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Meat Quality Characteristics of Small East African Goats and Norwegian Crosses Finished under Small Scale Farming Conditions

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ABSTRACT: The aim of the experiment was to study the effect of feeding system on meat quality characteristics of Small East African (SEA) goats and their crosses with Norwegian (SEA×N) goats finished under small scale farming conditions. Twenty four castrated goats at the age of 18 months with live body weight of 16.7±0.54 kg from each breed (SEA and SEA×N) were distributed in a completely randomized design in a 2×3 factorial arrangement (two breed, and three dietary treatments). The dietary treatments were; no access to concentrate (T0), 66% access to *ad libitum* concentrate allowance (T66) and 100% access to *ad libitum* concentrate allowance with 20% refusal (T100) and the experimental period was for 84 days. In addition, all goats were allowed to graze for 2 hours daily and later fed grass hay on *ad libitum* basis. Daily feed intakes were recorded for all 84-days of experiment after which the animals were slaughtered. Feed intake of T100 animals was 536 g/d, which was 183 g/d higher than that of T66 group. Supplemented goats had significantly ($p<0.05$) better feed conversion efficiency. The SEA had higher ($p<0.05$) hot carcass weight (8.2 vs 7.9 kg), true dressing percentage (54.5 vs 53.3) and commercial dressing percentage (43.3 vs 41.6) compared to SEA×N. There was no significant difference ($p>0.05$) for dressing percentage and carcass conformation among supplemented goats except fatness score, total fat depots and carcass fat which increased ($p<0.05$) with increasing concentrate levels in the diet. Increasing level of concentrate on offer increased meat dry matter with subsequent increase of fat in the meat. Muscle pH of goats fed concentrate declined rapidly and reached below 6 at 6 h post-mortem but temperature remained at 28°C. Cooking loss and meat tenderness improved ($p<0.05$) and thawing loss increased ($p<0.05$) with ageing period. Similarly, meat tenderness improved ($p<0.05$) with concentrate supplementation. Shear force of muscles varied from 36 to 66, the high values been associated with *Semimembranosus* and *Gluteobiceps* muscles. The present study demonstrates that there are differences in meat quality characteristics of meat from SEA goats and their crosses with Norwegian breeds finished under small scale farming conditions in rural areas. Therefore, concentrate supplementation of goats of both breeds improves meat quality attributes.
(**Key Words:** Concentrate Supplementation, Fattening, Goats, Meat Quality)

INTRODUCTION

The demand for quality meat in Tanzania is growing due to expanding markets composed of tourism, mining industries, expatriates as well as increased income and purchasing power of the society (Mushi et al., 2006). The importance of goat farming has increased due to their fast economic return. Goats provide more meat and milk per unit live weight per year than other large ruminants. Goat production in tropical countries involves grazing on natural pastures whose availability and quality is highly variable. Moreover, these animals produce poor carcasses of low quality meat (low carcass weight, poor conformation and tenderness). Nutrition and management are considered crucial in determining the quantity, quality and economics of meat production (Agnihotri et al., 2006). Although there is now a considerable number of a published research on indigenous types of small ruminants in tropical areas of Africa, much of the published work has the disadvantage of having been carried out under controlled conditions at research stations and the results may not reflect the actual

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situation of small scale production systems prevailing in rural areas.

Data on station experimentation with animals fed on low quality roughage show improved performance and satisfactory fattening performance for both Small East African (SEA) and crossbred goats when they are supplemented with concentrate feeds (Hango et al., 2007; Mushi et al., 2009; Safari et al., 2009). However how these goats will perform in fattening dietary regime under small scale farming conditions in Tanzania is yet to be documented. However there are no studies, focusing on meat quality attributes of goats in connection with feeding and post slaughter handling of carcasses. Results of on station studies have seldom been extended to on farm verification. This being the case, replicability of on station results should be done under prevailing small scale farming conditions.

Differences in meat quality attributes in cattle and small ruminants caused by breed, feeding and management practices has been reported by Shija et al. (2013) who concluded that feedlot strategies under traditional animal production systems in the rural areas in the tropics may be different from that of modern production systems using improved breeds of animals. Concentrate supplementation besides having high feeding value, improves the utilization of roughage fed with them. Kochapakdee et al. (1994) have reported the importance of concentrate supplementation in growth and productivity of sheep and goats in a pasture based grazing. They further stressed on the need to study the quality of meat of goat from different breeds of goats under existing feeding systems in rural areas in order to come with appropriate improvement strategies for feedlotting goats. The aim of the experiment was therefore to study the effect of feeding forage alone or in combination with different levels of concentrate on meat quality characteristics of SEA goats and their crosses with Norwegian Goats under small scale farming system.

MATERIALS AND METHODS

Location of the study

The study was carried out in Gairo division in Kilosa district, Morogoro region, Tanzania. The altitude of the division ranges between 1,076 to 1,631 m above sea level. Gairo is characterized by unreliable and poorly distributed rains. The area receives an average of 600 to 800 mm of rain annually.

Animals and management

The study comprised of two breeds of goats i.e. SEA goats and their crosses with Norwegian (SEA×N). The experimental animals at the age of 18 months and live BW of 16.7±0.54 kg were purchased from auction markets in Gairo district and transported to a farm owned by a goat keeper in the area for effecting the experiment. Twenty four goats from each breed (SEA and SEA×N) were distributed in a completely randomized design in a 2×3 factorial arrangement (two breed and three dietary treatments). The three dietary treatments were; no access to concentrate (T0), 66% access to *ad libitum* concentrate allowance (T66) and 100% access to *ad libitum* concentrate allowance with 20% refusal (T100) respectively. The feeding trial extended for a period of 84 d. In addition, all animals were offered hay *ad libitum* throughout the experimental period.

Feeds and feeding of animals

The concentrate consisted of 70% maize bran, 28% sunflower seedcake, 1.3% lime, 0.5% mineral-vitamins mixture and 0.2% table salt (Table 1). During the adaptation period of 14 d, all goats were protected against internal and external parasites with Ivermectin. During the same period goats were group fed with hay *ad libitum* and in addition, those on T66 and T100 received 200 g of concentrate per goat per day in order for the animals to get used to the diet. Animals were grazed on pastures around the farm from 1000 to 1200 h after which they were brought back to their group feeding pens (four animals per pen) and animals had free access to drinking water. Feeding of concentrates and hay were done twice a day in two equal portions at 0830 h in the morning before grazing and in the afternoon at 1430 h. Feed intake was obtained by difference between feed offered and refusal. However, quantity of feed during grazing period was not possible. During experimentation, three goats (two from SEA×N crossbred and one from SEA) died from Orf disease (Contagious Ecthyma).

Slaughter procedure, carcass grading and measurements

Goats were slaughtered after 16 h fasting with access to

Table 1. Chemical composition of concentrate, grass hay and sward

Component (g/kg dry matter)	Concentrate	Grass hay	Sward
Dry matter	944.5	956.7	947.8
Organic matter	923.7	951.4	913.8
Ash	72.1	46.5	81.7
Crude protein	143.7	41.0	106.9
Ether extracts	91.1	5.5	6.6
Crude fibre	141.9	359.1	268.3
Nitrogen free extract	495.7	504.6	484.3
Neutral detergent fibre	410.6	791.4	662.7
Acid detergent fibre	170.8	481.5	365.8
In vitro dry matter digestibility	540	404	391
In vitro organic matter digestibility	553	411	373
Metabolizable energy (MJ/kg DM)	12.2	9.5	9.6

drinking water in the halal method according to Islamic tradition in which the head was removed at the atlanto-occipital joint and forefeet at the carpal-metacarpal joint and hind feet at the tarsal-metatarsal joint. Subsequently, the carcasses were divided longitudinally into two halves. Dressing percentages (DP) was calculated as the hot carcass weight (HCW) expressed as a percentage of empty body weight (True DP) or as a percentage of slaughter body weight (Commercial DP). Kidneys, kidney fat and pelvic fat were included in the definition of carcass. Carcasses were then scored for conformation (scale from E = excellent to P = poor) and fatness (scale from 1 = none or low fat cover to 5 = entire carcass covered with fat) based on EUROP classification system for goats (Johansen et al., 2006). Each of the five classes for conformation and fatness were divided into three subclasses; –, 0, or + to form 15 grades, Grade 1 is P- for conformation class and 1- for fat class. Grade 15 is E+ for conformation class and 5+ for fat class. Omental fat, mesenteric fat, kidney fat, pelvic fat, heart fat and scrotal fat were removed and weighed separately. Various linear measurements which were taken on the right half-carcasses were; internal carcass length (from the lumbo-sacrajoint to the cervico-thoracic joint), carcass depth (from the dorsal to the ventral edges of the carcass side along the 9th rib), hind leg length (from the ridge of the distal end of the tibia to the cut edge of the subcutaneous fat along a line joining the anterior pubic symphysis), and hind leg circumference (Moran and Wood, 1986). A digital thermometer and portable pH-meter (Knick-portamess 910, Germany) were used to measure temperature and pH of meat at 45 min, 6 h and 24 h after being chilled at 0°C at the same point on the geometric centre of *M. Gluteobiceps* of the right half carcasses.

Muscle sampling for physico-chemical properties and carcass composition

Ten muscles namely; *Semimembranosus*, *Semitendinosus*, *Gluteobiceps*, *Vastus lateralis*, *Rectus abdominis*, *Longismuss dorsi* (LD), *Psoas major*, *Supraspinatus*, *Infraspinatus*, and *Triceps branchii* were excised from the left half of carcasses 6 h post-mortem (PM). Further, LD muscle was split into 3 blocks measuring 7 cm long. They were then assigned to 0, 6, and 9 days of ageing and stored in plastic bags. The muscles were weighed before being stored in a refrigerator set at 4°C overnight. The LD samples for ageing remained in the refrigerator for 6 h (0 day), 6 and 9 days respectively before shifting into the freezer. The remaining parts of the left half-carcasses were dissected into muscle, fat and bone to estimate the carcass physical composition. Total weight of muscle was recorded and included weights of the ten muscles sampled at 6 h PM. Thereafter, muscle and fat tissues were thoroughly mixed together; minced (5 mm sieve) and three sub-samples were taken for chemical analyses according to AOAC (2000).

Estimation of thawing loss, cooking loss and Warner-Bratzler shear force

Each frozen muscle was weighed (W1), thawed at 4°C for 24 h. The bag was opened and muscles were then blotted dry with filter paper and weighed (W2). Thawing loss (%) was calculated as; ([W1–W2/W1)×100. For determination of cooking loss, samples were weighed (W3) in the water tight vacuum packed bags and then cooked in thermostatically controlled water bath (Fisher scientific, Pittsburgh, PA, USA) set at 75°C for 60 min as described by Hoffman et al. (2003). Following cooking, meat samples were cooled for 4 h and samples were taken from the bags dried with filter paper and reweighed (W4). Cooking loss was expressed as the percentage loss related to initial weight: ([W3–W4]/W3)×100. Three sub-samples, cut parallel to the muscle fibres direction with a cross section of 1×1 cm, were removed from each cooked muscle sample. Shear force values of sub-samples were determined using a Zwick/Roell (Z2.5, Ulm, Germany) equipped with a Warner Bratzler (WB). Each sub-sample obtained from cooked muscle sample was sheared twice and the forces obtained were recorded. Each sample was measured twice and a mean value was calculated as maximum shear force value.

Statistical analysis

Data were analyzed using the general linear model procedure of 9.2 version (SAS, 2002), for the effect of breed and dietary treatment on meat quality attributes. For carcass grading and meat quality, slaughter weight was used as covariate. Each animal served as an experimental unit for all the parameter assessed. Further, in the analysis of muscle physico-chemical properties fixed effects included breed, dietary treatment, muscle type and their interaction. In all analyses, when differences between means were significant in analysis of variance, they were separated by probability differences statement at $p<0.05$.

RESULTS

Feed intake

Grass hay dry matter (DM) intake declined from T0 by 0.32 and 0.39 kg for T66 and T100 goats, respectively, with corresponding increased concentrate DM intake by 0.03 and 0.14 kg (Table 2). The *ad libitum* concentrate intake of animals was 536 g/d, which was 183 g/d higher than the concentrate intake by goats in T100 and those in T66 and T0 was 123.9 and 154 g/d, respectively. The DM intake of grass hay and its metabolizable energy (ME) declined as a amount of concentrate increased. The results showed that the animals in T100 had very little hay intake which

Table 2. Means for feed intakes and DM intake (% live weight) of castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Breed (B)		Diet (D)		
	SEA×N	SEA	T0	T66	T100
Feed intake (g DM/d)					
Concentrate	454.1	435.1	-	352.9	536.3
Hay	351.2	324.1	459.8	137.5	78
Total feed intake	805.3	759.2	459.8	490.4	614.3
Metabolizable energy MJ (ME/d)					
Concentrate	5.5	5.3	-	4.3	6.5
Hay	3.3	3.1	4.4	1.3	0.7
Total ME intake	8.9	8.4	4.4	5.6	7.2
Intake (% body weight)	4.3	4.2	2.7	2.6	3.2
FCR (kg DM feed/gain)	27.5	35.3	39.8	12.2	10.8

DM, dry matter; SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; ME, metabolizable energy; FCR, feed conversion ratio.

constituted 12.7% of total intake. Efficiency feed utilization improved with concentrate supplementation, and T66 and T100 animals had better feed conversion ratio, almost three fold than that in T0.

Carcass yield, grading and classification

Genotype had a significant (p<0.05) effect on HCW, True and Commercial DP with SEA goats having the highest (p<0.05) HCW and DP (Table 3). The DP ranged from 52.7% to 54.9% and 37.2% to 45.7% for True and Commercial DP respectively. Diet had a significant effect (p<0.001) on Commercial DP and True DP (p<0.01). There was no significant difference observed for carcass conformation among supplemented goats but fatness score of the carcasses increased (p<0.05) with level of concentrate supplementation. Hind leg circumference (cm) was highly (p<0.001) affected by diet. Supplemented goats displayed comparable and greater values (p<0.05) for hind leg circumference than that of non-supplemented goats.

Fat depots

Goats fed on T100 had more fat depot than T66 except weight of kidney and pelvic fat were similar and higher than weight obtained in no supplemented goats (Table 4). The weight of the omental fat and total fat depot increased (p<0.05) with level of concentrate on offer. When depot were expressed as percentage of slaughter weight the score were four fold higher compared to those obtained from

Table 3. Carcass grading and measurement of castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Breed (B)		Diet (D)			Significance		
	SEA×N	SEA	T0	T66	T100	B	D	B×D
Body weight (kg)								
Initial	16.8±0.5	16.6±0.5	16.7±0.7	16.8±0.6	16.5±0.6	NS	NS	NS
Final	19.9±0.5	19.4±0.4	17.7±0.6[b]	20.3±0.5[a]	21.0±0.5[a]	NS	**	NS
Hot carcass	7.9±0.1[b]	8.2±0.1[a]	7.1±0.1[b]	8.3±0.1[a]	8.6±0.1[a]	*	***	NS
Dressing percentage (DP)								
True DP	53.3±0.3[b]	54.5±0.3[a]	52.7±0.5[b]	54.1±0.4[a]	54.9±0.4[a]	**	**	NS
Commercial DP	41.6±0.5[b]	43.3±0.5[a]	37.2±0.7[b]	44.3±0.6[a]	45.7±0.6[a]	*	***	NS
EUROP grading(1-15 points)								
Conformation	5.6±0.3	5.6±0.3	3.5±0.4[b]	6.2±0.3[a]	7.0±0.4[a]	NS	***	NS
Fatness	5.7±0.5	5.8±0.5	2.6±0.7[c]	6.2±0.6[b]	8.5±0.6[a]	NS	***	NS
Linear carcass measurements (cm)								
Carcass length	51.4±0.3	50.5±0.3	50.8±0.5	51.1±0.4	51.0±0.4	NS	NS	NS
Carcass depth	23.3±0.4	22.9±0.4	23.3±0.5	23.1±0.4	22.9±0.5	NS	NS	NS
Hind leg length	35.5±0.6	36.8±0.6	37.9±0.9	35.4±0.7	35.3±0.8	NS	NS	*
Hind leg circumference	28.6±0.4	29.3±0.4	26.9±0.5[b]	29.7±0.4[a]	30.2±0.5[a]	NS	***	NS

SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; NS, non significant.

[abc] Least square means with different superscripts within breed and diet in the same row differ (p<0.05) according to the indicated level of significance.

* p<0.05; ** p<0.01; *** p<0.001.

Table 4. Fat depots in castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Breed (B)		Diet (D)			Significance		
	SEA×N	SEA	T0	T66	T100	B	D	B×D
Weights (g)								
Kidney fat	68.0±9.10	67.4±8.89	26.2±12.74[b]	76.26±10.62[a]	100.6±10.96[a]	NS	***	NS
Pelvic fat	63.4±9.52	72.3±9.30	18.4±13.32[b]	78.1±11.10[a]	107.0±11.46[a]	NS	***	NS
Mesenteric	42.6±5.37	30.9±5.24	21.1±7.51[b]	32.4±6.26[b]	56.7±6.46[a]	NS	**	NS
Omental fat	188.1±26.62	230.7±26.01	92.3±37.26[c]	215.5±31.05[b]	320.4±32.05[a]	NS	***	NS
Heart fat	16.0±4.18	20.5±4.08	7.3±5.85[b]	16.2±4.87[b]	31.2±5.03[a]	NS	*	NS
Scrotal fat	41.5±6.01	46.4±5.88	19.9±8.42[b]	40.6±7.01[b]	71.3±7.24[a]	NS	***	NS
Total fat depots (kg)	0.4±0.05	0.5±0.05	0.2±0.07[c]	0.5±0.06[b]	0.7±0.06[a]	NS	***	NS
Depot % SWT	2.1±0.23	2.3±0.23	0.7±0.33[c]	2.3±0.27[b]	3.4±0.28[a]	NS	***	NS

SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; NS, non significant; SWT, slaughter weight.

[abc] Least square means with different superscripts within breed and diet in the same row differ ($p<0.05$) according to the indicated level of significance.

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

goats fed T0.

Carcass physical and chemical compositions

There was no significant ($p>0.05$) effect of breed on carcass physical composition (Table 5). Based on dietary levels, the mean proportions of the various carcass tissues ranged from 64% to 67%, 3% to 15%, and 21% to 30% for muscle, fat and bone respectively. Dietary levels had a significant effect ($p<0.001$) on proportion of fat and bone of carcasses. Fat as percent of carcass increased ($p<0.05$) with increasing level concentrate in the diet. As expected, goats fed T100 had highest ($p<0.05$) proportion of fat and lowest ($p<0.05$) proportion of bone followed by T66 and T0. On the other hand, the proportion of bone decreased ($p<0.05$) with increasing carcass fat.

Dietary levels had highly significant ($p<0.001$) on percentage of DM, moisture, ash, protein and fat. Concentrate supplemented goats had similar values for ash, protein and fat contents, lower ($p<0.05$) values for ash and protein but higher ($p<0.05$) value for fat content than non-supplemented goats. In addition, increasing levels of concentrates on offer increased ($p<0.05$) DM of the meat but decreased ($p<0.05$) content of water in the meat.

Post-mortem temperature and pH decline

Muscle temperature and pH were independent ($p>0.05$) of breed effect during PM temperature decline (Table 6). Differences in temperature between carcasses from goats fed different levels of concentrate were significant at 45 min ($p<0.01$) and 6 h ($p<0.001$) but were not significant at 24 h PM. Carcass temperature for goats under T0 was lower ($p<0.05$) up to 6 h PM. Similarly, the effect of dietary levels on pH decline at different times PM was significant ($p<0.05$) at 45 min and 6 h. Ultimate pH measured at 24 h PM did not differ between carcasses from different dietary levels. Muscle pH of goats fed concentrate declined rapidly

Table 5. Carcass physical and chemical compositions of castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Breed(B)		Diet (D)			Significance		
	SEA×N	SEA	T0	T66	T100	G	D	B×D
Carcass physical composition (%)								
Muscle	65.3±0.77	66.4±0.75	66.8±1.07	66.7±0.89	63.9±0.92	NS	NS	NS
Fat	9.8±0.62	8.4±0.61	3.0±0.87[c]	9.6±0.73[b]	14.7±0.75[a]	NS	***	NS
Bone	25.0±0.63	25.2±0.62	30.1±0.89[a]	23.7±0.74[b]	21.4±0.76[c]	NS	***	NS
Percentage								
Moisture	67.2±0.78	67.7±0.76	72.9±1.09[a]	66.1±0.91[b]	63.4±0.94[c]	NS	***	NS
Ash	3.6±0.13	3.5±0.13	4.4±0.19[a]	3.3±0.16[b]	3.0±0.16[b]	NS	***	NS
Protein	20.4±0.34	20.8±0.34	22.2±0.48[a]	20.2±0.40[b]	19.3±0.41[b]	NS	***	NS
Fat	6.0±0.70	5.3±0.69	2.3±0.98[b]	6.2±0.82[a]	8.4±0.85[a]	NS	***	NS
Dry matter	32.8±0.78	32.3±0.76	27.1±1.09[c]	33.9±0.91[b]	36.6±0.94[a]	NS	***	NS

SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; NS, non significant.

[abc] Least square means with different superscripts within breed and diet in the same row differ ($p<0.05$) according to the indicated level of significance.

*** $p<0.001$.

Table 6. Post-mortem temperature and pH decline in carcasses of castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Temperature			pH		
	45 min	6 h	24 h	45 min	6 h	24 h
Breed (B)						
SEA×N	32.8±0.48	27.9±0.15	4.5±0.16	6.5±0.07	5.9±0.05	5.8±0.05
SEA	32.7±0.47	27.6±0.15	4.7±0.15	6.4±0.07	6.0±0.05	5.8±0.05
Diet (D)						
T0	30.8±0.62[b]	26.8±0.21[b]	4.8±0.21	6.7±0.09[a]	6.1±0.07[a]	5.9±0.06
T66	33.4±0.56[a]	28.1±0.19[a]	4.6±0.19	6.3±0.08[b]	5.9±0.06[ab]	5.8±0.06
T100	34.0±0.56[a]	28.4±0.19[a]	4.5±0.19	6.3±0.08[b]	5.8±0.06[b]	5.7±0.06
Significance						
B	NS	NS	NS	NS	NS	NS
D	**	***	NS	*	*	NS
B×D	NS	NS	NS	NS	NS	NS

SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; min, minutes; h, hour; NS, non significant.

[ab] Least square means with different superscripts within columns differ (p<0.05) according to the indicated level of significance.

* p<0.05; ** p<0.01; *** p<0.001.

and reached 5.9 (T66) and 5.8 (T100) at 6 h PM but temperature was still high at 28°C at the same time. On the other hand, muscle pH for T100 goats was lower (p<0.05) at 45 min and 6 h PM than that of goats fed T0.

Thawing loss, cooking loss and Warner-Bratzler shear force

Least squares means of muscle physical properties are presented in Table 7. There was no significant (p>0.05) effect of breed on cooking loss and shear force of muscle. The SEA goats had higher (p<0.05) thawing loss than SEA×N crossbred goats. On the other hand, thawing loss was not affected by dietary levels. Goats finished on T66 had higher (p<0.05) cooking loss compared to the other groups. Shear force decreased (p<0.05) with concentrate supplementation, and T0 had higher (p<0.05) shear force values than goats fed *ad libitum* concentrate (T100).

There were significant differences among muscles with respect to thawing loss, cooking loss and Warner-Bratzler shear force (WBSF) (Table 6). *M. Semimembranosus* and LD which were analyzed without ageing had similar and highest (p<0.05) thawing loss followed by *M. Psoas major* but *M. Rectus abdominis* had the lowest (p<0.05) values for thawing losses followed by *M. Triceps branchii*. On the other hand, *M. Supraspinatus* and *Semimembranosus* had statistically similar and highest (p<0.05) values for cooking loss while lowest value was observed in *M. Rectus abdominis*. In addition *M. Gluteobiceps and Semimembranosus* had similar and highest values for shear force values, followed by *M. Vastus lateralis* and *Triceps branchii*. The lowest (p<0.05) shear force values were recorded for *M. Psoas major* and *Infraspinatus* followed by LD muscle. It is interesting to note that shear force for LD muscle decreased from 43 N units at day zero of aging to 36 N at day 9 of aging.

DISCUSSION

Feed intake

Concentrate supplementation reduced forage DM intake but increased total energy intake. Daily total ME intake for T0 goats of 4.4 MJ/kg DM was below the recommended value of 5.78 MJ/kg DM (Langston University 2000). DM intake of supplemented goats in this experiment (2.6% to 3.2% of body weight) was higher than the range reported by Hamed and Fliman (2010).

Carcass yield, grading and classification

Goats fed concentrate diets had higher values for HCW, carcass conformation, fatness score and hind leg circumference than the forage fed ones. Results of HCW for T0 goats of 7.1 kg agree to range of 5.9 to 7.1 kg for non-supplemented Black Bengal goats (Asaduzzaman et al., 2009). The trend for DP to increase with level of concentrate supplementation agrees with other studies (Melaku and Betsha, 2008; Liméa et al., 2009) which reported the increasing DP with concentrate supplementation in the diet. The superior DP found in heavier goats is associated with high energy intake (Mahgoub et al., 2005). Lack of significant differences of True DP among goats that fed on concentrate based diet are also reported by Hango et al. (2007) who did not find differences between different feeding regimes for this trait in SEA goats. True DP of the goats in the present study was similar to 51% to 54% for male goats of six genotypes (Dhanda et al., 2003). Differences in DP for two breeds

Table 7. Thawing loss, cooking loss and warner-bratzler shear force of muscles in castrated SEA×N and SEA goats under different levels of concentrate supplementation

Variable	Thawing loss %	Cooking loss %	Shear force (N)
Breed (B)			
SEA×N	5.77±0.16[b]	25.69±0.29	47.40±0.55
SEA	6.36±0.15[a]	25.33±0.28	47.94±0.52
Diet (D)			
T0	5.96±0.20	25.17±0.37[b]	49.32±0.69[a]
T66	5.97±0.18	26.28±0.33[a]	47.54±0.62[ab]
T100	6.26±0.18	25.09±0.34[b]	46.15±0.64[b]
Muscles			
LD-0D	8.61±0.37[b]	24.35±0.69[d]	42.97±1.31[d]
LD-6D	9.76±0.37[ab]	21.76±0.69[e]	42.00±1.31[d]
LD-9D	10.26±0.37[a]	22.77±0.69[de]	36.34±1.31[e]
Psoas major	6.97±0.37[c]	28.80±0.69[c]	34.96±1.31[e]
Rectus abdominis	1.05±0.37[g]	5.54±0.69[f]	NA
Triceps branchii	3.62±0.37[f]	27.97±0.69[c]	54.90±1.31[b]
Infraspinatus	4.06±0.37[ef]	24.79±0.69[d]	36.36±1.31[e]
Supraspinatus	5.62±0.37[d]	32.09±0.69[a]	48.87±1.31[c]
Semimembranosus	8.98±0.37[b]	31.30±0.69[ab]	65.56±1.31[a]
Semitendinosus	3.87±0.37[ef]	28.54±0.69[c]	47.18±1.31[c]
Vastus lateralis	4.86±0.37[de]	29.53±0.69[bc]	58.20±1.31[b]
Gluteobiceps	5.13±0.37[d]	28.71±0.69[c]	66.66±1.31[a]
Significance			
Breed(B)	**	NS	NS
Diet (D)	NS	*	**
Muscle (M)	***	***	***
B×D	***	***	NS
B×M	NS	NS	NS
D×M	***	*	NS
B×D×M	NS	NS	NS

SEA×N, small East African×Norwegian goats; SEA, small East African goats; T0, grazing+hay supplementation; T66, grazing+hay supplementation+66% of *ad libitum* concentrate; T100, grazing+hay supplementation+100% of *ad libitum* concentrate; LD-0D, *Longismuss dorsi* unaged; LD-6D, *Longismuss dorsi* aged for 6 days; LD-9D, *Longismuss dorsi* aged for 9 days; NA, not analysed; NS, non significant

[abcdefg] Least square means with different superscripts within columns differ ($p<0.05$) according to the indicated level of significance.

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

observed in the present study agrees with previous work which reported significant difference between various goat breeds for DP based on full body weight (Dhanda et al., 2003).

The higher scores for conformation in supplemented animals can be associated with concentrate allowance which resulted into higher energy intake for muscle development and carcass fat deposition. The carcass conformation and fatness scores for supplemented goats were 6.2 to 7.0 and 6.2 to 8.5 respectively and these values are within the range of 4.2 to 9.5 and 5.1 to 10.1 (Mushi et al., 2009; Safari et al., 2009). Hind leg circumference of goats under T100 was greater by 3.3 cm than those under T0 goats. Values of most carcass measurements in the present study were similar to values reported by Safari et al. (2009) using goats of similar carcass weights.

Fat depots

The trends for accumulation of fat depots were increasing with increasing amount of concentrate in the diet. The observed highest weight of kidney and omental fat in the present study agrees with the range of 0.02 to 0.2 kg and 0.03 to 0.4 kg for kidney and omental fat reported by Lapenga et al. (2009). Furthermore, weight values of kidney and omental fat for supplemented goats were higher compared to values of 12 to 13 g and 20 to 30 g of Creole goat reported by Alexandre et al. (2009). However, Daskiran et al. (2010) reported higher omental fat of 0.91 kg for Norduz male goats under semi intensive system, a value which is three times more than the value of 0.32 kg on goats under T100 in the current study. The difference in the fat depots reported by different workers can mainly be ascribed to level of feeding, age at fattening and breed characteristics.

Carcass physical and chemical compositions

The observed higher proportion of muscle and fat from concentrate supplemented goats compared to non-supplemented ones might be due to heavier carcasses in the former than in the latter. In the present study, T100 goats were fatter with lower proportion of bone. These findings are explained by the lower carcass weight of non-supplemented goats where the weight of bones accounted for a significant proportion. The observed proportions of 21% to 32% and 3% to 15%, bone and fat respectively in the present study are within the range reported for SEA×N crossbred goats as reported by other workers (Mushi et al., 2009). The increase of fat proportion with increasing concentrate level in the diet agree with findings with Somali goats fed hay with graded levels of peanut cake and wheat bran mixture (Melaku and Betsha, 2008). These observations might be due to higher levels of energy content in the concentrate supplemented goats (Table 1). Lean meat percentages are in agreement with findings from Borana and Arsi-Bale goats under different duration of feedlot management (Dadi et al., 2005).

Dry matter and fat of meat increased with increasing concentrate on offer and hence increasing weight but the content of moisture, ash and protein followed the reverse order. Hatendi et al. (1992) also reported a decline in moisture contents of goat meat with increasing weight. The range of 19% to 22% for protein content observed from the current study was comparable to the report of young goats of Majorera breed (ArqÜello et al., 2005). The observed higher levels of chemically determined fat in carcasses produced by supplemented goats are due to higher intake of energy from concentrate. These findings agree with various reports comparing effects of dietary energy density on carcass composition (Diaz et al., 2002; Santos-Silva et al., 2002). The higher value of fat in the meat for concentrate supplemented goats basically could be caused for its lower proportion of water, protein and ash than non-supplemented goats. Moreover, the higher fat content of (6.2% to 8.4% vs 4.3% to 5.1%) concentrate supplemented goats compared to yearling stall-fed Zaraibi goats of Egypt (El-Gallad et al., 1988) but lower than 10.3% to 14.0% produced by Ethiopian indigenous goats fed grainless diet varying in concentrate to roughage ratios (Sebsibe et al., 2007).

Post-mortem temperature and pH decline

Better meat quality, especially meat tenderness, is linked to the rate of pH and musculature temperature fall with time PM. Ultimate pH ranging from 5.49 to 5.86 in goats is considered normal (ArqÜ ello et al., 2005; Pratiwi et al., 2007). In the present study, the difference in carcass pH decline between animals fed different dietary levels could be a result of variation in their fat cover. Similarly Abdullah and Musallam (2007) observed differences on carcass temperature and pH decline between castrated and intact male goats with different levels of fat cover. The pH of 5.7 to 5.8 recorded at 24 h PM for supplemented goats in the current study falls within the normal range reported for goats (Shija et al., 2013). The observation of ultimate pH in the present study is <6.00 compared to observations reported by other workers (Safari et al., 2009). As expected, there was a decrease in pH and temperature with time. The difference in pH readings recorded at 45 minutes to 24 hours was not significant between breeds. The average pHu for goat carcasses at 24 h was not affected by level of supplementations.

Thawing loss, ccoking loss and Warner-Bratzler shear force

Apart from *M. Rectus abdominis*, percent cooking loss from muscles of the two breeds studied were in the range of 21.76 to 32.09 and within the normal range for goat muscles according to previous findings (Babiker et al., 1990). However, considering the similarity in ultimate pH of carcasses between dietary levels group, the observed differences in cooking loss in carcasses and individual muscles agree with Dhanda et al. (2003) and Pratiwi et al. (2007). The decrease in cooking loss as ageing increased was as expected because of enzymatic reactions by endogenous enzymes, such as collagenase progresses at faster rates as ageing increases (Mushi et al., 2009). The collagenase enzymes disintegrate the myofibrillar proteins and connective tissue thereby improving water holding capacity by proteins (den Hertog-Meischke et al., 1998). Cooking loss is affected by many complex factors such as heat transfer methods and surface and internal temperature of the meat (Shija et al., 2013) but was not considered in this study. Ageing muscle for 9 days in the present study did significantly improve meat tenderness by 15.43%. The observations indicate that meat tenderness of goats finished under small scale farming conditions can be improved by extended ageing time as demonstrated by previous workers (Shija et al., 2013).

On the other hand, the observed variation in thawing and cooking loss for individual muscles studied correspond with Pratiwi et al. (2007) that cooking losses are different for muscles taken from different anatomical regions. Although all dietary levels group produced relatively tender meat, supplemented goats with higher level of concentrate had more tender meat than non-supplemented goats. Results from the present study indicated that *M. Gluteobiceps* (66 N), *M. Semimembranosus* (65 N) and *M. Vastus lateralis* (58 N) were regarded as objectionably tough and the rest of muscles fall in the acceptable tender range of <55 N (Abdullah and Musallum, 2007). The results in the present study are also in agreement with findings by Safari et al. (2009) and Mushi et al. (2009). However, variation of individual goat's muscles in WBSF values may be associated with their content and structure (degree of cross-links of collagen fibres) of connective tissue due to differential involvement in physical activities (Gonzalez et al., 1983).

CONCLUSION

The present study demonstrates that there are differences in meat quality characteristics of meat from SEA goats and their crosses with Norwegian goats finished under small scale farming conditions in rural areas. Thus, effectively utilization of the available feed resources and appropriate concentrate supplementation for grazing goats appear to be the necessary steps to alleviate nutritional problems as well as improvement of goats meat quality. Therefore, concentrate supplementation of goats of both breeds improves meat quality attributes.

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