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

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Abstract

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

Keywords: Indigenous goats, carcass yield, carcass composition, primal cuts, non-carcass components
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Introduction

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

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

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

Materials and Methods

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

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

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

Table 1 Chemical composition of the dietary components and experimental diets (g/kg dry matter - DM)

Item	DM	Ash	OM	CP	NDF	ADF	ADL	Ca	P	IVDMD
Native grass hay	917.8	88.7	911.3	50.6	720.8	389.3	38.0	5.3	2.8	48.0
Wheat bran	870.3	43.4	956.6	191.9	442.0	128.4	24.3	2.1	10.8	68.7
Noug cake	919.3	100.5	899.5	345.0	353.4	270.3	106.4	8.5	13.7	63.2
Concentrate	887.9	65.8	934.2	216.6	398.3	141.1	35.4	3.2	10.9	68.9
Diet 1	897.8	81.1	918.9	153.1	579.6	267.2	33.9	3.9	7.9	57.0
Diet 2	895.3	78.9	921.1	175.6	514.8	229.0	35.5	3.7	9.4	61.3
Diet 3	891.5	70.6	929.4	196.2	436.4	187.3	30.9	3.0	10.8	66.7

OM – organic matter; CP – crude protein; NDF – neutral detergent fibre; ADL – acid detergent lignin; Ca – calcium; P – phosphorus; IVDMD – *in vitro* dry matter digestibility (%)

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

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

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

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

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

Results and Discussions

The crude protein (CP), NDF and IVDMD values of the native grass hay were comparable to the results reported by Zinash & Seyoum (1991). The CP, NDF and ADF values for wheat bran and noug cake were also similar to those reported by Seyoum & Zinash (1989) and Tesfaye *et al*. (2001). The low CP and high NDF values of the native grass hay suggested that it was of a poor quality roughage (Table 1).

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

Breed had a significant effect on most of the carcass parameters (Table 3), while dietary effects were statistically similar for most traits, except for DP and some non-carcass components. Most carcass measurements between the initial carcasses of the three breeds were similar ($P > 0.05$). Statistical differences between the breeds (Table 3) were evident for most carcass traits after correcting for initial weight. The LES breed had the highest (P < 0.001) pre-slaughter and slaughter weights, EBW, HCW and CCW. As with the growth performance, the Afar and CHG breeds had similar (P > 0.05) values for these parameters.

Table 2 Body weight and growth rates (least square mean ± s.e) of selected Ethiopian goat breeds stall-fed with a grainless diet

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

IBW - initial body weight; FBW - final body weight; ADG - average daily gain
CHG - Central Highland goat; LES - Long-eared Somali
[a b] Means within columns with different superscripts differ (P < 0.05)

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

The DP on an EBW basis was the highest (P < 0.01) on diet 1. Diet 1 also tended (P > 0.05) to have higher values for pre-slaughter and SBW, EBW, HCW, CCW and DP on a SBW basis. Kumar *et al.* (1991) reported that the plane of nutrition did not significantly affect carcass weights, DP and proportions of cuts in Gaddi goats at the age of 14 months. Reddy & Raghavan (1988), Hatendi *et al.* (1992), El Hag & El Shargi (1996) and Sheridan *et al.* (2003) recorded similar effects on DP on SBW and / or carcass weights. However, Mahgoub *et al.* (2005) indicated that increasing ME levels in the diet fed to Omani goats increased carcass weight, EBW and DP.

Chilling losses were higher (P < 0.01) in the carcass of initial CHG probably due to their lower fat content (Table 4). However, the chilling loss was similar (P > 0.05) between the fed groups, though the CHG had a 10% greater loss. Chilling losses ranging from 2.3 to 8.7% have been reported for different goat genotypes and weights (El Khidir *et al.*, 1998; Getahun, 2001).

Breed affected rib-eye area, fat thickness and total tissue depth. The rib eye area of the fed genotypes ranged from 6.4 to 8.3 cm^2 (Table 3). The LES had the larger area, though statistically similar to Afar. However, CHG had the lowest (P<0.001) rib-eye area. These values agree with the reports of Rao *et al.* (1985) and Getahun (2001) at similar weight or age.

Fat thickness in the initial carcass was not measurable and regarded as minimal. Among the stall-fed breeds, the CHG had the thinnest (P < 0.0001) fat cover of the three goat breeds (Table 3). Total tissue depth (fat + lean) differed (P < 0.0001), with the LES the highest and CHG the smallest.

The ultimate carcass pH of the initial slaughter group was between 5.78 and 5.94 (P < 0.05). The pH range in the carcasses of the experimental groups was between 5.61 and 5.67 and fitted into the range of 5.49 to 5.86 reported and considered normal by various authors (Dahanda *et al.*, 1999b; Arguello *et al.*, 2005). The relatively higher pH (5.94) of the carcasses of pre-experimental slaughtered CHG group could have been due to a lower glycogen reserve caused by either physical/emotional stress or inadequate nutrition from the extensive management system. High ultimate pH values for goat meat are also reported for different breeds and muscles in the literature (Webb *et al*., 2005).

Table 3 Carcass characteristics of Ethiopian goats fed a grainless diet (least square mean and PSE)

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

[+] Initial - slaughter made at the start of the study, [++] Fed groups - stall-fed
CHG - Central Highland goat; LES - Long-eared Somali;
SBW - slaughter body weight (SBW); EBW - empty body weight; PSE - pooled standard error
[a b c] Means within rows for different group with different superscripts differ ($P < 0.05$)

Conformation is an important visual criterion that has a bearing on the perceived market value of a carcass. Conformation, however, can be misleading since a subjective assessment of the conformation lamb carcasses accounts for <10% of the variation in meat yield (Bruwer, 1984). Leg length ($P < 0.001$), buttock circumference ($P < 0.01$) and tail weight ($P < 0.01$) differed between breeds. Leg length and tail weight were similar ($P > 0.05$) in CHG and LES but Afar had the shortest leg length and smallest tails ($P < 0.01$). The LES had a larger buttock circumference than Afar ($P < 0.01$) and CHG ($P < 0.05$). Carcass compactness ratios were 145.6 (LES), 130.8 (Afar) and 129.3 g/cm (CHG) ($P < 0.0001$). Mourad *et al*. (2001) reported a higher compactness index (0.19 kg/cm) than the present finding, which was mainly due to the shorter carcass length of West African Dwarf goats.

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

Fasting loss was similar ($P > 0.05$) between breeds and diets and ranged from 5.23 to 5.39% in the stall-fed goats (Table 3). This finding is in agreement with the starvation shrinkage reported by Ameha & Mathur (2000).

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

The physical composition, chemical fat, proportion of primal cuts, lean: bone and lean: fat ratios are shown in Table 4. Comparison of the composition of carcass of the initial slaughtered group with the carcass of fed groups indicated that the bone proportions decreased (P < 0.01) and the fat increased (P < 0.001) in the fed groups. The findings agree with Hatendi *et al.* (1992) and Mahgoub *et al.* (2005) who reported that the initial slaughter groups had lower carcass fat values than the fed groups. Singh *et al*. (1991) and Dhanda *et al.* (1999a) also documented that the percentage of bone decreased significantly with age and weight.

Among the initially slaughtered groups, CHG had the lowest fat proportion. The stall-fed CHG made considerable improvement in its fat proportion (3.3 times over its initial fat proportion). However, it still had the lowest fat proportion (P < 0.001) compared to LES and Afar under feedlot conditions. The same breed had the lowest (P < 0.001) chemical fat of all the breeds tested (Table 4). Significant differences in carcass fat content between goat breeds were also reported by Johnson *et al*. (1995).

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

Table 4 Physical composition, chemical fat, proportion of primal cuts, lean: bone and lean: fat ratios (least square mean and PSE) of selected Ethiopian goats stall-fed with a grainless diet

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

CHG - Central Highland goat; LES - Long-eared Somali; PSE - pooled standard error
$^{a\ b\ c}$ Means within rows for different groups with different superscripts differ (P < 0.05)

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

Lean to bone and meat (lean + fat) to bone ratios of the initial carcass were similar between genotypes. However, CHG had the highest lean : fat ratio (Table 4) due to its lowest fat proportion. Considering the fed genotypes, LES and Afar yielded similar lean : bone ratio and CHG had the lowest (P < 0.001) ratio. Moreover, LES and Afar had comparable (P > 0.05) lean : fat and meat : bone ratios but CHG had a lower meat : bone (P < 0.001) and wider (P < 0.001) lean : fat ratio. The effect of genotype on the different ratios was also reported by Dhanda *et al*. (1999a) and Getahun (2001). Carcass composition (ribs 9 - 11th) of Zaraibi yearling goats fed different concentrate to roughage ratios (El-Gallad *et al*., 1988) was 69.3 - 75.0, 5.0 - 12.6, 16.1 - 20.0, 4.3 - 5.1 % and 3.8 - 5.2 for lean, fat, bone, chemical fat and meat : bone ratio, respectively. These values are comparable with the present findings except that Ethiopian yearling goats fed a grainless diet had higher chemical fat (10.3 - 14.0%) and meat : bone ratios (4.03 - 5.01).

Table 5 Weights and proportion of non-carcass components of Ethiopian goats (least square mean and PSE)

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

EBW – empty body weight; GIT - gastro-intestinal tract; CHG - Central Highland goat; LES - Long-eared Somali; PSE - pooled standard error
$^{a\ b\ c}$ Means within rows for different groups with different superscripts differ (P < 0.05)

The weights and proportion of non-carcass components of Ethiopian goats are presented in Table 5. Breed significantly affected the weights of most edible and non-edible components of stall-fed goats. El Hag & El Shargi (1996) and Kadim *et al.* (2003) also observed genotype effects in different goats. The LES had the heaviest (P < 0.001) weights for liver, heart, kidney, total internal organ and empty GIT. The weights of blood, full GIT, digestive contents, skin and feet were significantly affected by breed. The proportions of head, blood and feet on EBW basis and digestive contents on SBW basis also differed between breeds. Most of the weights of non-carcass components are comparable with the report of Getahun (2001) for Somali goats. The head and the skin proportions of Maradi (Adebowale, 1981) and South African indigenous goats (Tshabalala *et al.*, 2003) were also similar to Ethiopian goats. The weights of kidney, pancreas and total internal organs were affected by diet and these weights were less (P < 0.01) in diet 1. Significant effect of diet on pluck weight was also reported in Mubende goats (Okello *et al*., 1994). However, the other non-carcass components were not affected (P > 0.05) by diet. This finding agrees with those of Kumar *et al.* (1991) and El Hag & El Shargi (1996).

Distribution of non-carcass fat of Ethiopian goats is shown in Table 6. In the carcass of initial sample, breed did not significantly affect the weight of internal fats. However, each fat depot of stall-fed goats was significantly affected by breed and did not differ (P > 0.05) between dietary treatments. As for the carcass traits, CHG had the lowest scrotal fat (P < 0.001), kidney, pelvic, gut fat (P < 0.05) and total internal fat (P < 0.01) compared to the other breeds. The values obtained for the LES were the highest and comparable with those of Afar goats. Differences in deposition of internal fat in various breeds of goats were also reported by Mahgoub & Lu (1998) and Kadim *et al.* (2003).

Table 6 Distribution of non-carcass fat of Ethiopian indigenous goats fed a grainless diet (least square mean and PSE)

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

EBW – empty body weight; CHG - Central Highland goat; LES - Long-eared Somali;
PSE - pooled standard error
[a b c] Means within rows for different group with different superscripts differ (P < 0.05)

Comparison of stall-fed Ethiopian goats with tropical breeds, such as Indian goats (Sen *et al.*, 2004), at similar age and slaughter weight indicated that Ethiopian goats had less total non-carcass fat (3.01 *vs.* 6.74% on SBW basis) but more chemical fat (12.6 *vs.* 3.2%) than the Indian goats. The difference in the non-carcass fat can mainly be contributed to breed. However, the difference in chemical fat may be due to the difference in sample location and breed. Moreover, Ethiopian indigenous goats had more chemical fat (10.3 - 14.0 *vs.* 4.3 - 5.1%) compared to yearling stall-fed Zaraibi goats of Egypt (El-Gallad *et al*., 1988). The Ethiopian goats had less total non-carcass fat and relatively higher carcass fat, which may help to minimize chilling losses and improve the eating quality of the meat. Owen *et al.* (1978) indicated that even when the market requirement is for a lean carcass, a certain level of carcass fat (10 to 15%) could be desirable from the consumer's point of view so that the cooked meat does not become too dry. Mariniva *et al.* (2001) also documented that goat meat lacks juiciness and an increased amount of subcutaneous and intermuscular fat would prevent the carcass from drying out during hanging.

Conclusion

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

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

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