Chapter 6

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

(Submitted to Small Ruminant Research Journal)

6.1 Abstract

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

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

6.2 Introduction

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

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

6.3. Materials and Methods

6.3.1. Animals and management

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

6.3.2. Chemical composition

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

6.3.3. Meat physical characteristics

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

6.3.4. Long chain fatty acid (LCFA)

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

6.3.5. Statistical analysis

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

6.4. Results and discussion

6.4.1 Feed composition

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

6.4.2. Chemical composition of the muscle

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

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

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

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

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

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

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

[b] Fed groups =stall-fed

Sig [c] = Significance between initially slaughtered genotypes

Sig [d]= Significance between fed genotypes

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

6.4.3. Physical characteristics of Longissimus muscle

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

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

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

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

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

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

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

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

[b] Fed groups =stall-fed

Sig [c] = Significance between initially slaughtered genotypes

Sig [d]= Significance between fed genotypes

NS (P>0.05)

* * Significance (P<0.01)

* * * Significance (P<0.001)

6.4.4. LCFA composition

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

* Significance (P<0.05)

* * Significance (P<0.01)

* * * Significance (P<0.001)

* * * * Significance (P<0.0001)

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

6.5. Conclusion

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

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Chapter 7

7.0. General conclusions, recommendations and critical evaluation.

7.1. General conclusions

The objectives of the study were:

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

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

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

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

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

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

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

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

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

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

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

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

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

7.2. Recommendations

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

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

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

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

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

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

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

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

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

7.3. Critical evaluation

7.3.1. Contributions of the study

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

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

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

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

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

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

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

7.3.2 Retrospective comments on the study

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

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

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

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

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7.5. *Curriculum Vitae*

The author obtained his BSc. (Animal Science) degree in 1987 with distinction from Alemaya University of Agriculture, Ethiopia. He has been employed since September 1987 and served as a researcher at different capacities in the small ruminant research program, Ethiopia. He obtained his M.Sc. degree in 2000 from the Univeristy of J.N.K.V.V., India with a thesis entitled “Effect of concentrate supplementation on carcass characteristics of Barbari kids maintained on a tree leaves based feeding system.” The author has so far authored and co-authored 4 journal articles and 13 proceedings/workshop papers. He is a member of the Ethiopian Society of Animal Production, Animal Nutrition Society of India and South African Society of Animal Science. He enrolled for a PhD degree in January 2003 at the Department of Animal and Wildlife Sciences, University of Pretoria, South Africa.