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MANAGEMENT PRACTICE OF FARMERS', REPRODUCTIVE TRAITS AND PRODUCTIVE POTENTIAL OF SELECTED INDIGENOUS GOAT BREEDS IN NORTH ETHIOPIA

PhD Dissertation

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Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

PhD Program in Animal Production

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Bishoftu, Ethiopia

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A Dissertation Submitted in Partial fulfillment of the Requirements for the Degree of Doctor of Philosophy in Animal Production

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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: Theodros Tekle Melke Tsadik entitled Management Practice of Farmers', Reproductive Traits and Productive Potential of Selected Indigenous Goat Breeds in North Ethiopia and recommend that it be accepted as fulfilling the Dissertation requirement for the degree of: Doctor of Philosophy in Animal Production.

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BIOGRAPHIC SKETCH

Theodros Tekle was born on 14 February, 1961 E.C from his mother Mulu Legesse in Addis Ababa town. His school life started at Goba elementary school, then continued in Dodolla/Bale where he successfully completed Ethiopian School Leaving Certificate Examination. Then he got the chance to join Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. His academic development at the then Faculty of Veterinary Medicine (FVM) was successfully completed after working on a thesis entitled '*Diseases and health problems of camels in the southern rangelands: Borena'* for the attainment of Degree of Doctor of Veterinary Medicine (DVM) in July 1995. His working experience as Veterinarian started in the southern rangelands of Borena where he worked for 3 years as employee of Oromia Agricultural Bureau. Then he moved Filtu distrct, Liben zone of Somali region to work as veterinary expert and livestock sector head of the international NGO, COOPI (Cooperazione Internazionale) and local NGO, PCAE (Pastoralists Concern association Ethiopia), respectively. After 6 years of stay in the southern pastoral areas, he joined the horse health and welfare project at College of Veterinary Medicne, Bishoftu funded by SPANA where he worked as an equine clinician for 1.5 year. Then he went back to COOPI Ab'Ala field office, in Zone Afar, Afar to work as Project Manager. After 1 and ½ years of stay in Ab'Ala, Theodros was promoted to COOPI head quarter at Addis Ababa where he worked as Assistant Program Support and Assistant Project Manager of the Pastoralist Livelihood Initiative Program implemented in Telalak woreda, in Zone Five, Afar. Finally, he shifted to Faculty of Veterinary Sciences, Mekelle University to work as a lecturer and worked as an academic vice dean from June 2008 to October 2008 before joining the MSc program in Livestock Production and Pastoral Development offered at the Department of Animal, Rangeland and Wild Life Sciences, College of Dryland Agriculture and Natural Resources, Mekelle University. He has successfully complteted his MSc program with MSc Thesis research entitled 'Management and Performance of Camels (*Camelus dromedarius)* in the Pastoral and Agro-pastoral areas of North Afar'. Since August 2011, he has been pursuing his PhD study in Animal Production, at Department of Animal Production Studies, College of Veterinary Medicine and Agriculture, AAU.

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Finally, my special thanks is deserved to my mother (Mulu Legesse), my wife Selam Tadesse and my beloved daughters (Natanehem and Fasika); my beloved brothers (Getu Dheko, Abdulkerim Hassen and Abdulbasit Hassen) and my sister Elsa Tesfaye.

LIST OF ABBREVIATIONS

AIC	Akaike information criterion
AILD	Abergelle International Livestock Development
ANOVA	Analysis of variance
BCS	Body condition score
BL	Body length
BoPARD	Bureau of Pastoral, Agro-Pastoral and Rural Development
BW	Body weight
C (p)	Conceptual predictive criterion
CHG	Central-Highlands goat
CSA	Central Statistical Agency
DP	Dressing percentage
EARO	Ethiopian Agricultural Research Organization
EWt	Epididymal weight
FAO	Food and Agricultural Organization of the United Nations
FEMLE	Focus on Ethiopia's Meat and Live Animal Export
GLM	General linear model
HAW	Height at withers
HCW	Hot carcass weight
HG	Heart girth
HH	Household
LBMs	Linear body measurements
LSM	Least square mean
MM	Mass motility
PM	Progressive motility
PPI	Pair of permanent incisors
PW	Pelvic width
R^2	Coefficient of determination
RMSE	Root mean square error
SC	Scrotal circumference

LIST OF ABBREVIATIONS (Continued)

TC	Testicular circumference
TL	Testicular length
TV	Testicular volume
TWd	Testicular width
TWt	Testicular weight

DEDICATION

This thesis is dedicated

To

My beloved mother, Mulu Legesse

and

My late uncles Tesfaye Legesse and Kidanemariam Legesse.

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MANAGEMENT PRACTICE OF FARMERS', REPRODUCTIVE TRAITS AND PRODUCTIVE POTENTIAL OF SELECTED INDIGENOUS GOAT BREEDS IN NORTH ETHIOPIA

Theodros Tekle MelkeTsadik
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ABSTRACT

Studies were undertaken from December 2014 to June 2015, aimed at assessing the management practice and constraints of Afar and Central-Highlands goats (CHG); the reproductive traits and meat production potential of bucks of Abergelle, Afar and CHG which originated from traditional systems in north Ethiopia. In the cross sectional survey, pastoral system of Yallo district (Afar) and mixed crop-livestock system of Raya Azebo district (Tigray) were visited in order to assess the management practice and constraints of goat production. Studies on scrotal and testicular traits, linear body measurements (LBMs) and meat production potential were undertaken at Abergelle slaughterhouse, through recording of breed, age, body condition score, body weight (BW), scrotal circumference (SC) and LBMs as well as teticular traits, quality attributes of sperm recovered from tail of epididymis and hot carcass weight (HCW) taken after slaughter. In addition, dressing percentage (DP) was computed using BW and HCW. Descriptive statistics, chi square, rank analysis, analysis of variance and regression analysis were the statistical tools used to analyze the data. The survey showed goats to be highly preferred species kept for milk production and as source of income in Yallo and Raya Azebo districts, respectively. Goats were provided with differing type of shelter across the systems. In both systems, the traditional goat rearing practice was mainly based on naturally available feed resources with feed scarcity very common in the mixed farming system of Raya Azebo. Buck ownership varied with production system, in both systems mating was partially controlled through selection of breeding males. Milk production potential of the dam in Yallo and body size in Raya Azebo district were important buck selection criteria. Both production systems were faced with more or less similar constraints. A wider scrotal and testicular circumference as well as testicular and epididymal weights were recorded in bucks of CHG. Subsequently, CHG had a relatively good sperm quality in terms of motility, percent live, concentration with fewer morphological defects. The correlation between BW, SC and testicular traits was not uniform across the study bucks. Compared to BW, SC had better correlation with post-mortem testicular traits. Age had significant effect on LBMs (heart girth, height at withers, body length and pelvic width), BW, HCW and DP. Though bucks of CHG and Abergelle breed had comparable HCW, most of the LBMs and BW were higher in bucks of CHG. Dressing percentage of 44.8 %; 43.8 % and 43.7 % were recorded in Abergelle, Afar and CHG bucks, respectively. Models set for predicting HCW of bucks of Abergelle and CHG at age of 2 PPI and Afar bucks at age category of 0 PPI and 1 PPI were best explaining the variation in HCW compared with models set for predicting HCW of bucks of other age categories of their respective breed. Models set for predicting DP of bucks of Abergelle at age category of 1PPI; Afar at age category of 0 PPI and 2 PPI and CHG at age category of 0 PPI were best explaining the variation in DP compared with models set for predicting DP of bucks of other age categories of their respective breed. In order to improve performance of indeginous goat breeds, data on the management practice and the constraints, current reproductive and productive potential of goat breeds is required. The models set for predicting HCW and DP of the study bucks would be useful for selecting bucks for better meat production. Similar studies involving bucks at older age and all the indeginous goat breeds in Ethiopia are required.

Keywords: body and carcass weight; dressing percentage; gamate rescue; indigenous goats; linear body measurements, scrotal and testicular traits; regression models; Ethiopia

1. INTRODUCTION

The domestic goat (*Capra hircus*) is a multi-purpose and economically important livestock species, playing an important role on the economy and nutrition of resource poor farmers in developing countries (Khan *et al*., 2006). Goat production is an integral component of the agricultural sector in Ethiopia (Gizaw, 2008; Legesse, 2008). With an estimated goat population of 29.1 million (CSA, 2015), Ethiopia is home to diverse goat genetic resources. Ethiopian goats are grouped into eleven breeds/populations based on physical characteristics (FARM-Africa, 1996) and into eight breeds/populations on the basis of DNA or molecular characterization (Alemu, 2004).

Goats are kept by a larger part of the Ethiopian rural communities in the mixed crop-livestock, agro-pastoral and pastoral systems (Kebede *et al*., 2012). The goat contributes to the livelihood and food security of its owners directly as source of milk and meat and indirectly as source of income (Tadesse *et al*., 2014). The importance of goats as source of milk, meat, income, means of saving and investment, buffer system against natural calamities as well as their cultural and religious role at household (HH) level and their contribution to the national economy of Ethiopia as a means of generating hard currency through export of live goats, meat and skin is well recognized (Sebsibe, 2006; Hirpa and Abebe, 2008; Mekasha *et al*., 2008; FAO, 2009; Tadesse *et al*., 2014).

The indigenous goat breeds have great potential to contribute to the livelihood of people in the mixed crop-livestock, agro-pastoral and pastoral production systems (Kosgey and Okeyo, 2007; Legesse, 2008). According to Kebede *et al.* (2012), in order to increase the contribution of goats to the Ethiopian economy in general and to the livelihood of goat owners at all goat production systems in particular, improvement of performance through design of suitable breeding scheme would be required.

The demand for live goats or their meat (chevon) both for domestic consumption and national export earnings is increasing (Sebsibe, 2006). Such increasing demand is leading to a need for a change in the importance and scale of goat production whereas making use of such opportunity requires overcoming many barriers to the performance of goats in order to cope up with the competitive carcass quality demands at the international as well as specific export-markets (Sebsibe, 2006).

Despite the diverse and large size of Ethiopia’s goat population, the reproductive and productive potential of indigenous goat breeds in Ethiopia is generally low (Tsegahun *et al*., 2000) due to many factors which include low performing genotypes (EARO, 2000; Toe *et al*., 2000; Ayalew and Rowlands, 2004; Tibbo, 2006; Legesse, 2008; Abebe, 2008; Gizaw *et al*., 2011), absence of deliberate selection programs (EARO, 2000; Toe *et al*., 2000; Ayalew and Rowlands, 2004; Legesse, 2008; Abebe, 2008) and poor management practice (Gizaw *et al*., 2011). Poor fertility of breeding males is also indicated as a major constraint (McGowan, 2004; Mekasha, 2007).

The indigenous goat breeds in Ethiopia are found widely spread across diverse agro-ecologies, communities and production systems (Alemu *et al*., 2004; Legesse, 2008). Production environment and management practice are known to influence the performance of farm animals including goats (Legesse, 2008). Hence, an understanding of the existing diversity in goat management practice would help to identify constraints and opportunities for sustainable goat production (Legesse, 2008). Attempts to improve performance under the prevailing management practice must take into consideration the purposes of keeping goats in each production system and their performance potential under varying management level (Legesse, 2008).

In order to design sustainable genetic improvement schemes, a clear understanding of the management and breeding practice is required (Mbuku *et al*., 2006). The indigenous knowledge of farmers on goat management and breeding practice in the different production systems, which are based on diversified breeding objectives, would be an essential input (Ayalew *et al*., 2003). Description of the goat management practice is particularly relevant in developing regions where farm animals are kept under diverse agro-ecologies and for multiple purposes (Legesse, 2008).

A production system approach in goat research and development is expected to give better results since it takes into account the resource endowment of each system and its relative capability for improvement (Otte and Chilonda, 2003). A study based on production system is particularly useful for identifying possible intervention areas for improving performance within a particular system and scale-up the results to similar production system elsewhere (Legesse, 2008). Recognizing the peculiarities of a production system will positively contribute to the success of genetic improvement programs (Legesse, 2008). Analysis of the production constraints is also important for understanding the trends and status of the existing production systems in order to design appropriate interventions for improving the productivity and income from goats (FAO, 2012).

Genetic improvement strategies are being advocated (Kahi *et al*., 2005) as a means for improving the performance of livestock including goats. Selective and cross breeding are the two widely employed genetic improvement strategies (Abegaz and Awgichew, 2008). Selective breeding is based on identification of best performing breeds and individual animals within breeds. Selective breeding would help to breed best animals which are able to achieve the body weight (BW) and carcass yield required at a younger age (Sebsibe, 2006). According to Gizaw (2008), selective breeding can lead to significant genetic improvement and productivity under low-input systems and marginal environments.

Screening of bucks intended for breeding purpose is essential so as to improve the reproductive performance of a flock (Mekasha *et al*., 2008). Identification of males with superior reproductive potential requires breeding soundness evaluation (BSE) (Rege *et al.*, 2000; Toe *et al.*, 2000; Abegaz and Awgichew, 2008). Measurement of biometric parameters such as BW, scrotal circumference (SC) and post-mortem testicular traits is an essential component of breeding soundness evaluation (Mekasha *et al*., 2008; Agga *et al*., 2011; Ajani *et al*., 2015). Because of its strong correlation with BW and reproductive capacity (libido), particularly with sperm production (Brito *et al*., 2004), SC is widely employed criteria in breeding soundness evaluation. However, measurement of SC should not be used as the only criteria and should be supplemented with measurement of body and post-mortem testicular traits and sperm quality analysis, using sperm collected either from live animals or recovered from tail of epididymis at post- mortem (Mekasha *et al*., 2007). Evaluation of the motility [%], proportion of live/dead [%] and morphological abnormalities of spermatozoa are some of the commonly employed methods in the prognosis of male infertility under field condition (Alm-Packalén, 2009).

Body size, post-mortem testicular traits and the quality attributes of spermatozoa are influenced by many factors such as breed, age, nutritional status, season, climatic factors and pathologic conditions (Bielli *et al*., 2000; Dana *et al*., 2000; Karagiannidis *et al*., 2000; Rege *et al*., 2000; Toe *et al*., 2000; Mekasha *et al.*, 2008). Breed and nutrition are known to influence SC, testicular traits, the concentration and motility of spermatozoa in indigenous goat breeds of Ethiopia (Mekasha *et al*., 2007). According to Attah *et al*. (2004), breed, sex and body size expressed as BW are some of the factors which influence the body and carcass linear measurement traits to various degrees in goats. Age has also been reported to significantly affect different body parameters (Rahman, 2007) as weight and other body measurements increase with age (Sebolai *et al.,* 2012). Gut fill can have a large effect on DP while most morphometric measurements taken at one stage of growth or the other are highly correlated with empty BW (which excludes the gastro-intestinal tract contents) or DP (Attah *et al*., 2004).

The meat production potential of animals can be assessed by using such parameters like morphometric traits, BW, hot carcass weight (HCW) and dressing percentage (DP) (Dzakuma *et al*., 2004). Body weight and linear body measurements (LBMs) such as height at withers (HAW), heart girth (HG) and body length (BL) can be used to select goats for meat production. Assessment of the current productive potential of goats provides baseline data against which the success of future interventions will be measured (Legesse, 2008).

Review of literature on goat research in Ethiopia reveals that most of the research efforts were mainly based in the central, southern and eastern parts/highlands of the country as evidenced by the few studies (Sebsibe, 2006; Gidey, 2008; Ebrahim and Hailemichael, 2012; Deribe and Taye, 2013; Seid and Tesfay, 2014) targeted to goat breeds in north Ethiopia. So far, information on the reproductive traits of bucks of Afar, Boran, Woito-Guji (Mekasha *et al.*, 2008; Agga *et al.*, 2011), Arsi-Bale and Central-Highlands goat (Mekasha *et al.*, 2008) goat breeds raised under extensive husbandry system has been generated taking various age categories. In addition, data on the morphological attributes of sperm collected from tail of epididymis of bucks of five goat breeds (Afar, Boran, Woito-Guji, Arsi-Bale and Central-Highlands goat) was generated by Mekasha *et al*. (2007).

Considering the diverse goat genetic resource base found in Ethiopia, there is limited information on the management practice, scrotal and testicular traits as well as the linear body measurements and meat production potential of bucks of goat breeds indigenous to Ethiopia. To this end, information on the purpose/s of goat keeping, the management practice and the constraints of goat production in relation to production system; the scrotal and testicular traits as well as the linear body measurements and meat production potential of goat breeds under farmer's management practice in relation to age has not been adequately documented, especially for Abergelle, Afar and Central-Highlands (CHG) goat breeds in north Ethiopia. In addition, models for predicting HCW and DP of goat breeds indigenous to Ethiopia are lacking.

Knowledge on the purpose/s of goat keeping and the management practice, scrotal and testicular traits as well as the linear body measurements and meat production potential of indigenous goat breeds is useful to select for increased re/productive efficiency, designing appropriate breed-improvement plan and conservation of genetic biodiversity (Mekasha *et al*., 2008).

In this study it was hypothesized that: the purpose/s of keeping and the management practice of goats do not vary with production system with additional hypothesis that breed and age have no influence on scrotal and testicular traits as well as linear body measurements and meat production potential of indigenous goat breeds in north Ethiopia.

The general objective of the study was to assess: the purpose/s of keeping goats, the management practice, scrotal and testicular traits as well as linear body measurements and meat production potential of selected indigenous goat breeds in north Ethiopia.

The specific objectives of the study were to:

1. Assess the purpose/s of goat keeping, management practice and the constraints of goats kept under pastoral production system of Yallo district (Afar goat, Afar region) and mixed crop-livestock farming system of Raya Azebo district (CHG, Tigray region),

2. Describe the scrotal and post-mortem testicular traits and quality attributes of sperm recovered from tail of epididymis of Abergelle, Afar and Central-Highlands goat breeds taking three age categoriesin and

3. Generate data on LBMs, BW, HCW and DP of Abergelle, Afar and Central-Highlands goat breeds taking three age categories and develop models for predicting HCW and DP.

2. LITERATURE REVIEW

2.1. Goat Production Systems and Constraints in Ethiopia

2.1.1. Goat production systems

The indigenous goat breeds in Ethiopia are reared in a wide range of agro-ecological zones, management and production systems mainly because of their environmental adaptability (Aune *et al.*, 2001; Hirpa and Abebe, 2008; Legesse, 2008).

According to Legesse (2008), small ruminant production systems in Ethiopia are classified into two major categories namely as traditional and modern. In the traditional system, sheep and goats are kept as an adjunct to other agricultural activities along with other livestock species. On the other hand, modern small ruminant production system refers to an emerging sheep and goat rearing practiced in the urban and peri-urban centres (Taye and Abebe, 2000; Tegegne, 2004; Legesse, 2008).

A detailed account of the goat production systems in Ethiopia is given by Abegaz *et al*. (2014) and three major goat production systems were identified. The first is goat production in the mixed crop-livestock farming system, the second refers to pastoral and agro-pastoral goat production and the last category refers to urban and peri-urban goat production system.

2.1.1.1. Goat production in the mixed crop-livestock farming system

Such goat production system is commonly practiced in the mixed crop-livestock farming system where goats are an important component of the system mainly kept as a source of cash and meat (Alemu, 2004). In the mixed crop-livestock farming system, goats are kept in small flocks (Alemu, 2004; Peacock, 2005; Tibbo, 2006). Because of increasing human population, declining landholding and shrinking grazing land in the mixed crop-livestock farmimg systems, the relative importance and population of goats is increasing (Ayalew, 2000). In this sytem, milk production from goats is an important product (Takyi, 2008) along with kid growth which increases income from sale of growers. Major feed resources in such system include natural pasture, crop residues, industrial by-products and in some localities tree legumes in cut and carry system (Nigussie, 2010; Tsegaye, 2011; Fantahun, 2012; Urgessa *et al*., 2012). During the crop growing season and in some localities, animals are tethered (Nigussie, 2010) whereas in other places goats are kept freely or herded on the grazing land (Gemiyu, 2009; Fantahun, 2012). In most areas, water is available throughout the year and it is not considered as a limiting factor (Abegaz *et al*., 2014).

2.1.1.2. Pastoral and agro-pastoral goat production system

Pastoral and agro-pastoral goat production system is common to the lowlands and some mid-altitude areas. The system is based on extensive management system where milk production is an important product from goats (Takyi, 2008). Flock size is very large (Tibbo, 2006; Gebreyesus, 2010; Misbah, 2013) and feeding is predominantly on communal rangelands and water availability is usually a limiting factor (Gebreyesus, 2010). In this system, there is growing opportunity to increase goat production and productivity driven by expanding live animal and meat export markets (Abegaz *et al*., 2014).

2.1.1.3. Urban and peri-urban goat production system

As the name implies, this goat production system is commonly practiced in the urban and peri-urban centers throughout Ethiopia. A reliable quantitative data on such goat production system is lacking but it is common to observe goats (and sheep) in urban and peri-urban areas including the capital, Addis Ababa (Abegaz *et al*., 2008). In addition, small-scale sheep fattening is emerging as an important economic activity in many cities/towns of the country (Abegaz *et al*., 2014).

With the expansion of use of khat (*Catha edulis*) in almost all parts of the country, goats frequently serve as 'cleaners' of the leftovers (Abegaz *et al*., 2014). Feed resources are usually house hold and market area wastes, mill leftovers, by-products and road-side grazing (particularly in the peri-urban system). The viability of such goat production system depends on its acceptance into the formal extension services. The system could either be a high input / high output or low input / low output system. Information on the goat population, their economic role, the associated value chains and the environmental impact needs to be explored (Abegaz *et al*., 2008).

2.1.2. Constraints of goat production

Productivity of goats in Ethiopia is constrained by a number of factors (Tibbo, 2006; Hirpa and Abebe, 2008; Legesse, 2008). According to Legesse (2008), goat production constraints are categorized into two as macro and HH level constraints. At macro-level the goat production constraints include the recurrent droughts which occurred in the mid 1970s and 1980s and at the beginning of this century (Belay *et al*., 2005). Detailed account of the constraints of goat production at HH level is given by Tibbo (2000) and (2006); Kocho (2007), Hirpa and Abebe (2008) and Abegaz *et al*. (2014) as described below.

Low production potential (Tibbo, 2000; Kocho, 2007) and lack of appropriate breeding programs (Abegaz *et al*., 2014) are limiting long-term genetic improvement of goat production in Ethiopia. Feed shortage (both in quantity/availability and quality) (Tibbo, 2006; Mekasha *et al*., 2008; Gizaw *et al*., 2011) and seasonal fluctuations in feed resources (Gizaw *et al*., 2011) were reported as important factors hampering the productivity of goats in many parts of Ethiopia. In the highlands, grazing resources are diminishing due to expansion of cropping whereas bush encroachment and overgrazing has reduced the potential of the rangelands in the low lands (Desta and Oba, 2004; Tibbo, 2000, 2006; Kocho, 2007; Hirpa and Abebe, 2008).

High morbidity and mortality rates recorded in kids are the other constraints which are ascribed to widespread presence of a variety of goat diseases (Tibbo, 2000; Githiori *et al*., 2004; Tibbo, 2006; Kocho, 2007; Gizaw *et al*., 2011). The major goat diseases in Ethiopia include anthrax, sheep (goat) pox, *peste des petits ruminants*, fascioliasis, pasteurellosis, respiratory diseases (contagious caprine pleuro pneumonia) (Abegaz *et al*., 2014), foot and mouth disease, blue tongue, foot rot, babesiosis, anaplasmosis, trypanosomiasis, internal and external parasites. The widespread presence of diseases is further complicated by inadequate veterinary service coverage (Hirpa and Abebe, 2008). At times, certain disease conditions are also causing Ethiopian goats and their products to be banned from export markets (Hirpa and Abebe, 2008).

Poor marketing infrastructure is the other constraint affecting goat production (Tibbo, 2000; Kocho, 2007). The infrastructure necessary to transport livestock/goats or their products from remote rural areas where production is concentrated to market sites often at urban centers, which are often located at far distance, is lacking. The common practice is that animals are trekked long distances in search of feed and water and also for marketing, often without adequate supply of water and feed (Tibbo, 2000). Long marketing channels and lack of market information are also reported as common problems. Low product quality is the other constraint which prevents penetration into many export markets (Hirpa and Abebe, 2008).

In general, in Ethiopia goat production is not market oriented which would have been an important driving force for increased productivity (Halderman, 2004; Tibbo, 2006; Hirpa and Abebe, 2008). Absence or inadequate provision of credit service is also a common problem as livestock owners have difficulty to access credit to begin or expand their goat business and to purchase inputs. Lack of trained personnel, absence of record keeping, inadequate utilization of indigenous breeds, poor research and extension system are also indicated as important constraints of goat production (Tibbo, 2006). Uncontrolled grazing management and inappropriate land use system (tenure), water shortage, predation

(Tibbo, 2000; Kocho, 2007) and harsh environmental conditions (Tibbo, 2006) were also mentioned as important factors affecting goat production in Ethiopia.

2.2. Trends in Goat Production

Goat production is gaining increasing importance in the developing countries (Mekasha, 2007). Smallholder farmers in the mixed crop-livestock system, agro-pastoralists and pastoralists are realizing the importance of goats and relying more and more on goats. The increasing demand for goat meat has increased their importance in the agro-pastoral and pastoral areas as a source of cash income, food security and other benefits from goats (Hirpa and Abebe, 2008). A detailed account of the trends in goat production is given by Peacock (2005). According to the same author, livestock production systems are dynamic, constantly evolving with changing internal and external circumstances. For instance, in the agro-pastoral and pastoral areas prevalent in the arid and semi-arid lowlands, goats are kept nearly by all families, often in mixed flocks with sheep. In such systems, drought appears to be increasing in frequency with subsequent shift from cattle to camel and/or goat keeping, as it has happened in Afar region of Ethiopia (Peacock, 2005). Similarly, the highland areas of Ethiopia which are basically crop-livestock system are under stress because of shrinking cultivated land per HH, reduced feed availability and land degradation (Aune *et al.*, 2001). As a result, raising large ruminants is becoming increasingly difficult because of the ensuing lack of grazing land. This situation has increased the contribution of goats in the crop-livestock system in the highlands (Legesse, 2008).

There are many reasons for increasing trend towards goat keeping which are mainly attributed to special features of goats. Special features of goats which are often associated with higher production efficiency include small size with small space and capital requirement, lower feed/nutrient requirement and higher survival rates during drought conditions. As compared to large ruminants, goats have shorter production cycle, faster growth rate and greater environmental adaptability (Aune *et al.*, 2001; Hirpa and Abebe, 2008). For instance, in a study conducted by Desta and Oba (2004) in southern Ethiopia, it was noted that during seasons of feed scarcity, cattle suffered a higher mortality as compared to small ruminants. The short generation interval of goats coupled with high frequency of multiple births allows a rapid increase in animal numbers, which in turn builds financial capital through sale of surplus animals that can be immediately used in times of HH needs (Hirpa and Abebe, 2008). Very often, there are no banking facilities in remote rural areas and an easy way to store wealth for future needs is through rearing and building of flocks of goats and sheep. Hence, small ruminants have been described as 'village bank' in some rural areas (Hirpa and Abebe, 2008). In summary, goats have a unique niche in Ethiopian agriculture (Tibbo, 2006) as goats can be integrated easily into different farming systems (Hirpa and Abebe, 2008).

2.3. Contribution of Goats to Food Security and National Economy

The domestic goat plays an important socio-economic role (Mekasha, 2007). It is an important source of protein in the diets of the poor as well as income, supporting the survival of many people in the tropics and sub-tropics (Tibbo, 2006). The relative importance of the benefits from goats varies from area to area and is largely determined by socio-cultural and economic factors (Legesse, 2008). The contribution of goats to the wellbeing of people in terms of food (milk and meat), income, savings, as insurance against emergencies and their traditional (cultural) value is well known (Dibissa, 2000). Goats are also a source of other non-food products such as skin and manure (Abegaz *et al*., 2014) which are useful by-products. The socio-economic services from goats include cash income, security, gifts, loans, religious rituals and judicial role (Hirpa and Abebe, 2008). Goats play also a vital role in terms of asset creation for the HHs that can afterwards be used in times of need, such as during periods of drought, thereby increasing the sustainability of HH food security. In addition, goats have important role in the control of bush encroachment (Hirpa and Abebe, 2008).

The increasing domestic and international demand for goats, their meat and skin has also established them as important source of in-land revenue as well as foreign currency (Hirpa and Abebe, 2008). Goats together with sheep contribute a quarter of the domestic meat consumption; about 40% of fresh skin and 92% of the value of semi-processed skin and hide export trade (Hirpa and Abebe, 2008). There is also a growing export market for goat meat in the Middle Eastern Gulf States and some African countries. In general, the increasing demand for goats or their meat creates an opportunity to substantially improve food security and contribute to poverty alleviation (Hirpa and Abebe, 2008).

2.4. Performance of Indigenous Goat Breeds under Traditional Management System

The indigenous goat breeds in Ethiopia are characterized by varying physical, reproductive and productive potential (Awgichew and Abegaz, 2008). According to Tsegahun *et al*. (2000), the indigenous goat breeds evolved through a process of natural selection that favored adaptation and survival rather than productivity. Characterizing the re/productive traits of bucks of indeginous goat breeds is important for elucidating their re/productive potential and as an input for the design of appropriate strategies to improve fertility (Mekasha, 2007). The fact that Ethiopia has diverse goat breeds, agro-ecology and goat production systems indicates that undertaking such characterization under prevalent husbandry patterns would provide a benchmark for genetic improvement and biodiversity conservation (Mekasha, 2007). Evaluation of the linear body traits and meat production potential of goats can be used as useful criteria for selection of goats for meat production (Rahman *et al*., 2008).

2.4.1. Reproductive potential of indigenous goat breeds

Livestock production in the tropics is hampered by low fertility of breeding stock (McGowan, 2004; Mekasha, 2007). Body weight, SC, post-mortem testicular traits and sperm quality analysis are important traits used for evaluation of the reproductive potential of farm animals because of their close association with fertility (Chacon *et al*., 1999). In a study conducted by Mekasha *et al.* (2008), BCS, BW, SC, post-mortem testicular traits and morphological attributes of spermatozoa recovered from the tail of epididymis of bucks were the parameters used for evaluating the reproductive potential of goats of Afar, Arsi-Bale, Boran, Woito Guji and CHG breeds indigenous to Ethiopia. In the buck, the relationship between body and testicular size is important because sperm production capacity and the overall breeding efficiency are related to body and testicular size. Hence, body size, scrotal and post-mortem testicular traits are indicated as important parameters often used in evaluating breeding potential (Agga *et al*., 2011).

Evaluation of the quality attributes of spermatozoa is a useful tool for prognosis of male infertility (Purvis and Christiansen, 1992). A number of successful studies (Foote, 2000; James *et al*., 2002; James, 2004) on quality attributes of spermatozoa were reported based on the evaluation of sperm recovered from the tail of epididymis of deceased males of many domestic species. Foote (2000) has successfully harvested motile sperm from the epididymis of bulls, boars, rams and stallions within 24 to 48 hours after death. Harvesting and preserving epididymal sperm would be beneficial as a means to preserve endangered species and for further research in sperm preservation and assisted reproductive technologies (James, 2004).

There are a multitude of methods for evaluating the quality attributes of spermatozoa and each method attempts to assess the correlation between sperm quality attributes and fertility (James, 2004). According to Purvis and Christiansen (1992), conventional measurements of sperm quality and male fertility are inadequate and any assessment should involve several tests of sperm cell morphology and function to increase the fertility prognosis. Saacke (1983) categorized sperm quality traits into two as viability or morphological traits. The viability measurements of sperm cells include motility, sperm velocity, penetration of cervical mucosa, metabolic activity and structural integrity of the sperm cell membrane and its acrosome, ability to pass through a density gradient and ability of sperm to bind to *zona pellucida* (Saacke, 1983). A number of classification systems exist for morphological abnormalities of sperm which include: primary and secondary defects, which classify sperm abnormalities on the basis of their presumptive origin; major and minor defects where sperm defects are classified in terms of their perceived adverse effects upon male fertility and as compensable and un-compensable semen traits according to a theoretical increase in numbers of functionally competent sperm that will or will not solve the problem. A compensable defect is one where the defective spermatozoa either do not reach the site of fertilization or fails to initiate the fertilization process. Defects that lead to failed fertilization or early pregnancy loss are termed as un-compensable (Hafez, 1993). According to Hafez (1993), the sperm morphological defects are classified into head, mid piece or tail defects. Head defects include loose head, acrosome defects, acrosome abnormality, nuclear pouches, tapered, thin, micro and nicrocephalus, multiple heads, abnormal post acrosomal region and abnormal or absent acrosome. Mid-piece defects may be abnormal mid-piece, cytoplasmic droplets, thin mid piece, bent mid piece whereas tail defects include such defects like absent, short, irregular, multiple, simple bent, coiled tail (coiled tail under head and coiled tail double folded) (Hafez, 1993).

2.4.2. Linear body measurements, body weight, carcass weight and dressing percentage of indigenous goat breeds

The performance of live animals is commonly evaluated through determination of BW (Slippers *et al*., 2000) and other parameters such as LBMs (Attah *et al*., 2004). Linear body traits such as heart girth (HG), height at withers (HAW), body length (BL), height at rump (RH) and pelvic width (PW) are important parameters used for phenotypic characterization of farm livestock including goats. Body weight can be predicted using LBMs as predictor variables (Waheed, 2011; Gebreyesus *et al*., 2012; Tadesse *et al*., 2012; Tekle, 2014). Similarly, carcass weight and dressing percentage can be predicted using LBMs and BW as predictors (Rahman, 2007). Table 1 presents data on commonly utilized LBMs (HG, BL, HAW, PW and chest depth) of bucks of selected goat breeds indigenous to Ethiopia.

Table 1. Linear body measurements (mean) of bucks of selected indigenous goat breeds in Ethiopia

Goat types	Age	HG [cm]	BL [cm]	HAW [cm]	PW [cm]	Chest depth [cm]	Source
Abergelle	0 PPI	54.1	44.8	52.4	-	-	Tadesse *et al*. (2012)
Abergelle	1 PPI	57.1	47.4	55.9	-	-	Tadesse *et al*. (2012)
Abergelle	2 PPI	62.9	51.3	61.0	-	-	Tadesse *et al*. (2012)
Afar	0 PPI	60.6	57.9	55.8	14.2	23.9	Mekasha *et al*. (2008)
Afar	1 PPI	62.1	58.4	56.9	15.3	24.6	Mekasha *et al*. (2008)
Afar	2 PPI	60.5	56.4	56.9	14.4	25.1	Mekasha *et al*. (2008)
Afar	0 PPI	53.8	48.8	51.0	10.3	-	Tekle (2014)
Afar	1 PPI	67.6	63.5	62.5	12.4	-	Tekle (2014)
Afar	2 PPI	75.2	65.7	68.0	14.1	-	Tekle (2014)
Arsi Bale	0 PPI	67.0	61.1	60.4	15.2	26.7	Mekasha *et al*. (2008)
Arsi Bale	1 PPI	66.9	61.1	63.9	15.9	26.7	Mekasha *et al*. (2008)
Arsi Bale	2 PPI	69.8	60.6	60.8	15.1	27.3	Mekasha *et al*. (2008)
Boran	0 PPI	68.9	62.4	63.8	17.6	28.2	Mekasha *et al*. (2008)
Boran	1 PPI	69.5	64.3	63.9	17.3	28.1	Mekasha *et al*. (2008)
Boran	2 PPI	71.0	61.2	65.7	17.4	27.6	Mekasha *et al*. (2008)
CHG	0 PPI	69.2	63.8	65.1	16.1	28.1	Mekasha *et al*. (2008)
CHG	1 PPI	70.3	62.9	66.3	16.2	28.4	Mekasha *et al*. (2008)
Woito Guji	0 PPI	67.5	59.7	62.1	16.5	27.7	Mekasha *et al*. (2008)
Woito Guji	1 PPI	66.4	60.9	61.7	16.4	27.6	Mekasha *et al*. (2008)
Woito Guji	2 PPI	70.8	61.4	64.2	17.7	28.8	Mekasha *et al*. (2008)

CHG: Central Highlands; HG: heart girth; BL: body length; HAW: height at withers; PW: pelvic width

In bucks of Afar breed at age categories of no pairs of permanent incisors (PPI), 1 PPI and 2 PPI, respectively RH (cm) of 46.2, 64.8 and 69.2 and NC (cm) of 24, 29.3 and 35.6 were recorded (Tekle, 2014).

Data on BW at slaughter, HCW and DP of goat breeds indigenous to Ethiopia is presented on Table 2. On Table 2 it is shown that the indigenous goat breeds in Ethiopia had differing BW at slaughter (range 13.8-28.9 kg), HCW (range 5.9-12.8 kg) and DP (range 38.9-51.0 %). The highest BW at slaughter (28.9 kg) and HCW (12.8 kg) were recorded by Mesfin (2007) in Arsi-Bale goats, closely followed by the BW at slaughter (28.7 kg) and HCW (11.2 kg) recorded in CHG by Deribe and Taye (2013) (Table 2). In goat breeds indigenous to Ethiopia, estimated average HCW of 8-10 kg was recorded which represents one of the lowest carcass weight values in sub-Saharan Africa (EARO, 2000; Sebsibe, 2006; Hirpa and Abebe, 2008). The DP (on empty BW basis) recorded in Arsi-Bale goats (47.9 - 51 %) by Berihun *et al*. (2013) represents the highest DP so far recorded in goat breeds indigenous to Ethiopia (Table 2).

Table 2. Body weight, carcass weight and dressing percentage of indigenous goat breeds kept under extensive system of Ethiopia

Goat types	**BW [kg]**	**HCW [kg]**	**DP [%]**	**Source**
Abergelle	17.3	-	-	Tadesse *et al*. (2012)
Afar	18.6	8.5	45.5	Abera *et al*. (2002)
Afar	13.8	5.9	43.1	Sebsibe *et al*. (2007)
Arsi-Bale	21.0	9.5	45.4	Abera *et al*. (2002)
Arsi-Bale	28.9	12.8	44.2	Mesfin (2007)
Arsi-Bale	10.4	5.3	47.9-51.0	Berihun *et al*. (2013)
Central Highland	13.9	5.9	42.5	Sebsibe *et al*. (2007)
Central Highland	28.7	11.2	38.9	Deribe and Taye (2013)
Long eared Somali	13.9	5.9	42.9	Sebsibe *et al*. (2007)
Short eared Somali	16.6	6.9	41.7	Melaku and Betsha (2008)
Woito Guji	19.4	8.8	45.2	Abera *et al*. (2002)

Key: BW: body weight at slaughter; HCW: hot carcass weight; DP: dressing percentage

3. MATERIALS AND METHODS

3.1. Description of the Study Locations

A cross sectional survey aimed at assessing the livestock species kept, livestock holding and farmers' preference, purposes of keeping goats, the management practice and constraints of goat production was conducted in two adjacent districts, namely Yallo in Afar region and Raya Azebo in Tigray region (Figure 1) in which two contrasting production systems are practiced.

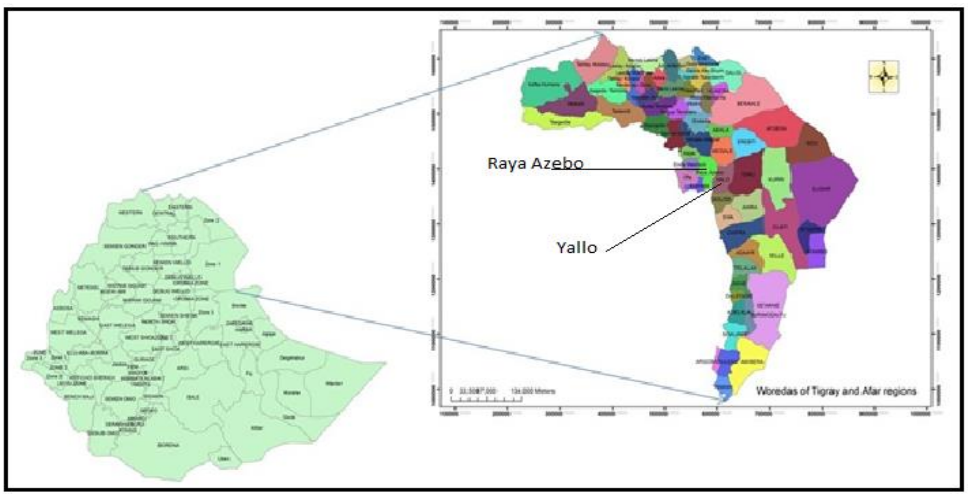

Figure 1. Location of the survey districts

With a total land area of 164,900 km^2, Yallo district is one of the districts in Zone Four (*Fenti-Resu*) of Afar region. The administrative center for Yallo district is Gubi-dora, a small rural village located at geographic coordinates of 12°21'N and 39°52'E. The altitude ranges from 1,000 to 1,700 meter above sea level (m.a.s.l). The human population in the district was estimated as 30,000 who are mainly pastoralists. The climate is characterized as arid, with monthly temperature ranging from 15 to 37.8°C and mean annual rainfall of 590 mm (BoPARD, 2008). The vegetation consists mainly of sparse cover of low shrub and bush such as *Acacia millifera*, *A. senegal*, *A. torrtilis, Prosopis juliflora,* *Commiphora* and *Avena* species and associated grasses like *Aristida, Chloris, Entropagon, Panicum and Cynodon* species. Maize, sorghum, teff, different types of vegetables and fruits are grown in the district. The total livestock population in the district was estimated as 97,594 consisting of 46, 706 goats; 19,372 cattle; 17,800 sheep; 11,817 camels and 1,899 equines mainly donkeys (BoPARD, 2008). The goat population in the district is represented mainly by an indigenous goat breed known as Afar goat locally known as '*widar*'.

Raya-Azebo district is part of the Southern administrative zone of Tigray region. It is located at geographic coordinates of 2.8^0N and 39.6^0E with an altitude ranging from 1.400 to 2300 m.a.s.l. The administrative center of Raya Azebo district, Mehoni town is located at geographic coordinates of 12^o47'N and 39^o38'E; at a distance of 150 and 665 km from the regional capital (Mekelle) and the Ethiopian capital (Addis Ababa), respectively. The district has total land coverage of 176,867 hectares and shares border with Afar region to the east, and Amhara region to the south. The total population size of the district is estimated to be 150,162, out of these 94,810 are males and 75,352 are females. About 71 % and 29 % are followers of Orthodox and Muslim religion, respectively.

Raya Azebo district covers three climatic zones: *kolla* (18.6%), *Woynadega* (80%) and *Dega* (1.4%). About 90 % of the district is described as 'midland' and 10 % as 'lowland. Eighty five percent of the land setting is midland, especially the area around the edge of Maychew Mountains while the remaining 15 % is lowland. The area is characterized as semi-arid receiving a bimodal rain fall, the *belg (*short rainy season) rains occurring in March to May and the *meher* (main rainy season) rain lasting from June to September. The annual rainfall recorded is within the range of 400 to 900 mm. The mean daily minimum and maximum temperatures were 13.9 and 23district.

Crop farming and livestock production (mixed farming) are the major economic activities or livelihood for the majority of the population in the district. Livestock production and trading are also important livelihoods and economic activities in the area.The main crops grown in the district include cereals (sorghum, teff, maize, barley, wheat and finger millet), haricot bean, chick pea/wheat, different fruits, vegetables (cactus, papaya, citrus, guava, banana, onion, garlic, tomato, green pepper and potato), pulses (field pea, chickpea) and oil crops.

The lower part of the district is covered with lowland woodlands, bush and Acacia trees (*Acacia abyssinica*). Bush is the dominant land cover. There are also significant acacia woodlands. The vegetation in Raya Azebo district includes remnants of trees, shrubs and grasses. Cactus has invaded a considerable part of the land. The major sources of livestock feeds in the district are crop residuse and natural pasture. Pasture is available in communal grazing lands. Crop residues mainly the stover of maize and sorghum; starw of teff, wheat and barley are used to feed livestock. Chopped cactus and starw are used to feed cattle whenever there is a severe shortage of feed during the dry season.

According to the Raya Azebo district Finance and Economic Development Office, the livetock population found in the district is about 298,214 out of which 143, 510 are cattle; 36, 257 are goats and sheep; 15, 088 donkeys; 646 mules and horses; 11, 800 camels and 90, 913 poultry. In addition, there are 2,289 traditional and 734 modern beehives. The goat population in the district is represented mainly by an indigenous goat known as Central-Highlands goat (CHG) breed.

The two studies on assessment of the scrotal and testicular traits as well as linear body measurements and meat production potential of goats of Abergelle, Afar goat and CHG breeds which originated from traditional/extensive management system were undertaken at Abergelle International Export Slaughterhouse. Abergelle Slaughterhouse is located at geographic coordinates of 13^{o}33’N and 39^{o}30’E, at a distance of 9 km north of Mekelle town. It is a modern Slaughterhouse and uses many advanced slaughter techniques. Abergelle Slaughterhouse is equipped with large cold rooms, vacuum packing system and waste treatment facilities. At full production capacity, the Slaughterhouse has a capacity of processing 30 tons of beef and 9 tons of goat and sheep meat per day (AILD, 2010; FEMLE, 2010).

3.2. Study Animals

In the cross sectional survey, goats of Afar and CHG breeds reared in Yallo (Afar) and Raya Azebo district (Tigray), respectively were targeted as study animals. On the othe hand, the studies on evaluation of the scrotal-testicualr traits and quality attributes of sperm as well as the LBMs and meat production potential of indeginous goats in north Ethiopia were conducted using un-castrated bucks belonging to goats of Abergelle, Afar and CHG breeds, selected from a batch of bucks delivered for slaughter at Abergelle International Export Slaughterhouse.

Abergelle goat breed has developed specific adaptations to survive and produce under extremely adverse conditions where there is feed and water shortage, that make the breed suitable for use in traditional low input system (Alemayehu, 1994). Abergelle goats are stocky, compact and well built, with straight to concave facial profile and in most cases males have much bigger, magnificent spiral horns directed backwards. The coat color is mostly reddish-brown with some individuals having plain or patchy colors. The hair coat is short and smooth in both sexes and males have ruff and beard (FARM-Africa, 1996).

Abergelle goat breed is mainly reared under extensive system, in the mixed crop-livestock and agro-pastoral production system, along River Tekeze and some parts of Alamata district in Tigray region and in Wag-Himra (Sekota) and East Gondar zones of Amhara region. Feed resources for Abergelle goats include native pasture on communal grazing lands and fallow plots, occasionally provided with straw, crop residues and stubble (aftermath) depending on the season. During the cropping season, livestock including goats are largely dependent on hillsides, field margins and roadside grazing (FARM-Africa, 1996).

Afar goat breed is a goat breed which is known for its adaptation to harsh environmental and climatic condition. The breed is characterized by physical characteristics of concave facial profile, narrow face, pricked ear, leggy body conformation, long and thin upward-pointing horns, variable coat color, patchy being common. Afar goats have fine and short hair coat, majority of the male goats have ruff, beard and wattles (FARM-Africa, 1996).

Afar goat is a goat breed predominantly found in the pastoral and agro-pastoral areas of Afar region where livestock including goats graze freely on the arid and semi-arid rangelands. Afar goats are managed together with sheep in a mixed flock under traditional (extensive) management system (Peacock, 2005; Tekle, 2014). According to Seid and Tesfaye (2014), during the dry season, the major feed resources for Afar goats (and sheep) include the communal rangeland, hill side grazing and indigenous bush whereas under agro-pastoral condition, aftermath grazing, hay and roadside grazing constitute additional feed resources.

Central-Highlands goat (CHG) breed is a famous breed found widely distributed in the the central highlands of Ethiopia. The breed is characterized by medium-body size, broad-face and variable coat color, the predominant color being reddish-brown. The breed is characterized by predominantly straight facial profile, all males have curved or straight horns which are oriented backwards (FARM-Africa, 1996; Mekasha *et al*., 2008).

Central-Highlands goat (CHG) is commonly kept under mixed crop-livestock farming system practiced in the central highlands. Livestock including goats are grazed freely on hill sides, farm fields and grazing lands during the dry season whereas during the crop-growing season the goats are allowed to graze on hillsides or tethered (Mekasha *et al*., 2008; Deribe and Taye, 2013).

Abergelle, Afar and CHG goat breeds were selected purposively because of their abundance in the study area comprising the main slaughtered goats at Abergelle Slaughterhouse. For the purpose, a total of 1062 bucks belonging to the three goat breeds

(Abergelle, Afar and CHG) were sampled at equal proportion of breed and age (0 PPI, 1 PPI and 2 PPI) categories (Table 3) for collecting data related to assessment of the scrotal and testicular traits as well as LBMs and meat production potential whereas 60 bucks (20 from each of the three goat breeds) at age category of 1 PPI and 2 PPI were used for epididymal gamate rescue and evaluation of the spermat.

Table 3. Slaughtered bucks of study goats by breed and age categories

Breed	0 PPI	1 PPI	2 PPI	Total
Abergelle	118	118	118	354
Afar	118	118	118	354
CHG	118	118	118	354
Total	354	354	354	1062

PPI: pair of permanent incisors; CHG: Central-Highlands goat

Because Abergelle Slaughterhouse was dealing mainly with slaughter of goats of younger age, this study was limited to the three age categories: 0 PPI, 1 PPI and 2 PPI (Table 3).

Flock owners and/or traders in the rural areas (rural traders) are the major suppliers of goats to Abergelle Slaughterhouse. The goats are transported using all possible means of transport including trucks/isuzu or trekked to reach animal collection and quarantine sites of Abergelle Slaughterhouse at Beri Teklay/Alamata or Agbe. At times, purchasers of the Slaughterhouse reach those remote marketing areas. The animal collection and quarantine sites at Beri Teklay and Agbe are located at distance of 150 and 100 km, respectively from Abergelle Slaughterhouse. In the animal collection sites, clinical examination and screening of the bucks is undertaken by experts of the Slaughterhouse focusing mainly on the health of the bucks for accepting (purchasing).

Upon acceptance, the goats are rested for a period of 21-30 days at the animal collection and quarantine sites and grazed on fenced natural grazing land. After such resting period, the bucks are re-examined for health, body condition and weight and those found fit for slaughter are transported using animal truck to reach Abergelle Slaughterhouse, which generally takes less than 4 hours derive. At the lairage, during the first 24 hours, the goats are provided with hay, water and salt. Then, the goats are fasted overnight with free access to water.

After overnight fasting, BW of the bucks is recorded immediately prior to slaughter. Slaughtering is done by cutting the major blood vessels around the throat (Halal method) so that optimal bleeding occurs. Following that, the carcass is suspended by the hind legs (hauled) to take advantage of the rail system and for optimal bleeding, followed by start of flaying (ripping). Then, removal of the head, the fore and hind feets is done at the atlanto-occipital, carpal and tarsal joints, respectively. Then the skin (together with the testis) is removed completely using automated technique. After flaying, the carcass is washed followed by evisceration (removal of the stomach, intestines, visceral organs (heart, liver, spleen, lungs and kidneys), urinary bladder as well as internal fats from the stomach, kidney, heart and intestines). The carcass is washed again and the water allowed to drip followed by recording of the carcass weight (HCW) done with the help of built-in automatic electronic weighing scale available within the rail system of the abattoir. Then the carcass is chilled (at + 4^{o}C) until packaging and dispatching.

3.3. Study Design

3.3.1. Cross sectional survey

For undertaking the cross sectional survey, the method employed was a single visit formal survey technique (ILCA, 1990). A purposive sampling procedure was employed in selecting the two districts and the primary sampling units (*tabias*[1] in Raya Azebo and pastoral associations (PAs) in Yallo district). The presence of sufficient goat flocks and road accessibility were the criteria considered. Therefore, in Raya Azebo district, three

[1] Administrative centres currently in use in Tigray region comprised of kushets.

tabias namely Adis-Kegn, Bala and Korme and in Yallo district, three PAs namely Rukub-Dora, Kulina-Gabule and Wale were selected. A multi-stage sampling procedure was adopted for selecting the secondary sampling units (*kushets*[2] in Raya Azebo and pastoral encampments in Yallo district) and target HHs. In the first stage, from each of the selected *tabias* and PAs, the study *kushets* and pastoral encampments, respectively were selected on random basis. In the second stage, from each of the selected *kushets* and pastoral encampments, a list of goat owning HHs was obtained from the development agents (DAs) who were working in the selected *tabias* in Raya Azebo district and the chairmen of the PAs in Yallo district. Using the list thus obtained from each *kushets* and pastoral encampments, the target HHs were selected on random basis. Therefore, a total of 216 HHs (108 each from the two districts) were approached for interview. The sample size (N) was determined using the formula as described in Arsham (2005):

$N = 0.25/(SE)^2$ where N is sample size and SE is standard error. Standard error of 4.7 % was considered for determination of sample size.

A pre-tested, semi-structured questionnaire (Appendix 1) was used to collect primary data through face to face interview, administered to the goat owning target HHs selected from each district. In each district, focus group discussions comprising of 10 - 15 participants were also held in the presence of key informants, livestock health and production experts in order to cross check and complement the information collected through individual interview and to elicit data which were difficult to obtain during individual interview. In addition, in each district field observation was made to take note of goat flocks at grazing, watering points and at their home.

3.3.2. Scrotal and testicular traits and sperm quality attributes

For the purpose of assessing the scrotal and testicular traits as well as quality attributes of sperm recovered from the tail of epididymis of bucks of the three goat breeds (Abergelle, Afar and CHG), randomly selected bucks of the three goat breeds which were

[2] The lowest administrative unit currently in use in Tigray region.

delivered for slaughter to Abergelle Slaughterhouse were utilized. Together with the veterinarian and animal production experts of the abattoir, ante-mortem clinical examination was performed at the lairage in order to assess the general health of each study buck with due emphasis made to the reproductive organs during clinical examination. Therefore, apparently healthy bucks which were representative of the study goat breeds were selected following stratified random sampling technique considering proportion of breed and age. The selected bucks were identified using plastic ear tag, for use throughout the study which involved ante- and post-mortem data collection.

3.3.3. Linear body measurements and meat production potential

The same bucks of the three goat breeds (Abergelle, Afar and CHG) which were sampled for the purpose of evaluating the scrotal and testicular traits were utilized for generating data related to LBMs and meat production potential. Description of the procedure on selection of study animals and ante-mortem clinical examination is presented under section 3.3.2.

3.4. Data Collection

Data collection was performed during the dry season, from December 2014 to June 2015.

3.4.1. Cross sectional survey

Primary data collection was targeted to the livestock species kept, livestock holding and their preference, purpose/s of keeping goats, the management practice and constraints of goat production. Data on the goat management practice was addressed to herding, housing, water sources, feed resources and breeding management (mating system, buck ownership, selection of breeding bucks and selection criteria).

Yallo district Office of Pastoral, Agro-Pastoral and Rural Development office and Raya Azebo district Office of Agriculture and Rural Development were sources of secondary information on livestock population, localities of high goat population and list of goat keeping HHs in each district.

3.4.2. Scrotal and testicular traits and sperm quality attributes

For the purpose of assessing the scrotal/testicular traits and sperm quality attributes of bucks of the three goat breeds, ante-mortem data on live animal attributes such as breed, age, BCS, BW at slaughter and SC were taken at the lairage.

Bucks which were representative of the goat breeds under study were selected based on the physical (phenotypic) characteristics of the goat breeds using the guide developed by FARM-Africa (1996) and Gizaw (2008). Age categorization was performed based on the number of erupted pairs of permanent incisors (PPI). The study animals were comprised of three major age categories; the first age group consisted of bucks younger than 1 year old referring to bucks with full milk teeth (0 PPI); the second age group consisted of bucks which were 1 to 2 years old, referring to bucks with one pair of permanent incisors (1 PPI) and the last age category consisted of bucks which were 2-3 years old comprised of bucks with two pairs of permanent incisors (2 PPI) as described in Abegaz and Awgichew (2008). Body condition was categorized subjectively into emaciated or very thin (BCS 1), poor or thin (BCS 2), moderate or acceptable (BCS 3) and fat (BCS 4) following the guide developed by Abebe and Yami (2008) (Appendix 2).

Body weight [kg] at slaughter was determined using a hanging scale (capacity 50 kg), taken after overnight fasting (Melaku and Betsha, 2008). Measurement of SC [cm] was taken using a flexible measuring tape at the largest diameter of the scrotum with the tape placed around the scrotum after both testicles have been positioned beside each other in the scrotum.

In addition, post-mortem data post-mortem testicular traits were collected and sperm was recovered from tail of epididymis. The scrotum of each buck was opened to access both the right and left testicles. The testicles were identified, packed separately using plastic bag and transported inside icebox (~ 15^{o}C) to the pathology laboratory at College of Veterinary Medicine, Mekelle University for detailed examination and measurement. In the laboratory, a series of systematic dissections were made into the tissue of the testis and epididymis for checking any gross pathological conditions (Agga *et al*., 2011). Samples with obvious abnormalities such as severe scrotal lesions, orchitis, epididymitis, abnormal consistency, adhesion and asymmetry were discarded (Regassa *et al*., 2003).

Measurements of post-mortem traits were taken without delay within 4 hours of slaughtering as follows: TC [cm] was measured at the widest part of the testis using flexible measuring tape; TWd [cm] was taken using vernier-caliper; TL [cm] was measured from the base of testis to its distal pole including the end of the tail of epididymis as described in James (2004). Testicular volume [ml] was measured by using a water displacement technique as described in Toe *et al*. (2000) whereas TWt [g] and EWt [g] were determined using a sensitive balance. The recording was done separately for the left and right testis. The ante- and post-mortem data related to measurement of of testicular traits were recorded using a format prepared for the purpose (Appendix 3).

For microscopic examination of the quality attributes of spermatozoa, sperm sample from the *cauda epididymis* was obtained at post-mortem and the collection was done separately for the left and right epididymis following the procedure in Appendix 4 (a). The right and left epididymis were carefully separated from the testes and the tail of epididymis was separated from the rest of the epididymis, sliced several times using sterile scalpel blade and washed using 5ml of an extender based on skimmed milk into a clean petri-dish (Appendix 4, b). To avoid cold shock, the collected sperm sample was kept in water bath at 37^{o}C and subjected to microscopic examination for evaluating the mass and individual motility [%]; percent live [%]; morphological abnormalities [%] and concentration (number of spermatozoa/ml).

Mass motility [%] was determined by putting aliquot (5µ1) of fresh undiluted sperm sample on a clean, pre-warmed (37°C) slide and examined under microscope at lower magnification (X 10). Progressive/individual motility [%] was determined from fresh sperm sample at higher magnification (X 40). Sperm concentration was determined using hemocytometer, expressed as number of spermatozoa per ml using the formula given by Bearden *et al*. (2004) where:

No. of spermatozoa/ml= No. of sperm cells in 0.1mm^3 * 10 * dilution rate * 100

Percent live spermatozoa [%] was determined by examining 200 spermatozoa counted after making a smear of a mixture of 5µ1 of sperm, equal volume of 1 % eosin and 2.6 % of sodium citrate (James, 2004; Lemma *et al*., 2015). The proportion of morphologically abnormal spermatozoa was determined by examining 200 spermatozoa in an eosin smear under high magnification (10 X 100).

The ante- and post-mortem data related to the evaluation of the quality attributes of sperm recovered from tail of epididymis were recorded in a separate format (Appendix 5).

3.4.3. Linear body measurements and meat production potential

For the purpose assessing the LBMs and meat production potential of the three goat breeds, the same set of ante-mortem data on breed, age and BW recorded for the purpose of assessing the scrotal and testicular traits of of goat breeds were used. Details of the procedure on breed characterization, age categorization and BW determination are presented in section 3.4.2. For the purpose of evaluating the linear body traits and meat production potential, data on LBMs [cm] were taken before slaughtering at the lairage using measuring scale with the bucks held comfortably in upright and standing position on a flat surface. The LBMs considered were: heart girth (HG) measured as the distance around the animal taken directly behind the front legs; height at withers (HAW) measured as the height of a standing buck perpendicular to the ground on a flat surface and body length (BL) measured from 'base of tail' (where it joins the body) to the first thoracic vertebrate or to the front of chest (Abebe and Yami, 2008) and pelvic width (PW) was measured as distance between the two pelvic bones across the dorsum.

In addition, post-mortem data on carcass weight [kg] of each buck was recorded after evisceration within 45 minutes after slaughtering with the help of built-in automatic electronic weighing scale. Dressing percentage [%] was computed as HCW expressed as percentage of BW at slaughter as described in Marichala *et al*. (2003):

$$DP\ (\%) = \frac{\text{HCW taken after evisceration}}{\text{BW at slaughter}} * 100$$

The ante- and post-mortem data collected for assessing the LBMs and meat production potential of the goat breeds was registered using a separate format (Appendix 6).

3.5. Data Analyses

3.5.1. Cross sectional survey

Descriptive statistics such as frequency/proportion were used to summarize qualitative data on the goat management practice (herding, pattern of grazing, housing, watering management and buck ownership.

Differences in the response of qualitative variables on livestock preference, purpose of keeping goats, goat management practice (herding, housing, water sources, feed resources, buck ownership, buck selection criteria and constraints of goat production) collected through questionnaire survey were analyzed using Pearson Chi-square test.

In analyzing the ranking order of livestock preference, purposes of keeping goats and constraints of goat production**,** index was computed with the principle of weighted average using the following formula as used by Musa *et al*. (2006):

Index = sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for rank 4] given for an individual variable divided by the sum of [4 for rank 1 + 3 for rank 2 + 2 for rank 1 + 1 for rank 4] summed over all variables.

3.5.2. Scrotal and testicular traits and sperm quality attributes

The collected data on BCS, BW, SC, post-mortem testicular traits and the quality attributes of sperm recovered from tail of epididymis were stratified into breed and age classes. Kolmogorov–Smirnov statistics and Levene's test were used to check the normality of the residuals of the quantitative variables and the homogeneity of variance of the categorical variables, respectively using SAS (2002). Multinominal logistic regression was used to test the normality of BCS. For analysis of data generated for paired organs (post-mortem testicular measurements), average values were used.

The data on sperm concentration was log transformed whereas data on sperm morphological abnormalities was square-root transformed and the transformed data were used during data analyses. General Linear Model (GLM) of SAS (2002) was used to test the effect of breed and age on BCS, BW, SC, post-mortem testicular traits, the motility (mass and individual), viability (live/dead ratio), morphological defects and concentration of spermatozoa recovered from the tail of epididymis. For each goat breed, the association between BW, SC and post-mortem testicular traits was assessed using Pearson correlation coefficient.

In order to eliminate the effect of age differences and also the effects of variation in BW on SC, SC was compared for bucks at similar BW. In the regression model, BW was taken as covariate. In addition, regression analysis of BW on sperm quality was performed in order to determine the optimal BW for maximum fertility. For the purpose, three (14-18 kg, 18.5-22 kg and > 22.5 kg) BW classes were formed on the basis of mean $\pm$ SD and mean $\pm$ 2 SD.

The following statistical model was used to assess the effect of breed and age on BCS, BW, SC, post-mortem testicular traits and quality attributes of spermatozoa recovered from the tail of epididymis:

$Y_{ijk} = \mu + \tau_i + \alpha_j + \varepsilon_{ijk}$ (Model 1)

Where: Y_{ijk} = k^{th} observation of measured at j^{th} age and i^{th} breed individual

μ = the overall mean,

τ_i = the effect of i^{th} breed (i = 1, 2, 3), i.e. 3 breeds: Abergelle, Afar and CHG,

α_j = the effect of j^{th} age category (j = 1, 2, 3), i.e. 3 age categories: 0 PPI, 1 PPI and 2 PPI,

ε_{ijk} = random error associated with Y_{ijk} observation error assumed to be normally and independently distributed with mean zero and variance δ^2, i.e. NID (0, δ^2).

3.5.3. Linear body measurements and meat production potential

To assess the effect of breed and age on LBMs, BW at slaughter, HCW and DP, the collected data on LBMs, BW, HCW and DP were stratified into breed and age classes. Kolmogorov–Smirnov statistics was used to test the normality of the residuals of the quantitative variables (LBMs, BW, HCW and DP) using SAS (2002). The homogeneity of the variance of the categorical variables (breed and age) was checked using Levene's test. General Linear Model (GLM) procedure of SAS (SAS, 2002) was employed to assess differences in LBMs, BW, HCW and DP taking breed and age as class variables. Pearson correlation coefficient was used to assess the association between LBMs, BW, HCW and DP for each goat breed.

The following statistical model was used to assess the effect of breed and age on LBMs, BW at slaughter, HCW and DP:

$Y_{ijk} = \mu + \tau_i + \alpha_j + \varepsilon_{ijk}$ (Model 2)

Where: Y_{ijk} = k^{th} observation on variable under j^{th} age and i^{th} breed individual,

μ = overall mean,

τ_i = effect of i^{th} breed (i= 1, 2, 3), i.e. 3 goat breeds: Abergelle, Afar and CHG,

α_j = effect of j^{th} age category (j = 1, 2, 3), i.e. 3 age categories: 0 PPI, 1 PPI and 2 PPI,

ε_{ijk} = random error assumed to be normally and independently distributed with mean zero and variance δ^2, i.e. NID (0, δ^2).

In order to determine the optimal BW which yields maximum carcass yield (DP), within breed regression analysis of DP on BW was done using three (14-18 kg, 18.5-22 kg and > 22.5 kg) BW classes formed on the basis of mean $\pm$ SD and mean $\pm$ 2 SD.

For developing models for predicting HCW of bucks of the three goat breeds of each age categories, LBMs and BW were used as predictor variables. For developing models for predicting DP of bucks of study goat breeds of each age categories, BW and HCW were used as predictor variables.

Univariate analysis was performed to check the independent association between an individual predictor variable and a dependent variable (HCW or DP). Collinearity diagnostics was performed by checking Variance Inflation Factor (VIF) where VIF > 10 was taken as a cutoff point (Kaps and Lamberson, 2004). Multivariate analysis of variance (MANOVA) was performed using only those predictor variables which had significant ($P < 0.05$) independent association with a dependent variable (HCW or DP) in the univariate analysis. Predictor variables which remained to have significant ($P < 0.05$) association with a dependent variable (HCW or DP) in the multivariate analysis were used to set the best fit models for predicting HCW or DP. The best fit prediction models were chosen using coefficient of determination (R^2), root mean square error (RMSE), conceptual predictive criterion [C (p)] and Akaike information criterion (AIC) (Kaps and Lamberson, 2004).

Coefficient of determination (R^2) was used as an indicator of the variation in the dependent variable (HCW or DP) explained by the model. It was used as an indicator of which variables will notably increase the R^2. Regression equations with small MSE were chosen so as to maximize the precision of the predicted values. Root mean square error was used as an indicator of the variation in the response variable not explained by the model. AIC was used to compare models so that a model with the smallest AIC was considered optimal. C (p) was used to determine a model maximizing the explained variability with as few variables as possible in the model. It was used as a measure of the goodness of fit of a prediction model. Conceptual predictive criterion was based on the number of predictor variables included in the model.

The following regression equation was used to develop models for predicting HCW of bucks of the three goat breeds of each age category:

$$Y = ß_0 + ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 \quad \text{(Model 3)}$$

Where: Y represents the dependent variable HCW (after evisceration),

$ß_0$ denotes the intercept,

$ß_1$-$ß_5$ represents the regression coefficients of the independent variables X_1 to X_5, respectively,

X_1 - X_5 denote the independent variables (X_1 = HAW, X_2 = HG, X_3 = BL, X_4 = PW, X_5 = BW at slaughter).

The following regression equation was used to develop models for predicting DP of bucks of the three goat breeds of each age category:

$$Y = ß_0 + ß_1X_1 + ß_2X_2 \quad \text{(Model 4)}$$

Where: Y represents the dependent variable, DP,

$ß_0$ denotes the intercept,

$ß_1$and $ß_2$ represent the regression coefficients of the independent variables X_1 for BW at slaughter and X_2 for HCW,

X_1 and X_2 denote the independent variables X_1 for BW at slaughter, and X_2 for HCW.

In all the models involving effect test, the effect of class variables were expressed as Least Square Means (LSM $\pm$ SE) and means were separated using Tukey-Kramer HSD test. In all the comparisons, the level of significance was set at $\alpha = 0.05$.

4. RESULTS

4.1. Management Practice and Production Constraints of Goats

4.1.1. Livestock holding and preference

In the pastoral system of Yallo district, mean (± SD) holding of goat, camel, sheep and cattle of 31.5 ± 9.0, 11.2 ± 0.8, 5.4 ± 3.4 and 6 ± 1.5, respectively were recorded whereas in the mixed crop-livestock system of Raya AZebo district, holding of 8.3 ± 1.3, 0.1 ± 0.3, 6.9 ± 1.4 and 6.9 ± 1.7, respectively were recorded. In the pastoral system of Yallo district as well as mixed crop-livestock system of Raya Azebo district, goats were ranked as species of high priority. In the pastoral system of Yallo district, poultry and donkey had very little value, hence these livestock species were not ranked (Table 4).

Table 4. Ranking of the preference of the various livestock species under pastoral system of Yallo and mixed farming system of Raya Azebo district

	Production system			
	Pastoral		**Mixed CL**	
Species	**N (index)**	**Rank**	**N (index)**	**Rank**
Goat	52 (0.33)	1	54 (0.38)	1
Camel	38 (0.30)	2	0 (0.05)	5
Sheep	10 (0.19)	3	15 (0.16)	3
Cattle	8 (0.18)	4	39 (0.36)	2
Poultry	-	Not ranked	0 (0.07)	4
Donkey	-	Not ranked	0 (0.04)	6

N: Number of respondents ranking species, i.e. ranks 1, 2, 3 and 4

CL: crop-livestock

4.1.2. Purposes of keeping goats

Table 5 summarizes the major purposes of keeping goats in the two production systems. In the pastoral system of Yallo district as well as in the mixed crop-livestock farming system of Raya Azebo district, goats were kept for multiple reasons. The purposes of keeping goats significantly varied ($P < 0.05$) with production system. The traditional and religious value of goats was mentioned by respondents who belonged to pastoral system of Yallo district (Table 5).

Table 5. Purposes of keeping goats under pastoral system of Yallo and mixed farming system of Raya Azebo district

	Production system			
	Pastoral	**Mixed CL**	**Test**	
Purposes of keeping goats	**(N) %**	**(N) %**	**X^2 value**	**P-value**
Milk	38 (35.2)	31 (28.7)	2.02	0.03
Income	30 (27.8)	39 (36.1)	4.09	0.05
Meat	19 (17.6)	25 (23.1)	11.10	0.07
Breeding/live animal saving	8 (7.4)	9 (8.3)	6.84	0.05
Skin	7 (6.5)	4 (3.7)	6.69	0.07
Traditional and religious value	6 (5.6)	0 (0.0)	17.10	0.00

N: refers to number of respondents. CL: crop-livestock

Ranking of the purposes of keeping goats under the two production systems is presented in Table 6. In the pastoral system of Yallo district, milk production was ranked as the top reason whereas in the mixed crop-livestock farming system of Raya Azebo district, income generation was reported as the primary reason for keeping goats (Table 6).

Table 6. Ranking of the purposes of keeping goats under pastoral system of Yallo and mixed farming system of Raya Azebo district

	Production system			
	Pastoral		Mixed CL	
Purposes of keeping goats	**N (index)**	**Rank**	**N (index)**	**Rank**
Milk	45 (0.29)	1	4 (0.15)	3
Income	32 (0.26)	2	57 (0.35)	1
Breeding/live animal saving	16 (0.22)	3	41 (0.30)	2
Meat	11 (0.14)	4	6 (0.14)	4
Traditional/religious value	4 (0.07)	5	-	-
Skin	0 (0.02)	6	0 (0.06)	5

N: Number of respondents ranking purposes of keeping goats, i.e. ranks 1, 2, 3 and 4
CL: crop-livestock

4.1.3. Management practice

Herding and housing of goats

Some of the goat management aspects such as herding, flock separation, age based separation and type of housing significantly ($P < 0.05$) varied with production system (Table 7). According to the respondents from pastoral system of Yallo district, herding of goats is one of the routine and regular duties of pastoral HHs undertaken throughout the year whereas in the mixed crop-livestock farming system of Raya Azebo district, 21 % of respondents reported that there are times (during the non-cropping season and when child labour is not available) when goats were not herded. In both systems, herding of goats was the responsibility of young children.

According to respondents from pastoral system of Yallo district, goats and sheep were grazed together in a mixed flock but kept apart from other livestock species including goat flocks belonging to other HHs. On the contrary, in the mixed crop-livestock farming system of Raya Azebo district, the common practice (100 %) is that all livestock (goats, sheep, cattle/oxen and donkeys) belonging to a household, family or neighbors were herded together.

Table 7. Some management aspects (herding, flock separation and housing) of goats under pastoral system of Yallo and mixed farming system of Raya Azebo

	Production system		**Test**	
	Pastoral	**Mixed CL**		
Managements aspects	**N (%)**	**N (%)**	**X^2- value**	**P-value**
Herding of flocks	108 (100.0)	85 (78.7)	14.71	0.00
Housing based on age	100 (92.6)	53 (49.1)	35.3	0.00
Separation of flocks	108 (100.0)	40 (37.0)	31.5	0.00
Separation of age groups	90 (83.3)	33 (30.6)	40.1	0.00
Type of housing				
✓ Stone made house (*uguh*)	102 (94.4)	58 (53.7)	21.3	0.00
✓ *Gajima*	12 (11.1)	103 (95.4)	23.6	0.00
✓ Kraal for adult goats	105 (97.2)	22 (20.4)	16.84	0.000

N refers to number of respondents, CL: crop-livestock

In the pastoral system of Yallo district, as a common practice, for a period of around two months, un-weaned kids together with lambs stay around homestead whereas weaned kids are herded separately in the grazing field. In contrast, in the mixed crop-livestock system of Raya Azebo district such well-defined management of young stock was practiced by very few (12 %) goat owners.

In both production systems under study, flock owners provided a separate house/shelter/enclosure for goats but the type of housing/shelter varied significantly ($P < 0.05$) (Table 7). In the pastoral system of Yallo district, un-weaned kids and lambs were kept in a shelter made of stone locally known as '*uguh*' (Figure 2); during the night weaned kids together with lambs were kept in a separate house with a false roof (Figure 3, A) whereas adult goats together with sheep were enclosed in a kraal (Figure 3, B). In the pastoral system of Yallo district, the shelter for goats (*uguh* and the kraal) was constructed not adjacent to the family house.

Figure 2. Shelter (*uguh*) for un-weaned kids and lambs, Yallo district, Afar

A B

Figure 3. Shelter for weaned kids (A) and enclosure (kraal) for adult goats, Yallo district, Afar

In the mixed farming system of Raya Azebo district, a house (*gajima*) constructed from a wall made of wood and mud, a roof made of polythene plastic sheet or grass or corrugated iron sheet and a floor made of soil was made available for kids (Figure 4, A) and adult goats (Figure 4, B). The location of the house for goats (and sheep) may or may not be adjacent to the main house of the family.

A B

Figure 4. House (*gajima*) for kids (A) and adult (B) goats in Raya Azebo district, Tigray

According to the repondents from both systems, the house/kraal for goats was cleaned daily by children (Figure 5, A). The manure was piled as shown in the figure below (Figure 5, B).

A B

Figure 5. Cleaning of kraal by children (A) and accumulated manure (B), Yallo district

Water sources and watering management

Depending on season of the year, different water sources (surface water, family ponds, temporary streams, springs, rivers, pipe water and traditional wells) were used for watering livestock including goats. In the pastoral system of Yallo district, traditional wells (*ela*) were mentioned as important water sources particularly during the dry season which was not mentioned by majority (72 %) of the respondents from the mixed crop-livestock farming system of Raya Azebo district.

The goat keeping HHs from pastoral system of Yallo district indicated that watering frequency for goats was dependent on season so that goats were watered every 2-3 days during the dry season and daily during the wet season whereas in the mixed crop-livestock system of Raya Azebo district, irrespective of season goats were watered every day.

Feed resources

Table 8 presents data on the major feed resources available for goats in the two production systems. The feed resources available to goats significantly ($P < 0.05$) varied with production system (Table 8). In the pastoral system of Yallo district, irrespective of season, livestock including goat flocks were kept on the communal rangeland where goats graze/browse on natural pasture and vegetation comprising of bush, shrubs and trees whereas in the mixed crop-livestock farming system of Raya Azebo district, during the non-cropping season goats were grazed on natural pasture on the farm lands as well as grazing field in addition to crop residues and aftermath but during the cropping season livestock including goats were grazed on hill side or may be tethered. In both production systems, with the exception of salt, goats were not supplemented with commercial feeds of any kind but in the pastoral system of Yallo district, during the long dry season (drought), owners cut trees or pods to feed goats.

Table 8. Feed resources available for goats in the pastoral system of Yallo and mixed farming system of Raya Azebo district

	Production system		**Test**	
	Pastoral	**Mixed CL**		
Feed resources	**N (%)**	**N (%)**	**X^2- value**	**P-value**
Pasture, bush, shrubs and trees	108 (100.0)	49 (45.4)	21.8	0.00
Pasture and crop residue	10 (9.3)	108 (100.0)	18.30	0.00

N refers to number of respondents, CL: crop-livestock

Breeding management

In both production systems, mating in goats was partially controlled through selection of breeding buck/s. Breeding bucks representative of Afar and CHG breed are shown in Figure 6 (A) and (B), respectively.

A

B

Figure 6. Selected breeding bucks: Afar goat breed (A) in Yallo district and Central-Highlands goat breed (B) in Raya Azebo district

Buck ownership and the sources of breeding bucks significantly varied (P < 0.05) with production system (Table 9). In the pastoral system of Yallo district, majority (86 %) of the goat owning HHs reported that in a goat flock at least one breeding male is maintained and if the flock size is very large, flock splitting each with a breeding buck was done. As opposed to the situation in the pastoral system of Yallo district, a lower proportion (29 %) of respondents in the mixed farming system of Raya Azebo district kept a breeding buck. The common sources of breeding bucks mentioned by respondents from Yallo and Raya Azebo districts are shown in Table 9.

Table 9. Buck ownership and the sources of breeding bucks under pastoral system of Yallo and mixed farming system of Raya Azebo district

	Production system		**Test**	
	Pastoral	**Mixed CL**		
Breeding characteristics	**N (%)**	**N (%)**	**X^2- value**	**P-value**
Buck ownership	93 (86.0)	31 (29.0)	30.6	0.000
Source of buck				
✓ Born	98 (90.7)	17 (15.7)	33.1	0.000
✓ Bought	12 (11.1)	57 (52.8)	14.7	0.000
✓ Borrowed	4 (3.7)	25 (23.1)	13.6	0.000

N refers to number of respondents, CL: crop-livestock

The respondent HHs from both systems had a good understanding of the criteria used for selection of a breeding buck but most of the selection criteria mentioned by the respondents varied significantly ($P < 0.05$) with production system (Table 10). In the pastoral system of Yallo district, milk production of the dam and conformation were given more emphasis whereas in Raya Azebo district, body size and conformation were mentioned as important criteria for selecting breeding buck.

Bucks with patched color in pastoral system of Yallo district and brown color in the mixed crop livestock system of Raya Azebo district were reported as preferred coat colors. According to the respondents, conformation was referred to wider hip, longer height and long body.

Table 10. Buck selection criteria in under pastoral system of Yallo and mixed farming system of Raya Azebo district

	Goat breed		**Test**	
	Afar	**CHG**		
Buck selection criteria	**(N) %**	**(N) %**	**X^2 –value**	**P-value**
Milk production of the dam	104 (96.3)	67 (62.0)	36.1	0.00
Conformation	91 (84.3)	80 (74.1)	2.47	0.19
Coat color	79 (73.1)	74 (68.5)	2.76	0.92
Body size	78 (72.2)	95 (88.0)	3.02	0.05
Horn orientation	42 (38.9)	59 (54.6)	14.0	0.04
Testicular size	31 (28.7)	45 (41.7)	24.0	0.001

N refers to number of respondents, CHG: Central-Highland goat breed

4.1.4. Goat production constraints

The major constraints of goat production identified by respondents in pastoral system of Yallo and mixed farming system of Raya Azebo districts are shown in Table 11. With the exception of problem of shortage of grazing land and bush encroachment which varied significantly ($P < 0.05$) with production system, the study districts were affected by more or less similar livestock/goat production constraints (Table 11).

The ranking order of the constraints of goat production in the two production systems is displayed in Table 12. In the pastoral system of Yallo district and in the mixed crop-livestock farming system of Raya Azebo district respectively, drought and feed shortage were ranked as the most important/primary constraints of goat production, followed by feed shortage in Yallo district and shortage of grazing land in Raya Azebo district (Table 12).

Table 11. Constraints of goat production in under pastoral system of Yallo and mixed farming system of Raya Azebo district

Production	**Production system**		**Test**	
	Pastoral	**Mixed CL**		
Constraints	**(N) %**	**(N) %**	**X^2 -value**	**P-value**
Bush encroachment	103 (93.5)	10 (9.3)	35.3	0.00
Shortage of grazing land	10 (9.3)	102 (94.4)	40.1	0.00
Drought	104 (96.3)	101 (93.5)	2.1	0.90
Diseases	101 (93.5)	99 (91.7)	2.3	0.31
Feed shortage	99 (91.7)	106 (98.1)	2.1	0.07
Poor veterinary service	91 (84.3)	100 (92.6)	4.1	0.30
Labor shortage	87 (80.6)	82 (75.9)	3.3	0.07
Predators	79 (73.1)	69 (63.9)	3.6	0.21
Theft	29 (26.9)	33 (30.6)	2.4	0.09

N refers to number of respondents, CL: crop-livestock

During the group discussion, the respondents from both districts stated that there is increasing interest towards goat keeping mainly due to recurrent droughts, lack of pasture/grazing land. In addition, because young boys and girls were sent to schools, labor shortage was reported as an emerging constraint of livestock/goat production in Yallo district. In both Yallo and Raya Azebo districts, hyena, baboon, fox and other wild carnivores were the predators which were reported attacking goats whereas *peste des petits ruminants*, contagious caprine pleuro-pneumonia, goat pox, internal and external parasites were reported as major diseases commonly affecting goats in both districts.

During field observation, wide spread bush encroachment due to invasion of the rangeland by *Prosopis species* was witnessed in the pastoral system of Yallo district. In Raya Azebo district animals in cluding goats were suffering from lack of feed as a result majority of the goats were in very poor body condition.

Table 12. Ranking of the constraints of goat production under under pastoral system of Yallo and mixed farming system of Raya Azebo district

Production Constraints	Production system			
	Pastoral		Mixed CL	
	N (index)	Rank	N (index)	Rank
Drought	42 (0.23)	1	26 (0.16)	3
Bush encroachment	26 (0.16)	3	-	Not ranked
Feed shortage	19 (0.20)	2	42 (0.26)	1
Diseases	11 (0.14)	4	3 (0.13)	4
Predators	10 (0.09)	6	0 (0.05)	6
Labor shortage	0 (0.02)	8	0 (0.03)	8
Poor veterinary service	0 (0.11)	5	3 (0.10)	5
Theft	0 (0.05)	7	0 (0.04)	7
Shortage of grazing land	-	Not ranked	34 (0.24)	2

N: Number of respondents ranking constraints of goat production, i.e. ranks 1, 2, 3 and 4

CL: crop-livestock

4.2. Scrotal and Testicular Traits and Sperm Quality Attributes

4.2.1. Body condition score, body weight, scrotal circumference and post-mortem testicular measurements

The relative proportion of the various body condition categories of bucks of study goat breeds is depicted in Figure 7. Overall, the sampled bucks had very thin (BCS 1), poor (BCS 2), moderate (BCS 3) and fat (BCS 4) body condition corresponding to 79 (7.4 %), 603 (56.8 %), 319 (30.0 %) and 61 (5.8 %), respectively. At breed level, very thin (BCS 1) bucks were mainly from CHG (64.6 %) followed by Afar (35.4 %). The proportions of bucks in poor/thin body condition (BCS 2) were 233 (38.7 %), 204 (33.8 %) and 166 (27.5 %) which belonged to CHG, Afar and Abergelle breed, respectively. The proportions of bucks with moderate body condition (BCS 3) were 151 (47.4 %), 99 (31.0 %) and 69 (21.6 %) for Abergelle, Afar and CHG breed, respectively. There were 37 (60.7 %) and 24 (39.3 %) fat bucks (BCS 4) which belonged to Abergelle and Afar, respectively (Figure 7).

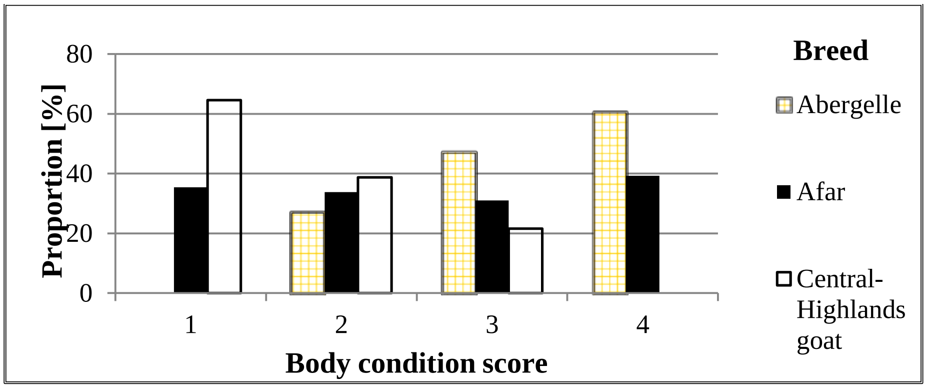

Figure 7. Body condition of bucks slaughtered at Abergelle Slaughterhouse

The effect (LSM ± SE) of breed and age on BCS, BW, SC and post-mortem testicular traits of the three goat breeds is displayed in Table 13. The body condition of bucks significantly (P < 0.05) varied with breed. Overall and at all (0 PPI, 1 PPI and 2 PPI) age categories, significantly higher (P < 0.05) body condition was recorded in Abergelle bucks compared to the body condition recorded in Afar and CHG goats. Overall and at early (0 PPI) age category, the body condition recorded in Afar goats was higher than that recorded in CHG but it did not reach significant level (Table 13).

Breed and age were mainly responsible for the significant difference (P < 0.001) in BW of the study goats. Overall, CHG had a significantly higher (P < 0.05) BW followed by Abergelle. Body weight increased with age and differences in BW were more remarkable at later (1 PPI and 2 PPI) age compared to early (0 PPI) age. In the youngest (0 PPI) age category, Abergelle and CHG goats had comparable BW which was significantly higher (P < 0.05) than that recorded in Afar breed. Among bucks at age category of 1 PPI, Afar and Abergelle had comparable (P > 0.05) BW which was significantly lower (P < 0.05) than the BW recorded in CHG. At age category of 2 PPI, CHG had a higher ($P < 0.05$) BW followed by Abergelle (Table 13).

Measurement of SC significantly varied ($P < 0.05$) with breed and age. Overall, a significantly wider ($P < 0.05$) SC was recorded in CHG whereas Abergelle and Afar had comparable ($P > 0.05$) SC which was significantly narrower ($P < 0.05$) than the SC recorded in CHG. In Abergelle and CHG goats, SC increased with age and a significantly wider ($P < 0.05$) SC was recorded at later (2 PPI) age. In Afar breed, on the contrary, a significantly wider ($P < 0.05$) SC was recorded in goats at intermediate age (1 PPI). At age categories of 0 PPI and 2 PPI, the three goat breeds had comparable ($P > 0.05$) SC. Afar and CHG goats at age category of 1 PPI had comparable ($P > 0.05$) SC and it was significantly wider ($P < 0.05$) than the SC recorded in Abergelle (Table 13).

Comparison of SC of goat breeds at similar BW revealed that bucks of Afar had significantly wider ($P < 0.05$) SC (20.6 cm) compared with the SC recorded in Abergelle (20.2 cm) whereas the SC recorded in Abergelle (20.2 cm) and CHG (20.4 cm) bucks and that of Afar (20.6 cm) and CHG (20.4 cm) breed were comparable ($P > 0.05$).

Testicular circumference was influenced ($P < 0.05$) by breed and age. Overall, a wider ($P < 0.05$) TC was recorded in CHG whereas Abergelle and Afar had comparable ($P > 0.05$) TC and it was significantly narrower ($P < 0.05$) than that recorded in CHG. In breed Abergelle, a wider ($P < 0.05$) TC was recorded at early (0 PPI) age compared to Afar and CHG breed, which attained a wider ($P < 0.05$) TC at age of 1 PPI. At early (0 PPI) age category, Abergelle and CHG had comparable ($P > 0.05$) TC which was significantly wider ($P < 0.05$) than the TC recorded in Afar goats of age 0 PPI. At age category of 1 PPI, a significantly wider ($P < 0.05$) TC was recorded in CHG compared to the TC recorded in Abergelle and Afar which had comparable ($P > 0.05$) TC (Table 13).

Table 13. Least square means (± SE) of body condition score, body weight, scrotal circumference and post-mortem testicular traits of bucks according to goat breed and age category

Variables	BCS	BW [kg]	SC [cm]	TC [cm]	TWd [cm]	TL [cm]	TV [ml]	TWt [g]	EWt [g]
Breed									
Ab	2.6 ± 0.03[a]	19.9 ± 0.2[a]	20.2 ± 0.1[a]	11.5 ± 0.1[a]	3.7 ± 0.02[a]	9.5 ± 0.04	64.5 ± 0.7	74.7 ± 0.7[a]	9.2 ± 0.1[a]
AF	2.3 ± 0.04[b]	19.1 ± 0.1[b]	20.4 ± 0.1[a]	11.3 ± 0.1[a]	3.9 ± 0.02[b]	9.6 ± 0.1	66.9 ± 0.7	74.3 ± 0.8[a]	9.2 ± 0.1[a]
CH	2.1 ± 0.03[b]	20.7 ± 0.2[c]	20.7 ± 0.1[b]	11.8 ± 0.1[b]	3.8 ± 0.02[ab]	9.5 ± 0.1	66.5 ± 0.8	79.8 ± 0.9[b]	9.5 ± 0.1[b]
Age categories									
0 PPI (N = 354)									
Ab	2.5 ± 0.1[a]	19.2 ± 0.2[a]	20.0 ± 0.1	11.6 ± 0.1[a]	3.7 ± 0.04	9.4 ± 0.1	62.5 ± 1.1	74.5 ± 1.1[a]	8.8 ± 0.1
AF	2.2 ± 0.1[b]	17.6 ± 0.1[b]	20.0 ± 0.2	11.2 ± 0.1[b]	3.8 ± 0.04	9.6 ± 0.1	64.8 ± 1.4	73.8 ± 1.7[a]	8.9 ± 0.2
CHG	2.0 ± 0.1[b]	19.9 ± 0.2[a]	20.4 ± 0.2	11.7 ± 0.1[a]	3.7 ± 0.04	9.5 ± 0.1	64.8 ± 1.5	80.2 ± 1.5[b]	9.1 ± 0.2
1 PPI (N = 354)									
Ab	2.7 ± 0.1[a]	19.5 ± 0.3[a]	20.2 ± 0.1[a]	11.4 ± 0.1[a]	3.8 ± 0.04	9.3 ± 0.1	63.0 ± 1.3	73.2 ± 1.3[a]	9.1 ± 0.2
AF	2.3 ± 0.1[b]	19.5 ± 0.3[a]	20.7 ± 0.2[b]	11.4 ± 0.1[a]	3.8 ± 0.04	9.5 ± 0.1	64.6 ± 1.2	72.8 ± 1.0[a]	9.3 ± 0.1
CHG	2.1 ± 0.1[c]	20.4 ± 0.3[b]	20.7 ± 0.2[b]	11.9 ± 0.1[b]	3.9 ± 0.04	9.4 ± 0.1	66.8 ± 1.6	79.5 ± 1.8[b]	9.6 ± 0.2
2 PPI (N = 354)									
Ab	2.7 ± 0.1[a]	20.9 ± 0.3[a]	20.5 ± 0.1	11.3 ± 0.1	3.7 ± 0.04[a]	9.9 ± 0.1	68.1 ± 1.1	76.4 ± 1.4	9.5 ± 0.1[ab]
AF	2.4 ± 0.1[b]	20.0 ± 0.3[b]	20.4 ± 0.2	11.3 ± 0.1	3.9 ± 0.04[b]	9.7 ± 0.1	71.2 ± 1.6	76.3 ± 1.8	9.3 ± 0.2[b]
CHG	2.1 ± 0.1[c]	21.9 ± 0.4[c]	20.9 ± 0.2	11.7 ± 0.1	3.8 ± 0.03[ab]	9.8 ± 0.1	67.9 ± 1.4	79.5 ± 1.4	9.8 ± 0.1[a]

[a-c]: means with different superscripts in the same column are significantly different at $P < 0.05$.
SE: standard error; Ab: Abergelle; AF: Afar; CHG: Central-Highlands goat; PPI: pair of permanent incisors; N = sample size; BCS: body condition score; BW: body weight; SC: scrotal circumference; TC: testicular circumference; TWd: testicular width; TL: testicular length; TV: testicular volume; TWt: testicular weight; EWt: epididymal weight

Breed and age were responsible for the differences ($P < 0.05$) in TWd noted among the study goats. The TWd recorded in CHG was comparable ($P > 0.05$) with that recorded in Abergelle and Afar but the TWd recorded in Afar was significantly wider ($P < 0.05$) than the TWd recorded in Abergelle. In Abergelle and CHG, a significantly wider ($P < 0.05$) TWd was recorded at age category of 1 PPI. Comparison of TWd of goats at age category of 2 PPI revealed that Afar and CHG breed had comparable ($P > 0.05$) TWd and the TWd recorded in Afar bucks was significantly wider ($P < 0.05$) than that recorded in Abergelle (Table 13).

In bucks of the three goat breeds, a significantly longer ($P < 0.05$) testis was recorded in bucks at age category of 2 PPI (Table 13) compared to that recorded at early age (0 PPI and 1 PPI). Testicular weight was influenced ($P < 0.05$) by breed and age. Overall and at age category of 0 PPI, CHG bucks had heavier ($P < 0.05$) testis whereas Abergelle and Afar bucks had comparable ($P > 0.05$) TWt and it was significantly lighter ($P < 0.05$) than that recorded in CHG. ($P > 0.05$) TWt. Measurement of TWt of the three goat breeds increased with age and significantly heavier ($P < 0.05$) testis was noted in bucks at later age (2 PPI) (Table 13).

Epididymal weight was influenced ($P < 0.05$) by breed and age. Overall, significantly heavier ($P < 0.05$) epididymis was recorded in CHG whereas Abergelle and Afar had comparable ($P > 0.05$) EWt and it was significantly lighter ($P < 0.05$) than that recorded in CHG. At later (2 PPI) age, the EWt recorded in CHG and Abergelle was comparable ($P > 0.05$) but it was significantly heavier ($P < 0.05$) than that recorded in Afar (Table 13).

4.2.2. Motility, percent live, concentration and morphological defects of spermatozoa recovered from tail of epididymis

Least square means ($\pm$ SE) on motility (mass and progressive), percent live, concentration and morphological defects of spermatozoa recovered from tail of epididymis of bucks ($n = 60$) are presented in Table 14.

Table 14. Least square means (± SE) on motility, percent live, concentration and morphological defects of spermatozoa recovered from tail of epididymis of bucks of study goats

Variables	MM [%]	PM [%]	PLS [%]	SPC ($x 10^6$ml)	% morphological defects: Head	Mid-piece	Tail	TMD [%]
Breed								
Ab	70.8 ± 1.5[a]	3.1 ± 1.4[a]	74.5 ± 0.8[a]	4300 ± 510[a]	23.8 ± 0.5[a]	17.7 ± 0.3[a]	28.1 ± 0.1[a]	4.8 ± 0.1[a]
AF	68.4 ± 1.4[a]	2.9 ± 1.6[a]	73.2 ± 0.9[b]	4200 ± 520[b]	24.8 ± 0.5[a]	18.4 ± 0.3[a]	27.3 ± 0.1[a]	4.6 ± 0.2[b]
CHG	75.3 ± 1.5[b]	4.0 ± 1.4[b]	79.9 ± 0.8[c]	5500 ± 500[a]	18.2 ± 0.3[b]	14.0 ± 0.4[b]	23.9 ± 0.3[b]	4.1 ± 0.3[b]
Age categories								
1 PPI (N = 30)								
Ab	70.0 ± 1.5[a]	3.4 ± 1.4[a]	75.8 ± 0.8[a]	4200 ± 510[a]	22.1 ± 0.5[a]	15.7 ± 0.3[a]	27.1 ± 0.1[a]	4.8 ± 0.1[a]
AF	68.9 ± 1.4[a]	3.1 ± 1.6[a]	73.8 ± 0.9[a]	4200 ± 520[a]	23.7 ± 0.5[b]	18.1 ± 0.3[b]	27.3 ± 0.1[a]	4.6 ± 0.2[b]
CHG	74.0 ± 1.5[b]	3.9 ± 1.4[b]	78.2 ± 0.8[b]	5400 ± 500[b]	18.2 ± 0.3[c]	14.3 ± 0.4[c]	24.4 ± 0.3[b]	4.0 ± 0.3[c]
2 PPI (N = 30)								
Ab	71.5 ± 1.5[a]	3.3 ± 1.4[a]	76.1 ± 0.7[a]	4400 ± 500[a]	22.0 ± 0.5[a]	14.7 ± 0.3[a]	27.5 ± 0.1[a]	4.8 ± 0.1[a]
AF	68.0 ± 1.4[a]	2.9 ± 1.6[a]	73.5 ± 0.8[b]	4200 ± 510[a]	23.8 ± 0.5[a]	19.4 ± 0.3[b]	26.9 ± 0.1[a]	4.6 ± 0.2[b]
CHG	76.0± 1.5[b]	4.0 ± 1.4[b]	80.1 ± 0.8[c]	5600 ± 500[b]	18.2 ± 0.3[b]	13.9 ± 0.4[a]	23.0 ± 0.3[b]	4.2 ± 0.3[c]

[a-c]: means with different superscripts in the same column are significantly different at $P < 0.05$.
SE: standard error; MM: mass motility; PM: progressive motility; PLS: percent live sperm; SPC: sperm concentration; Ab: Abergelle, AF: Afar; CHG: Central-Highlands goat, PPI: pair of permanent incisors; N: sample size

The mass and progressive motility, as well as percent live/dead and concentration of spermatozoa varied ($P < 0.05$) with breed and age (Table 14). The highest ($P < 0.05$) mean mass and progressive motility, percent live and concentration of spermatozoa were recorded in bucks of CHG compared to that recorded in Abergelle and Afar (Table 14). In addition, sperm collected from bucks of CHG had significantly fewer ($P < 0.05$) percent total morphological defects.

The most commonly noted sperm head defects were narrow, small, pear-shaped and detached head. Mid piece defects encountered were mainly droplets located at the junction of the mid piece with the tail whereas tail defects were coiled, double-tail, dag, cork screw and filamentous sperm.

Sperm of better quality in terms of concentration was recorded in bucks at higher BW. In Abergelle and CHG breeds, a sperm of higher ($P < 0.05$) concentration was recorded in bucks at later age (2 PPI) age. In Afar goats at age categories of 1 PPI and 2 PPI, a sperm of comparable ($P > 0.05$) concentration was recorded.

In breed Abergelle, goats in the BW categories of 18.5-22 kg and those with BW higher than 22.5 kg had a comparable ($P > 0.05$) sperm concentration which was higher ($P < 0.05$) than the sperm concentration recorded in BW category of 14-18 kg. In Afar breed, bucks in the heaviest BW category (greater than 22.5 kg) had a higher ($P < 0.05$) sperm concentration compared to the sperm concentration recorded in bucks of BW categories of 14-18 kg and 18.5-22.5 kg. The sperm concentration recorded in bucks of Afar at BW category of 18.5-22 kg was higher ($P < 0.05$) than the sperm concentration recorded in bucks of BW category 14-18 kg. In breed CHG, the sperm concentration recorded in the BW categories of 14-18 kg and 18.5-22 kg was comparable ($P > 0.05$) and lower ($P < 0.05$) than the sperm concentration recorded in bucks of BW category greater than 22.5 kg.

4.2.3. Correlation between body weight at slaughter, scrotal circumference and post-mortem testicular traits

The correlation coefficients (r) of the associations between BW, SC and post-mortem testicular traits of Abergelle and Afar breed are presented in Table 15 and that of breed CHG is presented in Table 16. Except the significant ($P < 0.001$) and moderate correlation BW had with SC noted in Abergelle and Afar ($r = 0.46$) and CHG ($r = 0.45$) which were comparable, the linear association between BW, SC and post-mortem testicular traits were not uniform across the goat breeds (Tables 15 and 16).

The highest linear association between BW and testicular measurements was the moderate correlation BW had with TWt and EWt ($P < 0.001$; $r = 0.47$) recorded in CHG (Table 16). The highest linear association between SC and testicular measurements was the strong correlation SC had with TC recorded in Afar ($r = 0.60$) (Table 15) and CHG ($r = 0.61$) (Table 16). The significant ($P < 0.001$) linear association SC had with TWt recorded in CHG ($r = 0.59$) was higher compared to the association between the same parameters recorded in Abergelle ($r = 0.50$) and Afar ($r = 0.54$).

A better linear association between SC and EWt and between TWt and EWt was recorded in Afar breed compared to the association between the respective parameters recorded in Abergelle and CHG (Tables 15 and 16). The significant ($P < 0.001$) moderate linear association between SC and EWt recorded in Afar breed ($r = 0.53$) was higher compared to the association between the same parameters recorded in Abergelle ($r = 0.44$) and CHG ($r = 0.48$). The significant ($P < 0.001$) and strong linear association between TWt and EWt recorded in Afar ($r = 0.81$) was higher compared to the association between TWt and EWt recorded in Abergelle ($r = 0.62$) and CHG ($r = 0.79$) (Tables 15 and 16).

Table 15. Correlation coefficients (r) between body weight, scrotal circumference and post-mortem testicular measurements for bucks of Abergelle (above main diagonal) and Afar (below main diagonal) breed

Parameters	**BW**	**SC**	**TC**	**TWd**	**TL**	**TV**	**TWt**	**EWt**
BW		0.46***	0.19***	0.04ns	0.24***	0.22***	0.32***	0.35***
SC	0.46***		0.52***	0.13*	0.25***	0.38***	0.50***	0.44***
TC	0.25***	0.60***		0.19***	0.10*	0.15**	0.48***	0.43***
TWd	0.28***	0.32***	0.29***		0.16**	0.29***	0.13*	0.12*
TL	0.09ns	0.39***	0.53***	0.18***		0.44***	0.41***	0.41***
TV	0.18***	0.42***	0.48***	0.34***	0.60***		0.63***	0.47***
TWt	0.19***	0.54***	0.61***	0.24***	0.71***	0.76***		0.62***
EWt	0.21***	0.53***	0.57***	0.27***	0.72***	0.69***	0.81***	

Table 16. Correlation coefficients (r) between body weight, scrotal circumference and post-mortem testicular measurements for bucks of Central-Highlands goat breed

Parameters	**BW**	**SC**	**TC**	**TWd**	**TL**	**TV**	**TWt**
BW							
SC	0.45***						
TC	0.42***	0.61***					
TWd	0.07ns	0.17**	0.22***				
TL	0.36***	0.53***	0.48***	0.08ns			
TV	0.22***	0.39***	0.45***	0.38***	0.57***		
TWt	0.47***	0.59***	0.65***	0.21***	0.75***	0.73***	
EWt	0.47***	0.48***	0.54**	0.17**	0.68***	0.58***	0.79***

***: $P < 0.0001$, **: $P < 0.001$, *: $P < 0.05$; ns: $P > 0.05$.
BW: body weight; SC: scrotal circumference; TC: testicular circumference;
TWd: testicular width; TL: testicular length; TV: testicular volume; TWt: testicular weight, EWt: epididymal weight

4.3. Linear Body Measurements and Meat Production Potential

4.3.1. Linear body measurements, body weight at slaughter, carcass weight and dressing percentage

Table 17 displays the effect (LSM ± SE) of breed and age on LBMs, BW at slaughter, HCW and DP of the studied goat breeds.

The result in Table 17 demonstrates that there were significant differences ($P < 0.05$) between the three goat breeds with regards to the linear body traits. Breed and age influenced ($P < 0.05$) HG, HAW and BL whereas PW was influenced ($P < 0.001$) by age. Overall, CHG had a significantly higher ($P < 0.001$) HG, HAW and BL than Afar and Abergelle. Abergelle and CHG breed had similar ($P > 0.05$) PW and it was significantly higher ($P < 0.001$) compared to that recorded in Afar breed.

Linear body measurements of bucks increased with age. Abergelle and CHG at similar age had comparable ($P > 0.05$) values for most of the LBMs. Across all the age (0 PPI, 1 PPI and 2 PPI) categories, Abergelle and CHG had comparable ($P > 0.05$) HG. At youngest (0 PPI) age, the PW recorded in Abergelle and CHG were comparable ($P > 0.05$); at age category of 1 PPI, Abergelle and CHG had comparable ($P > 0.05$) HAW, BL and PW whereas at age category of 2 PPI, Abergelle and CHG had comparable ($P > 0.05$) BL. In general, except for the comparable ($P > 0.05$) measurement of PW recorded in bucks of all the goat breeds at age category of 2 PPI, Afar had a significantly lower ($P < 0.05$) measurement of the linear body traits (Table 17).

The effect of breed and age on BW of the study goat breeds is described in section 4.2.1 which showed that overall; CHG had significantly higher ($P < 0.05$) BW than Afar followed by Abergelle.

Table 17. Least square means (± SE) of bucks of the three goat breeds for linear body measurements, body weight, carcass weight and dressing percentage in three age categories

Breed/age categories	HG [cm]	HAW [cm]	BL [cm]	PW [cm]	BW [kg]	HCW [kg]	DP [%]
Breed							
Ab	64.0±0.2[a]	64.0±0.2[a]	60.2±0.2[a]	10.2±0.1[a]	19.9±0.2[a]	8.9±0.1[a]	44.8±0.3[a]
AF	61.5±0.2[b]	61.7±0.2[b]	59.6±0.2[a]	9.9±0.1[b]	19.1±0.1[b]	8.4±0.1[b]	43.8±0.3[b]
CH	64.8±0.2[c]	65.6±0.2[c]	61.4±0.2[b]	10.3±0.1[a]	20.7±0.2[c]	9.1±0.1[a]	43.7±0.3[b]
Age categories							
0 PPI (N = 354)							
Ab	62.8±0.3[a]	62.9±0.4[a]	58.9±0.4[a]	10.0±0.1[a]	19.2±0.2[a]	8.6±0.1[a]	45.1±0.4[a]
AF	59.7±0.3[b]	60.9±0.3[b]	58.0±0.4[a]	9.4±0.1[b]	17.6±0.1[b]	7.5±0.1[b]	42.8±0.4[b]
CH	63.6±0.3[a]	64.9±0.4[c]	60.4±0.4[b]	9.8±0.1[a]	19.9±0.2[a]	8.6±0.1[a]	43.5±0.4[b]
1 PPI (N = 354)							
Ab	63.8±0.3[a]	63.9±0.3[a]	59.9±0.4[ab]	10.1±0.1[a]	19.5±0.3[a]	8.6±0.1	44.2±0.5[a]
AF	61.4±0.3[b]	61.9±0.3[b]	59.4±0.4[b]	9.7±0.1[b]	19.5±0.3[b]	8.6±0.2	43.9±0.4[ab]
CH	64.8±0.3[a]	64.9±0.4[a]	60.9±0.4[a]	10.2±0.1[a]	20.4±0.3[b]	8.8±0.1	42.9±0.4[b]
2 PPI (N = 354)							
Ab	65.5±0.3[a]	65.2±0.3[a]	61.6±0.4[ab]	10.6±0.1	20.9±0.3[a]	9.4±0.2[ab]	45.1±0.5
AF	63.5±0.4[b]	62.4±0.3[b]	61.3±0.4[b]	10.7±0.1	20.0±0.3[b]	8.9±0.2[b]	44.7±0.7
CH	66.2±0.5[a]	67.0±0.5[c]	62.7±0.4[a]	10.7±0.1	21.9±0.4[c]	9.8±0.2[a]	44.7±0.5

[a-c] : means within column and section with one letter in common are not significantly separated ($P > 0.05$).
SE: standard error; Ab: Abergelle goat; AF: Afar goat; CHG: Central-Highlands goat; PPI: pairs of permanent incisors; N = sample size; HG: heart girth; HAW: height at withers; BL: body length; PW: pelvic width; BW: body weight; HCW: hot carcass weight; DP: dressing percentage.

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Breed and age had significantly affected ($P < 0.001$) HCW. Overall, the HCW recorded in Abergelle and CHG was comparable ($P > 0.05$) but it was significantly higher ($P < 0.05$) than that recorded in Afar. Hot carcass weight of the slaughtered goats increased with age. At age category of 0 PPI and 2 PPI, Abergelle and CHG had comparable ($P > 0.05$) HCW but it was significantly higher ($P < 0.05$) than that recorded in Afar. At age category of 1 PPI, the three goat breeds had comparable ($P > 0.05$) HCWt (Table 17).

Breed and age had significantly influenced ($P < 0.05$) DP. Overall, a significantly higher ($P < 0.05$) DP (calculated on slaughter BW basis) was noted in Abergelle whereas Afar and CHG breed had similar ($P > 0.05$) DP which was significantly lower ($P < 0.05$) than the DP of Abergelle (Table 17). Dressing percentage increased with age. At age category of 0 PPI, Abergelle breed had a significantly higher ($P < 0.05$) DP whereas the DP of Afar and CHG breeds was comparable ($P > 0.05$) but it was significantly lower ($P < 0.05$) than that noted in Abergelle. At age category of 1 PPI, with similar value ($P > 0.05$), the DP of Abergelle and Afar breed was significantly higher ($P < 0.05$) than that of CHG breed whereas at later age (2 PPI) category, the DP of the three goat breeds was comparable ($P > 0.05$) (Table 17).

Regression analysis of DP on BW categories within each goat breeds showed that in breed Abergelle, no significant ($P > 0.05$) difference in DP was noted among the three BW categories. On the contrary in Afar and CHG, the highest ($P < 0.05$) DP was noted in in bucks of BW category of 18.5-22 kg compared to the DP recorded in bucks of BW category of 14-18 kg and those greater than 22.5 kg

4.3.2. Correlation between linear body measurements, body weight at slaughter, carcass weight and dressing percentage

The correlation coefficients (r) for the associations between BW, LBMs, HCW and DP for Abergelle and Afar are shown in Table 18 and that of CHG is presented in Table 19.

Table 18. Correlation coefficients (r) between body weight, linear body measurements, carcass weight and dressing percentage for bucks of Abergelle (above main diagonal) and Afar breed (below main diagonal).

Parameters	BW	HG	BL	HAW	PW	HCW	DP
BW		0.48***	0.26***	0.37***	0.18***	0.76***	-0.05ns
HG	0.47***		0.49***	0.61***	0.29***	0.44***	0.07ns
BL	0.39***	0.45***		0.54***	0.14**	0.30***	0.14**
HAW	0.43***	0.46***	0.49***		0.01ns	0.36***	0.09ns
PW	0.31***	0.42***	0.20***	0.21***		0.22***	0.12*
HCW	0.77***	0.47***	0.43***	0.44***	0.29***		0.58***
DP	0.16**	0.24***	0.28***	0.26***	0.15**	0.74***	

Table 19. Correlation coefficients (r) between body weight, linear body measurements, carcass weight and dressing percentage for Central-Highlands goat breed

Parameters	BW	HG	BL	HAW	PW	HCW
BW						
HG	0.60***					
BL	0.52***	0.56***				
HAW	0.61***	0.61***	0.63***			
PW	0.41***	0.37***	0.34***	0.39***		
HCW	0.84***	0.52***	0.53***	0.62***	0.36***	
DP	0.11*	0.09*	0.23***	0.25***	0.09*	0.61***

***: P < 0.0001, **: P < 0.001, *: P < 0.05.
BW: body weight; HG: heart girth; BL: body length; HAW: height at withers;
PW: pelvic width; HCW: hot carcass weight; DP: dressing percentage.

At breed level, the correlation between BW, LBMs, HCW and DP were not uniform (Tables 18 and 19). In breed CHG, a moderate (P < 0.0001; r = 0.52 - 0.62) correlation between BW and LBMs (HG, BL, HAW and PW) were recorded which were higher when compared with that recorded in Abergelle (P < 0.0001; r = 0.18 – 0.48) and Afar (P < 0.0001; r = 0.31 – 0.51). In Afar breed, the highest correlation was that noted between BW and HG (r = 0.48) (Tables 18 and 19).

Common to all the three goat breeds, BW had a strong correlation with HCW ($P < 0.0001$; $r = 0.76 – 0.84$). A higher correlation between BW and HCW was that recorded in CHG ($r = 0.84$) compared with that recorded in Abergelle ($r = 0.76$) and Afar ($r = 0.77$). In CHG, the correlation HCW had with LBMs (HG, BL, HAW and PW) was moderate ($P < 0.0001$; $r = 0.36 – 0.63$) but it was higher than that recorded in Abergelle ($P < 0.0001$; $r = 0.22 – 0.44$) and Afar ($P < 0.0001$; $r = 0.29 – 0.59$) (Tables 18 and 19).

Hot carcass weight had the highest correlation with HAW recorded in bucks of CHG ($P < 0.0001$; $r = 0.62$) and Abergelle ($P < 0.0001$; $r = 0.44$). In bucks of the three goat breeds, HCW had a moderate association with DP ($P < 0.0001$; $r = 0.58$ - 0.74) and in Afar breed, a higher association between HCW and DP ($r = 0.74$) was recorded (Table 19).

4.3.3. Prediction of carcass weight and dressing percentage

For setting models for predicting HCW, univariate analysis of variance for each age category of the three goat breeds showed differing individual correlation between the dependent (HCW) and the predictor variables (LBMs and BW). In breed CHG at all age (0 PPI, 1 PPI and 2 PPI) categories; in Abergelle breed at youngest (0 PPI) age category and in bucks of Afar at age category of 0 PPI and 1 PPI, HCW had significant ($P < 0.05$) independent association with all the predictor variables (LBMs and BW). In Abergelle breed, at age category of 1 PPI, except BL all the predictor variables had significant ($P < 0.05$) independent association with HCW. In Abergelle and Afar breed, at age category of 2 PPI, except PW, all the predictor variables had significant ($P < 0.05$) independent association with HCW.

Multivariate analysis of variance (MANOVA) for each age category of the three goat breeds revealed differing association between the dependent variable (HCW) and the predictor variable/s. In Abergelle breed at youngest (0 PPI) age category, BW was the only predictor which had significant ($P < 0.05$) association with HCW. In bucks of CHG at youngest (0 PPI) age category, HCW had significant ($P < 0.05$) association with HG, BL and BW. In bucks of Afar breed at age categories of 0 PPI and 1 PPI, HCW had significant ($P < 0.05$) association with PW and BW. In bucks of CHG at age category of 1 PPI; in Abergelle and Afar breed at age category of 2 PPI, HCW had significant ($P < 0.05$) association with BW. In Abergelle breed at age category of 1 PPI, HCW had significant ($P < 0.05$) association with HAW and BW. In bucks of CHG at age category of 2 PPI, HCW had significant ($P < 0.05$) association with HAW, PW and BW.

Similarly, for setting models for predicting DP, univariate analysis of variance for each age category of the three goat breeds was performed which showed that in Afar and CHG breed of all age (0 PPI, 1 PPI and 2 PPI) categories and bucks of Abergelle breed at age categories of 0 PPI and 2 PPI, DP had significant ($P < 0.05$) independent association with HCW. On the contrary, in bucks of Abergelle at age category of 1 PPI, the predictor variables BW and HCW had significant ($P < 0.05$) independent association with DP. Multivariate analysis of variance (MANOVA) analysis was performed for bucks of Abergelle breed at age category of 1 PPI which showed the predictor variables BW and HCW to had significant ($P < 0.05$) association with DP.

The best fit models for predicting HCW (Table 20) for each age category of the three goat breeds were set using only those predictor variables which had significant ($P < 0.05$) association with the dependent variables (HCW) in the multivariate analysis. Similarly, the best fit models for predicting DP (Table 21) for each age category of the three goat breeds were set using only predictor variable/s which had significant ($P < 0.05$) association with DP.

Table 20. Best fit models for predicting carcass weight of bucks of Abergelle, Afar and Central-Highlands goat breed

Age categories	Regression models	R^2	RMSE	AIC	C (p)
0 PPI (N = 354)					
Ab	HCW = 0.75 + 0.4 BW	0.55	0.8	-39.5	2
AF	HCW = - 9.4 + 0.2 PW + 0.4 BW	0.74	0.6	-123	3
CHG	HCW = - 0.5 - 0.1 HG + 0.04 BL + 0.5 BW	0.73	0.8	-52.3	4
1 PPI (N = 354)					
Ab	HCW = - 1.5 + 0.1 HAW + 0.3 BW	0.49	1.0	14.6	3
AF	HCW = - 3.6 – 0.2 PW + 0.4 BW	0.76	0.8	-45.9	3
CHG	HCW = - 1.32 + 0.4 BW	0.61	1.0	-4.30	2
2 PPI (N = 354)					
Ab	HCW = - 3.9 +0.4 BW	0.69	1.1	16.9	2
AF	HCW = - 5.3 + 0.5 BW	0.51	1.5	104	2
CHG	HCW = - 6.4 + 0.1 HAW - 0.3 PW + 0.3 BW	0.84	0.9	-20.5	4

R^2: coefficient of determination; RMSE: root mean square error; AIC: Akaike information criterion; C (p): conceptual predictive criterion; PPI: pair of permanent incisors; N = sample size; Ab: Abergelle goat; AF: Afar goat; CHG: Central-Highlands goat; HCW: hot carcass weight; BW: body weight; PW: pelvic width; HG: heart girth; BL: body length; HAW: height at withers.

Table 21. Best fit models for predicting dressing percentage of bucks of Abergelle, Afar and Central-Highlands goat breed

Age categories	Regression models	R^2	RMSE	AIC	C (p)
0 PPI (N = 354)					
Ab	DP = 27 + 2.1 HCW	0.32	3.7	313.2	2
AF	DP = 20.8 + 2.9 HCW	0.57	2.8	247.6	2
CHG	DP = 28 + 1.8 HCW	0.41	3.2	278.1	2
1 PPI (N = 354)					
Ab	DP = 43.6 – 1.9 BW + 4.5 HCW	0.97	0.8	- 45.8	3
AF	DP = 28.9 + 1.7 HCW	0.41	3.4	292.3	2
CHG	DP = 27.5 + 1.8 HCW	0.34	3.9	325.8	2
2 PPI (N = 354)					
Ab	DP = 28.3 + 1.7 HCW	0.40	4.1	334.3	2
AF	DP = 18.9 + 2.9 HCW	0.64	4.7	368.2	2
CHG	DP = 30.8 + 1.4 HCW	0.36	4.2	340	2

R^2: coefficient of determination; RMSE: root mean square error; AIC: Akaike information criterion; C (p): conceptual predictive criterion; PPI: pair of permanent incisors; N = sample size; Ab: Abergelle goat; AF: Afar goat; CHG: Central-Highlands goat; DP: dressing percentage; HCW: hot carcass weight; BW: body weight;

5. DISCUSSION

In this study, which was conducted in north Ethiopia, the species preference, purposes of keeping, the management practice and production constraints of goats in two contrasting production systems (pastoral system of Yallo/Afar and mixed crop-livestock system of Raya Azebo/Tigray) was assessed. In addition, the scrotal/testicular characteristics as well as the LBMs and meat production potential of three goat breeds (Abergelle, Afar and CHG) at three age categories (0 PPI, 1 PPI and 2 PPI) was investigated using randomly selected bucks which were slaughtered at Abergelle Slaughter house. Because the Slaughterhouse was dealing mainly with slaughter of younger goats, this study was limited to the three age categories (0 PPI, 1 PPI and 2 PPI). In addition, the age of the study bucks was estimated based on their dentition pattern. This was because under the prevailing traditional livestock management systems, there is no record keeping. As a result, the age range within study age groups (in months) could possibly be very wide as is the BW range within the age categories. In addition, the actual ages of the bucks depends on the sample size, for instance for age class of 1 PPI of a breed, the sampled bucks could be close to one year whereas for the other breed/s, the sampled bucks could be of age close to 2 years. Hence, this is considered as one drawback of the study. On the otherhand, the study goats were kept under similar traditional (extensive) livestock management systems which are generally characterized as low input systems. During the dry season the traditional and extensive management of the goats is constrained by feed shortage and this is generally common to all production systems. However, this difference in feeding regime of the goats could be taken as additional confounding factor. Further more, in order to obtain sufficient sample size within the shortest possible time, the study was undertaken during the dry season, as it coincides with season of the year when the slaughterhouse's throughput is at its maximum.

5.1. Management Practice and Production Constraints of Goats

5.1.1. Livestock holding and preference

The present study revealed a higher goat holding by HHs in the pastoral system of Yallo district which is consistent with the report of Ebrahim and Hailemichael (2012) who noted a higher holding of goats per HHs in the lowland agro-ecology compared with HHs in the highland or mid highland agro-ecology. In addition, Tadesse *et al*. (2014) reported a higher holding of goats in the pastoral and agro-pastoral areas compared with the holding of goats in the mixed crop-livestock system practiced in the highlands. According to Tolera and Abebe (2007), the type and size of livestock holding is influenced by agro-ecological setting of an area where climatic, edaphic and biotic factors could directly affect the availability/amount, quality and distribution of animal feed resources. Due to availability of shrubs and bushes, the low land agro-ecology where pastoralism and agro-pastoralism are dominant is purely suitable for goat and camel production (Tessema *et al*., 2003). According to Tsegahun *et al*. (2000) and Tessema *et al*. (2003), because of abundance of browse, goat production has experienced success in the lowlands. Hence, average holding of goats per HHs in the pastoral/lowland area is higher compared with the goat holding in the highland or mid highland agro-ecological zones.

In the pastoral system of Yallo district, goats were reported as the most preferred species (Table 4) which is in agreement with previous studies (Tsegahun *et al*., 2000; Seid and Tesfay, 2014). In the mixed farming system of Raya Azebo district too, goats were found as the most preferred species (Table 4) which is in contrast to previous studies (IBC, 2004; Ebrahim and Hailemichael, 2012) who reported cattle as the most preferred species in all agro-ecological zones. Considering the dynamic nature of a production system (Peacock, 2005), the role and importance livestock have in a production system might change overtime so that goats might have become more important and ranked first in the mixed farming system of Raya Azebo district. Group discussion held in Raya Azebo district has also revealed that frequent drought is commonly affecting the area so that crop production and large ruminant keeping is becoming unreliable whereas goat keeping is increasing and expanding from time to time. Such increasing trend towards goat keeping may be explained by goats' best adaptation to harsh environment, browsing habit, adaptation to poor feed resources and high milk yield per lactation (Seid and Tesfay, 2014).

5.1.2. Purposes of keeping goats

In this study, it was demonstrated that goats are kept for multiple reasons (Table 5). Similar to the finding of this study, previous studies (Gizaw *et al*., 2010; Seid and Tesfay, 2014; Tadesse *et al*., 2014) undertaken in different parts of Ethiopia have also shown the diverse purposes of goat keeping irrespective of production system. This study has also shown the dependency of pastoral HHs on goats as source of milk which is in line with the finding of Seid and Tesfay (2014). According to Seid and Tesfay (2014), the ranking of milk production as the first purpose of goat keeping in the pastoral system is because milk is the staple diet of many pastoral societies. Different from the finding of this study, Tadesse *et al*. (2014) reported cash generation as the first purpose of goat keeping in the pastoral/agro-pastoral systems. On the otherhand, in the mixed crop-livestock system of Raya Azebo district, Tigray region, income generation was indicated as the major reason for goat keeping (Table 6) which is consistent with the finding of previous studies (Legesse *et al*., 2008; Tadesse *et al*., 2014) undertaken in the southern highlands of Ethiopia but it is different from the report of Kebede *et al*. (2012) who reported milk production as the first purpose of keeping goats in the mixed crop-livestock farming system of the rift valley of Ethiopia. The social, cultural and religious purposes of goats were the reasons for the increasing interest and dependency of pastoral HHs on goats as indicated in previous studies (Mekasha, 2007; Tadesse *et al*., 2014). The trend for preference of keeping goats will likely to continue because of the ongoing climatic change and its effects which include frequent drought, shrinking grazing land, feed and water shortage as well as bush encroachment (Peacock and Sherman, 2010).

5.1.3. Management practice

In the pastoral system of Yallo district as well as mixed farming system of Raya Azebo district, goats were provided with a shelter/enclosure but the type of housing is not uniform acroos the two districts (Table 7). Previous studies (Assefa, 2007; Kocho, 2007; Kebede *et al*., 2012) have shown also that sheltering/enclosure of goats as a common management practice with additional information that the type and location of the shelter may vary from area to area. According to Kebede *et al*. (2012), the range of goat sheltering include a separate house for adults, suckling kids and adult goats may share family house or corrals or yards may be used as night enclosure for adult goats or kids may be kept with adult goats but with no contact with dams. Goats may be provided with a separate house (Shenkute, 2009; Urgessa *et al*., 2012) and thorny enclosure is common in pastoral areas with separate pens made available for kids (Gebreyesus, 2010). Different from the way goats are housed in the current study locations, previous studies (Assefa, 2007; Kocho, 2007; Kebede *et al*., 2012) reported that in most cases, owners and goats may share a house. In addition, keeping adult and young goats together as reported by Kebede *et al*. (2012) needs care as it might increase chances of disease transmission mainly parasitic diseases from adults to young stock.

The water sources for goats which were identified in the current study areas are common to other goat rearing areas of the country as reported in previous studies (Assefa, 2007; Urge *et al*., 2007; Shenkute, 2009; Tadesse *et al*., 2014). Reports indicate that water sources are seasonal and watering frequency is dictated by water availability which in turn depends on season and agro-ecology (Assefa, 2007; Urge *et al*., 2007; Shenkute, 2009; Tadesse *et al*., 2014). According to Tadesse *et al*. (2014), most of the water sources in the pastoral production system dry up during the dry season as a result goats are forced to stay without water for three or more days. Long watering frequency is a challenge to the goat owners as lactating goats are unable to produce adequate milk for their kids and for use by the pastoralists (Urge *et al*., 2007).

The feed resources available to goats noted in this study (Table 8) are in agreement with the result of previous studies (Gidey, 2008; Ebrahim and Hailemichael, 2012; Tadesse *et al*., 2014) who reported grass, forb and browse in natural grazing lands as major feed resources for goats in the lowlands. Feed resources for goats kept in the mixed system which is commonly practiced in the highlands include natural pasture in the grazing fields and farm lands in addition to crop residue (straw) and aftermath and weed. In the majority of goat rearing areas of Ethiopia including the localities where this study was undertaken, supplementation of goats was uncommon. Hence, the traditional (extensive) goat management system is generally characterized as low input system (Deribe and Taye, 2013).

The current study revealed that both in the pastoral system of Yallo district and mixed crop-livestock systems of Raya Azebo district, mating was partially controlled through selection of breeding bucks. Uncontrolled mating as a common breeding practice was reported by different scholars (Kebede *et al*., 2012; Seid and Tesfaye, 2014). Kebede *et al*. (2012) indicated that since goat flocks share common grazing land and the number of breeding bucks is insufficient, mating is uncontrolled. In the mixed farming system of Raya Azebo district a lower proportion of goat owners keep breeding male because of high offtake, and the communal grazing and use of bucks.

In this study it was found that the respondents from both study systems keep breeding males (Table 9) which are either born to own flock, bought or burrowed from neighbors. Males intended for breeding purpose are selected on the basis of some defined criteria (Table 10). As compared to the result of this study, much more criterion of selection of breeding bucks were reported by Kebede *et al*. (2012) which include physical characteristics (such as size, conformation, leg length, ear and horn), color, testicular characteristics, libido, growth rate, prolificacy and disposition/character of bucks with slightly more emphasis being given to morphological (physical) characteristics and color. Farmers want to own breeding goats adaptive to their environment, which have better milk production potential, with large body size, fast growth rate and better reproductive performance in terms of kidding interval and prolificacy (Kebede *et al*., 2012). Kebede *et* *al*. (2012) further reported that buck selection criteria might differ with breed, production system and availability of market opportunity.

5.1.4. Goat production constraints

With the exception of reported problem of shortage of grazing land and bush encroachment, the goat production constraints identified in the two production systems were more or less similar (Table 11). In the pastoral system of Yallo district and mixed farming system of Raya Azebo district, drought and feed shortage, respectively were ranked as the most important constraints of goat production, followed by feed shortage in Yallo and shortage of grazing land in Raya Azebo district (Table 12). Though the extent and ranking order of the constraints of goat production may differ, the goat production constraints identified in this study in the pastoral system of Yallo district and mixed farming system of Raya Azebo district are common to other goat rearing areas of the country. For instance, in a study involving pastoral HHs of Chifra district (Afar region), Seid and Tesfaye (2014) reported feed shortage, drought and health problems as the three most important constraints of small ruminant production. In addition, recurrent drought (Kebede *et al*., 2012), goat diseases, feed shortage (Tibbo, 2006; Kocho, 2007; Shenkutie, 2009; Gizaw *et al*., 2010; Kebede *et al*., 2012; Tadesse *et al*., 2014), parasites, predators (Shenkutie, 2009; Tadesse *et al*., 2014), shortage of grazing land (Kocho, 2007; Shenkutie, 2009; Kebede *et al*., 2012), labor shortage (Tadesse *et al*., 2014) and poor veterinary service (Ebrahim and Hailemichael, 2012) were reported as major constraints of goat production in different parts of Ethiopia.

The goat breeds under study were kept under traditional (extensive) livestock management systems which are characterized as low input systems (Deribe and Taye, 2013). In the mixed crop-livestock farming systems, in which Abergelle and CHG breeds are reared there is encroachment of arable land for crop production with resultant lack of grazing land forcing livestock to be maintained on unproductive hillsides, crop stubble or over-grazed communal grazing land with resultant inadequate nutrition which affects livestock productivity (Mekasha *et al*., 2008). Similarly, the pastoral and agro-pastoral systems from where Afar and Abergelle goat breeds are originating are also constrained by different factors such as feed shortage, drought and livestock diseases which affect the productivity of livestock including goats. In relation to this, in a study conducted by Ebrahim and Hailemichael (2012) involving the highland, mid land and lowland agro ecologies of Tigray region, shortage of feed and health problem were identified as the first and second constraints to small ruminant production both in the highland and midland agro ecologies whereas in the lowland agro ecology, animal health problem was rated as the first most important constraint to small ruminant production followed by shortage of feed, scarcity of water and drought (Ebrahim and Hailemichael, 2012). In another study conducted by Seid and Tesfaye (2014) involving pastoral and agro-pastoral production system of Afar region, it was found that small ruminant production in the pastoral production system is constrained by feed shortage, drought, health problems and water shortage whereas in the agro-pastoral system, feed shortage, drought and unavailability of supplementary feed were reported as major constraints to small ruminant production with conclusion that feed shortage and drought are equally important in both production systems. In general, the availability of feed resources is seasonal, being governed by seasonal rainfall pattern. Animal productivity is thus determined by the fluctuation in the availability of feed resources (Mekasha *et al*., 2008). In addition, poor nutrition and parasitic load may mask the true genetic potential of the animals (Kefyalew Berihun *et al*., 2013).

5.2. Scrotal and Testicular traits and Sperm Quality Attributes

The scrotal and testicular traits and sperm quality attributes have essential implication as indirect selection criteria in breed improvement programs.

5.2.1. Body condition score, body weight, scrotal circumference and post-mortem testicular measurements

Over half (56.8 %) of the bucks of the three goat breeds used in this study were in poor body condition (BCS 2) (Figure 7) and this finding contrasts well to the report made by

Agga *et al*. (2011) who found a higher proportion (66.6 %) of slaughtered bucks to have poor body condition. In this study, it was found that at breed level, breed Abergelle was in a better body condition than Afar and CHG (Table 13). The differences in body condition of breeds might be explained by the nutritional status of the animals which in turn is associated with farming or production system and agro-ecology as described by Mekasha *et al*. (2008) and Agga *et al*. (2011). In the cross sectional survey, feed scarcity was ranked as the first constraint in the mixed crop-livestock system of Raya Azebo which could explain the poor body condition noted in CHG goats.

Breed and age were responsible for differences in BW of the study goat breeds. Overall and at age categories of 1 PPI and 2 PPI, CHG was the heaviest followed by Abergelle whereas Afar breed was the lightest (Table 13). The variation in BW noted among the study goat breeds is important as it is closely associated with testicular mass (Nsoso *et al*., 2004) which is known to affect the reproductive capacity (Mekasha *et al*., 2008). There is a wealth of information indicating that sperm production capacity and the overall breeding efficiency of small ruminants is a reflection of their body size, which inturn is influenced by age, breed, season and nutritional status (Karagiannidis *et al*., 2000; Rege *et al*., 2000; Toe *et al*., 2000; Mekasha *et al*., 2008; Ugwu, 2009).

This study has demonstated that breed and age had contributed to differences in measurement of SC and the widest SC was recorded in CHG which were the heaviest (Table 13). In addition, cmparison of SC of goat breeds at similar BW revealed that SC recorded in bucks of CHG was comparable to the SC recorded in Abergelle and Afar whereas the SC recorded in Afar breed was wider than that recorded in Abergelle. The result of this study on effect of breed and age on SC is in agreement with previous studies (Mekasha *et al*., 2008; Agga *et al*., 2011) who reported breed and age as important factors affecting SC with additional information that large-sized breeds are characterized by a wider SC.

Comparison of SC of Afar and CHG at specific age category recorded in this study with SC of bucks of their respective breed at similar age category recorded in previous studies

(Mekasha *et al*., 2008; Agga *et al*., 2011) revealed differences. For example, the SC recorded (20.7 ± 0.2) cm in the current study in Afar goats at age category of 1-2 years old is lower than the SC recorded in Afar bucks as (22.3 ± 0.5) cm and 21.3 cm by Mekasha *et al*. (2008) and Agga *et al*. (2011), respectively. In the same age category, the SC of CHG recorded (20.7 ± 0.2) cm in this study was lower than the SC of CHG recorded as (21.3 ± 0.6) cm by Mekasha *et al*. (2008). Such variation in SC might be explained by differences in body size, nutrition (Bielli *et al*., 2000; Mekasha *et al*., 2008), season (Bielli *et al*., 2000), management system and age (which is in a range that inturn could gives rise to differences in BW within age groups depending on sample size). According to Chacon *et al*. (2002), SC is considered as major component of BSE because it indirectly tells about testicular mass and provides indications on size and growth. Scrotal circumference is reported as a dependable measurement of reproductive status, spermatogenic capacity and seminal characteristics in post-pubertal goats (Daudu, 1984) and it is also taken as a reliable guide to sperm production capacity (Raji *et al*., 2008; Ugwu, 2009). Age (which is in a range) could also give rise to differences in reproductive status, spermatogenic capacity and seminal characteristics in post-pubertal goats, hence age adjustment is essential.

In the current study, it was demonstrated that breed and age had differing influence on testicular traits (Table 13). This study showed also that breed CHG which were the heaviest ($P < 0.05$) had the widest ($P < 0.05$) TC as well as the heaviest ($P < 0.05$) TWt and EWt. The finding of this study on effect of breed and age on testicular traits is consistent with the findings of previous studies (Mekasha *et al*., 2008; Agga *et al*., 2011). Similar association between BW and testicular/epididymal parameters was also reported by Al-Ghalban *et al*. (2004) and Agga *et al*. (2011) who found the highest testicular parameters and EWt in bucks with higher BW. According to Agga *et al.* (2011) such relationship between body size and testicular/epididymal measurements is attributed to genotype or breed effect.

Comparison of the post-mortem testicular traits of the goat breeds at specific age category recorded in this study with the testicular measurement of bucks of their respective breed at similar age category reported in previous studies (Mekasha *et al*., 2008; Agga *et al*., 2011) showed differences. For instance, the testicular traits of goats belonging to the three age (0 PPI, 1 PPI and 2 PPI) categories of Afar goats recorded in this study were highly inconsistent when compared with the testicular traits of bucks of the same breed at similar age categories reported by Agga *et al*. (2011). Differences in testicular measurements can be explained by the nutritional status of the animals which has a direct influence on testicular and epididymal growth (Mekasha *et al*., 2008). The same authors stated also that the difference in TWt of bucks at various constant age-groups is important because of its implication on the existence of genetic diversity which is required for breed improvement. According to Harder *et al.* (1995), comparison of TWt at a constant age may be a useful indicator trait to select for increased reproductive efficiency. A heavier EWt can support high spermatozoa reserve and a better endocrinological basis with the latter having a positive influence on the maturation and subsequent storage of spermatozoa (Mekasha *et al*., 2007).

5.2.2. Motility, percent live, concentration and morphological defects of spermatozoa recovered from tail of epididymis

The mass and progressive motility, percent live, concentration and total morphological attributes of spermatozoa recovered from tail of epididymis were influenced by breed and age (Table 14). A sperm of higher ($P < 0.05$) mass and progressive motility, percent live and concentration with fewer ($P < 0.05$) morphological defects was recorded in CHG. In a study undertaken by Mekasha *et al*. (2007), a sperm with a higher ($P < 0.05$) proportion of coiled tails; greater ($P < 0.05$) proportion of spermatozoa with double-folded coiled tails; under the head coiled tails and total tail defects was recorded in bucks of Afar and CHG. Mekasha *et al*. (2007) have also noted that sperm of bucks at younger age (< 1 years old) had an increased ($P < 0.05$) proportion of loose heads whereas sperm of bucks at older age (1 to 2 years old) had an increased ($P < 0.05$) proportion of tail defects compared to sperm collected from bucks at younger age (< 1 years old). The sperm of bucks at older age (around age of 2 years) had greater ($P < 0.05$) proportion of simple bent tails as compared to sperm of goats at younger (< 1 years old) and intermediate (14 to 19.5 months old) age (Mekasha *et al*., 2007). In mature Damascus bucks, Al-Ghalban *et al*. (2004) recorded a higher (P < 0.05) viable sperm concentration associated with lower (P < 0.05) percentage of abnormal sperm cells. In a study conducted by Kabiraj *et al*. (2011) involving Black Bengal bucks of Bangladesh, a higher proportion of live spermatozoa (85.6 $\pm$ 0.8) was noted in bucks at age category of 1.5 to 2 years old compared to bucks at age categories of 6 months to 1 years and 2.5 to 3 years old but the difference did not reach significance level (P > 0.05). According to Mekasha *et al*. (2007), bucks of lowlands origin (Afar, Borena and Woito Guji) had a higher proportion of abnormal sperm cells compared to bucks of highland origin (e.g. CHG) which could be attributed to the high ambient temperature prevalent in the lowlands which can possibly affect the scrotal skin temperature (Pinto *et al*., 2001; Nichi *et al*., 2006; Mekasha *et al*., 2008). An accurate morphological examination of spermatozoa enables the elimination of males with potentially low fertility (Rodriguez-Martinez and Barth, 2007).

In Aberegelle and CHG goats, bucks at later age (2 PPI) category had sperm of higher concentration whereas in Afar breed the sperm concentration recorded in bucks at age categories of 1 PPI and 2 PPI was comparable. In addition, sperm of higher concentration was noted in heavier bucks particularly in Afar and CHG whereas in bucks of Abergelle breed, bucks in the BW categories of 18.5-22 kg and > 22.5 kg had a comparable (P > 0.05) sperm concentration which was higher than the sperm concentration recorded in BW category 14-18 kg. These results can be considered as as additional criteria in the selection of breeding bucks of optimum fertiltity.

5.2.3. Correlation between body weight at slaughter, scrotal circumference and post-mortem testicular measurements

This study has shown that except the comparable, significant (P < 0.001) and moderate correlation BW had with SC recorded in Abergelle and Afar (r = 0.46) and CHG (r = 0.45) breeds, the correlations between BW, SC and post- mortem testicular traits recorded in the three goat breeds were not uniform (Tables 15 and 16). The moderate association noted between BW and SC (r = 0.45 - 0.46) recorded in this study was lower than the correlation between the same parameters recorded by Agga *et al*. (2011) (r = 0.58) and Mekasha *et al*. (2008) (r = 0.61). In this study, it was found that the significant (P < 0.001) correlation SC had with the testicular measurements (r = 0.21 - 0.58) was higher than the correlation noted between BW and SC (r = 0.45 - 0.46) which is in a similar pattern to the correlation between the same parameters reported in previous studies (Mekasha *et al*., 2007; 2008; Agga *et al*., 2011). The strong correlation SC had with post-mortem testicular traits could provide a good basis for predicting post-mortem testicular measurements using SC which is recorded on live animals (Agga *et al.*, 2011). The correlation between BW and testicular measurements is influenced by breed, physiological status, nutrition and management (Mekasha *et al*., 2008). The strong association BW had with SC and TWt indicate that the growth of the genital organ occurs in parallel to increase in body mass (Mekasha *et al*., 2008). The correlation between SC and body measurements demonstrates that all growth variables are interrelated showing that improvement in one variable cannot be achieved without influencing the others (Mekasha *et al*., 2008).

5.3. Linear Body Measurements and Meat Production Potential

5.3.1. Linear body measurements, body weight at slaughter, carcass weight and dressing percentage

The present study demonstrated that differences in linear body measurements of bucks were due to effects of breed and age. The highest HG, HAW and BL were recorded in CHG followed by Abergelle whereas the lowest values of most of the LBMs were recorded in Afar breed. On the other hand, comparable PW was recorded in Abergelle and CHG (Table 17). Similar finding was noted by Mekasha *et al*. (2008) who reported that breed had noticeable effect on physical linear traits of bucks of five indigenous goat (Afar, Arsi-Bale, Boran, CHG and Woito Guji goats) breeds. According to Nsoso *et al*. (2004), the physical linear traits of a specific animal breed are important phenotypic descriptors which can assist in the identification of animal populations with special adaptation traits that have acceptable production performance.

The result of this study on the BW of Afar and CHG breeds which were noted as lighter and heavier, respectively (Table 17), is in agreement with the finding of a study conducted by Mekasha *et al*. (2008) who categorized Afar breed as small sized and light breed whereas CHG as a medium and heavy breed. Comparison of the BW of Afar and CHG goats at specific age recorded in this study with the BW of bucks of their respective breed at similar age recorded in earlier studies (Mekasha *et al*., 2008; Agga *et al*., 2011) showed differences. For instance, at age category of 2 PPI, the BW of Afar breed recorded (20.0 ± 0.3) kg in this study was higher than that reported (17.6 ± 1.0) kg for Afar by Mekasha *et al*. (2008) but it was lower than the BW recorded (21.1 kg) for bucks of the same breed by Agga *et al*. (2011). Similarly, the BW of Abergelle bucks recorded (19.9 ± 0.2) kg in this study was lower than the matured BW recorded (33.6 ± 5.9) kg for bucks of Abergelle breed by Berhane and Eik (2006c). In the literature, it is well documented that differences in BW are due to many factors which include breed, age (Bielli *et al*., 2000; Mekasha *et al*., 2008; Agga *et al*., 2011), season of slaughter, nutrition (Bielli *et al*., 2000; Mekasha *et al*., 2007; Rahman *et al*., 2008) and supplementation (Melaku and Betsha, 2008). Physical condition, agro-climate, housing, disease control and other management practices were reported as additional factors which have potential influence on BW (Rahman *et al*., 2008).

Though the highest BW was recorded in CHG, overall and at age categories of 0 PPI and 2 PPI, Abergelle and CHG breeds had comparable HCW and it was heavier than the HCW recorded in Afar bucks. Whereas in bucks at age category of 1 PPI, the three goat breeds had comparable HCW (Table 17). Abera *et al*. (2002) reported HCW of 8.5 kg for Afar goat which is in very close similarity to the HCW of Afar bucks recorded (8.4 ± 1.8) kg in this study. The HCW recorded (9.1 ± 0.1) kg in CHG bucks in this study is lower than that recorded by Deribe and Taye (2013) as (mean ± SE) (11.2 ± 0.5) kg in CHG kept on grazing without any supplementation.

The finding of this study regarding the effect of breed on DP is in line with Sebsibe *et al*. (2007) who reported breed to have significant effect on DP. In this study, overall the highest DP (44.8 %) was recorded in Abergelle whereas the DP recorded in CHG (43.7

%) and Afar (43.8 %) breeds was comparable. A similar pattern was also noted in the youngest (0 PPI) age category where Abergelle breed had the highest DP whereas at age category of 1 PPI, Abergelle and Afar breed had comparable DP and it was higher than the DP recorded in CHG. However, at later age (2 PPI) the three goat breeds had comparable DP (Table 17). Abera *et al*. (2002) recorded DP of 45.5 % in bucks of Afar breed which is higher than the DP (43.8 %) recorded in Afar breed in this study.

In a study conducted by Sebsibe *et al*. (2007) involving three goat breeds (Afar, CHG and Long eared Somali goat), it was found that on slaughter weight basis bucks of Long eared Somali and Afar goat had higher and similar ($P > 0.05$) DP compared with the DP recorded in CHG. According to Sebsibe *et al*. (2007), the DP (on slaughter weight basis) recorded in Afar, CHG and Long eared Somali goat breeds was found to be within the range of 42.5 to 44.6%. In breed CHG kept on grazing (without any supplementation), Deribe and Taye (2013) recorded DP (mean $\pm$ SE) of (38.9 $\pm$ 1.0) % (calculated on BW at slaughter basis) which is found to be lower than the DP recorded (43.7 $\pm$ 0.3) % in CHG in this study. On the other hand, compared to the result of this study, Berihun *et al*. (2013) reported a higher mean DP (47.9 – 51) % in Arsi-Bale goats reared under farmers' management condition.

The result of this study on the DP of the three goat breeds (43.7 % in CHG, 43.8 % in Afar and 44.8 % in Abergelle) is generally within the range of the DP (calculated on slaughter BW basis) of 42 to 45 % reported for most indigenous goat breeds of Ethiopia (Table 2) by Tadesse *et al*. (2015). In this study, it was also shown that in Abergelle breed, BW had little influence on DP whereas Afar and CHG goats in the BW category of 18.5-22 kg had a higher DP indicative of the better meat production efficiency. The higher DP recorded in Abergelle might be associated with the better body condition noted in Abergelle bucks. Generally, differences in carcass parameters (HCW and DP) are ascribed to effects of breed (Attah *et al*., 2004; Dzakuma *et al*., 2004; Sebsibe *et al*., 2007), age (Dzakuma *et al*., 2004; Sebolai *et al.*, 2012), nutritional status (Mekasha *et al*., 2008) and BW at slaughter (Attah *et al*., 2004).

5.3.2. Correlation between linear body measurements, body weight at slaughter, carcass weight and dressing percentage

The correlations (r) between BW, linear body measurements (LBMs), HCW and DP varied with breed (Tables 18 and 19). With the exception of the strong linear association noted between HCW and DP (r = 0.74) in Afar breed, higher correlations between BW, LBMs, HCW and DP were recorded in CHG than in Afar and Abergelle breeds. In this study, it was also noted that BW and HCW are highly correlated whereas BW and DP had low negative correlation which varies with breed. It shows that DP is more important as an indicator of the meat production efficiency than BW which is influenced by a number of factors such as gutfill. The outcomes of this study regarding the correlations between BW and LBMs are in line with Mekasha *et al*. (2008) who reported that bucks with higher BW had higher HG (r = 0.64) and PW (r = 0.59) but medium HAW (r = 0.55) and BL (r = 0.54). Body weight had a strong correlation with HG (r = 0.94), BL (r = 0.95) and HAW (r = 0.96) (Rahman *et al.*, 2008). The same authors reported also that such strong and positive correlation BW had with HG, BL and HAW can be used as a tool for selection and for predicting BW and meat production from goats. According to Attah *et al*. (2004), LBMs (such as HG, HAW and PW) taken at one stage of growth or the other are highly correlated with DP. Differences in the phenotypic correlations between BW and LBMs are explained by variations existing between breeds, birth weight of the individual, agro-climatic condition and management practice (nutrition) (Rahman *et al.*, 2008).

5.3.3. Prediction of carcass weight and dressing percentage

Age specific models for predicting HCW were set for the tthree goat breeds considered in this study using LBMs and BW as predictor (Table 20). The differing linear associations HCW (the dependent variable) had with LBMs and BW (the predictor variables) noted in the three goat breeds justify the need for developing breed specific regression models. Models developed for predicting HCW of Abergelle and CHG breeds at later (2 PPI) age had a higher R^2 (0.69 in Abergelle and 0.84 in CHG) showing that such models were better explaining the variation in HCW compared to those models developed for predicting HCW of both Abergelle and CHG at age categories of 0 PPI and 1 PPI in which a lower R^2 was recorded (Table 20). The model developed for predicting HCW of Afar goats at age category of 1 PPI had a higher R^2 (0.76) as compared to the models developed for goats of the same breed at age categories of 0 PPI and 2 PPI (Table 20).

In this study it was shown that the predictor BW was common to all the models developed for predicting HCW in all age categories of the three goat breeds (Table 20). Body weight stood as the only predictor in the model developed for predicting HCW of Abergelle breed at youngest (0 PPI) age (Table 20). It was also noted that BW is an important and common predictor variable in the models set for predicting HCW of Afar and Abergelle breed at age category of 2 PPI and bucks of CHG at age category of 1 PPI. The models set for predicting HCW in Afar breed at age categories of 0 PPI and 1 PPI were based on similar predictor variables (PW and BW) (Table 20).

In addition, age specific models for predicting DP of the three goat breeds were set using BW and HCW as predictors (Table 21). In Table 21, it was shown that models developed for predicting DP of Abergelle breed at age category of 1 PPI had a higher Adj R^2 (0.97) showing that the model would explain the variation in DP better than those models developed for predicting DP of Abergelle goats at age categories of 0 PPI and 2 PPI. In Afar breed, the model developed for predicting DP of bucks at age category of 2 PPI had a higher Adj R^2 value (0.64) as compared to the models developed for bucks at age category of 0 PPI and 1PPI. The models set for predicting DP of CHG at all age categories had lower Adj R^2 value (0.34-0.41) showing that the models have little importance in exaplaining the variation in DP of CHG. The predictor HCW was common to all the models developed for predicting DP of all age categories of the three goat breeds of. In addition to HCW, BW was found to be useful predictor variable in the model developed for predicting DP of Abergelle breed at age category of 1 PPI.

Selection of the best fit models for predicting HCW and DP was made based on a number of criteria which is in line with Sebolai *et al*. (2012) who recommended the use of multiple criteria for determining the best fit prediction models. Mallow's C (p) statistic was used because it is an important measure of the goodness of fit of a prediction model and regression equations with small MSE were selected in order to improve the precision of the predicted values as proposed by Sebolai *et al*. (2012). Since the value of R^2 is affected by the incorporation of additional predictor variables into the model, the use of R^2 as the only criterion for determining best fit models is not promising (Sebolai *et al*., 2012). From Tables 20 and 21, HCW and DP could be estimated more accurately by a combination of predictor variables than a single predictor variable which also improves the value of R^2. For instance, in breed CHG the model for prediction of carcass weight which have the highest Adj R^2 (0.84) was set using three predictor variables (HAW, PW and BW) (Table 20). However, taking measurement of too many predictor variables may not be so easy under field condition, for example in the harsh and remote areas of Afar region. In addition, taking measurement of too many different predictor variables will have time and cost implications. Therefore, models which are based on few but important predictor variables would be convenient and applicable.

6. CONCLUSION AND RECOMMENDATIONS

Conclusions

In both systems (pastoral system of Yallo, Afar and mixed farming system of Raya Azebo, Tigray) considered in this study, goats were found to be the most preferred species kept for multiple reasons which is an evidence for the increasing importance of goats. However, goat holding, purposes of keeping goats, some of the management practice such as herding, flock separation, type of housing/shelter, watering frequency and buck ownership varied with production system. The traditional and low-input goat keeping noted in both production systems was based on naturally available feed resources. A better goat breeding practice in terms of buck ownership was noted in the pastoral production system of Yallo district. Selection of breeding bucks was a common practice related to the reasons/production objectives of the goats. Mating was partially controlled through selection of breeding bucks. With the exception of drought and feed shortage which were ranked as the major constraint of goat production in the pastoral system of Yallo district and in the mixed crop-livestock farming system of Raya Azebo district, respectively, booth production systems were affected with more or less similar production constraints.

Breed CHG were the heaviest, had the widest TC as well as the heaviest TWt and EWt. Sperm of higher mass and progressive motility, percent live and concentration with fewer morphological defects was recorded in CHG. In Aberegelle and CHG, bucks at later age (2 PPI) category had sperm of higher concentration whereas in Afar, the sperm concentration recorded inbucks at age categories of 1 PPI and 2 PPI was comparable. Sperm of higher concentration was noted in heavier bucks particularly in Afar and CHG. A higher correlation between BW and SC; SC and testicular measurements and between TWt and EWt was recorded. The scrotal and testicular traits and sperm quality attributes recorded in this study have essential implication as indirect selection criteria in breed improvement programs.

Body weight at slaughter and most LBMs were the highest in breed CHG. Abergelle and CHG had comparable HCW and a higher DP was recorded in breed Abergelle. In general, in all breeds a higher correlation between BW and HCW was noted, in CHG, the correlation HCW had with LBMs (HG, BL, HAW and PW) was the highest. The models set for predicting HCW and DP may be used for selection of individual animals within breed for better carcass yield.

Recommendations

- The traditional low-input goat management practice needs to be improved taking into consideration the specific production constraints in each system. In addition, in the mixed farming system of Raya Azebo district, buck ownership/availbiliy should be given due attention
- For maximum fertility, in Aberegelle and CHG, bucks at later age (2 PPI) category whereas in Afar breed bucks at age category of 1 PPI and 2 PPI could be used for breeding. In addition, in Afar and CHG breed, bucks of heavier body weight are recommended for breeding whereas in Abergelle breed, bucks in the BW categories of 18.5-22 kg and > 22.5 kg could be used for breeding.
- For maximum meat production efficiency, Afar and CHG bucks in the BW category of 18.5-22 kg should be slaughtered whereas in Abergelle breed bucks of any weight could be considered
- The results of this study on the quality attributes of sperm recovered from the tail of epididymis were based on routine laboratory techniques. Similar studies based on modern sperm quality analysis techniques are recommended
- This study was undertaken during the dry months when the slaughterhouse’s throughput is at its maximum. Hence, there is need to undertake similar research during the rainy season because of better feed availbility and body condition

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8. APPENDICES

Appendix 1. Structured questionnaire used during the cross sectional survey.

Date______________

Name of interviewer__________________District____________

Tabia/Pastoral association ____________ Kushet/past. encampment:_______________

Production system: a. Pastoral b. Mixed crop-livestock

Name of household head owning goats_____________________

Livestock species kept

Camel/herd size_____Cattle/herd size____Sheep/flock size____Goats/flock size_____

Equines: Donkey____Horse______Mule_____

Other species for example: poultry________ Bee_______

Livestock preference

Preference/ranking order of livestock

Livestock	Rank	Reason for choosing
Camel		
Cattle		
Goat		
Sheep		

Other species kept if any: Equine__________Poultry__________Bee colony_______

Purposes of keeping goats and their rank.

Purposes	Tick here(√)	Rank
Source of cash/income		
Milk production		
Meat production		
As means of saving/store wealth		
Traditional values*		
Skin		
Others/specify		

*traditional values refer to cultural and religious uses of goats

Management practice

1. Herding

Is a flock of goat herded or not? Yes [ ] No [ ]

Who is responsible to look after your goats? ____________________

How are goats herded at the grazing field? a. separately b. with sheep c. with others

Is there contact between flocks? Yes [ ] No [ ]

2. Housing

Do you provide your goats with housing/shade? Yes [ ] No [ ]

Do you have separate housing for goats? Yes [ ] No [ ]

Housing by age categories: a. Suckling kids b. Weaned c. Adults together

Type of housing by age categories

Type of housing	**Tick here(√)**	**Remark**
In family house		
Separate house		
Kraal		
Other		

What are the materials used for house construction?

No	**Material**	**Roof**	**Wall**	**Floor**
1	Stone			
2	Grass			
3	Wood			
4	Earth/mud			
6	Others/specify			

How frequent do you clean the kraal/house of goats? ____________________

Who is responsible for cleaning the shelter/kraal: ______________

3. Feed resources and feeding management

How do you graze goats? a. Separately b. Mixed with other species

If mixed, with which species? ________________

Are kids and lambs grazed/fed with adults? Yes [ ] No [ ]

What are the major feed resources for your goats during the dry and wet season? (tick one or more and rank the top five feed resources in the second column).

No	Source	Dry	Wet
1	Rangeland/ indigenous bush, shrubs and trees		
2	Crop residues (straw, maize stover)		
3	Farm lands		
4	Hill side		
5	Road side		
6	Fenced grassland		
7	Others (specify)		

Is there seasonal variation in the availability of feed resources?

Yes [ ] No [ ]

Which type of grazing/feeding do you practice for goats during the dry and wet season?

Season	Type of grazing				
	Herded	**Un-herded**	**Cut and carry/**	**Seasonal movement**	**Others (specify)**
Dry season					
Wet season					

4. Water sources and watering management

What are the major water sources for your goats by season?

Season	Water sources							
	river	pond	Borehole	Spring	pipe water	hand dug well	rain water	*Ela*
Dry								
Wet								

Others specify by season______________________________________

What is the frequency of watering during the dry and wet season?

a. Freely available b. Once a day c. Once in 2 days d. Once in 3 days

e. Others (specify) ________________

5. Breeding management

Type of mating used: a. Controlled b. Uncontrolled

What is your source of breeding male?

Source	Buck	Source	Buck
Own		Neighbors	
Bought		Communal	
Donated		Unknown	
Borrowed			

Do you select male goat for breeding purpose? Yes [ ] No [ ]

If yes, what are the criteria to select breeding males (buck)?

Criteria	Tick	Criteria	Tick
Body size		Conformation	
Color		Dam performance	
Performance		Horns	
Appearance		Testicular size	

6. Production constraints

Fill the following table on the major production constraints related to goat production?

Constraints/ problems	Tick	Rank	Constraint/ problems	Tick	Rank
Shortage of grazing land			Low breed performance		
Health problem/abortion			Lack of shelter		
Scarcity of labor			Drought problem		
Predator/s			Lack of veterinary service		
Water scarcity			Poor extension service		
Market problem			Others/specify		

Appendix 2. Scales for body condition scoring of goats.

Condition	Score	Lumbar region	Rib cage	Sternum
Very thin	1	The spinous processes are prominent and sharp. The transverse process are also sharp, the fingers pass easily under the ends, and it is possible to feel between each process. The eye muscle areas are shallow with no fat cover.	Ribs are clearly visible.	Sternal fat is easily grasped and moved from side to side.
Thin	2	The spinous processes feel prominent but smooth, and individual processes can be felt only as fine corrugations. The transverse processes are smooth and rounded, and it is possible to pass the fingers under the ends with a little pressure. The eye muscle areas are of moderate depth, but have little fat cover.	Some ribs can be seen. There is a small amount of fat cover. Ribs are still felt.	Sternal fat is wider and thicker but can still be grasped and moved slightly from side to side.
Moderate	3	The spinous processes are detected only as small elevations; they are smooth and rounded and individual bones can be felt only with pressure. The transverse processes are smooth and well covered, and firm pressure is required to feel over the ends. The eye muscle areas are full, and have a moderate degree of fat cover.	Ribs are barely seen; an even layer of fat covers them. Spaces between ribs are felt using pressure.	Sternal fat is wide and thick. It can still be grasped but has very little movement.
Fat	4	The spinous processes can be detected with pressure as a hard line between the fat covered eye muscle areas. The ends of the transverse processes cannot be felt. The eye muscle areas are full with thick covering of fat.	Ribs are not seen.	Sternal fat is difficult to grasp and cannot be moved from side to side.

Appendix 3. Format used for collecting data on live body attributes (breed, age, body condition score, body weight, scrotal circumference) and post-mortem testicular measurements of bucks of the three goat breeds.

ID	**Breed**	**Age**	**BCS**	**BW**	**SC**	**TC**		**TWd**		**TL**		**TV**		**TWt**		**EWt**	
						L	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**
1																	
2																	

Key: ID: Tag number; BCS: Body condition scoring; BW: Body weight at slaughter; SC: Scrotal circumference; TC: Testicular circumference; TWd: Testicular width;

TL: Testicular length; TV: Testicular volume; TWt: Testicular weight; EWt: Epididymal weight; L: Left; R: Right.

Appendix 4. Procedure for recovery and examination of quality attributes of sperm recovered from tail of epididymis.

Chemicals and reagents required

Extender/skimmed milk/, eosin, eosin working solution is prepared by dissolving 1gm of eosin into 100ml distilled water, negrosin, Na-acetate, glucose, penicillin G/ crystalline penicillin, streptomycin, distilled water and warm water or water heated at $37^{o}C$ using water bath.

Equipment required

Heater, microscope, microscopic slide, and cover slip; micropipette (Eppen dorf pippete), 10-100µl and Eppen dorf tips, Mc Master counting chamber/heamocytometer, centrifuge, test tubes, beaker/milk container/, scalpel blade, syringe and needle, petridsh and gauze.

4 a. Recovery of sperm from tail of epididymis

Collect testis, pack separately in labeled plastic bag and transport to lab in cool box (with ice pack).

Laboratory procedure

- ✓ Put the collected testis at room temperature ($20\text{-}21^{0}C$),
- ✓ Weigh the left and right testis separately,
- ✓ Dissect off the epididymis, do separately for the left and right,
- ✓ Remove the tail of epididymis and take the weight (separately for the left and right),
- ✓ Slice the tail of epididymis several times and rinse with extender on petri-dish (use 5-10ml of extender for both testes),
- ✓ Put the sperm sample into a test tube and keep it in a water bath at $37^{0}C$,
- ✓ Use sample to study the quality attributes of the sperm cells.

4 b. Preparation of extender /skimmed milk/

Double filtering (centrifugation followed by filtering of the milk) is required.

Laboratory procedure

- ✓ Fresh milk was obtained (100 ml),
- ✓ The milk was poured into a sterile test tube, then centrifuged at 3000 rpm (revolution per minute) for 5 minutes,
- ✓ The milk fat /fat layer or cream was carefully removed from the top using a spatula,
- ✓ The remaining skimmed milk was filtered several times using sterile gauze to remove the remaining fat globules,
- ✓ The skimmed milk was heated at 100^0C for 15 minutes,
- ✓ The heated skimmed milk was allowed to cool to 37^0C,
- ✓ 4 g of glucose for every 100 ml of skimmed milk was added,
- ✓ Crystalline penicillin (150,000IU= 0.089 gm) and streptomycin (150,000 = 0.15 gm) was added (James, 2004).

4 c. Sperm quality analysis

Motility

- ✓ Heat the stage of the microscope by switching on the microscope ahead of the examination,
- ✓ Take aliquot of 10µl of 1: 20 sperm solution on a pre-warmed slide and cover it with cover slide,
- ✓ Examine the mass motility (MM) under lower magnification (x 10) and progressive motility (PM) under x 40 magnification,
- ✓ The mass and progressive motility were rated (in percent) subjectively. The minimum recommended motility is 30%.

Viability (live to dead ratio)

- ✓ Mix the sperm sample well,
- ✓ A thin smear was made using a mixture of 5µ1 aliquot of sperm, equal volume of 1 % eosin and 2.6 % of sodium citrate and the smear was dried very fast,

- ✓ Evaluate live to dead ratio using x100 magnification (James, 2004) by counting 200 sperm cells,
- ✓ Tally the number of stained (dead) or unstained (vital) sperm cells.

Concentration (Bearden et al., 2004)

Sperm cell concentration was expressed as the number of cells per ml using the following formula:

Number of sperm cells/ml = Number of sperm in 0.1mm^3 * 10 * Dilution rate * 1000

Morphological defects/abnormalities of sperm cells

The morphology of sperm cells was examined using the same slides prepared to examine % live spermatozoa, by counting 200 sperm cells and the morphological defects of sperm cells were categorized as head, mid-piece and tail defects.

Appendix 5. Format used for collecting data on breed, age and quality attributes of sperm recovered from tail of epididymis.

ID	**Breed**	**Age**	**MM [%]**	**PM [%]**	**PLS [%]**	**SPC (x 10^{6}ml)**	**% morphological defects**		
							head	**mid piece**	**tail**
1									
2									

Key: ID: Tag number; MM: mass motility; PM: progressive motility; PLS: % live sperm; SPC: sperm concentration.

Appendix 6. Format used for collecting data on breed, age, linear body measurements, body weight and carcass weight of bucks of the three goat breeds.

ID	**Breed**	**Age**	**HG**	**HAW**	**RH**	**NC**	**BL**	**PW**	**BW**	**HCW**	**DP**
1											
2											

Key: ID: Tag number; HG: Heart girth; HAW: Height at withers; RH: Rump height; NC: Neck circumference; BL: Body length; PW: Pelvic width; BW: Body weight at slaughter; HCW: Hot carcass weight; DP: Dressing percentage.