# 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).

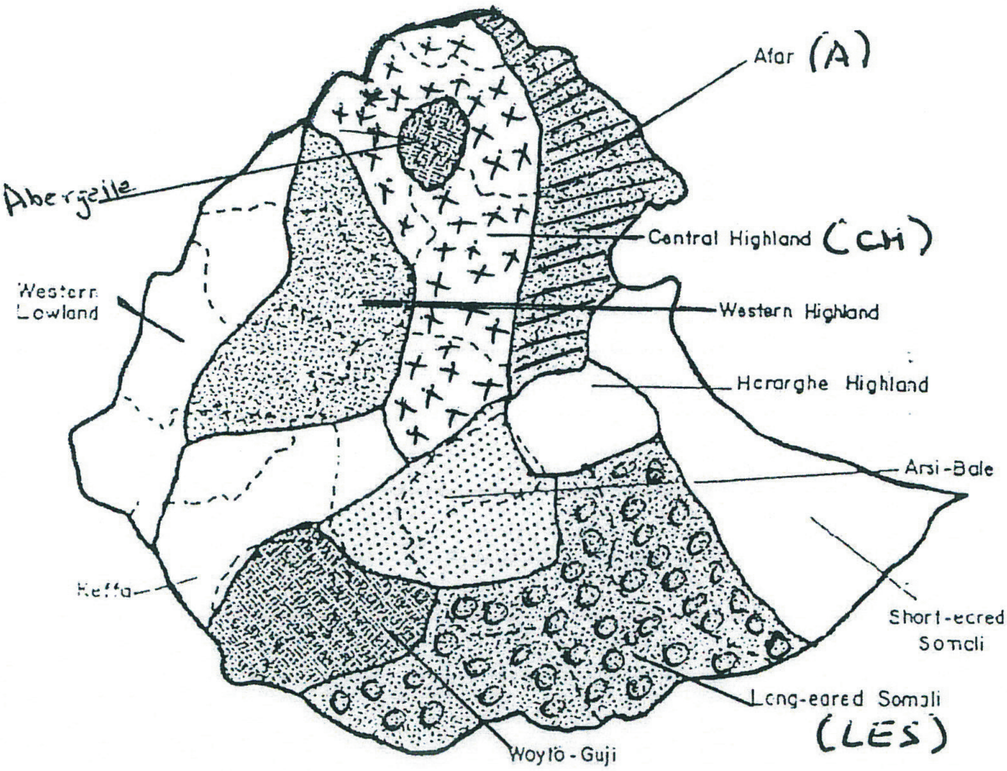



**Fig. 1. Geographic distribution of goat genotypes of Ethiopia (Adapted from Farm-Africa, 1996).**

**_____ 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).

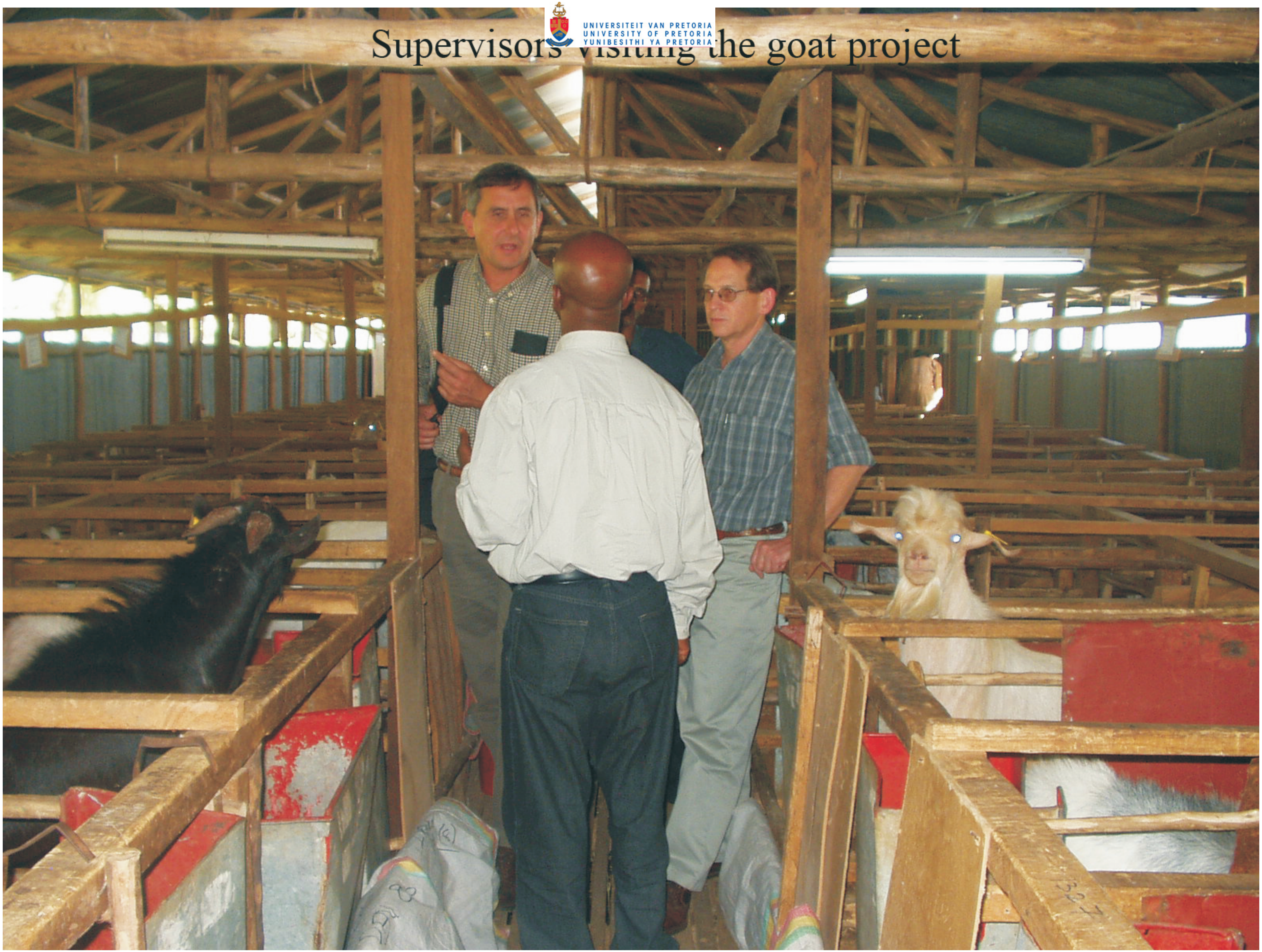
3. The central Highland goat (CHG): It is also called the brown goat. It is a medium sized, broad faced, thick horns, and mainly reddish brown in colour. It has a predominantly straight facial profile. The horns are mainly straight and pointed backwards. The population is

Fig. 2 : Photograph of Afar goats

Fig 3 : Photograph of Long-eared Somali goats

Fig 4 : Photograph of Central Highland goats

# 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 $12/13^{th}$ 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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