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)

3.6 References

Akbar, M.A., Lebzien, P. & Flachowsky, G., 2002. Measurement of yield and *in situ* dry matter degradability of maize varieties harvested at two stages of maturity in sheep. Anim. Feed Sci. Technol. 100, 53–70.

AOAC, 1990. Official Methods of Analysis. 15th Ed., Association of Analytical Chemists, Virginia, USA, 684pp.

Barlow, R., Ellis, K. J., Williamson, P. J., Costigan, P., Stephenson, P. D., Rose, G. & Mears, P. T., 1988. Dry-matter intake of Hereford and first-cross cows measured by controlled release of chromic oxide on three pasture systems. Journal of Agricultural Sci. (Camb.). 110, 217-231.

Bondi, A. A., 1987. Animal Nutrition. John Wiley & Sons Ltd, UK.

Bruno-Soaresa, A.M., Abreua, J.M.F., Guedesb, C.V.M. & Dias-da-Silvab, A.A., 2000. Chemical composition, DM and NDF degradation kinetics in rumen of seven legume straws. Anim. Feed Sci. Technol. 83, 75-80.

Central Statistics Authority (CSA), 2004. The 2001/02 Ethiopian Agricultural Sample Enumeration, Executive Summary, May 2004, Addis Ababa, Ethiopia.

ChemLab Instruments Ltd., 1981. Continuous Flow Analysis. Method Sheet No. CW_2-008-17, Horn Chruch, Essex, UK.

Devendra, C. & Burns, M., 1983. Goats production in the tropics. Technical communication. Agricultural Bureau, Farnham Royal, U.K.

Dhanoa, M.S., 1988. On analysis of dracon bag data for low degradability feeds (Research Note). Grass Forage Sci. 43, 441-444.

El-Gallad, T.T., Allam, S.M., Gihad, E.A. & El-Bedawy, T.M., 1988. Effect of Energy Intake and Roughage Ratio on the Performance of Egyptian Nubian (Zaraibi) Kids from Weaning to One Year of Age. Small Rumin. Res. 1, 343-353.

Erdman, R., Proctor, G. & Vandersall, J., 1986. Effect of rumen ammonia concentration on in situ and extent of digestion of feedstuff. J. Dairy Sci.69, 2312-2320.

Ethiopian Export Promotion Agency (EEPA), 2003. Meat export statistics. EEPA, Addis Abeba, Ethiopia.

FARM-Africa, 1996. Goat types of Ethiopia and Eritrea. Physical description and management systems. Published by FARM-Africa and ILRI, Nairobi, Kenya. pp.1-76.

Getahun, L., 2001. Growth pattern and carcass characteristics of Somali and Mid-rift valley goats. MSc thesis, Alemaya Univesity, 2001.

Getenet, B., Alemu, Y. & Mekonnen, H., 1999. Performance of lactating Somali does supplemented with different proportions of groundnut cake and wheat bran. In. Livestock production and the environment-Implications for sustainable livelihoods. Ethiopian Society of Animal Production (ESAP) Proceedings, Addis Abeba, Ethiopia.

Gryseels, G. & Anderson, F.M., 1983. Research on farm and livestock productivity in the central high lands: Initial results, 1977-1980. Research report. International Livestock Center for Africa (ILCA), Addis Abeba, Ethiopia.

Hatendi, P.R., Smith, T., Ndlovu, L. & Mutisi, C., 1992. Fattening mature indigenous (Matabele) goats: Effects on animal performance, body and carcass composition. In: Small ruminant research and development in Africa, Proceedings of the first biennial conference of the African small ruminant research network, ILCA, Kenya.

Huanga, H.J., Chioua, P.W.S., Chen, C.R., Chiang, J.K. & Yu, B., 1999. Effects of dried rice distillers' and grain supplementation on the performance of lactating cows. Anim. Feed Sci. Technol. 77, 303- 315.

Institute of Agricultural Research (IAR), 1976. Results of experiments in Animal production (1966/67 to 1975). Animal production report No 1. IAR, Addis Ababa, Ethiopia.

Juárez, R.A.S., Montoyal, E.R., Nevarezl, C.G., Cerrillol, S.M.A. & Mould, F.L., 2004. *In situ* degradability of dry matter and neutral-detergent fibre of thorn scrubland forage consumed by goats in the semi-arid region of north Mexico. British Society of Animal Science, 79, 505-511.

Kadim, I.T., Mahgoub, O., Al-Ajmi, D.S., Al-Maqbaly, R.S., Al-Saqri, N.M. & Ritchie, A., 2003. An evaluation of the growth, carcass and meat quality characteristics of Omani goat breeds. Meat Sci. 66, 203-210.

Kaitho, R.J., Tegegne, A., Umunna, N.N., Nsahlai, I.V., Tamminga, S., Van Bruchem, J. & Arts, J.M., 1998. Effect of Leucenana and Sesbania supplementation on body growth and scrotal circumference of Ethiopian highland sheep and goats fed teff straw basal diet. Livest. Prod. Sci. 54, 173-181.

Kearl, L.C., 1982. Nutrient requirements of ruminants in developing countries. International feedstuff Institute, Uttah, USA.

Kendall, E.M., Ingalls, J.R. & Boila, R.J., 1991. Variability in the rumen degradability and post-ruminal digestion of dry matter, nitrogen and amino acids of canola meal. Can. J. Anim. Sci. 71, 739–754.

Khalili, H., Varvikko, T. & Osuji, P.O., 1993. Supplementation of grass hay with molasses in crossbred (Bos *taurus X Bos indicus)* nonlactating cows: effect of timing of molasses supplements on feed intake, digestion, DM degradation and rumen fermentation. Anim. Feed Sci. Technol. 41, 39-50.

Kidane, G.M., Alemu, Y. & Varvikko, T., 1996. Rumen degradability characteristics of natural pasture hay harvested at different cutting dates. Proceedings of the 4th conference, Ethiopian Society of Animal Production. pp. 164-168.

Kirk, J. A., Cooper, R. A. & Kamwanja, L.A., 1994. Growth, carcass composition and its prediction in the indigenous Malawi goats. J. Anim. Sci. 58(3) 480 (Abstract).

Kumar, S. & Narang, M.P., 1991. Effects of different planes of nutrition on the performance of Gaddi male kids using concentrate rations and kikuyu grass hay. Indian J.Anim.Sci. 61(8), 869-872.

Liu, X., Wang, Z. & Lee, F., 2005. Influence of concentrate level on dry matter intake, N balance, nutrient digestibility, ruminal outflow rate, and nutrient degradability in sheep. Small Rumin. Res. 58, 55–62.

Mahgoub, O., Lu, C.D., Hameed, M.S., Richie, A., Al-Halhali, A.S. & Annamalai, K., 2005. Performance of Omani goats fed diets containing various metabolizable energy densities. Small Rumin. Res. 58, 175-180.

Mavimbela, D.T., 1999. The nutritional value of broiler litter as a feed source for sheep during periods of feed shortage. PhD thesis, University of Pretoria.

McDonald, P., Edwards, R.A. & Greenhalgh, J.F.D, 1995. Animal Nutrition (5th Ed.) Longman Group (UK) LTD, Essex, UK.

Nhan, N.T.H., 1998. Effect of *Sesbania grandiflora, Leucaena leucocephala, Hibiscus rosa-sinensis* and *Ceiba pentadra* on intake, digestion and rumen environment of growing goats. Livestock Research for Rural Development. Vol.10, No.3. www.cipav.org.co/irrd/

Ngwa, A.T., Nsahlai, I.V. & Iji, P.A., 2002. Effect of supplementing veld hay with a dry meal or silage from pods of *Acacia sieberiana* with or without wheat bran on voluntary intake, digestibility, excretion of purine derivatives, nitrogen utilization, and weight gain in South African Merino sheep. Livest. Prod. Sci. 77, 253–264.

Oosting, S.J., 1993. Wheat straw as ruminant feed. Effect of supplementation and ammonia treatment on voluntary feed intake and nutrient availability. PhD thesis, Agricultural University of Wageningen, The Netherlands.

Orskov, E., 1992. Protein Nutrition in Ruminants. Academic Press, London. p.155.

Orskov, E.R., Oiwang, I. & Reid, G.W., 1988. A study on consistency of differences between cows in rumen outflow rate of fibrous particles and other substrates and consequences for digestibility and intake of roughages. Anim. Prod. 47, 45-51.

Peacock, C., 1996. Improving Goat Production in the Tropics, Farm-Africa Publ., London. p.386.

Perdok, H.B. & Leng, R.A., 1989. Role of Protozoa and Fungus in Ruminant Digestion. Eds. Nolan, J.V., Leng, R.A., Demeyer, D.E., Penumbul Books, Armidale, Australia. pp. 291–293.

Perkin Elmer, 1982. Analytical Methods for Atomic Absorption Spectrophotometer. Perkin Elmer Corporation. Norwalk, Connecticut, USA. No.0303-0152.

Preston T.R. & Leng, R. A., 1987. Matching ruminant production systems with available resources in the tropics and sub-tropics. Penambul Books. Armidale, New South Wales, Australia.

Rao, C.K., Reddy, T.J. & Raghavan, G.V. 1996. Studies on rumen metabolic profile in sheep fed Sunflower cake. Indian Vet. J. 73, 741-745.

Rao, D.V., Naidu, M.M. & Raghavan, G.V., 1998. Effect of feeding complete feed containing poultry droppings on rumen nitrogen and total volatile fatty acids in sheep and goats. Indian Vet. J. 75,662-664.

Rotger, A., Ferret, A., Calsamiglia, S. & Manteca, X., 2006. *In situ* degradability of seven plant protein supplements in heifers fed high concentrate diets with different forage to concentrate ratio. Anim. Feed Sci.Technol. 125, 73-87.

Said, A. N. & Adugna, T., 1993. The supplementary value of forage legume hays in sheep feeding. Feed intake, Nitrogen retention and body weight change. Livest. Prod. Sci. 33, 229-237.

SAS Institute Inc., 1999. SAS /STAT users' Guide version 7, SAS Institute, Cary NC, USA.

Satter, L.D. & Slyter, L.L., 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. Br. J. Nutr. 32, 199–208.

Sen, A.R., Santra, A. & Karim S.A, 2004. Carcass yield, composition and meat quality attributes of sheep and goat under semiarid conditions. Meat Sci. 66, 757-763.

Seyoum, B. & Zinash, S., 1989. The composition of Ethiopian feedstuffs. IAR Research Report No.6. IAR, Addis Ababa, Ethiopia.

Shem, M.N., Orskov. E.R. & Kimambo, A.E., 1993. Prediction of voluntary intake and growth rate of cattle fed on crop residues and forages on smallholder farms using the nylon bag technique. Proceedings of the IFS scientific workshop for East African grantees (Animal Production), 21-37.

Supelco Inc., 1990. Analyzing fatty acids by packed column Gas Chromatograph (GC). Bulletin 856. Supelco Inc., Gland, Switzerland.

Tesfaye, W. M., Osuji, P.O., Asfaw, Y. & Alemu, Y., 2001. Effect of wheat bran supplementation on feed intake, body weight change and retained energy in the carcass of Ethiopian highland Zebu (*Bos indicus*) oxen fed Teff straw (*Eragrostis tef*) as basal diet. Proceedings of the 9th Ethiopian Society of Animal Production, Ethiopia, Addis Abeba.

Umunna, N.N., Nsahlai, I.V. & Osuji, P.O., 1995. Degradability of forage protein supplements and their effects on the kinetics of digestion and passage. Small Rumin. Res. 17,145-152.

Urge, M., Merkel, R.C., Sahlu, T., Animut, G. & Goetsch, A.L., 2004. Growth performance by Alpine, Angora, Boer and Spanish wether goats consuming 50 or 75% concentrate diets. Small Rumin. Res. 55, 149-158.

Van Arendonk, J.A.M., Vos, H. & Van Der Werf, J.H.J., 1991. Genetic aspects of feed intake and efficiency in dairy cows. In: Proc. Aust. Assoc. Anim. Brd. and Genetics. 9, 37-44.

Van Niekerk, W.A., 1997. Inname en parsiele verteerbaarheid van 'n aantal weidingsgewasse deur skape en die gebruik van enkele kwaliteitsparameters om inname te voorspel. PhD Tesis, Universiteit van Pretoria, Pretoria.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant. (2nd Ed.). Cornell University Press, Ithaca, New York, USA.

Van Soest, P.J. & Robertson, J.B., 1985. Analysis of forages and fibrous foods. A laboratory manual for animal science. Cornell University, Ithaca, New York, USA.

Van Soest, P.J., Robertson, J.B. & Lewis, B.A., 1991. Methods for dietary, neutral detergent fibre, and non-starch polysaccharides in relation to animal nutrition. Symposium: carbohydrate methodology, metabolism, and nutritional implications in dairy cattle. J. Dairy Sci. 74, 3583-3597.

Varga, G.A. & Hoover, W.H., 1983. Rate and extent of neutral detergent fiber degradation of feedstuffs *in situ*. J. Dairy Sci. 66, 2109-2115.

Wagner, M.W., Havstad, K.M., Doornbos, D.E. & Ayers, E.L., 1986. Forage intake of rangeland beef cows with varying degrees of crossbred influence. J. Anim. Sci. 63, 1484-1490.

Woyengo, T.A., Gachuiri, C.K., Wahome, R.G. & Mbugua, P.N., 2004. Effect of protein supplementation and urea treatment on utilization of maize stover by red Massai sheep. S. Afr.J. Anim.Sci. 34, 23-30.

Zaman, M.S., Mir, Z., Mir, P.S., El-Meadawy, A., McAllister, T.A., Cheng, K.J., ZoBell, D. & Mathison, G.W., 2002. Performance and carcass characteristics of beef cattle fed diets containing silage from intercropped barley and annual ryegrass. Anim. Feed Sci. Technol. 99, 1-11.

Zinash, S. & Seyoum, B., 1991. Utilization of feed resources and feeding systems in the central zone of Ethiopia. Proceedings of the third National Livestock Improvement Conference. IAR, Addis Ababa, Ethiopia. pp.129–132.

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

Anjaneyulu, A.S.R. & Joshi, H.B., 1995. Carcass characteristics and composition of goat meat in Indian breeds- an overview. In: National Symposium on production and marketing of goat meat, CIRG and ISSGPU, India.

AOAC, 1975. Official Methods of Analysis. Association of Analytical Chemists, pp. 497-498.

AOAC, 1990. Official Methods of Analysis. 15th Ed., Association of Analytical Chemists, Virginia, USA, pp. 684.

Arguello, A., Castro, N., Capote, J. & Solomon, M., 2005. Effects of diet and live weight at slaughter on kid meat quality. Meat Sci. 70, 173-179.

Banskalieva, V., Sahlu, T. & Goetsch, A.L., 2000. Fatty acid composition of goat muscles and fat depots: a review. Small Rumin. Res. 37, 255–268.

Bas, P., Dahbi, E., El Aich, A., Morand-Fehr, P. & Araba, A., 2005. Effect of feeding on fatty acid composition of muscles and adipose tissues in young goats raised in the Argan tree forest of Morocco. Meat Sci. 71, 317-326.

Beserra, F.J., Madruga, M.S., Leite, A.M., da Silva, E.M.C. & Maia, E.L., 2004. Effect of age at slaughter on chemical composition of meat from Moxoto goats and their crosses. Small Rumin. Res. 55,177-181.

Carlucci, A., Girolami, A., Napolitano, F. & Monteleone, E., 1998. Sensory evaluation of young goat meat. Meat Sci. 50, 131–136.

Casey, N.H., Van Niekerk, W.A. & Spreeth, E.B., 1988. Fatty acid composition of subcutaneous fat of sheep grazed on eight different pastures. Meat Sci. 23, 55-63.

Casey, N.H., Van Niekerk, W.A. & Webb, E.C., 2003. Goat Meat. In: Encyclopedia of Food Sciences and Nutrition. Eds. Caballero, B., Trugo, L., & Finglass, P., Academic Press, London, pp. 2937-2944.

Central Statistics Authority (CSA), 2004. The 2001/02 Ethiopian Agricultural Sample Enumeration, Executive Summary, May 2004, Addis Ababa, Ethiopia.

Department of Health, 1994. Nutritional aspects of cardiovascular disease. Report on health and social subjects. No. 46. HMSO, London.

Demirel, G., Ozpinar, H., Nazli, B. & Keser, O., 2006. Fatty acids of lamb meat from two breeds fed different forage: concentrate ratio. Meat Sci. 72, 229–235.

Dhanda, J.S., Taylor, D.G, Murray, P.J. & McCosker, J.E., 1999. The influence of goat genotype on the production of Carpetto and Chevon carcasses. 2. Meat quality. Meat Sci. 52, 363-367.

Dhanda, J.S., Taylor, D.G, Murray, P.J., Pegg, R.B. & Shand, P.J., 2003. Goat Meat Production: Present Status and Future Possibilities. Asian-Aust. J. Anim.Sci. 16(12), 1842-1852.

Dikeman, M.E., 1996. The relationship of animal leanness to meat tenderness. Reciprocal Meat Conference Proceedings. 49, 87–101.

El-Gallad, T.T., Allam, S.M., Gihad, E.A. & El-Bedawy, T.M., 1988. Effect of Energy Intake and Roughage Ratio on the Performance of Egyptian Nubian (Zaraibi) Kids from Weaning to One Year of Age. Small Rumin. Res. 1, 343-353.

Enser, M., Hallett, K., Hewitt, B., Fursey, G.A.J., Wood, J.D. & Harrington, G., 1998. Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. Meat Sci. 49, 329–341.

Ethiopian Agricultural Research Organization (EARO), 1999. Livestock and Nutrition Research Program Strategy. EARO, Addis Abeba, Ethiopia.

Ethiopian Export Promotion Agency (EEPA), 2003. Meat export statistics. EEPA, Addis Abeba, Ethiopia.

Ewunetu, E., Rege, J.E.O., Anindo, D.O., Hibret, A. & Alemu, Y., 1998. Carcass and edible non-caracss component yields in Menz and Horro ram lambs. Proceedings of Ethiopian Society of Animal Production, pp. 217-222.

FARM-Africa, 1996. Goat Types of Ethiopia and Eritrea. Physical description and management systems. Published jointly by FARM-Africa, London, UK, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 76 pp.

Field, R.A., Kemp, J.D. & Varney, W.Y., 1963. Indices for lamb carcass composition. J. Anim. Sci. 22, 218.

Fisher, A.V. & de Boer, H., 1994. Carcass measurements and dissection procedures. The EAAP standard method of sheep carcass assessment. Livest. Prod. Sci. 38, 149-159.

Folch, J., Lees, M. & Stanley, G.H.S., 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226, 407-500.

Getahun, L., 2001. Growth pattern and carcass characteristics of Somali and Mid-rift valley goats. MSc thesis, Alemaya Univesity, Ethiopia.

Gibb, M. J., Cook, J. E. & Treacher, T. T., 1993. Performance of British Saanen, Boer x British Saanen and Anglo-Nubian castrated male kids from 8 weeks to slaughter at 28, 33 or 38 kg live weight. Anim. Prod. 57, 263-271.

Gipson, T. A., 1998. Current market trends and potential for meat goat production. J. Anim. Sci. 76(1) (Abstract).

Gryseels, G. & Anderson, F.M., 1983. Research on farm and livestock productivity in the central highlands: Initial results, 1977-1980. Research report. International Livestock Center for Africa (ILCA), Addis Abeba, Ethiopia.

Hankins, O.G., 1947. Estimation of composition of lamb carcasses and cuts. USDA Tech. Bull. 944.

Hoffman, L.C., Styger, E., Muller, M. & Brand, T.S., 2003.The growth and carcass and meat characteristics of pigs raised in a free-range or conventional housing system. S. Afr. J.Anim.Sci.33 (3), 166-175.

Honikel, K.O., 1998. Reference methods for the assessment of physical characteristics of meat. Meat sci. 49, No.4, 447-457.

Horrocks, L.A. & Yeo, Y.K., 1999. Health benefits of Docosahexaenoic acid (DHA). Pharmacological Research, Vol. 40, No. 3. www.idealibrary.com

Hugo, A., Roodt, E. & Van Schalkwyk, F., 2003. Fat quality of pork and its significance in meat technology. In: Consistency of quality, International Meat Symposium. Abstracts and Proceedings. South Africa.

Indian Standard Institution (ISI), 1963. Indian Standard Specification for mutton and goat flesh: Fresh, chilled and frozen. IS.2536. Indian Standard Institution. NewDelhi.

Johnson, D.D., McGowan, C.H., Nurse, G. & Anous, M.R., 1995. Breed type and sex effects on carcass traits, composition and tenderness of young goats. Small Rumin. Res. 17, 57-63.

Kadim, I.T., Mahgoub, O., Al-Ajmi, D.S., Al-Maqbaly, R.S., Al-Saqri, N.M. & Ritchie, A., 2003. An evaluation of the growth, carcass and meat quality characteristics of Omani goat breeds. Meat Sci. 66, 203-210.

Kamble, V.J., Bonde, H.S., Kulkarni, K.D. & Kulkarni, D.N., 1989. Quality aspect of Osmanabadi goat meat. J. Food. Sci.Technol. 26, 99-101.

Latif, M.G.A., Abdelsalam, M.M. & Abdel El Aziz, N.M., 1987. Meat production characteristics of Egyptian Baladi and Angora goats. Meat Sci. 20, 211–216.

Link, B.A., Bray, R.W., Cassens, R.G. & Kauffman, R.G., 1970. Fatty acid composition of bovine skeletal muscle lipids during growth. J. Anim. Sci. 30, 726.

Mahgoub, O., Khan, A. J., Al-Maqbaly, R. S., Al-Sabahi, J. N., Annamalai, K. & Al-Sakry, N. M., 2002. Fatty acid composition of muscle and fat tissues of Omani Jebel Akhdar goats of different sexes and weights. Meat Sci. 61, 381–387.

Mahgoub, O. & Lu, C.D., 1998. Growth body composition and carcass tissue distribution in goats of large and small sizes. Small Rumin.Res. 27, 267–278.

Mariniva, P., Banskalieva, V., Alexandrov, S., Tzvetkova, V. & Stanchev, H., 2001. Carcass composition and meat quality of kids fed sunflower oil supplemented diet. Small Rumin. Res. 42, 219-227.

Mourad, M., Gbanamou, G. & Blade, I.B., 2001. Carcass characteristics of West African dwarf goats under extensive system. Small Rumin. Res. 42, 83-86.

Mtenga, L.A. & Kitaly, A.J., 1990. Growth performance and carcass characteristics of Tanzanian goats fed *Chloris gayana* hay with different levels of protein supplement. Small Rumin. Res. 3, 1-8.

Owen, J. E. & Norman G. A., 1977. Studies on the meat production characteristics of Botswana goats and sheep-Part II: General body composition, carcass measurements and joint composition. Meat Sci. 1, 283-304.

Owen, J.E., Norman G. A., Philbrooks, C.A. & Jones, N.S.D., 1978. Studies on the meat production characterstics of Botswana goats and sheep. Part III: Carcass tissue composition and distribution. Meat Sci. 2, 59-74.

Payne, W.J.A. & Wilson, R.T., 1999. An Introduction to Animal Husbandry in the Tropics, 5th Ed. Blackwell Science Ltd, London, U.K. pp. 815.

Peacock, C., 1996. Improving Goat Production in the Tropics, Farm-Africa Publ., London, pp. 386.

Ponnampalam, E. N., Hosking, B. J. & Egan, A.R., 2003. Rate of carcass components gain, carcass characteristics and muscle longissimus tenderness in lambs fed dietary protein sources with a low quality roughage diet. Meat Sci. 63, 143-149.

Pratiwi, N.M.W., Murray, P.J., Taylor, D.G. & Zhang, D., 2005. Comparison of breed, slaughter weight and castration on fatty acid profiles in the longissimus thoracic muscle from male Boer and Australian feral goats. Small Rumin. Res. (In press).

Purchas, R.W., 1990. An assessment of the role of pH differences in determining the relative tenderness of meat from bulls and steers. Meat Sci. 27, 129-140.

Raes, K., De Semet, S. & Demeyer, D., 2004. Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in, lamb, beef and pork meat: a rewiev. Anim. Feed Sci. Technol. 113, 199–221.

Rao, V.K., Anjaneyulu, A.S.R., Lakshamanan, V., Kowale, B.N. & Sharma, G.C., 1988. Effect of breed, age, sex and conformation on carcass characteristics of market slaughter goats. Indian J. Anim. Sci. 58, 819-822.

Ruvuna, F., Taylor, J.F., Okeyo, M., Wanyoike, M. & Ahuya, C., 1992. Effects of breed and castration on slaughter weight and carcass composition of goats. Small Rumin. Res. 7, 175-183.

Saikia, G., Baruah, K.K., Buragohain, S.C., Saikia, B.N. & Brahma, M.L., 1996. Effect of various energy levels on carcass characteristics and body composition of male cross-bred kids. Indian Vet. J. 73, 31-34.

Samuels, M.L., 1989. Statistics for the life sciences. Collier MacMillan Publishers, London.

Sanudo, C., Santolaria, M.P., Maria, G., Osoria, M. & Sierra, I., 1996. Influence of carcass weight on instrumental and sensory lamb meat quality in intensive production systems. Meat Sci. 42, 195-202.

Smith, G.C., Carpenter, Z.L. & Shelton, M., 1978. Effects of age and quality level on the palatability of goat meat. J. Anim. Sci. 46, 1229–1235.

Snowder, G.D., Glimp, H.A. & Field, R.A., 1994. Carcass characteristics and optimal slaughter weights in four breeds of sheep. J. Anim. Sci. 72, 932-937.

Statistical Analysis Systems (SAS), 2001. SAS User's Guide. Statistics Version 8, SAS Institute Inc. Cary, NC, USA.

Tesfaye, A.T., Fidalis, M.N., Hoeven, E., Yadav, B.R., Hanotte, O. & Hanlin, H., 2004. Genetic characterization of indigenous goat populations of Ethiopia using microsatellite DNA markers. In. 29th International conference on animal genetics, ISAG September 11-16, 2004, Tokyo, Japan.

Tshabalala, P.A., Strydom, P.E., Webb, E.C. & de Kock, H.L., 2003. Meat quality of designated South African indigenous goat and sheep breeds. Meat Sci. 65, 563-570.

Ulbricht, T.L.V. & Southgate, D.A.T., 1991. Coronary heart disease: seven dietary factors. Lancet 338, 985–992.

Webb, E.C., 1992. The influence of dietary energy levels on subcutaneous fatty acid profiles and meat quality in sheep. M.Sc thesis, University of Pretoria.

Webb, E.C. & Casey, N.H., 1995. Genetic differences in fatty acid composition of subcutaneous adipose tissue in Dorper and South African Mutton Merino wethers at different live weights. Small Rumin. Res. 18, 81-88.

Williams, C., 2000. Dietary fatty acids and human health. Annales de Zootechnie, 49, 165–180.