b}	34.4 ± 1.8^{c}	31.1 ± 1.8^{d}	33.1 ± 1.0^{c}	31.3 ± 1.0^{d}	**
FBW	45.5 ± 1.4^{a}	42.4 ± 1.4^{b}	35.2 ± 1.3^{c}	31.6 ± 1.4^{d}	34.4 ± 0.7^{c}	32.4 ± 0.7^{d}	***
BWC	16.1 ± 1.1^{a}	13.4 ± 1.1^{b}	8.9 ± 1.1^{c}	7.5 ± 1.1^{d}	6.0 ± 0.6^{e}	5.9 ± 0.6^{e}	**
ADG/g	178.5 ± 12.3^{a}	148.3 ± 12.4^{b}	98.4 ± 12.2^{c}	83.5 ± 12.3^{d}	66.6 ± 6.7^{e}	65.2 ± 6.7^{e}	**

*, P<0.05; **, P<0.01; ***, P<0.001; ABW, average body weight gain; FBW, final body weight gain; BWC, body weight change; ADG, average daily weight gain; T1, supplemented; T2, not-supplemented; superscript with the same letter is not significant and different letter has significant difference (across the row); SE, standard error of the mean.

The average daily body weight gain had significant variation both between and within groups of the three genotypes. Hence, both supplemented and non supplemented Awassi F_1 crossbreds had significantly higher average daily weight gain than Wollo highland breed and Washera F_1 crossbreds. Likewise, Wollo highland breed ram lambs had significantly higher average daily weight gain than Washera F_1 crossbred lambs. Hence, Washera F_1 crossbreds had significantly lower average daily body weight gain and final body weight change than others (Table 19).

The total body weight changes from initial to final body weight higher in supplemented Awassi crossbred lambs and followed by their non supplemented group. Supplemented and non-supplemented Wollo highland lambs observed better growth performance than Washera F_1 crossbreds. Therefore, on-station feed supplementation effect had fastest growth performance record with Awassi F_1 crossbred lambs than Wollo highland and Washera F_1 crossbred lambs. Supplemented Wollo highland lambs had faster growth rates than their non supplemented group. Supplemented Washera crossbred lambs had a comparable body weight change to non supplemented group.

Even though, Wollo highland breed had faster body weight change and average daily gain than Washera F_1 crossbred lambs, the supplemented group of Washera crossbred lambs had higher final body weight gain than supplemented Wollo highland breed lambs. The final body weight of non supplemented Washera crossbred lambs had higher than non supplemented Wollo highland lambs.

4.8. Genotypes and Supplementation Effects on Carcass Traits

4.8.1. Genotypes and supplementation effect on carcass characteristic performance

Carcass and non carcass yield characteristics included, pre-slaughtered weight, slaughter body weight, empty body weight, fasting loss, hot carcass weight, cold carcass weight, total edible proportion, non-carcass organs, rib-eye-area, fat and lean meat thickness and commercial yield were presented in Table 21.

Slaughtered and empty body weight bases of the supplemented and non-supplemented groups didn’t significant difference for each genotype. However, significant variations recorded between the three genotypes. Subsequent to 24 hours of fasting period (except water) the body weight losses and hot carcass weight had comparable value within breeds. However, Awassi crossbred lambs lost more than Washera crossbred and Wollo highland breed lambs. Even though, Awassi F_1 crossbred lambs lost higher body weight than others during fasting period, it is significantly (P<0.05) higher hot carcass weight than Washera F_1 crossbreds and Wollo highland ram lambs. Nevertheless, fasting loss and hot carcass weight have comparable between supplemented and non-supplemented Wollo highland and Washera crossbred lambs.

Table 20. Analysis of variablity for genotype and diet effects on carcass traits.

Carcass traits	Awassi F_1 crossbreds		Wollo highland breed		Washera F_1 crossbreds		
	T1	T2	T1	T2	T1	T2	Sig.L
SBW (kg)	47.4±0.8^{a}	44.6±0.6^{b}	32.5±1.4^{c}	29.3±1.1^{d}	32.6±0.5^{c}	32.2±0.5^{c}	***
EBW(kg)	35.3±1.3^{a}	32.4±1.3^{a}	24.5±1.7^{b}	20.5±1.7^{b}	26.9±0.9^{c}	26.8±0.9^{c}	**
HCW (kg)	20.8±1.6^{a}	20.2±1.6^{a}	14.7±1.2^{b}	13.5±1.2^{b}	16.0±0.5^{c}	13.2±0.5^{b}	***
CCW (kg)	18.3±1.4^{a}	18.2±1.4^{a}	11.7±1.0^{b}	11.6±1.0^{b}	14.9±0.4^{c}	12.5±0.4^{cb}	**
HCWDP (%)	43.9±3.2^{a}	45.3±3.2^{b}	45.2±3.2^{b}	46.1±3.2^{b}	49.1±0.3^{c}	41.0±0.3^{d}	*
CCWDP (%)	38.6±2.9^{a}	40.8±2.9^{b}	36±5.2^{c}	39.6±5.2^{ab}	45.7±1.8^{d}	38.8±1.8^{a}	*
TEP (kg)	25.1±1.8^{a}	23.8±1.8^{a}	17.4±1.6^{b}	17.2±1.6^{b}	19.6±0.7^{c}	17.6±0.7^{b}	**
REA (cm^2)	15.9±0.2^{a}	15.5±0.2^{a}	7.3±0.1^{b}	6.5±0.1^{b}	9.2±0.1^{c}	7.3±0.1^{b}	**
TNCW (kg)	14.5±1.3^{a}	12.2±1.3^{ab}	10.8±1.3^{b}	6.9±1.3^{c}	10±1.3^{b}	12.9±1.3^{b}	*
FT (mm)	0.3±0.1^{a}	0.3±0.1^{a}	0.2±0.0^{b}	0.2±0.0^{b}	0.3±0.2^{a}	0.2±0.2^{b}	*

T1, supplemented; T2, non-supplemented; SBW, sloughter body weight; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; HCWDP, hot carcass weight dressing percentage; CCWDP, cold carcass weight dressing percentage; TEP, total edible propertion; REA, rib-eye-area; TNCW, total non carcass weight; superscript with the same letter is not significant and different letter has significant difference.

Awassi F_1 crossbred lambs' cold carcass weight was greater than Washera F_1 crossbreds and Wollo highland breed lambs. The cold carcass weight had not significant variation between supplemented and non-supplemented groups of each genotype and proportional chilling loss. However, significant differences between genotypes and Awassi crossbred lambs recorded higher cold carcass weight than others and followed by supplemented Washera crossbred lambs. Both between and within genotypes, hot and cold carcass weight dressing percentage non-significant differences recorded. Total edible proportion and rib-eye-area had significant variation between genotypes, however not significantly different within breeds except Washera F_1 crossbred lambs. Non-supplemented Wollo highland and Washera F_1 crossbred lambs had proportional amount of total edible proportion and rib-eye-area recorded.

Fat thickness of both supplemented and non-supplemented groups of Awassi crossbred lambs had significantly higher than Wollo highland and non-supplemented Washera crossbred lambs. Despite the fact that, supplemented Washera crossbred lambs, had comparable fat thickness with supplemented Awassi crossbred lambs. Awassi crosses had significantly higher a total non-carcass weight than both Washera and Wollo highland breed lambs, but did not show within breed difference. Between supplemented and non-supplemented Washera genotype and supplemented local Wollo highland breed did not have significant variation of total non-carcass components and non-supplemented Wollo highland lambs significantly lower than others.

4.8.2. Carcass yield traits correlation coefficient analysis

Slaughtered body weight had strong positive and significant correlation with empty body weight, hot and cold carcass weight, rib-eye area (cm^2), fat thickness (mm^2) and slight positive correlation with lean thickness (mm^2). However, it had inverse correlation with commercial yield % (cold carcass weight /slaughtered body weight *100) carcass trait. Empty body weight has strong and positive correlation with cold and hot carcass weight, and rib-eye area (cm^2). However, poor and positively associated with lean meat thickness (mm^2).

Table 21. Pearson correlation coefficient of carcass yield characterestics

Body weight (kg)	SBW	EBW	HCW	CCW	REA	LMT
EBW	$.87^{**}$					
HCW	$.82^{**}$	$.77^{**}$				
CCW	$.86^{**}$	$.79^{**}$	$.98^{***}$			
REA (cm^2)	$.82^{**}$	$.77^{**}$	$.99^{***}$	$.98^{***}$		
LMT (mm^2)	$.52^{*}$	$.50^{*}$	$.54^{*}$	$.554^{*}$	$.54^{*}$	
CY %	-.15	-.01	.42	.36	.42	.08

SBW, sloughter body weight; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; REA, rib eye area; LMT, lean meat thikness; CY, commercial yield; ***Correlation is significant at the 0.001 level (2-tailed),** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

Hot carcass weight had perfect positive significant correlation with rib-eye area (cm^2) of lean meat composition and which have medium positive correlation with fat thickness as well as poorly correlated with amount of commercial yield (Table 21). The cold carcass weight trait has positive and intermediate correlation with rib-eye area and with lean meat thickness and poorly positive correlation with commercial yield feature. Likewise, rib-eye area carcass trait contents had medium positive association with fat thickness and lean meat thickness attribute. However, it had poor and positive correlation with commercial yield percentage composition. While, fat thickness amount of the carcass had positive and medium correlation with lean meat thickness in entire carcass, but negatively correlated with commercial yield percentage composition. In other ways lean meat content of the carcass had poor positive correlation with commercial yield of the whole carcass composition (Table 21).

4.8.3. Genotype and supplementation diet effects on carcass morphometric traits

Carcass morphometric characteristics of the present study were described by carcass length, lean meat weight, lean meat length, compactness index, chest width, shoulder width, and lean meat thickness presented in Table 22. Hence, the length of the carcass and lean meat had significantly higher for Awassi and followed by Washera crossbred lambs. Between the supplemented and non-supplemented group of each genotypes, comparable carcass and lean meat length were recorded, however, significantly different between genotypes were observed. Lean meat thickness significantly higher for both supplemented and non-supplemented Awassi F_1 crossbred lambs. Between supplemented and non-supplemented groups of Wollo highland breed and Washera, crossbred lambs had significant difference.

Table 22. Between and within genotype carcass morphometeric traits variablity

Carcass morphometric traits	Awassi F_1 crossbreds		Wollo highland breed		Washera F_1 crossbreds	
	T1	T2	T1	T2	T1	T2
Carcass length (cm)	74.3±1.2^{a}	73.7±1.2^{a}	63.0±1.9^{b}	64.0±1.9^{b}	70.3±2.2^{c}	68.0±2.2^{c}
Lean meat thickness (mm)	12.5±2.4^{a}	11.0±2.4^{a}	9.0±0.7^{b}	6.4±0.7^{c}	12.0±0.5^{a}	6.3±0.5^{c}
Lean meat weight (kg)	0.7±0.03^{a}	0.7±0.03^{a}	0.5±0.1^{b}	0.5±0.1^{b}	0.6±0.1^{b}	0.5±0.1^{b}
Lean meat length (cm)	55.3±1.2^{a}	54.7±1.2^{a}	44.0±1.9^{b}	45.0±1.9^{b}	51.3±2.2^{c}	49.±2.2^{c}
Compactness index (g/cm)	12.1±0.8	12.0±0.8	11.8±0.8	11.9±0.8	12.4±0.9	10.5±0.9
Chest width (cm)	13.9±0.6^{a}	13.7±0.6^{a}	9.2±1.0^{b}	8.1±1.0^{b}	10.9±0.9^{b}	8.8±0.9^{b}
Shoulder width (cm)	17.7±0.6	18.1±0.6	14.4±0.6	14.2±0.6	17.1±0.6	15.0±0.6

T1, supplemented; T2, non-supplemented; cm, centimeters, kg, kilograms, mm, millimeters, g, gram and superscript with the same letter is not significant and different letter has significant difference.

The carcass composition of lean meat weight amount significantly higher with Awassi crossbred lambs than Washera crossbred and Wollo highland breed lambs. Supplemented Wollo highland lambs and Washera crossbred lambs had proportional amount of lean meat weight. The carcass compactness index is measured by grams of lean meat per centimeters of its length. Carcass compactness index, chest and shoulder width had comparable records for all genotypes except chest width for Awassi genotype.

On the other hand, there were not significant differences, both supplemented diet and genotype effects on carcass compactness index, chest and shoulder width of carcass morphometric trait. However, Awassi crossbred lambs had significantly higher chest width than others.

4.8.4. Genotype and supplementation effects on non carcass fat distribution

The effects of genotype and supplementation diet effect on non-carcass fat distribution presented in Table 23. Thus, the non-carcass fat contents around the scrotal fat organ had not significant variation between supplemented and non supplemented group of each genotypes. However, between Wollo highland breed and Awassi crossbred lambs had a significant variation of scrotal fat contents. Likewise, Washera and Awassi crossbred lambs had significant differences between supplemented and non supplemented groups of scrotal fat contents. While, kidney fat composition of Awassi crossbred lambs and Wollo highland breed lambs had significantly lower than that of Washera crossbred lambs (Table 23).

The fat composition around kidney organ significantly higher for Washera crossbred lambs and comparable contents recorded between Wollo highland breed and Awassi crossbred lambs. The supplemented and non-supplemented groups in each genotypes were didn't have significant variation in kidney fat composition. However, significant variation of kidney fat composition recorded between Wollo highland breed and non supplemented Washera crossbred lambs. Whereas, mesentery fat composition was higher in Awassi crossbred lambs and followed by Washera crosses.

Between the three genotypes mesentery fat content had significant variation, however, between supplemented and non supplemented groups not significant difference in each genotypes. Generally, between supplemented and non-supplemented groups total non carcass fat content didn't have significant variation.

Table 23. Non-carcass fat distribution traits variablity between and within genotypes

Non carcass fat traits (g)	Wollo highland breed		Awassi F_1 crossbreds		Washera F_1 crossbreds	
	T1	T2	T1	T2	T1	T2
Scrotal fat	8.7±2.9^{c}	10.7±2.1^{c}	33±6.7^{b}	40±6.7^{b}	13.7±4.4^{c}	15.7±4.4^{c}
Pelvic fat	29.3±3.5^{a}	26.7±3.5^{a}	30.7±3.1^{a}	27.7±3.1^{a}	47.0±10.6^{c}	38.3±10.6^{c}
Kidney fat	25.3±2.0^{a}	23.3±2.0^{a}	60±18^{a}	63±18.0^{a}	171.0±52.4^{c}	89.3±52.4^{c}
Mesentery fat	55.3±8.5^{a}	43.3±8.5^{a}	414±38.7^{b}	317.7±38.7^{b}	233.3±64.1^{c}	145.0±64.1^{c}
Overall	117.7±12.6^{a}	103.6±12.6^{a}	537.7±54.7^{c}	448.4±54.7^{d}	465±129.7^{c}	288.3±129.7^{b}

T1, supplemented; T2, non-supplemented; g, grams and superscript with the same letter is not significant and different letter has significant difference.

Whereas, significant difference recorded between three genotypes of total non carcass fat contents. Both supplemented and non supplemented group of Awassi F_1 crossbred lambs had higher composition of total non-carcass fat contents followed by Washera crossbred lambs. In general all supplemented groups were comprised of higher numerical value of non carcass fat composition, but not significantly different with non supplemented groups.

4.8.5. Genotype and feed effects on non-carcass edible and non-edible components

According to intellectual prohibited cultural and religious taboo of the local communities the edible components of non carcass organs were presented as liver, tongue, heart, kidney, empty gastrointestinal part and tail fat were the most common. Hence, liver and heart weight comparable for Wollo highland and Washera crossbred lambs, however, Awassi crossbred significantly higher amount of liver and heart weight.

At the same time, non significant record was observed between supplemented and non supplemented groups of all genotypes. While, the kidney and empty gastrointestinal weight had comparable for all genotypes and feeding type factors. There was not significant difference both within and between genotypes and feeding types. Whereas, the tail weight had comparable between the three genotypes. However, Washera crossbred had a numerically higher quantity of tail weight than others (Table 24).

In general, except kidny weight of non-supplemented Awassi and Washera F_1 crossbreds and supplemented Wollo highland breed lambs, the edible non-carcass components not significant variation between supplemented and non-supplemented groups. However, except kidney weight and GIT empty weight, genotype had significant variation on non-carcass edible components. Except tail fat weight composition, in all edible non carcass components of the Awassi crossbred lambs had the largest portion (Table 24). Wollo highland breed had a comparable tail fat composition with Awassi crossbred lambs. However, both genotype and supplementation diet didn’t had significant differences with kidney and empty gastrointestinal weight of supplemented and non supplemented groups. Subsequently, the non-edible, non-carcass components were, skin, head, testicle and genital organ, blood, bladder, pancreas, feet, digesta contents and spleen which prohibited by the local communities cultural and religious taboo.

Table 24. Genotype and diet effects on edible and non-edible non-carcass components

Non carcass components	Awassi crosses (Means)		Wollo highland breed (Means)		Washera crosses (Means)			
	T1	T2	T1	T2	T1	T2	SE	P-value
I. Edible non carcass traits								
Liver (g)	717.0^{a}	541.3^{a}	332.0^{b}	384.3^{b}	445.0^{c}	453.0^{c}	76.0	**
Tongue (g)	137.8^{a}	143.2^{a}	109.3^{b}	114.3^{b}	91.9^{c}	89.8^{c}	7.0	***
Heart (g)	190.3^{a}	127.3^{a}	61.3^{c}	68.3^{c}	68.3^{c}	75.3^{c}	25.5	**
Kidney (g)	63.3^{a}	66.0^{b}	64.3^{ab}	59.0^{c}	54.0^{c}	66.0^{b}	31.4	*
GIT empty (g)	1900.0	1633.3	1611.3	2215.0	1779.3	1633.3	330	Ns
Tail fat (g)	987.3	951.0	1106.7	920.0	1151.3	1213.3	100.9	NS
II. Non edible non carcass traits								
Skin (g)	3600.0^{a}	3766.7^{a}	3700.0^{a}	3133.3^{b}	5100.0^{c}	5033.3^{c}	255.0	**
Head (g)	1773.3^{a}	1733.3^{a}	2110.0^{b}	2206.7^{b}	2660.0^{c}	2763.3^{c}	134.9	**
Testicle (g)	420.0^{a}	420.0^{a}	310.0^{b}	310.0^{b}	540.0^{a}	430.0^{a}	56.0	***
Blood (g)	1336.7^{a}	1300.0^{a}	873.3^{b}	937.3^{b}	2033.3^{c}	1823.3^{c}	181.3	**
Bladder (g)	67.3^{a}	68.7^{a}	57.3^{b}	63.3^{b}	$72.3.0^{a}$	64.0^{a}	2.3	**
Feet (g)	247.7^{a}	249.7^{a}	214.0^{a}	194.7^{b}	203.7^{b}	217.7^{a}	16.4	*
Digestive content (g)	8400.0^{c}	8300^{c}	4222.0^{a}	5551.7^{b}	3466.7^{a}	4337.3^{a}	725.2	**
Spleen (g)	41.7	44.0	32.7	45.0	33.7	30.3	4.7	Ns

T1, supplemented; T2, non-supplemented; ns, non-significant; GIT, gastrointestinal track and SE, standard error of the mean and superscript with the same letter is not significant and different letter has significant difference.

The skin weight of Awassi and Wollo highland breed had comparable both supplemented and non supplemented groups. While, Washera crossbred ram lambs had significantly higher skin weight than Awassi and Wollo highland lambs. Whereas, the head, testicle with a penis, bladder and foot weight had proportional amount between Awassi and Washera crossbred ram lambs and significantly greater than Wollo highland breed. The digesta content of rumen was significantly higher in Awassi crossbred ram lambs and followed by non supplemented Wollo highland breed ram lambs. On the other hand, comparable record was observed between both supplemented and non supplemented Washera crossbreds and supplemented Wollo highland breed lambs.

5. DISCUSSION

5.1. On-Farm Sheep Flock Size and Composition and Management Practice

Average flock size is one of the factor which affect sheep reproductive and productive performance, income and wealth value, selection intensity and grant for household activities. It's a long history of traditional on-farm sheep producers were more interested in the number of animals rather than their productivity performance improvement anticipation. The overall average flock size in the current study was slightly greater than reported by Gizaw (2008) in the sub-alpine area (20.1) and lower than the same author reported in the lowland area of Ethiopia. Nevertheless, Yenesew *et al.* (2013) reported 3.7±2.4 heads of sheep per household at on-farm condition of Burie district, and much lower than the current report. Tsedeke (2007) also noted an average flock size of 7.4 sheep in Alaba Zone of Southern region, Ethiopia, which was lower than the present report. However, Awigichew (2000) and Samuel (2005) reported an average flock size of 30 to more than 100 sheep per households for higher altitudes of 2800-3000 m.a.s.l, sheep production area which much higher than current report (Table 9).

The present finding of average flock size greater than reported by Gizaw *et al.* (2013) except the sub-alpine sheep barely production system of 31.4±15.1 sheep per flock. On the other hand, the same author reported lower average flock size than the present finding in the perennial crop-livestock system, cereal livestock system and pastoral systems of 11.3±1.3, 8.2±2.1 and 23.0±16.5 of sheep, respectively. Hence, the overall average flock size of the current study in agreement with Gizaw *et al.* (2013) for pastoral production system. Taye *et al.* (2010), Asresu *et al.* (2013) and Hundie (2015) also reported, 9.6, 4.2 and 9.3 average flock size for Washera sheep in Dangila and Horro sheep in Horro Guduru area which were much lower than present report. The overall flock size in the present study was higher than the findings of Hundie (2015), Asresu *et al.* (2013), Taye *et al.* (2010), Tsedeke (2007) and Yenesew *et al.* (2013) in the country.

Comparable with the present study, Gizaw *et al*. (2010a) revealed, large flock size usually is related to extensive sheep breeding practices and which generated a large number of lambs for sale per annum. This indicated that, smallholder households usually experienced on non-fattened yearling lambs'sale for income generation and for urgent household needs which might have negative effect on selection intensity and breed improvement practices. The large flock size in the subalpine sheep–barley and pastoral systems might be due extensive mode of production system. Generally the overall average flock size of Wollo highland sheep production system have large flock size, but becoming decreasing tendency than previous flock size report. Therefore, the reason behind this fact, might be shortage of feed, producers' responsiveness for reducing large flock size, productivity performance improvement practice, limitation of grazing land and increasing frequency of prevailing drought occurrence.

5.1.1. Flock structure and composition

Flock structure is the proportion (in terms of head) of the flock of sheep, which is formed by different age and sex classes of animals. Flock composition in terms of age and sex classes has been taken as an indicator of production objectives of the owner and the production system of a given flocks. Therefore, in the current study flock structure and composition was composed of the number of ewes, rams, pre-weaned ewe and ram lambs, unproductive ewes, castrated and fattened rams (Table 9). The number of ewes, pre-weaned ewe and ram lambs, unproductive ewes, castrated and fattened rams and annual offtake rate were higher in the Washera genotype flocks than Awassi genotype flocks and Wollo highland breed flocks. However, the higher number of rams Wollo highland breed flocks than Awassi genotype flocks and Washera genotype flocks, the reason might be, rams may not be selected for breeding purpose. The number of ewes, rams, pre-weaned ewe lambs and unproductive ewes in Wollo highland breed flocks than Awassi genotype flocks was due to the traditonal way of flock management practices. However, the large number of ewes and rams in Wollo highland breed flocks didn't show an effect on number of weaning lambs and annual off-take rate. The reason behind this might be the poor fertility, and managemental condition of the flock. Whereas, Awassi genotype had higher number of pre-weaned ram lambs, castrated and fattened sheep and annual off-take rate than Wollo highland breed flocks and it might be due to the better fertility rate performance of the breed contributed to more number of lambs weaned and which is in agreement with Hussein *et al*. (2004).

In the present study, relatively higher proportion of breeding ewes were observed as compared with previous result reported by Niftalem (1990), Abebe (1999), Tesfaye (2008) and Agyemang *et al*. (2011) report. On the contrary the present finding indicated lowest proportion of flock composition than reported by Agyemang *et al.* (2011) of 74.8 % female, 22.4% entire males and 2.8% castrated Menz sheep in the traditional sector of the Ethiopian highlands. Taye (2008) revealed, flocks of Washara sheep constituted 81% females, 17.3% intact males and 1.7% castrated in traditional system in Amhara region and which had more females per flock than present report. Comparable with the present finding, Samuel and Belay (2011) furthermore revealed, the total sheep enumerated had 40% ewes, 7.5% rams, 51.9% lambs in the flock.

According to Taye *et al.* (2010), larger proportion of breeding ewes would be implied that, production of a larger number of lambs which in turn might increase the intensity of selection and saleable lambs per flock. The different research result indicated, the number of ewes in the flock were higher, but the number of lambs and ewes in the flock not proportional and which indicated, reproductive loss might be the factors to be reduced the expected number of lambs/ewes. Unproportional flock composition and structure might be indicative of external factors such as feed, disease and breeding management problems affecting the given flock.

5.1.2. On-farm sheep producers' culling practice

In the present study, sheep producers' culling rationale comprehensively composed of sickness, reproductive failure, old age, physical defects and unwanted color (Figure 9). Corresponding with the culling rational, the common methods of culling practices were concerned with, sale removal and slaughtered for meat consumption. Furthermore, sick animals subjected to culling through condemnation, slaughtering for meat consumption and sale for cash income with decreasing order of their importances. Consequently, large numbers of diseased animals exposed to condemnation. The majority of animals having reproductive problems were culled through sale removal and slaughtered for meat consumption. Similarly, the largest part of physically defective animals and unwanted physical appearance removed by means of sale and slaughtering for meat consumption in decreasing order of importances.

Tsedeke (2007) reported 45.5% of total loss of sheep in the flock was by sheep mortality and it was found to be the major cause of flock size reduction in Alaba area, Ethiopia. The same author revealed, an average sale removed sheep per flock were 1.5 per year and it comprised a total disposal of 31.1% of sheep per flock. Similarly, the present study reported, large percentage of culling practice conducted through markete sale for immediate cash income. In agreement with present study, Workneh (2000) also reported that, 35.7% of the exit was done through sales in eastern Ethiopia.

Comparatively, in agreement with the current study, Mekuriaw *et al.* (2012) and Verbeek *et al.* (2007) also reported, most farmers (96.1%) were used to cull unproductive animals during feed shortages by market sale. The same author revealed, the main reasons for culling were old age (41.2%), poor physical condition (29.4%), fertility problems (19.6%), susceptibility to disease (9.8%) and comparatively in agreement with present finding. Moreover, Workneh (2000) elucidated a total disposal of 14.3% by slaughter, 1.0% by predators, 5.9% by share holding was apparent in sheep flocks total disposal and which was different from the present study (Figure 9).

The present finding comprised the majority of sheep with superior performance in the flock culled through market sale and slaughtered for meat consumption. Hence, such a detrimental type of practice implied, the presence of negative selection which had considerable effect on the genetic improvement practice. Hence, negative selection had a contradictory effect on best performed animals selection procedure to present in the flock as a parent for future progenies. This study revealed, 72% of animals in the flock during drought period culled through market sale instead of purchasing supplementary feed. Hence, feed shortage was one of the reasons for culling to reduce producers' flock size. For this reason, a large number of sheep were exposed to seasonal marketing during drought time and sold with least cost benefits. Therefore, the best selected parent animals during the drought time were sold and honestly influenced genetic potential improvement practices of smallholder farmers' local breed. In general, smallholder sheep producers' culling practice had negative effects on productive and reproductive genetic performance improvement practices. This indicated, farmers sold higher performance sheep to gain better income and to save lost due to drought and disease occurrence.

5.2. Farmers' Breeding Strategies and Rams Breed Source

In the current study sheep breeding strategies were characterized by village community based controlled breeding, private controlled breeding, random mating and mixed type of breeding strategies (Table 10). In this finding random mating users were the lowest number of beneficiaries than other breeding strategy users. Private controlled breeding followed by village controlled breeding and mixed type of breeding practices had largest number of beneficiaries in the order of their importance. The typical character of village based controlled breeding strategy had common social, cultural, economic interest and traditionally well defined area in the course of breeding practice.

In private controlled breeding strategy, sheep producers were selected and controlled their own breeding rams in their flock and sometimes might be borrowed from their neighbor and random mating was mostly controlled. Hence, each producers had their own breeding objectives and traits of interest during breeding rams and ewes selection process as parents for subsequent generation. Whereas, mixed type of breeding strategy used all breeding strategies mixed together knowingly or unknowingly. This means, if a certain circumstance is accessible, the producers had their own breeding objectives and traits of interest to be used controlled breeding strategies. But, when conditions doesn't allowed to select their breeding ram and ewes, beneficiaries might be used in random mating. Therefore, if situations are furnished those mixed type breeding strategy users had possiblity to entirely used controlled breeding strategies and so as easy for developmental intervention for genetic potential improvement practices.

In agreement with present finding, Gizaw *et al.* (2013) revealed that village community based control breeding strategies was applied in Menz, Bonga, Horro and Afar areas as a model for designing breeding program. However, former genetic improvement attempts mainly focused on crossbreeding of indigenous local breeds with exotic sheep by top to down breeding approach and that wasn't brought the expected level of result in genetic improvement practices. Tesfaye (2008) and Gizaw *et al.*(2013) stated, breeding strategies were generally uncontrolled or indiscriminate mating in both Menz and Afar areas, except only to some extent in the Afar area in the previous genetic improvement progress. Thus, the major problems of conventional sheep crossbreeding approach as indicated by Workneh (2000) and Tibbo (2006) were lack of clear vision of breeding strategies, performance recording at smallholder level and the incompatibility of the genotype with the existing environment to bring impact. Consequently, Tesfaye *et al.* (2016) reviewed, indiscriminate crossbreeding without analysis of crossbreds suitability for a given production environment and without clear breeding objectives, presents a potential threat to better adapted indigenous breeds.

In the present study, the use of exotic breeds with the supports of governmental and non governmental organizations, smallholder sheep producers' also trying to achieve their breeding objectives through introduction of superior performance indigenous breeding rams for crossbreeding purpose from domestic market of available area (Table 10). Therefore, selection of indigenous breed was based on phenotype trait performance of subjective breeding ram selection criteria. Through, controlled breeding strategy, random mating restricted via castration, fattening and selling of unwanted ram lambs before sexually mature. Seem

5.2.1. Breeding objectives and trait selection criteria

Smallholder sheep producers' breeding objectives attributes and trait selection criteria were described and ranked as growth rate, body size, weaning rate, body conformation, age at first lambing, lambing rate, drought resistance, color type, disease resistance, hair type, twin rate, horn type and tail type were ranked in the order of their importance. In agreement with the current finding, Kosgey (2004) reported, the smallholder sheep producers' traits of interest were body size, growth performance, breed type, body conformation, temperament, color and horns ranked in their order of importance. Gizaw *et al*. (2013) also reported, breeding objectives of Menz, Bonga, Horro and Afar sheep production area owners ranked by body size as first preferred traits for breeding objective achievement and while, in the present study growth rate ranked the first trait of interest, so both traits were size explanatory and compatible traits. The reason behind this, body size is one of the productive performance improvement trait and desirable for market to generate better income.

The second preference traits by the same author ranked, growth rate in Menze, color in Bonga, tail size and shape in Horro and Afar. However, body size in the present study ranked second and comparable with Menz area second ranked trait (Gizaw *et al.,* 2013). Tesfaye (2008) reported, about 62.5% of smallholder farmers in Menz area and 77.4% of pastoralists in Afar area were able to identify the sire of a new born lamb by relating to lamb color and appearance or body conformation, respectively. Yet again the same author stated, lambing interval, mothering ability and milk yield traits in both crop-livestock and pastoral systems important traits of interest in the choice of breeding ewes. Yadeta *et al.* (2016) also illustrated farmers ranked body size, coat color and lamb survival rate as first, second and third traits of interest for breeding ewes selection in the three agro-ecological zones. The present study (Table 11) is comparatively in agreement with Kosgey (2004), Helen *et al.* (2013) and Yadeta *et al.* (2016) regarding breeding ewes selection criteria.

According to Fewson (1993), breeding objective is defined as "developing vital animals which will ensure, profit as high as possible under future commercial production conditions". Kosgey and Okeyo (2007) stated, subsistence farmers unlike commercial ones tend to keep animals for family need rather than purely as an economic enterprise. Kosgey *et al.* (2004) also confirmed smallholder sheep producers' kept multi-purpose animals which produce meat, milk, wool, skin beside their ceremonial purpose and pleasure service. For that reason, it is important to consider all tangible and intangible roles of the breed, when defining breeding objectives at breed level.

Yadeta *et al.* (2016) recently reported, farmers' trait preferences were affected by agro-ecological zones. Hence, similar to the current finding, body size more preferred by highland producers, color type by midland producers and survival rate by both mid and low land sheep producers. Generally, most researchers agreed, the smallholder sheep producers usually preferred body size, color type, growth rate, breed type and horn type for breeding rams' performance evaluation criteria and body size, coat color and lamb survival rate, lambing interval, twin rate and milk yield used as breeding ewes selection criteria. However, milk yield and lamb survival rate most common in pastoral area breeding ewe selection criteria. Even though, producers had multiple traits of interest, overall traits were difficult to join together from a given breed at the same genetic improvement period. Therefore, traits have to be prioritized and analysed compatable traits to be considered through genetic improvement practices and subsequently flock productivity improvement program for long term plan of research and development activities. In general, smallholder sheep producers more focused on economical traits of interest in household income generation activities. The influence of each economical traits on genetic improvement programs need to investigate for both small scale and commercial sheep production perspectives.

5.2.2. Breeding ewe's selection criteria and farmers traits of interest

In the present study, breeding ewes selection criteria were, lamb survival rate, twin rate, parental history, lambing interval, temperament, lamb growth rate, tail type and body conformation mentioned in the order of their importances' (Table 12). Tesfaye (2008) revealed, Menz area sheep breeders considered lambing interval, mothering ability, multiple birth (twinning rate) and coat color as the first four breeding ewes' selection criteria and which in agreement with the present report. The same author stated, Afar sheep breeders considered, milk yield, mothering ability, appearance and/or size of ewes' and lambing interval were the four common traits and which were slightly different from the present study. Asresu *et al.* (2013) reported, body conformation trait was first ranked for both breeding rams and ewes selection criteria and which support the current finding.

In agreement with the current results (Table 12), Kosgey *et al.* (2003) and Kahsa (2009) reported, litter size was one of the most economically important attributes of breeding ewes selection criteria. Producers' select their breeding ewes, by the consideration of many attribute's to be transferred to their progenies. However, most researchers often distinguished only first three top traits of interest as breeding ewes' selection criteria. Therefore, multiple trait selection needs to be integrated for the wide-ranging turnover of the flock productivity through highly correlated traits identification. The breeding ewes selection criteria were based on the factors that determine productivity and reproductive performance of the next generation. Thus, sheep producers, researchers and development agents have to common understanding of important traits genetic improvement practices. As a result, sheep producers participatory based breeding objective determination is an important for sustainable genetic improvement practices. Smallholder farmers sometimes pointed out their interested traits from their long years previous experiences to achieve their breeding objectives and might be disagreement with the scientific point of view. However, researchers and development workers should have to understand and attempt to incorporate farmers' interest through scientific rational genetic improvement activities in order to create own perception and sustainable genetic improvement programs.

5.2.3. Breeding ram selection criteria and farmers traits of interest

When producers select their breeding rams for genetic improvement purposes, the major considerable attributes are presented in Table 13 in the order of their importance. Hence, body size, growth rate and marketing value were the first, second and third rank of ram selection criteria. In agreement with the present finding, Tesfaye (2008) reported, body conformation of breeding rams ranked first for both Menz and Afar sheep owners. Yadeta and Manzur (2016) reported body conformation selected as first preferences trait for breeding ram selection criteria in all the three agro-ecological zones of the country which support the current finding report. Zewudu *et al*. (2012) in the Adiyo Kaka district of Kaffa zone was presented body size as first preference attribute, color type as second and tail formation was third ram selection criteria and which mostly comparable with the present report. In-line with the current finding, Fsahatsion (2013) in Gamo Gofa zone reported, body size as primary criteria in mid-altitude. This indicated that, body size was the common and the first trait of interest to select breeding rams in all agro-ecological zone of the country. Generally, the above mentioned authors in agreement with the present report, large body size, fast growth rate, marketing value, body conformation, drought tolerance, coat color, tail formation, horn orientation, libido and hair type desirable attributes for future genetic improvement practices at smallholder production condition.

Based on the preferable traits for breeding ram selection, village community had ram exchange experiences during breeding practices for long period of time. This experience enabled them to have a common interest of breeding objectives and mutually genetic improvement efforts. Even though, past breed improvement efforts didn't realized genetic improvement target, producers obtained lessons from their efforts. Therefore, nowadays village community had their own breeding objectives for genetic potential improvement of local breed through introduction of the new ram breed type from the available area according to their common traits of interest. Phenotype performances evaluation of rams were the major observable parameters for producers decision making during the selection of their interested attributes (Table 13).

5.3. Flock Reproductive Performance Assessment

On-farm traditional flock management system characterized by year round breeding practices with minimal inputs. This reasonable good opportunity for rams to join with ewes at any time. In the current finding flock reproductive performance evaluated by the computable parameters of number of ewes mated/flock, pregnant ewe/flock, abortion rate/flock, number of service/conception (NSC), age at first mating, age at first lambing, birth type, number of parturition per ewes/year, weaning rate and lambing interval traits. While, the reproductive performance of breeding ewes were evaluated by fertility rate, prolificacy rate, weaning rate, mortality rate, lamb survival rate (at birth to 90, 91 to 180, 181 to 270 and 271 to 365 days) in the current study (Table 14).

5.3.1. The number of ewes and rams proportion in the flock

The number of breeding rams between the three genotype flocks did not have significant differences in the present finding. However, number of ewes between the three genotype flocks had significant variations ($p<0.05$) and higher in the Wollo highland genotype flocks compared with Washera genotype and Awassi genotype flocks (Table 14). The current finding of overall mean number of ewes per/flock much lower than reported by Fsahatsion (2013a) with 15.9±0.62 and 8.45±0.22 ewes/flock in the highland and mid-highland of Tigray region in Ethiopia, respectively. Likewise, Gizaw *et al*. (2013a) reported, 14.7±8.6, and 11.3±7.8 ewes/flock, respectively in the sub-alpine sheep barely and pastoral production system and much higher than the current finding. The same author also reported, in perennial crop-livestock and cereal livestock production system were 3.7±2.7 and 3.9±2.8 ewes/flock, respectively and which is lower than the current finding. Agyemang *et al.* (2011) reported, 74.8% females, 22.4% males and 2.8 % castrated for Menz sheep in the traditional sheep production systems of the Ethiopian highlands and which were much greater than the present results (Table 14).

Taye (2008) also reported, Washara breed in Dangila constituted 81% of ewes, 17.3% of intact males and 1.7% of castrated male in the traditional way of production system. The current finding revealed, 39% lambs, 29.2% breeding ewes, 13.3% breeding rams and the remaining were fattened and infertile sheep (Table 14) and relatively in agreement with Tesfaye *et al.*(2010; 2011). Furthermore, Abebe (1999) and Abegaz (2007) reported, 1:7.5 for Menz sheep and 1:6.7 for Gumuz sheep, respectively of ewe to ram ratio and which more than the present finding.

Generally in the present study, the number of male to female ratio much lower than reported by Abebe (1999), Abegaz, *et al.* (2005; 2007) and Tesfaye (2008). Therefore, the current finding indicated, lower proportions of male to female ratio and that might have advantage to reduce inbreeding coefficient. Hence, the current finding a single ram had a chance of mating with fewer number of breeding ewes and presence of more number of rams/flock and that might be diversified the parents of their progenies. The present report had lower number of ewes/flock than most other previous findings, but relatively large number of lambs/flock/year produced. That is why, the prolificancy and annual lambing rate of ewes/flock were better.

In the current study, results pertaining to the rams used pattern indicated, most of the rams owned by the farmers themselves and which kept for dual purpose of breeding and fattening objectives. Whereas, those owners didn't have ram in their flocks were usually used from their neighbors and the rest respondents purchased for breeding purposes. In general, the present study revealed, the ratio of rams to ewes below the recommended level and extra number of rams keept, and that might be increased feed cost and other management input. Conversely, higher number of rams to ewes ratio might be important to keep individual animal diversity in the flock. Correspondingly, higher number of males /flock can increase annual incom generation through ram lambs and fatten rams market sale and input for fattening activities. To compromise this, the recommended number of rams to ewe ratio have to be used and random matting need to be controlled through castration and fattening.

5.3.2. Number of lambs born/ year/ flocks

The overall mean number of lambs born/year/flock had significant difference ($p<0.05$) between the three genotype flocks (Table 14). Thus, Washera genotype flocks had significantly higher ($p<0.05$) number of lambs/flock and lambs/ewes than first and Wollo highland breed flocks. The reason behind this might be the prolific nature of the ram breed effect in Washera genotype flocks (Washera ram) than Awassi genotype ram used flocks and local Wollo highland ram breed flocks. The same breed type of dam used in all genotype flocks, however, a different ram breed type and the number of ewes/flock might have also effect on the number of lambs born/year/flocks.

According to Tibbo *et al*. (2006) reported, 0.92 lambs/ewes/year were recorded for Menz indigenous breed type and which less than the finding of present study. While Kosgey (2004) reported, the average number of lambs/ewes/year was 1.5 in the smallholder farmers of pastoral area and which similar with tropical region and slightly lower than current finding. Hence, the current finding reported, the overall average number of lambs/ewes/year greater than reported by Kosgey (2004) and Tibbo (2006). Whereas, Deribe (2009) also revealed, annual lambing rate of Alaba ewes in the Southern Region of Ethiopia was 1.2 lambs/ewes/year and which much lower than the current funding.

Gizaw *et al*. (2013a) also reported, the mean number of lambs/flock/year in sub-alpine sheep barely, perennial crop-livestock, cereal livestock and pastoral sheep production system were 6.3±4.2, 4.0±1.6, 1.9±1.3 and 5.4±4.7 lambs, respectively. However, the current study had more overall average number of lambs/flock than Gizaw *et al*. (2013a) and that might be the effect of prolificacy rate and short lambing interval performance. Tesfaye *et al*. (2013) also reported, 1.86 lambs born/ewes/flock in Wollo highland smallholder farming condition and which in agreement with the present study (Table 14). Tesfaye (2008) also reported, 6.3±4.2 lambs/ flock in the crop-livestock production system and which was less than the overall number of lams/flock of the current finding.

Large number of lambs per flock implies higher lambing rate of ewes and in turn might increase the intensity of within breed selection and increased the number of saleable lambs in the flock. In smallholder sheep production context high lambing rate of ewes were more important to increase flock size and amount of cash income from number of saleable lambs. Hence, sheep producers had long year experience of exploitation of lambs as cash crop for their immediate household needs. For this reason, fast growing once were sold in early aged and kept for a short duration of time in the flock most of the time before sexually maturing, but slow growing lambs kept for a long period of time within the flock that mostly attain sexual maturitu before achieving valuable marketing size and used breeding purposes and resulted negative selection of genetic potential improvement practice of the local breeds.

5.3.3. Age at first mating and lambing

In the current study age at first mating (puberty) of ewe lambs were attained at 6.1±2.5 months and significant ($p<0.001$) variation between the three genotype flocks recorded due to the effect of sire breed type. Washera genotype ewe lambs had significantly ($p<0.001$) younger age at first mating than Awassi genotype and Wollo highland breed ewe lambs. In agreement with current finding, Mukasa-Mugerwa *et al.* (1993) revealed, in most situations estrus was observed in ewe lambs at the age of 5 to 6 months and which indicated, puberty might be attained at an earlier age, but fertility will only improve with age and weight. However, Begum *et al.* (2014) revealed, age at first puberty varied from five to eleven months and ewe lambs on supplemented group reached puberty at younger age (6.2±1.3 months) than controlled group (8.4±1.2 months). Mukasa-Mugerwa and Lahlou-Kassi (1995) reported, the level of supplemental feed increased from low, medium and high energy level, the age at first mating decreased by 71, 153 and 155 days, respectively. However, the current finding, age at first mating (puberty) at smallholder sheep producers' management conditions inagreement with reported by Begum *et al.* (2014) and Mukasa-Mugerwa *et al.* (1993) and puberty attained at an earlier age. The current report presented, age at first mating and lambing at younger age and the reason behind this might be the effects of earlier maturing behavior of the local breed or the effect of hybrid-vigour of the dam and sire. Hence, there should be further research work is essential on this point of view with the controlled management condition.

The age at first lambing in the present study younger than reported by Berhanu and Aynalem (2009), Mukasa and Lahlou-Kassi (1995) with 13.5 months of age under village management conditions in southwestern Ethiopia and with 15 months of age for Menz ewes, respectively. Conversely, the age at first lambing reported, 16.5 (Gautsch, 1987), 17 (Niftalem, 1990) and 15-22 months of age (Abebe, 1999) at different part of the country. Moreover, Zewdu and Tesfaye (2008) reported, age at first lambing of 13.3 and 15.7 months in Horro and Menz sheep breed, respectively. However, the current study revealed, short and faster age at first lambing and which below the national average of 11.4±3.6 months of age at smallholders sheep production circumstances (Table 14). The reason behind this might be the potential of the breed endowed with early maturing behaviors and the effects of hybrid vigour. Local Wollo highland ewes crossed with an indigenous Washera rams of their F_1 crossbred progenies indicated, younger age at first mating and lambing than Awassi rams crossed with Wollo highland ewes' F_1 crossbreds. The plausible reason behind this might be the effect of sire breed difference. Therefore, controlled reproductive performance evaluation across a season, breed type, and supplementary diet effect might be an interesting research question for further genetic improvement programs. Generally, age at first mating and lambing of the current study comparatively younger than most other research finding in the country.

5.3.4. Service per conception and abortion rate per flock

Reproductive performances of ewes/flock were also determined by the average number of service/ conception, parturition/flocks and abortion/ewes/flock. Hundie (2015) recently reported, average number of services/conception were 1.3±0.56 for Horro ewes under traditional management situation in Western Ethiopia Horro Guduru area and which inagreement with the current reports of 1.3±0.1 number of services/conception (NSC). Accordingly, reported by Mukasa-Mugerwa *et al.* (2002), conception rate of 88.2% and 79.1% of Menz sheep breed at dry and wet season, respectively at the first mating. The author also revealed, 77.6% and 71.7% of Horro sheep breed in the dry and wet season, respectively through hormonal treatment of synchronization. Whereas, Mukasa-Mugerwa and Lahlou-Kassi (1995) reported conception rate with a first mating of 69% and 78% for pubertal and mature ewes, respectively and comparatively in agreement with the present report.

Mukasa-Mugerwa and Lahlou-Kassi (1995) presented, conception and lambing rates (lambs born/ewes mated) affected by breed type. Hence, Berhan and Van-Arendonk

(2006) revealed, lambing rate of 81% for Menz and 76% for Horro ewes with similar management condition, and 19% and 24% of abortion rate for Menz and Horro ewes, respectively. However, in the current study, 86% of lambing rate at farmers' situation is greater than from both Menz and Horro ewes. Comparable with reported by Mukasa-Mugerwa and Lahlou-Kassi (1995) the current finding overall mean number of abortion rate was 0.7 to 9.3%/flock. In the present study abortion rate had significantly higher ($p<0.05$) in Washera genotype flocks than Wollo highland breed and Awassi genotype ewes/flock. Service/conception also significant difference ($p<0.05$) between the three genotype flocks and higher in Washera genotype flocks than Wollo highland breed and Awassi genotype ewes/flock. The reason behind this might be the effect of sire breed and management differences. Therefore, further investigation on sire fertility effect on service/conception and abortion rate might be important.

The overall abortion rate in the current study, was lower compared with Berhan and Van-Arendonk (2006) and Mukasa-Mugerwa and Lahlou-Kassi (1995), but its challenging factor affecting sheep productive and reproductive performance. As a result, further investigation is essential for the characterization of the cause of abortion rate and its degree of importances. The number of services/conception might be affected by management practices and rams' fertility. Hence, fertile ram selection with management improvement practice need to realize for number of service/conception and abortion rate improvement options.

5.3.5. Twinning or prolificacy rate

The number of twins and single birth/flock/year had significant difference ($p<0.001$) between the three genotypes. The higher twin birth was recorded in Washera genotype flocks followed by Wollo highland flocks (Table 15) and the reason behind this fact might be ram breed effect on the flock prolificacy rate of the Washera genotypes. The number of twin birth per flock between Washera genotype and Wollo highland breed flocks had no significance differences. Whereas, the number of single birth per flock was significantly ($p<0.001$) higher in Awassi genotype flocks than Washera genotype and

Wollo highland breed flocks. This indicated that Awassi genotype had a lower possibility of prolificacy rate than local Wollo highland breed and Washera F_1 crossbreds genotype. However, the overall mean number of twin and single birth per flock was 2.2±0.9 and 2.9±1.1, respectively at smallholder farming condition. In the current study, the annual prolificacy rate (number of offspring produced /ewes gives birth/year *100) were 134.4, 150.0 and 143.8%, respectively for Awassi genotype, Washera genotype and Wollo highland breed flocks. Both annual twin births per flock and prolificacy rate were higher in Washera genotype flocks than Awassi genotype and Wollo highland breed flocks. In general, the overall annual prolificacy rate was 142.7% in the present study.

Ermias *et al.* (2014) reported, litter size mainly influenced by breed, level of nutrition, season and age extensively. The average litter size or prolificacy rate was obtained by Fsahatsion *et al.* (2013) in the traditional sheep breeding practice in the Gamogofa Zone of Southern Ethiopia was 1.3 (130%) lambs per head and slightly lower than the current finding. Whereas, Mukasa-Mugerwa *et al.* (2002) reported 1.13 (113%) for Menz and 1.14 (114%) for Horro Ethiopian highland sheep and much lower than the current finding. Similarly, Hundie (2015) reported, average litter size per ewes were 1.57±0.52 (157%) in Western Ethiopia Horro Guduru area and which inagreement with tWashera genotype flocks of the current finding. In addition, according to Zewdu (2008) twinning rate of 39.9 % or litter size of 1.40 (140%) and 36 % or litter size of 1.36 (136%) were obtained for Horro and Bonga sheep breeds, respectively and inagreement with the current finding of Wollo highland breed and Awassi genotype flocks, respectively.

In general, the annual prolificay rate of the present finding (Table 15) was greater than Menz and Horro sheep breed when compared with reported by Mukasa-Mugerwa *et al.* (2002), however, inagreement with reported by Hundie (2015) for Horro sheep breed. The management system is the major source of variation in litter size as reported by Mekuriaw *et al.* (2013). This is indeed in the case of Washera sheep significantly higher under farm management condition in comparison with on-station management situation of annual prolificacy rate. The overall prolificacy rate of local Wollo highland sheep and their crosses had considerable value for breed improvement activities. Prolificacy rate is an economical traits determine the annual cash income of smallholder sheep producers, keeping the other condition constant. Washera ram crossed with Wollo highland ewes indicated higher prolificacy rate and which attracted farmers' interest using selected superior performance indigenous breed for genetic improvement purpose instead of using exotic breeds.

5.3.6. Lambing interval

Lambing interval was the interval between two successive parturitions and it can be affected by the season of lambing or nutritional accessibility, breed types, number of parities of ewes and management practice (Amelmal, 2011). In the current study lambing interval was significantly shorter in Washera genotype ewes than Awassi genotype and Wollo highland breed ewes. However, lambing interval not significantly difference between Awassi genotype and Wollo highland breed ewes. Reproductive efficiency also affected by the length of parturition interval, i.e. ewes with long lambing interval had a lower lambing rate efficiency (Deribe, 2009). Girma (2008) reported at least three times lambing is expected per two consecutive years under normal circumstances which was accomplished in the current finding. Tesfaye (2008) reported, lambing interval was recorded 8.5 months in Menz sheep and 9 months for Afar sheep which are longer than the present report (Table 15).

Abegaz (2007) reported, short lambing interval of 6.64 months for Gumuz sheep breed, however, the present finding overall lambing interval slightly shorter than even Gumuz sheep breed, which produced three times lambing within two consecutive years under the traditional management condition. According to Zewdu (2008) finding, lambing interval was around 8.9 months for Bonga ewes and 7.8 months for Horro ewes and it also greater than the current finding of lambing interval. Hence, the current study overall mean lambing interval is the smallest one compared with rported by Abegaz (2007), Tesfaye (2008), Zewdu (2008) and Mekuriaw (2013) for Gumuz, Menz and Afar; Bonga and Arsi-bale; Menz and Washera local sheep, respectively.

Generally, Wollo highland sheep had shortest lambing interval than most other Ethiopian sheep breeds and greater possibility to collect the largest number of offspring/year/ewes with large flock size. If the traditional flock management practice improved, this breed might be contributed potential effect on reproductive genetic potential improvement practices and annual income advancement at smallholders' farming condition. Lambing interval is one of the producers' reproductive trait of interest in the smallholders' sheep production condition and used for breeding ewes' selection criteria.

5.3.7. Fertility rate

Fertility rate is defined as the number of females that given birth per total number of females exposed to mating in the given flocks. The current study revealed, the annual overall fertility rate of ewes per flock was 86%, however numerical variation between three strata observed and the reason behind this might be sire breed effect affecting reproductive performance of ewes. The best fertile ram breed type might be produce better conception rate of ewes per asingle mating and inturn large number of ewes will come to birth per annum per thos ewes exposed to mating. Consequently, Awassi genotype ewes had a higher annual fertility rate than Washera genotype ewes, and Wollo highland ewes. The present study overall fertility rate was higher than reported by Berhan and Arendonk (2006) for Menz and Horro sheep breeds of 70.2 and 79.5%, respectively. Derbie (2009) also reported, fertility rate of 54.04% for south western part of Ethiopian sheep breed and much lower than the current finding. On the other hand, fertility rate of the present finding slightly comparable with reported by Tsedeke (2007) 83.6% in Southern Ethiopia. However, Mukasa-Mugerwa and Lahlou-Kassi (1995) reported, higher fertility rates of 90% for Menz ewes which was greater than the current finding. On the other study Mukasa-Mugerwa *et al.* (2002) once again reported fertility rate were 73% and 65%, for Menz and Horro ewes, respectively and much lower than the present finding.

Various literatures indicated, within breed difference of fertility rate were observed and the reason might be variability of producers' management practices. Rosa *et al.* (2007)

also reported for Romney Marsh and Merino Branco ewes had 96 and 93% of the fertility rate, respectively at intensive management condition. While, Moural *et al.* (2014) had presented 86.8% and 98.3% of fertility rate in the dry and rainy season for Santa Inês ewes in eastern Amazon at intensive management situation. These implied, at intensive management situation, fertility rate was increased. According to Mukasa-Mugerwa *et al.* (2002), the effect of breed, season and year had significant variation on fertility rate.

Even though, the management system has its own effect on the sheep fertility rate, in the present study on-farm management practice fertility rate is comparatively higher, because of the genotypes were adopted to the environment and its genetic merits. Controlled or intensive management system of fertility rate evaluation might be important for the confirmation of the potential effect of these breeds. If the management system improved the fertility rate of this breed might be improved because of ovulation rate and estrus cycle influenced by nutrition. Generally, Wollo highland sheep breed and their crosses had imperative fertility rate with the existing production condition. Hence, if this breed commercially used for reproductive performance improvement purpose with improved management condition, there might be imperative genetic potential improvement practice of the country.

5.3.8. Lamb survival and mortality rate

The survival rate is the total number of offspring weaned per total number of offspring produced. Survival rate was observed increasing rate in all strata at the age of birth to 365 days or when the age of lambs increased more lambs were survived. In the present study the overall survival rate at the age between birth to weaning (90 days) was 87.6%, which is slightly lower than Menz and appreciably higher than Horro lambs (Awgichew *et al.*, 2000). This author reported that survival rate between birth and weaning (90 days) age was 89% and 76% for Menz and Horro breeds, respectively. Kahsa (2009) presented, Menz lambs shown higher survival rate from birth to 180, 270 and 365 days of 81, 71 and 62%, compared to Horro 51, 39 and 37%, respectively. However, its lower than the result of the present study at the age of birth to 90, 91to180, 181 to 270 days (Table 15). On the other hand, its slightly greater in Washera genotype and Wollo highland breed lambs than the Awassi genotype lambs from the age of 180 to 365 days. It might be due to adaptation differences between genotypes. Taye *et al.* (2011b) reported, 98.4, 93.6, 91.2, 90.0 and 89.9% of survival rate at the age of 30, 90, 180, 270 and 365 days, respectively and which is slightly comparable with the current finding (Table 15).

In agreement with the performance of Awassi F_1 crosses of the present study (Table 15), Tibbo (2006) reported, pre-weaning mortality rate of 33.1% for Horro and 19.2% of Menz sheep were recorded. However, compared with the overall mortality rate (31.6%) of the current finding, Berhan and Van-Arendonk (2006) found relatively lower overall mortality rate for Menz and Horro breeds of 13.5% and 27%, respectively at on-station management condition. The reason behind this might be the hybrid-vigour effect of parents in the current finding and the management differences. Gizaw and Tesfaye (2009) revealed, 11.4%, 10.1% and 9.4% of annual lamb mortality rate for local, Awassi and Coriedial ram F_1 crossbred lambs, respectively under village management condition and which is lower than the current mortality rate for Awassi and Washera ram crossbred progenies and local Wollo highland breed lambs. Mandal *et al.* (2007) was also reported, an average pre and post-weaning mortality rate of 6.6% and 6.0%, respectively, and overall lamb mortality from birth to 365 days were 12.6% at on-station management condition. However, in the current study the trend of lamb mortality was decreasing order from birth to yearling age and inagreement with the findings of Mandal *et al.* (2007), but higher mortality was observed, due to poor flock management situation. Therefore, it's the major challenges for smallholder sheep producers and extensively affect number of lambs that might be present for market sale.

Sulieman *et al.* (1990) elucidated, the survival rate of lambs birth to weaning was affected by the age of the ewes, type of birth (single, twin or triplet born), season of birth (wet or dry season) and birth weight of the lambs. This could be mainly due to lower body weight of twins birth lambs, compared to single birth lambs and seasonal feed availability. Gemeda *et al.* (2005) yet again presented, survival rate for Horro breed was significantly affected by birth weight of lambs. The lightest lambs generally had the highest mortality rate. Moreover, Niftalem (1990) revealed, lambs born from heavier dams had significantly higher survival rate at all levels of age, than those of lighter ewes. However, Tibbo (2006) noted, there is sufficient within and between breed genetic variation of survival rate, which can be exploited through selective breeding for permanent improvement of the breeds.

In the current study there are a slight survival rate difference between local and their crossbred progenies or between genotypes (Table 15). Hence, Awassi F_1 crosses had some extent lower survival rate than Wollo highland breed lambs and slightly higher than Washera F_1 crosses, however, this genotype being presentation of acceptable adoptive attributes of producers' interst. Hence, crossbreeding practices of local sheep breed with indigenous Washera sheep breed being adopted by smallholder sheep producers that needs to be enhanced and continued. The current research output indicated, the genetic improvement practice should have to revised according to smallholder sheep producers' traits of interest and potential effect of different genotypes and production environments. Therefore, local sheep breeds genetic improvement practices through crossbreeding with selected exotic and superior indigenous breed are crucial to continued for coming genetic improvement program.

5.4. On-Farm Lamb Growth Performance Evaluation

5.4.1. Yearling lamb growth rate performance

The present study reported, annual lamb growth performance trend characterized by a simple linear types of body weight change and age association. From the age of 3 to 6 months body weight gain slightly increased and from 6 to 9 months indicated increasing rate. Similarly from 9 to 12 months body weight gain showed moderately increasing growth performance.

On-farm yearling growth performances of Awassi and Washera F_1 crossbred progenies and local Wollo highland breed lambs graphically presented in Figure 12. The body weight of Awassi F_1 crossbred progenies have comparable average daily weight gain with

Washera F_1 crosses from birth to 30 days of age than local Wollo highland breed lambs. The reason behind this might be the effect of genetic potential of the breed as stated by Hassen (2004), Tibbo (2006); Taye (2009) and the hybrid-vigour effect of their parents. In agreement with the present study, Gizaw and Tesfaye (2009), Gizaw *et al.* (2014) reported, 25 to 50% Awassi blood level crossbred lambs had higher body weight gain than pure local Wollo highland lambs at birth to yearling age. Likewise, from the age of 30 to 120 days, Washera F_1 crossbred lambs had faster growth rate than both Awassi F_1 crossbred and local Wollo highland breed lambs and in agreement with pure Washera breed lambs growth (Taye, 2009). The present study reported, Washera F_1 crossbred lambs had faster growth rate at pre-weaning age compared with Menz and Horro sheep breeds (Awgichew, 2000); Hassen *et al.* (2002) and Tibbo *et al.* (2004). Nevertheless, from the age of 120 to 365 days Awassi F_1 crossbred lambs higher growth rate than Washera F_1 crossbreds and local Wollo highland lambs. This might be profound effects of genotype (Awgichew, 2000; Taye, 2009) of lambs. In agreement with the current finding, Mekuriaw *et al.*(2013) demonstrated, the F_1 crossbred of indigenous Washera breed crossed with indigenous Farta breed had higher average body weight gain than pure Farta breed (Figure 10).

The growth rate of local Wollo highland lambs slower than both Awassi and Washera F_1 crossbred lambs at all age groups of the present finding and the growth rate variation increasing from weaning to yearling age. The reason behind this might be when the age increases, adaptation of crossbreds adding value for body weight gain could be enhanced and the hybrid-vigour of genetic potential difference of the crossbred lambs. However, the growth rate between Awassi and Washera F_1 crossbred lambs more closely related each other from birth to 30 and 240 to 365 days of age (Figure 13). Therefore, the crossbred progenies of Awassi and Washera rams with Wollo highland breed ewes had better growth performance than local Wollo highland breed lambs at smallholders' sheep production management system. The current study confirmed, smallholder farmers' genetic improvement practices using indigenous Washera rams with local Wollo highland breed ewes have tangible reality of growth and reproductive performance improvement objectives. Because, of the growth rate of F_1 crossbred progenies of Wollo highland ewes with Awassi and Washera rams significantly higher than pure Wollo highland breed lambs. As the result, the genetic potential improvement practice has to be encouraged by governmental and non governmental institutions at smallholder farming condition.

5.4.2. Effect of genotype, sex, birth type and parity on lamb body weight gain

The birth weight of Awassi and Wahera F_1 crossbred progenies and Wollo highland breed lambs has significantly different ($p<0.001$) each other. The reason behind this might be the effect of genetic potential of the different genotypes of their parents. Consequently, Awassi F_1 crossbreds have higher birth weight than both Washera F_1 crossbreds and Wollo highland breed lambs (Table 16). The birth weight of Awassi crossbred lambs at on-farm management condition was comparable with at on-station management condition of Horro and Menz breeds reported by Niftalem (1990), Awgichew (2000) and Tibbo (2006), respectively. Washera F_1 crossbreds lambs' average birth weight comparable with Menz breed lambs' average birth weight at on-station management condition (Awgichew, 2000; Gizaw, 2002b; Tibbo, 2006).

The effect of birth type on birth weight was significantly ($p<0.05$) higher with single births than twin lambs' birth and which is inagreement with Menz, Horro, Washera and Jordan breed lambs reported by Hassen (2004), Taye (2009) and Momani *et al.*(2010), respectively. Because, twin lambs pregnant dams might have not sufficient nourishment for their lambs both at pre-natal and post-natal stage of lamb growth than single lamb pregnant dams. For both single and twin birth type Awassi crosses had significantly ($p<0.05$) higher average birth weight than Washera F_1 crossbreds and Wollo highland breed lambs. Ttherefore, birth type had significant effect on birth weight performance of lambs at on farmers' management condition (Table 16).

Parity and sex type didn't have significant variation in lamb body weight gain from birth to yearling age between Washera crosses and Wollo highland breed lambs (Table 16). Both Washera F_1 crosses and Wollo highland breed lambs average body weight had concurred with pure Washera, Simien; and Dorper and Wollo tikure crossbred lambs reported by Taye *et al.* (2009), Surafel *et al.* (2012) and Lakew *et al.* (2014), respectively.

In the current finding, the overall average body weight at 3 months of age (weaning), comparable with reported by Awigichew (2000) and Hassen (2004); Yibrah (2008), Taye *et al.* (2009) and Surafel *et al.* (2012) at on-farm management condition of Menz breed lambs, on-station management condition of Afar and Black head Somali breed lambs, on-farm management situation of Washera breed lambs, and on-farm management condition of Simien breed lambs, respectively. However, between the three genotypes of the present finding, average body Weight at 3 months (weaning) had significant ($p<0.001$) difference. Since, F_1 crossbred lambs have significantly ($p<0.05$) higher body weight gain than local Wollo highland breed lambs at weaning and birth to yearling age. Therefore, the F_1 crossbred progenies of both Awassi and Washera rams with Wollo highland breed ewes superior growth performance than pure Wollo highland breed lambs. This because, of the cumulative effect of parents induced to their crossbred progenies as hybrid-vigour trait makes better growth rate of crossbred progenies compared with localWollo highland breed lambs.

At 6 months of age, the overall average body weight of Wollo highland and their crosses was 18.8±0.3kg. Hence, this finding comparatively concur with reported by Surafel *et al.* (2012), Taye *et al.* (2009), Yibrah (2008) and Gizaw (2002) finding for selected superior indigenous breeds of Simien (on-farm), Washera (on-farm), Afar (on-station), Black Head Somali (on-station) and Horro breed (on-station), respectively. Awassi F_1 crosses had significantly ($p<0.001$) higher average body weight at 6 months compared with Washera crosses and local Wollo highland lambs. The current comparative evaluation indicated, Awassi F_1 crossbred lambs had higher average body weight gain than other pure indigenous breed and their crossbred lambs at 6 months of age which reported by Lakew *et al.* (2014), Belay and Haile (2009), Taye *et al.* (2009) and Surafel *et al.* (2012). The reason behind this might be due to the genotype of hybrid-vigour effect. Whereas, Washera F_1 crosses average body weight at 6 months were significantly ($p<0.05$) greater than local Wollo highland lambs and comparable with Seka and Dedo (on-farm), Wollo

Tikur (on-station) Afar (on-station) and Barbados (on-station) breeds and which reported by Belay and Haile (2009); Lakew *et al.* (2014), Yibrah (2008) and Gizaw *et al.* (2006), respectively. Even though, local Wollo highland breed lambs had comparatively lower average body weight gain than their crosses, this local breed had relatively compatible average body weight with Menz lambs (Niftalem, 1990) and Wollo Tikur breeds (Lakew *et al.*, 2014) and potential effect on genetic improvement practice through crossbreeding with other selected exotic and superior indigenous breeds.

At 9 months of age, overall average body weight of Wollo highland and their F_1 crosses comparable with pure Washera breed at on-farm management condition (Taye, 2009) and Wollo Tikur and Dorper crosses at on-station management situation (Lakew, 2014) and Seka and Dedo breed lambs (Belay and Haile, 2009) at on-farm management situation. The average body weight gain of Awassi and Washera F_1 crossbred lambs significantly higher than local Wollo highland lambs at 9 months of age and this might be due to the potential effects of their genotype and management difference of crossbred sheep owners and local breed owners. The current report of Awassi and Washera F_1 crossbred lambs average body weight gain comparable with Dorper F_1 crossbred lambs (Lakew *et al.*, 2014) at on-station management condition and Dedo breed lambs (Belay and Haile, 2009) at on-farm management condition. Average body weight of Wollo highland breed lambs at 9 months of age comparable with Menz breed lambs at on-farm (Niftalem, 1990) and Wollo Tikur breed lambs (Lakew *et al.*, 2014) at on-station management situation.

Similarly, at 12 months of age average body weight of Awassi and Washera F_1 crossbred lambs not significant difference (Table 16). However, crossbred lambs had significantly ($p<0.001$) higher average body weight than Wollo highland breed lambs. The average body weight gain of Awassi F_1 crossbreds at on-farm management condition comparable with Dorper and local Wollo Tikur crossbred lambs (Lakew *et al.*, 2014) and Horro breed at on-station management condition (Yohannes *et al.*, 2013). Whereas, Washera F_1 crossbreds had corresponding average body weight with Seka and Dedo breed lambs (Belay and Haile, 2009) but, higher average body weight gain than local Wollo highland breed lambs. In agreement with the present study, Gizaw and Tesfaye (2009) reported, indigenous Washera and Farta F_1 crossbred lambs had higher growth performance than pure Farta breed lambs. The overall average body weight at 12 months of age in the present study concurred with reported by Belay and Haile (2009) for Seka and Dedo sheep breeds at on-farm management situation. Similarly, it was comparable with Wollo Tikur and their crosses of Dorper breed at on-station management (Lakew *et al*., 2014) situation. However, it was greater than pure Washera breed lambs at on-farm management condition (Taye *et al*., 2009), Black head Somali breed (Yibrah, 2008), Horro breed (Gizaw, 2002) and Menz breed lambs (Mukasa-Mugerwa *et al*., 1994) at on-station management condition. Nevertheless, the current finding of the overall average body weight gain was lower than Horro breed lambs at on-station management condition (Yohannes *et al*., 2013).

In general, growth performance of Awassi F_1 crossbred lambs were better than Washera F_1 crossbred lambs at birth and 6 months of age. However, at 3, 9 and 12 months of age the growth performance of both Awassi and Washera F_1 crossbred lambs comparable each other. In other ways, local Wollo highland breed lambs have slower growth rate from 3-9 months age, but, appreciably increasing growth performance observed at 9-12 months. Both Awassi and Washera F_1 crossbred lambs' growth rate indicated, promising weight gain performance for future genetic improvement practices at smallholder farming condition. In addition to this, the accessibility of parent stock and adaptability issue with the local environment, indigenous Washera breed gives more acceptance for smallholder farmers' genetic improvement practice through crossbreeding.

5.4.3. Effects of genotypes and sex on pre and post weaning daily weight gain

Weaning weight is a trait of great economic importance in meat sheep production since it has influence on growth and survival rate of lambs (Taye *et al*., 2009). Thus, weaning weight and post-weaning growth rate of lambs is as important as the pre-weaning growth performances, mainly when the objective is producing meat through lamb production.

The average daily gain of Washera and Wollo highland F_1 crossbred lamb's were greater than Arsi-bale and Adilo breeds (Getahun, 2008) and Seka and Dedo indigenous breed lambs (Belay and Haile, 2009) at pre-weaning age. However, Taye *et al.* (2009) and Hassen *et al.* (2004) reported, equivalent average daily gain with Awassi and Wollo highland F_1 crossbred lambs at pre-weaning growth rate. While, on-station management condition, Dorper and local Wollo Tikur F_1 crossbred lambs' pre-weaning average daily gain greater than both Washera and Awassi F_1 crossbred lambs of the present finding at on-farm management condition (Lakew *et al.*, 2014). The reason behind this, might be due to managemente variation (on-station and on-farm management) of the production condition.

Washera F_1 crossbred lambs at pre-weaning average daily gain significantly ($p<0.001$) greater than local Wollo highland lambs and slightly greater than Awassi F_1 crossbred lambs (Figure 4). Likewise, male and female pre-weaning average daily weight gain of Washera F_1 crossbred progenies were greater than others in the current study. Therefore, this F_1 crossbred lambs at pre-weaning growth rate faster than Awassi F_1 crossbred and local Wollo highland breed lambs. Not only for this breed, but faster than pure Washera breed (Taye, 2009) and this indicated, hybrid-vigour might be the main reason. Similarly, Awassi F_1 crossbred lambs pre-weaning growth rate significantly greater than local Wollo highland breed lambs. In general, pre-weaning age growth rate (average daily weight gain) of Awassi and Washera F_1 crossbred progenies were significantly higher than Wollo highland breede lambs. Therefore, genetic potential improvement of Wollo highland lambs had an implication of posetive result with growth rate trait of the F_1 crossbreed progenies greater than pure local breed.

Annual post-weaning female Awassi F_1 crossbred lambs average daily weight gain had to some extent greater than the male one. However, in the case of Washera F_1 crossbred lambs the female annual post-weaning average daily gain were significantly greater than male (Appendex 1; Table 1). The reason behind this might be female reproductive organ at this age group ready to conceive fetus and faster to develop due to reproductive hormon effect than the male one. However, the male might be loss weight due to sexually maturity at this age and frequent mating at on-farm management situation. The male Wollo highland lambs annual post-weaning average daily weight gain greater than the females. The reason behind this might be, female physologically didn't well developed their reproductive organ at this age compared with Awassi and Washera F_1 crossbred ewe lambs due to slow growth rate. Weldeyesus *et al.* (2017) reported, Dorper with local highland crossbred lambs average daily weight gain significantly higher than local highland lambs at post-weaning growth period. Generally at post-weaning period average daily weight gain higher in Awassi F_1 crossbred lambs than others in the current study. The profound factors might be genetic potential of the breed affected post-weaning growth rate and keeping the other factors constant. Inagreement with the current finding of crossbred lambs average daily gain, comparable with Dorper and local crosses (Lakew *et al.,* 2014) at on-station management, pure local Washera (Taye, 2009) lambs at on-farm and Bonga (Belay and Haile, 2009) at on- farm, management condition.

The local Wollo highland breed lambs post-weaning average daily gain was by far less than their crosses. Henec, in the current study crossbreds had better growth performance than Wollo highland breed lambs. The genetic improvement practices of smallholder farmers' hypothetical knowledge had its own reality of genetic potential improvement practice of the local breed growth rate improvement and need to be supported with developmental research and the same time need to consider genetic resource conservation practices of the local breed. For the adevancement of genetic potential improvement practice, breeding plan designing is the cretical point.

5.4.4. Linear body measurement trait correlation

Linear body measurements traits considered as a quantative growth indicator which reflect the conformational changes occurring during the life span of animals. In the current study growth performances indicator body measurement traits were presented as body weight, body length, chest girth, back width, chest width, height at withers and rump height, hip width and hip length (Table 17). Hence, the age of lambs' has positive significantly ($p<0.05$) correlated with chest girth, height at withers and rump height.

Therefore, body weight have positive and strong correlation with rump height, chest girth and height at withers in the order of their importance. Inagreement with the current study, Tibbo (2004), Tesfaye (2008), Taye (2010 and 2011) and Younas *et al.* (2013) revealed, positive and strong correlations between body weight and chest girth traits. In the present study,the age of lambs significantly ($p<0.05$) correlated with chest girth, height at withers and rump height were the three strong positively correlated traits. The body weight gain had strong and posetively correlated with rump height, chest girth, height at withers, body length, back width, hip length and testicular size with decreasing order of impotance. Similarly, body length had strong and posetively correlated with back width, rump height, height at wither, chest girth and testicular size in the decreasing order of their importance. While, chest girth was the most strong correlated trait with height at withers, rump height, back width, and moderately correlated with testicular size, chest width and hip length body measurement traits.

Taye (2011b) reported, those traits with the highest correlation coefficient were, chest girth and wither height of lambs. However, traits with the highest correlation coefficient presented, chest girth with rump height, age, height at wither and body length comparable with reported by Taye (2011b) and Tesfaye (2008) for Washera and Menz breed lambs, respectively. Hence, the current finding rump height, chest girth and height at withers were the three body measurement traits which strong and positively determined the body weight gain. However, body length, back width and hip length had moderately correlated with lamb body weight gain performance at smallholder sheep production condition. But, testicular size inadequately correlated with lambs body weight performance. Generally, the body weight gain performance of lambs indicated by the conformational performance of linear body measurment traits. The strong and positive correlated traits have good prediction for growth performance of lambs and important for selection intensity.

5.4.5. Variablity of linear body measurement traits

In the current study, the linear body measurement traits were taken as body weight, body length, heart girth, back width, chest width, height at withers, rump height, hip width, hip length and testicular size presented in Table 18.

Awassi F_1 crossbreds had higher linear body measurement traits except chest width (Table 18). Therefore, the highest variablity of linear body measurement trait for Awassi F_1 crossbreds was chest width and the lowest variablity trait was body length. This means, chest width had strong within Awassi crossbred lambs variation and body length is the lowest variation. In the case of Washera F_1 crossbred lambs the largest standard devation was hip length and lowest one was heart girth. Likewise, Wollo highland breed lambs had the highest standard devation of testicular size and the lowest was height at wither trait. Therefore, the largest standard devation of linear body measurment traits has paramount importance for within breed selection intensity. Parés-Casanova *et al*. (2013) reported, 23.7 % CV of body length recorded for Zambian indigenous Fat-tailed sheep. According to Fourie *et al*. (2002) report, the higher coefficient of variations were 13.1% and 13.7% recorded for young Dorper rams' skin thickness in the Northern Cape and South Africa, respectively. The greater variability of linear body measurement traits is better growth performance indicator and that implied, diversification of both within and between breeds is important to increase the intensity of selection for genetic improvement practices. Therefore, chest width for Awassi F_1 crossbred lambs, hip length for Washera F_1 crossbred lambs and testicular size for Wollo highland breed lambs had the largest within breed variablity of linear body measurement traits and these might be used as better growth performance indicator traits within the breed and with their compatable posetively correlated traits.

5.5. Genotype and Supplemented Effects on Body Weight Gain and Carcass Traits

The availability and supply of animal feed in the tropics is not constant in terms of both quantity and quality particularly in arid and semiarid regions seasonal fluctuation in the growth rate of animal in these regions (Gatenby, 1986; Awgichew *et al.*, 2000). This is particularly true in the study area, where the main source of animal feed is grazing on natural pasture. For this reason, to use whatever available resource more economically, it will be advantageous to identify those breeds of animals which are more efficient meat producers (Terrill and Maijala, 1991) or animals which have high performance in feed conversion efficiency to produce saleable products (Parker *et al.*, 1991).

5.5.1. Effects of genotype and supplementation on body weight gain performance

Genotypes and supplementation feed effects on ram lambs' body weight gain presented in Table 19. Initially the body weight gain of the three genotypes significantly different ($p<0.05$) each other and the differences were come from breed effects but not significant differences within group in each treatment. To avoid the effects of initial body weight on the successive body weight gain, covarate analysis was used and the adjusted initial body weight at 26.56 kg of all genotypes. In the present study, significantly higher average daily weight gain observed on the supplemented group implied, there was adequately fed and satisfied their maintenance and growth nutrient requirements compared with non supplemented groups (grazing only).

The average daily weight gain (ADG), the rate of body weight change and final body weights of supplemented group of Awassi, and Washera F_1 crossbred and Wollo highland breed ram lambs were significantly higher ($p<0.05$) than non-supplemented groups. As a result, Awassi F_1 crossbred lambs' growth rate had significantly greater ($p<0.05$) than both Wollo highland and Washera F_1 crossbred ram lambs throughout the experimental period and followed by supplementing Wollo highland breed ram lambs (Table 18). The reason behind this might be the genetic potential difference of the three genotypes affecting average daily weight gain efficiency with different extent. Therefore, genotype is the limiting factors affecting average daily weight gain of lambs and inagreement with reported by Hammel and Laforest (1999) for Polled Dorset, Hampshire and Romanov breeds. Inagreement with the present finding of lamb growth rate particularly during early stages of growth is strongly influenced by breed (genotype) reported by Notter and Copenhaver (1980); Gatenby (1986); Burfening and Kress (1993) and Bathaei and Leroy (1996).

Concurred with the current result, Guesh and Mengistu, (2014) reported, urea-molasses block and urea-atela blocks feed supplemented on natural pasture hay had significant effect on body weight gain of male Ogaden blackhead sheep. Berg and Walters (1983) reported, fast growing breeds are more efficient in converting feed energy to lean tissue than those which are slow growing fatter breeds. The present finding reported, Awassi F_1 crossbred ram lambs has faster average daily weight gain than Wollo highland breed and Washera F_1 crossbred lambs. Even though, Washera F_1 crossbreds had significantly higher initial body weight gain than Wollo highland breed, the final body weight gain of supplemented Wollo highland breed ram lambs significantly greater ($p<0.001$) than supplemented Washera F_1 crossbreds.

The total amount of body weight change and the rate of daily weight gain indicated, local Wollo highland breed lambs were significantly greater than both supplemented and non-supplemented groups of Washera F_1 crossbred lambs. This indicated, improved grazing management condition and supplementation diet of Wollo highland breed lambs can have comparable body weight gain potential with their Washera F_1 crossbreds with the same management condition.

Conversely, the non-supplemented Wollo highland breed ram lambs final body weight was comparable with Tigray highland breed lambs (Zemichael, 2009) and Menz breed at on-farm grazing management condition (Awgichew *et al.*, 2000). The supplemented groups of Wollo highland and Washera crossbred lambs comparable final body weight gain with reported by Awgichew *et al.* (2000) for Horro breed lambs. Therefore, Wollo highland ram lambs had the ability to increase their body weight as far as their nutritional requirement maintained.

In the current study, the average daily weight gain was significantly ($P<0.001$) higher in the supplemented Awassi crossbred and Wollo highland breed ram lambs compared with their non supplemented groups. The reason behind is, the effects of supplemented concentrate diet have efficient nutrient composition for lamb growth and body weight gain requirement. However, between supplemented and non-supplemented groups of Washera crossbred ram lambs not significant difference of average daily weight gain, but slightly numerical difference observed with supplemented one. The reason behind this might be the maximum feed conversion efficiency of the breed to use the concentrate feed efficiently and the effect of natural pasture quality might be satisfied their growth and maintainance requirements of non supplemented group of Washera genotype.

Both supplemented and non-supplemented groups of Awassi crossbred lambs average daily weight gain significantly ($P<0.001$) greater than Washera crossbreds and Wollo highland breed lambs. The current finding is in agreement with Fitwi and Gebrehiwot (2013), Zemichael (2009) for Tigray highland sheep breed, Awgichew *et al*. (2000) for Menz and Horro breed. Hence, the supplemented groups were significantly higher than non-supplemented groups for improving the daily weight gain. On the other hand, the effect of genotypes on average daily weight gain has significant ($P<0.001$) difference and higher with Awassi crossbred lambs. The supplemented Wollo highland breed lambs' average daily weight gain higher than supplemented and non supplemented Washera F_1 crossbred lambs' through compensatory growth rate. This indicated, if the nutritional requirement limitation avoided, this local Wollo highland breed could give a comparable weight gain with Washera F_1 crossbred lambs and other selected indigenous breed types of the country. However, it was significantly less than Awassi F_1 crossbred lambs. Therefore, the effects of genotype and supplementation diet are profound factors to enhance body weight gain through growth performance improvement. Consequently, both on-farm and on-station management condition Awassi genotype has superior growth performance than Wollo highland and Washera F_1 crossbred lambs.

In the current finding, the average daily weight gain of Awassi F_1 crossbred ram lambs greater than Dorper and local Tigray highland crosses (Weldeyesus, 2017) and Dorper and Wollo Tikur crosses (Lakew *et al.*, 2014). Whereas, local supplemented Wollo highland breed lamb average daily weight gain had relatively comparable with Tigray highland local breed (Fitwi, 2013) and Hararghe highland breed ram lambs (Gebeyew *et al.*, 2015; Salo, 2016). On the other hand, this breed had a higher average daily gain than local Wollo Tikur breed (Lakew *et al.*, 2014; Abebe and Tamir, 2016), Adilo breed (Assefa *et al.*, 2015), Arsi-Bale breed (Geleta *et al.*, 2013) and Horro and Menz breed (Awgichew *et al.*, 2000) ram lambs.

Both supplemented and non-supplemented Washera F_1 crossbred ram lambs average daily body gain significantly lower than Awassi crossbreds and Wollo highland breed lambs. However, the average daily weight gain comparable with Dorper and Wollo Tikur crosses reported by Lakew *et al.* (2014), Hararghe highland reported by Gebeyew *et al.* (2015) and Tigray highland breed lambs which reported by Fitwi and Gebrehiwot (2013). On the other hand, this genotype was greater than Black Head Somali breed (Fesaha, 2014), Menz and Horro breed (Awgichew, 2000), local Wollo Tikur breed (Abebe and Berhan, 2016; Lakew *et al.* (2014), Arsi-Bale breed (Geleta *et al.*, 2013) and Tigray breed lambs (Weldegebriel and Kefelegn, 2014).

Awassi F_1 crossbred ram lambs body weight change was significantly higher ($p<0.001$) than Wollo highland and Washera crossbred ram lambs. Whereas, local Wollo highland lambs significantly greater than Washera F_1 crossbreds both supplemented and non-supplemented groups. Nevertheless, of that Washera crossbred ram lambs had lower rates of total body weight change than the other genotypes in the present study. This might be the potentials of feed conversion and consumption efficiency of the breed and this thoroughly revealed by Bathaei and Leroy (1996), Burfening and Kress (1993), Gatenby (1986), Notter and Copenhaver (1980). The rate of body weight change in the local Wollo highland breed was observed dramatically change in supplemented group and which verified as compensatory growth rate mode of the breed (Table 18). It's strongly greater than reported by Assefa and Urge (2015) for Adilo breed type and Abebe and

Tamir (2016) for Wollo Tikur breed type average total body weight change through the experimental period.

In general the Awassi F1 crossbred ram lambs has a promising growth performance with supplementation of local available concentrate feed. Hence, with controlled management condition of natural pasture grazing has contributed to better growth performance of ram lambs body weight gain. Furthermore, Washera F_1 crossbreed lambs has an imperative body weight change and can be another alternative to enhance genetic potential of pure local Wollo highland breed and inaddition to this inbreeding coefficient risk can reduced. Moreover, cost effective concentrate feed supplementation on natural pasture grazing need appropriate attention by fatteners, and other sheep producers. Together with this private controlled grazing management system had also played a great role to improve the body weight gain of ram lambs through quality pasture production.

5.5.2. Genotype and supplementation effects on carcass yield characteristics

Carcass composition used as a tool to characterize breeds for possible identification of potential genetic resource for lean lamb production and also to identify management alternatives to suit different breeds (Snowder *et al*., 1994). Therefore, breed is known to influence not only carcass composition and quality, but also carcass conformation as well, differences in carcass merits between breeds is likely to govern the choice and development of breeds for specific production objectives.

Slaughter and empty body weight between supplemented and non-supplemented groups variation not significant for all genotypes. The reason behind this might be less significant variation between supplemented and non-supplemented body weight before slaughter and relatively comparable amount of fasting loss. Nevertheless, significant variations between the three genotypes recorded, and which in agreement with Walstra and de Greef (1995) and Orr (1982). Subsequent to 24 hours of fasting period, the body weight losses had a comparable amount for all genotypes and not significant variation observed. The loss of rumen contents through defecation and urination effects of fasting period not significantly different among genotypes (Table 20).

The hot carcass weight has comparable between supplemented and non-supplemented groups. However, between genotypes a significant variation ($p<0.001$) reported and which in agreement with Walstra and Greef (1995) and Orr (1982). Therefore, Awassi F_1 crossbred ram lambs significantly higher ($p<0.001$) hot carcass weight than Wollo highland and Washera F_1 crosses (Table 19). This is because of higher slaughtered body weight and higher average daily weight gain (ADG) effect and their comparable fasting loss. Assefu (2012) reported, there was no breed effect in hot carcass weight between Horro and Washera breeds and which disagree with present study. Nevertheless, Snowder *et al.* (1994), Taylor *et al.* (1989), Walstra and de Greef (1995), and Orr (1982) reported, due to strong breed influence on body composition, there could be better opportunities to select among breeds for hot carcass yield differences. Generally the present study and the reports of Snowder *et al.* (1994), Taylor *et al.* (1989), Walstra and de Greef (1995) and Orr (1982) confirmed breed differences of carcass merits influence the choice and development of breeds for specific production objectives. It could be realized through strategic identification and utilization of existing breeds. Therefore, hot carcass weight trait is one of the productive performance indicator parameter and used to explain production amount of saleable product of meat animals. Consequently, selection of best breed based on their hot carcass weight extent can be utilised productivity improvement practice in the course of genetic potential improvement practices of the local breed.

Among supplemented and non-supplemented group of Wollo highland breed lambs and non-supplemented group of Washera crosses had not significant difference in hot carcass weight extent. However, the supplemented group of Washera crosses had significantly higher than their non-supplemented group and Wollo highland breed ram lambs. Hence, Washera genotype might have better carcass development and growth traits efficiency. On the other hand, hot carcass weight between supplemented and non-supplemented group of Awassi crosses and Wollo highland breed type not significant difference. This might be the quality, accessibility and better grazing management system satisfied the maintenance and carcass development requirement of non-supplemented groups. In addition to this, non-supplemented groups might be efficiently utilized the available forage resource, because, the whole night and resting time no supplementation and that makes more hunger and effective to graze during grazing time (Table 20).

Cold carcass weight used as commercial carcass yield indicator trait used for productive performance tools to evaluate the productivity of a given meat animals. Awassi crossbred lambs' cold carcass weight significantly ($p<0.05$) greater than both Washera crosses and Wollo highland breed lambs. Within each genotype, cold carcass weight did not have significant difference because of the higher amount of chilling loss rate of supplemented groups (Table 20). This indicated, the supplemented feed does not bring significant impact on cold carcass weight, and in agreement with reported by Awgichew *et al.* (2000) for Menz and Horro breed lambs and Jorge *et al.* (2013) for Chilote and Suffolk breeds in Chile Island. The chilling loss of cold carcass weight may vary between 1 and 7%, usually found close to 2.5% (Rozanski *et al.*, 2017). Moreover, sex, weight, fat covering of the carcass, temperature, and humidity in the cold storage chamber and the handling of the carcasses (Moreno *et al.*, 2008) influence cold carcass characteristic. Despite the fact, significant differences recorded between the three genotypes cold carcass weight and the highest has recorded in Awassi crossbred lambs and followed by supplemented Washera crossbred lambs significantly higher than Wollo highland breed lambs.

Dressing percentage is described as the proportion of carcass weight to slaughtered body weight and it helps to assess meat productivity of the animals. Nutrition influences dressing percentage through variation in weight of mesentery contents and variation in actual organ weights (Warinington and Kirton, 1990; Payne, 1999). In agreement with the present finding, Awgichew *et al.* (2000) reported, regardless of the clear tendency of Horro lambs having a heavier hot and cold carcass weight, but did not differ significantly from Menz breed in dressing % and the loss of carcass moisture (shrinking %) after an overnight cooling. The present finding reported, hot carcass weight dressing percentage (HCCWDP) does not have significant difference both between and within genotype and which in agreement with Awgichew *et al.* (2000) and Jorge *et al.* (2013). Concurring with this report, an experimental trial conducted by Mazemder *et al.* (1998) on grazing local sheep without supplementation and with supplementation of 100, 200 and 300 grams of concentrate feed/day, dressing percentage was similar among the treatments.

In concurrence with the current finding, Abebe and Tamir (2016), Salo *et al.* (2016), Michael and Yaynshet (2014) and Gebeyaw *et al.* (2015) reported, different feed supplementation didn't show significant differences of hot carcass weight dressing percentage. The plausible reason for this might be corresponding increase in relatively higher slaughter weight and large extent of non-carcass components, which reduced both hot and cold carcass weight. Therefore, this might be indicators of those meat producing lambs need select appropriate genotype and appropratly formulated diet for carcass and tissue development despite random supplementation of concentrate feed and which endorse non carcass organ development than a carcass.

In the present study, cold carcass weight dressing percentage has significant difference between supplemented and non-supplemented groups of each three genotypes. The cold carcass dressing percentage values reported in this study was slightly comparable with reported by Simachew (2009) for Washera sheep of dressing percentage with 46-52% on the empty body weight basis (Table 20). Inagreement with the current finding, Abebe has (2008) reported for Washera sheep dressing percentage of 42.4-46.8% of slaughter body weight bases and lower than 49.8-54.2% on the empty body weight basis. The higher, though not significantly different dressing % for Menz lambs (49.1±0.57%) compared to Horro (48.0±0.64%), could indicated Menz lambs have advanced relatively nearer to slaughter maturity than the Horro (Awgichew *et al.*, 2000). This informed that, the only body weight differences are not adequate to estimate the productive performance of meat animal selections.

Rib-eye muscle area is mostly used as a tool to indicate the proportion of carcass muscling (Wolf *et al.*, 1980). In the present study the supplementation diet didn't have a significant impact on rib-eye muscle area but numerical difference was observed. In line with the current finding, Simret and Gizaw (2008) reported, supplementation didn't have significant effect on rib-eye muscle area in Somali goats fed hay and supplemented with different levels of peanut cake and wheat bran mixture. However, unlike this finding, Matiwas *et al*. (2008) and Wondesn (2008) reported, supplementation diet had a significant and positive effect on rib-eye muscle area. In concurrence with this finding, Matiwas *et al*. (2008), Wondesen (2008); Simret and Gizaw (2008) reported, rib-eye-area had a significant variation between breeds. However, did not significant variation between supplemented and non-supplemented groups of Awassi crosses and Wollo highland breed lambs (Table 20). Nevertheless, supplemented and non-supplemented groups of Washera crossbreds had significant differences of rib-eye-area composition. This fact is an indicator of better muscle development of supplementing Washera crosses than non-supplemented one. Hence, this rib-eye-area muscle development is one of the merits to select Washera F_1 crossbred lambs for meat production objective. Both supplemented and non-supplemented Wollo highland and non-supplemented Washera crossbred lambs have relatively comparable rib-eye-area muscle development (Table 20).

Except dressing percentage, almost all carcass characteristic extent both supplemented and non-supplemented Awassi crossbred had significantly higher than Wollo highland and Washera F_1 crossbred lambs. Hence, crossbreeding effect on genetic improvement practices using Awassi exotic breed had significant response associated with growth and carcass yield characteristic traits. As a result Awassi F_1 crossbred lambs had potential effect on meat production improvement objective and advisable to be selected for further breed productivity improvement program.

In concurrence with present study of Washera F_1 crossbred lambs, Roberto *et al*. (2010) has reported, supplemented diet had significant effect ($P<0.05$) on subcutaneous fat thickness. Washera F_1 crossbred supplemented group had significantly ($P<0.05$) higher subcutaneous fat than non-supplemented one and comparable with Awassi crossbred lambs. However, unlike Roberto *et al*. (2010), the current finding, genotype effects had significant ($P<0.001$) differences between Awassi crossbred and Wollo highland breed lambs subcutaneous fat thickness. Because, the effect of slaughtered body weight, might be certainly influenced the fat extent of the breed (Macedo *et al*., 2000). The same author also revealed, supplemented diet with high energy density presented higher subcutaneous fat thickness, which not influenced by the genotype. The same author reported, the scrotal fat didn't show significant differences when different levels of urea treated feed was used in lamb ration. Fat is the largest carcass component variation when age increasing at slaughter weight (Macedo *et al*., 2000).

The total non-carcass weight (TNCW) of Awassi and Washera F_1 crossbred lambs and supplemented Wollo highland breed lambs significantly greater than non-supplemented Wollo highland genotype. On the other hand, non-significant difference of non-carcass components between supplemented and non-supplemented Washera F_1 crossbreds, non-supplemented Awassi F_1 crossbred and supplemented Wollo highland breed (Table 20) recorded. These imitate, genotype influence governing most carcass and non-carcass characteristics traits in the present study. This put together Awassi genotype has better growth and carcass development than local breeds and prominent for lamb finishing purposes.

Supplementation diet effect on hot carcass weight (HCW), both hot and cold carcass weight dressing percentage (DP) and rib-eye-muscle area (RIA) recorded within breed variation of Washera F_1 crossbred lambs. The supplemented groups of Wollo highland ram lambs had higher total non-carcass weight, compared with other genotypes in the present study. Hence, relatively higher weight of offal and other non-carcass components of Wollo highland breed slaughtered lambs vanished (Table 20). As the result hot carcass weight, cold carcass weight, rib-eye-area extent and both hot and cold carcass weight dressing percentage more pronounced for Washera and Awassi crossbred ram lambs. The dressing percentage value for Washera crossbred ram lambs is an indicator of more productive breed for meat animal genetic improvement practices. Hence, the amount of dressing percentage value was an indicator of yield grade, marketable and consumable products of meat animals.

5.5.3. Genotype and supplementation effects on carcass morphometric traits

Carcass morphometric traits were used to quantify carcass development performance and conformational change occurring during the life span of animals. It will be particularly useful when it is not possible to take direct measurements of the main meat production traits such as body weight and carcass traits.

Carcass morphometric characteristics of the present study described by carcass length, lean meat weight, lean meat length, compactness index, chest Width, shoulder width, and lean meat thickness presented in Table 22. Awassi crossbred ram lambs carcass length, lean meat weight, lean meat length and chest width traits significantly ($p<0.05$) higher than Washera crossbred and Wollo highland ram lambs. The reason behind this might be genotype effects of large body size induced significantly largest slaughtered and empty body weight. Between supplemented and non-supplemented groups has comparable carcass weight and lean meat length, and significantly differences between genotypes were recorded. In agreement with the current finding, Rozanski *et al.* (2017) and Alves *et al.* (2014), Felicidade *et al.* (2011) were reported, carcass length, leg length, carcass compactness index and chest width not influenced by supplementation diet of palm kernel cake diet. Edmilson *et al.* (2013) also presented not significant variation of carcass length, chest width and leg length of lambs finished at feedlot management condition of different frame sized sheep.

The carcass composition of lean meat weight and length of Awassi F_1 crossbred lambs significantly higher than Washera F_1 crossbreds and Wollo highland lambs and this is due to genotype effect, which enabled them maximum attainment. Both supplemented and non-supplemented Wollo highland lambs had comparable lean meat weight with non-supplemented Washera crossbred lambs (Table 22). For both lean meat weight and length, not significant difference within Wollo highland breed was observed.

Carcass compactness index is the relationship between carcass weight and carcass length, showing the amount of tissue deposited in the carcass. Roberto *et al.* (2010) revealed, effect of diet on carcass compactness index significant at ($P<0.05$) difference. The author also elucidated diet of highest energy level presented carcass compactness index higher and inagreement with current finding of Wollo highland breed lambs. As the carcass increases in weight, it becomes relatively shorter, broader and compact (Roberto *et al.*, 2010). In agreement with present report, Roberto *et al.* (2010) described, genotype did not influence ($P > 0.05$) carcass compactness index and similar result was observed by Cartaxo *et al.* (2008) in Santa Inez and Dorpper × Santa Inez crossbreed genotypes. The carcass compactness index had comparable value for all genotypes and not significantly different in the present finding. As the result, the present finding has an attractive level of compactness indexes recorded and which further confirmation of these genotypes is recommendable issue interms of potential meat production and for market supply of finishing purposes.

Chest width and leg length were another carcass productivity indicator traits. Therefore, Awassi crossbred lambs chest width significantly greater than others genotypes. This might be positive and direct correlation effects of slaughtered body weight and carcass weight. The present finding disagree with reported by Macedo *et al.* (2000) on genotype has not significant effect on chest width and leg length morphometric carcass traits. Similarly, both between and within Washera crossbred and Wollo highland ram lambs had not significant variation of chest width and leg length morphometric carcass traits. This is the result of comparable slaughtered body weight and body frem of the two genotypes. In agreement with the present finding, Michel *et al.* (2015), Rozanski *et al.* (2017) and Felicidade *et al.* (2011) were revealed, chest width and leg length didn't have significant difference with supplementation diet of cassava feed (M*anihot psedoglaziovii*) Chilean lambs, different level of urea supplementation of Dorper crossbred lambs and palm kernel cake for Bahia lambs, respectively.

5.5.4. Genotype and supplementation effects on non-carcass fat distribution

The effects of genotype and supplementation diet on non-carcass fat distribution was presented in Table 23. Thus, non-carcass fat contents around the scrotal organ had not significant variation between supplemented and non supplemented groups of the three genotypes. However, between Wollo highland breed lambs and Awassi F_1 crossbred lambs, significant variation of fat arround scrotal organ observed. Likewise, between supplemented and non-supplemented groups of Washera and Awassi F_1 crossbred lambs have significant difference fat arround scrotal organ recorded. Subcutaneous fat content between Wollo highland and Awassi crossbred lambs was comparable value. However, Awassi crossbred and Wollo highland breed lambs significantly lower subcutaneous fat content than Washera crossbred lambs. The reason behind this is the genotype effect on fat deposition efficiency of Washera F_1 crosses more noticeable than others.

The current study showed mesentery fat, kidney fat and subcutaneous fat decreased in non-supplemented ram lambs fed on natural pasture forage diet only. The current result in agreement with reported by Karim *et al.* (2007) and Papi *et al.* (2011) on lambs with high forage quality tended to deposit less subcutaneous and intestinal fat contents. Lambs fed a concentrate diet displayed considerably greater fat accumulation than lambs raised on forage based diets (Jacques *et al.*, 2011). The reduced non-carcass fat attributed to lower energy intake from forage (Karim *et al.*, 2007). In addition, high starch consumption the supplemented concentrate diets produces higher amounts of propionate, which ultimately increases insulin secretion and stimulates fat synthesis (Jacques *et al.*, 2011). In agreement with this finding, Ibrahim *et al.* (2016), Salo *et al.* (2016), Roberto *et al.* (2010) and Abebe and Tamir (2016) reported, the total fat contents of non-carcass components were significantly affected by the type of diet used. However, in the current finding, in addition to the effects of diet, genotype effects also significant ($P<0.05$) different on total non-carcass fat contents. Even though, supplemented Awassi and Washera crossbred lambs had comparable total non carcass fat composition, Washera F_1 crossbred lambs showed comparatively higher fat contents than Awassi F_1 crossbreds in relation to their body weight difference.

5.5.5. Genotype and supplementation effects on edible and non edible, non-carcass part

Accordingly, the intellectual prohibited cultural and religious taboo of local communities the edible components of non-carcass organs were presented as liver, tongue, heart, kidney, empty gastrointestinal content and tail fat were the most common and presented in Table 24. Hence, liver and heart weight comparable between Wollo highland and Washera crossbred lambs, however, Awassi crossbred lambs had significantly ($P<0.05$) higher than the other. The reason behind this might be, larger body size and physiological appearance of the genotype. However, non-significant variation between supplemented and non-supplemented groups of all genotypes were recorded. While, the kidney and intestine weight had a comparable amount for all genotypes and feeding type. Basically, the raghage part of animal feed obvious that to feel rumen content and the green forge grazing was accessible to all genotypes and which was the reason for comparable intestinal weight. Whereas, the tail size had comparable for Awassi crossbred and Wollo highland breed ram lambs, but Washera crossbred lambs had a significantly ($P<0.05$) largest tail size than other two genotypes. This also indicated that, Washera F_1 crossbred lambs shown fat development nature make large tail weight.

In agreement with current finding, Teklu (2016) and Riley *et al.* (1989) were reported, the majority of edible offal components was not affected ($P>0.05$) by the supplemented feed. As a remarkable feature of Awassi crossbred lambs had more advanced with liver, tongue and heart weight. This perceptible difference resulted from large body size and genotype effect. In concurrence with the current result, Riley *et al.* (1989) indicated, differences in internal organs more influenced by age, breed and sex of the animals rather than plane of nutrition. Whereas, kidney and empty gastrointestinal track weight cover the largest portion of edible non-carcass components and comparable with all genotypes and which aligned with Teklu (2016). This implies that, animals consume more feed, their stomach may be enlarged to accommodate the larger ingesta and thicker to resist the work load on it and this may increase the volume and weight of the gastrointestinal tract as a whole.

The non-edible offal components of the current study were presented in Table 24. Except lung with trachea and spleen, all non-edible offal components were not affected by supplemented diet and indicating that variation of supplementation diet not influenced the non-edible non-carcass components. The non-edible non-carcass contents of head, digestive content and blood volume significant difference ($p<0.05$) among genotypes and this might be slaughtered body weight differences and the inherent genotype effect. Inagreement with the current study, Prasad and Kirton, (1992) reported, live weight status of the animals could affect the production efficiency of carcass offal and considered as depressing factor for hot and cold carcass weight extent and their dressing percentage. However, the nutritional effect not significantly visible for most non edible non carcass component weight and which in agreement with Teklu (2016) but disagree with Michael and Yaynshet (2014). In general the larger extent of non-carcass non-edible components could be reduced the edible carcass and non-carcass amount, hence, through breed selection task, need to be considered the non-carcass non-edible content of genotype.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

The study conducted at on-farm productivity, and feedlot performance evaluation of Wollo highland sheep breed and their F_1 crossbreeds of Awassi and Washera sheep in Ethiopia. The objectives of the research were, flock size and composition assessment, farmers' breeding objective and trait of interest selection criteria identification; flock and ewes' reproductive and lamb growth performance evaluation and feeding trial productive performance assessment of Wollo highland sheep breed and their F_1 crosses.

Stratified proportional to size sampling method was used to clustered flock owners into three genotypes based on their location of the peasant association, type of breeding strategies and type of ram genotypes used for crossbreeding purpose. The main achievement of data collection conducted through, continuous recall multiple visit single subject survey, participatory group discussion, on spot observation of flock monitoring and on-station supplementation diet feeding trial methods were performed.

The overall average smallholder sheep producers' flock size characterized by large flock size, but becoming decreasing tendency contrast with previous flock size report due to productive performance improvement practices, limitation of grazing land and increasing frequency of prevailing drought occasion.

Diversified flock composition due to different age and sex classes taken as an indicator of the flock management practices of sheep producers. Unproportional flock composition might be indicator of external factors affecting the given flock productivity. Smallholder farmers' using traditional sheep breeding practices characterised by large flock size than controlled crossbreeding practices users. Therefore it is the reflection of producers' interest to improve productive performance beyond keeping large number of sheep per flock. Those producers' having large flock size and traditional breeding system, ewes performed poor conception rate, because of poor fertility rate and miserable management situation.

Sheep breeding strategies characterized by village community based controlled breeding, private owned controlled breeding strategies were the most common practices. Village community based controlled sheep breeding practices was new approach by smallholder producers' interest and its imperative to expand through extension services. In the current study, the top six sheep producers' traits of interest were growth rate, body size, weaning rate, body conformation, age at first lambing and lambing rate ranked according to their order of importance.

Lamb survival rate, twinning rate, parental history were first, second and third attributes of interest as breeding ewes selection criteria. Whereas, body size, growth rate and marketing value were the first, second and third traits of interest, respectively as breeding ram selection criteria.

Fast growing lambs sold at early age and kept for up to weaning age in the flock or before attaining sexual maturity. On the other hand, slow growing lambs (stagnated growth) kept for a long period of time in the flock and mostly used for breeding purposes knowngly or unknowngly and resulted as negative selection.

On-farm monitoring information indicated, Awassi F_1 crossbred lambs comparatively higher fertility rate and lower overall mortality rate than Washera F_1 crossbred and Wollo highland lambs. Hence, this crossbred lambs had accustomed to the cool highland and inadequate feed shortage and drought prone area. As a result, due to good adaptablity issue this genotype has the possibility to used as a parent stock for genetic improvement practices.

Short age at first lambing, higher lambing rate, prolificacy rate and the lambing interval were most promising reproductive performance attributes of Washera F_1 crossbred progenies. The birth weight of Awassi and Wahera F_1 crossbreed progenies and local Wollo highland lambs significantly different and higher birth weight is recorded in their order of importances. The effect of genotype, sex and birth type significantly affected birth weight and Awassi F_1 crossbreed progenies had higher followed by Washera F_1

crossbreed progenies. Birth type has significantly affected the body weight gain of the three genotypes. Therefore, single birth type has higher average weight gain than twin birth type lambs and significantly affect lamb growth performance from birth to yearling age. However, parity and sex type didn't have significant variation on lamb growth performance both between and within breeds. Washera F_1 crosses and Wollo highland male lambs had significantly higher average daily weight gain than females at pre-weaning age.

On-farm management of smallholder farm, average body weight of Awassi and Washera F_1 crossbred lambs comparable with Wollo Tikur and Dorper F_1 crossbred progenies at on-station management condition. The growth performance of Awassi and Washera F_1 crossbred lambs at 3 to 9 and 9 to 12 months of age groups has comparable body weight gain. Local Wollo highland breed lambs shown slower growth performance from 3-9 months of age but, compensatory growth performance was observed from 9-12 months of age. Hence, during compensatory growth period the local Wollo highland breed lambs growth rate was increased considerably within three months.

Both Awassi and Washera F_1 crossbred lamb growth performance has promising for genetic potential improvement practices at smallholder farming condition. Awassi F_1 crossbred lambs had higher body weight and faster growth performance followed by Washera crossbred one. Therefore, the existing local breed productive performance improvement practices have to continued with adjustment of breeding strategies and with a definite breeding plan.

Linear body measurement traits additional indicator of growth performance of lambs at on-farm management condition. Lambs having fast growth rate performed larger body measurement values and higher body weight and vice versa for lambs with slower growth rate. Hence, in this finding rump height, chest girth and height at withers traits are the three linear body measurement variables which strong positively correlated with body weight of lambs and can be used as lamb growth performance indicator traits and can be used as selection index traits.

The average daily weight gain (ADG), total body weight change and final body weights of supplemented group Awassi F_1 crossbred and Wollo highland ram lambs significantly higher than non-supplemented groups. Awassi F_1 crossbred lambs growth performance significantly higher than Wollo highland and Washera F_1 crossbred lambs and followed by supplemented Wollo highland breed lambs. Wollo highland breed had ability to increase their body weight comparable with other selected indigenous breed type of the country and have potential value for fattening purpose and productive potential genetic improvement practice, as far as their nutritional requirement maintained.

The effect of genotypes on average daily weight gain of Awassi crossbred ram lambs had the largest value of breed selection in the current study. Therefore, the effect of both genotype and supplementation diet have an advanced value for lamb body weight gain improvement practices. Moreover, cost effective concentrate feed supplementation on natural pasture controlled grazing have to give appropriate attention by smallholder sheep producers and fatteners.

Carcass composition used as a tool to characterize breeds for possible identification of potential genetic resource of lean meat type of lamb production and identify management alternatives to suit different breeds. Differences in carcass merits between genotypes are likely to govern the choice and development of breeds for specific production objective. Natural pasture controlled grazing management important alternative for productive and organic product improvement practices.

Supplementation diet doesn't significant effect on hot carcass weight dressing percentage however, further research is important to confirm at different level of supplementation feeding trial. Cold carcass weight dressing percentage (CCWDP) significant difference between supplemented and non-supplemented groups of each of the three genotype in the present study and its important parameter for carcass productivity improvement practice.

6.2. Recommendations

1. Washera F_1 crossbred progenies designated for good weaning rate, body size, short marketing age, fast age at first lambing, good temperament, and large litter size traits and makes it impressive opportunity for genetic improvement practices of the existing local Wollo highland breed.

2. Utilization of the exotic breeds for genetic improvement through crossbreeding, selection of genetically superior indigenous breed type is crucial for productive and reproductive performance improvement practices of local Wollo highland breed.

3. Awassi F_1 crossbred progenies designated for promising attributes for higher body weight gain and carcass yield characteristics productive trait and good fertility rate however, further research verification activities suggested with different blood level of the crossbred progenies performance evaluation.

4. The crossbreeding practice at smallholder farming circumstance commenced with indiscriminate crossbreeding practice without any conservation strategies of the pre-existing local breed and need of urgent intervention.

5. Development agents, researchers, policy makers and stakeholders want to improve the productive performance of the pre-existing sheep breed have to be considered farmers' traits of interest to create ownership perception of farmers' for sustainable genetic improvement practice.

6. Without adequate full information of genetic performance analysis of the local breed, the only phenotype performance evaluations considered as a predisposal factor for genetic erosion of pre-existed adaptive local breeds and have to lunch breeding policy and strategies.

7. Local Wollo highland breed has potential for meat production comparable with other indigenous breeds and good lamb survival rate.

8. The genotype and supplementation diet effect has profound factors to enhance productive and farmers' production objectives decision. Hence, researchers need to investigate farmers' interest and potential of available breed type through genetic and phenotype performance study.

9. Effective concentrate feed supplementation on controlled natural pasture grazing had significant impact on ram lambs productive performance improvement and it's crucial to create appropriate understanding for fatteners, traders and other sheep producers.

7. REFERENCES

Abebe H. (2008). Supplementation of graded levels of concentrate mixture on feed intake, digestibility, body weight and carcass characteristics of Washera sheep fed urea treated Rice straw. MSc thesis, Haramaya University, Ethiopia.

Abebe H. and Tamir B. (2016). Effects of supplementation with pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpurium*) on feed intake, body weight gain and carcass characteristics in Wollo sheep fed grass hay. *International Journal of Advanced Research Biological Science (IJARBS),* **3(2)**:280-295.

Abebe M. (1999). Husbandry practices and productivity of sheep in Lalo-mama Midir woreda of central Ethiopia. MSc thesis, Alemaya University, Dire Dawa, Ethiopia.

Abegaz S. (2007). In situ characterization of Gumuz sheep under farmers' management in north western lowland of Amhara region. MSc thesis, Haromaya University, Dire Dawa, Ethiopia 66p.

Abegaz S., Duguma G., Galmessa U., Soresa B. and Terefe F. (2005). Small ruminant product ion system in East Wellega and West Shewa Zones. Research Report, Oromiya Agricult ural Research Institute, Bako Research Center. 31p.

Abegaz S., Duguma G., Rege J., Van-Wyk J., Neser F. and Erasmus G. (2000a). Early grow th, survival and litter size in Ethiopian Horro sheep. *South African Journal of Animal Science (SAJAS),* **30**:1–3.

Aden T. (2003). Evaluation of local sheep under traditional management around rural area of Dire Dawa. MSc thesis, Alemaya University, Dire Dawa, Ethiopia.

Afonso J. and Thompson, J. (1996): Changes in body composition of sheep selected for high and low back fat thickness during periods of adlibitum and maintenance feeding. *Animal Science (AnS)*, **63**: 395-406.

Agyemang K., Negussie A., Voorthuizen A. and Anderson F. (2011). A rapid survey of sheep production in the traditional sector of Debre Berhan, Ethiopian Highlands. In: ILCA Proc eeding Conference, Addis Ababa, Ethiopia, 30 Sept-4 Oct., pp: 175-185.

Aklilu Y., Hawkes P., King A. & Sullivan G. (2005). Sanitary and phytosanitary standards (SPS) and livestock-meat marketing assessment for Ethiopia. Consultative report on Feb.9, 2005 for USAID in Washington.

Alves E., Pedreira M., Moreira B., Freire L., Lima T. and Santos-Cruz C. (2014). Carcass cha racteristics of sheep fed diets with slow release urea replacing conventional urea. *Journal of Acta Scientiarum Animal Science* (ASAS), **36 (3)**: 303-310.

Amelmal A. (2011). Phenotypic characterization of indigenous sheep types; in Dawuro zone and Konta special woreda of SNNPR, Ethiopia. MSc thesis, Haramaya, Ethiopia: Haram aya University.

Anous M. (1991). A comparative study of muscle-bone relationship in the hind limb of goats and sheep. *Journal of Animal Production (AP),* **53**:81-87.

AOAC (1990). Official methods of analysis. Association of Official Analytical Chemists, (15th Ed) Washington DC. 1298p.

Asresu Y., Mengistie T., Agraw A. and Getenet Z. (2013). Community-based improvement scheme for washera sheep: Lessons from Yilmanadensa and Quarit Districts in Westren Amhara Region, Ethiopia; *African Journal of Agricultural Research* (AJAR), **8 (44)**: 5485-5491.

Assefa F., Urge M. and Animut G. (2015). Weight Gain and Carcass Characteristics of Adilo Sheep Fed Urea Treated Wheat Straw Supplemented with Enset (Ensete Ventricosum), Atella and Their Mixtures. *Journal of Biology, Agriculture and Healthcare (JBAHC)*, **5 (11)**: 2224-3208

Assefu G. (2012). Comparative feedlot performance of Washera and Horro sheep fed differ ent roughage to concentrate ratio. Msc thesis, Haramaya University, Diredawa, Ethiopia.

Awgichew K. (2000). Comparative performance evaluation of Horro and Menz sheep of Ethiopia under grazing and intensive feeding conditions. PhD dissertation, Humboldt University, Berlin, Germany.

Baker R.L. and Gray G. (2004). Worm control for small ruminants in Tropical Asia. ACIAR monograph series. ISBN 1 86320 4717.

Bathaei S. and Leroy P. (1996). Growth and mature weight of Mehraban Iranian fat tailed sheep. *Journal of Small Ruminant Research (JSRR)*, **22**: 155-162.

Begum F., Azizunnesa M., Faruk I., Golam S. and Farida Y. (2014). Reproductive Perfor mances of Indigenous Ewes in Bangladesh; *Journal of Agriculture and Veterinary Science (JAVS)*, **7 (5)**: 64-72.

Belay B. and Haile A. (2009). Factors affecting growth performance of sheep under village management conditions in the southwestern part of Ethiopia. *Journal of Livestock Resea rch for Rural Development (LRRD),* **21 (11)**: http://www.lrrd.org/lrrd21/11 /bela2 189.htm.

Belete S. (2009). Products and marketing systems of small ruminants; in Goma district of Jimma zone, western Ethiopia. Msc thesis, Hawassa University, Hawassa, Ethiopia: 38-54.

Berg R. and Walters, L. (1983). The meat animal: Changes and challenges. *Journal of Animal Science (JAS)*, **57 (2)**: 133-146.

Berhan A. and Van Arendonk J. (2006). Reproductive Performance and Mortality Rate in Menz and Horro Sheep Following Controlled Breeding in Ethiopia. *Journal of Small Ruminant Research (JSRR)*, **37**: 105–110.

Bogale S., Melaku S., Yami A. (2008). Matching livestock systems with available feed resour ces in the Bale Highlands of Ethiopia. *Outlook Agricultural Journal (OAJ)*, **37**:105–110.

Brand A.A., Cloete S.W., De-Villiers T.T. (1985). Factors that influence mortality amongst lambs in the Elsenburg Dormer and SA Mutton Merino flocks. *South African Journal of Animal Science (SAJAS)*, **15**: 155–161.

Burfening P. J. and Kress D. D. (1993). Direct and maternal effects on birth and weaning weight in sheep. *Journal of Small Ruminant Research (SRR)*, **10**: 153-163.

Cartaxo F.Q., Sousa W.H. and Cezar M. (2008). Effects of genotype group and the body condition of the performance of lambs finished in feedlots. *Revista Braileira de Zoote cnia (RBZ)*, **3**:1483-1489.

Castro-Gámez, H., Perezgrovas, R., Campos-Montes, G., López-Ordaz, R. and Castillo-Juárez, H. (2008). Genetic parameters for fleece quality assessed by an ancient Tzotzil indigenous evaluation system in Mexico. *Journal of Small Ruminant Research (JSRR)*, **74**: 107–112.

Chipman J. (2003). Observations on the potential of Dangila sheep for improved food security around Quarit and Adet, West Gojjam, northwestern Ethiopia. Field study report hosted by the International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia, 2003.

Colomer-Rocher F., Kirton A., Merer J. and Duganzich, D. (1992). Carcass composition of New Zealand Saanen goats slaughtered at different weights. *Journal of Small Ruminant Research (JSRR),* **7:** 161-173.

CSA (Central Statistical Authority) (2015). Ethiopia Belmont analysis and reassessment of crop production and marketing final report, Addis Ababa, Fedral Demorratic Republic of Ethiopia.

CSA (2017). Agricultural Sample Survey, 2012, Volume II: Report on Livestock and livestock characteristics Private peasant holdings) Statistical Bulletin 585. Addis Ababa, Federal Democratic Republic of Ethiopia.

Dalton D.C., Knight T.W. and Johnson, D.L. (1980). Lamb survival in sheep breeds in New Zealand hill country. *New-Zealand Journal of Agricultural Research (NZJAR)*, **23:**167–173.

DBSBMC (Debre Berhan Sheep Breeding and Multiplication Center). (2007). Synthesis report of the 39 years activity of the center. Debre Berhan, Ethiopia.

De-Boer H., Dumont B.L., Fomeroy R.W., Weniger J.H. (1974). Manual on reference meth ods for the assessment of carcass characteristics in cattle. *Journal of Livestock Prod uction Science (JLPS)*, **1**:131–164. [Cross Ref].

Dejene A. (2003). Integrated Natural Resources Management to Enhance Food Security: The Case for Community-Based Approaches in Ethiopia. Working paper No. 16. Rome, Italy.

Deribe G. (2009). On-farm performance evaluation of indigenous sheep and goats in Alaba, Southern Ethiopia. Msc thesis, Hawassa University, Awassa, Ethiopia.

Dibissa N. (2000). Sheep production for smallholder farmers in the Ethiopian Highlands-a farming system Approach. PhD dissertation, Humboldt University, Berlin, Germany.

Ebangi A.L., Nwakalor L.N., Mbah D.A and Abba D. (1996). Factors affecting the birth weight and neonatal mortality of Massa and Fulbe sheep breeds in a hot and dry environ ment, Cameroon. *Revue d'Elevage Médecine Vétérinaire des Pays Tropicaux (JRMVDP T)*, **49**: 349–353.

Edea Z. (2008). Characterization of Bonga and Horro indigenous sheep breeds of smallhol ders for designing community-based breeding strategies in Ethiopia. MSc thesis, Haram aya University, Ethiopia.

Edmilson L., Souza J., Wandrick H., Edgard C., Severino G., Felipe Q., Marcílio F. (2013). Effect of frame size on performance and carcass traits of Santa Inês lambs finished in a feedlot. *Revista Brasileira de Zootecnia (RBDZ)*,**42 (4)**: 284-290.

Ehoche O.W., Alhassan W.S., Umoh J.E., Buvanendran V. and Umunna N.N. (1992). Growth performance and carcass characteristics following feed restriction and re-alimentation in zebu bulls. *African Livestock Research (ALR)*, **1**: 24-30.

Ermias B., Gebeyehu G. and Berhan T. (2014). On-farm performance evaluation of Dorper sheep breed crosses in Wolaita and Site zones, Southern Ethiopia, MSc thesis, Addis Aba ba University, Bishoftu, Ethiopia.

Ermias E., Yami A. and Rege J. (2002). Fat deposition in tropical sheep as adaptive attribute to periodic feed fluctuation. *Journal of Animal Breeding and Genetics (JABG)*, **119**: 235–246.

FAO. (2009). The state of food and agriculture (2009). Livestock in the balance. FAO, Rome, Italy.

Felicidade M., Ronaldo L., Adriana R., Gherman G., Larissa P. and Mauricio C. (2011). Productive performance and carcass characteristics of lambs fed diets containing different levels of palm kernel cake. *Journal of Revista MVZ Córdoba (JRC)*, **16 (3):** 2659-2667.

Fewson D. (1993). Design of livestock breeding programs. Animal Genetics and Breeding Unit (AGBU), p. 53-58, Armidale, Australia.

Fitwi M. and Gebrehiwot T. (2013). Effect of sesame cake supplementation on feed intake, body weight gain, feed conversion efficiency and carcass parameters in the ration of sheep fed on wheat bran and teff (E*ragrostis teff*) straw. *Momona Ethiopian Journal of Science (MEJS)*, **5 (1)**: 89-106.

Flint M. (2005). Management guide for lot feeding goats. http://www.dpi.qld. ov.au/sheep/ 151 53.html

Fourie P.J., Neser F.W., Olivier J.J. and Westhuizen C. (2002). Relationship between produc tion performance, visual appraisal and body measurements of young Dorper rams. *South African Journal of Animal Science (SAJAS)*, **32 (4)**: 256-257.

Fsahatsion H. Aberra M. and Sandip B. (2013a). Traditional sheep production and breeding practice in Gamogofa Zone, Southern Ethiopia. *International Journal of Livestock Produ ction Research (IJLPR)*, 1 (3): 26 – 43.

Gatenby, R.M., (1986). Sheep Production in the Tropics and Subtropics. Longman Inc., New York, 351 pp.

Gautsch K. (1987). Comparative productivity of indigenous sheep in the highlands of Ethiopia and Rwanda. Working document, No.14. ILCA (International Livestock Center for Afric a), Addis Ababa, Ethiopia.

Gebeyew K, Animut G, Urge M, Feyera T. (2015).The Effect of feeding dried tomato pomace and concentrate feed on body weight change, carcass parameter and economic feasibility on Hararghe highland sheep, eastern Ethiopia. *Journal of Veterinary Science and Techno logy (JVST),* **6 (2)**: 2157-7579.

Gebremedhin B., Hoekstra D. and Jemaneh S. (2007). Heading towards commercialization, the case of live animal marketing in Ethiopia, improving productivity and market success (IPMS) of Ethiopian farmers project working volume 5. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Gebretsadik Z., Anal A. and Gebreyohanis G. (2012). Assessment of the sheep production system of northern Ethiopia in relation to sustainable production and sheep meat quality. *International Journal of Advanced Biological Research (IJABR)*, **2 (2)**: 302-313.

Geleta T., Negesse T., Abebe G. and Goetsch A. (2013). Effect of supplementing grazing Arsi-Bale sheep with molasses-urea feed block on weight gain and economic return under farmers' management condition. *Journal of Cell and Animal Biology (JCAB)*, **7 (10)**: 125-131.

Gemeda D. (2009). On-farm performance evaluation of indigenous sheep and goats in Alaba, Southern Ethiopia. MSc thesis, Hawassa University, Hawassa, Ethiopia.

Gemeda D., Kumsa T., Galmessa U., Abegaz S. and Gebreyohannes G. (2005). Mortality rate and major clinical signs in Horro sheep at smallholder farms in East Wollegga and West Shoa zones, Western Oromia, Ethiopia. *Ethiopian Journal of Animal Production (EJAP)*, **5**:33-42.

Gemeda Duguma (2010). Participatory definition of breeding objectives and implementation of community based sheep breeding programs in Ethiopia. PhD dissertation, Boku University, Vienna, Austria.

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

Girma A., Alemu Y. and Merkel, R. (2008). Reproduction in sheep and goats. In: Sheep and goat Production Hand Book for Ethiopia. Ethiopia Sheep and Goats Productivity Improv ement Program (ESGPIP), Addis Ababa, Ethiopia: 57-72.

Gizaw S. (2006). Genetic diversity and conservation priorities for Ethiopian sheep. In: Procee dings of a workshop on sheep breeding strategies for Ethiopia held at ILRI, Addis Ababa, Ethiopia on 21 November 2006.

Gizaw S. (2002b). Genetic evaluation of Menz and Awassi × Menz crossbred sheep in Ethiopia. MSc thesis. Karnal, India.

Gizaw S. and Tesfaye G. (2009). Awassi-Menz sheep crossbreeding project in Ethiopia: Ach ievements and lessons learnt. In: Proceedings of ESGPIP sheep and goat project review conference. Hawassa, Ethiopia, 13-4 March 2009: 53–62.

Gizaw S., Johan A., Olivier H., Hans K., Johann S., Dessie T., Van der Z. and Herbert H. (2008a). Sheep resources of Ethiopia: genetic diversity and breeding strategy. PhD thesis, Wagenin gen University, Wageningen, the Netherlands.

Gizaw S., Komen, H. and van Arendonk, J. (2010c). Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems. *Journal of Livestock Science (JLS),* **128**:67–74.

Gizaw S., Lemma S. and Tesfaye G., (2014). Design of Village-based Awassi sheep crossbreeding scheme. In:Proceedings of the 6th and 7th Annual Regional Conference on Livestock Completed Research Activities 25-27 January, 2012 and 22-24 January, 2013, Bahir Dar, Ethiopia: 138–157.

Gizaw S., Tegegne A., Gebremedhin B., Hoekstra D. (2010a). Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement. IPMS Working Paper 23. Nairobi, Kenya.

Gizaw S., Tesfaye G. and Sisay L. (2012b). Growth performance of different genotypes of Awassi local crossbred sheep under low-input village production system. In: Proceedings of the 5th ARARI annual conference on December 2010. Bahir Dar, Ethio pia.

Gizaw S., Tesfaye G., Sisay L., Dereje T. and Abebe M. (2008b). Study on the response to improved feeding of Menz sheep selected for yearling weight. In: Proceedings of the 1st Annual Regional Conference on August 2006, Bahir Dar, Ethiopia.

Gizaw S., Tesfaye G., Zewdu E., Tadele M., Gemeda D., Markos T., Barbara R., Okeyo Mwai, Tadelle D., Maria W., Johann S. and Aynalem H. (2013a). Characterization of indigenous breeding strategies of the sheep farming communities of Ethiopia; ICARDA working paper *International Center for Agriculture in Dry Areas* (*GSRR)*, **63**: 297-303.

Gizaw S., Tesfaye Getachew, Ayinalem Haile and Tadelle Dessie. (2011a). Congruence between selection of breeding rams based on breeding values for production traits and farmers ram choice criteria. *Journal of Animal (JA)*, **5 (7):** 995–1001.

Gizaw S., van Arendonk, J., Komen H. Windig, J. and Hanotte O. (2007b). Population struct ure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Journal of Animal Genetics (JAG),* **38**: 621–628.

Guesh F. and Mengistu U. (2014). Comparison of supplementing urea-molasses block and urea-atela blocks on body weight change and carcass characteristics of male blackhead Ogaden sheep fed natural pasture hay. *Journal of Biology, Agriculture and Healthcare (JBAH)*, **4 (20)**: 2224-3208.

Hagos A., Mengistu U. and Getachew A. (2015). Effects of supplementation with air dried leaves of the African Wild Olive (Olea Africana), red thorn (Acacia Lahai) and their mixtures on the performance of Tigray highland sheep fed grass hay. *Global Journal of Agricultural Research* (GJAR), **1 (1)**: 001-009.

Haile A., Wurzinger M., Mueller J., Mirkena T., Duguma G., Mwai O., Sölkner J. and Rischkowsky B. (2011). Guidelines for setting up community-based sheep breeding programs.

Hammell K. and Laforest J. (1999). Evaluation of the growth performance and carcass characteristics of lambs produced in Quebec. *Canadian Journal of Animal Science*, www. nrcresearchpress.com.

Hassen Y, Solkner J, Fuerst-Waltl B.(2004). Body weight of Awassi and indigenous Ethiopian sheep and their crosses. *Journal of Small Ruminant Research (JSRR)*, **(55)**: 51-56.

Hassen Y., Sölkner S., Solomon G., Baumung R. (2002). Performance of crossbred and indigenous sheep under village conditions in the cool highlands of central-northern Ethiopia: growth, birth and body weights. *Journal of Small Ruminant Research (JSRR)*, **43**:195-202.

Helen N., Yoseph M., Kefelegn K., Solomon A. and Sanjoy K. (2013). Production objectives, breeding practices and selection criteria of indigenous sheep in eastern Ethiopia. *Livestock Research for Rural Development (LRRD)*, **25 (9)**, http://www.lrrd. org/lrrd25/9/ nigu25157.htm.

Hirpa A. and Abebe G. (2008). Economic Significance of Sheep and Goats. In: Yami, A., Merkel, R.C. (eds), sheep and goat production handbook for Ethiopia. Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP), 1–4.

Hundie D. and Geleta G. (2015). Assessment of production situation and breeding practices of 'Horro sheep' under traditional management in Horro Guduru, and East Wollega Zones, West Ethiopia. *Global Journal of Animal Breeding and Genetics (GJABG)*, **3 (3)**: 146-152.

Ibrahim A., Mutassim M., Abdullah H., Rifat U., Mohamed Y., Al-Saiady R. and Faisal A. (2016). Effect of alfalfa hay on growth performance, carcass characteristics, and meat quality of growing lambs with ad-libitum access to total mixed rations. *Journal of Revista Brasileira de Zootecnia (JRBZ)*, **45 (6)**: 302-308.

ILCA (International Livestock Centre for Africa). (1990). Livestock systems research manual. Working Paper 1, Vol. 1. ILCA, Addis Ababa, Ethiopia: 287pp.

Jacques J., Berthiaume R. and Cinq-Mars D. (2011). Growth performance and carcass character rustic of Dorset lambs fed different concentrates, forage rations or fresh grass. *Journal of Small Ruminant Research (JSRR),* **95:** 113-11.

Jorge R.R., Rodrigo M., Eugenia M. and Rodrigo B. (2013). Effect of breed and feeding on the carcass characteristics of the Chilote breed lamb. *Chilean Journal of Agricultural Research (CJAR),* **73 (1)**.

Kadim I.T., Mahgoub O., Al-Ajmi D.S., Al-Maqbaly R.S., Al-Saqri N.M. and Ritchie A. (2003). An evaluation of the growth, carcass and meat quality characteristics of Omani goat breeds. *Journal of Meat Science (JMS)*, **66**:203–210

Kahsa T., Johann S., Birgit F., Maria W. and Jan P. (2009). Estimates of economic values for important traits of two indigenous sheep breeds of Ethiopia. MSc thesis, University of Austria, Vienna, Austria, Vienna.

Karim S. A., Powell, K., Kumar S. and Singh V. (2007). Carcass traits of Kheri lambs maintai ned on a different system of feeding management. *Journal of Meat Science (JMS)*, **76**: 395-401.

Kassa B.T., Haile A.G. and Essa J.A. (2011). Determinants of sheep prices in the highlands of northeastern Ethiopia, implication for sheep value chain development. *Journal of Tropical. Animal Health and Production (JTAHP)*, **43**: 1525–33.

Kitaba A. and Tamir B. (2007). Effect of harvesting stage and nutrient levels on nutritive values of natural pasture in the central highlands of Ethiopia. *Journal of Agricultural Tropical and Subtropical (JATS)*, **40**: 7–13.

Kosgey I. and Okeyo A. (2007). Genetic improvement of small ruminants in low-input, smal lholder production systems. *Journal of Small Ruminant Research (JSRR)*, **70**:76–88.

Kosgey I., Baker R., Udo H. and Van-Arendonk J. (2006). A review of successes and failures of small ruminant breeding programs in the tropics:. *Journal of Small Ruminant Research (JSRR)*, **61**: 13–28.

Kosgey I., Van Arendonk J. and Baker R. (2003). Economic values for traits of meat sheep in medium to high production potential areas of the Tropics. *Journal of Small Ruminant Research (JSRR)*, **50**:187-202.

Kosgey I., Van Arendonk J. and Baker R. (2004). Economic values of traits in breeding objec tives for sheep in the tropics: impact of tangible and intangible benefits. *Journal of Livestock Production Science (JLPS)*, **88**: 143–160.

Laes-Fettback, C. and Peters, K (1995): A comparative study of performance of Egyptian goat breeds. II. Growth performance and productivity. *Journal of Arch. Tierz. Dummerstorf (JATD)*, **38 (5)**: 563-575.

Lakew M., Haile-Melekot M., Mekuriaw G. (2014). Evaluation of Growth Performance of Local and Dorper × Local Crossbred Sheep in Eastern Amhara Region, Ethiopia. Iranian Journal of Animal Science, 4:123-126.

Lemma S. (2002). Phenotypic classification and description of indigenous sheep types in the Amhara National, Regional State of Ethiopia. MSc thesis, University of Natal, Pieter maritz burg, South Africa.

Luís Cuadros M. (2016). Formulas for feed and forage analysis calculations; Formulas for Feed and Forage Analysis Calculations, Agricultural Service Laboratory, Clemson Unive rsity.

Macedo F., Siqueira E., Martins E. and Macedo R. (2000). Qualidade De Carcaças De Cordeiros Corriedale, Bergamácia x Corriedale e Hampshire Down x Corriedale, termin ados em pastagem e connamento. *Journal of Revista Brasileirade Zootecnia (JRBZ)*, **29 (5)**: 1520-1527.

Mandal, Ajoy, H. Prasad, Ashok Kumar, R. Roy, and Nagendra Sharma. (2007). Factors Assoc iated with Lamb Mortalities in Muzaffarnagari Sheep. *Journal of Small Ruminant Research* (JSRR), **71** (3): 273–79.

Mathios S., Solomon M., and Adugna T. (2008). The Effect of different level of cotton seed cake supplementation on feed intake, digestibility body weight change and Carcass param eter of Sidama goats. *Journal of Livestock Science (JLS)*, **119**:137-144.

Mayaka T. B., Tchoumbone J., Manjeli Y. and Teguia A. (1995). Estimation of live body weight in West African Dwarf goats from heart girth measurements. *Journal of Tropical Animal Health and Production (JTAHP)*. **28**: 126-128.

Mazemder M.A., Hossain M.M. and Khter S.A. (1998). Effect of levels of concentrate suppl ement on live weight gain and carcass characteristics in sheep on restricted grazing. *Journal of Animal Science (JAS)*. **11**: 17-20.

Mekuriaw S., Mekuriaw Z., Taye M., Yitayew A., Assefa H., & Haile A. (2012). Traditional management system and farmers' perception on local sheep breeds (Washera and Farta) and their crosses in Amhara Region, Ethiopia. *Journal of Livestock Research for Rural Development (JLRRD)*, **24 (4)**.

Mekuriaw S., Taya M., Mekuriaw Z., Mekuriaw G., Mazengia H., Haile A.(2013). Evaluation of reproductive performances and survival rate of Washera sheep under farm and station management systems in Amhara region, Ethiopia. *Journal of Agricultural Advances (JARA)*, **2 (7)**: 206-215.

Mengesha M. and Tsega W. (2012). A review of indigenous sheep production in Ethiopia: *Iranian Journal of Applied Animal Science (IJAAS)*, **2**: 311–318.

Michael Y. and Yaynshet T. (2014). Feed utilization, digestibility and carcass parameters of Tigray highland sheep fed wheat straw supplemented with mixtures of wheat bran and cotton seed cake, in Tigray, Ethiopia. *Journal of ABC Research Alert (JABCRA)*, **2 (1)**.

Momani S., Kridli M., Abdullah R., Malinová A., Sanogo M., Šáda S. And Lukešová I. (2010). The effect of crossbreeding European sheep breeds with Awassi sheep on growth efficiency of lambs in Jordan. *Journal of Agricultural Tropical Subtropical (ATST)*, **43** (2): 2010.

Moreno G., Loureiro C. and Souza H. (2008). Carachterísticas of qualitative ovina. *Journal of Revista Nacional da Carne, São Paulo (JRNDCSP)*, **1 (381)**: 76-90.

Moural A., Teixeira P., Coutinho L., Paz1C., Santos V., Soares F., Oliveira M., Vicente W., Araújo A. and Rodrigues, L. (2014). Reproductive performance of Santa Inês ewes durin g dry and rainy seasons in eastern Amazon; *Journal of Animal Reproduction (JAR)*, **11 (1)**: 44-48.

Mueller (2006). Breeding and conservation programs with local communities. Presentation at FAO expert meeting sustainable utilization of animal genetic resources, Italy, 2–4 July 2006, 489p.

Mukasa-Mugerwa E. and Lahlou-Kassi, A. (1995). Reproductive performance and productiv ity of Menz sheep in the Ethiopian highlands. *Journal of Small Ruminant Research (JSR R),* **17**: 167-177.

Mukasa-Mugerwa E., Anindo D., Sovan S., Lahlou-Kassi A. and Tembely S. (2002). Reproductive performance and productivity of Menz and Horro sheep lambing in the wet and dry seasons in the highlands of Ethiopia. *Journal of Small Ruminant Research (JSRR)*, **45**: 261–271.

Mukasa-Mugerwa E., Said A., Lahlou-Kassi A., Sherington J. and Mutiga E.R. (1994). Birth weight as a risk factor for perinatal lamb mortality, and the effects of stage pregnant ewe supplementation and gestation weight gain in Ethiopian Menz sheep. *Journal of Prevent ive Veterinary Medicine (JPVM)*, **19**: 45–56.

Mukasa-Mugerwa M. and Mutiga E. (1993). Prepubertal Plasma Progesterone Patterns in Ethiopian Menz Ewe Lambs. *Journal of Applied Animal Research (JAAR),* **3 (1)**: 31-38.

Musa L., Peters K. and Ahmed M. (2006). On farm characterization of Butana and Kenana cattle breed production systems in Sudan; *Journal of Livestock Research for Rural Deve lopment (JLRRD)*, **18**: 56-61.

Negussie E., Rottmann O., Pirchner F., Rege E. (2004). Growth and carcass composite on of tropical fat tailed Menz and Horro sheep breeds. *Journal of Animal Sciences (JAS)*, **78 (2)**: 245-252.

Niftalem D. (1990). On-farm study of reproductive and growth performance of the Menz sheep in Debre Berhan-Ethiopia. MSc thesis, Alemaya University, Dire Dawa, Ethiopia: 93p.

Notter D.R. And Copenhaver J.S. (1980). Performance of Finnish Landrace crossbred ewes under accelerated lambing. *Journal of Animal Science (JAS)*, **51 (5)**: 1043-1050.

Orr R.M. (1982). Animal production, animal physiology. In: Haley R. T. (17th edition) the agricultural note book. Butterworths and Co. (Publishers) Ltd., London. Pp: 305-318.

Papi N., Mostafa-Tehrani A., Amanlou H. and Memarian M. (2011). The effects of dietary forage-to-concentrate ratios on performance and carcass characteristics of growing fat-tailed lambs. *Journal of Animal Feed Science and Technology (JAFST)*, **163**: 93-98.

Pares C., Pere M., Mwaanga E., Caballero M., Sabaté J. and Valenzuela, S. (2014). Biome trical multivariate study of the Zambian indigenous Fat-tailed sheep Animal production and husbandry. *African Journal of International Scholars (AJIS)*, **1 (1)**: 014-019.

Parés-Casanova P.M., Mwaanga E.S., Caballero M., Sabaté J., and Valenzuela S. (2013). Biometrical multivariate study of the Zambian indigenous fat-tailed sheep. *International Journal of Livestock Production (IJLP)*, **4 (9)**: 148-154.

Parker W.J., McCutcheon S.N. and Wickham G.A. (1991). Effect of administration and ruminal presence of chromic oxide controlled release capsules on herbage intake of sheep. *New Zealand Journal of Agricultural Research (NZJAR)*. **34**: 193-200.

Payne W.J. (1999). An introduction to animal husbandry in the tropics. In: Longman scientific and Technical United States, New York. 44:233-240.

Ponnampalam E.N., Hosking B.J. and Egan A.R. (2003). The rate of carcass components gain, carcass characteristics and muscle longissimus tenderness in lambs fed dietary protein sources with a low quality roughage diet. *Journal of Meat Science (JMS)*, **63**: 143-149.

Prasad V. and Kirton S. (1992). Carcass and non-carcass traits of Muzaffarnagri lambs at different maturity levels. *Indian Journal of Animal Science (IJAS)*, **62 (2)**: 159-164.

Riley R.R., Savell J.W., Shelton M. and Smith, G.C. (1989). Carcass and offal yields of sheep and goats as influenced by market class and breed. *Journal of Small Ruminant Research (JSRR)*, **2 (3)**: 265-272.

Roberto G. C., José T. Wandrick H., Severino G. N., Marta S. M. and Angelina B.F. (2010). Effect of diet and genotype on carcass characteristics of feedlot hair sheep. *Journal of Revista Brasileira de Zootecnia (JRBZ)*, **39 (12)**: 2763-2768.

Rosa H., Ventura P., Sousa B., Moreira D., Borba A. and Rego O. (2007). Productive and reproductive performance of Romney Marsh and Merino Branco sheep in the Azores under different feeding regimens. *Journal of Small Ruminant Research (JSRR)*, **67**: 296–301.

Rozanski S., Vivian D.R., Kowalski L.H., Rogerio P.O., Fernandes S.R., Souza J.C. and Freitas J.A. (2017). Carcass and meat traits and non-carcass components of lambs fed ration containing increasing levels of urea. *Journal of Ciências Agrárias (JCA)*, **38 (3)**: 1577-1593.

Ruvuna F., Taylor J.F., Okeyo M., Wanyoike M. and Ahuya C. (1992). Effects of breed and castration on slaughter weight and carcass composition of goats. *Journal of Small Ruminant Research (JSRR)*, **7**: 175-183.

Salo S, Urge M, and Animut G (2016). Effects of Supplementation with different forms of barley on feed intake, digestibility, live weight change and carcass characteristics of Hararghe highland sheep fed natural pasture. *Journal of Food Processing Technolology (JFPT)*, **7 (3)**: 2157-7110.

Samuel G. and Belay D. (2011). Small ruminant production systems in southwestern Ethiopia, rearing practices in urban and pre-urban area of Jimma. Lambert Acadamic publishing; https://www.resea rcHGate.net/ public ation/24447 6174.

Samuel M. (2005). Characterization of the livestock production system, a case study of yerer watershed, ad-liben Woreda of east Showa, Ethiopia. MSc thesis, Haromaya University, Dire Dawa Ethiopia.

Simiret B. and Slomon M. (2008), Body weight and carcass characteristics of Somali goats fed hay supplemented with graded levels of peanut cake and wheat bran mixture. http:// www. Springer link.com/content/166266668.

Smachew G. (2009). Effects of supplementation with maize bran, noug seed cake (*Guizoitia abyssinica*) and their mixtures on feed utilization and carcass characteristics of Washera Sheep fed hay. MSc thesis, Haramaya University, Ethiopia: 33-41.

Snowder G. D., Glimp H. A. and Field R. (1994). Carcass characteristics and optimal slaught er weights in four breeds of sheep. *Journal of Animal Science (JAS)*, **72**: 932-937.

Sölkner J., Nakimbugwe H. and Valle-Zarate A. (1998). Analysis of determinants of success and failure of village breeding programs. In: World 6th Congress on Genetics Applied to Livestock Production, vol. 25, Armidale, NSW, Australia.

Suileman A., Sayers A. and Wilson R. (1990). Evaluation of Shugor, Dubasi, and Watish sub types of Sudan sheep at El-Hunda national sheep research station, Gezera province. In: ILCA Research report 18, Addis Ababa, Ethiopia.

Surafel M., Mekuriaw Z., Gizaw S. and Taye M. (2012). Community based characterization of Simien sheep based on growth performance and farmers' breeding objectives in Simien Mountain, Ethiopia. *Research Journals of Animal Science (RJAS)*, **6 (3)** 47-55.

Tadesse D., Mengistu U., Getachew A. and Yoseph M. (2016). Growth and carcass charact eristics of three Ethiopian indigenous goats concentrate at different supplementation levels. *Journal of SpringerPlus (JSP)*, **5**: DOI 10.1186/s40064-016-2055-2

Takele T. (2005). On-farm phenotypic characteristic of Sheko breed of cattle and their habitat in Bench Maji zone, Ethiopia. MSc thesis, Alemaya University, Dire Dawa, Ethiopia: 10 5p.

Taye M. (2008). On-farm performances of Washera sheep at Yilmanadensa and Quarit distr icts of Amhara National Regional State. MSc thesis, Hawassa University, Hawassa, Ethio pia.

Taye M., Abebe G., Gizaw S., Lemma S., Mekoya A., & Tibbo M. (2010). Growth perform ances of Washera sheep under smallholder management systems in Yilmanadensa and

Quarit districts, Ethiopia. *Journal of Tropical Animal Health and Production (JTAHP),* **42 (4)**: 659-667.

Taye M., Girma A., Sisay L., Gizaw S., Abebe M. and Markos T. (2011b). Reproductive performance and survival of Washera sheep under traditional management systems. *Journal of Animal and Veterinary Advances (JAVA)*, **10 (09)**: 1158–1165.

Taye M., Girma A., Sisay L., Solomon G., Abebe M. and Marikos T. (2010). Traditional management systems and linear body measurements of Washera sheep in the western highlands of the Amhara National Regional State, Ethiopia. *Livestock Research for Rural Development (LRRD)* **22 (9),** http://www.lrrd.org/lrrd22/9/taye22169.htm.

Taye, M., Abebe G., Gizaw S., Lemma S., Mekoya A. and Tibbo M., (2009). Growth performances of Washara sheep under smallholder management systems in Yilmanadens a and Quarit districts, Hawassa, Ethiopia South. *Journal of Africa Animal Science (JAA S)*, **42**:1-11.

Taylor S.C., Murray J.I. and Thonney M.L. (1989). Breed and sex differences between equally mature sheep and goats, Carcass muscle fat and bone. *Journal of Animal Product ion* (JAP), **49**: 385-409.

Teklu W.F. (2016). The effects of feeding different varieties of faba bean (*Vicia faba L.*) straws with concentrated on feed intake, digestibility, body weight gain and carcass chara cteristics of Arsi-Bale sheep MSc thesis, Haramaya University, Ethiopia.

Terrill C. and Maijala K. (1991). Breed comparisons for meat production in sheep. In: Maij ala, K (ed.). Genetic resources of pig, sheep and goat. *Journal of World Animal Science (JWAS)*. **8**: 257-276.

Tesfaye G. (2008). Characterization of Menz and Afar indigenous sheep breeds of smallho lders and pastoralists for designing community-based breeding strategies in Ethiopia. MSc thesis, Haramaya University, Ethiopia.

Tesfaye G., Gizaw S., Wurzinger M., Abegaz S. and Sölkner J. (2013a). The effect of crossbr eeding indigenous sheep with Awassi and Corriedale sires on reproductive performance under smallholder production system. *Journal of Agriculture Conspecious Science (JAC S)*, **78**: 187-191.

Tesfaye G., Haile A., Tibbo M., Sharma A., Sölkner J. and Wurzinger M. (2010). Herd mana gement and breeding practices of sheep owners in a mixed crop-livestock and a pastoral system of Ethiopia. *African Journal of Agricultural Research (AJAR).* **5(8)**: 685–691.

Tesfaye G., Haile A., Wurzinger M., Rischkowsky B., Gizaw S., Abebe A. and Sölkner J. (2016). Review of sheep crossbreeding based on exotic sires and among indigenous breeds in the tropics: an Ethiopian perspective. *African Journal of Agricultural Research* (AJAR), **11 (11)**: 901-911.

Tesfaye G., Solomon G., Sisay L. and Mengistie T. (2011). Breeding practices, growth, and carcass potential of fat-tailed Washera sheep breed in Ethiopia. *Journal of Tropical Animal Health and Production (JTAHP)*, **43**:1443–1448.

Tesfaye G., Solomon G., Sisay L., Maria W., Solomon A. and Johann S. (2013). The effect of crossbreeding indigenous sheep with Awassi and Corriedale sires on reproductive perfo rmance under smallholder production system in Ethiopia. *Journal of Agriculture Conspec tus Scientificus (JACS)*, **78 (3)**: 187-191.

Tesfaye Getachew, Alemu B., Sölkner J., Gizaw S., Haile A., Gosheme S., & NotterD. R. (2015b). Relative resistance of Menz and Washera sheep breeds to artificial infection with Haemonchus contortus in the highlands of Ethiopia. *Journal of Tropical Animal Health Production (JTAHP)* **47** (4).

Tibbo M. (2006). Productivity and health of indigenous sheep breeds and crossbreds in the central Ethiopian highlands. PhD dissertation, Swedish University of Agricultural Scien ces, Uppsala, Sweden: 11-63.

Tibbo M., Ayalew W., Awgichew K., Ermias E. and Rege J. (2004). On-station characteriza tion of indigenous Menz and Horro sheep breeds in the central highlands of Ethiopia. FAO/UNEP Animal Genetic Resources Information, 35:61–74.

Tsedeke K. (2007). Production and marketing of sheep and goats in Alaba, SNNPR. MSc. Thesis, Hawasa University, Hawasa, Ethiopia.

Van Soest P.J. and Robertson B.J. (1990). Analysis of forage and fibrous feeds, laboratory manual for animal science. *Journal of Dairy Science (JDS),* **74**: 3583-3597.

Verbeek E. and Kanis R. (2007). Socioeconomic factors influencing small ruminant breeding in Kenya. Retrieved on July 14, 2008, 19(77):http://www.cipav.org.co/lrrd/ lrrd19/6/verb 190 77.htm.

Walstra P. and de Greef K.H. (1995). Aspects of development and body composition in pigs. In: Ender K. (2nd.ed.), proceedings of 2nd Dummerstorf muscle-workshop. Muscle grow th and meat quality, Rostock, 1995:183-190.

Warmington B.G. and Kirton A.H. (1990) .Genetic and non-genetic influences on growth and Carcass traits of goats. *Journal of Small Ruminant Research (JSRR)*, **3**: 147-165.

Wayne W. (1995). Biostatistics: A Foundation for Analysis in Health. 6th ed., New York

Weldegebriel B. and Kefelegn M. (2014). Body weight gain and carcass parameters of Tigray highland sheep supplemented with acacia seyal pods and wheat bran mix in hay based feeding. *Journal of Biology, Agriculture and Healthcare (JBAH)*, **4 (17)**: 2224-3208.

Weldeyesus G., Mengistu R. and Awet E. (2017). Improving live body weight gain of local sheep through crossbreeding with high yielding exotic Dorper sheep under smallholder farmers. *International Journal of Livestock Production (IJLP)*, **8 (5)**: 67-71.

Wilson R T., Peacock C P and Sayers AR. (1985b). Pre-weaning mortality and productivity indices for goats and sheep on a Masai group ranch in south-central Kenya Animal Production 41:201-206.

Wilson R.T. (1986). Livestock production in central Mali: Long term studies on cattle and small ruminants in the agro-pastoral system. ILCA Research Report No. 14. Addis Ababa.

Wilson R.T. (1991). Small ruminant production and the small ruminant genetic resource in tropical Africa. FAO Animal Production and Health Paper 88. Rome, Italy.

Wolf B.T., Smith C. and Sales D.I. (1980). Growth and carcass composition in the crossbred Progeny of six terminals sire breeds of sheep. *Journal of Animal Production (JAP),* **31**: 307-313.

Wondesn Alemu (2008). Effects of supplementing hay from natural pastures with oil seed cakes on feed intake, digestibility and body weight change of Sidama goats. MSc thesis, Haramaya University, Ethiopia: 62p.

Workneh A. (2000). Do smallholder farmers benefit more from crossbred (Somali x Anglo-Nubian) than from indigenous goats. PhD dissertation, Georg-August University of Goettingen, Goettingen, Germany.

Yadeta N. and Manzur A. (2016). Production and reproduction performances, producers' trait preferences and marketing system of small ruminants in Ada-Barga and Ejere Districts of west shoa zone, Ethiopia. Msc thesis, Addis Abeba University, Bishoftu, Ethiopia.

Yapi C.V., Boylan W.J. and Robinson R.A. (1990). Factors associated with causes of lamb pre-weaning mortality. *Journal of Preventive Veterinary Medicine (JPVM)*, **10**: 145–152.

Yeheyis L., Sebsibe A., Girma A. (2004). On-farm evaluation of the effect of supplementing grazing Menz sheep during the dry season in Gerakeya Woreda, North Sea. In Proceedings of the 12th annual conference, August 12-14. Addis Ababa, Ethiopia: 371–375.

Yenesew A., Solomon M. and Azage T. (2013). Assessment of sheep marketing system in Burie district, North West Ethiopia. *Wudpecker Journal of Agricultural Research (WJAR*, **2 (3)**: 097-102.

Yeshitila A., Tessema Z. and Azage T. (2008). Availability of livestock feed resources in Alaba Woreda, Southern Ethiopia. In: Proceedings of the 16th annual conference of the Ethiopian Society of Animal Production (ESAP), October 8 to 10, 2008, Addis Ababa, Ethiopia.

Yibrah Y. (2008). Environmental and genetic parameters of growth, reproductive and survival performance of Afar and Blackhead Somali sheep at Werer agricultural research center report, International Livestock Research Institute (ILRI) and the Ethiopian Institute of Agricultural Research (EIAR), Ethiopia.

Yohannes M., Degefu H., Tolosa T., Belihu K., Cutler R. and Cutler S. (2013). Review on brucellosis in Ethiopia. *African Journal of Microbiology Research (AJMR)*, **7 (14)**: 1150-1157.

Younas U., Abdullah M., Bhatti J.A., Pasha T.N., Ahmad N., Nasir M. and Hussain A. (2013). Interrelationship of body weight with linear body measurements in Hissardale sheep at different stages of life. *Journal of Animal & Plant Sciences (JAPS)*, **23 (1)**: 40-4.

Zelalem A. and Fletcher I. (1991). Small ruminant productivity in central Ethiopia mixed farming system. In: Proceeding of the 14th national livestock improvement conference November 1991, Addis Ababa, Ethiopia: 140-148.

Zemichael G. and Solomon M. (2009). Intake, digestibility, body weight and carcass characteristics of Tigray sheep fed tef straw supplemented with a sesame seed meal. *East African Journal of Sciences (EAJS*), **3**: 37–42.

Zewdu E. (2008). Characterization of Bonga and Horro indigenous sheep breeds of smallho lders for designing community-based breeding strategies in Ethiopia. MSc thesis, Haram aya Univer sity, Ethiopia.

Zewudu E., Haile A., Tibbo M., Sharma J., Sölkner J. and Wurzinger M. (2012). Sheep production systems and breeding practices of smallholders in western and southwestern Ethiopia. Livestock Research for Rural Development (LRRD), 24 (7), http://www.lrrd.org/ lrrd24/7/edea24117.htm.

8. APPENDICES

APPENDICES

Appendix I. List of supplementary data tables

Apendix I; Table 1. Least squares mean of sex effect on average daily weight gain.

Breeds	Awassi F1 crossbred		Washera F1 Crossbred		Wollo highland breed		
Sex	Female	Male	Female	Male	Female	Male	
Variable	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Sig.L
BiW	2.38±0.0^{a}	2.36±0.1^{a}	2.13±0.1^{b}	2.15±0.0^{b}	1.92±0.0^{c}	1.87±0.0^{c}	ns
ADG3	122.18±7.7^{a}	113.13±9.9^{a}	133.21±6.0^{a}	138.01±5.3^{a}	65.03±9.4^{b}	73.51±8.9^{b}	
ADG6	90.79±11.4^{a}	95.91±13.8^{a}	23.55±13.8^{b}	44.14±14.6^{a}	30.216±5.5^{c}	43.19±6.1^{b}	
ADG9	43.33±5.2^{a}	30.76±4.1^{a}	51.79±5.1^{a}	54.51±4.6^{a}	15.86±8.2^{b}	20.49±7.0	
ADG12	53.73±4.0^{a}	52.58±4.3^{a}	59.44±6.2^{a}	42.29±12.8^{a}	19.72±3.3^{b}	20.17±3.7^{b}	

SEM, Standard error of the mean; BiW, Birthweight; ADWG, Average daily weight gain with age per months; S.L, significancy level.

Appendix I; Table 2. Breed * Sex * Parity interaction effect on average body weight gain.

Breed * Sex * Parity			BiW	ADG3	ADG6	ADG9	ADG12
Breed	Sex	Parity	Mean+SE	Mean+SE	Mean+SE	Mean+SE	Mean+SE
A	F	1.0	2.4±0.1	117.9±16.9	76.0±22.5	32.5±13.3	47.94±14.4
		2.0	2.3±0.1	140.3±15.8	90.3±21±1	65.6±12.4	47.8±13.4
		3.0	2.4±0.1	108.7±13.5	125.9±17.9	37.7±10.2	66.3±11.5
		4.0	2.4±0.2	138.9±31.6	-48.8±42.1	23.3±24.8	28.9±26.8
	M	1.0	2.2±0.1	130.6±22.3	105.6±29.8	29.4±17.6	52.8±18.9
		2.0	2.4±0.1	125.7±15.8	114.6±21.1	34.9±12.4	58.9±13.4
		3.0	2.5±0.1	89.6±18.2	98.2±24.3	25.1±14.4	50.4±15.5
		4.0	2.3±0.1	105.8±22.3	45.6±29.8	31.9±17.6	43.1±18.9
L	F	1.0	2.0±0.1	69.6±25.8	22.6±34.4	17.4±20.3	30.4±21.9
		2.0	1.2±0.1	74.4±22.3	42.5±29.8	27.8±17.6	28.1±18.9
		3.0	1.92±0.1	49.2±12.4	28.5±16.5	22.9±9.8	20.6±10.5
		4.0	1.9±0.1	74.8±13.5	37.7±17.9	-0.80±10.6	18.6±11.4
		5.0	1.8±0.2	18.8±31.6	-39.4±42.1	4.3±24.9	3.2±26.8
	M	1.0	1.8±0.1	62.0±19.9	48.2±26.7	41.8±15.7	29.1±16.9
		2.0	1.7±0.1	65.1±19.9	35.5±26.7	11.1±15.7	8.2±16.9
		3.0	1.9±0.1	85.1±16.9	60.0±22.5	26.0±13.3	23.2±14.4
		4.0	1.9±0.1	65.2±16.9	32.2±22.5	16.8±13.3	9.4±14.4
		5.0	1.9±0.2	111.6±31.6	39.9.±42.1	34.4±24.8	42.8±26.8

Appe ndix I Table 2 (Continued)

W	F	1.0	2.2±0.1	129.6±19.9	-1.3±26.6	39.3±15.7	56.4±16.9

Table 2.(Continued)

		2.0	2.2±0.2	153.9±31.6	55.0±42.1	53.3±24.8	64.4±16.8
		3.0	2.10±0.1	128.5±25.8	33.7±34.4	47.4±20.3	71.1±21.9
		4.0	1.95±0.1	140.6±22.3	10.8±29.8	45.6±17.5	47.5±18.9
		5.0	1.9±0.1	140.6±16.9	31.6±22.5	56.0±13.3	50.6±14.3
	M	1.0	2.2±0.2	136.5±15.8	44.7±21.1	62.5±12.4	46.4±13.4
		2.0	2.1±0.1	141.1±25.8	79.3±34.4	62.6±20.3	65.6±21.9
		3.0	2.2±0.1	147.8±18.2	43.3±24.3	53.7±14.6	-11.3±15.5
		4.0	2.2±0.1	147.3±19.9	23.1±26.7	45.8±15.7	39.1±16.9
		5.0	2.2±0.1	125.3±22.3	64.2±29.8	61.1±17.5	73.9±18.9

A, Awassi crosses; L, Local Wollo highland breed lambs; W= Washera crosses, F, female lambs and M= Male ADG, Average body weight gain per months.

Appendix I; Table 3. Parity and breed interaction effect on average daily weight gain.

Breeds *Parity			BiW	ADG3	ADG6	ADG9	ADG12
Breed	Parity	N	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
A	1.0	32	2.32±0.07	124.25±14.00	90.79±18.67	30.99±11.02	50.36±11.90
	2.0	30	2.31±0.06	132.99±11.17	102.43±14.90	50.21±8.79	53.33±9.49
	3.0	46	2.47±0.06	99.16±11.34	112.05±15.12	31.52±8.93	58.32±9.63
	≥4.0	33	2.36±0.10	122.36±19.35	1.67±25.80	27.64±15.23	35.97±16.44
Sig. L			ns	ns	ns	Ns	ns
L	1.0	32	1.88±0.09	65.82±16.32	35.41±21.76	29.59±12.84	29.74±13.86
	2.0	30	1.83±0.08	69.78±14.99	39.03±19.98	19.44±11.80	18.13±12.73
	3.0	46	1.90±0.06	67.16±10.47	44.23±13.97	24.47±8.25	21.88±8.89
	4.0	33	1.92±0.06	69.99±10.80	34.95±14.40	8.01±8.50	13.97±9.18
	≥5.0	15	1.87±0.12	65.27±22.34	0.28±29.79	17.22±17.58	21.39±18.98
Sig. L			ns	ns	ns	Ns	ns
W	1.0	32	2.21±0.07	133.04±12.74	21.69±16.98	50.92±10.03	51.41±10.82
	2.0	30	2.15±0.11	147.50±20.39	67.13±27.20	57.96±16.06	65.00±1732
	3.0	46	2.125±0.08	138.15±15.80	38.52±21.06	50.55±12.44	29.91±13.42
	4.0	33	2.06±0.08	143.94±14.99	16.97±1998	45.67±11.80	43.30±12.73
	≥5.0	15	2.07±0.07	132.96±14.00	47.88±18.67	58.57±11.02	62.26±11.90
Sig.			ns	ns	ns	Ns	ns

A, Awassi crosses; L, Local Wollo highland breed lambs and W, Washera crosses; ADG, Average body weight gain per months; SE, Standard error of the mean.

Appendix I; Table 4. Least square mean analysis of ewe's parity effect on daily weight gain.

Dependent Variable	Parity	Mean±SE	LSD	Sig.L
Birth Weight	1st Parity	2.14±0.04	0.17	ns
	2nd Parity	2.08±0.04	0.18	
	3rd Parity	2.17±0.04	0.14	
	4th Parity	2.13±0.04	0.17	
	5th and above parity	2.15±0.04	0.17	
Average daily body weight gain 1-3 months age	1st Parity	107.34±7.73	30.54	ns
	2nd Parity	117.58±8.15	32.17	
	3rd Parity	99.64±6.51	25.71	
	4th Parity	110.68±7.75	30.59	
	5th and above parity	107.08±7.86	31.02	
Average body weight gain 3-6 months age	1st Parity	49.93±10.52	41.53	ns
	2nd Parity	67.67±11.08	43.75	
	3rd Parity	66.10±8.86	34.97	
	4th Parity	34.43±10.54	41.60	
	5th and above parity	51.17±10.69	42.19	
Average body Weight gain 6-9 months age	1st Parity	38.05±6.05	23.90	ns
	2nd Parity	44.59±6.38	25.17	
	3rd Parity	36.99±5.10	20.12	
	4th Parity	25.62±6.06	23.94	
	5th and above parity	36.34±6.15	24.28	
Average body weight gain 9-12 months age	1st Parity	42.61±6.73	26.56	ns
	2nd Parity	42.08±7.09	27.98	
	3rd Parity	37.37±5.67	22.37	
	4th Parity	33.57±6.74	26.61	
	5th and above parity	50.26±6.84	26.99	

SE, Standard error of the mean; LSD, Least significant difference of the mean and ns, non-significant different of the mean.

Appendix II. List of questionnairies survey for on farm flock characterestics

On-farm sheep flock characterestics and reproductive performance evaluation and farmer is breeding objective assessment survey questionnaire.

General introduction: This assessment work designed to enhance smallholders' sheep productive and reproductive potential through intensive research activities. Therefore, everyone who will be participated on this work should be free from any other disappointment. It is for the benefits of local sheep breed genetic improvement practice.

Name of the respondent: ______________ Age ________ Sex______ Mobile No (Optional): ______.

Address: Sub-Peasant Association (Got) _______. Peasant Association (PA) ______ District_______.

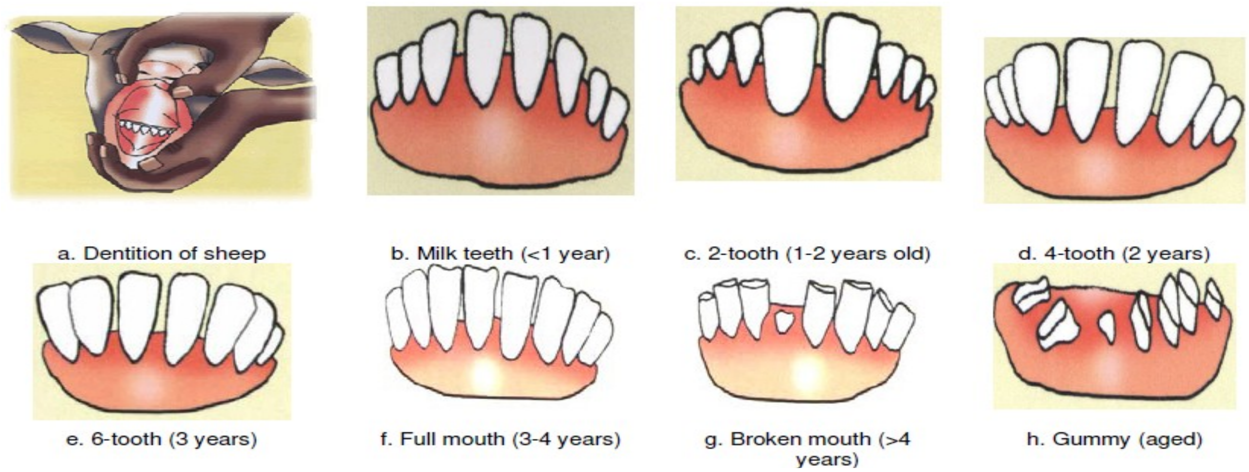
1. How many lambs do you have currently in your flock? Lambs with one day old________, 1-3 month old lambs ________, 3 month old lambs __________, 3-6 month old lambs __________ and 1year old lamb's _________.
2. Do you have pregnant ewes in your flock? Yes □ No □: If yes" how many of them are with 1st parity ___, 2st parity ___, 3st parity ___, 4st parity ___, 5st parity ___, 6st parity ___, 7st parity____, 8st parity____, 9st parity _____, 10st parity____, 11st parity_____, 12st parity___.
3. If your answer is "yes" in question "2": At how many month of pregnancy period are they? If you have more than one pregnant ewes in your flock give number as: Ewe number 1____ month/s, ewe number 2____ month/s, ewe number 3____ month/s and ewe number 4____ month/s of pregnancy period.
4. Do you have ram for mating purpose in your flock? Yes □ No □: If "yes" how many ram do you have? __________, and what type of breed is it?___________. If more than one rams pleas, mention them: castrated __________ enact_________ ram lambs__________ ram___________.
5. If your answer is "No" in question "4" from where do you do have the ram for mating your ewes? A) Free from neighboring b) From governmental donation c) From NGos donation, d) Using random mating in the communal grazing land.
6. Do you know the ram that mated each your pregnant ewes? Yes □ No □:

7. If your answer for question number "6" is "yes" which breed type of the ram do you have used for each individual pregnant ewe? A) Awassi ram, b) Washera ram, c) Local Wollo highland ram, d) Dorper ram, e) if other breed type of ram was used pleas mention her: _________.
8. Are you interested to have exotic or other local ram in your flock for crossbreeding purpose for future genetic improvement program? Yes □ No □:
9. If "Yes" in the above question, Which breed type do you more interested? A) Awassi ram, b) Washera ram, c) Selected local ram, d) Dorper ram, e) if other pleas mention her: _________.
10. If you were select one of the given alternative in question number "9" why would you select the breed of that ram? a) due to its meat quantity and quality and rank____b) due to its big body frame and rank____ c) due to its wool/fiber type and rank____, d) due to its prolificacy rate and rank____, e) due to its short lambing interval and rank____, f) due to its short weaning time and rank____, g) due to its early maturing and rank____, h) due to its high milk yield and rank, ____ and if you have other purpose pleas mention here, _______________________ and rank, ____.
11. Which of the following are most interested your traits of interest?
    a) Meat, b) Milk, c) Skins, d) Fiber, e) if other please specifies _______________________.
12. What is the average age of first lambing of your ewes? __________________________.
13. Do you have aborted ewes in your flock since the last 12 months? Yes □ No □
14. How many of the pregnant ewes given birth since the last 12 month in your flock? ____
15. How many of lambs born in your flock since the last 12 months? Total _________________ Male ________________ and Female_____________________.
16. How many lambs do you have? _________ and which of them with the age of 1 day _________, less than 15 days ___________, 15 days- 30 days __________,30-60 days (1-2 months) __________, 60-90 days (2-3 months) __________, 90 days (3 months), and 90-120 days (3-4 months), 120 -150 days (4-5 months) and 150-18-days of age (5-6 months).
17. What is the average lambing interval of your ewes per flock? ______________________.
18. What is the average number of lambing / ewes / year/ flock? ________________________.
19. What is the average number of pre-weaned lambs / ewes / year / flock? _______________.
20. What is the average number of post-weaned lambs / ewes / year / flock? _______________.

21. Have you observed death in your flock since the last 12 months? Yes □ No □, If yes how many total death in your flock? ____.
22. Which breed/ crossbred type of lambs more frequently die? A) Local x Washera lambs, B) Local x Awasi lambs, C) Local lambs.
23. Do you know the cause of the death? If "Yes," please mention here___________________.
24. Have you ever sold sheep since last 12 months? Yes □ No □, If "yes" how many number of sheep do you have been sold since the last 12 months? _____________________________.
25. What is the approximate average marketing age of your sheep? ____________ Fill the blank space with the age of animals, which sold the last 12 months: Age of the ram __________, age of the ewe's _________, age of the ram lamb's _________, age of the ewe lamb's __________, age of the male lamb's __________ and age of the female lamb's __________.
26. Which type of lamb performance do you usually prefer for marketing ______________ at what age do you usually sold lambs?_________ and what type of sex type usually used for marketing.
27. How many sheep do you have slaughtered since the last 12 months? male _____, female____,
28. Have you ever used crossbreeding of local sheep with exotic breed? Yes □ No □
29. If your answer is "yes" for question number 28: How long do you ever been used crossbreeding? a) for 1 year, b) for 2 years, c) for three years, d) for four years, e) more than five years.
30. What breed type of the ram you ever been used or using in your flock? A) Awassi, b) Dorper, c) Washera, d) Cordial, e) Hampshire, f) if other mention here:_____________.
31. If you were used exotics or some other local ram for crossbreeding, how can you access the ram? a)Self initiative, b) government initiative, c) nongovernmental initiative, d) Gift from somebody or organization.
32. Do you have experiences for adopting selecting best ram for breeding purpose? Yes □ No □
33. If "yes" for the above question, what type of parameter do you have used to select best productive ram breed type? __________ a) Body weight and its' rank, ___ b) Color type and its' rank _____, c) Meat characteristics and its' rank _____, d) Hair type and its' rank _____, e) Body condition and its' rank _____, f) Marketing value and its' rank _____, g) Prolificacy rate and its' rank _____, h) Milk yield and its' rank _____, i) Annual lambing

rate and its' rank _____, j) Weaning rate and its' rank _____, K) Survival rate and its' rank _____, l) If some others _________________ and its' rank ____________.

34. How do you control indiscriminate crossbreeding between the selected exotic or selected local ram and with non-selected local ram during mating in your flock? A) controlled by community based breeding approach, b) controlled by individual flock based breeding approach, c) no controlling mechanisms, d) if you have any other mechanism write here:_________________.
35. What type of breeding strategies have you used/ using? __________________ and from where do you have got your breeding ram type?____________ fill the following table.
36. From the information's of crossbreeding practice in your area; which breed type of ram do you prefer more for future breeding purpose?________. A) Awassi, b) Dorper, c) some other local ram (Washera), d) Cordial, e) Hampshire and e) their own local breed type.
37. How do you compare each ram breed type? a) based on their body condition, b) based on their weight, c) based on their hair type, d) based on their ability to cope with our environment, e) based on their fast growing rate, f) based on their meat value, g) based on their marketing value.
38. What do you expect from your crossbreeding activities? a) improving meat productivity, b) improving milk productivity, c) improving wool productivity, d) improving number of lambs born per year per ewes, e) improving household income, f) increasing flock size
39. What is the ratio of local versus crossbred sheep in your flock? __________________.
40. How many numbers of crossbred progenies do you have? _____________________.
41. What are the comparative advantages of crossbred sheep versus local one?__________.
42. What do you suggest about future crossbreeding practice in your flock? _____________
43. How do you evaluate the performance of your flock? __________________________
44. Estimate age of sheep based on description of dentition that corresponding age estimation and to make sure use pectoral presentation of dentition aging system.



Appendix II Figure 1. Pictorial presentation of dentition class for sheep

Appendix III; Table 1. Analysis of Varianc table for birth body weight gain

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.035	50	0.141	2.733	0.000
Intercept	200.2	1	200.2	3888.3	0,000
Breed type	1.470	2	0.735	14.3	0.000
Birth type	0.059	1	0.059	1.2	0.287
Sex type	0.026	1	0.026	0.5	0.479
Parity	0.718	10	0.072	1.4	0.197
Breed type * Birth type	0.016	2	0.008	0.2	0.853
Breed type * Sex type	0.064	2	0.032	0.6	0.54
Breed type * Parity	0.225	8	0.028	0.6	0.818
Birth type * Sex type	0.127	1	0.127	2.5	0.12
Birth type * Parity	0.065	3	0.022	0.4	0.737
Sex type * Parity	0.714	8	0.089	1.7	0.102
Breed type * Birth type * Sex type	0.000	0			
Breed type * Birth type * Parity	0.000	0			
Breed type * Sex type * Parity	0.240	6	0.040	0.8	0.59
Birth type * Sex type * Parity	0.059	1	0.059	1.1	0.288
Breed type * Birth type * Sex type * Parity	0.000	0			
Error	4.376	85	0.051		
Total	648.7	136			
Corrected Total	11.41	135			

a. R Squared = .736 (Adjusted R Squared = .575)

Appendix III; Table 2. Analysis of Varianc table for weaning body Weight gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	613.447[a]	51	12.028	1.94	0.003
Intercept	179.487	1	179.487	28.954	0.000
Birth Weight	1.848	1	1.848	0.298	0.587
Breed type	177.701	2	88.85	14.333	0.000
Birth type	23.058	1	23.058	3.72	0.057
Sex type	0.001	1	0.001	0	0.992
Parity	24.988	10	2.499	0.403	0.942
Breed type * Birth type	27.08	2	13.54	2.184	0.119
Breed type * Sex type	23.086	2	11.543	1.862	0.162
Breed type * Parity	69.131	8	8.641	1.394	0.211
Birth type * Sex type	7.663	1	7.663	1.236	0.269
Birth type * Parity	18.738	3	6.246	1.008	0.394
Sex type * Parity	43.109	8	5.389	0.869	0.546
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	41.469	6	6.911	1.115	0.361
Birth type * Sex type * Parity	2.53	1	2.53	0.408	0.525
Breed type * Birth type * Sex type * Parity	0	0			
Error	520.711	84	6.199		
Total	24457.4	136			

a. R Squared = .541 (Adjusted R Squared = .262)

Appendix III; Table 3. Analysis of Varianc table for six months body weight gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1803.899[a]	51	35.371	4.582	0.000
Intercept	336.266	1	336.266	43.564	0.000
Birth Weight	0.436	1	0.436	0.056	0.813
Breed type	290.869	2	145.435	18.841	0.000
Birth type	66.658	1	66.658	8.636	0.004
Sex type	0.459	1	0.459	0.059	0.808
Parity	115.98	10	11.598	1.503	0.153
Breed type * Birth type	12.716	2	6.358	0.824	0.442
Breed type * Sex type	56.47	2	28.235	3.658	0.030
Breed type * Parity	50.798	8	6.35	0.823	0.585
Birth type * Sex type	1.526	1	1.526	0.198	0.658

Appendix III Table 3 (Continued)					
Birth type * Parity	16.741	3	5.58	0.723	0.541
Sex type * Parity	120.37	8	15.046	1.949	0.063
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	41.198	6	6.866	0.89	0.506
Birth type * Sex type * Parity	5.203	1	5.203	0.674	0.414
Breed type * Birth type * Sex type * Parity	0	0			
Error	648.391	84	7.719		
Total	56178.39	136			
Corrected Total	2452.29	135			

a. R Squared = .736 (Adjusted R Squared = .575)

Appendix III; Table 4. Analysis of Varianc table for nine months of body weight gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2297.628[a]	51	45.052	4.282	0.000
Intercept	364.966	1	364.966	34.687	0.000
Birth Weight	5.316	1	5.316	0.505	0.479
Breed type	486.899	2	243.449	23.138	0.000
Birth type	73.232	1	73.232	6.96	0.010
Sex type	0	1	0	0	0.996
Parity	88.381	10	8.838	0.84	0.592
Breed type * Birth type	11.834	2	5.917	0.562	0.572
Breed type * Sex type	135.627	2	67.813	6.445	0.002
Breed type * Parity	70.472	8	8.809	0.837	0.573
Birth type * Sex type	13.518	1	13.518	1.285	0.260
Birth type * Parity	33.461	3	11.154	1.06	0.371
Sex type * Parity	174.867	8	21.858	2.077	0.047
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	54.734	6	9.122	0.867	0.523
Birth type * Sex type * Parity	11.193	1	11.193	1.064	0.305
Breed type * Birth type * Sex type * Parity	0	0			
Error	883.823	84	10.522		
Total	81791.29	136			
Corrected Total	3181.451	135			

a. R Squared = .722 (Adjusted R Squared = .554)

Appendix III; Table 5. Analysis of Varianc table for yearling body weight gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4833.848[a]	51	94.781	3.82	0.000
Intercept	232.014	1	232.014	9.351	0.003
Birth Weight	112.458	1	112.458	4.533	0.036
Breed type	865.849	2	432.925	17.449	0.000
Birth type	22.606	1	22.606	0.911	0.343
Sex type	9.086	1	9.086	0.366	0.547
Parity	82.246	10	8.225	0.331	0.970
Breed type * Birth type	50.895	2	25.448	1.026	0.363
Breed type * Sex type	266.989	2	133.494	5.38	0.006
Breed type * Parity	230.971	8	28.871	1.164	0.331
Birth type * Sex type	25.22	1	25.22	1.017	0.316
Birth type * Parity	44.809	3	14.936	0.602	0.615
Sex type * Parity	212.791	8	26.599	1.072	0.391
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	157.805	6	26.301	1.06	0.393
Birth type * Sex type * Parity	17.926	1	17.926	0.722	0.398
Breed type * Birth type * Sex type * Parity	0	0			
Error	2084.126	84	24.811		
Total	114580.5	136			
Corrected Total	6917.973	135			

a. R Squared = .699 (Adjusted R Squared = .516)

Appendix III; Table 6. Analysis of Varianc for pre-weaning average daily weight gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14122.589[a]	51	276.914	3	0.000
Intercept	4251.796	1	4251.796	46.068	0.000
Birth Weight	0.006	1	0.006	0	0.994
Breed type	3948.75	2	1974.375	21.392	0.000
Birth type	583.491	1	583.491	6.322	0.014
Sex type	38.84	1	38.84	0.421	0.518
Parity	569.279	10	56.928	0.617	0.796
Breed type * Birth type	392.873	2	196.436	2.128	0.125
Breed type * Sex type	614.298	2	307.149	3.328	0.041
Breed type * Parity	1116.761	8	139.595	1.513	0.165
Birth type * Sex type	115.802	1	115.802	1.255	0.266
Birth type * Parity	257.21	3	85.737	0.929	0.430
Sex type * Parity	839.914	8	104.989	1.138	0.347
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	944.38	6	157.397	1.705	0.13
Birth type * Sex type * Parity	54.925	1	54.925	0.595	0.443
Breed type * Birth type * Sex type * Parity	0	0			
Error	7752.69	84	92.294		
Total	720305.2	136			
Corrected Total	21875.28	135			

a. R Squared = .646 (Adjusted R Squared = .430)

Appendix III; Table 7. Analysis of Varianc for post-weaning average body daily gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14122.589	51	276.914	3	0.000
Intercept	4251.796	1	4251.796	46.068	0.000
Birth Weight	0.006	1	0.006	0	0.994
Breed type	3948.75	2	1974.375	21.392	0.000
Birth type	583.491	1	583.491	6.322	0.014
Sex type	38.84	1	38.84	0.421	0.518
Parity	569.279	10	56.928	0.617	0.796
Breed type * Birth type	392.873	2	196.436	2.128	0.125
Breed type * Sex type	614.298	2	307.149	3.328	0.041
Breed type * Parity	1116.761	8	139.595	1.513	0.165
Birth type * Sex type	115.802	1	115.802	1.255	0.266
Birth type * Parity	257.21	3	85.737	0.929	0.430
Sex type * Parity	839.914	8	104.989	1.138	0.347
Breed type * Birth type * Sex type	0	0			
Breed type * Birth type * Parity	0	0			
Breed type * Sex type * Parity	944.38	6	157.397	1.705	0.130
Birth type * Sex type * Parity	54.925	1	54.925	0.595	0.443
Breed type * Birth type * Sex type * Parity	0	0			
Error	7752.69	84	92.294		
Total	720305.2	136			
Corrected Total	21875.28	135			

a. R Squared = .796 (Adjusted R Squared = .672)

Appendix III; Table 8. Analysis of Varianc table for Model fitness of body weight gain.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10 days	755.819[a]	6	126.0	82.805	0.000
	20 days	857.087[b]	6	142.8	65.517	0.000
	30 days	873.604[c]	6	145.6	50.933	0.000
	40 days	1016.573[d]	6	169.4	60.414	0.000
	50 days	1027.443[e]	6	171.2	32.255	0.000
	60 days	1062.098[f]	6	177.0	32.192	0.000
	70 days	1198.038[g]	6	199.7	34.911	0.000
	80 days	1305.981[h]	6	217.7	37.556	0.000
	FBWG	1705.867[i]	6	284.3	86.971	0.000
	ABWC	472.218[j]	6	78.7	36.246	0.000
	ADG	58298.054[k]	6	9716.3	36.237	0.000

ADG, Average daily gain; IBW, Initial body weight; df, degree of freedom

Appendix III; Table 9. Analysis of Varianc table for effect of initial body weight on average body weight gain

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
IBW	10 days	5.1	1	5.1	3.368	0.077
	20 days	6.5	1	6.5	2.989	0.094
	30 days	2.9	1	2.9	1.001	0.325
	40 days	4.7	1	4.7	1.675	0.206
	50 days	13.3	1	13.3	2.510	0.124
	60 days	22.3	1	22.3	4.057	0.053
	70 days	23.5	1	23.5	4.104	0.052
	80 days	25.4	1	25.4	4.375	0.045
	FBWG	13.7	1	13.7	4.188	0.050
	ABWC	0.3	1	0.3	0.151	0.700
	ADG	41.3	1	41.3	0.154	0.697

ADG, Average daily gain; IBW, Initial body weight; df, degree of freedom

Appendix III; Table 10. Analysis of Varianc table for effect of breed type on average body weight gain.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Breed type	10 days	52.8	2	26.4	17.364	0.000
	20 days	60.7	2	30.3	13.912	0.000
	30 days	95.5	2	47.8	16.709	0.000
	40 days	124.4	2	62.2	22.171	0.000
	50 days	109.7	2	54.9	10.334	0.000
	60 days	100.9	2	50.5	9.179	0.001
	70 days	140.0	2	70.0	12.241	0.000
	80 days	158.3	2	79.2	13.660	0.000
	FBWG	280.6	2	140.3	42.919	0.000
	ABWC	263.9	2	132.0	60.779	0.000
	ADG	32595.6	2	16297.8	60.782	0.000

ADG, Average daily gain; IBW, Initial body weight; df, degree of freedom

Appendix III; Table 11. The effect of feeding type on average body weight gain.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Feeding type	10 days	10.8	1	10.8	7.130	0.012
	20 days	12.7	1	12.7	5.804	0.023
	30 days	9.3	1	9.3	3.253	0.082
	40 days	14.7	1	14.7	5.225	0.030
	50 days	38.8	1	38.8	7.309	0.011
	60 days	60.6	1	60.6	11.022	0.002
	70 days	50.9	1	50.9	8.898	0.006
	80 days	68.0	1	68.0	11.739	0.002
	FBWG	74.7	1	74.7	22.864	0.000
	ABWC	17.5	1	17.5	8.081	0.008
	ADG	2165.0	1	2165.0	8.074	0.008

ADG, Average daily gain; IBW, Initial body weight; df, degree of freedom

Appendix III; Table 12. Analysis of Varianc table for effect of breed and feed type interaction on average weight gain.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Breed type * Feed type	10 days	13.9	2	6.9	4.553	0.019
	20 days	18.0	2	9.0	4.120	0.027
	30 days	8.4	2	4.2	1.471	0.246
	40 days	7.1	2	3.5	1.261	0.298
	50 days	0.7	2	0.3	0.063	0.939
	60 days	1.2	2	0.6	0.113	0.893
	70 days	2.7	2	1.4	0.239	0.789
	80 days	4.6	2	2.3	0.396	0.677
	FBWG	4.2	2	2.1	0.649	0.530
	ABWC	10.0	2	5.0	2.302	0.118
	ADG	1238.1	2	619.0	2.309	0.117

ADG, Average daily gain; IBW, Initial body weight; df, degree of freedom

Appendix III; Table 13. Analysis of Varianc table for effect of breed type * feed type on average body weight. gain

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Ten days body weight	755.819a	6	125.970	82.805	.000
	Twenty days body weight	857.087b	6	142.848	65.517	.000
	Thirty days body weight	873.604c	6	145.601	50.933	.000
	Forty days weight	1016.573d	6	169.429	60.414	.000
	Fifty days weight	1027.443e	6	171.240	32.255	.000
	Sixty days weight	1062.098f	6	177.016	32.192	.000
	Seventy days weight	1198.038g	6	199.673	34.911	.000
	Eighty days weight	1305.981h	6	217.663	37.556	.000
	Final body weight	1705.867i	6	284.311	86.971	.000
	Average body weight change	472.218j	6	78.703	36.246	.000
	Average daily weight gain	58298.054	6	9716.342	36.237	.000
Intercept	Ten days body weight	45.839	1	45.839	30.132	.000
	Twenty days body weight	41.020	1	41.020	18.814	.000
	Thirty days body weight	63.565	1	63.565	22.236	.000
	Forty days weight	59.385	1	59.385	21.175	.000
	Fifty days weight	40.251	1	40.251	7.582	.010
	Sixty days weight	30.475	1	30.475	5.542	.026

Appendix III Table 13 (Continued)

	Seventy days weight	32.025	1	32.025	5.599	.025
	Eighty days weight	33.193	1	33.193	5.727	.023
	Final body weight	59.459	1	59.459	18.188	.000
	Average body weight change	12.547	1	12.547	5.779	.023
	Average daily weight gain	1553.862	1	1553.862	5.795	.023
IBW	Ten days body weight	5.124	1	5.124	3.368	.077
	Twenty days body weight	6.516	1	6.516	2.989	.094
	Thirty days body weight	2.862	1	2.862	1.001	.325
	Forty days weight	4.698	1	4.698	1.675	.206
	Fifty days weight	13.327	1	13.327	2.510	.124
	Sixty days weight	22.309	1	22.309	4.057	.053
	Seventy days weight	23.473	1	23.473	4.104	.052
	Eighty days weight	25.359	1	25.359	4.375	.045
	Final body weight	13.689	1	13.689	4.188	.050
	Average body weight change	.329	1	.329	.151	.700
	Average daily weight gain	41.342	1	41.342	.154	.697
Breed type	Ten days body weight	52.833	2	26.416	17.364	.000
	Twenty days body weight	60.666	2	30.333	13.912	.000
	Thirty days body weight	95.533	2	47.766	16.709	.000
	Forty days weight	124.355	2	62.178	22.171	.000
	Fifty days weight	109.721	2	54.860	10.334	.000
	Sixty days weight	100.949	2	50.474	9.179	.001
	Seventy days weight	140.030	2	70.015	12.241	.000
	Eighty days weight	158.333	2	79.166	13.660	.000
	Final body weight	280.606	2	140.303	42.919	.000
	Average body weight change	263.946	2	131.973	60.779	.000
	Average daily weight gain	32595.603	2	16297.802	60.782	.000
Feed type	Ten days body weight	10.847	1	10.847	7.130	.012
	Twenty days body weight	12.654	1	12.654	5.804	.023
	Thirty days body weight	9.299	1	9.299	3.253	.082
	Forty days weight	14.652	1	14.652	5.225	.030
	Fifty days weight	38.805	1	38.805	7.309	.011
	Sixty days weight	60.607	1	60.607	11.022	.002
	Seventy days weight	50.892	1	50.892	8.898	.006
	Eighty days weight	68.038	1	68.038	11.739	.002
	Final body weight	74.743	1	74.743	22.864	.000
	Average body weight change	17.547	1	17.547	8.081	.008
	Average daily weight gain	2164.991	1	2164.991	8.074	.008

Appendix III Table 13 (Continued)

Breed type * Feed type	Ten days body weight	13.854	2	6.927	4.553	.019
	Twenty days body weight	17.968	2	8.984	4.120	.027
	Thirty days body weight	8.410	2	4.205	1.471	.246
	Forty days weight	7.075	2	3.538	1.261	.298
	Fifty days weight	.666	2	.333	.063	.939
	Sixty days weight	1.248	2	.624	.113	.893
	Seventy days weight	2.730	2	1.365	.239	.789
	Eighty days weight	4.589	2	2.295	.396	.677
	Final body weight	4.246	2	2.123	.649	.530
	Average body weight change	9.997	2	4.998	2.302	.118
	Average daily weight gain	1238.097	2	619.048	2.309	.117
Error	Ten days body weight	44.117	29	1.521		
	Twenty days body weight	63.229	29	2.180		
	Thirty days body weight	82.902	29	2.859		
	Forty days weight	81.330	29	2.804		
	Fifty days weight	153.960	29	5.309		
	Sixty days weight	159.464	29	5.499		
	Seventy days weight	165.865	29	5.719		
	Eighty days weight	168.075	29	5.796		
	Final body weight	94.802	29	3.269		
	Average body weight change	62.970	29	2.171		
	Average daily weight gain	7775.932	29	268.136		
Total	Ten days body weight	31535.870	36			
	Twenty days body weight	31132.550	36			
	Thirty days body weight	36137.760	36			
	Forty days weight	37814.850	36			
	Fifty days weight	38791.540	36			
	Sixty days weight	40716.500	36			
	Seventy days weight	42891.550	36			
	Eighty days weight	45350.340	36			
	Final body weight	50826.010	36			
	Average body weight change	3858.710	36			
	Average daily weight gain	476399.640	36			
Corrected Total	Ten days body weight	799.936	35			
	Twenty days body weight	920.316	35			
	Thirty days body weight	956.506	35			
	Forty days weight	1097.903	35			

Appendix III Table 13 (Continued)

Fifty days weight	1181.402	35
Sixty days weight	1221.562	35
Seventy days weight	1363.903	35
Eighty days weight	1474.056	35
Final body weight	1800.670	35
Average body weight change	535.188	35
Average daily weight gain	66073.986	35

Appendix III; Table 14. ANOVA for breed and feed type effect on carcass and carcass yield.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Pre slaughter weight	886.213[a]	5	177.243	51.416	.000
	Slaughtered body weight	796.084[b]	5	159.217	52.653	.000
	Empty body weight at slaughtered body weight base	430.805[c]	5	86.161	16.252	.000
	Fasting loss	7.712[d]	5	1.542	30.176	.000
	Hot carcass weight	208.885[e]	5	41.777	9.880	.001
	Cold carcass weight	191.978[f]	5	38.396	12.136	.000
	Chilling lose	6.456[g]	5	1.291	.788	.578
	Hot carcass weight DP	54.731[h]	5	10.946	.533	.748
	Cold carcass weight DP	97.371[i]	5	19.474	.499	.772
	Total edible proportion	230.473[j]	5	46.095	7.165	.003
	Carcass length	341.778[k]	5	68.356	6.951	.003
	Leg length	100.684[l]	5	20.137	7.337	.002
	Rib-eye area	2.538[m]	5	.508	9.891	.001
	Fat thickness	.028[n]	5	.006	5.843	.006
	Half carcass weight	53.901[o]	5	10.780	11.950	.000
	Lean meat thickness	111.405[p]	5	22.281	3.305	.042
	Commercial yield cold carcass weight per slaughtered weight	97.371[i]	5	19.474	.499	.772
Intercept	Pre slaughter weight	23936.720	1	23936.720	6943.771	.000
	Slaughtered body weight	22204.269	1	22204.269	7342.951	.000
	Empty body weight at slaughtered body weight base	13827.845	1	13827.845	2608.207	.000
	Fasting loss	26.645	1	26.645	521.315	.000
	Hot carcass weight	5821.205	1	5821.205	1376.714	.000
	Cold carcass weight	5113.976	1	5113.976	1616.358	.000
	Chilling lose	469.201	1	469.201	286.486	.000
	Hot carcass weight DP	46675.309	1	46675.309	2271.120	.000
	Cold carcass weight DP	41731.517	1	41731.517	1068.886	.000

Appendix III Table 14 (Continued)

	Total edible proportion	7661.772	1	7661.772	1191.019	.000
	Carcass length	85422.222	1	85422.222	8687.006	.000
	Leg length	28068.702	1	28068.702	10227.462	.000
	Rib-eye area	70.694	1	70.694	1377.313	.000
	Fat thickness	1.095	1	1.095	1139.990	.000
	Half carcass weight	1396.561	1	1396.561	1548.151	.000
	Lean meat thickness	1641.645	1	1641.645	243.507	.000
	Commercial yield cold carcass weight per slaughtered weight	41731.517	1	41731.517	1068.886	.000
Breed	Pre slaughter weight	862.333	2	431.167	125.077	.000
	Slaughtered body weight	781.108	2	390.554	129.156	.000
	Empty body weight at slaughtered body weight base	393.490	2	196.745	37.110	.000
	Fasting loss	7.630	2	3.815	74.641	.000
	Hot carcass weight	195.510	2	97.755	23.119	.000
	Cold carcass weight	183.781	2	91.891	29.044	.000
	Chilling lose	1.788	2	.894	.546	.593
	Hot carcass weight DP	1.071	2	.536	.026	.974
	Cold carcass weight DP	.077	2	.038	.001	.999
	Total edible proportion	214.060	2	107.030	16.638	.000
	Carcass length	331.444	2	165.722	16.853	.000
	Leg length	89.524	2	44.762	16.310	.000
	Rib-eye area	2.376	2	1.188	23.143	.000
	Fat thickness	.022	2	.011	11.502	.002
	Half carcass weight	50.253	2	25.126	27.854	.000
	Lean meat thickness	49.723	2	24.862	3.688	.056
	Commercial yield cold carcass weight per slaughtered weight	.077	2	.038	.001	.999
Treatment	Pre slaughter weight	22.222	1	22.222	6.446	.026
	Slaughtered body weight	.889	1	.889	.294	.598
	Empty body weight at slaughtered body weight base	24.734	1	24.734	4.665	.052
	Fasting loss	.027	1	.027	.533	.480
	Hot carcass weight	8.681	1	8.681	2.053	.177
	Cold carcass weight	3.209	1	3.209	1.014	.334
	Chilling lose	4.601	1	4.601	2.809	.120
	Hot carcass weight DP	2.136	1	2.136	.104	.753
	Cold carcass weight DP	11.924	1	11.924	.305	.591
	Total edible proportion	9.347	1	9.347	1.453	.251
	Carcass length	2.000	1	2.000	.203	.660
	Leg length	4.302	1	4.302	1.568	.234
	Rib-eye area	.105	1	.105	2.055	.177
	Fat thickness	.001	1	.001	.792	.391

Appendix III Table 14 (Continued)

	Half carcass weight	3.001	1	3.001	3.327	.093
	Lean meat thickness	47.694	1	47.694	7.074	.021
	Commercial yield cold carcass weight per slaughtered weight	11.924	1	11.924	.305	.591
Breed * Treatment	Pre slaughter weight	1.658	2	.829	.240	.790
	Slaughtered body weight	14.088	2	7.044	2.329	.140
	Empty body weight at slaughtered body weight base	12.581	2	6.291	1.187	.339
	Fasting loss	.054	2	.027	.533	.600
	Hot carcass weight	4.694	2	2.347	.555	.588
	Cold carcass weight	4.988	2	2.494	.788	.477
	Chilling lose	.068	2	.034	.021	.980
	Hot carcass weight DP	51.524	2	25.762	1.254	.320
	Cold carcass weight DP	85.370	2	42.685	1.093	.366
	Total edible proportion	7.066	2	3.533	.549	.591
	Carcass length	8.333	2	4.167	.424	.664
	Leg length	6.858	2	3.429	1.249	.321
	Rib-eye area	.057	2	.029	.556	.588
	Fat thickness	.005	2	.003	2.710	.107
	Half carcass weight	.647	2	.324	.359	.706
	Lean meat thickness	13.988	2	6.994	1.037	.384
	Commercial yield cold carcass weight per slaughtered weight	85.370	2	42.685	1.093	.366
Error	Pre slaughter weight	41.367	12	3.447		
	Slaughtered body weight	36.287	12	3.024		
	Empty body weight at slaughtered body weight base	63.620	12	5.302		
	Fasting loss	.613	12	.051		
	Hot carcass weight	50.740	12	4.228		
	Cold carcass weight	37.967	12	3.164		
	Chilling lose	19.653	12	1.638		
	Hot carcass weight DP	246.620	12	20.552		
	Cold carcass weight DP	468.505	12	39.042		
	Total edible proportion	77.195	12	6.433		
	Carcass length	118.000	12	9.833		
	Leg length	32.933	12	2.744		
	Rib-eye area	.616	12	.051		
	Fat thickness	.012	12	.001		
	Half carcass weight	10.825	12	.902		
	Lean meat thickness	80.900	12	6.742		

Appendix III Table 14 (Continued)

	Commercial yield cold carcass weight per slaughtered weight	468.505	12	39.042		
Total	Pre slaughter weight	24864.300	18			
	Slaughtered body weight	23036.640	18			
	Empty body weight at slaughtered body weight base	14322.270	18			
	Fasting loss	34.970	18			
	Hot carcass weight	6080.830	18			
	Cold carcass weight	5343.920	18			
	Chilling lose	495.310	18			
	Hot carcass weight DP	46976.660	18			
	Cold carcass weight DP	42297.392	18			
	Total edible proportion	7969.440	18			
	Carcass length	85882.000	18			
	Leg length	28202.320	18			
	Rib-eye area	73.848	18			
	Fat thickness	1.134	18			
	Half carcass weight	1461.288	18			
	Lean meat thickness	1833.950	18			
	Commercial yield cold carcass weight per slaughtered weight	42297.392	18			
Corrected Total	Pre slaughter weight	927.580	17			
	Slaughtered body weight	832.371	17			
	Empty body weight at slaughtered body weight base	494.425	17			
	Fasting loss	8.325	17			
	Hot carcass weight	259.625	17			
	Cold carcass weight	229.944	17			
	Chilling lose	26.109	17			
	Hot carcass weight DP	301.351	17			
	Cold carcass weight DP	565.876	17			
	Total edible proportion	307.669	17			
	Carcass length	459.778	17			
	Leg length	133.618	17			
	Rib-eye area	3.154	17			
	Fat thickness	.040	17			
	Half carcass weight	64.726	17			
	Lean meat thickness	192.305	17			
	Commercial yield cold carcass weight per slaughtered weight	565.876	17			

Appendix III; Table 15. Genotype and feed type effect on non-carcass edible components.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Liver weight (g)	278728.500[a]	5	55745.700	3.219	.045
	Tongue weight (g)	7546.698[b]	5	1509.340	10.314	.001
	Heart weight (g)	39008.500[c]	5	7801.700	3.990	.023
	Kidney weight (g)	36203.111[d]	5	7240.622	2.444	.095
	GIT weight empty	821025.611[e]	5	164205.122	.502	.769
	Tail weight (g)	1312082.944[f]	5	262416.589	8.588	.001
Intercept	Liver weight (g)	4127064.500	1	4127064.500	238.341	.000
	Tongue weight (g)	235503.845	1	235503.845	1609.360	.000
	Heart weight (g)	174640.500	1	174640.500	89.315	.000
	Kidney weight (g)	163973.556	1	163973.556	55.354	.000
	GIT weight empty	58021582.722	1	58021582.722	177.547	.000
	Tail weight (g)	23322173.389	1	23322173.389	763.275	.000
Treatment	Liver weight (g)	6689.389	1	6689.389	.386	.546
	Tongue weight (g)	34.445	1	34.445	.235	.636
	Heart weight (g)	1200.500	1	1200.500	.614	.448
	Kidney weight (g)	18176.889	1	18176.889	6.136	.029
	GIT weight empty	18240.500	1	18240.500	.056	.817
	Tail weight (g)	57460.500	1	57460.500	1.881	.195
Breed	Liver weight (g)	228244.000	2	114122.000	6.591	.012
	Tongue weight (g)	7459.623	2	3729.812	25.488	.000
	Heart weight (g)	32908.000	2	16454.000	8.415	.005
	Kidney weight (g)	10333.778	2	5166.889	1.744	.216
	GIT weight empty	135764.778	2	67882.389	.208	.815
	Tail weight (g)	784070.111	2	392035.056	12.830	.001
Treatment * Breed	Liver weight (g)	43795.111	2	21897.556	1.265	.317
	Tongue weight (g)	52.630	2	26.315	.180	.838
	Heart weight (g)	4900.000	2	2450.000	1.253	.320
	Kidney weight (g)	7692.444	2	3846.222	1.298	.309
	GIT weight empty	667020.333	2	333510.167	1.021	.390
	Tail weight (g)	470552.333	2	235276.167	7.700	.007
Error	Liver weight (g)	207790.000	12	17315.833		

Appendix III Table 15 (Continued)

	Tongue weight (g)	1756.007	12	146.334
	Heart weight (g)	23464.000	12	1955.333
	Kidney weight (g)	35547.333	12	2962.278
	GIT weight empty	3921536.667	12	326794.722
	Tail weight (g)	366664.667	12	30555.389
Total	Liver weight (g)	4613583.000	18	
	Tongue weight (g)	244806.550	18	
	Heart weight (g)	237113.000	18	
	Kidney weight (g)	235724.000	18	
	GIT weight empty	62764145.000	18	
	Tail weight (g)	25000921.000	18	
Corrected Total	Liver weight (g)	486518.500	17	
	Tongue weight (g)	9302.705	17	
	Heart weight (g)	62472.500	17	
	Kidney weight (g)	71750.444	17	
	GIT weight empty	4742562.278	17	
	Tail weight (g)	1678747.611	17	

Appendix III; Table 16. ANOVA for breed and feed type effect on non-carcass non edible components

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Skin weight (g)	9944444.444[a]	5	1988888.889	10.199	.001
	Head weight (g)	2809644.444[b]	5	561928.889	10.294	.001
	Testicle and other genital organ (g)	.138[c]	5	.028	7.114	.003
	Blood Weight (g)	3252706.667[d]	5	650541.333	6.601	.004
	Bladder weight (g)	401.167[e]	5	80.233	5.140	.009
	Feet weight (g)	7759.778[f]	5	1551.956	1.932	.162
	Digestive content weight (g)	69300358.944[g]	5	13860071.789	8.784	.001
	Spleen weight (g)	613.111[h]	5	122.622	1.842	.179
Intercept	Skin weight (g)	296055555.556	1	296055555.556	1518.234	.000
	Head weight (g)	87737088.889	1	87737088.889	1607.233	.000
	Testicle and other genital organ (g)	2.645	1	2.645	680.143	.000
	Blood Weight (g)	34478208.000	1	34478208.000	349.832	.000
	Bladder weight (g)	77224.500	1	77224.500	4946.765	.000
	Feet weight (g)	880906.889	1	880906.889	1096.640	.000

Appendix III Table 16 (Continued)

	Digestive content weight (g)	587479216.056	1	587479216.056	372.328	.000
	Spleen weight (g)	25840.222	1	25840.222	388.250	.000
Treatment	Skin weight (g)	108888.889	1	108888.889	.558	.469
	Head weight (g)	12800.000	1	12800.000	.234	.637
	Testicle and other genital organ (g)	.005	1	.005	1.286	.279
	Blood Weight (g)	16683.556	1	16683.556	.169	.688
	Bladder weight (g)	.500	1	.500	.032	.861
	Feet weight (g)	5.556	1	5.556	.007	.935
	Digestive content weight (g)	156240.500	1	156240.500	.099	.758
	Spleen weight (g)	64.222	1	64.222	.965	.345
Breed	Skin weight (g)	9414444.444	2	4707222.222	24.140	.000
	Head weight (g)	2777211.111	2	1388605.556	25.438	.000
	Testicle and other genital organ (g)	.130	2	.065	16.714	.000
	Blood Weight (g)	3178396.000	2	1589198.000	16.125	.000
	Bladder weight (g)	240.333	2	120.167	7.698	.007
	Feet weight (g)	6899.111	2	3449.556	4.294	.039
	Digestive content weight (g)	65496248.111	2	32748124.056	20.755	.000
	Spleen weight (g)	360.111	2	180.056	2.705	.107
Treatment * Breed	Skin weight (g)	421111.111	2	210555.556	1.080	.371
	Head weight (g)	19633.333	2	9816.667	.180	.838
	Testicle and other genital organ (g)	.003	2	.002	.429	.661
	Blood Weight (g)	57627.111	2	28813.556	.292	.752
	Bladder weight (g)	160.333	2	80.167	5.135	.024
	Feet weight (g)	855.111	2	427.556	.532	.601
	Digestive content weight (g)	3647870.333	2	1823935.167	1.156	.347
	Spleen weight (g)	188.778	2	94.389	1.418	.280
Error	Skin weight (g)	2340000.000	12	195000.000		
	Head weight (g)	655066.667	12	54588.889		
	Testicle and other genital organ (g)	.047	12	.004		
	Blood Weight (g)	1182679.333	12	98556.611		
	Bladder weight (g)	187.333	12	15.611		
	Feet weight (g)	9639.333	12	803.278		
	Digestive content weight (g)	18934270.000	12	1577855.833		
	Spleen weight (g)	798.667	12	66.556		
Total	Skin weight (g)	308340000.000	18			
	Head weight (g)	91201800.000	18			
	Testicle and other genital organ (g)	2.830	18			
	Blood Weight (g)	38913594.000	18			
	Bladder weight (g)	77813.000	18			
	Feet weight (g)	898306.000	18			
	Digestive content weight	675713845.000	18			

Appendix III Table 16 (Continued)

	Spleen weight (g)	27252.000	18
Corrected Total	Skin weight (g)	12284444.444	17
	Head weight (g)	3464711.111	17
	Testicle and other genital organ (g)	.185	17
	Blood Weight (g)	4435386.000	17
	Bladder weight (g)	588.500	17
	Feet weight (g)	17399.111	17
	Digestive content weight (g)	88234628.944	17
	Spleen weight (g)	1411.778	17

Appendix IV. List of Supplementary Pictorial Data Representation

Appendix IV Figure 1.Wool production from Awassi F_1 crossbred lambs at smallholders' farm.

Appendix IV Figure 2. Smallscale farmers making womens’ bag from sheep wool and hair

Appendix IV Figure 3. Researcher measuring on-farm monitoring of lamb body weight.

Appendix IV Figure 4. On-farm smallholder sheep feed supplementation management system.

Appendix IV Figure 5. Awassi private sheep multiplication and distribution center.

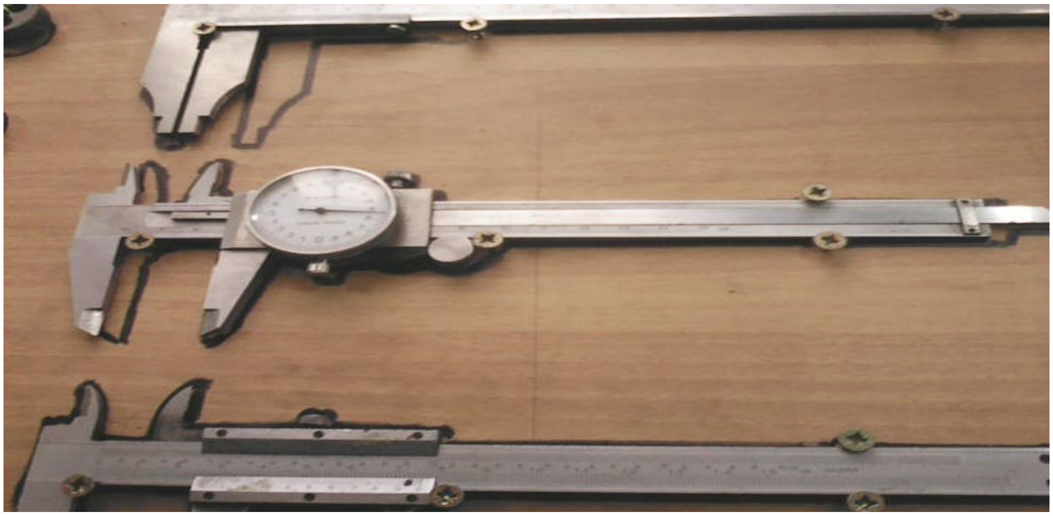
Appendix IV Figure 6. Smallholder farmers purchasing sheep manure from private Awassi sheep multiplication center for crop fertilizer.

Appendix IV Figure 7. Attendants visiting smallscale sheep producers' flock.

Appendix IV Figure 8. Washera rams and Wollo highland ewes crossbreeding area.

Appendix IV Figure 9. Experimental animals grazing in controlled natural pasture.

Appendix IV Figure 10. Experimental animals grazing area grass composition.



Appendix IV Figure 11. Lean meat and fat thikness measuring caliper.

Appendix IV Figure 12. Smallholder sheep producers observing experimental animals.

Appendix V. Figure 1. list of publication

1. Tadesse Amare, Gebeyehu Goshu and Berhan Tamir (2017). Reproductive Performance and Farmer's Traits of Interest and Selection Criterion Studies of Wollo Highland Sheep and Their F1 Crossbreed Progenies, *Canadian Journal of Scientific Research* 6(2): 23-37, 2017.

2. Tadesse Amare, Gebeyehu Goshu and Berhan Tamir (2018). Flock Composition, Breeding Strategies and Farmers' Traits of Interest Evaluation of Wollo Highland Sheep and Their F_1 Crosses, *Journal of Animal Science and Technology* (JAST) 60:14: https://doi.org/10.1186 /s40781-018-0173-9.

3. Smallholder Farmers' Sheep production's Traits of Interest, Breeding Ram and Ewes Selection Criteria and Reproductive Performance Evaluation of Wollo Highland Sheep and Their F_1 Crossbreeds, (Accepted, Ref No, BMC, ASTJ-D-17-00090R1) https://janimscitechnol.biomedcentral.com/.

4. Lamb Growth Performance Evaluation of Wollo Highland Sheep and Their F1 Crossbreds on Smallholder farm in South Wollo, Ethiopia (*Review completed*) https:// trop.editorialmanager.com/.

5. On-station body weight gain and carcass characteristics comparison of Wollo highland breed and their F1 crossbreds (on-going) https://janim scitechnol.Biomedcentral.com/.

Appendix V. Researcher recognition for smallholders practical training given

Appendix V Figure 1. Researcher recognition letter for practical training given for smallholders farmers.

የምስክር ወረቀት

ለተመራማሪ ታደሰ አማረ

ከ2008 ዓ.ም ጀምረው በቀበሌያችን በተለያ የበግ ዝርያዎች ላይ በመመራመርና ውጤቱን ለአካባቢው ህብረተሰብ በማሳወቅ ልዩነታቸውን ለአርሳደሮችና ሙያተኞች ስልጠና አዘጋጅተው በመስጠት በአርሶ አደሩና በሙያተኛው ላይ ከፍተኛ ግንዛቤ በመፍጠር እንዲሁም የሴቶችና ወጣቶች የሥራ እድል ለመፍጠር ከወሎ ኒቨርሲቲና ከቀበሌው ጎን በመሆን ፕሮጀክት በመቅረጽ ስልጠና በመስጠት እንዲሁም የማሰልጠኛ ማዋሎችን በማዘጋጀት ሴቶችና ወጣቶችን ተጠቃሚ እንዲሆኑ በማድረግ ከፍተኛ ድርሻ የነበረዎት በመሆኑ ይህን የምስክር ወረቀት ከታላቅ ምስጋናና አክብሮት በቀበሌው ስም ሰተናቸዋል

የ13 ቀበሌ አስተዳዳሪ
መሀመድ ሁሴን

የ013 ግብርና ፅ/ቤት ኃላፊ
ጥላሁን ግዛኸኝ

የምስክር ወረቀት

ለተመራማሪ ታደሰ አማረ

ከ2008 ዓ.ም ጀምረው በቀበሌያችን በተለያ የበግ ዝርያዎች ላይ በመመራመርና ውጤቱን ለአካባቢው ህብረተሰብ በማሳወቅ ልዩነታቸውን ለአርሳደሮችና ሙያተኞች ስልጠና አዘጋጅተው በመስጠት በአርሶ አደሩና በሙያተኛው ላይ ከፍተኛ ግንዛቤ በመፍጠር እንዲሁም የሴቶችና ወጣቶች የሥራ እድል ለመፍጠር ከወሎ ኒቨርሲቲና ከቀበሌው ጎን በመሆን ፕሮጀክት በመቅረጽ ስልጠና በመስጠት እንዲሁም የማሰልጠኛ ማዋሎችን በማዘጋጀት ሴቶችና ወጣቶችን ተጠቃሚ እንዲሆኑ በማድረግ ከፍተኛ ድርሻ የነበረዎት በመሆኑ ይህን የምስክር ወረቀት ከታላቅ ምስጋናና አክብሮት በቀበሌው ስም ሰተናቸዋል

የ12 ቀበሌ አስተዳዳሪ
ይማም ደምሴ

የ012 ግብርና ፅ/ቤት ኃላፊ
አይተነው መከተ

WOLLO UNIVERSITY

Certificate of Participation

This Certificate is awarded to **Tadesse Amare Sisay** in recognition of his successful community service training he delivered on **"Sheep fattening techniques training for joless youngsters in Boru Meda (Kebele 013) & Kurkur(kebele 012) in Dessie Town"** on 27 Feb.2017 – 07 March 2017.

Gashaw Ferede (PhD)