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Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats

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ABSTRACT

Effects of concentrate supplementation on carcass and meat quality of feedlot finished Small East African (SEA) goats were assessed using 23 animals (14.5 months old and 20.1 kg body weight). Goats were subjected to four levels of concentrate supplementation: *ad libitum* concentrate allowance (T100), 66% of *ad libitum* concentrate allowance (T66), 33% of *ad libitum* allowance (T33) and no concentrate (T0). All goats were slaughtered after 90 days of experimental period. The *ad libitum* concentrate intake attained by the goats was about 370 g DM/d. All concentrate-supplemented goats had similar ($P>0.05$) total dry matter intake. T100 goats had 31 g and 14 g higher ($P<0.05$) daily body weight gain than T33 and T66 goats, respectively. T100 and T66 goats were comparable in final live weight and empty body weight but both were heavier ($P<0.05$) than that of T33 and T0 goats. Hot and cold carcass weights for both T100 and T66 goats were 3 kg heavier ($P<0.05$) than that of T0 goats. Concentrate-supplemented goats had similar ($P>0.05$) EUROP scores for carcass fatness. T100 and T66 goats had 6.5 and 3 units higher ($P<0.05$) scores for conformation than T0 and T33 goats, respectively. Dressing percentage increased with levels of concentrate supplementation in a curvilinear fashion, with highest values in T66 goats. At 6 h post-mortem, muscle pH for concentrate-supplemented animals was significantly lower compared with T0 goats. Carcass fat content was 9% higher ($P<0.05$) in concentrate-supplemented goats than in their contemporaries. No differences in cooking loss or shear force were observed among treatments, while these variables were affected by the type of muscle. It is concluded that feedlot finishing of SEA had limited effects on meat quality. Finishing SEA goats at 66% of their *ad libitum* concentrate intake, however, significantly improved weight gains and carcass fatness. Cost–benefit analyses are recommended before embarking on a large scale feedlot finishing of SEA goats.

1. Introduction

Goats are known to be hardy and prolific animals that survive in various climatic zones and produce under different systems of husbandry (El Muola et al., 1999). Goat is a good source of lean meat with desirable fatty acids, since goats deposit relatively higher proportion of polyunsaturated fatty acids compared to other ruminants (Banskalieva et al., 2000; Mushi et al., 2008). Moreover, goat meat is described to have higher water holding capacity, dark red colour and low fat, the attributes which make goat meat suitable for further processing. Goat meat is preferred to other types of meat in many tropical countries, inter alia, based on the above mentioned benefits (Atti et al., 2004). However, the leanness of goat meat may be a discredit to some consumers due to its consequent low juiciness, palatability and tenderness (Marinova et al., 2001).

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Increasing level of carcass fatness, to an optimum level, may improve the quality of goat meat. Shahjalal et al. (1992) reported increased carcass weight, dressing percentage, *longissimus* area, dissected lean and chemical fat weight of British Angora goats with increasing levels of high-energy concentrate diets. On the other hand, Johnson and McGowan (1998) working with Florida native kids noted that feeding system did not affect proportions of carcass dissectible tissues. Difference in feeding system and breed used between studies are possible factors for the observed discrepancy. Further studies should therefore be carried out to elucidate the possible effect of breed × feeding interaction and implication of such interaction on meat production from goats.

Small East African goats (SEA), the main goat breed in Tanzania, are kept mainly for meat production. The productivity of these goats, however, is still low attaining a market weight of 20 kg at 2 years of age (Mushi, 2004). Under present management systems, these animals produce carcasses of low uniformity and meat of low-quality, mainly of low tenderness. This situation has caused lack of prime prices for locally produced meat, especially in niche markets. Consequently, despite the large population of goats in Tanzania (13.1 million), large amount (765 t/year) of chilled and frozen meat products are imported into the country (WHO/AFRO, 2009). The low productivity of these animals has been attributed to poor feeding, although there are limited reports on the response of SEA goats to higher plane of nutrition. The objective of this study was therefore to evaluate the response of SEA goats to different levels of concentrate finishing diet and its effects on carcass and meat quality.

2. Materials and methods

2.1. Animals and treatments

Twenty-three castrated Small East African goats (14.5 ± 0.5 months old and 20.1 ± 1.2 kg BWT), were bought from Mulbadaw Farm in the Northern part of Tanzania and transported to the experimental unit at the Department of Animal Science, Sokoine University of Agriculture, Morogoro. Goats were then allotted into 6 weight blocks and assigned at random, within blocks, to one of four dietary treatments in a completely randomised block design. Dietary treatments were T0 where no concentrate supplementation was offered and T33 and T66 where amount of concentrate on offer consisted 33% and 66%, respectively, of *ad libitum* concentrate intake. The fourth treatment, T100, involved feeding concentrate *ad libitum* allowing 10% refusal rate. Following the death of one animal caused by septicaemia before the end of the experiment, the number of animals in T33 and other treatments were 5 and 6, respectively. Goats were individually fed, having free access to water. Grass hay was offered *ad libitum* at 20% refusal rate.

2.2. Feeding and management

Animals were given a three-week adaptation period during which they were treated with Ivermectin against internal and external parasites. Hay (20% refusal rate) and concentrate were fed twice daily and water was freely available. During the experimental period of 90 days, animals were stall-fed in individual pens. Feed allocations and refusals were recorded daily for each goat. Animals were weighed weekly before morning feeding.

2.3. Measurements at slaughter

Goats were weighed on two consecutive days before slaughter to obtain final live weight (FLW), fasted for about 16 h and weighed again to get the slaughter live weight (SLW). Animals were slaughtered for three consecutive days, with two animals from each dietary treatment slaughtered each day. After slaughtering, the head was removed at the atlanto–occipital joint and fore and hind feet removed at the carpus–metacarpal and tarsus–metatarsal joints, respectively (Garcia-Valverde et al., 2008). Gut fill was calculated as the difference between the weights of full and empty digestive tract. Empty body weight (EBW) was computed as the difference between slaughter weight and gut fill.

Carcasses (with kidneys, kidney and pelvic fat) were weighed immediately after slaughter to get hot carcass weight (HCW) and scored for conformation and fatness based on EUROP classification system for goats (Kosum et al., 2003; Johansen et al., 2006). Carcasses were classified 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). 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. High value for conformation class indicates a carcass with well to excellent rounded muscles. High value for fat class indicates a carcass with a high degree of external fat (subcutaneous).

2.4. Measurements on carcasses

Carcasses were dissected into two halves through the median plane and both weights were recorded. Temperature and pH on the right half-carcasses were measured 45 min and 6 h post-mortem (PM), at the same point on the geometric centre of *M. gluteobiceps* using a penetrating electrode (Mettler Toledo) of a portable pH-meter (Knick-portamess 910, Germany). The pH probe was calibrated with pH 4 and 7 standard buffer solutions. Carcasses were then chilled at 0 °C for 24 h before ultimate pH (pHu) and temperature were recorded.

After 24 h of refrigeration at 0 °C, weights of right half-carcasses were recorded and doubled to obtain cold carcass weights (CCW). This recording was later used to calculate abattoir, commercial and true dressing percentages and chilling losses. Chilling loss was calculated as the weight lost after chilling the right half-carcasses at 0 °C for 24 h. Various linear measurements were taken on the cold half-carcasses to determine carcass conformation: internal carcass length (CL, from the lumbo–sacral joint to the cervico–thoracic joint), carcass depth (CD, from the dorsal to the ventral edges of the carcass side along the 9th rib) and hind leg length (LL, 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) (Moran and Wood, 1986). Internal

Table 1
Physical compositions of concentrate, chemical composition of concentrate and grass hay and digestibility (*in vitro*) data of such ingredients.

	Feeds	
	Concentrate	Grass hay
Ingredients (g/kg DM)		
Maize bran	700	–
Sunflower seed cake	280	–
Lime (calcium carbonate)	13	–
Salt	2	–
Mineral premix	5	–
Components (g/kg DM)		
Dry matter	922.0	834.5
Organic matter	921.0	902.0
Crude protein	162.0	32.8
Ether extract	134.0	12.0
Crude fiber	146.0	353.3
Neutral detergent fiber	472.1	831.0
Acid detergent fiber	156.1	474.0
Ash	51.0	98.0
Nitrogen free extract	429.4	338.4
In vitro dry matter digestibility	546.0	396.0
In vitro organic matter digestibility	546.4	417.0
Metabolisable energy (MJ/kg DM)	13.4	9.2

carcass length was used to determine carcass compactness (CCW/CL).

2.5. Muscle sampling for cooking loss and WBSF analyses

Ten muscles namely: *Semimembranosus, Semitendinosus, Gluteobiceps, Vastus lateralis, Rectus abdominis, Longismuss dorsi, Psoas major, Supraspinatus, Infraspinatus* and *Triceps brachii* were excised from the left half of carcasses, 6 h PM. Further, *M. longissmus dorsi* (LD) was split into 5 blocks measuring approx. 7 cm long. The five blocks of LD were assigned to samples for 0, 6 and 9 days ageing, proximate analyses and fatty acid analyses, in that order from anterior to posterior end. All the muscles samples were weighed (W1) then packed in PVC bags and stored in a fridge set at 4 °C overnight before being frozen at −25 °C. LD samples for 6 and 9 days ageing remained in the fridge for further 6 and 9 days, respectively and then stored at −25 °C.

The remaining part of the left half-carcasses were chilled at 0 °C for 24 h after which they were dissected into muscle, fat and bone for estimation of carcass composition. Total weight of muscles included weights of the 10 muscles sampled at 6 h PM. Thereafter, muscle and fat tissues were thoroughly mixed together, minced (5 mm sieve) and three sub-samples taken for chemical analyses.

2.6. Cooking loss and Warner–Bratzler shear force (WBSF)

The 10 muscles were thawed at 4 °C overnight before analyses. The muscles in the water-tight PVC bags were boiled in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) set at 70.5 °C for a total of 50 min. The muscles were then kept at room temperature for 2 h and stored in a refrigerator at 4 °C for 12 h. Muscles were then blotted dry with paper towel and weighed (W2). Cooking loss was calculated as $((W1-W2)/W1)\times 100$. Six to 10 cubes measuring $1\times1\times1$ cm, 2 cm long were prepared from each muscle for WBSF assessment. Preparation of such cubes was done in such a way that muscle fiber direction was parallel to the cube length. Warner–Bratzler shear blade, with a triangular slot cutting edge, attached to Zwick/Roell (Z2.5, German) instrument was used to determine the force (N/cm^2) required to shear through a muscle cube at right angle to the muscle fiber direction. The Zwick was set with 1 KN load cell, with a crosshead speed of 100 mm/min. The average shear force for 6–10 cubes per muscle sample was considered as a peak force for a particular muscle (Abdullah and Musallam, 2007).

2.7. Physical compositions of dietary feeds, chemical composition of dietary feeds, minced meat and LD samples

The grass hay consisted of *Bracharia spp* (70%) and *Bothrocloa spp* (30%). Chemical and fibre compositions of both the grass hay and concentrate were analyzed according to AOAC (2000) and Van soest et al. (1991), respectively. *In vitro* dry matter digestibility and organic matter digestibility were analysed following the method of Tilley and Terry (1963). The composition and nutritive value of diets used in the present study are shown in Table 1. Metabolisable energy contents of feeds were estimated from their chemical composition following the equation of MAFF (1975): ME (MJ/kg DM) = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE.

Water content was determined by weight loss of 3 g minced meat and LD samples dried for 48 h in a 104 °C oven according to AOAC (2000). Ash content was determined by ashing the dried samples in a 600 °C muffle furnace for 6 h. Total lipid content (g fat/100 g sample) was estimated in 5 g samples after a 6-cycle extraction with petroleum ether in a Soxhlet apparatus. Crude protein content was determined using a 1 g sample following the Kjeldahl method as described in the AOAC (2000).

2.8. Statistical analysis

Experimental data were analysed using the General Linear Model Procedure of SAS (2001). Dietary treatments were considered as fixed effects and residual as random effect. Each individual animal served as an experimental unit for all the parameters assessed. Due to small variation in age of animals within treatments, all traits were corrected by animal age as a covariate. Further, in the analysis of cooking loss, weights of raw muscle samples served as covariates. Analyses of WBSF data included both dietary treatment, muscle type and their interaction as fixed effects. However, dietary treatment × muscle type interaction was not significant ($P>0.05$); hence only the effects of the main factors are reported and discussed in the present study. In all analyses, when means were significantly different at $P<0.05$, they were separated by Least Significant Difference test.

3. Results

3.1. Diet intake and kid growth

The *ad libitum* concentrate intake attained by Small East African goats (T100) was about 370 g DM/day, which was 230 g and 90 g higher than that of goats with 33% (T33) and 66% (T66) access to *ad libitum* concentrate allowance,

Table 2
Live weights, intakes, feed efficiency, fasting loss, empty body weight and condition scores of Small East African goats under different levels of concentrate supplementation.

Variable	Treatment			
	T0	T33	T66	T100
Initial age (months)	14.70 ± 0.45	15.00 ± 0.50	13.83 ± 0.45	14.70 ± 0.45
Live weights (kg):				
Initial	20.32 ± 1.18	19.14 ± 1.29	20.28 ± 1.18	20.41 ± 1.18
Final	17.98 ± 1.10^{c}	21.7 ± 1.17^{b}	23.95 ± 1.10^{a}	25.40 ± 1.10^{a}
Slaughter[1]	16.70 ± 1.10^{b}	20.2 ± 1.33^{ab}	22.5 ± 1.10^{a}	24.0 ± 1.10^{a}
Gains:				
Total (kg)	−2.10 ± 0.5^{b}	2.0 ± 1.0^{a}	3.0 ± 1.0^{a}	4.3 ± 1.0^{a}
Daily (g)	−23.6 ± 3.0^{d}	18.3 ± 3.0^{c}	35.8 ± 3.0^{b}	49.5 ± 24.7^{a}
Intakes:				
Concentrate, as fed (g/day)	–	150.0 ± 11.0^{c}	300.0 ± 11.0^{b}	396.7 ± 11.0^{a}
Hay, as fed (g/day)	405.0 ± 25^{a}	306.0 ± 27.0^{b}	193.3 ± 20.0^{c}	120.0 ± 25.0^{d}
Total dry matter (TDMI, g/day)	336.7 ± 22^{b}	393.6 ± 24^{a}	437.8 ± 22^{a}	465.8 ± 22^{a}
Dry matter (% live weight)	2.0 ± 0.1	2.4 ± 0.1	2.1 ± 0.1	2.2 ± 0.1
Total energy (MJ, ME/day)	3.1 ± 0.2^{c}	4.4 ± 0.2^{b}	5.0 ± 0.2^{ab}	5.6 ± 0.2^{a}
Total crude protein (g/day)	11.1 ± 1.8^{d}	33.1 ± 1.9^{c}	49.8 ± 1.8^{b}	62.5 ± 1.8^{a}
FCR (kg DMI/kg weight gain)	−14.2 ± 0.4^{d}	13.9 ± 0.4^{c}	9.6 ± 0.4^{b}	7.8 ± 0.4^{a}
Fasting loss (%)	3.0 ± 0.7	2.6 ± 0.7	2.3 ± 0.7	1.1 ± 0.7
Empty body weight–EBW (kg)	12.8 ± 1.0^{c}	14.4 ± 1.0^{bc}	17.4 ± 1.0^{a}	17.5 ± 1.0^{a}
Body condition score (1–5)	1.8 ± 0.24^{c}	2.4 ± 0.24^{bc}	3.10 ± 0.22^{a}	3.20 ± 0.22^{a}

[1]After 16 h of fasting.
[a,b,c,d]Least square means in the same row lacking a common letter differ ($P<0.05$). T0, T33, T66 and T100 refer to Zero, 33%, 66% and 100% access to *ad libitum* concentrate allowance, respectively. FCR is feed conversion ratio.

respectively (Table 2). Consumption of grass hay declined ($P<0.05$) with increase in concentrate allowance. Intake of hay in T100 goats was 240, 155 and 60 g DM lower than in T0, T33 and T66 goats, respectively. Despite the variation in hay and concentrate intake between diet groups, all concentrate-supplemented goats had similar ($P>0.05$) total dry matter intake (TDMI), which was higher ($P<0.05$) than that of non-supplemented ones. Goats in different diet groups had similar dry matter intake when expressed as percentage of animals' live weights. Although T100 goats were comparable to T66 goats with respect to daily metabolisable energy (ME) intake, ME intake by T100 was 81% and 27% higher than that of T0 and T33 goats, respectively. Moreover, T100 goats had 51, 29 and 13 g higher daily intake of crude protein than T0, T33 and T66 goats, respectively.

Supplemented goats had similar ($P>0.05$) total live weight gains (Table 2). Daily weight gains, however, were significantly different among dietary groups leading to 31 g and 14 g lower ($P<0.05$) daily gains for T33 and T66 goats, respectively, than that of T100 goats. Accordingly, T100 goats had the highest feed utilisation efficiency with 6 and 2 units lower ($P<0.05$) feed conversion ratio (FCR) than T33 and T66 goats, respectively. T0 goats lost weight during the experimental period. Body condition score for both T100 and T66 goats were "average" (3 units) but higher ($P<0.05$) than that of both T0 and T33, which were "thin" (2 units).

Table 3
Killing out characteristics of Small East African goats under different levels of concentrate supplementation.

Variable	Treatment			
	T0	T33	T66	T100
Carcass weights (kg):				
Hot (HCW)	7.0 ± 0.6^{b}	8.3 ± 0.6^{ab}	10.2 ± 0.6^{a}	10.1 ± 0.6^{a}
Cold (CCW)	5.6 ± 0.6^{c}	7.5 ± 0.6^{b}	9.6 ± 0.6^{a}	9.2 ± 0.6^{a}
EUROP grading (1–15 points):				
Conformation	1.8 ± 0.5^{c}	5.2 ± 0.6^{b}	8.2 ± 0.6^{a}	8.3 ± 0.5^{a}
Fatness	1.8 ± 0.6^{b}	5.3 ± 0.7^{a}	7.1 ± 0.6^{a}	6.8 ± 0.6^{a}
Linear cold carcass measurements (cm):				
Carcass length	51.2 ± 1.1	48.2 ± 1.1	51.3 ± 1.1	51.4 ± 1.0
Chest depth	23.4 ± 1.0	21.7 ± 1.0	23.6 ± 1.0	23.1 ± 1.0
Hind leg length	36.5 ± 0.7	36.4 ± 0.7	38.0 ± 0.7	36.7 ± 0.7
Hind leg circumference	28.2 ± 1.0^{b}	30.6 ± 1.0^{a}	31.3 ± 1.0^{a}	31.4 ± 1.0^{a}
Dressing percentages (%):				
TD	54.5 ± 1.0^{b}	57.5 ± 1.0^{a}	58.5 ± 1.0^{a}	57.3 ± 1.0^{a}
AD	38.5 ± 1.0^{b}	43.7 ± 1.0^{a}	46.3 ± 1.0^{a}	44.8 ± 1.0^{a}
CD	42.0 ± 1.0^{b}	47.7 ± 1.1^{a}	49.8 ± 1.1^{a}	48.8 ± 1.0^{a}
Carcass compactness (g/cm)	136.4 ± 8.8^{b}	166.3 ± 10.0^{a}	189.8 ± 9.4^{a}	188.6 ± 8.8^{a}
Chilling loss (%)	5.5 ± 1.3	4.0 ± 1.3	3.4 ± 1.2	3.7 ± 1.1

[a,b,c,d]Least square means in the same row lacking a common letter differ ($P<0.05$).T0, T33, T66 and T100 refer to Zero, 33%, 66% and 100% access to *ad libitum* concentrate allowance, respectively. EBW is empty body weight. TD is true dressing (HCW × 100/EBW); AD is abattoir dressing (CCW × 100/SLW); CD is commercial dressing (HCW × 100/SLW).

3.2. Killing out characteristics

Ad libitum fed goats (T100) and those with reasonably higher levels of concentrate supplementation (T66) had similar empty body weight (EBW) but were 4.4 and 2.6 kg heavier ($P<0.05$) than that of T0 and T33 goats, respectively (Table 2). Similarly, hot carcass weights for T100 and T66 goats were 3 kg heavier ($P<0.05$) than that of T0 goats (Table 3). Carcass weight for T33 goats was in between the three groups. In addition, T100 and T66 goats had similar cold carcass weights but both were about 4 kg and 2 kg heavier ($P<0.05$) than that of T0 and T33 goats.

Although all concentrate-supplemented goats had comparable EUROP scores for carcass fatness, both T100 and T66 goats had 6.5 and 3 units higher ($P<0.05$) scores for conformation than T0 and T33 goats, respectively. Overall, carcass conformation increased with level of concentrate supplementation while increase in carcass fatness displayed a non linear pattern. Concentrate-supplemented goats displayed comparable values for both carcass compactness (g/cm) and hind leg circumference (cm), but all were greater ($P<0.05$) than that of non-supplemented goats. Dressing percent, expressed in three different forms, increased with levels of concentrate supplementation in a curvilinear fashion. T66 goats had highest values for all the three forms of dressing percentages.

3.3. Carcass physical and chemical compositions

The weight of dissectible fat in carcasses increased ($P<0.05$) slightly with level of concentrate supplementation while that of muscle did not change significantly (Table 4). However, as expected, supplemented goats had higher ($P<0.05$) weights for both carcass fat and muscle than non-supplemented ones. On the other hand, weight of carcass bone was independent ($P>0.05$) of concentrate supplementation. When expressed as a proportion of total carcass tissue weight, percentage of carcass fat was higher ($P<0.05$) while that of bone was lower ($P<0.05$) in concentrate-supplemented goats. Percentage of carcass muscle was independent ($P<0.05$) of concentrate supplementation.

Minced meat from concentrate-supplemented goats had significantly lower contents of water, protein and ash, while fat contents were higher (Table 4). Meat quality is often assessed using *M. longismus dorsi* (LD). Concentrate supplementation

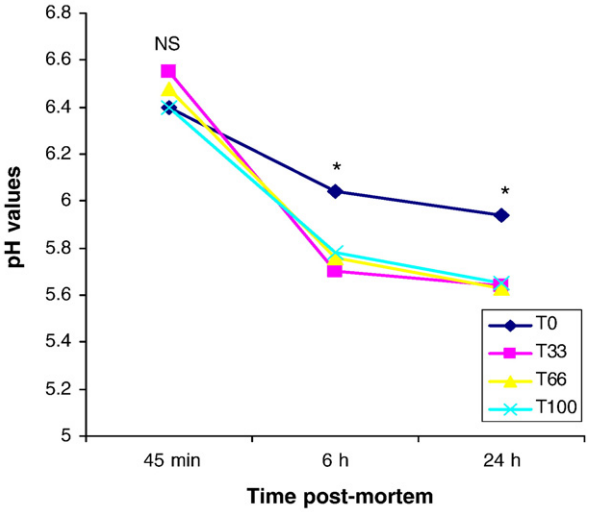

Fig. 1. pH decline post-mortem for carcasses from castrated Small East African goats under different levels of concentrate supplementation. NS = non significant, * = $P<0.05$.

Table 4
Weights and proportions of carcass tissues and chemical composition of carcass and *M. longismus dorsi* (LD) for Small East African goats under different levels of concentrate supplementation.

Variable	Treatment			
	T0	T33	T66	T100
Carcass tissue weight (kg)				
Muscle	2.1 ± 0.2^{b}	2.5 ± 0.2^{ab}	3.0 ± 0.2^{a}	3.0 ± 0.2^{a}
Fat	0.2 ± 0.1^{c}	0.5 ± 0.1^{b}	0.6 ± 0.1^{ab}	0.7 ± 0.1^{a}
Bone	0.9 ± 0.1	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.1
Carcass physical composition[1] (%)				
Muscle	65.5 ± 1.3	68.1 ± 1.5	65.0 ± 1.4	65.0 ± 1.3
Fat	5.6 ± 1.2^{b}	13.8 ± 1.3^{a}	13.4 ± 1.2^{a}	14.6 ± 1.2^{a}
Bone	29.0 ± 1.0^{a}	22.7 ± 1.0^{b}	21.0 ± 1.0^{b}	20.5 ± 1.0^{b}
Carcass chemical composition (%)				
Moisture	68.4 ± 0.8^{a}	60.5 ± 0.9^{b}	61.8 ± 0.9^{b}	60.6 ± 0.8^{b}
Protein	21.2 ± 0.7^{a}	18.5 ± 0.8^{b}	18.8 ± 0.7^{b}	18.4 ± 0.7^{b}
Fat	7.4 ± 1.2^{b}	18.7 ± 1.4^{a}	16.9 ± 1.3^{a}	18.9 ± 1.2^{a}
Ash	3.1 ± 0.1^{a}	2.3 ± 0.1^{b}	2.4 ± 0.1^{b}	2.1 ± 0.1^{b}
LD chemical composition (%)				
Moisture	75.5 ± 1.0	73.5 ± 1.0	74.1 ± 1.0	73.4 ± 1.0
Protein	21.4 ± 0.6	22.7 ± 0.6	23.1 ± 0.6	21.3 ± 0.6
Fat	0.3 ± 0.2^{b}	0.4 ± 0.2^{ab}	0.8 ± 0.2^{a}	0.9 ± 0.2^{a}
Ash	4.7 ± 0.2^{a}	4.0 ± 0.2^{b}	4.2 ± 0.2^{b}	4.2 ± 0.2^{b}

[1]percentage of total carcass tissue weight.
[a,b,c,d]Least square means in the same row lacking a common letter differ ($P<0.05$). T0, T33, T66 and T100 refer to Zero, 33%, 66% and 100% access to *ad libitum* concentrate allowance, respectively.

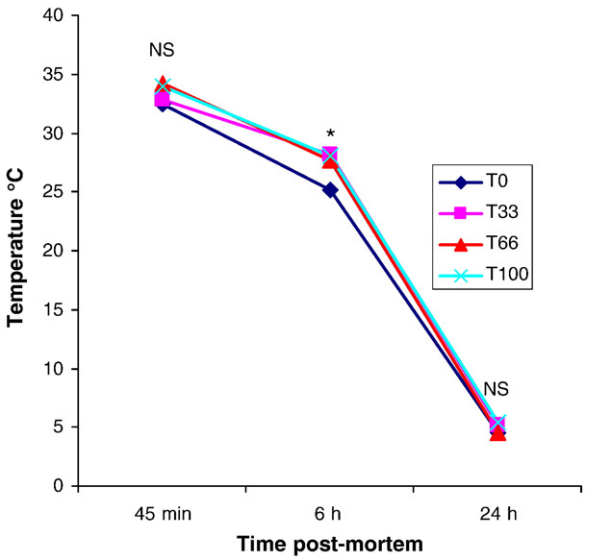

Fig. 2. Temperature decline post-mortem for carcasses from castrated Small East African goats under different levels of concentrate supplementation. NS = non significant, * = $P<0.05$.

affected only the proportion of fat and ash in LD muscle. Proportion of fat increased ($P<0.05$) while that of ash decreased ($P<0.05$) with level of concentrate supplementation.

3.4. Muscle physico-chemical properties

Muscle pH measured at 45 min post-mortem (PM) was not significantly affected by concentrate supplementation (Fig. 1). After 45 min, muscle pH for concentrate-supplemented goats declined faster ($P<0.05$) than that of non-supplemented ones, and reached below 6 after 6 h PM. At 24 h PM, ultimate pH (pHu) was 5.6 and 5.9 for supplemented and non-supplemented goats, respectively. Carcass temperature measured at 45 min PM did not differ between treatments (Fig. 2), while at 6 h PM, carcass temperature for non-supplemented goats was 3 °C lower ($P<0.05$) than that of supplemented ones. After 24 h of cooling, carcasses from all dietary groups had similar temperatures.

There was no difference ($P>0.05$) both in cooking loss and shear force attributable to concentrate supplementation (Table 5). However, muscles of different anatomical locations differed with respect to these parameters. Of the muscles analysed, *M. rectus abdominis* had the lowest ($P<0.05$) cooking loss, followed by *M. infraspinatus*, LD muscle aged for 6 and 0 days. *M. gluteobiceps* had the highest ($P<0.05$) value for shear force, followed by *M. vastus lateralis* and *semimembranosus*. The lowest ($P<0.05$) shear force values were recorded for *M. psoas major*, followed by *M. infraspinatus* and LD muscle aged for 9 days. Overall, variation in cooking loss and shear force of LD muscle with ageing followed the following order: LD-9D>LD-0D = LD-6D for cooking loss and LD-0D>LD-6D = LD-9D for shear force.

Table 5
Cooking loss and Warner–Bratzler shear force values for different muscles of Small East African goats under different levels of concentrate supplementation.

	Variable	
	Cooking loss (%)	Shear force (N)
Treatment:		
T0	27.5 ± 1.0	60.8 ± 2.0
T33	26.7 ± 1.0	57.8 ± 2.0
T66	26.0 ± 1.0	56.7 ± 2.0
T100	26.0 ± 1.0	56.3 ± 2.0
Muscles:		
Triceps brachii	27.6 ± 1.5^{a}	67.7 ± 3.0^{cd}
Infraspinatus	25.0 ± 1.5^{b}	36.6 ± 3.0^{h}
Supraspinatus	29.1 ± 1.5^{a}	59.4 ± 3.0^{e}
LD-0D[1]	26.5 ± 1.7^{b}	59.7 ± 3.0^{de}
LD-6D[2]	25.4 ± 1.7^{b}	46.5 ± 3.0^{fg}
LD-9D[3]	31.3 ± 1.6^{a}	41.7 ± 3.0^{gh}
Psoas Major	27.7 ± 1.6^{a}	33.4 ± 3.0^{h}
Rectus Abdominis	12.0 ± 1.5^{c}	NA
Semimembranosus	28.7 ± 1.7^{a}	71.3 ± 3.0^{bc}
Semitendinosus	29.7 ± 1.5^{a}	53.8 ± 3.0^{ef}
Vastus lateralis	27.2 ± 2.0^{ab}	79.2 ± 3.0^{b}
Gluteobiceps	27.8 ± 1.5^{a}	87.6 ± 3.0^{a}
Significance:		
Treatment (T)	NS	NS
Muscle (M)	***	***
T*M	NS	NS

T0, T33, T66 and T100 refer to Zero, 33%, 66% and 100% access to *ad libitum* concentrate allowance, respectively.
[1,2,3]*M. longismuss dorsi* aged for zero, 6 and 9 days respectively.
[a,b,c,d,e,f,g]Least square means in the same column lacking a common letter differ ($P<0.05$). *, ** and *** = $P<0.05$, 0.01 and 0.001, respectively. NS = Not significant. NA = not analysed.

4. Discussion

4.1. Diet intake and kid growth

The reduced forage intake with increased access to energy supplement in the present study indicates that feed intake is determined mainly by the need to meet energy requirements. Energy intake, rather than physical fill, appears to be the dominant factor influencing DMI from diets (Lu and Potchoiba, 1990). Moreover, the observed similarity in TDMI for concentrate-supplemented groups, despite their difference in both concentrate and hay intake, suggests that T33 and T66 goats compensated for low dry matter and energy content in their diet by having higher hay intake compared to T100. Physical fill of the gut, however, may have restricted the amount of hay consumable by T33 goats resulting in overall lower energy intake compared to T66 and T100 groups. Results from the present study, on the other hand, suggest that goats have a limit as to the amount of concentrate they can consume and a certain combination of concentrate and roughage is desirable (Caton and Dhuyvetter, 1997).

The observed similarity in final weight but difference in slaughter weight (after 16 h of fasting) between T66 and T100 goats is a reflection of higher digestive content in the former than in the latter. For goats and sheep, live weight shrinkage increases steadily with fasting peaking at 7% after 21 h of fasting, depending on the nutritional status of animals. Such shrinkage is attributed to the reduction in gut content (Diaz et al., 2002; Kannan et al., 2002). On the other hand, the similarity in total live weight gain among the concentrate-supplemented goats might be due to both low magnitude of difference in energy intake and poor genetic potential of the SEA goats for growth. Total confinement of local goats might have caused the poor feed intake. Mahgoub and Lu (2004) recorded poor performance for goats under total confinement. Goats are naturally browsers, and specialized in selecting nutritious parts of browse plants when grazing. In this experiment, animals were confined and subjected to a feed ration of concentrate and low-quality hay only; still improvements in weight gains and carcass fatness were observed. If goats had access to the conventional diet with a variety of feed, performance may have improved. Nonetheless, to test this hypothesis further requires experimentation with goats where some are maintained indoors and others given chance to graze, but both having access to similar levels of concentrate supplementation. The small difference in energy intake in the present study, however, caused a small but significant difference in daily body weight gain among supplemented goats.

Through centuries, SEA goats have been adapted to changing climate, which include long period of food shortages. Compared with temperate goat breeds, SEA goats in the present study responded to higher levels of concentrate supplementation by depositing storage fat with limited increase in carcass weight. This breed difference is supported by the higher response of F1-crosses (SEA × Norwegian Dairy Breed) under similar feeding regime (Mushi et al., 2009).

Small East African goats normally put on weight at the beginning of dry season when feed is available and parasite burden is low. Part of this is lost during peak dry and rainy seasons. Hence goats are normally kept for a period of 2 years or more before slaughter. Feedlot finishing of goats, when properly undertaken, should reduce this period to less than 2 years. In Tanzania goat meat is normally sold fresh. Therefore prices, ranging from 2 to 5 USD a kilo, depend strongly on consumers demand being in connection with religious festivals and at times when few animals are available. Introduction of feedlot finishing of goats will allow farmers to have animals ready for slaughter at times when prices are high.

4.2. Killing out characteristics

Lower gut fill resulted in higher EBW and hot carcass weights for T100 and T66 goats. The observed similarity in carcass fatness among concentrate-supplemented goats is attributable to the small difference in concentrate intake. In addition, the minimal difference in carcass fatness among dietary groups (both supplemented and non-supplemented ones) could be attributed to the unique fattening pattern of goats; they deposit most of the fat around viscera and less of it in the carcass (Babiker et al., 1990; Webb et al., 2005). On the other hand, the increased levels of carcass conformation with concentrate allowance suggest that goats respond to nutritional treatment by accretion of more muscle protein (Sheridan et al., 2003).

4.3. Carcass physical and chemical compositions

The observed higher weights of carcass fat and muscle in concentrate-supplemented goats compared to that of unsupplemented one is chiefly due to heavier carcasses in the former than in the latter. On the other hand, lack of difference among diet groups with respect to bone weights is explained by the early maturing nature of bone tissue (Kerth et al., 2007). Bone tissue matures early in lifetime such that its turnover rate is slower than that of fat and muscle later in life (Atti et al., 2004). However, when expressed as a proportion of total carcass tissue weight, percentage of bone was higher in the non-supplemented group. These findings are explained by the lower carcass weight for non-supplemented group where the weight of bones accounted for a significant proportion. Results from the present study support those of Hango et al. (2007) and Kamalzadeh et al. (1998). Lack of significant difference in proportions of carcass dissectible tissue among concentrate-supplemented goats could be attributed to small difference in concentrate intake among treatments. Johnson and McGowan (1998) working with Florida native goat breed reported similar findings.

The slightly higher chemically determined fat in minced meat for concentrate-supplemented goats is the cause for its lower proportion of water, protein and ash than that of unsupplemented goats. Fat content in minced meat for concentrate-supplemented goats was above the threshold (10–15%) below which consumers find the meat to be too dry when cooked (Sebsibe et al., 2007). Although LD muscle composition was slightly affected by concentrate supplementation compared to the whole carcass, a higher proportion of chemical fat in concentrate-supplemented goats could still be detected.

4.4. Muscle physico-chemical properties

Presence of dietary effect on muscle pH decline is in disagreement with Kannan et al. (2006) and Abdullah and Musallam (2007). The difference in dietary energy intake between supplemented and non-supplemented goats could be the cause of the discrepancy. The rates of muscle pH and temperature decline during the immediate post-mortem period have remarkable effects on meat quality attributes (Diaz et al., 2002). Decline of muscle temperature to below 15 °C during the early post-mortem with a pH value higher than 6–6.4 leads to cold-shortening and slow meat tenderisation (Kannan et al., 2006). The ultimate muscle pH (pHu) for supplemented goats was, however, within the acceptable range (5.6–5.8) reported for goats (Pratiwi et al., 2007). The higher ultimate pH for non-supplemented goats can be attributed to low glycogen reserves caused by nutritional insufficiency. Similarly, the displayed higher cooling rate in carcasses for this group may be due to lower fat cover.

Values displayed for cooking loss in the present study were within the range (26.5–29.2%) reported by Abdullah and Musallam (2007). However, considering the difference in ultimate pH between supplemented and non-supplemented goats, the observed similarity in cooking loss is in disagreement with Dhanda et al. (2003) and Pratiwi et al. (2007). High pH promotes high water binding (low drip loss and cooking loss) due to higher net charges and greater space between myofilaments (Huff-Lonergan and Lonergan, 2005). As the net charge of myofilaments approaches zero (isoelectric point) with decline in pH to nearly 5.1, repulsion of myofilaments is reduced allowing them to pack more closely together. The observed discrepancy suggests that although cooking loss in muscle may depend on ultimate pH and cooking condition, pH variation must however be of a certain magnitude in order to affect cooking loss. On the other hand, the observed variation in cooking loss for individual muscles studied concurs with Pratiwi et al. (2007) that cooking losses are different for muscles taken from different anatomical regions. Muscles composed predominantly of fast glycolytic muscle fibers (type II), as opposed to those rich in slow oxidative muscle fibers (type I), are likely to have higher cooking loss due to their lower pHu (Sazili et al., 2005). The lowest values for cooking loss recorded for *M. rectus abdominis* can be attributed to its structure: high fasciae and intramuscular fat content (Keith et al., 1985). Generally, severe cooking loss is detrimental to the rating of meat quality and may lead to dryness and toughness.

The observed lack of dietary effect on Warner–Bratzler shear force is in agreement with the findings of Johnson and McGowan (1998) and Kannan et al. (2006). However, it might be considered surprising that the difference in tenderness between non-supplemented and supplemented goats was so small. Slight difference in carcass fatness, optimized slaughtering and cooling of carcasses are probably responsible for the discrepancy. In the present study, condition was not favourable for cold-shortening to occur as carcasses were maintained at temperature slightly above 15 °C for the first 6 h post-mortem. Dissection of muscles from the carcass at

6 h PM was considered of limited effect on muscle contraction because in goats rigor sets in approximately 5 h PM (Devine et al., 2002). On the other hand, the observed variation in shear force value between muscles of different location in the carcass is probably a reflection of their differential involvement in physical activity and contents and structure (extent of cross-links) of collagen fibres. Overall, meat from all the goats studied had shear values above 55 N. In addition, except for *M. psoas major*, LD aged for 6 and 9 days, *M. infraspinatus* and *M. semitendinosus,* all other muscles studied had shear force value above 55 N. Meat with Warner–Bratzler shear force values that exceed 55 N would be considered as objectionably tough both by a trained sensory panel and by consumers (Abdullah and Musallam, 2007). The lower shear force values recorded for *M. infraspinatus* in the present study coincide with findings by Keith et al. (1985). Higher tenderness for *M. infraspinatus* is associated with its higher values for intramuscular fat, despite the higher collagen content (17.8 mg/g). Anatomical structure of *M. infraspinatus* (with pronounced connective lamina in the middle), however, makes it troublesome to obtain good muscle cubes for textural analysis. Overall, for individual muscle applications, *M. gluteobiceps* (88 N), *M. vastus lateralis* (79 N), *M. Semimembranosus* (71 N) and *M. Triceps brachii* (68 N) can be regarded as objectionably tough whereas the remaining muscles fall in the tender to moderately tender range.

5. Conclusion

It is concluded that feedlot finishing of SEA had limited effects on meat quality. Finishing SEA goats at 66% of their *ad libitum* concentrate intake, however, significantly improved weight gains and carcass fatness. Such intervention may give farmers the opportunity to exploit seasonal price fluctuations and shorten the time needed for raising meat animals. Cost–benefit analyses are recommended before embarking on a large scale feedlot finishing of SEA goats.

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References

Abdullah, A.Y., Musallam, H.S., 2007. Effect of different levels of energy on carcass composition and meat quality of male black goats kids. Livest. Sci. 107 (1), 70–80.

AOAC, 2000. Official Methods of Analysis, 17th ed. Association of Official Analytical Chemists, Arlington, VA.

Atti, N., Rouissi, H., Mahouachi, M., 2004. The effect of dietary crude protein level on growth, carcass and meat composition of male goat kids in Tunisia. Small Rumin. Res. 54 (1–2), 89–97.

Babiker, S.A., Elkhider, I.A., Shafie, S.A., 1990. Chemical-composition and quality attributes of goat meat and lamb. Meat Sci. 28 (4), 273–277.

Banskalieva, V., Sahlu, T., Goetsch, A.L., 2000. Fatty acid composition of goat muscles and fat depots: a review. Small Rumin. Res. 37 (3), 255–268.

Caton, J.S., Dhuyvetter, D.V., 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. J. Anim Sci. 75 (2), 533–542.

Devine, C.E., Payne, S.R., Robyn, W., 2002. Effect of muscle restraint on sheep meat tenderness with rigor mortis at 18 °C. Meat Sci. 60 (2), 155–159.

Dhanda, J.S., Taylor, D.G., Murray, P.J., 2003. Part 1. Growth, carcass and meat quality parameters of male goats: effects of genotype and live weight at slaughter. Small Rumin. Res. 50 (1–2), 57–66.

Diaz, M.T., Velasco, S., Caneque, V., Lauzurica, S., de Huidobro, F.R., Perez, C., Gonzalez, J., Manzanares, C., 2002. Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. Small Rumin. Res. 43 (3), 257–268.

El Muola, I.H.A., Babiker, S.A., El Khidir, O.A., Ibrahim, S.E., 1999. Meat production from female goat kids compared with males. J. Agric. Sci. 133, 223–226.

Garcia-Valverde, R., Barea, R., Lara, L., Nieto, R., Aguilera, J.F., 2008. The effects of feeding level upon protein and fat deposition in Iberian heavy pigs. Livest. Sci. 114 (2–3), 263–273.

Hango, A., Mtenga, L.A., Kifaro, G.C., Safari, J., Mushi, D.E., Muhikambele, V.R.M., 2007. A study on growth performance and carcass characteristics of Small East African goats under different feeding regimes. J. Livest. Res. Rural Dev. 19 (9) http://www.cipav.org.co/lrrd/lrrd19/9/hang19130.htm.

Huff-Lonergan, E., Lonergan, S.M., 2005. Mechanisms of water-holding capacity of meat: the role of postmortem biochemical and structural changes. Meat Sci. 71 (1), 194–204.

Johansen, J., Aastveit, A.H., Egelandsdal, B., Kvaal, K., Roe, M., 2006. Validation of the EUROP system for lamb classification in Norway; repeatability and accuracy of visual assessment and prediction of lamb carcass composition. Meat Sci. 74 (3), 497–509.

Johnson, D.D., McGowan, C.H., 1998. Diet/management effects on carcass attributes and meat quality of young goats. Small Rumin. Res. 28 (1), 93–98.

Kamalzadeh, A., Koops, W.J., van Bruchem, J., Tamminga, S., Zwart, D., 1998. Feed quality restriction and compensatory growth in growing sheep: development of body organs. Small Rumin. Res. 29 (1), 71–82.

Kannan, G., Terrill, T.H., Kouakou, B., Gelaye, S., Amoah, E.A., 2002. Simulated preslaughter holding and isolation effects on stress responses and live weight shrinkage in meat goats. J. Anim. Sci. 80 (7), 1771–1780.

Kannan, G., Gadiyaram, K.M., Galipalli, S., Carmichael, A., Kouakou, B., Pringle, T.D., McMillin, K.W., Gelaye, S., 2006. Meat quality in goats as influenced by dietary protein and energy levels, and postmortem aging. Small Rumin. Res. 61 (1), 45–52.

Keith, F.K.M., Vol, D.L.D., Miles, R.S., Bechtel, P.J., Carr, T.R., 1985. Chemical and sensory properties of thirteen major beef muscles. J. Food Sci. 50 (4), 869–872.

Kerth, C.R., Braden, K.W., Cox, R., Kerth, L.K., Rankins, J., 2007. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (*Lolium multiflorum*) forage or on a high-concentrate diet. Meat Sci. 75 (2), 324–331.

Kosum, N., Alcicek, A., Taskin, T., Onenc, A., 2003. Fattening performance and carcass characteristics of Saanen and Bornova male kids under an intensive management system. Czech J. Anim. Sci. 48 (9), 379–386.

Lu, C.D., Potchoiba, M.J., 1990. Feed-intake and weight-gain of growing goats fed diets of various energy and protein-levels. J. Anim Sci. 68 (6), 1751–1759.

MAFF, 1975. Energy allowances and feeding systems for ruminants. Ministry Agric. Fish. Food Tech. Bull. 33 (London).

Mahgoub, O., Lu, C.D., 2004. Influence of various levels of metabolisable energy on chemical composition of whole carcass and non-carcass portion of goats and sheep. S. Afr. J. Anim. Sci. 34, 81–84.

Marinova, P., Banskalieva, V., Alexandrov, S., Tzvetkova, V., Stanchev, H., 2001. Carcass composition and meat quality of kids fed sunflower oil supplemented diet. Small Rumin. Res. 42 (3), 219–227.

Moran, J.B., Wood, J.T., 1986. Comparative performance of 5 genotypes of Indonesian large ruminants. 3. Growth and development of carcass tissues. Aust. J. Agric. Res. 37 (4), 435–447.

Mushi, D.E. (2004). Studies on marketing of meat goats and carcass composition — A case study of Gairo auction markets. Dissertation for award of MSc degree at Sokoine University of Agriculture, Morogoro, Tanzania.

Mushi, D.E., Eik, L.O., Thomassen, M.S., Sorheim, O., Adnoy, T., 2008. Suitability of Norwegian short-tail lambs, Norwegian dairy goats and Cashmere goats for meat production — Carcass, meat, chemical and sensory characteristics. Meat Sci. 80 (3), 842–850.

Mushi, D.E., Safari, J., Mtenga, L.A., Kifaro, G.C., Eik, L.O., 2009. Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African × Norwegian crossbred goats fed low quality grass hay. Livest Sci. 124 (1-3), 148–155.

Pratiwi, N.M.W., Murray, P.J., Taylor, D.G., 2007. Feral goats in Australia: a study on the quality and nutritive value of their meat. Meat Sci. 75 (1), 168–177.

SAS, 2001. Statistical Analysis System. User's guide, version 8.2. SAS Institute, INC, Carry. NC. USA.

Sazili, A.Q., Parr, T., Sensky, P.L., Jones, S.W., Bardsley, R.G., Buttery, P.J., 2005. The relationship between slow and fast myosin heavy chain content,

calpastatin and meat tenderness in different ovine skeletal muscles. Meat Sci. 69 (1), 17–25.
Sebsibe, A., Casey, N.H., van Niekerkl, W.A., Tegegne, A., Coertze, R.J., 2007. Growth performance and carcass characteristics of three Ethiopian goat breeds fed grainless diets varying in concentrate to roughage ratios. S. Afr. J. Anim. Sci. 37 (4), 221–232.
Shahjalal, M., Galbraith, H., Topps, J.H., 1992. The effect of changes in dietary-protein and energy on growth, body-composition and mohair fiber characteristics of British Angora-goats. Anim. Prod. 54, 405–412.
Sheridan, R., Hoffman, L.C., Ferreira, A.V., 2003. Meat quality of Boer goat kids and Mutton Merino lambs–1. Commercial yields and chemical composition. Anim. Sci. 76, 63–71.
Tilley, J.M.A., Terry, R.A., 1963. A two-stage technique for the *in vitro* digestion of forage crops. J. Br. Grassl. Soc. 18, 104–111.
Van soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74 (10), 3583–3597.
Webb, E.C., Casey, N.H., Simela, L., 2005. Goat meat quality. Small Rumin. Res. 60 (1–2), 153–166.
WHO/AFRO, 2009. Food Safety Regional Programme Evaluation Report Part II: Country Profiles. http://www.afro.who.int/des/fos/country_profiles/tanzania.pdf. Site visited on 13 march 2009.