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Meat quality of selected Ethiopian goat genotypes under varying nutritional conditions.

By

AMEHA SEBSIBE

Submitted in partial fulfillment of the requirements for the degree

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Doctor of Philosophy (Animal Science) (Meat Science)

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Pretoria

Supervisor: Prof. N.H. Casey

Co-supervisors: Prof. W.A. Van Niekerk and Dr. Azage Tegene

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I dedicate this thesis to the almighty GOD

who

gave me the strength and patience to complete this study.

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Declaration

I hereby declare that this thesis submitted by me to the University of Pretoria for the degree of PhD (Animal Science) (Meat Science) has not previously been submitted for a degree at any other University.

Ameha Sebsibe
Pretoria
June 2006

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ABSTRACT

Meat quality of selected Ethiopian goat genotypes under varying nutritional conditions

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The study evaluated the effects of genotype and grainless diets under stall-fed (n=72) conditions on the following parameters using the Afar, Central Highland goats, (CHG) and Long-eared Somali, (LES) goats. The diets varied in concentrate: roughage ratios. Diet 1 was a 50: 50 ratio (8.5 MJ ME/kg DM), Diet 2, 65:35 (9.2 MJ ME/kg DM) and Diet 3 an 80:20 ratio (10 MJ ME/kg DM), respectively. The same genotypes reared under the extensive grazing systems were also evaluated.

Intake, feed efficiency (FE) and rumen parameters

Total DMI ranged between 2.6 and 3.0 % on a body weight basis and between 53.5 and 62.3 g per kg metabolic body weight. The LES had a higher ($P<0.001$) DM roughage intake, total DMI ($P<0.01$) and FE ($P<0.05$). Goats on Diet 3 had higher ($P<0.001$) total DMI (g/d). Diet 1 however, displayed higher ($P>0.05$) FE. The mean concentration of NH_3-N (39.4-53.7 mg/100ml rumen fluid) was above the N requirements for optimal microbial activity. The mean pH was similar between diets and ranged from 6.43 to 6.63. Total VFA was depressed ($P<0.01$) with increased grainless concentrate in the diet. Diet 1 recorded a higher ($P<0.01$) total VFA and lower ($P<0.01$) NH_3-N concentration, indicating that feed

nitrogen was more efficiently utilized in Diet 1. The molar proportions of acetate, propionate and butyrate varied (P>0.05) from 64.5 to 65.7, 17.7 to 18.8 and 10.7 to 12.8 %, respectively. The ratio of acetic: propionic was not affected by diet (P>0.05) and ranged from 3.5 to 3.81. The values for degradation constants were similar (P>0.05) between the diets. However, the hay DM and neutral detergent fibre were more degradable (P<0.05) in goats fed Diet 1. Differences in DMI and FE between the genotypes were recorded with the LES breed being superior. Among the grainless diets, the 50:50 ratio created a favorable rumen environment and resulted in a better FE under a feedlot system.

Carcass characteristics and meat quality of extensively managed goats

Genotypes were similar (P>0.05) for most of carcass traits, at an average slaughter weight of 13.8 kg. The genotypes had a mean hot carcass weight of 5.9 kg and a dressing percentage (DP) on a slaughter body weight basis of 42.8 %. The CHG had a 52 % higher (P<0.01) chilling loss than the other genotypes. The rib physical composition was similar between genotypes, except for fat proportion. The CHG had the lowest (P<0.05) fat proportion. The chemical composition was similar between the genotypes, with the CHG having the lowest (P>0.05) chemical fat percentage.

The composition of most muscle fatty acids was affected by genotype. The LES breed presented a beneficial ratio of n-6: n-3 PUFA favorable to consumers' health. The goats under the extensive system in general, were characterized by a lower carcass weight and poor carcass fat cover. Hence, to improve the carcass characteristics it is essential that grazing goats should be supplemented or stall-fed with locally available concentrates depending on the grazing resources of the agro-ecologies and the objectives of the goat farmers.

Growth and carcass characteristics of stall-fed goats

The LES breed had significantly higher growth rates (ADG), heavier pre-slaughter, slaughter, empty body weight (EBW) and carcass weights than the Afar and CHG goats.

Effect of diet was also significant on ADG, but similar for carcass traits, except for DP on EBW basis and some non-carcass components. The DP on an EBW basis, was the highest (P<0.01) for Diet 1. Stall-feeding of the goats improved the mean carcass weight by 38 % over the initial slaughtered groups. Genotype affected the DP and it ranged from 42.5 to 44.6 % and 54.3 to 55.8 % on a slaughter weight and on EBW basis, respectively. The ultimate carcass pH was between 5.61 and 5.67 and chilling losses ranged from 2.5 to 3.1 %. The rib physical composition (fat and bone) differed between genotype and ranged from 72-73 %, 6.9-10.9 % and 17.1-20.2 % for muscle, fat and bone respectively. The findings indicate that breed differences were reflected in carcass characteristics.

Meat quality of stall-fed goats

Genotype significantly influenced the carcass fat and crude protein (CP) concentration, with the values ranging from 10.3 to 14.0 % and 19.3 to 21.1%, respectively. The Afar and LES goats had higher fat concentration (P<0.001) compared to the CHG while the CP was higher (P<0.01; P<0.05) for the CHG. The effect of diet was significant on CP %, but was similar for fat concentration although Diet 3 tended to have a higher value. Cooking and drip loss differed (P<0.01, P<0.05) between genotypes and both traits increased with increased fatness. The effect of diet however, was similar for cooking and drip loss. Genotype and diet significantly influenced the composition of most muscle fatty acids. An interaction between genotype and diet was also exhibited on certain fatty acids. Compared to CHG, Afar and LES breeds had a higher PUFA, MUFA and UFA: SFA ratio, which are considered healthier for human consumption due to their lowering effect of cholesterol content. The relatively higher carcass fat, which is useful in reducing chilling loss and improves eating quality, the absence of C12:0 and lower concentration of C14:0, hypercholesterolemic, and higher C18:1, hypocholesterolemic fatty acids, are some of the important traits observed in

Ethiopian goats. These findings suggest that a potential exists in the use of Ethiopian goat breeds fed a grainless diet, for the production of meat with specific quality characteristics.

Keywords: Indigenous Ethiopian goats; growth; carcass yield and composition; meat chemical composition and long chain fatty acid; intake; feed efficiency; rumen parameters; grainless diet.

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CHAPTER 1

1 INTRODUCTION

Goats (*Capra hircus*) are found across all agro-ecological environments and in nearly all livestock production systems (Winrock International, 1983) and are suitable for very extensive to highly mechanized production systems (Wilson, 1982; FAO, 1987). There are approximately 570 breeds and types of goats in the world, of which 89 are found in Africa (Galal, 2005). Ethiopia has the largest livestock population of any country in Africa, and is endowed with different agro-ecological zones of highlands, sub-humid, semi-arid and arid environments (Farm Africa, 1996). The animal sector contributed 18 % of the Gross Domestic Product (GDP), 40 % of the agricultural GDP and 17 % of the export income in 2001, in Ethiopia (LMA, 2002). There were 23 million goats in Ethiopia (CSA, 2004), which is 13.5 % of the African goat population (FAO, 1991) and these goats are grouped into nine distinct genetic entities (Tesfaye *et al.,* 2004).

Small ruminants are kept for various purposes. Their role for income generation, food supply (meat and milk), and financial security for the rural poor population is documented (Gryseels, 1988; Zelalem and Fletcher, 1993; Barrs, 1998; Workneh Ayalew, 1999). These animals provide 46 % of the value of national meat production and 58 % of the value of hide and skin production and play an integral part in the production systems of the country (Tembely, 1998).

The major factors that affect the productivity of small ruminants in Sub- Saharan Africa are feed supply, genotype, animal management, policy and institutional constraints (Ibrahim, 1998). Similar factors are also responsible for affecting the performance of small ruminants in Ethiopia. The major feed resource in the country, natural pasture, has shown remarkable seasonality in yield and quality and lacks the critical nutrients that support animal growth particularly during the dry season (Zinash and Seyoum, 1991). However, agro-industrial by-products, which may have the potential to supplement and improve the performance of animals, have not been adequately tested with the local animals, and have not been effectively utilized as animal feed (Getenet *et al.,* 1999).

An increase in human population, coupled with urbanization, has resulted in a higher demand for meat per capita. If we continue to produce livestock and their products at the current rates, the increase in livestock production will lag behind the human population increase. The FAO (1990) estimated that animal production should be increased by 4 % annually to meet the demand of the human population by the year 2010. The potential of small ruminants is not yet fully tapped and currently special markets for small ruminants are expanding. The annual total meat demand of the Middle East countries is about 207 thousand ton of meat and 12 million head of cattle, camels, sheep and goats. Similarly, the African countries annual demand is about 86 thousand ton of meat and 3.2 million head of cattle, sheep and goats (Belachew and Jemberu, 2003). These figures demonstrate how large the demand is if the country is able to produce the required quantity and quality of animal protein in a sustainable manner.

In Ethiopia, goat meat is in demand for domestic consumption as well as for the export market mainly to the Middle East countries. Goat meat valued at USD 4 million was exported to Middle East countries in 1998 (EEPA, 2003), while the annual national goat meat production was estimated at 66 thousand metric ton (FAO, 1991). Both the export volume and the goat meat produced are low due to various reasons, which require urgent attention (Chapter 2.2.2.).

The proximity of Ethiopia to the Middle East and their adaptation to the indigenous animals are some of the advantages for the Ethiopian export market (Belachew and Jemberu, 2003). However, the international market for meat has become more competitive and the meat traders have had to adopt improved practices in production, processing and packaging of meat. Strict quality control measures to meet specific export market demands need to be implemeted. Market requirements also differ both in sizes of carcass and the level of fatness of the carcass.

In the tropics, the interest in goat production has begun to grow in recent years. This has come about with the realization that goats are an underutilized and poorly understood resource. An in depth understanding of their role, capabilities and outputs will contribute further to increase the overall productivity of tropical goat farming systems. Despite the large goat population, diversity and their economic significance, the research attention given to the indigenous goats of Ethiopia has been minimal (EARO, 1999; Getnet *et al*., 1999).

The information so far available on goats is very limited and fragmented (Farm Africa, 1996; Getahun, 2001; Addisu, 2001). Most of the indigenous goats have not been compared and characterized in terms of growth, carcass and meat quality using improved nutrition. Hence, their merits remain largely unknown. As indicated by Laes-Fettback and Peters (1995) and Vercoe and Frisch (1987), it is necessary to identify the merit of all available genetic resources, the possible integration of the animals into various production systems and to make effective use of their potential in order to quantify the existing breed differences in growth rate, and the response of the animals to different feeding challenges. Oman *et al*. (1996) have also reported that the effect of breed type and diet on goat carcass characteristics has only been investigated in a limited number of studies.

The NRC (1981) reported that excessive walking increases the nutrient requirements of goats. Lachica and Aguilera (2003) also reported the maintenance energy requirements of free ranging goats to be from 0 to 75 % greater than animals in confinement; the costs of locomotion contributing substantially to this increase. Presently, more and more grazing land is being brought under cultivation; deforestation and overgrazing have also led to environmental degradation. For most of the year animals move around the farm even during the absence of adequate grazing material. These situations aggravate body weight loss of goats under extensive systems and animals take more time to reach a target market weight. Hence, exploitation of the goat as a meat producer seems feasible under stall-fed conditions. More over, it has been identified that exporters faced lack of uniform and constant supply of goats, and therefore they have to cover large areas and take longer time to fetch the required type and number of goats from the extensive systems. Feedlot operations however, could help augment the indicated supply. Huston and Waldron (1996) reported very little information to be available on feedlot performance of goats and Dhanda *et al*. (2003) also recommended studying how goats perform under feedlot conditions.

Comparisons of carcass characteristics and meat quality between breeds give information on the suitability and performance level of the breeds under defined management and environmental conditions. Moreover, the information to be generated on meat production traits of indigenous goat genotypes will help in the development of a breeding strategy to be used in further improvement.

1.1. Objectives of the study:

- To assess the effect of genotype and grainless diets on dry matter intake and feed efficiency of young goats under stall-fed conditions and to determine the effect of a grainless diet on rumen degradability and fermentation in adult indigenous goats.
- To assess the genotypic effect on carcass characteristics and meat quality of extensively managed indigenous goats.
- To evaluate the effect of genotype and grainless diets on growth performance and carcass characteristics
- To measure the effect of genotype and grainless diets on meat quality of stall-fed Ethiopian goats.

1. 2. Hypothesis tested (Null hypothesis)

- Indigenous goat genotypes under the same nutritional regimes will have similar growth performance and do not produce carcasses of different quality.

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CHAPTER 2

2 Literature Review

2.1. Goat meat

2.1.1. Global consumption

Goat meat is the most consumed red meat, which has a high degree of acceptance by 80 % of the world population. World consumption was estimated to be 540 million carcasses per annum (BGBAA, www.boergoat.une.edu.au). This "old world meat" is the new red meat for health conscious consumers of the new millennium. The amount of goat meat imported into the USA has more than quadrupled during the past decade. In the Middle East; goat meat is an important part of the national diet. For instance, in Saudi Arabia it has a special religious significance to many. The Caribbean uses goat in curry dishes and stews. Goat meat is an accepted red meat as a part of cultural heritage and tradition in Italy, Greece, Arab Gulf, Lebanon, Pakistan, SE Asia and Korea. Goat meat is used in celebrations of the Chinese New Year. Asia and Africa consume 63 % and 27 % respectively of the total world consumption. The demand for goat meat in Asia, South America, Europe, and the Caribbean is substantially not satisfied (www.mountainmeatgoats.com). With such a high demand for goat meat, research should provide adequate information on suitable genotypes; improved management practises and other relevant packages and producers should work to capitalize from the market.

2.2 Overview of goats and goat meat production in Ethiopia

According to the CSA (2004), there are 23.3 million goats and the goat types have been phenotypically identified (Farm Africa, 1996). Recently, Tesfaye *et al.* (2004) also reported on the genetic characterization of indigenous goat populations in Ethiopia, using microsatellite DNA markers. It was indicated that the Ethiopian goat populations are genetically distinct from the populations of Europe, Asia, Middle East and other African countries and grouped into 9 distinct genetic entities i.e. Arsi-Bale, Gumez, Keffa, Long-eared Somali, Woito-Guji, Abergelle, Afar, Highland goats, and goats of Hararghe. The geographical distribution of goat genotypes in Ethiopia is presented in Fig. 1. In the semi-arid lowland areas of Eastern Ethiopia, the average herd composition per household comprised 50.2, 67.5, and 144.2 goats and sheep in sedentary, transhumance, and nomadic systems, respectively (EARO, 1999).

2.2.1. Social and cultural role

The goat has a great social, cultural and economic importance in the country. As they are a readily tradable livestock item, they also serve as a reliable source of cash income and thereby complement crop production in mixed farming production systems. Generally, it is said that goat meat is preferred to mutton by the lowland dwellers. However, there is no taboo preventing its consumption in the country and most people of any region eat goat meat. A similar opinion has also been reported by Casey (1992), that there are virtually no religious or cultural taboos against goat meat consumption and thus goats are readily acceptable to societies in which eating beef, pork or other meat types are prohibited. During the major holidays of the Christians and Moslems, the rural people raising animals slaughter mainly either goats or sheep for their families. Gryseels and Anderson (1983) also reported that goat meat and mutton as compared to beef accounts for most of the domestic meat consumption. Goat meat generates a higher price than mutton or beef in some towns of the eastern regions of Ethiopia, particularly during the Moslem holidays (Farm Africa, 1996).

Goats are also commonly used to pay for brides in the Afar region. In some societies, goats are also slaughtered to fulfil ritual customs, when a woman gives birth, during burials or other cultural ceremonies or to honour important visitors. They are also highly regarded for traditional healing (Farm Africa, 1996).

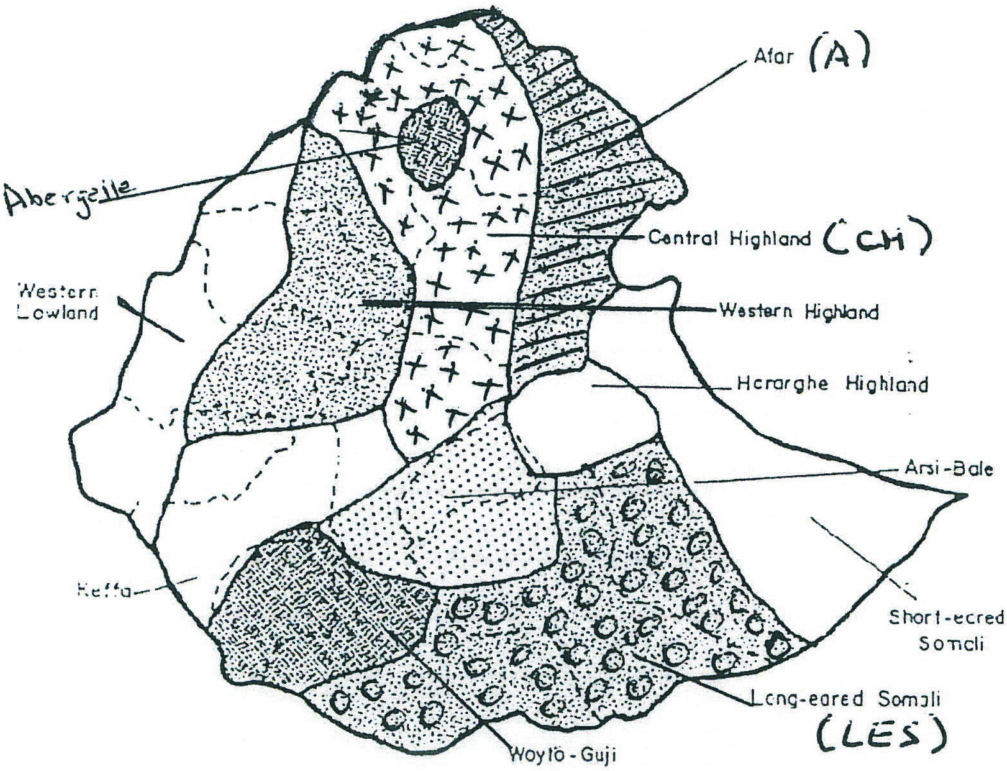

Fig. 1. Geographic distribution of goat genotypes of Ethiopia (Adapted from Farm-Africa, 1996).

_____ Afar

XXX, CH

0000, LES

2.2.2. Economic role

2.2.2.1. Domestic market and traditional preparation

To meet the domestic animal protein needs arising from population, urbanization and economic growth, livestock productivity has to increase. Locally, goats are required for various purposes, as indicated in 2.2.1. The age or the weight of goats required depends on the occasion, the region/society and the financial status of the family. Some families also believe that goats yield more meat than sheep at a comparable age and prefer to buy goat if the ceremony/function is to be attended by more people.

Methods of preparing goat meat and the non-carcass components may differ in different areas, but commonly fresh goat meat may be roasted and eaten on its own or made into a sauce (*Wot*) or boiled as a soup (*kikil*) and eaten with Injera (like bread but thinly made) or cooked with rice. It is also common to find dishes exclusively made from edible offals such as *Dulet,* (made from liver, rumen, and kidney), *Milasna-senber* (mainly fried tongue) and *Tripa* (boiled rumen). Therefore, as it has been indicated by Peacock (1996) and Payne and Wilson (1999), dressing percentage (a measure to describe the proportion of edible carcass), underestimates the relative contribution of goat meat to the national meat supply as different non-carcass components that are consumed in most developing countries are not taken into account.

Raw meat from castrated adult goats is also eaten with chilli sauce (*Awaze*) and is sold in a number of butcheries in towns and cities in Ethiopia and fetches more money per kg than mutton or beef. The raw goat meat eaters advocate the medicinal value of the meat. In most areas preservation is performed by cutting the meat into strips and air-drying it. However, in some places when they want to preserve it longer, the meat is fried in butter or in animal fat and keet in a container (*odka*). In the Afar region, the society enjoys the meat of kids younger than one-month of age. According to the people of this region, fresh blood is also consumed to help treat malaria and bullet wounds. Pastoralists in the South Omo area of Ethiopia sometimes collect blood from live goats by piercing the blood vessel in the neck and consuming it, mixed with milk. Various goat products including the intestines and rumen contents are also used in traditional medicine. Traditionally goat milk, manure and skins have several uses in different regions of Ethiopia, but these aspects have not been covered in this review.

2.2.2.2. Export market

The FAO (1991) estimated the annual goat meat production in Ethiopia to be about 66 thousand metric tons. This amount is less due to the lighter average carcass weight, which resulted from the slaughtering of undernourished or immature and undersized goats. In terms of the volume of goat meat output, Ethiopia produced 31 and 11 % of the total East Africa and Africa, respectively. The growth of goat meat production was only 1.4 %, which was below the estimated population growth of 3 % in Ethiopia (FAO, 1991).

Ethiopia is currently exporting goat meat mainly to countries such as Saudi Arabia, United Arab Emirates, Yemen and Djibouti. The EEPA (2003) reported goat meat valued at USD 4 million was exported to the Middle East countries in 1998. According to FAO (www.fao.org, 2003), Ethiopia exported 2094 metric tons of goat meat in 2003. Compared to the volume exported in 1996, this tonnage has increased. However, in view of the potential of the country (23 million goats and off-take rate of 38 %), the export volume is very small. On the other hand, Australia has about 4 million feral goats with over 90 % of all feral goat products being exported (11 thousand tons) to different countries (Elliott and Woodford, 1998). This shows that Australia is working hard at dominating the goat meat exports of the world.

Various opportunities and constraints regarding the growth of the export in Ethiopia were identified during the planning phase of this study via discussions with stakeholders (export abattoirs, Livestock Marketing authority, livestock department, ministry of agriculture and Ethiopian export promotion agency), the visiting of abattoirs and some livestock meat shops and from documented reports. The items listed below are not complete and have not been listed according to priority. However, the items will be useful as baseline information/departure points and can be fine-tuned in future to improve the livestock meat industry and in particular the goat meat sector.

2.2.2.2.1. Potential/Opportunities

- Proximity to Middle East countries and their adaptation to the taste of Ethiopian goats
- High goat population and diverse genotypes
- Diverse agro-ecologies
- Increasing number of export abattoirs
- The expansion of the agro-industries and the increase of by-product feeds
- Establishment of a pastoral women group in Southern Ethiopia supplying goats to export abattoirs (Getachew *et al.,* 2004).
- The possibility of expansion and export to Asian markets such as Malaysia, which require halal-slaughtered, frozen skin-off carcasses and less stringent hygienic regulations. The weight categories are less than 12 kg, 12-18 kg, and greater than 18 kg (Elliott and Woodford, 1998). Currently in Ethiopia at least the former weight category can be targeted. Meat shortages have also been reported in Egypt and Central Africa countries such as Rwanda, Burundi and Democratic Republic of Congo (King, 2002).

2.2.2.2.2. Constraints/weaknesses

- Inadequate research and extension programs in the production, processing and marketing of goat meat

- Inadequate knowledge and technologies to make optimal use of local animal feed resources in diets
- Livestock diseases and inadequate veterinary support services
- Inadequate application of HACCP (Hazard Analysis and Critical Control Points)
- Lack of constant and uniform supply of goats
- Inadequate infrastructures on the routes and at the markets
- Lack of marketing information and cooperative system for the marketing of their animals. Hence, exploitation by the middlemen.
- Lack of export abattoirs, particularly closer to the major goat production areas (provided that refrigerated storage and transport are available, the establishment of a slaughter house in a central place with goat breeders will have an advantage).
- Lack of a grading system (i.e. based on weight and meat quality) to provide incentives to producers and to assist the development of meat exports. In most markets, there are no weighing facilities and animals are subjectively sold according to appearance and size.
- Insufficient market promotion work.
- Lack of support to value adding
- Inadequate knowledge at the level of meat handlers
- Contraband trade around the lowland borders of the country
- Lack of an integral connection between the stakeholders involved in the production chain
- Inadequate study tours to establish export requirements and opportunities

Although there is an increasing market demand for goat meat, there are also problems in meeting market specifications. Therefore, appropriate breeds and technologies have to be used to increase the off-take as well as productivity per animal with acceptable quality and to ensure a constant and uniform supply of goats. Strengthening of meat export market would provide a means of reducing poverty levels and the emerging investors would be the first to benefit, but this motivation of export prices would gradually be felt in the traditional sector, which is the major source of animal production. Exports would also be an incentive to improved livestock nutrition and management. The relevant authorities should thus give due attention to the constraints/ weakness indicated above.

2.2.3. Description of the studied goats

The study was conducted using three selected indigenous goat genotypes (Afar, Fig. 2; Long-eared Somali, Fig.3; Central Highland goat, Fig.4) each of these belongs to the respective goat families (Rift-Valley, Somali and Small East African goat) found in Ethiopia. These goats were chosen for the study considering their geographical coverage, relatively large population and the existing market situation.

1. The Afar. It is also called the Adal or Danakil. The goat is well adapted to the semi arid and arid environments with a concave facial profile, narrow face, prick-eared, leggy, long thin upward-pointing horns, and patchy coat color. They are kept mainly by the Afar ethnic group in the rift valley strip, Danakil depression, Gewane, northern and western Hararghe of Ethiopia (Farm-Africa, 1996). Their population is estimated at 2 million (Zeleke, 1997).

2. The long- eared Somali (LES). Its local names are Digodi, Melebo, Galla, and Degheir. It is a large white goat with predominantly straight facial profile. Horns are mainly curved and pointed backwards. The estimated population is 1.5 million. They are mainly distributed throughout Ogaden, the lowlands of Bale, Borana and Southern Sidamo of Ethiopia (Farm-Africa, 1996).

3. The central Highland goat (CHG): It is also called the brown goat. It is a medium sized, broad faced, thick horns, and mainly reddish brown in colour. It has a predominantly straight facial profile. The horns are mainly straight and pointed backwards. The population is

Fig. 2 : Photograph of Afar goats

Fig 3 : Photograph of Long-eared Somali goats

Fig 4 : Photograph of Central Highland goats

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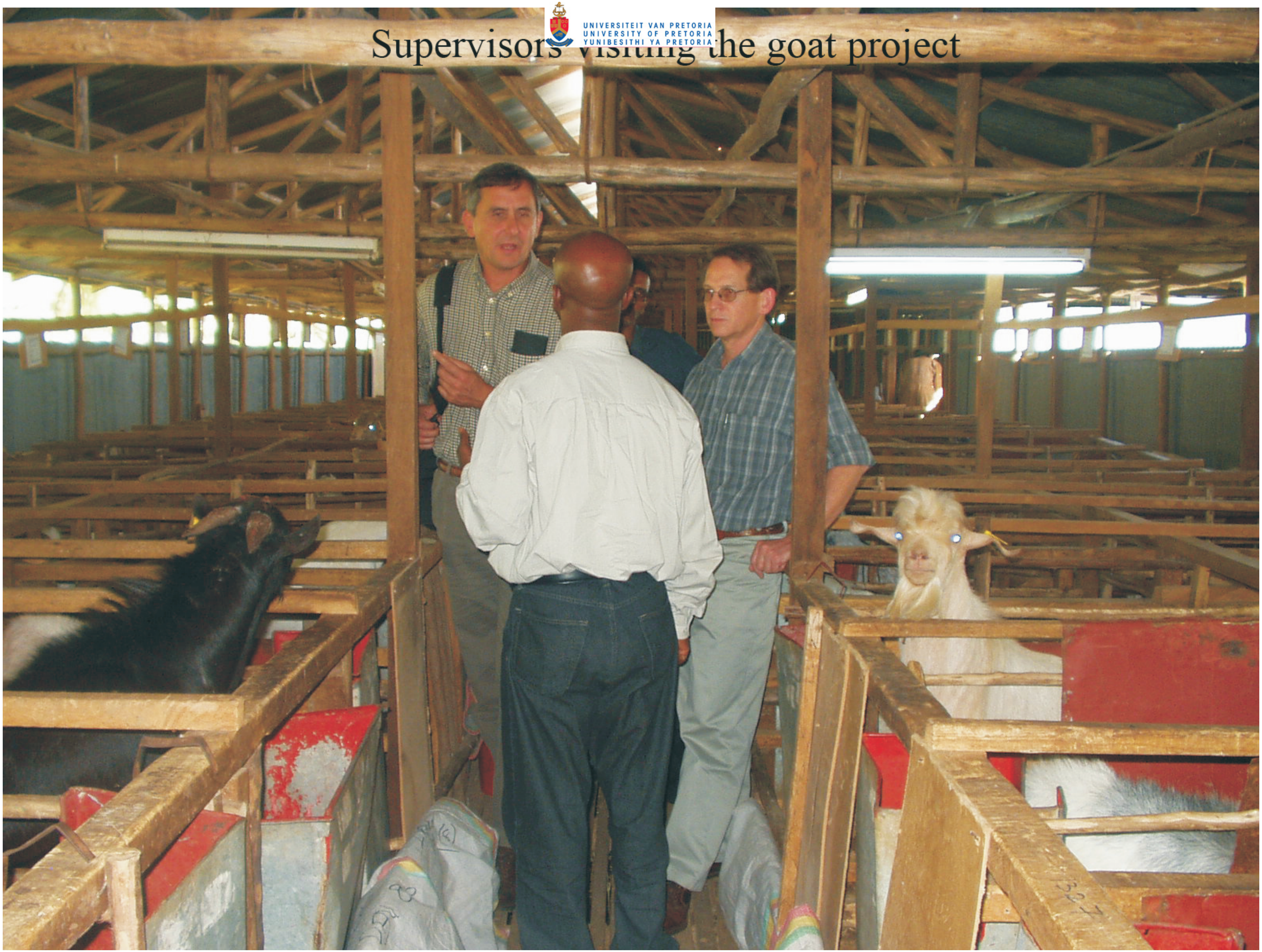
Supervisors visiting the goat project



estimated to be about 6 million, including some highlands of Southern Eritrea. These goats are mainly found in the central highlands west of the rift valley escarpment in central Tigray, Wollo, Gondar and Shoa of Ethiopia (Farm-Africa, 1996).

2.3 Natural pastures and agro-industrial by-products in Ethiopia

2.3.1. Significance of the feedstuffs

Due to inadequate or fluctuating nutrient supply, undernutrition is a major constraint to animal production in Ethiopia and often results in low rates of reproduction and production as well as increases in susceptibility to livestock diseases and subsequently mortality. Much of the feeds are utilised to support the maintenance requirements of the animals, with little surplus left for production, mainly because of the marked seasonality in the quantity and quality of available feed resources. Like most of the goats, the Afar and Long-eared Somali goats are reared extensively on arid to semi-arid rangelands and flocks may move to highland areas during the dry season. The Central Highland goats, however, graze freely on the hillsides and communal grazing areas during the dry season and are tethered during the cropping season (Farm Africa, 1996).

The major feed resources of the country are the natural pasture, crop residues and agro-industrial by-products. The pasture area has been estimated to be about 40 million ha accounting for 36 % of the total land area of the country (FAO, 1994). Currently, the pastureland is believed to be decreasing due to the expansion of arable farming and different infrastructures. Use of improved forage crops in the country is uncommon and mostly restricted to research centres, higher learning institutions and some pocket areas for various reasons, including the availability of adapted forage seeds. Grains are expensive and highly valued as human food in Ethiopia and currently cannot be used as sources of concentrate for ruminants. Use of industrial and farm by-products such as wheat bran and noug cake however, would save grain not only for human consumption, but could also be used more efficiently in monogastric animals such as in poultry diets.

There is no resource base study undertaken so far to describe the number and distribution of agro-industrial by-products in Ethiopia. However, estimates by the AAMC (1984) suggest an annual total production of half a million ton and this figure could now be increased substantially because of the increase in related industries over the past 21 years. The major agro-industrial by-products produced in Ethiopia include oilseed cakes, flourmill by-products (wheat bran and wheat middling), grain screenings, molasses, brewers' grain, coffee pulp and abattoir by-products.

The strategy for improving goat production should be maximizing the utilization of available feed resources in the rumen, by providing optimum conditions for microbial growth and then by supplementation to provide nutrients that complement and balance the products of digestion to requirements. Appropriate and alternative technologies, which can optimise the utilisation of available feed resources to replace traditional practices, are not yet fully developed and databases are lacking both at feed and animal levels (EARO, 1999).

2.3.2. Production and nutritive value of the feedstuffs

Native pasture hay, noug cake (*Guizotia abyssinica*) and wheat bran were used in this study and locally available literature on these ingredients is summarized below. The biomass yield of native pasture and its quality depends on location, the grazing system, season and botanical composition. Cossins and Upton (1987) reported that the annual pasure productivity of Borena rangelands in the lowlands ranged from 1.5 ton/ha in the Western zone to 2.7 ton/ha in the Northern zone whereas in the central highlands, dry matter yield of native pasture varied from 3.0 ton/ha in August to 6.0 ton/ha in October with a mean annual yield of 4.2 ton of DM/ha. The crude protein (CP) also varied from 3.2 % in January to 12.1 % in July while the IVOMD ranged from 42 % during the dry season to 57 % during the main rainy season of the central highlands (Zinash and Seyoum 1991). In the same study, the critical nutrient lacking in native pasture was noted to be protein and the supply of this nutrient falls below 50 % of the maintenance requirement of ruminant livestock for about 6 months of the year. Grazing trials at Holetta and Bako also suggested animals kept on a sole native pasture diet, lost up to 20 % of their live weight especially during the dry season (IAR, 1976). Preliminary observations on the stocking rate of native pasture in a semi-arid environment suggested that native pasture could maintain one mature cattle (Birru *et al.,* 1995) whereas in the highlands the stocking rate was 2-3 mature cattle or 8-10 sheep/ha (Lulseged and Hailu, 1985; Ameha and Fletcher, 1993).

Ethiopian oilseed cake generally has a high CP (35 %), low (32 %) neutral detergent fibre (NDF) and a modest level (67 %) of digestibility. Studies on rumen degradability characteristics of oilseed cake have also indicated that most oilseed cake has high rumen degradable protein and low undegradable dietary protein (Seyoum, 1995; Meissner, 1999). In a comparative evaluation of oilseed cake in layer diets, better performance was noted for noug cake than peanut cake and this difference was attributed to a better protein quality of noug cake than peanut cake (Maaza and Beyene, 1984). In other studies, it was reported that noug cake had 35.5 % CP, 33.3 % NDF, 28.2 % ADF and 12.5 % EE (Seyoum and Zinash, 1989). It was also documented that noug cake sampled from vertisols in Ethiopian highlands had a CP of between 29.6-37.8 % and was rich in P (Lemma and Smit, 2005). The demand for noug cake has also increased in peri-urban dairying and feedlot programs due to the positive response of animals probably due to the protein that is often inadequate in grass hay and cereal residues.

Wheat bran and wheat middling also have a high nutritive value and usually serve as sources of energy in most of concentrate mixtures. Getenet *et al.* (1999) reported that wheat bran had 17.2 % CP, 48.9 % NDF, 13.69 % ADF, 5.29 % ash and 65.9 % IVDMD. Kaitho *et* *al*. (1998) and Tesfaye *et al*. (2001) also reported the values for the chemical composition of wheat bran to be 89.1 and 89.2 % (DM), 3.9 and 5.4 % (ash), 96.1 and 94.6 % (OM), 16.6 and 16.3 % (CP) and 46.9 and 47.6 % (NDF) respectively. Kaitho *et al.* (1998) also reported ADF value of 15.5 %. However, Seyoum and Zinash (1989) reported a higher value of NDF and ADF i.e. 52.2 % and 17.3 % respectively and a CP of 17 % and 4.6 % EE. Wheat bran provides energy to ruminants primarily from its highly degradable fibre (Hess *et al*., 1996) and also contains less acid insoluble ash (Banerjee, 1986).

2.4 Dry matter intake, feed efficiency, rumen fermentation and degradation

2.4.1. Dry matter intake and feed effeciency

Dry-matter intake (DMI) is a key factor in the utilization of roughage by ruminants and is a critical determinant of energy intake and the performance of small ruminants. The existence of feed intake differences between genotypes has been reported in several studies (Wagner *et al.,* 1986; Barlow *et al.,* 1988; Van Arendonk *et al*., 1991). The relationship between intake and productivity is very complex and depends on several factors including nutrition and genetics. Said and Tolera (1993) indicated that plant cell-wall is the major restrictive determinant of feed intake and further stated that the actual feed intake of an animal depends on its genotype, physiological state, the quality and quantity of the feed available. Conrad (1966) has also reported that voluntary feed intake is regulated by rumen digesta load (fill), rate of passage, and rate of digestibility with forage-based diets. Silanikove *et al.* (1993) reported that breed differences in nutrient intake and digestibility might improve feeding program strategies of animals in rangeland or confinement conditions.

The feed conversion ratio (FCR) is also an important economic factor. The objective is to lower the amount of feed used per unit of weight gained and therefore a lower FCR. Hatendi *et al.* (1992) studied the effect of rations on Matabele goats using diets containing different hay levels ranging between 50 % and 10 %. Diet did not affect DMI and FCR though it tended to improve with a decrease in dietary hay. The feed conversion ratios were 12.9, 11.4, 9.5 and 11.3 for hay: concentrate ratios of 50:50, 33:67, 22:78 and 10:90 respectively.

The DMI of stall-fed Omani goats ranged between 2.8 and 3.2 % body weight (BW) and between 74.6 and 89.9 g/kg $W^{0.75}$. There were no significant effects of diet, breed or their interactions on the DMI. However, there was a trend of increasing feed intake with increasing ME density (8.67 low, 9.95 medium or 11.22 high MJ ME/kg DM (Mahgoub *et al*., 2005). On the other hand, Lu *et al.* (2004) reported that dietary ME density above 11.7 MJ ME/kg depresses intake and reduces the growth rate in growing goats.

Getahun (2001) reported that the total intake of stall-fed Somali goats (572.1 g) was significantly higher than Mid-Rift valley goats (523.4 g). The total intakes in g/kg $W^{0.75}$ per day were 68 and 64.7 for Somali and Mid-Rift valley goats respectively. The feed conversion ratio was better in Somali (19.5) than Mid-Rift valley goats (33.8).

Indigenous goats in the tropics fed to appetite have a daily DMI in the range 1.8-4.7 % BW, equivalent to 40.5-131.1 g/kg $W^{0.75}$. Meat breeds however, had a daily dry matter intake of 1.8-3.8 % of body weight and 40.5-127.3 g/kg $W^{0.75}$ (Devendra and Burns, 1983). These ranges are wider probably due to the effects of multiple factors on DMI. Therefore, “fed to appetite DMI” must be used with caution.

Bhakt *et al*. (1987) reported the effect of dietary protein levels (17, 21, 25 and 29 %) on DMI of indigenous male goats of Bihar and differences were not significant ($P>0.05$). The DMI (kg/100 kg BW) values ranged between 4.21- 4.88 and DMI (g/kg $W^{0.75}$) ranged from 76.4-86.1. The concentrate intake increased with increasing CP levels until 25 % and the reverse was true for the roughage intake. The total DMI ranged from 469.3 to 477 g. In another study with lower levels of CP (13 and 19 %) and 5 protein sources varying in ruminal degradability, voluntary DM intake, average daily gain and gain efficiency were similar between CP levels and between sources of supplemental protein in Boer×Spanish wether goats. There were no interactions between the dietary CP level and the supplemental protein source (Soto-Navarro *et al.,* 2003).

Singh *et al.* (1999) indicated that replacement of barley grain with wheat bran had no adverse effect on wheat straw intake of the sheep. Dhakad *et al*. (2002) also reported similar DMI and FCR in growing sheep fed maize grain replaced at 50 % and 100 % wheat bran; with lower daily gain in the latter group. In growing bulls, Giri *et al.* (2000) indicated that the replacement of barley grain with wheat bran with the incorporation of nitrogenous feed ingredients did not affect the daily live weight gain, dry matter intake and digestibility between the treatment groups. Grains were also successfully replaced with wheat bran in the concentrate mixture of growing crossbred cattle calves (Mondal *et al*., 1996).

2.4.2. Fermentation parameters and rumen degradation

The optimum ammonia concentration may be defined as that which results in the maximum rate of fermentation or which allows the maximum production of microbial protein per unit of substrate fermented (Mehrez *et al*., 1977). It depends on quantity and degradability of N in ingested feed, the rate of incorporation of ammonia into microbial protein and rates of passage and absorption of ammonia from the rumen (Streeter and Horn, 1984; Oosting, 1993). For normal microbial activity, 5–7 mg (Satter and Slyter, 1974) and for maximum nutrient utilisation 15–20 mg ammonia nitrogen per 100 ml rumen liquor is required (Perdok and Leng, 1989). Weisbjerg *et al.* (1998) reported that positive effects on microbial activity were obtained with NH_3-N between 10 to 15 mg/100 ml rumen fluid. Erdamn *et al* (1986) and Orskov (1992) documented that with NH_3-N concentration higher than 24 mg/100 ml, more nitrogen is lost from the rumen and the urine. Van Niekerk (1997) also reported that higher values of NH_3-N could have a negative influence on animal performance particularly in young ones that have a high-energy requirement. Smith and

Oldham (1983) however, indicated that more important than an optimal NH_3-N concentration is a continuous supply of N**.**

Umunna *et al.* (1995) reported that sheep fed oats hay supplemented with Lablab or *Sesbania sesban* or wheat middling had 16.6-25.4 mg/100 ml rumen fluid whereas growing Vietnam goats fed *Sesbania* and *Leucaena* had 40 mg NH_3-N /100 ml rumen fluid (Nhan, 1998). Sheep fed different ratios of broiler litter-molasses diet were reported to have NH_3-N levels ranging between 51 and 56.4 mg/100 ml rumen fluid (Mavimbela, 1999). Similar values were also reported for beef cows fed poultry litter with wheat straw (Silanikove & Tiomkin, 1992).

The concentration of VFA is regulated by production, absorption across the rumen wall and utilization by micro-organisms (Van Soest, 1994). Its production however, depends on the availability of fermentable OM in the feed (Oosting, 1993). Total VFA concentration varies widely according to the animal's diet and the time that has elapsed since the previous meal and is normally in the range of 70-150 mmol/l rumen fluid (McDonald *et al.,* 1995). Senani & Joshi (1995) documented that total VFA concentration ranged from 9.57 to 11.55 meq./100 ml rumen fluid in Barbari goats maintained on a concentrate, *Leucaena* leaves and oats hay. Boer×Spanish wether goats were evaluated with diets containing 13 or 19 % CP (DM basis) and different protein sources. Ruminal fluid pH, ammonia N, total VFA concentrations, molar percentages of VFA and the acetate: propionate ratios were similar between CP levels and between supplemental protein sources (Soto-Navarro *et al.,* 2003).

The concentration of ammonia and total volatile fatty acids in sheep fed a complete ration containing mixed grass hay (50 %) was higher ($P<0.01$) at 2 hour followed by 4 hour post feeding. The pH was also significantly lower ($P<0.01$) at 2 hour post feeding (Rao *et al.*, 1996). The pH range for optimal microbial activity was reported to range between 6.2 and 7.2 and considered optimum for fibre digestion (Van Soest, 1994). Supplementation of veld hay with groundnut hay in sheep also increased the concentration of ammonia and volatile fatty acids in the rumen fluid, but the molar proportion of the individual VFAs was not affected by diet (Manyuchi *et al.,* 1997a). Angela and Givens (2002) reported that sheep fed different proportions of grass silage and soya bean meal had pH values of 6.13-6.32, NH_3-N 18.9-57.9 mg/100 ml rumen fluid and total VFA 7.7-8.4 mmol/100 ml.

Grass pastures alone, concentrate made of rolled barley and pelleted concentrate mixture fed to cows did not show difference on mean rumen pH (6.01-6.17) and total VFA concentrations (127-132 mmol/l rumen fluid). The NH_3-N concentration ranged from 12.8 to 18.9 mmol/l rumen fluid and was significantly affected by the dietary treatments (Khalili and Sairanen, 2000).

Ruminal degradability is one of the important measurements to consider when determining the nutritive value of any feed (Kendall *et al.,* 1991). Susmel *et al*. (1999) found that the main dietary factors affecting the disappearance of feeds are forage to concentrate ratio, intake level, diet composition and frequency of feeding. The nutritive value of forage is closely related to the rate of disappearance of material from the rumen (Ingvartsen, 1994; Stensig *et al.,* 1994); hence, the degradability of DM and NDF will directly influence the nutritive value of the feedstuffs (Van Soest, 1994). Juárez *et al.* (2004) also reported that NDF degradability, which is usually low, depends on the quantity and distribution of the lignin component in the feed.

Supplementation of veld hay with groundnut hay in sheep had no significant effect on *in sacco* degradation of veld hay (Manyuchi *et al.,* 1997a). Veld hay was also incubated in the rumen of sheep given napier and groundnut hay as supplements or as a sole feed and it showed no effect on the degradation pattern including rate of degradation (Manyuchi *et al*., 1997b).

2.4.3. Research gaps

By-product feeds such as wheat bran and oil cake could be useful feed resources in many countries where other feed supplements are not available or scarce or are too expensive for farmers to utilize for their livestock. However, the available literature on such feeds is limited to sheep and cattle and is mainly on DMI, nutrient balance and growth rate. Therefore, in view of the differences of goats to sheep and cattle (Lu, 1988; Reid *et al.,* 1990), information on DMI, rumen fermentation and degradation of by-product feeds and grainless diets using goats is lacking for better utilization of these resources.

2.5 Effect of nutrition on growth performance, carcass and meat quality traits

2.5.1. Growth performance

Nutritional treatment, especially dietary protein and energy variables, is the most important environmental factor affecting live weight gain and meat production in goats. In tropical countries like Ethiopia, where mainly extensive grazing systems are practised, the growth rate and consequently meat production of animals fluctuate because of the seasonality of forage availability and quality.

The management system significantly influenced both final weight and average daily gains of Somali and Mid-Rift valley goats. The goats under intensive and semi-intensive conditions had higher final weights and average daily gain than those kept under extensive conditions. The body weight loss of goats under an extensive system indicated that the grazing land could not support even the maintenance requirements of the animals. This study was conducted in the dry season when yield and quality of available feed was poor (Getahun, 2001).

According to Mtenga and Kitaly (1990) the performance of East African goats in Tanzania under varying levels of concentrate supplementation ranged between 23 and 63 g/day.

Gaddi goats were evaluated using different protein and energy levels and those fed a high energy level (low or high in protein) had a significantly ($P<0.05$) better feed conversion ratio (11.7-13.2) and weight gain (41 g/d) than the other groups (14.8-15.9 and 27 g/d respectively) (Kumar *et al*., 1991).

Barbari kids fed Khejri leaves (*Prosopis cineraria*) were evaluated for avearge daily gain (ADG) and DMI with different levels of concentrates (Sharma and Ogra, 1990). The ADG were 18.2, 41.1, 51.1 and 56.1 g/d for the control, 1, 2 and 3 % supplementation of their body weight respectively. The feed conversion ratio (11:1) was similar ($P>0.05$) for the supplemented groups. The DMI did not improve when the concentrate level was increased beyond 2 % of body weight.

Sheridan *et al.* (2003) reported no significant difference ($P>0.05$) in the average daily gain and feed conversion efficiency of Boer goats fed on high (11 MJ /kg DM) and low (9.89 ME MJ/ kg DM) energy diets after two feeding periods (28 and 56 days). Urge *et al*. (2004) also reported that differences in growth performance between Alpine, Angora, Boer and Spanish wether goats were not influenced by dietary concentrate levels in the range 50–75 %.

There was a significant effect of diet and breed on growth and feed conversion ratio (FCR) in Omani goats. The ADG and FCR of Batina goats were 50 g and 10 on low, 80 g and 7.5 on medium and 96 g and 6.3 on high ME diet respectively. The ADG and FCR of Dhofari goat however, was lower and had respective values of 46 g and 13, 53 g and 11.3 and 53 g and 11.3 (Mahgoub *et al.,* 2005). The same genotypes were tested with increasing dietary levels of Meskit dry pods (*Prosopis juliflora*). The group of goats on a control diet

(50 % Rhodes grass hay and 50 % concentrate; CP 14.9 % and NDF 39.9 %) had a daily gain of 37 g per day and a FCR of 10.8 (Mahgoub, 2005).

Tesfaye *et al.* (2000) reported lower mean yearling weights (13.0±2.6 kg) for Somali and Mid-Rift valley goats, which were managed extensively in the semi-arid area of Central Ethiopia. Parthasarathy *et al.* (1984) also indicated that under the extensive conditions, goats hardly achieved 13-15 kg live weight at 8-9 months of age. However, under the semi-intensive system with browsing and supplementation, an improvement of 44 and 66 per cent between 3 to 6 months and 6 to 9 months, respectively was achieved (Parthasarathy *et al.,* 1984). Average daily gain was increased from 19.4 to 108.2 g when kids were supplemented with fresh or a concentrate mixture or both in addition to browsing (Parthasarathy *et al.,* 1983).

Abule *et al.* (1998) and Hailu & Ashenafi (1998) reported that indigenous male goats grazing natural vegetation and supplemented with concentrates had a growth rate of 71.8 and 63.6 g/d respectively. In another study, yearling Adal goats grazing natural vegetation (G), G+ 500 g concentrate and G+ 250g alfalfa were compared and the feeding treatments did not have a significant effect on body weight and ADG. The respective daily gains were 37, 37 and 43 g (Solomon *et al*., 1991). Kamatali (1985) also reported a similar result in which the groups that received concentrates, did not perform better than those only fed grass. The similar performance in the grazing groups was probably because the pasture during the season had adequate quality and quantity of nutrients to support the indicated gain.

The effect of different feed supplements to Napier grass for young and intact Mubende goats was studied and the highest growth rate (30.1 g/d) was recorded in goats fed a cotton seed cake supplement (Okello *et al*., 1994).

The growth performance of indigenous Bihar male goats was studied using four levels of crude protein (17, 21, 25 and 29 %). Gain per day ($P<0.05$) increased with an increase in

CP levels up to 25 %, and then declined. The respective growth rates were 26.5, 39.4, 53.8 and 38.4 g/d (Bhakt *et al*., 1987). On the other hand, at lower levels (14 and 16.4 % protein) male Angora, Spanish and Boer X Spanish kids recorded similar growth rates (Huston and Waldron, 1996).

Crude protein levels (10, 13 and 16 %) were also compared in the local Tunisian goats. The diet containing 13 % CP had the highest ($P < 0.05$) growth rate (Atti *et al.,* 2004).

West African Dwarf goats (16-18 months of age) were fed a crop residue based diet (cocoa pod husk, groundnut shells and corncob) and the ADG ranged from 37 to 39 g per day (Aregheore, 1995).

2.5.2. Carcass traits

The level of nutrition affects live weight at slaughter, the proportion of carcass contents, carcass measurements and total edible meat production. Information on carcass yield is useful when comparing and determining the actual and potential values of different meat producing animals. Berg and Walters (1983) have reported that genetic differences exist in fat deposition between breeds due to different growth capacity and maturity. The level of nutrition is also another major factor influencing the fat deposition pattern of animals whereby a high level of nutrition promotes earlier fattening while a low level results in a delayed or slower fattening process. Gautsch (1987) also indicated that the lean to fat ratio and the distribution of meat and fat within the carcass are dependent on the stage of development of the animal and the nutritional level they were fed. Fatness varies a great deal according to the genotype of goat and the husbandry method employed. Therefore, to attain the high or low fat levels a particular market may demand, goat farmers can vary feeding regimes and husbandry methods (Fehr *et al.,* 1991).

The dressing percentage of meat animals depends on the level of nutrition, species, breed, sex, season, age, castration and live weight (Dhangar *et al*., 1992; Pinkerton *et al.,* 1994). It may be also influenced by amount of gut fill at slaughter, whether the carcass is weighed hot or cold and by the number of body components included in the yield calculation (Pinkerton *et al.,* 1994). Therefore, when comparisons are made between animals using dressing percentages, attention should be given to the above factors.

Payne and Wilson (1999) recorded an increase in dressing percentage with increasing proportions of concentrates in the ration. Thus, a high percentage of crude fibre and roughage with a low digestibility contribute to a low dressing percentage. Dhangar *et al.* (1992) reported that dressing percentage on slaughter weight basis varied from 38.6 % in small sized goats (black Bengal) to 49.7 % in large sized goats (Beetal).

Carcass characteristics of Desi goats under different planes of nutrition (roughage: concentrate ratios of 10:90, 30:70, 50:50 and 70:30) did not affect (P>0.05) the proportion of bone, muscle and fat, dressing percentage on a slaughter weight basis and bone: meat ratio. The mean dressing percentage on a slaughter weight basis, proportion of lean, bone and fat and bone: meat ratios were 48.7, 62.7, 21.4, 15.9 and 1:3.7 respectively (Reddy & Raghavan, 1988). Pinkerton (www.clemson.edu) also reported that the response to 60:40 roughage: concentrate (R:C) and 40:60 R:C ratios were similar.

Different protein and energy levels did not significantly affect the dressing percentage, carcass weights and proportions of cuts in Gaddi goats at the age of 14-15 months (Kumar *et al*., 1991). It was concluded that for meat production, Gaddi goats should be fed diets high in energy irrespective of the level of protein.

Hatendi *et al.* (1992) studied the effect of diets containing different hay levels ranging between 50 % and 10 % on carcass traits of Matabele goats. The initial slaughter group had significantly lower values for most parameters measured (P<0.05) than the fed groups. Between the fed groups, there were no differences (P>0.05) in carcass proportions, eye muscle area and back fat depth. The dressing percentages were 48, 54, 50, and 50 % for hay:

concentrate ratio of 50:50, 33:67, 22:78 and 10:90 respectively. The 48 % was ($P<0.05$) lower than the other dressing percentages.

Omani goats fed mixed diets containing 8.67 (low), 9.95 (medium) or 11.22 (high) MJ ME/kg DM. Increasing of ME levels in the diet of goats increased carcass weight, empty body weight (EBW), dressing out percentage, chemical fat percentage, but decreased crude protein in the carcasses. i.e. the low energy group had higher carcass protein and lower fat content than both the medium and high energy fed animals (Mahgoub *et al.,* 2005).

Saikia *et al.* (1996) studied the effect of three energy levels on carcass characteristics of crossbred male kids (Beetal X Assam local). The dressing percentages were 42.1, 43.6 and 44.5 5 %, length of carcass 44.5, 45.9 and 47.6 cm and loin eye area was 5.3, 5.7 and 6.2 cm^2 respectively in the different groups.

Srivastava and Sharma (1997) compared the effect of feeding pelleted *L. leucocephala* leaves and complete diet (control) on the carcass traits of Jamunapari goats. Live weight (19.6 vs 16.9), carcass weight (8.8 vs 7.4) and dressing percentage (45.1 vs 42.0 %) of control kids were superior to the pelleted leaves group. Diet had no significant effects on proportions of wholesale cuts, lean, bone and fat contents.

Barbari goats fed a tree leaves mixture (TLM) + concentrate had higher ($P<0.05$) final (19.6 vs 15.4 kg), shrunk (18.4 vs 13.8 kg), empty body weight (16.9 vs 11.9 kg), hot carcass weight (HCW) (8.4 vs 5.7 kg), dressing percentage on slaughter body weight (45.6 vs 41.5 %), loin eye area (9.7 vs 6.2 cm^2), back fat thickness (1.36 vs 0.5 mm) and lower fasting loss (6.2 vs 10.5 %), compared to the TLM fed group. None of the wholesale cuts was significantly affected by the dietary treatments and the pooled mean proportion of the cuts were 32.0, 12.6, 13.2, 28.1 and 14.0 % for leg, loin, rack, shoulder and neck and breast and shank respectively. Dietary treatments also did not affect ($P>0.05$) the lean meat proportion in any of the primal cuts. However, the proportion of fat and bone in some cuts (P<0.01) and edible offals (P<0.05) were affected by supplementation (Ameha & Mathur, 2000a).

The type of diet had no significant effect (P>0.05) on the slaughter weight, hot carcass weight, dressing percentage, empty body weight, loin eye area and gut fill of Dhofari and Cashmere goats. However, only slaughter weight, hot carcass weight and empty body weight were significantly different between breeds. All the offals were not affected by diet, but were affected by breed (P<0.05) except for the weight of kidneys. Dhofari, at a slaughter weight of 20.4 kg, had a hot carcass weight, empty body weight, dressing percentage and gut fill (% of slaughter weight) of 10.4, 18 kg, 51 % and 12.2 % respectively. The weight of the offals was 1.3, 1.7, 0.31, 0.16, 0.16 and 1.5 kg for head, skin, liver, kidney fat, kidneys and empty alimentary tract respectively (El Hag & El Shargi, 1996).

The effect of different feed supplements to Napier grass when fed to young and intact Mubende goats (10-12 months) was similar in final body weights (P>0.05) and the weights of some offals (head, full gut, empty gut, blood and kidney). However, dressing percentage, HCW and EBW were significantly affected by diet (Okello *et al.,* 1994).

The carcass traits of Adal goats were not affected (P>0.05) by supplementary feeding and the body weight ranged from 23.6 to 25.7 kg, carcass weight from 9.6 to 10.4 kg, eye muscle area from 12 to 12.5 cm^2 and the average dressing percentage was 40.5 % (Solomon *et al*., 1991).

The level of crude protein in a diet (10, 13 or 16 %) did not affect EBW, carcass weight, dressing percentage, and external (skin, head and feet) and thoracic organs (lungs and heart) in local Tunisian goats (Atti *et al*., 2004). However, animals receiving a 13 % CP diet had relatively more muscle (P< 0.01) and less fat (P< 0.05) in the carcass than those fed high protein diets. The bone proportion was comparable between diets.

Various studies also assessed the effects of management systems on goat carcass traits. Saini *et al*. (1986) and Saini *et al*. (1987) reported that kids of different breeds under intensive and semi-intensive systems had significantly higher dressing percentages and meat: bone ratios than kids kept under an extensive condition. Similarly, Oman *et al.* (1996) reported that feedlot goats had heavier ($P<0.05$) live and carcass weights and dissectable ($P<0.05$) fat and lean and less ($P<0.05$) bone, as a percentage of carcass weight, than did the carcasses of non-supplemented extensively managed goats.

The carcass characteristics of Beetal X Sirohi male kids (9 months) were evaluated under extensive (browsing alone), semi-intensive (browsing + *ad libitum* concentrate and roughage) and intensive systems (stall feeding of concentrate & roughage *ad libitum*). The lean proportions from the loin cut were similar and the respective lean values for the above systems were 74.7, 69.9 and 71.1 %. The fat proportions were 8.8, 14.6 and 16.2 % and the bone % was 13.1, 10 and 10.4 %. Proportions of fat and bone were affected by the management system. None of the proportions of cuts was significantly affected by the feeding system (Misra & Prasad, 1996). Intensive and semi-intensive systems of feeding goats were also compared using Sirohi, Marawari and Kutchi breeds and it was concluded that the dressing yield and carcass characteristics were better in intensively fed kids than the semi-intensive ones (Sahu *et al.,* 1995).

Young goats in Florida kept under intensive and semi-intensive conditions were compared for various carcass traits. The proportion of total soft tissue (fat+lean), fat, lean and bone and ratio of lean to bone were not significantly affected by management. Moreover, other indicators of carcass quality such as lean colour, marbling and lean firmness of the M. *longissimus dorsi* were not affected by the management system (Johnson and McGowan, 1998).

Digestive tract contents as percentage of live weight depend mainly on nutrition and age as well as the genotype of the animal. Gaili *et al*. (1972) documented that the contents of digestive tract as a proportion of live weight decreased significantly in fattened animals because of the higher quality feed in the diet. In young and mature non-fattened Sudan desert sheep, the digestive contents were 19.3 and 21.2 % respectively. However, after fattening for 60 days, the contents decreased to 9.3 and 7.9 % respectively. Hyder *et al.* (1979) reported that pre-slaughter starvation shrinkage of Muzaffarnagari lambs was more (13.8-14.4 %) in a high roughage fed group than a low roughage fed group (5.6-10.6 %). Moreover, Mahgoub *et al.* (2005) showed that there was a trend of decreasing gut content with increasing ME levels. Higher fibre content in the low ME diet may have been responsible for higher digestive tract contents. Agnihotri and Pal (1993) reported that Jamunapari male goats at an age of 10.3 and 18.1 months had a fasting loss of 9.7 and 10.5 % of their live weight respectively and Jakharana goats at an age of 11.3 months, lost 8 % of their live weight.

2.5.3. Meat quality

Diet, breed, species, age and pre-slaughter and post-slaughter environment could affect the quality of meat. Chevon consist of 74.2, 21.4, 3.6 and 1.1 % moisture, protein, fat and minerals respectively (Gopalan *et al.,* 1980). However, meat from goats at the finisher stage has a higher fat and lower moisture content than non-fattened goats (Anjaneyulu & Joshi, 1995).

Compared to the initial group, feeding decreased carcass water ($P<0.001$), crude protein and ash content ($P<0.001$) and increased carcass fat content ($P<0.001$) in Matabele goats. Between the fed groups, carcass water, CP, and ash were higher for hay: concentrate (50:50), but these differences were not significant. Carcass fat content was highest for the group fed the lowest (10 %) hay level (Hatendi *et al*., 1992).

The diet effect was similar on the meat chemical composition of Majorera goats. The meat protein percentages ranged from 17–20 %. Diets also had no effect on the carcass pH and ranged between 5.49 and 5.82 (Arguello *et al*., 2005). Similarly, there was no diet effect on the moisture, intramuscular fat, protein and ash contents of meat from Barbaresca lamb. The cooking losses and ultimate pH (5.6-5.7) were also not significantly affected by diet (Lanza *et al*., 2003). However, Gaffar and Biabani (1986) reported that a high dietary energy level significantly increased the fat content and the total energy deposited in the carcasses of Osmanabadi bucks.

Animal fat is important for human nutrition for its high-energy value, which is more than twice that of carbohydrates. Fat improves meat palatability as it affects it's texture, juiciness and flavour as well as being important for meat preservation. Fatty acids (FA) are the major component of lipids. The FA physical property that mostly affects quality is it's melting point as it determines the firmness of the tissue at a particular temperature. Melting point increases as the carbon chain lengthens and decreases with the introduction of unsaturated linkages (Wood, 1984). The fatty acid composition of fats determines it's degree of saturation, and therefore, significantly affects it's quality. Interest in meat fatty acid composition stems mainly from the need to find ways to produce healthier meat which has a higher ratio of PUFA to SFA and a more favourable balance between n-6 and n-3 PUFA. The British Committee on Medical aspects of Food and Nutrition Policy recommended a PUFA: SFA ratio of > 0.45 and <1.0 (Corino *et al.*, 2002). It was also indicated that a higher PUFA concentration could also result in a softer, oilier fat that could also be more prone to oxidation and rancidity, which has negative consequences for human health. Russo *et al.* (1999) also reported that excessive consumption of PUFA fats could increase the formation of oxygen radicals and aldehydes, which are thought to be partly responsible for carcinogenesis and tissue ageing.

Enser *et al.* (1998) reported Western diets to have an imbalance between the n-6 PUFA and the n-3 PUFA, with n-6: n-3 averaging around 10 instead of the preferred value below 5. Ruminant meat have a low PUFA: SFA ratio because of the hydrogenating action of the rumen microorganisms on dietary fatty acids, but the ratio (n-6: n-3) is beneficially low, especially on grass diets. Though the presence of the rumen makes fatty acid composition in beef and sheep more difficult to manipulate by changing diet, there are some clear effects of diet on tissue fatty acid composition (Wood *et al.,* 2003).

Young goats of Florida under intensive and semi-intensive management systems were compared for their fatty acid composition. The feeding system affected the fatty acid composition and C14:1, C16:0 and C18:2 were increased ($P<0.05$) by the intensive management system. The respective percentages for intensive and semi-intensive management were 3.4 and 3.1 for C14:0, 29.1 and 28 for C16:0, 22.3 and 22.0 for C18:0, 40.4 and 42.3 for C18:1, 2.1 and 1.9 for C18:2, 0.2 and 0.2 for C18:3. The corresponding values for SFA, MUFA, PUFA and UFA/SFA were 54.9 and 53.3, 42.3 and 44.3, 2.8 and 2.4 and 0.84 and 0.89 (Johnson and McGowan, 1998).

Casey *et al*. (1988) observed a high proportion of C18:1 (32.3 %) in the subcutaneous fat (SCF) compared to the low proportions on pastures (8.1 %). Similarily a high C18:2 (15.9 %) on pastures and low proportion (1.6 %) in the SCF were also reported by the same authors. These observations support the hypothesis of biohydrogenation of these fats in the rumen.

2.6 Effect of genotype on the growth performance, carcass and meat quality traits

2.6.1. Growth performance

Animals of large breeds grow at a faster rate than smaller breeds and have higher pre-slaughter live weights and carcass weights than those of smaller breeds at a similar age.

Average daily gain was 15.6 and 26.4 g/day for stall-fed yearling Mid-Rift valley and Somali goats respectively (Getahun, 2001). In another study, the post weaning growth of indigenous Malawi goats was reported to be 40 g/day (Kirk *et al*., 1994) whereas the Black Bengal at the age of 9-12 months was 23 g per day (Husain *et al.,* 1996). On the other hand, Malaysian intensively managed male Jamanapari x Kambing Katajang crosses at the age between 9 and 15 months had an average daily gain of 10 g/d (Mustapha and Kamal, 1982). The growth performance of Alpine, Angora and Nubian goats fed on winter wheat pastures was 46.5, 61.8 and 44.1 g/d, respectively (NCSU, 1998). These data show how big the variation is between the breeds and the importance of breed performance evaluation.

Three North West Indian breeds of goats were fed a diet (60 % concentrate mixture and 40 % dry pala leaves) and the average daily gain was non-significantly higher in Kutchi, while Marwari had the best feed conversion efficiency (Singh *et al*., 1995).

2.6.2. Carcass traits

Goat breeds in the world vary widely in their body sizes and carcass characteristics (Devendra and Owen, 1983; Warmington and Kirton, 1990). Comparison of carcass characteristics between breeds provides information on their performance levels and suitability under defined management and environmental conditions. The composition and quality of meat can be influenced by intrinsic (age, breed, sex-type, species and anatomical location) and extrinsic factors (diet, fatigue, stress, fear, pre-slaughter manipulation and environmental conditions at slaughter). Breed exerts the highest influence on parameters such as yield of cuts, lean to fat ratio, intramuscular fat distribution, firmness of fat and colour, tenderness and juiciness of cooked meat (Anjaneyulu *et al*., 1984; Schőnfeldt, 1989; Prasad & Kirton, 1992). Some breeds begin to fatten at lower weights and others at heavier weights. Breeds differ in the rate at which fat is deposited during the fattening stages.

A high proportion of muscle (lean), low proportion of bone and an optimal level of fat cover are characteristics of a superior goat carcass. The proportions are also mostly influenced by the stage of maturity or mature size of the animal. Due to a strong breed effect on body composition, one can select between breeds for targeted and acceptable proportions (Taylor *et al.,* 1989).

Dressing percentage in goats varies from 38-56 % in different breeds based on sex, age, and weight and conformation status of the animal at the time of slaughter. Barbari goats had a dressing percentage of (49.8 in males and 49.9 % in females) which was higher than Jamunapari goats (45.4 in males and 44.3 % in females). The bone in Jamunapari (19.5 to 20.7 %) was significantly more than Barbari goats (16.6 to 16.7 %). Barbari kids had a greater proportion of carcass components and lean meat than Jakhrana kids of similar weight and age (Prasad *et al*., 1992a). Verma *et al.* (1985) also reported that the dressing percentage of Barbari kids at the age of 6, 10 and 14 months was 39.4, 45.5 and 46.1 % respectively.

The slaughter weight (SW) in Somali (17.8 kg) was higher than Mid Rift-Valley (MRV) (15.3 kg) goats. Hot (7.4 kg) and cold carcass (6.8 kg) weights were also heavier ($P<0.01$) in Somali than those of MRV (6.4 and 6 kg respectively) goats. Dressing percentage on SW basis was similar ($P>0.05$) between the genotypes with a mean of 41.5 %. However, dressing percentage on EBW basis was higher ($P<0.01$) for Somali (50.6) than that of MRV goats (49.2 %). The proportion of fat was higher in Somali (14 %) while MRV had a higher proportion of lean meat (59 %). Lean meat to bone and lean-plus-fat to bone ratios were not influenced ($P>0.05$) by genotype. However, the lean-to-fat ratio of MRV (5.63) was significantly ($P<0.05$) higher than that of Somali (4.2). Rib-eye area ($P>0.05$) was similar between the two breeds (Getahun, 2001).

The values of slaughter weight, fasting loss, carcass weight and loin eye area of Barbari goats (1-2 years) were 21.9 kg, 7.3 %, 9.6 kg, 8.6 cm^2 respectively. The proportions of the primal cut yield were 27.8, 13.4, 13.3, 26.7 and 18.9 for leg, loin, rack, neck and shoulder and breast and shank respectively (Pal & Agnihotri, 1999). The same breed at a slaughter weight of 19.5 kg had a dressing percentage on SW and EBW basis of 55.4 and 63.6 respectively and the proportion of muscle, fat and bone were 71.9, 7.7 and 20.4 % respectively (Prakash *et al.,* 1990). The higher dressing percentage was achieved due to intensive feeding of a diet containing a concentrate: roughage ratio of 60:40.

The mean slaughter weights of the local Barbari breed of goat at the market ranged from 17.2 to 19.6 kg. Males were heavier and carcass weight ranged from 7.9 to 9.1 kg. The loin eye area varied from 5.9 to 8.0 cm^2 and carcass length from 53-93 cm in market female goats. (Rao *et al*., 1985).

According to Joshi *et al*. (1988) the lean, fat and bone components vary from 55-66, 5-25 and 20-32 % of the carcass respectively depending on the breed and conformation of the goats. Adegbuyi *et al*. (1979) on the other hand, reported that the leg and loin of Red Sokoto × West African goats had a percentage lean meat of 69.4 and 70.2 %, and a bone proportion of 19.1 and 16.0 %, respectively.

Dhanda *et al*. (2001) reported the influence of goat genotype on carcass traits of Capretto and Chevon. A significant effect of genotype on carcass weight, carcass length, eye muscle area and internal fats was recorded. The final live weight, HCW and dressing percentage on EBW for the Capretto group ranged from 15.1-16.4 kg, 6.3-7.2 kg and 49.2-51.5 % respectively. The range of values for carcass length (38.4-49.9 cm), eye muscle area (6.5-8.7 cm^2), fat thickness at the 12/13th rib (1mm), scrotal fat (0.1-0.3, % of EBW), kidney and pelvic fat (0.3-0.9, % of EBW) and the subjective score of muscle colour (1 pale and 5 red) ranged between 1.4 to 2. Carpenter *et al*. (2001) reported that visual colour determinations are the gold standard for assessing treatment effects and estimating consumer perception.

The composition of Capretto and Chevon carcasses had significant differences in muscle and fat content and small differences in bone content between genotypes. Similar observations on the composition were also reported by Bello & Babiker (1988) and Johnson *et al*. (1995) in different goat breeds.

Slaughter weight, EBW, carcass weight, dressing percentage on live weight and EBW of male yearling Cheghu goats were 16.5 kg, 14.1 kg, 6.6 kg, 39.7 % and 46.4 % respectively. The total lean, bone and fat percent and loin eye area (cm^2) were 70.5, 25.6, 8.7 and 7.1 respectively (Biswas and Koul, 1989).

The live weight, hot carcass weight, dressing percentage and loin eye area of yearling Gaddi goats were 16.4 kg, 6.6 kg, 40 % and 6.3 cm^2 respectively (Kulkarni *et al*., 1996). The proportions of the primal cuts were 32, 11.8, 9, 14.2 and 34.3 % for leg, loin, rack, breast and shank & neck and shoulder respectively (Kulkarni *et al.,* 1992).

Carcass weight and composition are important factors affecting chilling rate (Kastner, 1981). Smith and Carpenter (1973) reported that a fat covering of 2.5 mm for lamb carcasses would prevent excessive postmortem shrinkage during chilling and transit. Johnson *et al.* (1988) reported that lean tissue retained less water than adipose tissue 20 h postmortem and more moisture loss occurs from lean than from fat tissue. The major variables associated with reducing shrinkage are decreased surface area and/or increased subcutaneous fat covering. Increased fatness may decrease shrinkage by serving as a barrier against moisture loss (preventing evaporation from the lean meat), or it may act to minimize the total moisture content in the carcass (Smith and Carpenter, 1973).

El Khidir *et al*. (1998) reported that the mean shrinkage loss obtained after chilling the meat of Sudanese desert male goats (body weight 35.2 kg) for 24 hours was 4.3 %. However, Owen and Norman (1977) reported 8.72 % shrinkage for milk tooth Boer goats and Botswana goats (5.09 %). The shrinkage was higher ($P<0.01$) for Somali (8.74) than for

MRV goats (5.70 %). Carcasses of extensively managed goats also had a significantly (P<0.01) higher shrinkage loss than the carcasses produced under semi-intensive and intensive management systems (Getahun, 2001).

2.6.3. Meat quality

Traditionally meat quality is either eating quality or processing quality, implying that quality is directly associated with usage (Webb *et al*., 2005). Eating quality comprises palatability, wholesomeness, and being free of pathogens and toxins. Palatability includes tenderness, flavour, residue, and succulence. Each of these criteria is again dependent on a long list of other factors which include the animal's age and gender, physiological state and the biochemistry of the post-mortem muscle, fat and connective tissue, carcass composition and the contribution of the feed to flavour, protein and fat accretion and the characteristics of each of these, as well as the effect of genetics on the character of tissues and metabolism.

The moisture, ash, protein and fat composition determined from the soft tissue (fat and lean meat) were 69.8, 0.97, 24.83 and 7.9 % for South African indigenous goats and 69.4, 0.95, 22.76 and 10.45 % for the Boer goat respectively. The mean molar proportions of fatty acids in *longissimus dorsi* (meat and fat) were 6 (C14:0), 19.5 (C16:0), 20 (C18:0), 37.7 (C18:1), 3.9 (C18:3), 53.6 (total SFA), 46.4 (unsaturated, UFA), 42.5 (MUFA) and 3.9 % (PUFA) for indigenous goats kept under extensive conditions. Compared to Boer goats, the South African indigenous goats had higher (P<0.01) oleic acid and PUFA concentrations and lower (P<0.01) saturated fatty acids (Tshabalala *et al.,* 2003).

Meat composition of castrated male goats of the Moxotó breed and their crosses with Pardo Alpina and Anglo Nubiana was studied and moisture, ash contents and cholesterol level of meat varied with breed group, while moisture and fat contents varied with age. The major fatty acids recorded in the meat of these goats were oleic (28–44 %), palmitic (17–20 %) and stearic (12–18 %) acids (Bessera *et al*., 2004). Oleic acid increased with age i.e. 31 %

at 4-6 months to 43.0 % at 8-10 months. Values for unsaturated/saturated fatty acids [(MUFA+PUFA)/SFA] ratio at the age of 8–10 months ranged from 1.2 to 1.4.

The compositions for water, crude protein, crude fat and ash concentration were 75.4, 21.2, 2.2 and 1.4 % for Boer X Nanjiang Yellow goats. The respective values for Nanjiang Yellow goats were 76.1, 20.9, 2.5 and 1.34 %. None of the parameters was affected by the genotype (Hongping *et al*., www.iga-goatworld.org). Mahgoub *et al.* (2005) also reported no breed differences in the chemical composition of the carcasses of Omani goats.

Dahanda *et al.* (1999) reported that there was no significant differences between genotypes in muscle chemical composition for two age groups (Capretto and Chevon) except that Boer X Angora goat had significantly higher extractable fat concentration (7.2 %) compared to Boer X Sannen goats and Sannen X Feral goats (5 and 3.2 % respectively) for the Chevon group. The values for Capretto ranged from 74.7-75.7 % for moisture, 18.5-19.2 % for crude protein, 2.4- 3.9 % for ether extract and 1.1 % for ash. The moisture content decreased and crude protein and ether extract increased significantly while ash content remained unaffected with an increase in age. In a fat-tailed sheep genotype, muscle types also did not significantly affect the proportions of moisture, protein, fat and ash (Esenbuga *et al.,* 2001).

According to Banskalieva *et al.* (2000), the percentages of the major fatty acids in goat muscles were between 28 and 50 % for C18:1; 15 and 31 % for C16:0; 6 and 17 % for C18:0; and 4 and 15 % for C18:2. It was also mentioned that plasma cholesterol concentration is influenced by the fatty acids composition of dietary fats. High dietary levels of long chain saturated fatty acids (SFA) increased the plasma cholesterol level compared to high levels of MUFA and PUFA. The SFA, such as lauric (12:0), myristic (14:0) and palmitic acids (16:0) are hypercholesterolemic, while the saturated stearic (18:0), and unsaturated oleic, linoleic and linolenic, present a hypocholesterolemic action. The C10:0 also does not raise blood cholesterol levels (Knapp *et al.,* 1991). Kowale & Kesava Rao (1995) however, reported higher C18:0 (21 %) levels in the *longissimus dorsi* muscle of indigenous male goats, which is higher than the range indicated and they also recorded the presence of very low unsaturated fatty acids (40.1 %). Major fatty acids identified in the muscle of Boer, Spanish and Mixed Breeds were oleic, palmitic, stearic, capric, lauric, myristic and linoleic acids (Norma *et al.,* www.umes.edu/ard).

Banskalieva *et al.* (2000) reported that the ratio of PUFA: SFA varied between the various muscles of goats and ranged between 0.16 and 0.49. Information regarding n-6 and n-3 PUFA is limited in muscle of goats. It was also indicated that breed and diet affected the fatty acid compositions of muscle lipids. However, there are no data available examining interactions between diets, genotype, muscle type, age, live weight and rearing conditions. Rhee (1992) categorized all unsaturated fatty acids and C18:0 as desirable fatty acids (DFA). The average percentage of DFA in goat meat was estimated between 61 and 80 %.

Muscle tissue of Jebel Akhdar goats contained on average 51.3 and 48.7 % SFA and UFA, respectively (Mahgoub *et al*., 2002) while Potchoiba *et al.* (1990) reported values of 50.6 and 49.4 %, respectively for Alpine kids.

Webb & Casey (1995) reported that breed effect was observed on some of the fatty acids. Higher proportions ($P<0.01$) of C17:0, C17: 1 and C18:1 were detected in the subcutaneous fat (SCF) of Dorper than South African Mutton Merino sheep. However, the fatty acid content of subcutaneous and intramuscular fat in Lacha and Rasa Aragonesa lambs was not affected by breed (Beriain *et al.,* 2000).

One of the key factors in meat quality is pH. The potential for good quality meat only occurs between a pH of 5.4 and 5.7 (Coultate, 2002). The muscle of a living animal has a pH of 7.1. The extent the pH is lowered after the animal's death depends on how much glycogen was in reserve, prior to the animal's death. Ultimate pH for both Capretto and Chevon ranged from 5.6 to 5.8 (Dahanda *et al.,* 1999). However, for Spanish goat meat it was 6.07, 6.33 and 5.96 for leg, shoulder/arm and loin/rib respectively (Kannan *et al*., 2001).

Dhanda *et al*. (2001) reported that cooking loss was significantly affected by goat genotype and the values ranged from 34.1-39 % for Capretto and 32.5-51.5 % for Chevon. On the other hand, the value for *longissimus thoracics et lumborum* of Angora goats was 18.61 % and for Boer goat from the same muscle location 15.54 % (Schőnfeldt, 1989). Higher values of cooking loss, 58.9 and 62.2 % were also reported for Boer X Nanjiang Yellow and Nanjiang Yellow goats respectively (Hongping *et al*., undated). Schőnfeldt *et al.* (1993) reported that increased fat content in the carcass had higher drip, evaporation and total cooking loss. It was also indicated that drip loss increased significantly with increased animal age. In pork loins, it was reported that drip loss was significantly ($P< 0.01$) higher with longer storage times (Ockerman *et al*., 2001).

2.7 Research gaps

Information on the comparative performance of indigenous goat genotypes is very limited. Moreover, the available reports are limited to the use of grain-based concentrates, browses and herbaceous forages. On the other hand, the potential of by-product feeds for meat production has not been investigated and information on the growth, carcass and meat quality of goats using a grainless diet is lacking.

2.8 Other factors affecting meat quality

2.8.1 Pre and post slaughter management

The properties of meat that are of most interest to the consumer are strongly affected by the pre-and post slaughter treatment of animals and the carcasses (Sanz *et al*., 1996; Lahucky *et al*., 1998). The effects of pre-mortal handling are manifested through the level of glycogen at slaughter, the rate and extent of post mortem-glycolysis, the concomitant pH changes and the ultimate pH (pHu) attained. Muscle glycogen levels are affected by factors such as pre-slaughter hormonal status, nutritional condition and social and physical interactions (Brown *et al.,* 1990). Mishandled animals prior to slaughter have low muscle glycogen levels due to the physiological stress caused by physical activity and emotional excitement (McVeigh *et al.,* 1982). The content of glycogen in skeletal muscle is often in the range of 0.3 to 1 % depending on the nutritional status and activity of the animal and muscle type (Bechtel, 1986). In well fed and rested cattle, for instance, glycogen content ranges between 0.8 % and 1 % in *longissimus thoracis et lumborum* muscle (Warner *et al.,* 1998).

If at slaughter the animal has adequate glycogen reserves; and the slaughter and the storage processes are appropriate, glycolysis and the concomitant increase in lactic acid results in a pH fall from about 7.2 to about 5.5 (Graeser, 1986; Varnam and Sutherland, 1995). A pHu of 5.5 is desirable and is associated with light coloured palatable meat. However, if pre-mortem glycogen reserves are low (< 0.65 to 0.70 %) (Varnam and Sutherland, 1995), the glycogen will be depleted before a pH level of 5.5 is attained. The result is a high pH meat, which at extreme levels, such as pHu greater than 6.0 in beef (Brown *et al.,* 1990), causes an aesthetically unpleasant phenomenon of dark, firm and dry meat. Such meat is dark in colour, tough, has a high water holding capacity and is prone to bacterial spoilage (Warriss *et al.,* 1984). On the other hand, if there was a great lactic acid build up before slaughter, the pH of the meat declines too quickly after slaughter and a pale, soft, exudative condition may develop. As suggested by the name, the affected meat is pale, soft, and fluid may drip from the surface. Breed effects have also been observed on the rate of glycogen depletion pre-mortem. Some breeds are more prone to stress than others. Distance travelled and conditions of travel to the abattoir may also be a major pre-slaughter factors attributing to poor meat quality. Travelling long distances exerts substantial stress on the animals which could lead to greatly reduced pre-slaughter glycogen levels, particularly if they are not allowed adequate time for recovery in lairage (Jones *et al.,* 1988; Jeremiah *et al.,* 1988). The rate of glycogen repletion is particularly slow in animals that have been on poor quality diets and /or have been fasted prior to slaughter (McVeigh *et al*., 1982). It is thus recommended that slaughter animals be allowed recovery time in lairage so that glycogen reserves may be repleted. For cattle, a 24-hour rest period before slaughter is recommended to allow the animals to recover from the travel, adapt to their new environment and replenish glycogen reserves (Wythes *et al.,* 1988). The rate of glycogen repletion in lairage will also be affected by the stress caused by mixing with unknown animals.

To produce quality meat, appropriate temperature, airflow and relative humidity must be employed in the chillers. Chilling must be rapid enough to minimize microbial growth but avoid cold shortening. The airflow must be sufficient for even cooling and not to excessively dehydrate the carcass and humidity must be carefully controlled to reduce bacterial growth on the meat surface (Varnam and Sutherland, 1995).

2.8.2 Factors affecting meat colour

Meat colour is an important parameter in meat quality. There are several factors which affect the colour of uncooked meat. Some of these factors are species, age, sex, cut of meat, water holding capacity of the meat, surface drying of the meat, surface spoilage of the meat and wavelength of light striking the meat surface. Colour of the meat is largely determined by the content of myoglobin and its derivatives. The reddish colour of raw meat largely results from the presence of the pigment myoglobin in meat. Colour is also greatly affected by muscle pH. At a high pH, the muscle has a closed structure and hence appears dark and the meat tends to be tough (Purchas, 1990). It is quite normal for meat to change colour depending on the presence or the absence of air. For instance, leaving meat exposed to air causes it to change colour by reactions occurring between myoglobin and the oxygen in air. Colour is not especially associated with tenderness, although darker meat may have more flavour. Meat changes colour according to both the quantity of the myoglobin it contains and chemical changes in the myoglobin itself. The more myoglobin in the meat, the darker the colour. Butchers prefer carcasses to have at least some fat evenly distributed over the carcass. This aids keeping quality and maintains the attractive appearance of the lean by preventing it from drying out. Meat can also become discoloured before reaching the retail outlet if too much drying out occurs. Older sheep contain more muscle myoglobin and hence have darker meat than lambs and hoggets (Barwick and Thompson, 1982).

Meat colour is also affected by diet. Bulls fed forage-based, restricted diets had less glycogen, a higher muscle pH, and darker muscle colour than bulls fed *ad libitum* concentrates (Mancini and Hunt, 2005). Apple *et al*. (2000) reported that adding magnesium mica to growing-finishing diets improved the pork color. Frederic *et al.* (2004) also reported that magnesium could minimize stress before slaughter, influence intracellular calcium gradients, and promote high-energy phosphates involved in glycolysis. Meat colour in pork also improved using vitamin D3 and the authors suggested it may be to the advantage of pork intended for export purposes (Wilborn *et al*., 2004).

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Chapter 3

Dry matter intake, feed efficiency, rumen degradation and fermentation parameters of Ethiopian indigenous goats fed a grainless diet

(Submitted to Small Ruminant Research Journal)

3.1 Abstract

Dry matter intake (DMI) and feed efficiency (FE) of three Ethiopian goat breeds, the Afar, Central Highland goats, (CHG) and Long-eared Somali, (LES) were studied using three grainless diets varying in concentrate: roughage ratios. Diet 1 was 50: 50, Diet 2, 65:35 and Diet 3, 80:20. Seventy-two young intact male goats were randomly allocated into nine treatment groups. Total DMI ranged between 2.6 and 3.0 on % body weight basis and 53.5 and 62.3 g DM/kg W $^{0.75}$. The LES breed had higher ($P<0.001$) DM roughage intake, total DMI ($P<0.01$) and FE ($P<0.05$) than the other genotypes. Those goats fed on Diet 3 had higher ($P<0.001$) total DMI (g/d) and there was a trend of increasing feed intake with increasing levels of concentrate. However, Diet 1 displayed higher ($P>0.05$) FE compared to the other diets. There was no significant genotype by diet class interactions for DMI and FE.

Rumen fermentation and degradation were studied using twelve adult indigenous goats. The mean concentrations of ammonia nitrogen (NH_3-N) and total volatile fatty acids (VFA) were higher ($P<0.0001$) and the pH was lower ($P<0.0001$) 2 hours post-feeding than the other sampling times. In all the diets and at all sampling times, the mean concentration of NH_3-N (39.4-53.7 mg/100ml) was above the N requirements of rumen microbial population for maximum nutrient utilization. The mean pH was similar between diets ($P>0.05$) and ranged from 6.43 to 6.63. Total VFA was depressed ($P<0.01$) with increased grainless concentrate. Diet 1 (50:50 concentrate to roughage ratio, 8.5 MJ ME/kg DM and 153 g/kg CP) however, had higher ($P<0.01$) total VFA and lower ammonia concentration ($P<0.01$) indicating that feed nitrogen was more efficiently utilized in Diet 1. The mean molar

proportions of acetate, propionate and butyrate ranged (P>0.05) from 64.5 to 65.7, 17.7 to 18.8 and 10.7-12.8 %, respectively. The ratio of acetic: propionic was not affected by diet (P>0.05) and ranged from 3.5 to 3.81. The values for the soluble fraction, slowly degradable fraction, the rate of degradation, potential degradability and effective rumen degradability (ED) were similar (P>0.05) in all the diets. However, the hay DM and neutral detergent fibre were more degradable (P<0.05) in goats fed Diet 1. Differences in DMI and FE between the genotypes were observed and the LES breed was superior. Among the grainless diets, Diet 1 created favorable rumen environment and resulted in better feed efficiency under the feedlot system.

3.2 Introduction

Goats are the most important among livestock in Ethiopia and their population is estimated at 23.3 million (CSA, 2004). The domestic demand for goat meat is high (Gryseels and Anderson, 1983; Farm Africa, 1996) and it is also exported to a number of Middle East countries (EEPA, 2003).

The major feed resource, native pasture, has high seasonal variability in yield and quality and lacks critical nutrients to support growth particularly during the dry seasons (Zinash and Seyoum 1991). This situation has been exacerbated by shrinkage of the grazing land, deforestation and overgrazing. Grazing trials conducted at different locations in Ethiopia indicated that animals kept on native pasture lose up to 20 % of their live weight especially during the dry season (IAR, 1976). Grains are expensive and highly valued as human food in Ethiopia and similar countries and consequently are not readily used as sources of concentrate for ruminants. However, industrial and farm by-products and other feedstuffs could be formulated into grainless diets to achieve reasonable levels of animal production.

Feed intake differences between genotypes have been reported in several studies (Wagner *et al.,* 1986; Barlow *et al.,* 1988; Van Arendonk *et al*., 1991). Said and Tolera (1993) also reported that the actual feed intake of an animal depends on its genotype, physiological state and the quality and quantity of the feed available. Concentrate: roughage ratio is an important factor to be considered for improving feed efficiency (Liu *et al*., 2005). However, there is no information available on how efficiently the indigenous goats utilize grainless diets with different ratios of concentrate and roughage. Moreover, rumen degradability and fermentation data of these feedstuffs using goats are not documented in Ethiopia. Globally too, there is little information about the DM and NDF degradability of different feeds in goats (Juárez *et al.,* 2004) and changes in the rumen environment (Woyengo *et al*., 2004) as these parameters directly influence the nutritive value of foodstuffs (Van Soest, 1994). The objectives of this work were to evaluate the performance in feed intake, feed efficiency, *in situ* degradability and rumen fermentation in Ethiopian indigenous goats fed different concentrate: roughage ratio diets composed of three ingredients of potential interest as ruminant feeds: wheat bran, noug cake (*Guizotia abyssinica*) and native pasture hay.

3.3 Material and Methods

3.3.1 Animals and diets

Seventy-two young intact male goats of three genotypes, the Afar, Long-eared Somali (LES) and Central Highland goats (CHG) were used for the study at Debre-Zeit Research Station of the International Livestock Research Institute (ILRI), Ethiopia. In each genotype, eight goats were randomly allotted to each of the three dietary treatments (ratio of concentrate: roughage) i.e. Diet 1, 50: 50, Diet 2, 65:35 and Diet 3, 80:20 respectively. The roughage was native pasture hay and the grainless concentrate composed of 79 % wheat bran, 20 % noug cake (*Guizotia abyssinica*), and 1 % salt. The quantity of roughage and concentrate as per ratio of the diets were adjusted on the basis of body weight recorded to meet the dry matter requirements (Kearl, 1982). The goats were housed in individual pens and had free access to clean water and mineral block. The study was done under the supervision and approval of the ILRI's Ethics Committee for Animal Experimentation.

3.3.2 Dry matter intake (DMI) and feed efficiency (FE)

The adaptation period was for 14 days. Daily individual feed allocation and refusal were recorded from the young goats for each of the roughage and the concentrate. Feed efficiency was calculated as kg feed per kg body weight gain.

3.3.3 Rumen degradation

Twelve ruminally cannulated (Fig. 5) adult (2 pairs of permanent incisors) indigenous male goats (mean weight, 31 kg) were fitted with rumen cannula (internal diameter 5.5 cm; manufactured by Processing of Poly Industrial Chemicals). The animals were allocated to four blocks and in each block the goat was allocated at random to one of the three diets giving four replications per treatment in Randomized Complete Block Design. The hay, wheat bran, noug cake and the three diets were ground to pass through a 2 mm screen and 3 g of air-dried sample were placed per nylon bag (internal dimension of 6 cm X 12 cm and porosity of 41 μm; polymon, Switzerland). The feedstuffs were incubated in the rumen for 3, 6, 12, 24, 48 and 72 h. Each feedstuff was incubated in duplicate in each goat at each hour. The parameters studied were the DM and NDF degradation of the feeds. Nitrogen degradation however, was not measured for our ration had similar protein source. After withdrawal from the rumen, the bags were machine washed (Tefal Alternatic, Finland) with cold tap water. The washing was carried out for 30 minutes consisting of five rinsing cycles. Then the bags were dried in an oven at 60 ^{0}C for 48 h, cooled in a desiccator and weighed. The zero hour bags were not incubated, but washed and dried under similar conditions.

Fig 5 : Fistulated Ethiopian goats

3.3.4 Rumen fermentation

Rumen fluid was sampled from each ruminally-cannulated goat at 0, 2 and 4 h post feeding for determination of ammonia nitrogen and volatile fatty acid concentrations (VFA) (Rao *et al.,* 1996). Immediately after collection, it was strained through three layers of cheesecloth and this was closely followed by a pH reading. Three drops of concentrated sulphuric acid were added in a 50 ml rumen fluid sample as a preservative for determination of ammonia nitrogen concentration and stored for a later analysis.

3.3.5 Chemical analysis

Feed organic matter (OM) was determined according to AOAC (1990) and the neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest *et al.* (1991). The nitrogen (N) and rumen ammonia were measured using the micro-kjeldhal method**.** The calcium (Ca) was determined by wet digestion method using an Atomic Absorption Spectrophotometer (Perkin Elmer, 1982) and the phosporus (P) using a continuous flow auto-analyzer (ChemLab, 1981). *In vitro* dry matter digestibility was estimated by the methods of Tilley and Terry as modified by Van Soest and Robertson (1985). Volatile fatty acid concentrations were determined using gas-liquid chromatography (Supelco, Inc., 1990).

3.3.6 Statistical analysis

The effects of diet and genotype on DMI and FE were analyzed using the Proc GLM procedure of SAS (1999). There was no significant genotype by diet class interactions for DMI and FE and main effects are presented and discussed. Kinetics of DM and NDF degradation were described by the Dhanoa (1988) model $P = a + b\,[1 - \exp(-c\,(t - L))]$, where *a* is the immediately soluble fraction, *b* the insoluble but slowly degradable fraction, *c* the constant rate for the degradation of fraction *b*, L the lag time, and P the DM and NDF degradation after time t. The effective degradability (ED) was calculated using the formula

ED = a + [b*c/(c+k)] where a, b and c as defined above and k = rumen outflow rate which was assumed to be 0.03/h (Orskov *et al.,* 1988). The potential degradability (%) was calculated as a + b. Then the data collected (a, b, c) were analyzed using the Proc GLM procedure of SAS (1999). Rumen ammonia, pH and VFA were also analyzed using repeated measures analysis of variance and the same software package.

3.4. Results and Discussion

3. 4.1 Feeds, intake and feed efficiency

The chemical composition and feed values of experimental feedstuffs are shown in Table 3.1. Among the feed ingredients used, noug cake had the highest CP content followed in order by wheat bran and native grass hay. NDF content followed the reverse order. The CP, NDF, IVDMD values of the native grass hay were comparable to the report of Zinash and Seyoum (1991). The values for wheat bran and noug cake (*Guizotia abyssinica*) were also similar to the report of Seyoum and Zinash (1989), Getnet *et al*. (1999), Tesfaye *et al*. (2001) and Kaitho *et al*. (1998). The low CP and high NDF of the native grass hay show it was low quality forage. Based on conventional measures of quality such as the content of CP, NDF, ADF and IVDMD, inclusion of grainless concentrate at different levels improved the quality of the diets.

DMI and FE of young intact male goats are shown in Table 3.2. Total feed intake in g/d, % BW and g/Kg W $^{0.75}$ was significantly affected by both genotype and diet. In contrast to this finding, there were no significant effects of diet and breed on DMI in Omani goats (Mahgoub *et al.,* 2005). Total DMI in the present study ranged between 2.6 and 3.0 on % body weight basis and 53.5 and 62.3 on g /kg W $^{0.75}$ and these intakes were within the range

Table 3.1 Chemical compositions and feed values of ingredients and experimental diets (g/kg DM basis)

Item	Ash	OM	CP	NDF	ADF	ADL	Ca	P	IVDMD*	MJME /kg DM+
Native grass hay	88.7	911.3	50.6	720.8	389.3	38.0	5.3	2.8	48.0	7.20
Wheat bran	43.4	956.6	191.9	442.0	128.4	24.3	2.1	10.8	68.68	10.30
Noug cake	100.5	899.5	345.0	353.4	270.3	106.4	8.5	13.7	63.24	9.49
Concentrate	65.8	934.2	216.6	398.3	141.1	35.4	3.2	10.9	68.91	10.34
Diet 1	81.1	918.9	153.1	579.6	267.2	33.9	3.9	7.9	57.0	8.50
Diet 2	78.9	921.1	175.6	514.8	229.0	35.5	3.7	9.4	61.25	9.20
Diet 3	70.6	929.4	196.2	436.4	187.3	30.9	3.0	10.8	66.70	10.0

OM-organic matter, CP-crude protein, NDF-neutral detergent fiber, ADF-acid detergent fiber, ADL-acid detergent lignin, Ca-calcium, P-phosphorus, IVDMD * (% *In vitro* dry matter digestibility)
+ ME MJ/kg DM=calculated value

reported for indigenous goats and meat goat breeds (Devendra and Burns, 1983). The LES had higher (P<0.01) total DMI (g/d), higher (P<0.001) DM roughage intake and higher (P<0.001) average daily gain (ADG; Table 5.2). This is a desirable trait from the genotype as it could contribute to the efficiency of farms. Diet 3 promoted higher (P<0.001) total DMI (g/d) and there was a trend of increasing feed intake with increasing levels of concentrate. Similar observations were also reported by Mahgoub *et al.* (2005) with increasing ME density. Genotype affected FE and LES was more efficient (P<0.05) than the other genotypes. Similar values of FE were also reported for Matebele goats (Hatendi *et al.,* 1992), Gaddi goats (Kumar *et al.,* 1991) and stall-fed Dhofari goats (Mahgoub *et al.,* 2005). Though diet effect was not significant, Diet 1 tended to be more efficient compared to the other diets (Table 3.2).

3.4.2. Ruminal pH, VFA and ammonia nitrogen

Mean pH, ammonia-nitrogen (NH_3-N) and VFA concentrations are presented in Table 3.3. Diet did not affect the mean pH (P>0.05) and ranged from 6.43 to 6.63. These values are within the range (6.2-7.2) reported by Van Soest (1994) as being optimal for fibre digestion.

Table 3.2 Effect of genotype and diet on dry matter intake (DMI), and feed efficiency (FE) of Ethiopian goats (least square mean ± pooled standard error, PSE)

Parameters	Genotype (G)			Diet (D)				Effects	
	Afar	CHG	LES	D1	D2	D3	PSE	G	D
Total feed intake (g/d)	504.5	506.1	526.2	486.6	489.6	560.7	5.31	* *	* * *
Total feed intake (% BW)	2.91	2.71	2.58	2.56	2.65	3.00	0.04	* * * *	* * * *
Total feed intake (g/kg $W^{0.75}$)	59.4	56.4	54.8	53.5	54.8	62.3	0.63	* * * *	* * * *
Weight gain (g/d)	36.7	34.7	43.9	37.7	35.0	42.5	2.06	* * *	*
FE [++]	13.7	14.6	11.9	12.9	13.9	13.2	0.75	*	NS

CHG = Central Highland goats, LES = Long-eared Somali goats, [++] FE = kg feed/kg gain
D1 (50:50 concentrate: roughage), D2 (65:35), D3 (80:20)
PSE=pooled standard error of the means
* P < 0.05; * * P < 0.01; * * * P < 0.001; * * * * P < 0.0001; NS, P > 0.05

The rumen pH at each sampling time was above the cellulolytic threshold value and this seems a good attribute of the grainless diets compared with soluble carbohydrate-rich diets such as cereal grains and sugar-containing concentrates.

Sampling time affected pH, NH_3-N and total VFA. The concentration of NH_3-N and total VFA were higher (P<0.0001) and pH was lower (P<0.0001) 2 hours post-feeding compared to other times. Similarly, peak concentrations of total VFA were observed 2 hours post-feeding in goats and sheep (Rao *et al*., 1998). In all the diets and at all sampling times, the mean concentration of NH_3-N appeared to have been sufficient to meet the N requirements of the rumen microbial population as they were above the ranges reported for normal microbial activity (5–7 mg NH3 N/100 ml rumen liquor (Satter & Slyter, 1974) and for maximum nutrient utilization (15–20 mg/100 ml rumen fluid) (Perdok and Leng, 1989).

The NH_3-N for the grainless diets ranged from 39.4-53.7 mg/100ml. As literature is silent on such diets comparison was made with other feeds and it was higher than the values (16.6-25.4 mg/100ml) reported for oats hay supplemented with Lablab or *Sesbania sesban* or wheat middling in sheep (Umunna *et al.,* 1995) and comparable with growing Vietnam goats (40 mg/100 ml) fed *Sesbania* and *Leucaena* (Nhan, 1998) and sheep (51-56.4 mg/100 ml) fed different ratios of broiler litter-molasses diet (Mavimbela, 1999). However, Erdman *et al* (1986) and Orskov (1992) documented that with concentration higher than 24 mg/100 ml, more nitrogen is lost from the rumen and the urine. Van Niekerk (1997) also reported that higher values of NH_3-N could have a negative influence on animal performance particularly in young ones that have a high-energy requirement.

Diet 1(50:50, C: R) had lower ($P<0.01$) ammonia concentration and higher ($P<0.01$) concentration of total VFA (Table 3.3) than the other diets. Oosting (1993) recorded that increased VFA concentration indicates increased microbial activity, which is associated with increased utilization of ammonia. Hence, lower rumen ammonia N in Diet 1 means a more efficient use of feed nitrogen and this favorable rumen environment created by Diet 1 resulted in better FE (Table 3.2) and higher dressing percentage ($P<0.01$) and non-significantly higher final body weight (unpublished data).

The molar proportions of acetate and propionate in the ruminal fluid did not differ between diets ($P>0.05$). However, the proportion of butyrate was lower ($P<0.05$) in Diet 1. A lower molar proportion of butyrate was also observed in goats fed a diet that had 50 % concentrates than 75 % (Urge *et al.,* 2004). The type of feed consumed determines the proportions of acetic, propionic and butyric acids (Peacock, 1996) and the molar proportions of acetate, propionate and butyrate in the current study varied from 64.5 to 65.7, 17.7 to 18.8 and 10.7-12.8 %, respectively. These molar proportions obtained from the grainless diet (mean NDF 51 % & CP 17.5 %) were comparable with those of goats fed a diet (NDF 39 %

& CP 17.5 %) composed of 50 % hay and 50 % concentrate of which 30 % was corn grain (Urge *et al.,* 2004). Comparisons were made with grain-based diets because information on similar diets is lacking. Bondi (1987) and McDonald *et al*. (1978) reported that when the proportion of concentrate in the diet increases, the molar proportion of acetic acid falls and that of propionic rises both in cows and sheep, respectively. However, increasing the level of grainless concentrate in the diet did not (P>0.05) increase the proportion of propionic acid. Total VFA was also depressed (P<0.01) with increased grainless concentrate. The ratio of acetic: propionic was not significantly affected by diet (P>0.05). It ranged from 3.5 to 3.81. Similar ratios were also reported in different diets in cattle (Zaman *et al.,* 2002; Huang *et al*., 1999).

The ADG of the LES (44 g) with grainless diet was similar to those of the tropical breeds of Zaraibi (El-Gallad *et al*., 1988) Gaddi (Kumar *et al*., 1991), Malawi (Kirk *et al.,* 1994), Batina (Kadim *et al*., 2003), Indian goat (Sen *et al.,* 2004) and semi-intensively managed Somali and Mid Rift Valley goats (Getahun, 2001) at similar age and improved nutrition, containing grain concentrate. The ADG achieved from the grainless diets could have been higher than the indicated one, had it not been due to the proportion of propionic acid, the major glycogenic precursor in ruminants (Preston and Leng 1987), the higher proportion of wheat bran in the concentrate and higher fibre content (Table 3.1) and energy required for removal of excess NH_3-N (Van Niekerk, 1997). Preston and Leng (1987) also indicated that at a rumen acetate: propionate ratio above 3:1, the supply of readily available energy limits microbial protein synthesis. On the other hand, the acetic: propionic ratio (3.75) and proportion of propionic acid (17.8) produced by steers fed on barley/rye grass or barley silage supplemented with barley grain were similar to our findings but higher ADG was achieved in the steers (Zaman *et al.,* 2002). This suggests the limited capacity of indigenous goats to utilize such a diet may also have contributed to the relatively lower growth rates.

Tesfaye *et al*. (2001) also observed a limited capacity of Zebu oxen to utilize high energy feed at higher level.

3.4.3. Rumen degradation

Ruminal degradability is one of the important measurements to consider when determining the nutritive value of any feed (Kendall *et al.,* 1991). The mean DM disappearance (DMD) of each diet increased with increasing incubation time with Diet 3 being more (P<0.05) degradable (Table 3.4). NDF disappearance (NDFD) also increased with time however, it was similar between diets (P>0.05) at each incubation time. DM and NDF degradations of each of the diets were compared between incubation time and both parameters were the highest (P<0.0001) at 72 hours and the respective values for the diets ranged from 695-780 and 506-548 g/kg.

Table 3.3 Mean pH, ammonia-nitrogen and VFA concentrations of ruminal fluid from Ethiopian goats fed grainless diet.

Parameters	Diet 1[+]	Diet 2	Diet 3	SEM	P
Rumen pH	6.63	6.54	6.43	0.06	NS
Ammonia-nitrogen (mg/100 ml)	39.4	50.2	53.7	3.97	* *
Total VFAs (mmol/100 ml)	8.24	6.32	7.31	0.53	* *
Acetic (mmol/100 ml)	5.42	4.03	4.70	0.32	*
Propionic (mmol/100 ml)	1.47	1.20	1.41	0.14	NS
Butyric (mmol/100 ml)	0.88	0.82	0.89	0.07	NS
Acetic: propionic	3.81	3.66	3.51	0.20	NS

[+]Diet 1 (50:50 concentrate: roughage), Diet 2 (65:35), Diet 3 (80:20)
* Significance, (P<0.05); * * Significance, (P<0.01); NS, P > 0.05

The effect of diet on DMD and NDFD of the native pasture hay was significant (P<0.05) at 48 and 72 h (data not shown). The DMD of the hay at 48 and 72 h was 538 and 577, 479 and 519 and 482 and 551 g/kg in Diet 1, Diet 2 and Diet 3 respectively. The mean 48 h-DMD of the hay (500 g/kg) was comparable to the DMD of native grass hay (Khalili *et al.,* 1993) and *C. gayana* hay at 48 h (Shem *et al.,* 1993). NDFD of the hay was 448 and 505, 367 and 419 and 370 and 462 g/kg at 48 and 72 h in Diet 1, Diet 2 and Diet 3 respectively. Among the incubation hours, the DMD and NDFD of the hay were the highest (P<0.0001) at 72 hours. The rate of degradation of the hay DM in the present finding (3.1 %h) was comparable to the mean rate of degradation of native grass hay (Kidane *et al.,* 1996; Khalili *et al.,* 1993). The hay DM and NDF were more degradable (P<0.05) in goats fed Diet 1 probably due to favorable roughage: concentrate ratio, which resulted in better rumen environment (Table 3.3). The effect of diet on DMD and NDFD of wheat bran and noug cake was similar at each incubation time except that the NDF of noug cake had numerically higher degradation at 48 h (P>0.05) and 72 h (P<0.05) in goats fed Diet 1. The mean DMD of wheat bran (741g/kg) in the present study was comparable to the value reported by Ngwa *et al.* (2002). Comparison between incubation times showed that the DMD and NDFD of wheat bran were the highest at 72 h (857 and 695 g/kg) while the DMD and NDFD of noug cake were similar between 48 and 72 h in each of the diets. The mean values of noug cake at 72 hours were 755 for DMD and 382 g/kg for NDFD.

Degradation constants of grainless diets are depicted in Table 3.5. The values for the soluble fraction, slowly degradable fraction, the rate of degradation, potential degradability (PD) and effective rumen degradability (ED) were similar (P>0.05) in all the diets. Akbar *et al.* (2002) also reported non-significant differences (P>0.05) between certain maize varieties in potential degradability and degradation rate of DM in sheep. Forage to concentrate ratio also had no effect on degradation constants of the protein supplements in heifers (Rotger *et al*., 2006). The rate of degradation and ED of the diet's DM ranged from 2.5 to 3.1 % h and 536 to 591 g/kg respectively. NDF degradation parameters were also not affected by diet and ED of the NDF ranged from 355.1 to 402.2 g/kg. The PD of NDF was lower than the PD of DM, which agrees with the results reported by Bruno-Soaresa *et al.* (2000) and Varga and Hoover (1983) for different feedstuffs.

As most of the livestock from tropical countries face energy and protein deficiencies during the long dry season, relatively slower degradation (2.5 to 3.1 % h) could also be desirable for roughage grazing animals by promoting coupled fermentation as the grainless diets would produce available energy at a slower rate, which would match the low nitrogen content in the basal diet. The extent of degradation of NDF in Diet 3 was higher than the other diets. Diet 1 however, had a NDF content that was 1.3 times higher. Thus it would be supplying more degradable NDF and therefore energy to the rumen microbes. NDF time lag (1.52 - 3.63) was similar (P>0.05) between diets and it was shorter for Diet 1 (Table 3.5).

3.5 Conclusion

The LES had higher DM roughage intake, total DMI and average daily gain and better FE than the other goat genotypes. These attributes show its greater potential as a breed of choice for meat production under stall-feeding conditions. In all concentrate to roughage (C: R) ratios of the grainless diet, the mean concentration of ammonia nitrogen was above the range reported for maximum nutrient utilization. Total VFA was depressed with increased grainless concentrate. However, goats on Diet 1 (50:50 C: R, 8.5 MJ ME/kg DM and 153 g/kg CP) had a higher concentration of total VFA and utilized the feed nitrogen more efficiently. Moreover, the hay DMD and NDFD were more degradable in goats fed Diet 1. As a result, Diet 1 produced better FE, higher body and carcass weight and dressing percentage. The feedstuffs used in this diet are locally available and their use will significantly improve meat production for export as well as for the domestic market. The feedlot findings also show the advantage of supplementation to grazing/browsing goats under the smallholder systems, a strategy that should be adopted by the goat owners. Verification of the proposed feeding regime under smallholders and emerging goat enterprises is essential. When the objective of the enterprise would be to produce higher ADG and finish in a shorter period, then the possibility of including molasses or minimum level of grain should be investigated as improving the proportion of propionic acid increases the efficiency of ME utilization for body weight gain.

Table 3.4 Mean disappearance (g/kg) of dry matter (DM) and neutral detergent fibre (NDF) in Ethiopian indigenous goats fed grainless diet.

Feeds	Incubation time					
	3	6	12	24	48	72
DM						
Diet 1	429	470	516	591	659	695
Diet 2	498	533	561	621	675	717
Diet 3	540	587	615	689	746	780
SEM	5.08	6.93	9.23	8.56	9.02	7.69
P	*	*	*	*	*	*
NDF						
Diet 1	131	186	259	368	476	539
Diet 2	147	200	237	333	434	506
Diet 3	109	182	224	349	471	548
SEM	9.96	11.2	15.19	13.38	17.7	13.61
P	NS	NS	NS	NS	NS	NS

SEM=Standard error of the mean, NS, (P>0.05); * Significance (P<0.05)

Table 3.5 Rumen degradation characteristics of grainless diets fed to Ethiopian indigenous goats

	Diet 1	Diet 2	Diet 3	SEM	P
DM (g/kg)					
a	327.2	335.4	354.2	54.1	NS
b	431.5	451.9	465.8	50.3	NS
c	0.028	0.025	0.031	0.01	NS
PD	758.7	787.4	819.9	14.9	NS
ED	535.5	540.8	590.9	12.8	NS
NDF (g/kg)					
a	113.6	152.3	117.9	18.7	NS
b	468.1	436.7	578.4	48.6	NS
c	0.037	0.026	0.029	0.01	NS
PD	581.7	589.0	696.3	15.6	NS
ED	372.1	355.1	402.2	13.2	NS
Lag time (h)	1.52	3.63	3.51	1.54	NS

a, soluble fraction; *b,* slowly degradable fraction; *c*, rate of degradation of fraction *b*; PD, potential degradability; ED, effective rumen degradability measured at an outflow rate (*k*) of 0.03 h^{-1}; SE, standard error; NS, (P>0.05)

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Chapter 4

Carcass characteristics and meat quality of Ethiopian goats reared under an extensive system

(Submitted to Livestock Science)

4.1 Abstract

Carcass characteristics and meat quality of three Ethiopian goat breeds reared under extensive management system, the Afar, Central Highland goats, (CHG) and Long-eared Somali (LES) were evaluated using a total of 18 intact male goats. Genotypes were similar (P>0.05) for most of carcass traits and at an average slaughter weight of 13.8 kg; the genotypes had a hot carcass weight and dressing percentages on slaughter body weight basis (SBW) ranging from 5.9-6.0 kg and 42.5-43.1 %, respectively. The total edible proportion however, was between 61.6 to 62.3 % of SBW. Genotype significantly affected the chilling loss (P<0.01) and the CHG had 52 % greater loss than the other genotypes. The mean carcass length, buttock circumference and leg length were 54.1-55.4, 35.7-38.2 and 23.1-23.7 cm, respectively. The rib physical composition was similar between genotypes for the lean (74-77 %) and the bone (19.2-21.4 %) but they were significantly different in their fat proportions (1.6-6.3 %) and CHG had the lowest (P<0.05) fat content. The moisture (74.6-76.2), ash (1.2-1.34), protein (21.2-21.9) and fat (2.2-4.4 %) contents were similar between the genotypes. CHG however, had the lowest (P>0.05) chemical fat. Cooking loss differed (P<0.05) between genotypes and ranged from 23.7-26.4 %

The composition of most muscle fatty acids was affected by genotype grazing under the extensive system. It was chiefly composed of C18:1 (37.0-39.1 %), followed by C16:0 (23.4-24.1 %) and C18:0 (18.5-21.1 %). C10:0, C12:0 and C15:0 were not detected in the muscles. The MUFA was similar (P>0.05) between genotypes. The concentration of PUFA was between 4 and 7.3 % and CHG had the higher value (P<0.001) followed by LES. The

proportion of desirable fatty acids (65.9-67.1 %) and the ratio (C18:0+C18:1):C16:0 (2.34-2.49) did not differ between genotypes. The PUFA/SFA and UFA/SFA however, differed between genotypes. The LES breed followed by CHG presented beneficial ratio of n-6/n-3 PUFA favorable to human health. To improve the carcass characteristics, offer uniform and regular supply for the growing market, it is crucial that grazing goats should be supplemented or stall-fed with locally available feeds depending on the grazing resources of the agro-ecologies and the objectives of the goat farmers.

4.2. Introduction

Goats are found in most production systems in Ethiopia ranging from pastoral and agro-pastoral systems to smallholder mixed crop-livestock systems while being dominant in the former systems. The indigenous goat populations, 23.3 million (CSA, 2004), are recently grouped into nine distinct genetic entities (Tesfaye *et al,* 2004). They are important source of income both at the farm and national level. The local demand for goat meat has been high (Gryseels and Anderson, 1983) and the country is exporting to a number of Middle East countries (EEPA, 2003). Gipson (1998) also reported that the global demand for goat meat is growing. Goat meat could become an ideal choice of red meat for health conscious consumers (Johnson *et al.,* 1995; Carlucci *et al*., 1998) due to its lower fat percentage compared to beef and lamb (Casey *et al*., 2003; Dhanda *et al*., 2003) and a good source of desirable fatty acids (Banskalieva *et al.,* 2000; Mahgoub *et al.,* 2002).

Though goat resources are high and diverse in Ethiopia (Farm Africa, 1996; EARO, 1999; Tesfaye *et al.,* 2004), the attention given to the research and development of the indigenous goats has been negligible. There is little information on the carcass characteristics of the local goats and so far there is no documented report on the chemical composition, fatty acid profile or any other meat quality traits of Ethiopian goats reared under the extensive system. Globally too, Banskalieva *et al*. (2000) in a review emphasized that only a few incomplete reports are available on the mono-and polyunsaturated fatty acid content of goat muscles and suggested for more research attention. Since the major source of goats for meat purpose comes from the extensive system, it is felt essential to evaluate the carcass characteristics and meat quality of selected indigenous goat genotypes managed under the extensive system.

4.3. Materials and Methods

4.3.1 Animals and carcass evaluation

Three genotypes, the Afar, the Long-eared Somali (LES) and the Central Highland goat (CHG) were chosen for the study and a total of 18 intact male goats, six goats of similar weight (14.6 kg) and age (milk tooth about 8 months) per genotype were used. The Afar and LES goats were reared extensively on arid to semi-arid rangelands while the CHG grazed freely on hillsides, fallow land and communal grazing areas; all of which were unimproved grazing resources.

The goats were slaughtered at experimental abattoir of the Debre-Zeit Research Station of the International Livestock Research Institute, Ethiopia. They were weighed pre-fasting, fasted for 16 hours with access to water, reweighed and slaughtered by the Halal method. The dressed carcass comprised of the body without the skin, head, feet and the viscera. Weights recorded were hot carcass weight (HCW), blood, visceral organs (kidneys, liver, heart, lungs, spleen and pancreas), testicles, fat depots such as scrotal fat, kidney, pelvic and gut fat (omental + mesenteric fat) and intestines full and empty. Empty body weight (EBW) excluded the visceral content. Dressing percentage (DP) is hot carcass weight as a percentage of slaughter body weight (SBW) and EBW. Total edible proportion (TEP) is slaughter weight minus the digestive contents, skin, head, feet and lungs and trachea.

Cooler shrinkage was calculated from cold carcass weight (CCW), which was measured after 24 hours of chilling at 4 ^{0}C. Carcass length (caudal edge of the last sacral vertebra to the dorso-cranial edge of the atlas), leg length and buttock circumference were measured (Fisher and de Boer, 1994). Carcass compactness was recorded as the ratio of cold carcass weight and carcass length (Webb, 1992). After removing the tail, the carcass was split along the dorsal middle line with a band saw. The left half of the carcass was partitioned into leg, loin, racks, shoulder and neck, and breast and shank (ISI, 1963). The rib section (8-9-10th) from the right half of the carcass was dissected and the tissues were separated to estimate the total composition of lean, bone and fat (Casey *et al*., 1988). The eye muscle area was measured after tracing the eye muscle (*longissimus*) at the 12/13th rib position. Fat thickness and total tissue depths were measured at the 12th rib, 11 cm from the midline on the left side of the carcass (Ponnampalam *et al.,* 2003).

The ultimate pH was determined 24 hours post-slaughter, using a pH meter with a combined electrode and inserted into the eye muscle at the 12/13 rib site of the chilled carcass (Dhanda *et al*., 1999). Individual weighed samples from the loin were put into thin plastic bags and in a water bath at 75 ^{0}C and removed after one hour from the water bath, cooled under running water, blotted dry, weighed and the cooking loss determined (Honikel, 1998; Hoffman *et al*., 2003). The drip loss was evaluated by putting the sample in a net and then in an inflated plastic bag and suspended in a refrigerator at 4 ^{0}C for 24 hours (Honikel, 1998). The colour was assessed subjectively on the chilled carcass using a five-point scale where 1 is pale and 5 is red (Sanudo *et al.,* 1996; Dhanda *et al.,* 1999).

4.3.2 Chemical analysis

Proximate chemical composition of the rib meat (moisture, ether extract (EE), crude protein (CP) and ash) was analyzed using standard analytical procedures (AOAC, 1990).

Chemical composition of the rack/rib especially EE, has been reported to be highly correlated with the chemical composition of a dressed carcass (Hankins, 1947; Field *et al.,* 1963).

Lipid extraction and methyl esters preparations were made according to the methods described in Folch *et al.* (1957) and AOAC (1975), respectively with some modifications. The fatty acid methyl esters (FAME) were quantified by gas chromatography based on a Varian model 3300 instrument fitted with flame ionization detector. Identification of the sample fatty acids was made by comparison of the relative retention times of the FAME peaks from the samples with those of the standard FAME (Sigma Chemical Co., Ltd.). Individual fatty acids were expressed as percentages by weight of the total fatty acids content measured in each sample. Different ratios of fatty acid types were also calculated as indices of nutritive value.

4.3.3 Statistical Analysis

The data were analyzed using the General Linear Model procedures of SAS (SAS, 2001). Initial weight was included as a covariate for pre-slaughter and slaughter weights, EBW, carcass weights and weights of primal cuts. Chemical fat percentage was also included as a covariate for fat acid composition. Significant differences between means were determined using multiple comparisons by the Fisher test (Samuels, 1989).

4.4. Results and Discussion

4.4.1 Carcass characteristics

Carcass characteristics of Ethiopian indigenous goats reared under extensive system are shown in Table 4.1. The young male goats of the three genotypes at similar age and weight that were made available from the extensive system did not show differences (P>0.05) for most of carcass traits. At an average slaughter weight of 13.8 kg, the genotypes had a hot carcass weight (HCW) and dressing percentages (SBW) ranging from 5.9-6.0 kg and 42.5-43.1 %, respectively. The Osmanabadi male kids at similar age had similar slaughter weight, carcass weight and carcass length (Kamble *et al.,* 1989). However, at similar slaughter weight, Ethiopian goats had higher HCW compared to supplemented Tanzanian (5.4 kg) goats (Mtenga and Kitaly, 1990). The dressing percentage in the present finding is within the reported values (38-56 %) for different breeds based on sex, age, weight and conformation (Rao *et al.,* 1988; Anjaneyulu and Joshi, 1995).

In countries where edible offals are eaten (Ewnetu *et al*., 1998), dressing percentage that excludes edible offals reduce the relative contribution of goat meat to the national meat supply (Peacock, 1996; Payne and Wilson, 1999). Therefore, total edible proportion (TEP) could be a more valuable criterion to compare yields of various genotypes and inputs. In this study, the TEP ranged from 61.6 to 62.3 % of SBW of which nearly 20 % was the contribution of edible offals.

Genotype significantly affected the chilling loss (P<0.01). The CHG had 52 % greater loss than the other genotypes probably due to its lower (P<0.01) physical fat proportion (Table 4.1) and chemical fat composition (P>0.05; Table 4.3). This could affect the meat appearance of the CHG due to greater evaporative losses. However, chilling losses as high as 8.7 % were reported for different goats (Owen and Norman, 1977; Getahun, 2001). The latter author also reported that carcasses of extensively managed goats had significantly (P<0.01) higher losses than the carcass from semi-intensive and intensive systems of management.

Measurements on the intact carcass of the genotypes were 54.1-55.4 cm for carcass length, 35.7-38.2 cm for buttock circumference and 23.1-23.7 cm for leg length. The carcasses of Ethiopian goats were longer than West African Dwarf (46.8 cm) goats (Mourad *et al*., 2001) and Beetal x Assam local (44.5-47.6 cm) goats (Saikia *et al.,* 1996). There was no measurable fat thickness and was regarded as trace in all the genotypes probably reflecting the inadequate dietary nutrients from the extensive system. Total tissue depth was greater

($P<0.05$) in Afar and LES than CHG and the same genotypes had larger rib eye area ($P>0.05$) than CHG.

The rib physical composition was similar between genotypes for the lean (74-77 %) and the bone (19.2-21.4 %) but were significantly different in their fat proportions (1.6-6.3 %) and CHG had the lowest ($P<0.01$) fat content. Significant differences in carcass fat content between goat breeds were also reported by Ruvuna *et al.* (1992), Gibb *et al* (1993) and Jonson *et al* (1995). The present findings were comparable to the rib composition of Zaraibi yearling goats of lean (69.3-75.0 %) and bone (16.1-20.0 %). However, Zaraibi goats had higher fat proportion (5.0-12.6 %) because these goats were fed to different concentrate: roughage ratios (El-Gallad *et al*., 1988) and were older than the Ethiopian goats. At similar slaughter weight, CHG had lower physical fat ($P<0.01$), chemical fat ($P>0.05$), pelvic fat ($P<0.05$) and total internal fat ($P>0.05$) compared to the Afar and LES breed. Thus, CHG was assumed to be less physiologically mature than the other genotypes. Similar criteria were also used by Snowder *et al*. (1994).

The proportions of the primal cuts were similar ($P>0.05$) between genotypes and the leg was the major cut followed by shoulder and neck. The lean to bone and lean + fat to bone ratios were also similar between genotypes. However, CHG had the widest lean: fat ratio (Table 1; $P<0.001$) due to its lowest fat proportion. The effect of genotype on the different ratios was also reported by Dhanda *et al*. (1999) and Getahun (2001).

4.4.2 Non-carcass components

Proportion of non- carcass components (EBW) is shown in Table 4.2. Most of the non-carcass components were similar between genotypes. However, among the edible offals,

Table 4.1 Carcass characteristics of Ethiopian indigenous goats reared under extensive system (least square means ± pooled standard error (PSE).

Traits	Afar (n=6)	CHG (n=5)	LES (n=6)	PSE	P
Pre-slaughter weight (kg)	14.7	14.5	14.7	0.38	NS
Slaughter body weight, SBW (kg)	13.8	13.9	13.9	0.33	NS
Fasting loss %	5.78	4.32	5.39	0.30	NS
Empty body weight, (kg)	11.15	11.24	11.25	0.28	NS
Hot carcass weight, (kg)	5.98	5.91	5.98	0.17	NS
Cold carcass weight, (kg)	5.79	5.62	5.78	0.17	NS
Chilling loss %	3.4	5.2	3.4	0.21	* *
DP (SBW basis)	43.1	42.5	42.9	0.42	NS
DP (EBW basis)	53.5	52.5	53.1	0.27	NS
Total edible proportion (SBW)	61.7	61.6	62.3	0.48	NS
Carcass length (cm)	55.4	54.1	54.9	0.56	NS
Leg length (cm)	23.1	23.7	23.4	0.31	NS
Buttock circumference (cm)	38.2	35.7	36.3	0.56	NS
Compactness index (g/cm)	103.1	102.9	104.6	2.69	NS
Rib eye area (cm^2)	5.42	4.85	5.75	0.28	NS
Fat thickness (mm)	0	0	0	0.11	NS
Total tissue depth (mm)	6.66	5.40	6.50	0.20	*
Rib physical composition (%)					
Lean	73.9	76.9	76.8	0.77	NS
Bone	19.8	21.4	19.2	0.57	NS
Fat	6.3	1.6	3.9	0.58	* *
Proportion of primal cuts (%)					
Leg	33.20	33.30	33.80	0.27	NS
Loin	9.76	9.88	9.32	0.17	NS
Rack	14.23	13.99	13.72	0.24	NS
Breast & shank	14.06	12.96	13.40	0.30	NS
Shoulder & neck	28.77	29.82	29.76	0.41	NS
Ratio					
Lean: bone	3.80	3.67	4.09	0.14	NS
Lean: fat	12.37	51.70	20.92	0.96	* * *
Lean +fat: bone	4.11	3.75	4.30	0.16	NS

NS (P>0.05)

* Significance (P<0.05), * * Significance (P<0.01), * * * Significance (P<0.001)

liver, heart and spleen were affected by genotype and LES mainly had higher values ($P<0.05$, $P<0.01$). As for the carcass fat, CHG had significantly lower values ($P<0.05$) of pelvic fat and other non-carcass fats ($P>0.05$). It had 62 % lower total non-carcass fat compared to the mean values of LES and Afar breeds. Differences in deposition of internal fat in various breeds of goats were also reported by Latif *et al.* (1987), Mahgoub & Lu (1998) and Kadim *et al.* (2003). In the present finding, it was observed that the non-carcass fat lack firmness and was not white. Good quality fat was defined as firm and white (Hugo *et al.,* 2003). This may be an indication of the poor feeding conditions in the extensive system.

Table 4.2 Proportion of non- carcass components (EBW) of Ethiopian goats reared under extensive system (least square mean ± pooled standard error, PSE).

Traits	Afar	CHG	LES	PSE	P
Kidney	0.55	0.55	0.58	0.01	NS
Liver	2.55	2.66	2.88	0.04	*
Heart	0.74	0.83	0.81	0.01	*
Lung & trachea	1.79	1.67	1.63	0.02	NS
Spleen	0.24	0.26	0.32	0.01	* *
Head	8.82	8.95	8.79	0.10	NS
Skin	8.97	9.43	8.95	0.13	NS
GIT empty	7.9	8.1	8.7	0.15	NS
Blood	5.38	5.59	5.66	0.07	NS
Pancreas	0.18	0.19	0.17	0.01	NS
Total internal organ	6.05	6.16	6.38	0.06	NS
Digesta (SBW basis)	19.6	19.1	19.1	0.55	NS
Feet	3.7	3.9	3.7	0.06	NS
Testicles & other genitals	1.57	1.69	1.30	0.03	* *
Scrotal fat	0.16	0.06	0.12	0.02	NS
Kidney fat	0.24	0.11	0.17	0.06	NS
Pelvic fat	0.09	0.04	0.10	0.01	*
Gut fat	0.87	0.59	0.85	0.13	NS
Total non-carcass fat	1.35	0.80	1.24	0.19	NS

GIT= Gastro Intestinal Tract
NS ($P>0.05$)
* Significance ($P<0.05$), * * Significance ($P<0.01$)

4.4.3 Physico-chemical characteristics

The physical meat characteristics and chemical composition of the goats reared under extensive system is depicted in Table 4.3. The 24 hr pH of the carcass ranged from 5.78 to 5.94 and CHG had the higher (P<0.05) pH. However, the ultimate pH considered normal in goats and lambs were ranged from 5.49 to 5.86 (Sanudo *et al*., 1996; Dahanda *et al.*, 1999; Arguello *et al.*; 2005). The relatively higher pH (5.94) recorded in CHG may have been due to lower glycogen reserves caused by physical/emotional stress or inadequate nutrition from grazing in the extensive system. Cooking loss differed (P<0.05) between genotypes and ranged from 23.7-26.4 %. Dhanda *et al.* (1999) and Kadim *et al.* (2003) also reported significant effect of genotype. Subjective score for muscle colour was also affected by genotype. A similar report on effect of genotype on colour was made by Dhanda *et al.* (1999). The muscle of CHG had relatively darker colour (P<0.01) than Afar and LES. This was probably due to slightly higher (P<0.05) ultimate pH in CHG. Purchas (1990) also reported that at high pH the muscle has a closed structure and appears darker.

The moisture (74.6-76.2), ash (1.2-1.34), protein (21.2-21.9) and fat (2.2-4.4 %) contents were similar between the genotypes. CHG however, had the lowest (P>0.05) chemical fat. As information on the meat quality of the native Ethiopian goats was not available, comparison was made with goat genotypes from other countries. These values were comparable to Moxoto goats at 8-10 months of age (Beserra *et al*., 2004) and Osmanabadi male kids at the age of 6-8 months (Kamble *et al.,* 1989). On the other hand, Tshabalala *et al.* (2003) reported higher value of chemical fat (7.9 %) from extensively managed South African indigenous goats. This was mainly because the goats were castrated and older in age. Differences in the breeds and in grazing vegetation might have also contributed to the variation.

Though the market requirement is for a lean carcass, a certain level of carcass fat (10 to 15 %) could be desirable from the consumer's point of view so that the cooked meat does not become too dry (Owen *et al.*, 1978). Marinova *et al.* (2001) also reported that goat meat lacks juiciness and an increased amount of subcutaneous and intermuscular fat would prevent the carcass from drying out during hanging. One of the major concerns in commercial chevon production is also the poor subcutaneous fat cover which is well below the levels considered essential for effective carcass chilling without the risk of cold shortening (Smith *et al.*, 1978; Dikeman, 1996). Therefore, to alleviate the prevailing problems related to fat content and improve the carcass from the extensive system goats should be supplemented or stall-fed where appropriate.

Table 4.3 Physical meat characteristics and chemical composition (% on DM basis) of the Ethiopian goats reared under extensive system (least square mean ± pooled standard error, PSE).

Traits	Afar (n=6)	CHG (n=5)	LES (n=6)	PSE	P
Cooking loss (%)	25.33	23.72	26.40	0.38	*
Drip loss (%)	1.50	1.35	1.36	0.06	NS
Ultimate pH	5.78	5.94	5.82	0.02	*
Colour	2.72	3.26	2.73	0.05	* *
Moisture	74.60	75.84	76.22	0.72	NS
Ash	1.34	1.29	1.20	0.04	NS
Protein	21.51	21.86	21.19	0.44	NS
Fat	4.39	2.16	2.34	0.67	NS

NS (P>0.05), * Significance (P<0.05), * * Significance (P<0.01)

4.4.4. Fatty acid profiles

The long fatty acid composition of the rib muscle of Ethiopian goats reared under extensive system is presented in Table 4.4. Genotype affected the composition of most fatty acids. Reports by Banskalieva *et al.* (2000), Tshabalala *et al.* (2003) and Pratiwi *et al.* (2005) in different goats and Webb and Casey (1995) in sheep also documented the significant effect of breed on compositions of certain fatty acids. The fatty acid content was chiefly composed of C18:1 (37.0-39.1 %), followed by C16:0 (23.4-24.1 %) and C18:0 (18.5-21.1 %). These values are in line with the range reported by Banskalieva *et al.* (2000) and Tshabalala *et al.*

(2003). C10:0, C12:0 and C15:0 were not detected in the muscles. C14:0, C17:0, C20:0 and C21:0, C22:0 and C24:0 differed between genotypes while the concentrations of C16:0 and C18:0 were similar between genotypes. C14:0, that has four times the hypercholesterolemic effect of the others (Ulbricht and Southgate, 1991), ranged from 2.7 to 3.2 % and was lower (P<0.001) in CHG. Compared to Ethiopian goats, the concentration of C14:0 from South African indigenous goats (6%) managed under the extensive management (Tshabalala *et al.*, 2003) was about twice higher.

Genotype also significantly affected the proportions of C16:1, C17:1, *trans* oleic acid and C20:1 but were similar in the percentage of *cis* oleic. Afar had the highest C16:1(P<0.001), C17:1(P<0.01) and *cis* oleic acid (P>0.05). Among the polyunsaturated fatty acids (PUFA), *cis* linoleic acid tended to be higher (P>0.05) in CHG followed by LES and LES had the higher (P<0.01) concentration of C20:2. C18:3n6, C20:3n6 and C20:5n3 (eicosapentaenoic acid, EPA) were significantly affected by genotype. However, C22:6n3 (Docosahexaenoic acid, DHA) was similar between genotypes. SFA ranged from 48.3 to 50.4 %. Afar and CHG had lower SFA concentration (P<0.05) while the MUFA was similar between genotypes. The concentration of PUFA was between 4 and 7.3 % and CHG had the higher value (P<0.001) followed by LES. The proportion of desirable fatty acids (DFA) and the ratio (C18:0+C18:1):C16:0 did not differ between genotypes. The respective values were 65.9-67.1 % and 2.34-2.49. Both values are in agreement to the report of Banskalieva *et al.* (2000) for different muscle types and goat breeds.

The ratios, related to healthy nutrition, PUFA/SFA and UFA/SFA differed between genotypes (Table 4.4). Comparisons of these indices were made between Ethiopian and South African indigenous goats (Tshabalala *et al.,* 2003) managed under extensive system and the mean ratios of PUFA/SFA (0.11 vs 0.07) and UFA/SFA (0.95 vs 0.86) were higher in Ethiopian goats. In fact, it is important to mention that the South African goats were castrated and slightly older in age than the Ethiopian goats. The differences in value may be explained due to variation in age and fatness of the genotypes, which could affect the fatty acid composition (Link *et al*., 1970) and breed difference as PUFA/SFA ratio is mainly influenced by genetics (Raes *et al*., 2004). Nutritionists are trying to increase the muscle EPA and DHA that could have a profound influence on human health (Demirel *et al*., 2006). The crucial role of DHA, its positive effects on heart diseases, some cancers, diabetes mellitus and brain functioning, has also been documented (Horrocks and Yeo, 1999). The mean concentration of EPA and DHA (Table 4) was comparable to the mean value of outdoor raised Moroccan local yearling goats (Bas *et al.*, 2005).

The n-6/n-3 PUFA has been recognized as a vital index for the evaluation of fats because inappropriate balance of this ratio could contribute to a greater risk of coronary heart diseases in humans (Williams, 2000). The LES breed had n-6/n-3 PUFA of 4.15 and it is the closest value to the recommended ratio, 4.0 (Department of Health, 1994) followed by CHG. Raes *et al*. (2004) also reported that the ratio less than 5 as an acceptable value. This beneficial ratio was obtained probably due to the higher concentration of n-3 PUFA from the grazed vegetation in their respective regions. Enser *et al*. (1998) also reported that grass diets increase muscle concentrations of n-3 PUFA in beef and lamb. Mean n-3 PUFA from the extensive system was 4.2 times higher than the stall-fed goats of the same genotypes (unpublished data).

4.5. Conclusion

The three Ethiopian goat genotypes raised under the extensive system generally characterized by a lower carcass weight and poor carcass fat cover. However, compared at a similar slaughter weight, the CHG had lower carcass and non- carcass fat values and was assumed to be a less physiologically mature genotype. Significant genotype differences also exist in the muscle fatty acid content. The LES and CHG had beneficial ratio of n-6/n-3, higher PUFA/SFA and PUFA concentration, favorable to human health, than the Afar breed.

To improve the carcass characteristics, provide uniform and constant supply for the growing market, it is imperative that grazing goats should be supplemented or stall-fed with locally available feed concentrates depending on the grazing resources of the agro-ecologies and the objectives of the goat farmers.

Table 4.4 Effects of genotype on fatty acid composition of Ethiopian goats reared under extensive system (least square mean ± pooled standard error, PSE).

Fatty acids	Afar (N=5)	CHG (N=5)	LES (N=5)	PSE	P
C14:0	3.13[+]	2.71	3.18	0.22	* * *
C16:0	24.11	23.96	23.44	0.83	NS
C17:0	1.89	1.76	1.24	0.11	* *
C18:0	18.51	18.84	21.09	1.36	NS
C20:0	0.18	0.15	0.18	0.02	* *
C21:0	0.67	0.42	0.53	0.07	*
C22:0	0.19	0.28	0.27	0.03	*
C24:0	0.22	0.22	0.51	0.06	* * *
C16:1	2.55	0.92	1.47	0.22	* * *
C17:1	1.25	1.09	0.38	0.16	* *
C18:1n9t	1.83	1.39	1.92	0.18	*
C18:1n9c	37.25	35.63	35.39	1.75	NS
C20:1	0.60	1.11	1.08	0.07	* * *
C18:2n6t	0.26	0.19	0.17	0.03	NS
C18:2n6c	2.82	5.14	3.95	0.57	NS
C18:3n6	0.09	0.13	0.06	0.01	* *
C20:2	0.16	0.16	0.32	0.04	* *
C20:3n6	0.12	0.31	0.22	0.02	* *
C20:5n3	0.27	1.07	0.87	0.09	* * * *
C22:6n3	0.24	0.28	0.19	0.03	NS
SFA	48.68	48.34	50.44	1.38	*
MUFA	43.48	40.14	40.24	1.96	NS
PUFA	3.96	7.28	5.78	0.78	* * *
UFA/SFA	0.97	0.98	0.91	0.05	*
PUF/SFA	0.08	0.15	0.11	0.01	* * *
n6: n3	6.45	4.27	4.15	0.51	*
DFA	65.95	66.26	67.11	0.95	NS

NS (P>0.05), * Sig. (P<0.05), * * Sig. (P<0.01), *** Sig. (P<0.001),**** Significance (P<0.0001), [+]Percentage by weight of total identified fatty acids

4.6 References

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Chapter 5

Growth performance and carcass characteristics of three Ethiopian goat breeds fed grainless diets varying in concentrate to roughage ratios

(Sumitted to the South African Journal of Animal Science)

5.1 Abstract

Growth and carcass characteristics of three Ethiopian goat breeds, the Afar, Central Highland (CHG) and Long-eared Somali (LES) were evaluated using three grainless diets varying in concentrate: roughage ratios (diet 1 was 50: 50, diet 2, 65:35 and diet 3, 80:20) under feedlot conditions. The roughage was native grass hay and the concentrate consisted of wheat bran and noug cake (*Guizotia abyssinica*). Seventy two eight months old intact male goats (24 per breed) were randomly allotted to the dietary treatments, fed for 126 days and slaughtered at approximately the age of 12 months. The LES had higher average daily gain (ADG), heavier slaughter, empty body (EBW) and carcass weights than Afar and CHG goats. Diet significantlty affected ADG, but was similar on carcass traits except for dressing percentage (DP) on an EBW basis and some non-carcass components. The DP on an EBW basis was the highest on diet 1. Breed affected the DP, which ranged from 42.5-44.6% and 54.3-55.8% on slaughter weight and EBW basis, respectively. The LES had a greater buttock circumference and carcass compactness. The pH_{24} was 5.61-5.67 and chilling losses were between 2.5 and 3.1%. The physical carcass composition (8-10th rib-cut) ranged from 72-73, 6.9-10.9 and 17.1-20.2% for lean, fat and bone, respectively and the ether extract (fat) content of the meat ranged from 10.3 -14.0%. Breed affected the weights of internal fat depots. The findings indicate that breed differences were reflected in carcass characteristics.

5.2 Introduction

The Ethiopian indigenous goat population, estimated at 23.3 million (CSA, 2004), has been characterized phenotypically (Farm Africa, 1996) and by microsatelite DNA markers into nine distinct genetic entities (Tesfaye *et al.,* 2004). Ethiopia's domestic demand for goat meat is high (Gryseels & Anderson, 1983) with goat meat realising higher prices than mutton or beef in eastern parts of the country (Farm Africa, 1996). Ethiopia is also competing in the world market through the exportation of goat meat to a number of Middle East countries (EEPA, 2003). However, the production performances of these goat breeds have not been evaluated.

In general, the global demand for goat meat is growing (Gipson, 1998). This may have been because goat meat is an important part of the national diet and has a special religious significance in the Middle East. It is also an accepted red meat as part of the cultural heritage and tradition in Asia, Africa and some Mediterranean countries (www.mountainmeatgoats.com). Moreover, goat meat is characteristically lean, thus rich in nutrients that could attract health conscious consumers. However, the product can vary according to genotype, age, gender and nutrition (Casey *et al*., 2003; Dhanda *et al*., 2003).

The major feed resources in Ethiopia are native pasture, crop residues and agro-industrial by-products. The native pasture, however, is characterized by high seasonal variation in yield and quality and animals often lose condition during the dry season. Grains are expensive and economically not suitable to use as a supplement in animal nutrition. The challenge is to develop alternative feed resources that will sustain production through out the year. This paper presents the growth performance and carcass characteristics of three selected goat breeds fed a grainless diet that included Ethiopian native grass hay, wheat bran and noug cake.

5.3 Materials and Methods

Ninety young intact male goats of three breeds, the Afar, the Long-eared Somali (LES) and the Central Highland goat (CHG) were used in the study. The study was conducted at the Debre-Zeit Research Station of the International Livestock Research Institute, Ethiopia.

Thirty goats per breed were randomly allocated at 8 per treatment to the three experimental treatments and 6 to a pre-experimental slaughter group. The three dietary treatments were different ratios of concentrate: roughage, viz., diet 1, 50:50 (8.5 MJ ME/kg dry matter, DM), diet 2, 65:35 (9.2 MJ ME/kg DM) and diet 3, 80:20 (10.0 MJ ME/kg DM). The roughage component was native pasture hay and the concentrate consisted of 79% wheat bran, 20% noug cake (*Guizotia abyssinica*) and 1% salt (NaCl). The quantity of roughage and concentrate as per ratio of the diets was adjusted on the basis of body weight to meet the dry matter requirements of the goats (Kearl, 1982).

Feed DM and organic matter (OM) were determined according to AOAC (1990) and the neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest *et al.* (1991). The nitrogen (N) was measured using the micro-Kjeldal procedure (AOAC, 1990). The calcium (Ca) was determined by wet digestion method using an Atomic Absorption Spectrophotometer (Perkin Elmer, 1982) and the phosporus (P) using a continuous flow auto-analyzer (ChemLab, 1981). *In vitro* dry matter digestibility (IVDMD) was estimated by the methods of Tilley and Terry as modified by Van Soest & Robertson (1985).

Table 5.1 Chemical composition of the dietary components and experimental diets (g/kg DM)

Item	DM	Ash	OM	CP	NDF	ADF	ADL	Ca	P	IVDMD*
Native grass hay	917.8	88.7	911.3	50.6	720.8	389.3	38.0	5.3	2.8	48.0
Wheat bran	870.3	43.4	956.6	191.9	442.0	128.4	24.3	2.1	10.8	68.68
Noug cake	919.3	100.5	899.5	345.0	353.4	270.3	106.4	8.5	13.7	63.24
Concentrate	887.9	65.8	934.2	216.6	398.3	141.1	35.4	3.2	10.9	68.91
Diet 1	897.8	81.1	918.9	153.1	579.6	267.2	33.9	3.9	7.9	57.0
Diet 2	895.3	78.9	921.1	175.6	514.8	229.0	35.5	3.7	9.4	61.25
Diet 3	891.5	70.6	929.4	196.2	436.4	187.3	30.9	3.0	10.8	66.70

* = %

The goats were dewormed, dipped and vaccinated against known parasites and diseases during the quarantine period of 21 days and were adapted for 14 days to the experimental diets. The animals were kept under roof in individual pens with access to clean water and a mineral block and fed the experimental diets for 126 days. They were weighed once a week in the morning before watering and feeding. Four goats did not complete the study period due to Cenhorosis and pneumonia.

An initial sample from each genotype was slaughtered to estimate the initial carcass mass, wholesale cuts and physical composition of the goats at the onset of the study. The stall-fed goats were slaughtered at approximately 12 months of age. The goats were weighed pre-fasting, fasted for 16 hours, but with access to water, reweighed and slaughtered by the Halal method (Kadim *et al*., 2003). The goats were slaughtered and dressed using standard commercial techniques. The hot carcass comprised the body after removing the skin, head, fore feet (at the carpal-metacarpal joint), hind feet (at the tarsal-metatarsal joint) and viscera. Internal organs (kidneys, liver, heart, lungs, spleen and pancreas) and fat depots such as scrotal fat, pelvic, kidney and gut fat (omental + mesenteric fat) were also removed. Hot carcass weight (HCW) and the weights of blood, internal organs, testicles, fat depots and full and empty gastro-intestinal tracts were recorded. Empty body weight (EBW) excluded the gastro-intestinal tract contents. Dressing percentage (DP) was defined as the hot carcass weight expressed as a percentage of slaughter body weight (SBW). The total edible proportion (TEP) was the SBW minus the contents of gastro-intestinal tract, skin, head, feet and lungs and trachea.

Cold carcass weight (CCW) was measured after 24 hours of chilling at 4 ^{0}C and cooler shrinkage was calculated as the proportion of the difference between HCW and CCW to HCW. Carcass length (caudal edge of the last sacral vertebra to the dorso-cranial edge of the atlas), leg length and buttock circumference were also measured (Fisher & De Boer, 1994). Carcass compactness was defined as the ratio of cold carcass weight to carcass length (Webb, 1992).

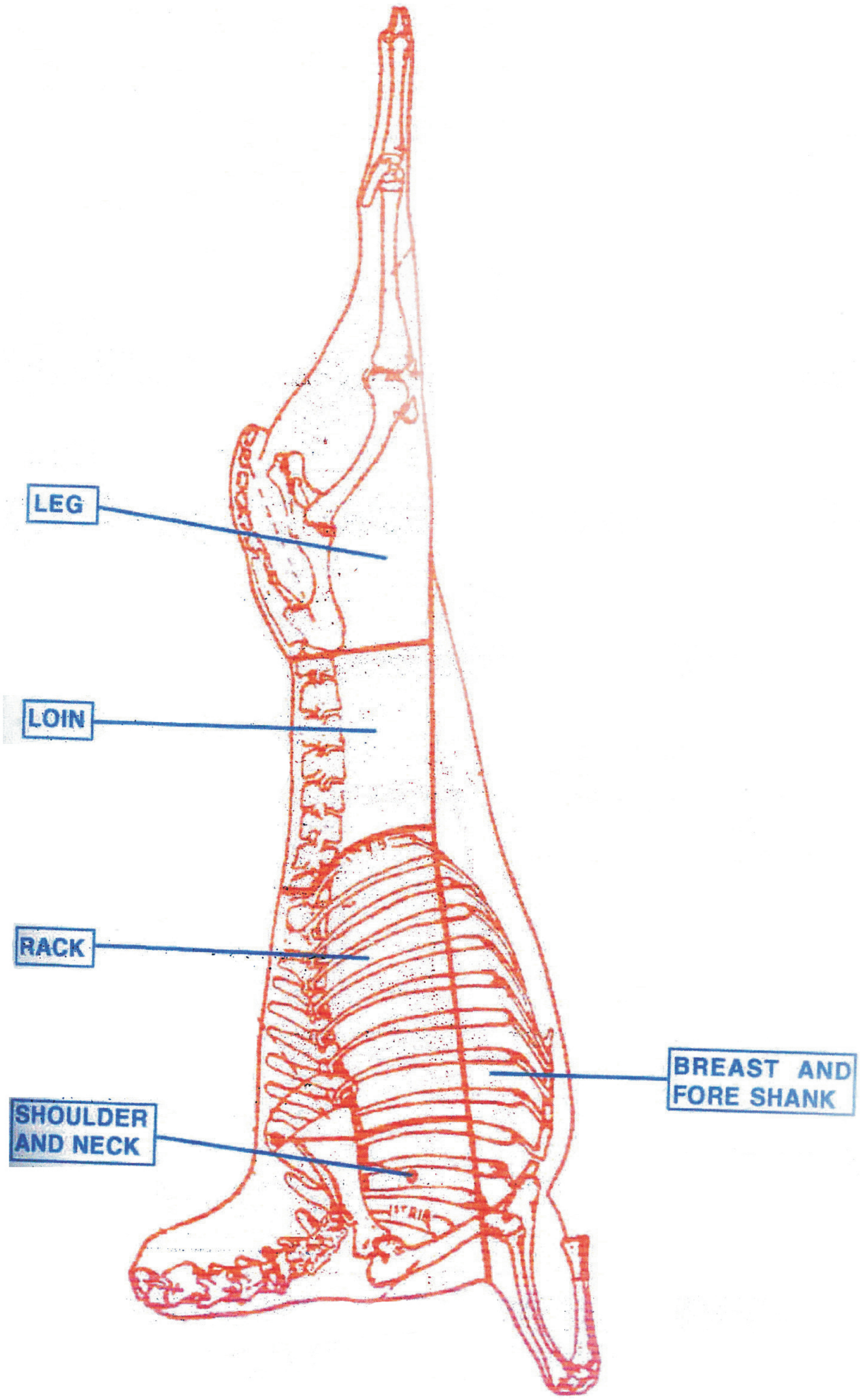
After removing the tail at the last sacral/first coccygeal vertebrae articulation, the cold carcass was split along the dorsal mid-line with a band saw. The left half of the carcass was partitioned into leg, loin, racks, shoulder and neck and breast and shank (Fig. 6; ISI, 1963). The rib section (8-9-10th) from the right half of each carcass was dissected and the tissues were separated to estimate the total carcass composition in terms of lean (muscle), bone and fat (Casey *et al*., 1988). The dissected lean and fat were minced together and the ether extract (fat) content measured (AOAC, 1990), which is highly correlated with the chemical composition of a dressed carcass (Field *et al.,* 1963). Eye-muscle (M. *longissimus dorsi*) area was measured after tracing the eye-muscle at the 12/13th rib position. Fat thickness and total tissue depths were measured at the 12th rib, 11 cm from the spinal cord on the left side of the carcass (Ponnampalam *et al.,* 2003). The pH_{24} was measured on M. *longissimus dorsi* 24 hours post mortem with a penetrating glass electrode (Orion 9106) that was rinsed with distilled water after every reading and recalibrated after every fourth reading.

The data were analyzed using the General Linear Model procedures of SAS (SAS, 2001) according to a 3 x 3 factorial arrangement with breed and diet as main effects in a Completely Randomized Design. No significant breed by diet class interaction was noted for growth rate and for most carcass traits, so the main effects were presented and discussed. Initial weight was included as a covariate for pre-slaughter and slaughter weights, EBW, carcass weights and weights of primal cuts. Significant differences between means were determined by multiple comparisons using the Fisher test (Samuels, 1989).

5.4 Results and Discussions

The crude protein (CP), NDF and IVDMD values of the native grass hay were comparable to the results reported by Zinash & Seyoum (1991). The CP, NDF and ADF

Fig. 6 : Primal cuts of goat meat



values for wheat bran and noug cake were also similar to those reported by Seyoum & Zinash (1989) and Tesfaye *et al*. (2001). The low CP and high NDF values of the native grass hay show it was of a poor quality roughage (Table 5.1).

Body weights and growth rates are presented in Table 5.2. The breed effect on final body weight (FBW) and ADG was highly significant ($P < 0.001$), which is in line with the results of El-Hag & El-Shargi (1996), Dhanda *et al.* (2001) and Mahgoub *et al*. (2005). The LES breed had the highest ADG. Diet 3 resulted in a higher ($P < 0.05$) ADG than diet 2 but the results did not differ ($P > 0.05$) from diet 1. This finding may be due to small differences in ME levels used in the current study since the lowest ME level probably was not low enough to attain a statistical difference. The growth rates reported in Table 5.2 were within the range of 23-63 g/d reported for Tanzanian East African goats by Mtenga & Kitaly (1990). However, indigenous goats, 15-18 months old, from the middle Rift Valley area of Ethiopia, grazing natural pastures supplemented with a concentrate (69% wheat bran and 30% noug cake) attained a higher ADG of 71.8 g/d (Abule *et al*., 1998). The higher ADG could be ascribed to a lower proportion of wheat bran (69 *vs* 79%) in their concentrate compared to our experimental diets and better quality vegetation during the season. Dhakad *et al*. (2002) reported lower ADG for growing lambs when wheat bran replaced grain in the concentrate (75% wheat bran and 22% ground nut cake) and suggested a threshold level of 50% inclusion, a level that does not affect lamb growth adversely. The current result *vis-à-vis* the proportion of wheat bran used by Abule *et al* (1998) indicates that a threshold level may also apply to goats. Nevertheless, the ADG of the LES was similar to those of the tropical breeds of Zaraibi (El-Gallad *et al*., 1988), Gaddi (Kumar *et al*., 1991), Malawi (Kirk *et al.,* 1994), Batina (Kadim *et al*., 2003), the Indian goat (Sen *et al.,* 2004) and semi-intensively managed Somali and Mid Rift Valley goats (Getahun, 2001) at similar age fed grain-based concentrate. The goats in the present study also had higher ADG than Mubende goats (Okello *et al*., 1994) and Malaysian intensively managed male Jamanapari x Kambing Katajang crosses (Mustapha and Kamal, 1982) at comparable ages. The LES breed had the highest (P < 0.001) FBW due to its better growth rate.

Table 5.2 Body weight and growth rates (least square mean ± s.e) of selected Ethiopian goat breeds stall-fed with a grainless diet

Parameters	IBW (kg)	FBW (kg)	ADG (g)
Genotype			
Afar	13.11±0.17 [b]	17.95±0.36 [b]	36.7±2.04 [b]
CHG	14.29±0.18 [a]	18.38±0.31 [b]	34.7±2.09[b]
LES	14.76±0.17 [a]	20.00±0.33 [a]	43.9±2.05[a]
Feeding regimen			
Diet 1	14.06±0.18	19.08±0.31	37.7±2.09 [a b]
Diet 2	14.27±0.17	18.33±0.30	35.0±2.04 [b]
Diet 3	13.85±0.18	18.93±0.30	42.5±2.05 [a]

IBW= Initial body weight, FBW=Final body weight, ADG=Average daily gain

Central Highland goat =CHG, Long-eared Somali =LES

[a b] Means within columns with different superscripts differ (P< 0.05)

Breed had a significant effect on most of the carcass parameters (Table 5.3), while dietary effects were statistically similar for most traits, except for DP and some non-carcass components. Most carcass measurements between the initial carcass of the three breeds were similar (P > 0.05). Statistical differences between the breeds (Table 5.3) were evident for most carcass traits after correcting for initial weight. The LES breed had the highest (P < 0.001) pre-slaughter and slaughter weights, EBW, HCW and CCW. As with the growth performance, the Afar and CHG breeds had similar (P > 0.05) values for these parameters.

Breed affected the DP that ranged from 42.5 to 44.6% and 54.3 to 55.8% on SBW and EBW basis, respectively. On a SBW basis LES and Afar had higher and similar (P > 0.05) DP, whereas CHG had the lowest (P < 0.01) DP. On an EBW basis, LES had the highest value (P < 0.01). Literature reports indicated that DP in goats varies between 38 and 56% by breed, sex, age, weight and conformation (Anjaneyulu & Joshi, 1995; El Hag & El Shargi, 1996; Dhanda *et al.,* 1999a; Getahun, 2001). According to Payne & Wilson (1999) the definition of DP that excludes edible offal, reduces the relative contribution of goat meat to the national meat supply. Dishes are made from non-carcass components such as liver, kidney, intestines, tongue and others are commonly available in most parts of Ethiopia (Ewunetu *et al.*, 1998). Total edible proportion (TEP) could be a more useful criterion for comparing yields by breed and production practices. In this study the TEP ranged from 60.9 to 63.8% of SBW with Afar having the highest ($P < 0.0001$), followed by LES. Adissu (2001) reported comparable yields of total usable products for the Afar breed.

The DP on an EBW basis was the highest ($P < 0.01$) on diet 1. Diet 1 also tended to have higher values for pre-slaughter and SBW, EBW, HCW, CCW and DP on a SBW basis. Kumar *et al*. (1991) reported that the plane of nutrition did not significantly affect carcass weights, DP and proportions of cuts in Gaddi goats at the age of 14 months. Reddy & Raghavan (1988), Hatendi *et al.* (1992), El Hag & El Shargi (1996) and Sheridan *et al.* (2003) recorded similar effects on DP on SBW and / or carcass weights. However, Mahgoub *et al.* (2005) indicated that increasing ME levels in the diet fed to Omani goats increased carcass weight, EBW and DP.

Chilling losses were higher ($P < 0.01$) in the carcass of initial CHG probably due to their lower fat content (Table 5.4). However, the chilling loss was similar ($P > 0.05$) between the fed groups, though the CHG had a 10% greater loss. Chilling losses ranging from 2.3 to 8.7% have been reported for different goat genotypes and weights (El Khidir *et al.,* 1998; Getahun, 2001).

Breed affected rib-eye area, fat thickness and total tissue depth. The rib eye area of the fed genotypes ranged from 6.4 to 8.3 cm^2 (Table 5.3). The LES had the larger area, though statistically similar to Afar. However, CHG had the lowest ($P<0.001$) rib-eye area. These values agree with the reports of Rao *et al*. (1985) and Getahun (2001) at similar weight or age.

Fat thickness in the initial carcass was not measurable and regarded as minimal. Between the stall-fed breeds, the CHG had the thinnest ($P < 0.0001$) fat cover of the three goat breeds (Table 5.3). Fig.7 also show less fat covering in the chilled carcasses of the CHG (#1317 and #1258) particularly in the thigh, buttock and rack areas compared to the others. Total tissue depth (fat + lean) differed ($P < 0.0001$), with the LES the highest and CHG the smallest.

Table 5.3 Carcass characteristics of Ethiopian goats fed a grainless diet (least square mean and PSE)

	Initial [+]			Fed groups [++]			
Traits	Afar (n=6)	CHG (n=5)	LES (n=6)	Afar (n=23)	CHG (n=22)	LES (n=23)	PSE
Pre-slaughter weight (kg)	14.7	14.5	14.7	18.94 ^{b}	19.44 ^{b}	21.16 ^{a}	0.38
Slaughter body weight (kg)	13.8	13.9	13.9	17.95 ^{b}	18.38 ^{b}	20.00 ^{a}	0.33
Fasting loss (%)	6.12	4.32	5.39	5.23	5.31	5.39	0.30
Empty body weight (kg)	11.15	11.24	11.25	14.59 ^{b}	14.38 ^{b}	15.66 ^{a}	0.28
Hot carcass weight (kg)	5.98	5.91	5.98	8.02 ^{b}	7.83 ^{b}	8.75 ^{a}	0.17
Cold carcass weight (kg)	5.79	5.62	5.78	7.81 ^{b}	7.59 ^{b}	8.52 ^{a}	0.17
Chilling loss (%)	3.4 ^{b}	5.2 ^{a}	3.4 ^{b}	2.8	3.1	2.5	0.21
DP (SBW basis)	43.1	42.5	42.9	44.6 ^{a}	42.5 ^{b}	43.7 ^{a}	0.42
DP (EBW basis)	53.5	52.5	53.1	55.0 ^{b}	54.3 ^{b}	55.8 ^{a}	0.27
Total edible proportion (SBW)	61.7	61.6	62.3	63.8 ^{a}	60.9 ^{b}	62.1 ^{b}	0.48
Carcass length (cm)	55.4	54.1	54.9	59.7	58.7	59.2	0.56
Leg length (cm)	23.1	23.7	23.4	23.5 ^{b}	25.5 ^{a}	25.3 ^{a}	0.31
Buttock circumference (cm)	38.2	35.7	36.3	42.3 ^{b}	43.3 ^{b}	44.9 ^{a}	0.56
Compactness index (g/cm)	103.1	102.9	104.6	130.8 ^{b}	129.3 ^{b}	145.6 ^{a}	2.69
Rib-eye area (cm^2)	5.42	4.85	5.75	7.72 ^{a}	6.43 ^{b}	8.26 ^{a}	0.28
Fat thickness (mm)	0	0	0	1.86 ^{a}	1.18 ^{b}	2.06 ^{a}	0.11
Total tissue depth (mm)	6.66 ^{a}	5.40 ^{b}	6.50 ^{a}	7.12 ^{b}	6.29 ^{c}	7.76 ^{a}	0.20
pH ultimate	5.78 ^{b}	5.94 ^{a}	5.82 ^{b}	5.66	5.67	5.61	0.02

[+] Initial=slaughter made at the start of the study, [++] Fed groups =stall-fed

Central Highland goat =CHG, Long-eared Somali =LES, pooled standard error =PSE

[a b c] Means within rows for different group with different superscripts differ ($P < 0.05$)

The ultimate carcass pH of the initial slaughter group was between 5.78 and 5.94 ($P < 0.05$). The pH range in the carcasses of the experimental groups was between 5.61 and 5.67

Fig 7 : Chilled goat carcasses of the different genotypes and fitted into the range of 5.49 to 5.86 reported and considered normal by various authors (Dahanda *et al.,* 1999b; Arguello *et al.*, 2005). The relatively higher pH (5.94) of the carcasses of pre-experimental slaughtered CHG group could have been due to a lower glycogen reserve caused by either physical/emotional stress or inadequate nutrition from the extensive management system. High ultimate pH values for goat meat are also reported for different breeds and muscles in the literature (Webb *et al*., 2005).

Conformation is an important visual criterion that has a bearing on the perceived market value of a carcass. Conformation, however, can be misleading since in the South African carcass classification system, lamb conformation score accounts for <10% of the variation in yield. Leg length ($P < 0.001$), buttock circumference ($P < 0.01$) and tail weight ($P < 0.01$) differed between breeds. Leg length and tail weight were similar ($P > 0.05$) in CHG and LES but Afar had the shortest leg length and tails ($P < 0.01$). The LES had a larger buttock circumference than Afar ($P < 0.01$) and CHG ($P<0.05$). Carcass compactness ratios were 145.6 (LES), 130.8 (Afar) and 129.3 g/cm (CHG) ($P < 0.0001$). Mourad *et al*. (2001) reported a higher compactness index (0.19 kg/cm) than the present finding, which was mainly due to the shorter carcass length of West African Dwarf goats.

Carcass lengths (58.7-59.7 cm) did not differ ($P>0.05$) between the breeds and are comparable to those reported by Dhanda *et al.* (2001) for the Chevon group, except for Boer X Saanen goats (62.1 cm). However, the carcasses of Ethiopian indigenous goats were longer than West African Dwarf (46.8 cm) goats at the age of 12-18 months (Mourad *et al*., 2001) and Beetal x Assam local (44.5-47.6 cm) goats (Saikia *et al.,* 1996).

Fasting loss was similar ($P > 0.05$) between breeds and diets and ranged from 5.23 to 5.39% in the stall-fed goats (Table 5.3). This finding is in agreement with the starvation shrinkage reported by Ameha & Mathur (2000).

The SBW was positively correlated with rib-eye area, but the coefficients varied between breeds, r=0.51; $P < 0.01$ for LES, r=0.33 for Afar and r=0.19 for CHG. The correlation between compactness index and rib-eye area was also positive and significant for LES (r=0.73; $P < 0.0001$) and Afar (r=0.41; $P < 0.05$), but for CHG it was not significant (r=0.28). Generally most measures of fat (physical fat, chemical fat, fat thickness and total internal fat) were positively correlated ranging from 0.53 to 0.86.

The physical composition, chemical fat, proportion of primal cuts, lean: bone and lean: fat ratios are shown in Table 5.4. Comparison of the composition of carcass from the initial slaughter group with the carcass of fed groups indicated that the bone proportions decreased ($P < 0.01$) and the fat increased ($P < 0.001$) in the fed groups. The findings agree with Hatendi *et al.* (1992) and Mahgoub *et al.* (2005) who reported that the initial slaughter groups had lower carcass fat values than the fed groups. Singh *et al*. (1991) and Dhanda *et al.* (1999a) also documented the percentage of bone decreased significantly with age and weight.

Among the initially slaughtered groups, CHG had the lowest fat proportion. The stall-fed CHG made considerable improvement in its fat proportion (3.3 times over its initial fat proportion). However, it still had the lowest fat proportion ($P < 0.001$) compared to LES and Afar under feedlot conditions. The same breed had the lowest ($P < 0.001$) chemical fat of all the breeds tested (Table 5.4). Significant differences in carcass fat content between goat breeds were also reported by Johnson *et al*. (1995).

Considering the lower fat values recorded in CHG for chemical fat ($P < 0.001$), physical fat ($P < 0.001$), fat thickness ($P < 0.0001$) and total internal fat ($P < 0.01$), this breed was assumed to be less physiologically mature than the other breeds. Snowder *et al*. (1994) used similar criteria. The DP of CHG was also lower ($P < 0.01$) probably due to the lesser quantity of fat in the same genotype.

Diet had no significant (P > 0.05) effect on the physical composition of the carcass. Similar findings were reported by Reddy & Raghavan (1988) and El-Gallad *et al*. (1988). The proportions of the primal cuts were similar between the breeds for each slaughtered group (initial and fed). As for the composition, diet had no significant effect on the proportions of the primal cuts. These results corroborate with the literature (Kumar *et al*., 1991; Ameha & Mathur, 2000). All the weights of the primal cuts except the rack, were significantly affected by breed after correcting for initial weight. The LES had the heaviest (P < 0.001) bone in weights for leg, breast and shank, loin and shoulder and neck. With regard to percent cuts, all the cuts were similar between the genotypes except the loin, which was lower (P < 0.05) in CHG.

Lean to bone and meat (lean + fat) to bone ratios of the initial carcass were similar between genotypes. However, CHG had the highest lean: fat ratio (Table 5.4) due to its lowest fat proportion. Considering the fed genotypes, LES and Afar yielded similar lean: bone ratio and CHG had the lowest (P < 0.001) ratio. Moreover, LES and Afar had comparable (P > 0.05) lean: fat and meat: bone ratios but CHG had a lower meat: bone (P < 0.001) and wider (P < 0.001) lean: fat ratio. The effect of genotype on the different ratios was also reported by Dhanda *et al*. (1999a) and Getahun (2001). Carcass composition (ribs 9-11 th) of Zaraibi yearling goats fed different concentrate to roughage ratios (El-Gallad *et al*., 1988) was 69.3-75.0, 5.0-12.6, 16.1-20.0, 4.3-5.1 % and 3.8-5.2 for lean, fat, bone, chemical fat and meat: bone ratio respectively. These values are comparable with the present findings except that Ethiopian yearling goats fed a grainless diet had higher chemical fat (10.3-14.0 %) and meat: bone ratios (4.03-5.01).

The weights and proportion of non- carcass components of Ethiopian goats are presented in Table 5.5. Breed significantly affected the weights of most edible and non-edible components of stall-fed goats. El Hag & El Shargi (1996) and Kadim *et al.* (2003) also observed genotype effects in different goats. The LES had the heaviest ($P < 0.001$) weights for liver, heart, kidney, total internal organ and empty GIT. The weights of blood, full GIT, digestive contents, skin and feet were significantly affected by breed. The proportions of head, blood, and feet on EBW basis and digestive contents on SBW basis also differed between breeds. Most of the weights of non-carcass components are comparable with the report of Getahun (2001) for Somali goats. The head and the skin proportions of Maradi (Adebowale, 1981) and South African indigenous goats (Tshabalala *et al.,* 2003) were also similar to Ethiopian goats. The weights of kidney, pancreas and total internal organs were affected by diet and these weights were less ($P < 0.01$) in diet 1. Significant effect of diet on pluck weight was also reported in Mubende goats (Okello *et al.,* 1994). However, the other non-carcass components were not affected ($P > 0.05$) by diet. This finding agrees with those of Kumar *et al.* (1991) and El Hag & El Shargi (1996).

Distribution of non-carcass fat (Fig. 8) of Ethiopian goats is shown in Table 5.6. In the initial carcass, breed did not significantly affect the weight of internal fats. However, each fat depot of stall-fed goats was significantly affected by breed and did not differ ($P > 0.05$) between dietary treatments. As for the carcass traits, CHG had the lowest scrotal fat ($P < 0.001$), kidney, pelvic, gut fat ($P < 0.05$) and total internal fat ($P < 0.01$) compared to the other breeds. The LES had the highest or comparable values with the Afar goats. Differences in deposition of internal fat in various breeds of goats were also reported by Mahgoub & Lu (1998) and Kadim *et al.* (2003).

Comparison of stall-fed Ethiopian goats with tropical breeds, such as Indian goats (Sen *et al.,* 2004), at similar age and slaughter weight indicated that Ethiopian goats had less total non-carcass fat (3.01 *vs* 6.74% on SBW basis) but more chemical fat (12.6 *vs* 3.2%) than the Indian goats. The difference in the non-carcass fat can mainly be contributed to breed. However, the difference in chemical fat may be due to the difference in sample location and

Fig 8 : Non-carcass fats in Ethiopian goats breed. Moreover, Ethiopian indigenous goats had more chemical fat (10.3-14.0 *vs* 4.3-5.1%) compared to yearling stall-fed Zaraibi goats of Egypt (El-Gallad *et al*., 1988). The Ethiopian goats had less total non-carcass fat and relatively higher carcass fat, which may help to minimize chilling losses and improve the eating quality of the meat. Owen *et al.* (1978) indicated that even when the market requirement is for a lean carcass, a certain level of carcass fat (10 to 15%) could be desirable from the consumer's point of view so that the cooked meat does not become too dry. Mariniva *et al.* (2001) also documented that goat meat lacks juiciness and an increased amount of subcutaneous and intermuscular fat would prevent the carcass from drying out during hanging in storage.

Table 5.4 Physical composition, chemical fat, proportion of primal cuts, lean: bone and lean: fat ratios (least square mean ± PSE) of selected Ethiopian goats stall-fed with a grainless diet

Traits	Initial			Fed			
	Afar	CHG	LES	Afar	CHG	LES	PSE
Rib physical composition (%)							
Lean	73.9	76.9	76.8	72.6	72.9	72.0	0.77
Bone	19.8	21.4	19.2	18.2 [b]	20.2 [a]	17.1 [b]	0.57
Fat	6.3[a]	1.6[b]	3.9 [a b]	9.1 [b]	6.9 [c]	10.9 [a]	0.58
Rib chemical fat (% DM)	4.39	2.16	2.34	13.4 [a]	10.3 [b]	14.0 [a]	0.66
Proportion of primal cuts (%)							
Leg	33.20	33.30	33.80	32.66	32.05	32.40	0.27
Loin	9.76	9.88	9.32	10.43 [a]	9.78 [b]	10.08 [a]	0.17
Rack	14.23	13.99	13.72	14.25	14.47	14.38	0.24
Breast & shank	14.06	12.96	13.40	13.29	12.98	13.39	0.30
Shoulder & neck	28.77	29.82	29.76	29.37	30.74	29.73	0.41
Ratio							
Lean: bone	3.80	3.67	4.09	4.11 [a]	3.53 [b]	4.44 [a]	0.14
Lean: fat	12.37[c]	51.70 [a]	20.92 [b]	8.70 [b]	13.36 [a]	7.30 [b]	0.96
Meat: bone	4.11	3.75	4.30	4.57 [a]	4.03 [b]	5.01 [a]	0.16

Central Highland goat =CHG, Long-eared Somali =LES, pooled standard error =PSE

[a b c] Means within rows for different group with different superscripts differ (P< 0.05)

5.5 Conclusion

This study indicated that breed contributed to differences in growth rates and carcass characteristics, which were influenced by diet. The breed, LES had better growth rates, heavier body and carcass weights with a higher fat content followed by the Afar breed. This illustrates the potential of LES goats as meat producing animals under feedlot systems using a grainless diet (Diet 1, 8.5 MJ ME/kg DM and 153 g CP/kg DM). The stall-feeding results also demonstrated the advantage of supplementation to grazing/browsing goats under the smallholders systems, a strategy that should be adopted by goat owners. The feed resources used in this study are locally available and their use will greatly increase meat production for the export and domestic market. On the basis of various carcass and non-carcass fat values, CHG was assumed to be the less physiologically mature breed.

Compared to reported chilling losses (2.3-8.7 %) for different goats and weights, the results obtained in the present study suggest relatively low values. This may be due to higher carcass fat in Ethiopian goats or a difference of the chilling environments. Therefore, it is suggested that the chilling losses of more carcasses representative of the LES and Afar breeds be quantified in commercial abattoirs. Such information will contribute to the determination of the optimum slaughter weight for these breeds at which chilling losses are minimal with suitable eating qualities.

Table 5.5 Weights and proportion of non-carcass components of Ethiopian goats (least square mean and PSE)

Traits	Initial			Fed			
	Afar	CHG	LES	Afar	CHG	LES	PSE
Weights							
Liver (g)	279.3	294.8	320.8	286.4^{c}	312.8^{b}	341.8^{a}	8.20
Heart (g)	80.3	93.0	89.7	105.2^{b}	105.4^{b}	120.9^{a}	2.76
Kidney (g)	50.6	51.4	54.5	53.7^{b}	58.6^{a}	61.6^{a}	1.08
Lung & trachea (g)	180.3	184.6	182.5	183.7^{b}	200.2^{a}	204.3^{a}	4.00
Spleen (g)	20.8^{b}	23.8^{ba}	31.5^{a}	24.8^{b}	25.3^{b}	33.9^{a}	1.49
Head (kg)	0.97	0.99	0.98	1.17^{b}	1.23^{a}	1.25^{a}	0.01
Skin (kg)	0.98	1.05	0.99	1.21^{b}	1.29^{b}	1.39^{a}	0.03
GIT empty (kg)	0.87	0.90	0.97	1.07^{b}	1.12^{b}	1.20^{a}	0.02
Blood (kg)	0.59	0.62	0.63	0.69^{b}	0.76^{a}	0.78^{a}	0.01
Pancreas (g)	19.8	21.0	19.0	26.3	26.9	28.1	0.85
Total internal organ (kg)	0.66	0.68	0.71	0.68^{c}	0.73^{b}	0.79^{a}	0.01
GIT full (kg)	3.54	3.51	3.59	4.33^{c}	5.15^{b}	5.62^{a}	0.13
Digestive contents (kg)	2.7	2.6	2.6	3.3^{c}	4.0^{b}	4.4^{a}	0.12
Feet (kg)	0.41	0.43	0.41	0.45^{b}	0.49^{a}	0.49^{a}	0.01
Testicles & other genitals (g)	172.0^{ab}	188.8^{a}	143.8^{b}	222.7	213.5	229.6	5.98
Tail (g)	19.0	16.8	19.8	23.0^{b}	29.1^{a}	27.5^{a}	1.06
Proportions on EBW							
Kidney	0.55	0.55	0.58	0.38	0.41	0.38	0.01
Liver	2.55^{b}	2.66^{ba}	2.88^{a}	2.03	2.15	2.13	0.04
Heart	0.74^{b}	0.83^{a}	0.81^{ab}	0.75	0.73	0.75	0.01
Lung & trachea	1.79	1.67	1.63	1.30^{b}	1.39^{a}	1.28^{b}	0.02
Spleen	0.24^{b}	0.26^{ba}	0.32^{a}	0.17^{b}	0.17^{b}	0.21^{a}	0.01
Head	8.82	8.95	8.79	8.36^{a}	8.53^{a}	7.81^{b}	0.10
Skin	8.97	9.43	8.95	8.59	8.82	8.70	0.13
GIT empty	7.9	8.1	8.7	7.6	7.8	7.5	0.15
Blood	5.38	5.59	5.66	4.91^{b}	5.25^{a}	4.88^{b}	0.07
Pancreas	0.18	0.19	0.17	0.19	0.19	0.18	0.01
Total internal organ	6.05	6.16	6.38	4.83	5.02	4.93	0.06
Digesta (SBW basis)	19.6	19.1	19.1	18.8^{b}	21.8^{a}	21.6^{a}	0.55
Feet	3.7	3.9	3.7	3.2^{ab}	3.4^{a}	3.1^{b}	0.06
Testicles & other genitals	1.57^{a}	1.69^{a}	1.30^{b}	1.58^{a}	1.47^{b}	1.43^{b}	0.03

GIT= Gastro Intestinal Tract, Central Highland goat =CHG, Long-eared Somali =LES, pooled standard error=PSE

$^{a\,b\,c}$ Means within rows for different group with different superscripts differ ($P < 0.05$)

Table 5.6 Distribution of non-carcass fat of Ethiopian indigenous goats fed a grainless diet (least square mean ± PSE)

Traits	Initial			Fed			
	Afar	CHG	LES	Afar	CHG	LES	PSE
Weights							
Scrotal fat (g)	17.3	7.2	13.7	58.44 [b]	43.78 [c]	69.92 [a]	3.72
Kidney fat (g)	26	12.4	19.2	132.7 [a]	100.9 [b]	137.6 [a]	10.21
Pelvic fat (g)	10.2	4.0	11.2	27.3 [b]	24.7 [b]	32.1 [a]	1.73
Gut fat (g)	95.83	66.20	93.83	357.5 [a]	324.6 [b]	388.0 [a]	20.68
Total non-carcass fat (kg)	0.149	0.089	0.137	0.576 [a]	0.494 [b]	0.628 [a]	0.03
Percent on EBW							
Scrotal fat	0.16	0.06	0.12	0.41 [a]	0.30 [b]	0.43 [a]	0.02
Kidney fat	0.24	0.11	0.17	0.93 [a]	0.69 [b]	0.86 [a]	0.06
Pelvic fat	0.09 [a]	0.04 [b]	0.10 [a]	0.19	0.17	0.20	0.01
Gut fat	0.87	0.59	0.85	2.54	2.23	2.41	0.13
Total non-carcass fat	1.35	0.80	1.24	4.08 [a]	3.40 [b]	3.90 [a]	0.19

Central Highland goat =CHG, Long-eared Somali =LES, pooled standard error=PSE

[a b c] Means within rows for different group with different superscripts differ ($P < 0.05$)

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Chapter 6

Meat quality of Ethiopian indigenous goats influenced by genotype and grainless diets

(Submitted to Small Ruminant Research Journal)

6.1 Abstract

This study was undertaken to examine the muscle chemical composition, fatty acid profiles and other meat quality traits in three Ethiopian goat genotypes, the Afar, Central Highland goats (CHG) and Long-eared Somali (LES) using three grainless diets (Diet 1, 8.5, Diet 2, 9.2 and Diet 3, 10 MJ ME/kg DM respectively). Seventy-two young intact male goats were randomly allotted into nine treatment groups. Genotype significantly influenced the carcass fat and crude protein (CP) content and the values ranged from 10.3 to 14.0 % and 19.3 to 21.1 % respectively. Afar and LES goats had higher fat content ($P<0.001$) than CHG whereas CP was higher ($P<0.01$; $P<0.05$) from CHG. The effect of diet was significant on CP % but was similar on fat content though Diet 3 tended to have a higher value. Cooking and drip loss differed ($P<0.01$, $P<0.05$) between genotypes and both traits increased with increased fatness. The effect of diet however, was similar on cooking and drip loss. Genotype and diet significantly influenced the composition of most muscle fatty acids in the Ethiopian indigenous goats. The muscle was primarily composed of oleic acid (43.1-45.4 %), followed by palmitic acid (23.1-24.3 %) and stearic acid (16.5-20.6 %). C10:0, C12:0 and C15:0 were not detected in the muscle tissue. Saturated fatty acid (SFA) was the lowest ($P<0.01$, $P<0.05$) in Afar goat while the polyunsaturated fatty acid (PUFA) was the highest ($P<0.05$) in LES. SFA ranged (43.6-50.1 %) and it decreased ($P<0.0001$) with increased grainless concentrate level in the diet. However, the concentration of *cis* oleic (39.6-45.8 %) and MUFA (44.7-51.5 %) increased ($P<0.0001$) with increased grainless concentrate level. An interaction

effect of genotype and diet was also exhibited on certain fatty acids such as cis C18:2n6, C20:5n3, C22:6n3, SFA, PUFA and PUFA/SFA. Compared to CHG, Afar and LES had higher PUFA, MUFA and UFA/SFA ratio, which are considered healthier through their lowering effect on cholesterol. The relatively higher carcass fat, which is useful to reduce chilling losses and improve eating quality, the absence of C12:0 and lower concentration of C14:0, hypercholesterolemic, and higher C18:1, hypocholesterolemic fatty acids are some of the important traits observed in Ethiopian goats. These findings suggest that potential exists in Ethiopian goat genotypes fed grainless diet for the production of meat with specific quality characteristics.

6.2 Introduction

Indigenous goats, estimated at 23.3 million (CSA, 2004), are one of the important farm animals in Ethiopia, contributing to the economy. There is a goat meat demand for domestic consumption as well as for export to Middle East countries (Gryseels and Anderson, 1983; Farm Africa, 1996; EEPA, 2003). There are also indications that the demand for goat meat in different parts of the world is increasing (Gipson, 1998; Stankov *et al*., 2002). Goat meat could become an ideal choice of red meat for health conscious consumers (Johnson *et al.,* 1995; Carlucci *et al*., 1998) due to its lower fat percentage compared to beef and lamb (Casey *et al*., 2003; Dhanda *et al*., 2003) and a good source of desirable fatty acids (Banskalieva *et al.,* 2000; Mahgoub *et al.,* 2002).

Despite the numerical importance and diversity of goats in Ethiopia (Farm Africa, 1996; EARO, 1999; Tesfaye *et al.,* 2004), the attention given to researching the indigenous goats has been minimal. So far there is no documented information on chemical composition, profile of long chain fatty acids and other meat quality traits of Ethiopian goats. Globally too there is little published information available on the effects of diet or the interaction of breed and diet on fatty acid composition of goat muscles (Banskalieva *et al*, 2000; Rhee *et al.*, 2000; Pratiwi *et al.,* 2005; Dawkins *et al*., undated). Most studies on the feeding of goats have included grain in the diet (El-Gallad *et al*., 1988; Kumar *et al*., 1991; Kirk *et al.,* 1994; Ameha and Mathur, 2000; Getahun, 2001; Kadim *et al*., 2003; Bas *et al*, 2005) and there is no information on the meat quality of goats fed a grainless diet based on locally available feed resources that are not in competition with food sources for humans. Therefore, this study was designed to evaluate meat quality traits of three Ethiopian goat breeds fed grainless diets in a feedlot environment.

6.3. Materials and Methods

6.3.1. Animals and management

Young intact male goats (24 per genotype) from three indigenous genotypes, the Afar, Long-eared Somali, (LES) and Central Highland goat (CHG) were randomly allotted and fed each of the three dietary treatments in which the ratio of concentrate to roughage were: Diet 1, 50: 50 (8.5 MJ ME/kg DM); Diet 2, 65:35 (9.2 MJ ME/kg DM) and Diet 3, 80:20 (10.0 MJ ME/kg DM), respectively. The roughage was native pasture hay and the grainless concentrate composed of 79 % wheat bran, 20 % noug cake (*Guizotia abyssinica*) and 1 % salt. The study was conducted at the Debre-Zeit Research Station of the International Livestock Research Institute, Ethiopia for 126 days. The goats were fasted for 16 hours with free access to water and slaughtered following the Halal method. The samples for the analysis of long chain fatty acid (LCFA) composition were obtained from a total of 60 carcasses and for the other analysis from 85 carcasses including the initial slaughter groups.

6.3.2. Chemical composition

The rib-section (8-9-10) was dissected (Casey *et al*., 1988) into lean and fat, freeze-dried and sub-sampled for analysis. Proximate chemical composition of the rib meat (moisture, ether extract (EE), crude protein (CP) and ash) was analyzed using standard analytical procedures (AOAC, 1990). Chemical composition of the rack/rib especially EE, has been reported to be highly correlated with the chemical composition of a dressed carcass (Hankins, 1947; Field *et al.,* 1963). The feedstuffs were analyzed for CP (AOAC, 1990), NDF (Van Soest *et al*., 1991) and *in vitro* dry matter digestibility using Tilley and Terry as modified by Van Soest and Robertson (1985).

6.3.3. Meat physical characteristics

The ultimate pH was determined 24 hours post-slaughter, using a pH meter with a combined electrode by insertion into the eye muscle at the 12/13 rib site on the chilled carcass (Dhanda *et al*., 1999). Individual weighed samples from the loin were put into thin plastic bags and in a water bath at 75 ^{0}C and removed after one hour from the water bath, cooled under running water, blotted dry, weighed and the cooking loss determined (Honikel, 1998; Hoffman *et al*., 2003). The drip loss was evaluated by putting the sample in a net and then in an inflated plastic bag and suspended in a refrigerator at 4 ^{0}C for 24 hours (Honikel, 1998). The colour was assessed subjectively on the chilled carcass using a five-point scale where 1 is pale and 5 is red (Sanudo *et al.,* 1996; Dhanda *et al.,* 1999).

6.3.4. Long chain fatty acid (LCFA)

Lipid extraction and methyl esters preparations were made according to the methods described in Folch *et al.* (1957) and AOAC (1975), respectively with some modifications. Ten ml phosphate buffered saline was added to the freeze-dried meat sample in a 30 ml test tube and 100 µl internal standard was added, properly homogenized and centrifuged. The supernatant was aspirated into 10 ml test tube and 2 ml chloroform and 1 ml 0.1N HCl were added. It was then centrifuged for 15 minutes and the chloroform (lower layer) was transferred to labeled 10 ml test tube. The extraction was repeated with 2 ml aliquot chloroform and it was combined with the previous chloroform extract. The chloroform was made to evaporate under a gentle stream of nitrogen until no liquid was available in the tubes. Following the evaporation, 1 ml of methanolic KOH was added to the tubes, closed and heated at 60 ^{0}C for 20 minutes. The samples were cooled, 1ml of BF_3 in methanol added (AOAC, 1975), closed and heated at 60 ^{0}C for 30 minutes, again cooled and 1 ml of saturated NaCl in water and 1 ml of hexane were added, closed and mixed well. Finally, the hexane (upper layer) was aspirated into labeled auto-sampler vials containing 100 mg anhydrous Na_2So_4. The fatty acid methyl esters (FAME) were quantified by gas chromatography based on a Varian model 3300 instrument fitted with flame ionization detector. The native hay, the grainless concentrate and the diets were also analyzed. Identification of the sample fatty acids was made by comparison of the relative retention times of the FAME peaks from the samples with those of the standard FAME (Sigma Chemical Co., Ltd.). Individual fatty acids were expressed as percentages by weight of the total fatty acids content measured in each sample. Different ratios of fatty acid types were also calculated as indices of nutritive value.

6.3.5. Statistical analysis

Data were analyzed using SAS (SAS, 2001) General Linear Model procedures for effects of genotype and diet and their interactions. Chemical fat percentage was included as a covariate for fatty acid composition. Correlation coefficients were also computed for certain traits (SAS, 2001). Significant differences between means were determined by multiple comparisons using the Fisher test (Samuels, 1989).

6.4. Results and discussion

6.4.1 Feed composition

The composition of the native hay was 50.6 for CP and 720 g/kg DM for NDF and the invitro dry matter digestibility was 48%. The respective values for the concentrate were 217, 398 g/kg DM and 69 % and for the diets ranged 153-196, 436-580 g/kg DM and 57-66.7 %. The native hay had the highest SFA (56%), which is about two times of the grainless concentrate and SFA in the diets ranged from 33.1 to 38.7 %. The most abundant in the diets (36-41%) was *cis* C18:2 followed by *cis* C18:1 (17.7-19.2 %). In the muscle the concentration of *cis* C18:2, however, was lower and *cis* C18:1 was higher compared to the composition of these fatty acids in the diets. This is probably due to the phenomenon of extensive hydrolysis and biohydrogenation in the rumen (Casey and Van Niekerk, 1988; Webb *et al*., 1994; Bas *et al.,* 2005).

6.4.2. Chemical composition of the muscle

The chemical composition of rib muscle of Ethiopian goats is shown in Table 6.1. There was no significant genotype by diet interaction effect on chemical compositions of the meat. Within the fed genotypes, moisture content did not differ between genotype and also between diets. The initial groups had more carcass water (P<0.0001) than the carcass from the fed goats. Hatendi *et al*. (1992) and Kamble *et al.* (1989) also reported a decline in moisture content of goat meat with increasing age or weight.

The ash content did not differ between genotype and diet. However, the initial carcass appeared to have more ash (1.28 vs 1.19 %) than the carcass from the fed goats. Gaili and Ali (1985b) and Hatendi *et al*. (1992) also recorded lower ash values for fattened Sudan and Matebele goats, respectively.

The CP was influenced by genotype and diet. Tshabalala *et al.* (2003) also reported significant effects of genotype on the CP of South African goats. The mean CP value of the initial carcass was 21.5 % while it ranged from 19.3-21.1 % for the carcass of the fed genotypes (Table 6.1). The values were comparable to the report of Anjaneyulu *et al.* (1995) and Arguello *et al.* (2005) for young goats. CHG had the highest CP (P<0.01, P<0.05). Among the diets, Diet 1 and Diet 2 had similar CP and were higher (P<0.01) than Diet 3. Gaili and Ali (1985b) also reported the effect of diet on protein and fat composition of Sudan goats.

Genotype affected carcass fat content. Dahanda *et al.* (1999) and Tshabalala *et al.* (2003) also recorded similar effect in different goat breeds. Afar and LES (13.4-14 %) had similar chemical fat percentage but higher (P<0.001) than CHG (10.3 %). Though Diet 3 tended to have a higher value, diet effect on fat content was similar. This finding may be due to small differences in ME levels used in the current study as the lowest ME level probably was not low enough to impact a statistical difference. Nevertheless, considerable effect of feeding (4.2 times) on carcass fat could be noted when comparing mean carcass fat of initial and fed-goats (Table 6.1). Diet effect was also similar on the chemical composition of Egyptian goats (El-Gallad *et al*., 1988), Barbaresca lambs (Lanza *et al.,* 2003), Saanen goats (Madruga *et al*., 2004) and Majorera goats (Arguello *et al.*, 2005).

Table 6.1 Proximate composition (% on DM basis) of the rib muscle from Ethiopian indigenous goats fed grainless diet (least square mean & pooled standard error, PSE)

Traits	Initial [a]				Fed groups [b]				
	Afar (n=6)	CHG (n=5)	LES (n=6)	Sig [c]	Afar (n=23)	CHG (n=22)	LES (n=23)	PSE	Sig [d]
Moisture	74.60	75.84	76.22	NS	66.95	67.66	66.25	0.72	NS
Ash	1.34	1.29	1.20	NS	1.13	1.24	1.21	0.04	NS
Protein	21.51	21.86	21.19	NS	19.35	21.14	19.86	0.44	* *
Fat	4.39	2.16	2.34	NS	13.40	10.25	14.00	0.67	* * *

[a] Initial=slaughter made at the start of the study

[b] Fed groups =stall-fed

Sig [c] = Significance between initially slaughtered genotypes

Sig [d]= Significance between fed genotypes

NS (P>0.05), * * Significance (P<0.01), * * * Significance (P<0.001)

6.4.3. Physical characteristics of Longissimus muscle

Physical characteristics of Ethiopian indigenous goats are presented in Table 6.2. The ultimate pH for the initial carcasses of the genotypes was between 5.78 and 5.94 and CHG had the higher (P<0.05) value. Sanudo *et al*. (1996), Dahanda *et al.* (1999) and Arguello *et al.* (2005) have recorded ultimate pH ranging from 5.49 to 5.86 in goats and lambs and were considered normal. The 24-pH of fed genotypes in the current study (5.61-5.67) was within the normal range. The relatively higher pH (5.94) in the initial carcass of CHG may have been due to lower glycogen reserves caused by physical/emotional stress or inadequate nutrition from the extensive system.

The initial carcass had lower (P<0.001) drip loss than the carcass from the fed goats. This finding was in agreement with Schönfeldt (1989) and Sheridan *et al.* (2003) who reported that drip loss increased with increased fatness or age respectively. Within the fed genotypes, drip loss was affected by genotype and CHG had the lowest (P<0.001) drip loss. However, diet effect was similar on drip loss. Sheridan *et al*. (2003) also reported the same. This was probably because the goats had sufficient glycogen reserves in all the diets while stall-fed. It was also reported that diet plays only a minor role in final meat quality provided there are no serious nutritional deficiencies (www.ag.ansc.purdue.edu). Moreover, Ellis *et al.* (1997) indicated that greater amounts of muscle glycogen at the time of death result in a lower ultimate pH, which results in a lower water-holding capacity.

Cooking loss differed between genotypes. Dhanda *et al.* (1999) and Kadim *et al.* (2003) also recorded significant effect of genotype. It ranged from 23.7-26.4 and 28.0-29.5 % for the initial carcass and carcass from the fed genotypes, respectively. Comparison within the initials and also within the fed genotypes indicated that CHG had the lower (P<0.01, P<0.05) cooking loss. This finding showed that cooking loss also increased with increased fatness (Table 6.1) and agrees well with the report of Schönfeldt (1989). Within the fed genotypes, diet effect was similar on cooking loss. This is also in line with the findings of Webb *et al.* (1994) who reported that cooking losses were not affected by dietary energy levels.

Subjective score for muscle colour was affected by genotype. A similar report on effect of genotype was made by Dhanda *et al.* (1999). Initial carcass of CHG had relatively darker colour (P<0.001) than Afar and LES. This was probably due to slightly higher

(P<0.05) ultimate pH in CHG (Table 6.2). Within the fed genotypes, however, colour was similar (P>0.05).

Table 6.2 Physical meat characteristics of Ethiopian indigenous goats fed grainless diet (least square mean & pooled standard error).

Traits	Initial [a]				Fed groups [b]				
	Afar (n=6)	CHG (n=5)	LES (n=6)	Sig [c]	Afar (n=23)	CHG (n=22)	LES (n=23)	PSE	Sig [d]
Cooking loss (%)	25.33	23.72	26.40	*	29.48	27.96	29.18	0.38	* *
Drip loss (%)	1.50	1.35	1.36	NS	3.37	3.09	3.40	0.06	* * *
Ultimate pH	5.78	5.94	5.82	*	5.66	5.67	5.61	0.02	NS
Colour	2.72	3.26	2.73	* *	3.63	3.71	3.48	0.05	NS

[a] Initial=slaughter made at the start of the study

[b] Fed groups =stall-fed

Sig [c] = Significance between initially slaughtered genotypes

Sig [d]= Significance between fed genotypes

NS (P>0.05)

* * Significance (P<0.01)

* * * Significance (P<0.001)

6.4.4. LCFA composition

Studies have shown fatty acid composition of muscle and adipose lipid tissue to be influenced by the breed of the animal, the quality and quantity of feed consumed, age/ bodyweight, sex and level of fatness (Kemp *et al*., 1981; Zembayashi and Nishimura, 1996; Enser *et al.,* 1998; Nurnberg *et al*., 1998; Itoh *et al.,* 1999; Cifuni *et al*., 2000, Rhee *et al*., 2000; Velasco *et al*., 2001) and fatty acid composition in turn affects the nutritive value and the organoleptic characteristics of meat (Diaz *et al*., 2005).

The fatty acid composition of the rib muscle of Ethiopian goats is presented in Table 6.3. The composition of most fatty acids was influenced by genotype. Reports by Banskalieva *et al.* (2000), Tshabalala *et al.* (2003) and Pratiwi *et al.* (2005) in different goats and Webb and Casey, (1995) in sheep also documented the significant effect of breed on compositions of certain fatty acids. The rib muscle fatty acid content (and presumably the carcass) of

Ethiopian indigenous goats was primarily composed of oleic acid (43.1-45.4 %), followed by palmitic acid (23.1-24.3 %) and stearic acid (16.5-20.6 %). These values are similar to the results reported by Banskalieva *et al.* (2000), Mahgoub *et al.* (2002), Tshabalala *et al.* (2003), Bas *et al*. (2005) and Pratiwi *et al.* (2005) for different goat muscles. C10:0, C12:0 and C15:0 were not detected. C16:0, C17:0, C18:0, C20:0 and C21:0 differed between genotypes. C16:0 was lower ($P<0.05$) in CHG and LES compared to Afar while C18:0 was the lowest ($P<0.001$) in Afar (Table 6.3). Genotype also significantly affected the proportions of C17:1, both *cis* and *trans* of oleic acid and C20:1 but were similar in the percentage of C16:1. Afar had the highest ($P<0.05$) *cis* oleic acid and C20:1. Among the polyunsaturated fatty acids (PUFA), *cis* and *trans* of linoleic acid, C18:3n6, C20:2 and C20:5n3 were significantly affected by genotype. However, C20:3n6 and C22:6n3 were similar. After correcting for chemical fat, *cis* linoleic acid was the highest ($P<0.01$) in LES. However, the proportions of C18:3n6 and C20:5n3 were higher ($P<0.01$) in Afar goats (Table 6.3).

SFA was the lowest ($P<0.01$, $P<0.05$) in Afar goats while the PUFA was the highest ($P<0.05$) in LES. The proportion of desirable fatty acids (DFA) and the ratio, (C18:0+C18:1):C16:0 were higher ($P<0.05$) in LES and CHG than Afar. According to Banskalieva *et al.* (2000), the ratio (C18:0+C18:1):C16:0 represents the majority of the fatty acids and could better describe possible health effects of different types of lipids. In the present finding, it ranged from 2.6 to 2.9 and is comparable to muscle fatty acids reported by Park & Washington (1993) and Matsuoka *et al.* (1997). The current ratio however, was higher than the values recorded by Johnson *et al.* (1995) and Potchoiba *et al.* (1990). The proportion of DFA in the present work (69.1-70.6 %) is also within the reported values (61.3-79.8 %) for different muscle types and goat breeds (Banskalieva *et al.,* 2000). The ratio (UFA/SFA) ranged from 1.03 to 1.15 and was higher ($P<0.01$, $P<0.05$) in Afar goats. The PUFA/SFA ratio however, was similar ($P>0.05$) between genotypes.

Generally, Afar and LES had a higher UFA and UFA/SFA ratio and lower SFA compared to CHG, which are considered desirable fatty acids that have either a neutral or cholesterol lowering affect (Rhee, 1992). However, the ratios of PUFA/SFA were very low in the muscles of all genotypes. These results are similar to those reported by Madruga *et al.* (2004) in male Saanen goats and Marinova *et al.* (1992) in lamb. Banskalieva *et al.* (2000) explained that the PUFA /SFA ratio in the muscles of all ruminants is relatively low compared to non-ruminants because of the biohydrogenation of dietary unsaturated fatty acids in the rumen.

Initial carcass of goats, reared in the extensive system, had higher C14:0 (P<0.01), C17:0 (P<0.05), C22:0 (P<0.01), C20: 3n6 (P<0.001), C20: 5n3 (P<0.001) compared to the carcass of the fed-genotypes. After correcting for chemical fat, C18:2n6 and PUFA was lower (P<0.001, P<0.05) in the carcass of fed goats than initial slaughtered goats. Bas *et al.* (2005) also reported a lower proportion of C18:2n6 and PUFA from indoor raised goats. These authors explained the low C18:2*n*6 content of indoor-raised goats could partly result to higher hydrolysis and hydrogenation of dietary fatty acids in the rumen and the lower PUFA proportion in indoor fed goats may be due to differences in fat content and thus in phospholipid proportion between outdoor- and indoor goats.

As shown in Table 6.3, diet significantly affected the concentration of some fatty acids in the muscle. The effect of diet on certain fatty acid compositions was also reported by Potchoiba *et al.* (1990), Rhee *et al* (2000) and Bas *et al.* (2005). C16:0 was similar (P>0.05) between diets and this is also in line with the findings of Rhee *et al.* (2000), Bas *et al.* (2005) and Sheridan *et al.* (2003). C14:0 also did not differ (P>0.05) between diets and Sheridan *et al.* (2003) noted the same. The concentration of C18:0 ranged between 15.7 to 21.5 % and it decreased (P<0.0001) with increased concentrate level and SFA (43.6-50.1 %) also followed the same pattern (P<0.0001). However, the concentration of *cis* oleic (39.6-45.8 %) and

MUFA (44.7-51.5 %) increased (P<0.0001) with increased concentrate level. These findings agree with the reports of Gaili and Ali (1985b) and Banskalieva *et al.* (2000) who indicated that fattened goats deposit more C18: 1. Diet also significantly influenced the UFA/SFA ratio (0.96-1.3) and the highest (P<0.0001) ratio was recorded from Diet 3. C18: 2n6 (*cis* and *trans),* DFA, PUFA were not affected (P>0.05) by diet. Sheridan *et al.* (2003) also reported that diet did not affect these fatty acids in stall-fed Boer goats and the values were comparable (C18:2n6; 2.2-2.5 % and PUFA; 3.4-3.7 %). However, the proportions reported for intensively fed Florida goats (Johnson and McGowan, 1998) were lower than our values. The ratio PUFA/SFA was similar (P>0.05) between diets.

In the present findings, the (n-6)/(n-3) ratio was above the recommended ratio (Wood *et al.,* 2003) probably due to the lower n-3 series obtained (0.14-0.38 %, Table 6.3) from the dietary treatments of the stall-fed goats. In indoor-fed Morocco goats, n-3 series fatty acids were also lower (Bas *et al.,* 2005). One option to increase these fatty acids could be through including whole linseed or linseed oil in the concentrate (Wood *et al.,* 2003). Therefore, the effect of inclusion of linseed, rich in C18:3 (Scheeder *et al.,* 2001) in the diet shall be investigated in future studies to attain a more favorable n-6:n-3 ratio.

The concentration of the major fatty acids, C16:0, C18:0, *cis* C18:1 and MUFA obtained from Diet 3 in the present findings were comparable to indoor-fed Morocco goats at similar age and slaughter body weight (SBW) (Bas *et al.,* 2005). Moreover, comparison of fatty acids of Ethiopian goats fed Diet 3 with intensively-fed Jebel Akhdar (Mahgoub *et al.,* 2002) goats at similar SBW indicated that concentrations of C16:0 and C18:0 were comparable but SFA was lower (43.6 vs 49.1 %), oleic acid (47 vs 35 %), UFA (54.8 vs 50.9 %) and UFA/SFA (1.3 vs 1.07) were higher in Ethiopian goats. The PUFA, however, was higher (7.8 Vs 3.3) in Jebel goats. The Ethiopian indigenous goats fed grainless diet also had lower SFA (47.2 vs 58.3 %), higher unsaturated fatty acids (51 vs 41.7 %) and a higher

UFA/SFA ratio (1.08 vs 0.71) than Indian male goats fed maize based concentrate at similar age (Rao *et al*., 2003). C12:0, C14:0 and C16:0 are hypercholesterolemic fatty acids and C14:0 has four times the hypercholesterolemic effect of the others (Ulbricht and Southgate, 1991). Compared to intensively fed Jebel goats at similar slaughter body weight (Mahgoub *et al.,* 2002), Ethiopian goats had a 2.4 times lower concentration of C14:0 whereas compared to stall-fed Florida goats (Johnson and McGowan, 1998), they were also lower by 1.43 times. These demonstrate the potential of Ethiopian goats to produce comparative or better quality meat with grainless diet.

An interaction effect of genotype and diet was exhibited in some fatty acids (Table 6.3). Of all the genotype and diet combinations, LES fed Diet 2 presented the highest ($P<0.001$, $P<0.05$) concentration of *cis* C18:2n6 and Afar fed Diet 3 displayed the highest ($P<0.001$) C20:5n3. Afar had lower ($P<0.01$, $P<0.05$) SFA on Diet 1 whereas on Diet 3 all the genotypes produced similar ($P>0.05$) SFA. LES on each of the diets and Afar on Diet 3 produced comparable and higher ($P<0.01$) PUFA than other treatments. The PUFA/SFA ratio was similar between Afar fed Diet 3, LES fed Diet 2 and Diet 3 and was higher ($P<0.01$, $P<0.05$) compared to other combinations.

Chemical fat was positively correlated with drip loss ($r=0.95$-0.98; $P<0.0001$) in each of the goat genotypes. Schonfeldt *et al.,* (1993) also noted a positive and significant correlation between fat code and drip loss. In LES, chemical fat was positively correlated with C18:1 ($r=0.54$; $P<0.05$) and MUFA ($r=0.56$; $P<0.05$) while it was negatively correlated with C18:0 ($r=0.52$; $P<0.05$) and SFA ($r=0.51$; $P<0.05$). Kemp *et al.* (1981) also observed similar correlations in lambs. Generally in each genotype, the correlations of the predominant fatty acids with the sums were positive and significant; C18:0 with SFA (0.77-0.95, $P<0.001$), C18:1 with MUFA (0.96-0.99; $P<0.01$), C18:2 with PUFA (0.87-0.96, $P<0.001$) and C18:2 with PUFA/SFA (0.81-0.83, $P<0.001$).

Table 6.3 Effects of genotype and diet on fatty acid composition of Ethiopian goats (least square mean & pooled standard error, PSE).

Types	Genotype (G)			Diet (D)				Effects		
	Afar	CHG	LES	+D1	D2	D3	PSE	G	D	G X D
C14:0	2.45	2.28	2.37	2.42	2.23	2.45	0.08			
C16:0	24.29	23.07	23.07	23.79	23.54	23.10	0.36	*		
C17:0	1.52	1.63	1.44	1.55	1.49	1.56	0.05	*		
C18:0	16.53	20.61	19.86	21.48	19.83	15.70	0.70	* * *	* * * *	
C20:0	0.06	0.06	0.09	0.08	0.06	0.08	0.01	* *		*
C21:0	0.60	0.41	0.50	0.56	0.51	0.44	0.03	* * *	*	
C22:0	0.09	0.13	0.11	0.09	0.12	0.13	0.01			*
C24:0	0.16	0.17	0.15	0.15	0.15	0.18	0.02			*
C16:1	2.41	2.18	2.32	2.09	2.06	2.76	0.11		* * *	
C17:1	1.37	1.30	1.06	1.07	1.07	1.59	0.08	*	* * *	
C18:1n9t	1.47	1.29	1.64	1.71	1.52	1.18	0.09	*	* * *	*
C18:1n9c	43.96	41.80	41.95	39.62	42.26	45.84	0.69	*	* * * *	
C20:1	0.20	0.15	0.15	0.22	0.16	0.11	0.01	* *	* * *	
C18:2n6t	0.24	0.15	0.19	0.19	0.21	0.18	0.01	* * *		
C18:2n6c	2.42	2.38	3.03	2.64	2.71	2.49	0.14	* *		* *
C18:3n6	0.07	0.05	0.05	0.06	0.06	0.06	0.01	*		
C20:2	0.10	0.14	0.09	0.12	0.09	0.13	0.01	*		
C20:3n6	0.05	0.06	0.06	0.05	0.06	0.06	0.01			
C20:5n3	0.10	0.08	0.06	0.08	0.06	0.11	0.01	*	*	* *
C22:6n3	0.14	0.16	0.14	0.09	0.08	0.27	0.01		* * *	* *
SFA	45.66	48.36	47.59	50.12	47.93	43.64	0.64	* *	* * * *	*
MUFA	49.41	46.72	47.12	44.71	47.07	51.48	0.77	*	* * * *	
PUFA	3.12	3.02	3.62	3.23	3.27	3.30	0.16	*		*
UFA/SFA	1.15	1.03	1.07	0.96	1.05	1.26	0.03	*	* * *	
PUF/SFA	0.07	0.06	0.08	0.06	0.07	0.08	0.00			*
DFA	69.06	70.35	70.60	69.42	70.17	70.48	0.44	*		

* Significance (P<0.05)

* * Significance (P<0.01)

* * * Significance (P<0.001)

* * * * Significance (P<0.0001)

+D1 (50:50 concentrate: roughage), D2 (65:35), D3 (80:20)

6.5. Conclusion

Significant genotype differences exist in carcass fat and CP content. The LES and Afar goats had higher fat content ($P<0.001$) than CHG whereas CP was higher ($P<0.01$; $P<0.05$) from CHG. Diet effect was significant on CP percentage but was similar on fat content. Cooking and drip loss differed ($P<0.01$, $P<0.05$) between genotypes and both traits increased with increased fatness. Diet effect, however was similar on cooking and drip loss. Genotype and diet significantly affected the composition of most muscle fatty acids. C10:0, C12:0 and C15:0 were not detected in the muscle tissue. Compared to CHG, Afar and LES had higher PUFA, MUFA and UFA/SFA ratio, which are considered healthier to humans through the reduction of plasma cholesterol level. Muscle SFA decreased with increased grainless concentrate level in the diet and was the lowest ($P<0.0001$) in Diet 3. Diet 3 also had the highest ($P<0.0001$) concentration of *cis* oleic and MUFA. However, DFA was similar ($P>0.05$) between diets. Interaction effect of genotype and diet was also observed in certain essential fatty acids, SFA, PUFA and PUFA/SFA. The relatively higher carcass fat, which is useful to reduce chilling losses and improve eating quality, the absence of C12:0 and lower concentration of C14:0 in the muscle tissue, hypercholesterolemic, and higher C18:1, hypocholesterolemic fatty acids are some of the important traits observed in Ethiopian goats. These findings suggest that potential exists in Ethiopian goats fed a grainless diet for the production of meat with specific quality characteristics.

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Chapter 7

7.0. General conclusions, recommendations and critical evaluation.

7.1. General conclusions

The objectives of the study were:

- To assess the genotypic effect on carcass characterstics and meat quality of extensively managed indigenous goats.
- To assess the effect of genotype and grainless diets on dry matter intake, feed efficiency, growth performance, carcass characteristics and meat quality of young goats under stall-fed conditions
- To determine the effect of a grainless diets on rumen degradability and fermentation of adult indigenous goats.

The null hypothesis tested, "Indigenous goat genotypes under the same nutritional regimes will have similar growth performance and do not produce different carcasses of different quality" was rejected, as significant differences were observed in most parameters measured.

This study has shown that there is a potential for improving goat meat production and quality of Ethiopian goats using grainless diets under stall-fed conditions. Significant variation also existed between the indigenous genotypes in DMI, FE, ADG, carcass characteristics and meat quality.

The goat genotypes (Afar, LES and CHG) raised under extensive conditions generally were characterized by a lower carcass weight and poor carcass fat cover. However, compared at similar slaughter weights, CHG had lower carcass and non-carcass fat values and was assumed to be a late maturing genotype. Significant genotype differences also existed in the muscle fatty acid content. The LES goats reared under extensive conditions presented a beneficial ratio of n-6/n-3 PUFA favorable to consumer's health. To improve the carcass characteristics, provide uniform and constant supply for the growing market, it is imperative that grazing goats should be supplemented or stall-fed with locally available feed ingredients depending on the grazing resources of the agro-ecologies and the objectives of the goat farmers.

The stall-fed LES had higher DM roughage intake, total DMI and average daily gain and better FE than the other goats. The capacity to utilize a ration consisting of more roughage is a good attribute observed in the breed. The improvement in FE is attributable to a lower intake of the diet per unit of gain and this will be an advantage for both the producer and consumers. Goats in Diet 1 (50:50 concentrate to roughage, 8.5 MJ ME/kg and 153 g CP /kg DM) had a lower total DMI and better FE due to the favorable rumen ecology created by the ration compared to the other diets.

The LES breed had the highest pre-slaughter and slaughter weights, EBW, HCW and CCW. An important carcass parameter such as fat thickness was also higher in LES followed by Afar. As for FE, goats in Diet 1 also had higher values of body weights, HCW, CCW and dressing percentages.

Stall-fed CHG had a 33 % lower chemical fat compared to LES and Afar breeds. Diet effect was similar in terms of fat content and Diet 1 significantly favored CP content. Therefore, it would be cheaper to use Diet 1 due to its higher roughage concentration while producing the reported values of carcass fat and protein. Compared to mean values of the initial carcass, fat thickness and chemical fat were improved in the fed genotypes by 1.7 and 4.2 times respectively. This improvement has an economic advantage in that chilling loss was reduced and the meat would meet eating quality requirements. Eventhough the market requirement is for a lean carcass, 10 to 15 % of carcass fat (Owen *et al.,* 1978) could be desirable so that the cooked meat does not become too dry or to improve goat meat juiciness

(Marinova *et al.,* 2001). Hence, Ethiopian goats fed a grainless diet were able to produce the required fat content and were better in this regard than some tropical breeds such as the Indian goats (Sen *et al.,* 2004) and stall-fed Zaraibi goats of Egypt (El-Gallad *et al*., 1988) compared at similar age and weight.

Stall-fed CHG also showed a similar pattern of having lower fat falues (Table 5.3; 5.4; 5.6) and was assumed to be less physiologically mature than LES and Afar breeds. Therefore, the producers/processors should treat this category of breeds separately since slaughtering of animals with different maturity type at constant weight results in different carcass fat and eating quality. Cooking and drip loss differed between genotypes and both traits increased with increased fatness. Diet effect, however was similar in both traits.

Genotype and diet significantly affected the composition of most muscle fatty acids. Compared to CHG, Afar and LES had higher PUFA, MUFA and UFA/SFA ratio, which are considered healthier to consumers through the reduction of plasma cholesterol levels. Muscle SFA was the lowest and *cis* oleic and MUFA were the highest in Diet 3. However, desirable fatty acids (DFA) were similar between diets. Interaction effect of genotype and diet was also observed in certain essential fatty acids, SFA, PUFA and PUFA/SFA.

Some of the very important carcass and meat quality traits observed in Ethiopian goats were lower chilling losses, less total non-carcass fat, relatively higher carcass fat (see chapter 5.4), absence of C12:0 and lower concentration of C14:0 in the muscle tissue (hypercholesterolemic) and higher C18:1 (hypocholesterolemic fatty acids; chapter 6.4.4) . In future, care needs to be taken that these and other useful characteristics of the indigenous goats are not lost in crossbreeding programs with exotic goats.

CHG was less suitable for stall-feeding condition because it performed poorer in terms of ADG, FE, carcass and meat quality traits compared to the other genotypes.

The mean rumen pH was similar between diets and was within the range recommended for optimal microbial activity. The mean concentration of ammonia nitrogen in the diets was above the range reported for optimal rumen conditions. Total VFA was depressed with increased grainless concentrate. However, goats in Diet 1 had a higher concentration of total VFA and utilized the feed nitrogen more efficiently. Moreover, the hay dry matter and neutral detergent fibre were more degradable in goats fed Diet 1. The results of rumen parameters (Table 3.3) substantiate the suitability of Diet 1 for the goats compared to the other diets. Hence, Diet 1 had a better FE, higher body weights, carcass weights and dressing percentages and similar desirable fatty acids compared to the other diets. The feedstuffs used in this ration are locally available and their use will significantly improve meat production and quality for export as well as the domestic market. The feedlot findings also demonstrate the benefit of supplementation to grazing/browsing goats under smallholder systems, a strategy that should be adopted by goat owners.

7.2. Recommendations

Diet 1 should be fed to young LES, Afar and similar genotypes for better growth, carcass and meat quality. Moreover, when the objective of the enterprise would be to produce a higher ADG than achieved and finish in a shorter period, the inclusion of a minimum level of molasses or grain should be investigated, as improving the proportion of propionic acid increases the efficiency of utilization of ME for body weight gain.

Chilling losses of fed-genotypes in the present finding were lower (2.5-3.1 %) compared to literature values of different goat breeds and weights (2.3-8.7 %). This may have been due to higher carcass fat in Ethiopian goats or a difference in the chilling environments. Therefore, it is suggested to verify the chilling losses using more carcasses of LES and Afar under the chilling environment of commercial abattoirs.

The current operation of Ethiopia's goat meat export to the Middle East countries could benefit from the results of this study and believed to improve its performance. However, to enter the new markets of Asia that require skin-off carcasses with less strict hygienic procedures and weight categories (Malaysia 12-18 and greater than 18 kg; Singapore ranging from 22-32 kg (Elliott and Woodford, 1998), it is suggested to immediately evaluate the performance of other potential indigenous goat genotypes with improved managements. It is also essential to plan selective breeding within existing indigenous stock and crossbreeding of some genotypes with meat breeds (such as Boer). The latter must be planned for agro-ecologies with higher feed potential.

To provide incentives to producers and assist the development of meat exports, a grading system based on weight and meat quality should be introduced.

During the dry season and other times when the natural pasture and browses are nutritionally insufficient in yield and quality, it is necessary to ensure adequate supplementary nutrients for maximum slaughter weight of growing goats at an early age. High cost of supplements/concentrates however, is a major constraint in most of the developing countries. It is therefore, important to investigate different options to achieve economic goat meat production. Crop residues and dry grasses relatively abundant in some agro-ecologies, should be processed to low-cost complete diets using agro-industrial by-products, farm wastes, non-conventional feedstuffs and browse leaves. The preparation of such diets not only reduces the cost of production but also prevents selection, reduces wastage, facilitates handling, storage and transport. The other alternative supplement that requires research attention is the production of balanced feed blocks for grazing goats using local feed resources and non-protein nitrogen.

The effects of inclusion of linseed, rich in C18:3 and/or forages rich in n-3 sources (Enser *et al*., 1998) in the diet should also be studied to attain more favorable n-6:n-3 ratio in the meat.

A free grazing system has led to overgrazing and degradation of many grazing areas. Therefore government should assist and facilitate the control of this malpractice. Grazing capacity of grasslands and rangelands should be assessed and recommendations should also be strictly followed. Considering the cost of establishing pasture, degraded grazing areas should be reclaimed with adaptable pasture legumes or grass-legume mixtures and the area should be kept stock-excluded until adequate biomass is available. After some years, the producers will feel the benefit from the plant-animal-man interactions through nitrogen fixing capacity of legumes, return of the manure to the field and provision of organic goat meat, which will gain a premium from discerning consumers. Enser *et al*. (1998) also reported that grass diets increase muscle concentrations of n-3 PUFA in beef and lamb. These fatty acids are beneficial to consumers through reducing the cholesterol levels.

One of the major problems to increase the volume of export market is lack of constant and uniform supply of meat. Thus, an intensive and/or semi-intensive system of managements should be encouraged/ adopted depending on the agro-ecology/availability of vegetation, the objectives of the goat owners and economics of the activity.

Stakeholders' networks should be established that assist in harmonization of research and development activities in the area of livestock meat /goat meat. Proper planning, policy formulations and the fixing of accountability at various levels are also critical for ideal marketing of goat meat.

7.3. Critical evaluation

7.3.1. Contributions of the study

This study is original and met both the academic (contribution to science) and practical objectives. The output for the latter objectives could be easily understood from the general conclusion. The contributions of this study to science have been briefly indicated as follows.

Diet: The available studies on the growth of goats and /or on carcass characteristics, used diets either grain-based and/or browse/herbaceous legume supplementation (El-Gallad *et al*., 1988; Kumar *et al*., 1991; Kirk *et al.,* 1994; Srivastava and Sharma, 1997; Ameha & Mathur, 2000; Getahun, 2001; Kadim *et al*., 2003; Sen *et al.,* 2004; Mahgoub *et al.,* 2005). However, grain is also required for humans and expensive feed ingredients in many developing tropical countries. Their inclusion in the diet increases the cost of animal production. Sing *et al.* (1999) suggested that it is neither logical nor desirable to feed cereals to animals in developing countries. Except for some limited research efforts on using by-product feeds on sheep and cattle on DMI, growth and /or digestibility (Mondal *et al*., 1996; Singh *et al*., 1999; Giri *et al.,* 2000; Dhakad *et al*., 2002), research on the effects of a grainless diet on growth, particularly on carcass and meat quality of indigenous goats, has not been done elsewhere. Hence this study presents a useful contribution to science.

Breeds: There are limited data on the performance evaluation of indigenous goats; in some cases local populations are threatened with extinction before their genetic value is even properly described and studied (Hodges, 1990; Madalena, 1993). It is thus necessary to identify the merit of available genetic resources (Vercoe and Frisch, 1987; Laes-Fettback and Peters, 1995). This study contributed to the database of indigenous breed performance. Some of the observed useful characteristics of Ethiopian goats (less total non-carcass fat, relatively higher carcass fat, lower chilling losses, absence of C12:0 and lower concentrations of C14:0

and higher concentrations of C18:1 in the muscle tissue) may attract the attention of goat farmers/breeders interested in the industry.

Interaction effect: Banskalieva *et al.* (2000) in their review on fatty acid composition of goat muscles emphasized that there are no data available examining interactions between diet, genotype, muscle type, age and live weight. This work reported interaction effects observed on LCFA between diet and indigenous breeds at the yearling age.

Stall-feeding: Performance data of goats under different systems of management is scarce and researchers (Huston and Waldron, 1996; Sormunen-Cristian and Kangasmaki, 2000; Dhanda *et al*., 2003) reported that little is known about the performance of goats under intensive feedlot conditions. Moreover, the prevailing situations in a number of countries (inadequate grazeable material, overgrazing and degradation of many grazing lands and shrinking of grazing areas) require urgent attention and need optional systems. Therefore, the present findings on the performance of indigenous goats using a grainless diet under stall-fed conditions will add value to the knowledge regarding their response to the system.

Rumen parameters: Goats differ in feeding behavior, level of intake and rate of eating compared to sheep and cattle (Lu, 1988; Reid *et al.,* 1990) and have a faster ruminal fractional rate of passage (Garcia *et al.,* 1995). De Peters *et al.* (1997) and Juárez *et al.* (2004) also reported that there is little information concerning rumen degradability of by-product feeds/ different feeds in goats and changes in rumen environment (Woyengo *et al*., 2004). To optimize the feeding value of these by-product feeds/grainless diets, knowledge of their ruminal degradation properties is needed for proper ration formulation programs. For example, by-product feeds with very rapid ruminal rates of starch degradation may result in a low ruminal pH and cause lactic acidosis (Nocek and Russell, 1988; Nocek, 1995), if this degradation characteristic is not accounted for in ration formulation. On the other hand, by-product feeds that are low in rumen-available carbohydrate may reduce microbial protein production (Stokes *et al*., 1991a, b). Therefore, the outputs from this study will contribute to better understanding of the nutritive value of rations containing similar feedstuffs.

7.3.2 Retrospective comments on the study

In the present study, three genotypes and three diets were evaluated using 72 individual pens. Inclusion of a grain-based concentrate as a 4th diet to compare the performances with the grainless diets was felt essential. However, it was not possible due to insufficient individual feeding pens. Additional construction of pens was not undertaken due to budgetary reasons. One of the grainless diets was not omitted because the three dietary treatments (roughage: concentrate ratio) were set to observe the potential performance of the goats with a low, medium and high roughage inclusion. The other possibility to include this treatment was through reducing the sample size per group; this idea was dropped for the benefit of precision of the analysis. Moreover, with smaller sample size, it would have been difficult to provide a solid recommendation. Therefore, comparisons were made with results done elsewhere on grain concentrates at similar age and /or weight of indigenous goats.

Information on the nutrient requirement (essential nutrients for various physiological functions) of indigenous animals is not available in Ethiopia. Most of the research and commercial work has so far been based on findings with temperate breeds and this information is less useful to the animals in tropical countries (Mahgoub *et al*., 2000). For this study nutrient recommendations as suggested by Kearl (1982) was used, entitled nutrient requirements of ruminants in developing countries. However, the mean energy and protein values used to predict the nutrient requirements in these nutrient tables were determined by combining values in the literature and those provided in personal communication with animal nutritionists in the developing countries. Respiration calorimetry and comparative slaughter have frequently been used to assess the energy requirements of livestock. These methods are labour intensive, need good facilities and/or high analytical costs and respiration calorimetry requires unnatural conditions for measurement. Sahlu *et al.* (2004) reported that there is a need for simple, inexpensive and non-terminal means of assessing body composition. In the current study, if the goats were fed *ad libitum* and had more experimental units per dietary treatment, metabolizable energy requirement of the growing Ethiopian indigenous goats could have been estimated by using ADG as indirect measure of energy retention, with regression analysis (Early *et al.*, 2001). Though this method has some disadvantages (McDonald *et al.*, 1977; Rohr & Daenicke, 1984), it is a common method due to its advantages (Van Soest, 1994; Mahgoub *et al*., 2000; Luo *et al*., 2004).

Slaughter weight and/or the levels of carcass fat required can vary greatly from market to market. In this study, one slaughter weight (average 18 kg) was used which is the commonly required body weight. This was mainly due to limited financial resources and the limited study period. Had it not been for the indicated reasons, a set of serial slaughterings for more information on the same genotypes could have been used. At the outset, if 3 genotypes X 3 diets X 3 target slaughter weights =27 treatment groups were planned, it would have been unmanageable and it would have taken a longer feeding period to attain the higher slaughter weights. However, if there were adequate funds in the project, an M.Sc. student could have been incorporated and the study could have been phased. During the first phase, the three genotypes could have been evaluated with the three diets and during the second phase, the three genotypes (another batch) fed one suitable diet, could have been slaughtered using the three target weights required by the different markets.

The comprehensive literature search, the ruminal, carcass and meat evaluation studies and the discussions made with the supervisors, at different stages of the study, have given the author additional knowledge and a broader perspective in life; these, together with the additional qualification will enable him to carry out his duty more efficiently.

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7.5. *Curriculum Vitae*

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