Strategies for improving productivity of Small Ruminants in Tanzania

Philosophiae Doctor (PhD) Thesis

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Table of Contents

Papers I-V

To my family

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Abstract

This thesis presents three areas of emphasis, all related to feeds, feeding and performance of small ruminants. The first area (Paper I) focuses on seasonality and its effect on chemical composition of forage species most preferred by SEA goats, grazing behaviour and performance of goats as assessed in the rainy (February-May), mid dry (July-August) and late dry seasons (October-November). Evaluation of these forages showed a marked decline in quality as the season changed from rainy to dry. The crude protein (CP) and energy content of all forages decreased while the neutral detergent fibre content increased. The decline in feed quality varied with forage class. Unlike forbs and browses, the mean CP of grasses, for example, declined below the critical maintenance level for goats from the end of the rainy season through late dry season. Mineral concentrations varied among species and forage classes and were all low in phosphorous level. Changes in season were clearly associated with shifts in diet selection, grazing and non grazing activities. Whereas herbaceous vegetation was the main diet in the rainy season, browses and forbs were important dietary sources in the dry season. Observation on grazing activities and performance of goats in the same study showed that the proportion of time allocated for various activities varied with the changing season. For example, feeding time changed from 0.57 (57 %) in the rainy season to 0.68 (68 %) in the late dry season. Body weight gains and condition scores were highest in the middle of the dry season while the least performance of these variables was recorded late in the dry season.

The second area of this work (Paper II) presents an investigation of the influence of pre-mating dietary supplementation and the season of kidding on reproductive characteristics of SEA goats and growth performance of their off springs. The seasons were either early dry (season 1) or late dry (season 2). Results from three groups of 30 does each subjected to 0, 200 or 400 g of concentrate diet/doe/day for a period of 60 days prior to mating showed that pre-mating dietary supplementation improved ($P<0.05$) weight gains but the reproductive performance was not improved. Doe weight changes and growth rates of kids were affected by the season of kidding. Body weight changes of does, pre-weaning growth and weight of kid weaned per kg doe kidding and the weight of kid weaned per doe kidding were higher for kidding taking place in season 1 compared with that in season 2. Results suggest that production efficiency of goats can be

increased by restricting goat breeding activities in January-March for kidding to take place early in the dry season (June-August).

The third area (Papers III, IV and V) focused on growth performance, carcass yield and meat quality characteristics of small ruminants when supplemented with concentrate diets with either hay and/or treated straws as basal diets. In Papers III and IV, 32 sheep and goats were subjected to either *ad libitum* untreated wheat straw (UTS), wheat straw treated with urea and lime (TS), straw and *ad libitum* hay (UTSH) or TS and *ad libitum* hay (TSH). In addition, each animal received 220 g of concentrate diet/day (on as fed basis) for 84 days. Treatment of straw increased ($P<0.05$) dry matter intake (42.3 vs. 33.7 g/kg$W^{.75}$/day), energy intake (4.6 vs. 3.7 MJ ME/day) and the average daily gain (40.7 vs. 23.1 g) of sheep. The corresponding values for goats were (41.7 vs. 30.9 g/kg$W^{.75}$/day), (4.55 vs. 3.30 MJ ME/day) and (16.9 vs. 8.1 g). Animals on TS also produced heavier ($P<0.05$) carcasses with superior conformation than animals on UTS. Results also showed that muscles from goats were less tender compared with those from sheep.

In the final study (Paper V), 23 castrated SEA goats were used in a 90-day experiment. These goats were divided into four groups that were fed either *ad libitum* concentrate allowance (T100), 66 % of *ad libitum* concentrate allowance (T66), 33 % of *ad libitum* allowance (T33) or no concentrate (T0). For each animal, grass hay was offered *ad libitum* at 20 % refusal rate. Daily body weight gain for T100 goats was 31 g and 14 g higher ($P<0.05$) than that of T33 and T66 goats, respectively. Hot and cold carcass weights for both T100 and T66 goats were 3 kg heavier ($P<0.05$) than that of T0 goats. Results in Papers III and IV showed that temperature decline in goat carcasses proceeded at a lower rate than the decline in sheep carcasses and that the effect of diet on pH values was not significant ($P>0.05$). On the other hand, goat meat had slightly higher pH both at 45 min PM and 24 h PM than sheep meat. Post-mortem ageing of sheep meat improved ($P<0.001$) tenderness especially after 9 days of ageing. The Warner-Bratzler shear force value of m. *longissimus dorsi* aged for 9 days was 20 % lower than that aged for 0 day. However, ageing of goat meat up to 9 days PM had no effect ($P>0.05$) on tenderness. Overall, results showed potential for increased productivity in small ruminants through improved nutrition and proper timing of mating periods. Where characteristics of meat quality were assessed, there were limited effects of dietary treatments on such characteristics.

List of Papers

I. Seasonal variation in chemical composition of native forages, grazing behaviour and some blood metabolites of Small East African goats in a semi arid area of Tanzania. Manuscript submitted to *Animal Feed Science and Technology*.

II. Influence of flushing and season of kidding on reproductive characteristics of Small East African does and growth performance of their progeny in a semi arid area of Tanzania *(Manuscript).*

III. Growth, carcass yield and meat quality attributes of Red Maasai sheep fed wheat straw-based diets. *Tropical Animal Health and Production.*doi10.007/s11250-010-9658-3.

IV. Growth, carcass and meat quality characteristics of Small East African goats fed straw-based diets. *Livestock Science* doi:1016/j.livsci.2010.07.003.

V. Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats. *Livestock Science* 125, 266-274.

Abbreviations

ADF	Acid detergent fibre
ADG	Average daily gain
ADL	Acid detergent lignin
BCS	Body condition score
BW	Body weight
CCW	Cold carcass weight
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
EBW	Empty body weight
EDTA	Ethylenediaminetetraacetic acid
FCR	Feed conversion ratio
FLW	Final live weight
GLM	General linear model
HCW	Hot carcass weight
IVOMD	*In vitro* organic matter digestibility
LD (0d)	m. *longissimus dorsi* aged for 0 day
LD (6d)	m. *longissimus dorsi* aged for 6 days
LD (9d)	m. *longissimus dorsi* aged for 9 days
LL	Leg length
ME	Metabolizable energy
RM	Red Maasai
Phu	Ultimate pH
PM	Post-mortem
SAS	Statistical analysis system
SEA	Small East African
TDMI	Total dry matter intake
TP	Total protein
WBSF	Warner-Bratzler shear force

1.0 Introduction

In the tropics, small ruminants are an important subsistence mode of production contributing substantially to the livelihoods of farmers through supply of a wide range of products and services. These include animal protein, income and non conventional utilities such as manure, asset, security, employment generation, farm integration and various social cultural and religious functions (Degen, 2007; Haddad and Obeidat, 2007; Ben Salem and Smith, 2008). Broadly, the production system within which these animals are raised is generally characterized by low input-low output, and increased production is invariably associated with an increase in livestock numbers rather than production efficiency. Consequently, production levels are often lower than the economic optimum and technical maximum (Kosgey and Okeyo, 2007). This system is also associated with low off take rates (Armbruster and Peters, 1993; Peacock and Sherman, 2010) partly due to lack of marketable animals, poor animal condition or lack of willingness to sell those few in good conditions or all of the above. Poor condition of animals especially in the dry season could also be one of the reasons for reluctance of farmers to sell their animals as they would receive low income. Unlike market-oriented commercial farmers, subsistence livestock producers follow broad production objectives that are driven more by their immediate subsistence needs rather than demands of a market, and the 'products' are often maintained as stock for later use (Ayalew et al., 2003).

Further, the production system of these animals relies on cereal by-products like straws and natural pastures e.g. standing hay which make up the bulk of the feed. The total amount and quality of these feed resources vary across seasons and agro-ecological zones depending on the amounts, distribution and reliability of rainfall (Devendra and Sevilla, 2001; Angassa and Oba, 2007; Boone and Wang, 2007). In dry areas and particularly during the drier months, these feeds are largely deficient in nitrogen and high in lignocelluloses. The low quality and seasonal nature of forage supply together with low intake by animals and the poor digestibility of forages are factors that contribute to the low productivity of these animals (Ngwa et al., 2000). This is reflected clearly in low growth rate, low reproductive efficiency, delays in attaining slaughter weight and low annual meat yield (Hary, 2004; Mapiye et al., 2009; Mushi et al., 2009). In addition, loss of body weight (BW) and condition as a result of seasonal shortages and low quality feeds is a common phenomenon (Oba, 2001; Butt, 2010), and such events often compromise reproduction, carcass yield and meat quality (Dziba et al., 2003; Muchenje et al., 2009).

Based on the aspect of reproduction, evidence from literature and practical experiences suggest that, besides its direct effect on reproduction, nutrition moderates the effects of other factors including genetic potential and physical environment on reproductive performance (Smith and Akinbamijo, 2000). Poor nutrition will not only reduce performance below genetic potential but also exacerbate detrimental environmental effects. In addition, nutritional factors perhaps more than all others are more readily to manipulate for positive outcomes, and in the light of the same aspect of reproduction, goats in the tropics are known for their ability to breed throughout the year. However, the impact of this natural ability on productivity is compromised by restricted feed supplies in certain periods of the year which may fail to support, for example, higher demands of nutrients during late pregnancy and lactation. The present work included investigations on appropriate period for which breeding activities of small ruminants would improve flock productivity.

In Tanzania, the livestock sector provides about 5.9 % of the National Gross Domestic Product (MLD, 2006). This contribution is low considering the large numbers of livestock resources in the country which include 18.8 million cattle; 13.1 million goats and 3.6 million sheep (MAFS, 2002). The meat industry has generally not been able to meet the domestic demand for meat which results in importation of large amount of chilled and frozen meat into the country each year (WHO/AFRO, 2009). One of the main reasons is the production of low quality carcass and meat in the country. For example, according to FAOSTAT (2009) data, based on 2008 statistics, goat and sheep carcasses in Tanzania weigh less than 13 kg. In the international meat market, such carcasses are generally considered to be of poor morphology and would be systematically penalized for their size (Russo et al., 2003). Attempts to improve size and weight of carcasses are therefore important aspects of production of small ruminants that need to be addressed by the Tanzania meat industry.

In respect of the meat quality in Tanzania, the subject has received strong emphasis particularly during the last few years. This is, in part, due to increase in demand for quality meat as a result of several factors including increase in the influx of tourists and expatriates in various service sectors. In addition, this rise in demand is possibly associated with the increase in the segment of affluent consumers in the country who search for quality meat. Experience from other countries shows that for consumers who are already aware and concerned with health issues, quality is one of the major factors that determine their acceptability and choice of meat (Arsenos et al., 2002; Grunert et al., 2004). The meat industry in Tanzania, therefore, needs to develop strategies that span the entire meat production chain that must assure consumers of high quality meat as it works to increase the share of marketable meat and meat products.

The term ‘meat quality’ covers inherent properties of meat decisive for the suitability of the meat for eating, further processing and storage including retail display (Andersen et al., 2005b). It includes attributes such as carcass composition and conformation, the eating quality of the meat, health issues, environmental impact and conditions under which the meat is produced (Maltin et al., 2003; Krystallis and Arvanitoyannis, 2006). Numerous studies show that meat quality is influenced by several genetic factors, such as breed (Teixeira et al., 2005; Esenbuga et al., 2009), slaughter weight (Okeudo and Moss, 2008; Peña et al., 2009; Waritthitham et al., 2010) and sex (Santos et al., 2007; Tejeda et al., 2008; Rodríguez et al., 2008). Other factors are environmental, which include type and level of feeding (Velasco et al., 2004; Castro et al., 2005; Kannan et al., 2006), pre-slaughter handling, post-slaughter carcass handling and the interactions of these factors (Okeudo and Moss, 2005; Vergara et al., 2005; Miranda-de la Lama et al., 2009). Current work deals mainly with carcass yield and physico-chemical properties of meat from animals raised on different type of diets.

Genetic and environmental factors can have effects on muscle/meat structure, and so too on meat quality attributes. For instance, differences in collagen content and solubility account for differences in tenderness among animal breeds and species (Tschirhart-Hoelscher et al., 2006; Lepetit, 2008). Various studies (e.g. Kadim et al., 2006; Ferguson and Warner, 2008; Muchenje et al., 2009) have also reported significant influence of pre-slaughter handling on meat quality characteristics particularly initial and ultimate pH (pHu), tenderness, water-holding capacity and colour. All these spell the need for continued research efforts that seek to optimize yield and quality of meat, and to establish good control and standardization of the post-slaughter environment.

Since production performance of small ruminants is constrained by poor nutrition as noted earlier on, it is imperative that nutritional strategies are identified in order to increase productivity in this sector. Prior to any nutritional intervention, however, it is important to verify the types and levels of limiting nutrients across seasons as a basis to the assessment of animal performance in its entirety. Thus, investigations herein referred to as study I were carried out to evaluate seasonal variation and chemical composition of widely used native forages, and to assess the relationship with body weight and condition together with changes in the levels of nutritionally related blood metabolites. Grazing behaviour of the animals involved was also observed for the purpose of determining the effects of changes in nutritional levels in native forages on grazing pattern of animals in a much broader context; since the variation in the feed resource and in the animal requirements causes selective foraging (Skarpe et al., 2007). The study involved testing the hypotheses that goats browse from feeds providing the highest levels of nutrients, that seasonal variation in nutritive values of feeds elicits foraging shifts in favour of the most nutritive feeds of the season and that changes in nutritive values of feeds impact biochemical indicators in the blood as well as animal performance.

Considerations on the role of nutrition on reproduction, growth performance, carcass yield and meat quality also prompted investigations on the effect nutritional flushing and the kidding season on reproductive performance (Study II). The hypothesis tested was that kidding after the long rains improves performance of SEA goats and that supplementary feeding during peak-dry season is needed if goats are to attain high conception rate. Two other similar studies involving utilization of wheat straw based diets using Red Maasai (RM) sheep (Study III) and Small East African (SEA) goats (Study IV) were also carried out. The background to these studies relates to the fact that in spite of the nutritional importance of cereal straws for livestock, these feed resources are generally of poor feeding values as digestible energy, crude protein (CP) and mineral content are all low beside their physical characteristics which limit intake and digestion. On the other hand, application of chemical treatment is known to upgrade the quality of such feeds. Treatment with chemicals such as alkalis alters the characteristics of straws and renders cell wall constitution more vulnerable to microbial attack in the rumen while adding nitrogen to the feed and thereby increasing feeding value, particularly digestibility and intake potential (Sundstøl, 1988; Zerbini and Thomas, 2003; Chen et al., 2008). In studies III and IV the following hypotheses were tested (1) feeding upgraded wheat straw improves growth performance of sheep and goats (2) addition of hay to upgraded wheat straw improves growth performance of sheep and goats and (3) based on hypotheses 1 and 2, such effects improve carcass characteristics and meat quality characteristics.

The fifth and final part of this work (study V) involved testing the effects of concentrate supplementation on carcass and meat quality of SEA goats. Here, goats were subjected to four levels of concentrate supplementation which were denoted as T100, T66, T33 and T0 for *ad libitum* concentrate allowance (370 gDM/day), 66 % of *ad libitum* concentrate allowance, 33 % of *ad libitum* concentrate allowance and no concentrate supplementation, respectively. The basis for this experiment was founded on the fact that use of low quality forages alone may not support the desired level of animal performance (Goodwin et al., 2004; Ben Salem and Smith, 2008; Morand-Fehr, 2005). Thus, testing various levels of supplementation and establishing the optimal level was required. In addition, much of the research carried out in relation to the use of low quality basal roughages such as hay, stover and straws (e.g. Tuen et al., 1991; Abebe et al., 2004; Berhane and Eik, 2006; Rubanza et al., 2007; Nurfeta et al., 2009) has not related the subject with evaluations of meat quality characteristics. Overall, current research on nutrition extends from response in reproduction and growth performance to carcass and meat quality characteristics of SEA goats and RM sheep. The data provide base-line information which may be useful for future research on small stock and meat industry in the country.

2.0 Objectives of the study

- To evaluate the nutritive value of grazed native forages and its implication on some blood metabolites and grazing behaviour of SEA goats under free-ranging grazing conditions (Study I)

- To investigate the effects of pre-mating supplementary feeding and the season of kidding on reproductive characteristics, weight changes of SEA does and growth performance of their off springs (Study II)

- To evaluate the effects of feeding treated wheat straw alone or in combination with grass hay on growth performance, carcass characteristics, non-carcass yield and meat quality characteristics of RM sheep and SEA goats (Studies III and IV)

- To evaluate the effects of different levels of concentrate diet on growth performance, carcass and meat quality of SEA goats (Study V)

3.0 Materials and methods

Study I was conducted to evaluate the chemical composition, digestibility and utilization of the most preferred forage species in the diet of goats grazing/browsing in a semi-arid area of Tanzania. Grasses, forbs and browses were collected during three seasons (rainy: February-May, mid dry: July-August and late dry: October-November). During these seasons, the grazing behaviours of sixteen non-pregnant, non-lactating SEA does (25±1.2 kg BW) were observed in addition to the assessment of changes in body weight, conditions scores, worm counts and nutritionally related blood metabolites. The activities recorded during grazing hours were: consumption of forage (grasses, forbs or browses), idling, walking, standing + ruminating, lying + ruminating, playing and scratching/self grooming.

In Study II, the effects of supplementary diet (flushing) and season of kidding either early dry (season 1) or late dry (season 2) on reproductive characteristics of SEA does and growth performance of their progeny were assessed for two successive years (November 2007-December 2009). Ninety grazing does were divided into three groups of 30 does each, which were balanced for age, parity and weight. The first group (control goats) was not flushed while the remaining two groups were supplemented with 200 or 400 g of concentrate diet /doe/day for 60 days before mating. Does were then exposed to sexually active bucks in the months of January through June 2008 and 2009 and monitored for the live-weight changes, BCS and reproductive characteristics such as fertility rate, prolificacy and fecundity. In addition, data obtained were analysed for the effects of type of birth (single or twin), parity of the doe (<3, 3-5 and >5) and the birth type x doe parity interactions on growth performance of kids.

In studies III and IV, thirty two castrated RM sheep (12.7 kg BW) and 32 castrated SEA goats (13.8 kg BW), aged 12-18 months were used in an 84-day feeding experiment to evaluate the potential of using treated wheat straw based diets on growth rate and yields of carcass and non-carcass components as well as the meat quality characteristics of sheep and goats. For each species, animals were blocked by weight into four similar groups and then randomly allotted into four dietary treatments with eight animals per treatment. The dietary treatments were either *ad libitum* amount of untreated wheat straw (UTS), treated wheat straw (TS), untreated wheat straw with hay (UTSH) or treated wheat straw with hay (TSH). Each experimental animal also received 220 g/day (on as fed basis) of a concentrate diet composed of maize bran (70 %), sunflower seedcake (28 %) and mineral mix (2 %). In study V, effects of supplementing SEA goats with different levels of concentrate diet on carcass and meat quality were assessed using 23 animals (14.5 months old; 20.1 kg body weight). The levels of concentrate diet were *ad libitum* (T100), 66% of *ad libitum* concentrate allowance (T66), 33% of *ad libitum* (T33) and no concentrate (T0). The experiment lasted for 90 days.

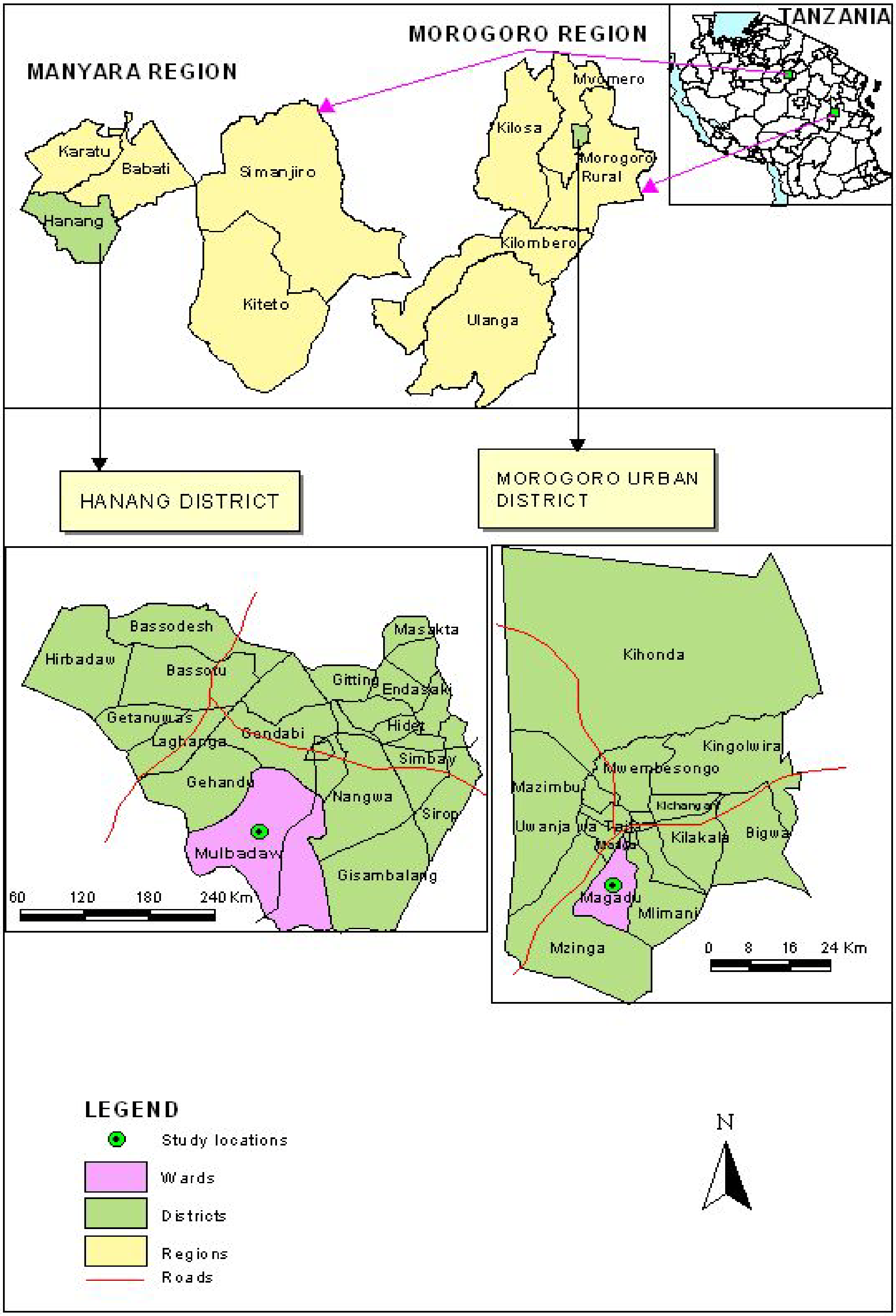

Fig 1. Location of the study areas

4.0 Main results

4.1 Seasonality, changes in quality of feed resources and animal performance

The CP and energy content of all forages decreased with advancing season (Figures 2 and 3) while NDF content increased (Paper I, Tables 1, 2 and 3). Crude protein content in browses and forbs was higher than that of grasses. The CP content ranged from 24.4 to 191.0, 45.7 to 241.6 and 97.5 to 228.4 g/kg DM for grasses, forbs and browses, respectively. Unlike grasses for which mean CP values declined below the critical maintenance requirement level for goats from the end of the rainy season through late dry season, the opposite was the case for browses and to some extent forbs. The content of neutral detergent fibre (NDF) and acid detergent fibre (ADF) ranged from 529.3 to 827.8 and 338.3 to 594.9 (grasses), 262.7 to 633.4 and 207.5 to 458.4 (forbs), and 288.5 to 619.9 and 161.7 to 450.1 g/kg DM (browses), respectively.

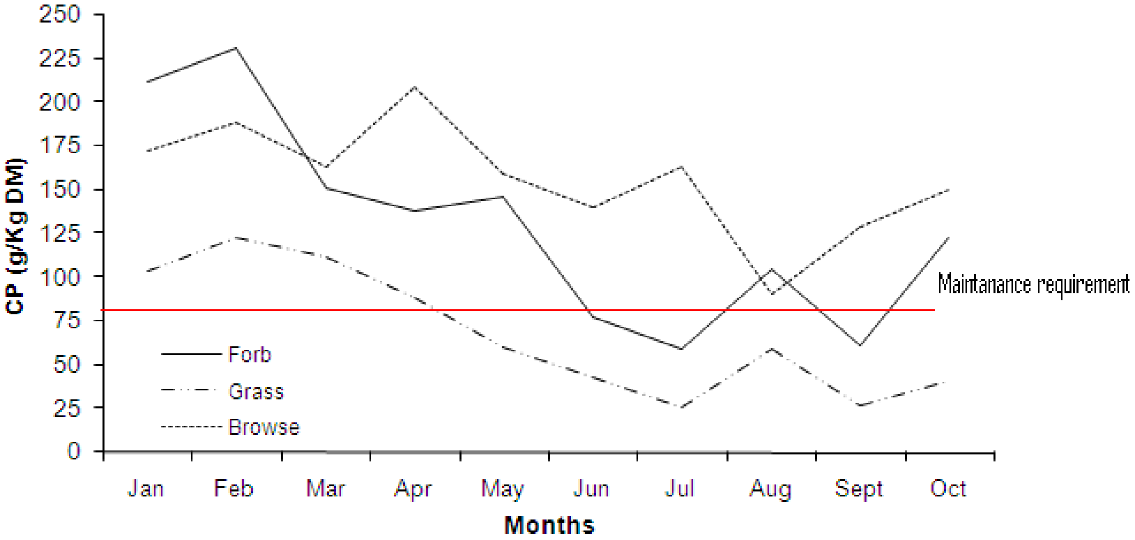

Fig 2. Trends in crude protein (CP) (g/Kg DM) of native grasses, forbs and browses harvested at Mulbadaw

In vitro organic matter digestibility (IVOMD) coefficients and predicted metabolizable energy (ME) density were in the range of 28.7 to 61.3 g/kg DM and 4.6 to 9.8 MJ/kg DM for grasses, 47.6 to 76.2 g/kg DM and 6.4 to 12.2 MJ/kg DM for forbs and 22.7 to 69.6 g/kg DM and 3.6 to

11.1 MJ/kg DM for browses, respectively. Mineral concentrations varied among species and were all low in phosphorous level. Most plants were rich in Ca. With exception of forbs and to some extent grass species, browses were deficient in Zn while Cu was only deficient in grasses.

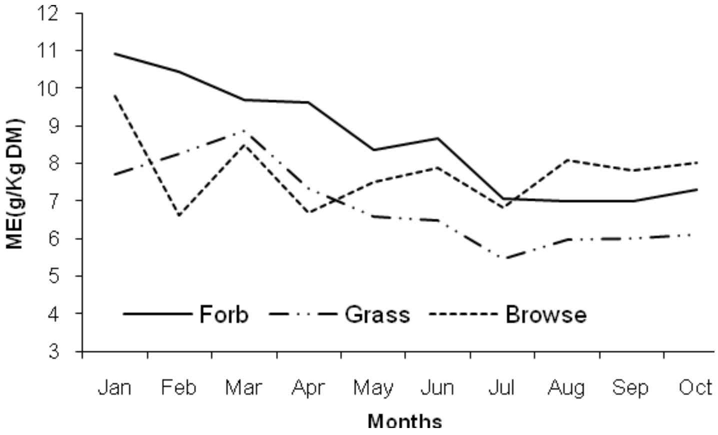

Fig 3. Trends in metabolizable energy (ME) (MJ/kg DM) of native grasses, forbs and browses harvested in Mulbadaw

Comparisons of the grazing behaviour of goats in different seasons (Paper I, Table 4) clearly indicated foraging shifts in terms of types of diets selected and changes in grazing and non grazing activities. Diet for the rainy season was mainly composed of herbaceous vegetation but more browses and forbs were consumed with advancing dry season. The proportion of time allocated to feeding changed from 0.57 in the rainy season to 0.68 in the late dry season. Meanwhile, the time spent idling decreased from 0.048 (rainy season) to 0.009 (late dry season). In addition to the variations in foraging activities by seasons, there were differences in body weight and conditions together with nutritionally related blood metabolites. Body weight gains and condition scores were highest during early dry season while the least performance of the same was recorded during late dry season. Serum total protein and urea concentrations were also low during late dry season which coincided with low protein levels in the forage.

4.2 Nutritional flushing, season of kidding and reproductive characteristics of SEA goats

Results presented in Paper II shows that dietary supplementation improved ($P<0.05$) weight gains with the highest record in T400 group. However, supplementary feeding during peak dry season does not seem to be necessary for local goats to conceive especially when goats are raised on lightly grazed rangeland. Period of mating/kidding was found to have profound effects on weight changes of does and kids. The relative weight increases of does during gestation, the live weight increase of kids from week 4 to 12, the weight of kid weaned per kg doe kidding and the weight of kid weaned per doe kidding were all higher in season 1 compared with those in season 2. Also, the proportion of loss in weight of does from kidding to weaning was lower in season 1 (6.1 %) than that in season 2 (8.9 %). Thus, restricting goat breeding activities in January-March for kidding to take place during early dry season (June-August) would improve productivity of goats in semi-arid areas of Tanzania.

4.3 Utilization of low quality feeds in production of RM sheep and SEA goats

This section summarizes results of three Papers based on studies III, IV and V. Comparisons are made particularly for studies III and IV in which sheep and goats were raised on the same diets and to a less extent, on meat quality characteristics in studies III, IV and V.

4.3.1 Feed intake and growth performance

Results in Papers III and IV show that for both sheep and goats, diet affected ($P<0.001$) feed intake and body weight (BW) gain. Treatment of wheat straw with urea and CaO improved ($P<0.05$) feed intake and BW gain of the experimental animals. Hay had positive effect on total DMI for goats on UTS only (Paper IV, Table 2). Total feed and DM intake as percentage of BW of sheep and goats were higher in diets containing treated wheat straw (TS, TSH) than in diets based on untreated wheat straw (UTS, UTSH). There were differences in total feed intake between species. The total DM intake for goats was 9 % lower than that of sheep. When intake of DM was expressed in metabolic body weight, the value for goats was 5 % lower than that of sheep. The T100, T66 and T33 goats consumed 370, 280 and 140 g DM/day of concentrates, respectively. However, the total dry matter intake of these goats were similar ($P>0.05$) and higher ($P<0.05$) than that of T0 goats (Paper V, Table 2).

Compared to sheep, the performance of goats in terms of BW gain and feed conversion ratio was poor (Paper III, Table 2; Paper IV, Table 2). The average daily gain varied from 8.1 to 26.8 g for goats and 23.1 to 47.8 g for sheep, depending on the diet on offer. It is intriguing to note that the BW gain of animals fed TS was nearly twofold higher than that of animals on UTS. Overall, sheep grew at 20 g/day higher than goats leading to 1.6 kg greater total weight gain in favour of sheep. The overall mean final body weight for sheep was 10 % higher than that of goats. In study V, the daily weight gains increased with an increase in concentrate allowance while T0 goats lost weight at a rate of 23.6 g/day (Paper V, Table 2)

4.3.2 Slaughter characteristics, carcass and non carcass composition

Diet caused significant differences on the mean final body weight (FBW), shrunk body weight (SBW), empty body weight (EBW) and commercial dressing percentage, being higher for animals fed treated straw than for those fed untreated straw based diets. Diets also affected ($P<0.05$) hot carcass weight (HCW) in sheep and goats with the main difference occurring between TS and UTS. Hot carcasses from TS and TSH were about 18 % heavier ($P<0.05$) compared with those from UTS (Paper III, Table 4; Paper IV, Table 6). Addition of hay to TS and UTS did not increase carcass weight. Goats had lower gut fill than sheep (16.5 % vs. 19.5 %) and higher ($P<0.01$) commercial dressing percentage than sheep (44.2 % vs. 40.2 %). Comparison of the dressing percentage between goats in study IV and study V shows higher values for the latter.

Muscles of animals on treated straw based diets were heavier ($P<0.05$) compared with those on untreated straw based diets (Paper III, Table 5; Paper IV, Table 7). Diets, however, had no ($P> 0.05$) effect on dissectible muscle contents of goat and sheep when expressed as percentage carcass weight. The percentage of fat tissue in the carcasses from goats and sheep fed TS, TSH and UTSH were similar ($P>0.05$) and higher ($P<0.05$) than that in carcasses from UTS. Dietary treatments had no effect ($P>0.05$) on the weight of bone tissue. When expressed as percentage of carcass weight, the proportions of bones were highest in goats and sheep maintained on UTS. There were no ($P>0.05$) dietary effects on the muscle: bone ratio.

Carcass fatness score was significantly affected by type of feed. Carcasses from TS had superior ($P<0.05$) conformation and fatness scores over those from UTS. Mean conformation scores were O for goats and O^- for sheep based on 15-point EUROP scale. Neither straw treatment nor hay inclusion influenced the linear carcass measurements. On the other hand, goats on T0 had the least carcass conformation and fatness scores (Paper V, Table 3). Except for the hind limb width, linear carcass measurements and indices were not influenced by diet (Paper III, Table 4; Paper IV, Table 6; Paper V, Table 3). Total non - carcass yield as the proportion of shrunk body weight in goats (32 %) was substantial and similar with that in sheep (33.3 %). With the exception of the heart fat, all other internal fat depots (omental, mesenteric, pelvic and kidney) as well as total non-carcass fat depot were in higher proportion for goats than for sheep.

4.3.3 Meat quality characteristics

4.3.3.1 pH and temperature changes

The effect of diet on pH values was not significant ($P>0.05$) in studies III, IV and V. However, animal species influenced the pattern of pH decline whereby goat meat had slightly higher pH than sheep meat both at 45 min PM and 24 h PM. The average pHu for goat meat was 6.2 after completion of glycolysis (24 h PM) while that of sheep was 5.7. Temperature decline in goat carcasses proceeded at a lower rate than the decline in sheep carcasses. Comparison of the proximate composition between goat and sheep meat indicated that most of the nutritional indices were little influenced by species under these feeding conditions.

4.3.3.2 Ageing, cooking loss and meat tenderness

Post-mortem ageing of sheep meat improved ($P<0.001$) tenderness especially after 9 days of ageing. The WBSF value of LD 9d was 20 % lower than that of LD 0d while post-mortem ageing of goat meat had no effect ($P>0.05$) on tenderness. In Paper V, however, ageing of goat meat for 6 and 9 days resulted in similar reduction of WBSF and these values were higher than that of meat aged for zero day. Except for m. *triceps brachii* and m. g*luteobiceps,* diet had no effect on the cooking loss (CL) of most of the individual muscles studied (Paper III, Table 7; Paper IV, Table 9). In study V, diet had no effect (P>0.05) on CL of any of the muscles studied. A wide variation, however, was observed in CL between muscles. In both sheep and goats, the CL for *m. semimembranosus* for example, was about twice as great as that from the m. *rectus abdominis* (Paper III, Table 7; Paper IV, Table 9; Paper V, Table 5). On the other hand, m. *longissimus dorsi* aged for 0 and 9 days, m. g*luteobiceps*, m. *psoas major* and m. *semimembranosus* in sheep exhibited higher CL than similar muscles in goats, and so too was the tendency in other muscles. With the exception of m. *longissimus dorsi* (0d) and m. *semitendinosus,* WBSF values were not affected by diet but wide variations between species was noted. Muscles from sheep had lower mean WBSF values compared to values obtained in goat muscles. For example, if means of WBSF values for m. g*luteobiceps* and m. *vastus lateralis* are pooled in all diets and compared, the values of the respective muscles are 30 % and 26 % higher in goats than the corresponding values in sheep.

5.0 General discussion

5.1 Seasonality, changes in quality of feed resources and animal performance

The decline in nutritive value found in all forage classes, albeit with a varying degree is a result of advancing maturity. Illustrations of these were given in Figures 2 and 3. Of the factors influencing nutritive values such as plant species, variety, growing conditions, plant fraction and stage of plant maturity at sampling (Moreira et al., 2004; Arzani et al., 2006; Chaves et al., 2006; Suyama et al., 2007), maturity influences forage nutritive value more than any other single factor (Hassen et al., 2007). This is mainly due to increase in the proportions of structural carbohydrates such as cellulose, hemicelluloses and lignin and a decrease in CP (Buxton and Fales, 2004; Kozloski et al., 2005). Such forages have impaired rates of cellulose and hemicelluloses digestion (Beever and Mould, 2000), and often constrain intake as the animal can eat no more than 1.2 % of its body weight as NDF (Mertens, 1992).

The observed persistence in higher levels of nitrogen in leguminous shrubs and tree species relative to other forage classes is well documented in other studies (Tainton, 1999; Ahmed and Elhag, 2003; Rubanza et al., 2007). For example, Yayneshet et al. (2009) reported the CP contents (g/kg DM) of 132.7 to 238.6 (long rains), 106.7 to 227.6 (dry period) and 145.2 to 290.6 (short rains) in leaves of five browse species from Tigray Region of Northern Ethiopia. Two important aspects explain the scenario of high nutrient content throughout the seasons. First, is the ability of these plants to fix atmospheric nitrogen via the symbiotic relationship with soil bacteria (Ammar et al., 2004). Second, most of these plants have deep rooting system that allows them to take up water and other nutrients from deep layers of soils (Dulormne et al., 2004). Based on the CP content, most of the browse species evaluated in the present study could be regarded as medium to high quality forages. The lowest CP content recorded for *O. kirkii* (97.5 g/kgDM) in mid dry season is still higher than the minimum threshold level (80 g/kgDM), which would limit intake of tropical forages (Minson, 1980). As depicted in Figures 2 and 3, tropical grasses are characterized by a rapid fall in nutritive value with advancing dry season, a feature also widely reported in literature (e.g. Bwire et al., 2004; Kozloski et al., 2005; Berhane and Eik, 2006; Mahieu et al., 2008). Grasses in the tropics are also known to contain 5 to 11

MJ/kgDM of ME and 20 to 200g/kgDM of CP (Wilkins, 2000), and because of these features, they may not provide nutrients adequately during certain months of the year. Pasture examined in the present study was predominantly composed of the grass species and was expected to have a low level of CP (i.e. <80 g/kgDM) for most of the year, unless it consisted of appreciable proportions of forbs and trees, which as indicated in Fig 2 or in Tables 2 and 3 (Paper I) contained high levels of CP. As such, additional supply of nitrogen rich forages as shown in a report by Rubanza et al. (2007) would help to meet the requirement for rumen degradable protein and improve animal performance.

In the case of minerals, the low levels of phosphorous noted is a feature prevalent in the tropics (Tainton, 1999; Ramirez-Orduña et al., 2005). The concentration of individual minerals in tropical forages varies widely depending on soil, plant species and management factors (McDowell, 2003). Such variations are also season dependent (Haenlein and Ramirez, 2007; Hassen et al., 2007; Khan et al., 2010). This is because the availability of nutrients in the soil and the capacity of the root system to absorb them are affected by weather patterns (Van Soest, 1994). Peak levels of minerals occur usually when growth is most active. Thereafter, the levels begin to decline. Most of the minerals studied in the present work were clearly at the lowest levels during late dry season. Based on chemical composition, species having low fibre and high CP levels such as *A. xanthophloea, O. kirkii, B. stepia, L. capensis, Sorghum spp* and *C. nlemfuensis* could be employed to improve the quality of standing hay. In addition, these forage species and other dicotyledonous species have potential advantage of enhancing the concentration of minerals e.g. *S. arundo* which contained relatively high levels of P. However, evaluation of ant-quality factors such as soluble phenolic and condensed tannin compounds for such plants is needed.

In view of feed selection, foraging preference for grasses exhibited during the rainy season (Paper I) could be explained by the fact that during this season, grasses are more succulent, less coarse and high in protein content. It has been demonstrated that goats and other grazing ungulates show high preference for forages with such attributes, so that grasses at this stage of growth, offer better choices than browses (Odo et al., 2001; Goodwin et al., 2004; Codron et al., 2007). On the other hand, low preference for grasses in the dry season is most likely attributed to increased concentrations of NDF and lignin which are known for their inhibitory effects on intake and digestion in grazing animals (Moore and Jung, 2001; Casler and Jung, 2006).

The importance of forbs and browse especially during the dry season is suggested by preferential browsing in their favour as plant species from these two classes often had higher levels of nutrients (crude protein, energy and minerals). Importantly, browse species serve as reserves that ensure continued supply of nutrients to grazing animals in the dry season when biomass of standing grass is low and deficient in nutrients for maintenance or production requirements. The shifts in choices of forage and time allocated for eating such as those observed in the present study supports the view that when animals detect sward heterogeneity, their foraging walks are not random but structured to efficiently utilize the sward structure in such a manner as to maximize intake of nutrients (Soder et al., 2007). This therefore, underlines the importance of diversity of plant species in grazing environments, the idea encompassing a wide range of plant species and the relative abundance of species present (Magurran, 2004). The outlined seasonal changes in quality of forages (Paper I, Tables 1, 2 and 3) were reflected in biochemical indicators in the blood and most likely contributed to the changes in body weight and condition in goats (Paper I, Table 5).

5.2 Nutritional flushing, season of kidding and reproductive characteristics of SEA goats

That flushing did not improve reproductive performance of grazing SEA does is contrary to the findings of Kiker et al. (2007) and Blache et al. (2008) who reported improved conception rates and generally the reproductive performance of flushed females over those that were not flushed. The present results are, however, similar to those of Acero-Camelo et al. (2008) who found that inclusion of concentrate diet did not improve reproductive performance in meat goats. Explanation for such differences is most likely the variations of animals used. For instance, earlier works have indicated a tendency for animals in good condition not to respond to flushing (Coop, 1966; Hart, 2008). In their evaluation of the effect of BCS on ovarian activity, Dapoza et al., (1995) recommended flushing for females with BCS below 2.5. In the present study, the average condition score of does at breeding was not far from the optimal range of 3.0 to 3.5 (Spahr, 2004; Robinson et al., 2006), and this is likely to have partly resulted in poor response to flushing. In addition, the small number (90) of goats used in this study might have contributed to the failure to depict significant differences in reproductive performance of goats under different levels of dietary supplementation. Another important aspect regarding interaction of nutrition and reproduction is the level of energy and protein on offer and the timing and duration of flushing. A review by Smith and Stewart (1990), for example, showed that feeding a high-energy ration for less than one oestrous cycle does not increase ovulation rate but high-protein supplementation increased ovulation in as fewer as six days. Generally, both early (i.e. grazing background) and, to a lesser extent, recent nutritional history (pre-mating flushing treatments) could affect body weight and condition at mating and hence the reproductive performance (Molle et al., 1995; El-Hag et al., 1998; Ocak et al., 2006). More work with respect to nutrition and reproduction of local goats in Tanzania is therefore needed in order to establish circumstances under which farmers can improve production efficiency of goats taking into account the multiple factors affecting reproduction under grazing conditions.

Depressed increase in gestational weight among does that kidded in season 2 (late dry) relative to their counterparts kidding in season 1(early dry) is probably due to insufficient nutrients available for the former group where, for example, available CP from forbs and grasses was found to be at the level below maintenance requirements (Fig 2). Equally, energy levels in season 2 were at the lowest point (Fig 3). When the dietary supply of nutrients is inadequate, increased nutritional requirements are met by mobilizing body reserves. Consequently, goats like other domestic species are sensitive to nutritional stress during pregnancy especially under extensive management conditions (Blache et al., 2008), and therefore, accelerated loss in body weight of dams is expected. Research work from other studies indicate that severe feed deprivation during varying stages of pregnancy seems to exacerbate live weight losses and increase the risk of reproductive wastage due to abortion, retardation of fetal growth, reduced birth weight and increased neonatal death rate (Mellado et al., 2004). Periods of severe nutritional stress pre-partum are also likely to affect levels of milk production, further increasing the likelihood of neonatal losses and depressed growth performance (Hary and Schwartz, 2002). An associated feature of the post-partum dietary effects is that where kidding/lactation period does not coincide with the adequate nutritional supply, post-partum oestrus cyclicity is impaired (Robinson et al., 2006). In respect of the weight changes of does post-partum observed in the current work, assumption is made that does kidding in season 2 were less able to withstand the increased physiological stress associated with milk production as compared with those kidding in season 1. Thus, in the context of nutritionally sensitive periods in goat production as well as other species in the farming system within which they are kept, it is necessary that breeding activities considers the availability of feed resources for such periods. And in the case of the present work, breeding should take place between January and March.

5.3 Utilization of low quality feeds in production of RM sheep and SEA goats

5.3.1 Feed intake and growth performance

The higher DM intake recorded for sheep compared with goats is supported by findings of Sormunen-Cristian and Kangasmaki (2000). A study by Haddad and Obeidat (2007) also showed that lambs consumed 218 and 216 % more DM and OM compared to kids, respectively and that the CP, NDF and ADF intakes showed a similar pattern. Differences in intake and digestion between sheep and goats appear to depend on nutritional quality of the diet or feed compared and the feeding systems generally. Van et al. (2007) reported that when stall fed *ad libitum*, goats have lower ability to digest low quality feeds than sheep but when given access to grazing, goats select better parts of plants and have the same or better ability to digest such feeds than sheep. Such illustrations were also presented by Salem et al. (2006) where goats consumed 3.9 % more DM than sheep per kg $BW^{.75}$, and that their ability to digest tree foliages as the basal diet was higher by 8 %. Tisserand et al. (1991) analysed the possible mechanisms for which good digestion of poor forage in goats could be explained; a conclusion was reached that goats tend to retain nutrients longer in the digestive tract, have a higher concentration of cellulolytic bacteria in the rumen and are more efficient in recycling blood urea.

The DM intakes obtained in studies III and IV are comparable to 43.4 g/kg $^{0.75}$ for sheep and 42.6 g/kg $^{0.75}$ for goats fed wheat straw as sole diet (El-Meccawi et al., 2009) while Sahoo et al. (2000) in India reported as high as 49.5 g/kg $^{0.75}$ intake in rams of Muzaffarnagari breed fed upgraded wheat straw. These variations could be due to the differences in quality of straws which in literature indications are that wheat straws cover a wide range of chemical composition (Labuschagne et al., 2000; Ryan et al., 2008; Mazzenga et al., 2009). The difference in genotypes of wheat which is also related to variations in the proportion of leaf and stem components of the straw produced, affect digestibility and mean retention time of digesta in the reticulorumen (Hadjigeorgiou et al., 2003). This alone may explain why chemical treatment does not have the effect of bringing different cultivars/genotypes to similar digestibility levels as reported by Habib et al. (1998). Other factors affecting intake include physiological state of animal and the level and frequency of feeding (Goetsch et al., 2004). Increased CP content in TS in the present study may explain the increase in DMI observed in sheep and goats fed TS based diets. Approximately 25 % increase in DMI due to urea treatment is common but variable, sometimes even between experimental periods of the same trial (Sahoo et al., 2000). Feed intake in both animal species in the present work was within the expected range of 2 to 5 % of the body weight per day for finishing sheep and goats (NRC, 1985). Results from the present study indicate potentials for treated straw to sustain small ruminants during the dry season. In study V, finishing of SEA goats at 66 % (244 gDM/day) of *ad libitum* concentrate intake seemed to be the optimal amount to improve weight gains and carcass fatness. In reference to growth performance and as noted earlier, poor growth and feed conversion ratio in goats could be associated with stall feeding system. Stall feeding limits feed selection and appears to be more unfavourable for goats than for sheep. Lower growth rate in goats compared to sheep could also be due to species differences in growth potentials. As for the unsupplemented goats (T0) in study V, the loss in weight in this group, implies that hay alone is not able to provide sufficient nutrients for maintenance.

5.3.2 Slaughter characteristics, carcass and non carcass composition

Feeding regimen is known to affect carcass composition of farm animals particularly the fat content when there is variation in energy concentration and intake of diets (Gruszecki et al., 2001; Mahgoub et al., 2005b; Attah et al., 2006). Results presented in Paper III for example, show that the dietary energy intakes were 4.61, 4.65, 3.48 and 4.00 MJ, ME/day for sheep on TS, TSH, UTS and UTSH respectively, and to a great extent, this accounts for the observed variations in fat content in the carcasses. Goats had higher total non carcass fat than sheep. The explanation is more likely to be that goats entered a fattening phase earlier than sheep as mature weight of SEA goats is lighter than that of RM sheep (25 kg *versus* 35 kg, Manson and Maule, 1960). Variations in fat content could also indicate species difference in fat accretion. This phenomenon has an economical implication on meat production. Early maturing animals should be slaughtered at a lower body weight than late maturing ones to avoid excess fat which is less desirable as it reduces feed conversion efficiency besides reduced value of carcass that may result from trimming (Sen et al., 2004). The finding that animals subjected to TS dressed higher than those fed UTS can be ascribed to the large gut and its content recorded for the latter group. In addition, dressing percentage increases with increasing slaughter weight (Vergara et al., 1999; Mahgoub et al., 2005a), lighter slaughter weights of 12.9 to 14.8 kg (study IV) *versus* 16.7 to 24 kg (study V) accounts for the corresponding low and high dressing percentages of the two groups of animals.

5.3.3 Meat quality characteristics

5.3.3.1 pH and temperature changes

High pH values (i.e. pHu >6.0) for goat muscles observed in studies IV and V is a phenomenon widely reported in literature (Marichal et al., 2003; Argnello et al., 2005; Webb et al., 2005; Atti et al., 2006; Mushi et al., 2009; Ding et al., 2010), indicating that goats are generally more prone to stress. However, the fact that there are reports of goat meat with normal pHu of 5.6 to 5.8 for example in Liuyang black (Zhong et al., 2009), Moxotó and Canindé (Madruga et al., 2008) and Greek goats (Arsenos et al., 2009), counters the idea that high pHu is an intrinsic characteristic of the species. Elevated pH affects several meat characteristics generally, including ageing potential, tenderness, appearance and water-holding capacity (Ding et al., 2010; Ekiz et al., 2010; Muela et al., 2010). On the other hand, the rate of pH fall post-mortem is inversely related to tenderness of the meat (Lawrie and Ledward, 2006).

The observed difference in temperature decline between goat and sheep carcasses in studies III and IV is probably due to the difference in fat coverage and size of goat and sheep carcasses. Leaner and small sized carcasses normally dissipate heat at a rapid rate during the immediate post-mortem period whereas large carcasses with high fat cover are associated with a slower temperature decline (Koohmaraie, 1988; Kouakou et al., 2005). Goats used in study IV were slightly older than sheep used in study III. Such differences have implication on variation in fatness. The effects of muscle pH and temperature on meat properties during the immediate post-mortem period are interlinked and can have profound effects on meat quality. For example, if rapid cooling occurs and the internal muscle temperature drops below 10°C within the first 10 h PM while pH > 6.0 'cold shortening' occurs (Muela et al., 2010), resulting in excessive shortening of muscle fibers with concomitant reduction in interfibrillar spacing (Offer, 1991; Choi and Kim, 2009). This reduces the ability of meat to bind water and increases meat toughness. Consequent low water holding capacity of muscles has undesirable effects on meat properties such as juiceness and tenderness (Lawrie and Ledward, 2006). Cold shortening, however, does not seem to have occurred in study III, IV or V as conditions favourable for its occurrence did not prevail.

Results that diet had no influence on meat pH (Papers III and IV) while recording the opposite effects in Paper V, can be explained by the wide range of energy densities between test diets in Paper V compared with diets in Papers III and IV. Variations in pHu are often the result of the differences in glycolytic potential (Immonen and Puolanne, 2000; Devine et al., 2002). Thus, animals fed concentrate diets expressed lower pHu compared to animals on no concentrate supplementation (Paper V, Fig 2). This relates to post-mortem glycogen conversion into lactate and H^+ resulting in a decrease in pH of meat, and glycogen level at slaughter is inversely related to the ultimate pH (Vestergaard et al., 2000). Another possible reason for the variations in pHu is related to the differences in response to pre-slaughter stress (Dhanda et al., 2003; Santos et al., 2007). This effect may, however, not been applicable in the current studies as pre-slaughter handling of the animals was the same for the three experiments.

5.3.3.2 Ageing, cooking loss and meat tenderness

Holding meat for an extended period in a chilled state (4^{o}C) immediately after slaughter is known as ageing or conditioning. As shown in the present work (Paper III, Table 8; Paper, IV Table 9), the rate of tenderization of meat varies with species (Dransfield, 1994; Warriss, 2004). While meat tenderness significantly improved with ageing of the muscles from sheep (Study III,

Table 9), the response of goat meat to ageing was poor (Study IV). This observation conforms with the view that goat meat does not readily attain a highly acceptable degree of tenderness even after a lengthy ageing period (Schönfeldt et al., 1993). This poor response to post-mortem ageing in goat meat could be due to high activity of calpastatins, which are known to inhibit the action of calpains in mediating meat ageing process (Kouakou et al., 2005; Melloni et al., 2006). Ageing itself involves biochemical and physical changes in meat. The processes include proteolysis of myofibrillar proteins, a progressive increase in membrane water permeability, and weakening of connective tissues (Sañudo et al., 2004; Damez et al., 2008).

Results for the cooking loss in the present work are comparable with that of other studies reporting a range of 26.5 to 29.2 % in muscles with pHu of 5.5 to 5.6 from different breeds of goats (Madruga et al., 2008; Todaro et al., 2004) or 23.8 to 26.7 % in sheep meat with pHu 5.0 to 5.8 (Kadim et al., 2009). However, Lee et al. (2008) reported low cooking loss of 16.69 % in lambs of different combinations of breeds and 16.95 % for chevon from Boar x Spanish goats. Such differences may arise from several factors including muscle location (Kadim et al., 2004), the rate of thawing (Uttaro and Aalhus, 2007) and cooking temperature (Jeremiah and Gibson, 2003). Considering temperature, Lepetit et al. (2000) reported a rise in CL as temperature increased, and in the range of 70 to 80°C, there was an increase of 20 to 32 % in CL. Not only does temperature affect physical characteristics of the final product but also the chemical properties of meat including concentration of iron and several compounds with potentially bioactive properties such as taurine, carnosine and coenzyme (Jeremiah and Gibson, 2003; Purchas et al., 2004). The variation in CL between muscles studied in the present work could be due to the differences in muscle structure, contractile properties, metabolic characteristics, intramuscular fat and moisture content (Abdullah and Qudsieh, 2009). Another factor that could influence CL is the pHu. Although pHu for the individual muscles studied was not measured in the present work, it is of note that higher pHu is associated with lower CL (Huff-Lonergan and Lonergan, 2005; Botha et al., 2007). The higher pHu observed in goat carcasses in studies IV and V may have enhanced water holding capacity, thus resulting in low CL in goat meat. Interspecies difference in CL can also be attributed to the difference in fatness and glycogen reserves as well. Leaner carcasses have higher water content and hence higher CL than fattier carcasses. The low CL observed in goat carcasses is of interest because water retained in the cooked meat is a major contributor to juiciness (Hedrick et al., 1994), and could partly explain the preference of goat meat in many tropical countries including Tanzania.

Consumers rate tenderness as the single most important quality trait of meat which determines whether they become repeated buyers (Bickerstaffe et al., 2001; Bernues et al., 2003; Okeudo and Moss, 2008). Thus, assessment of the major determinant factors of this trait is important in meat producing industry. The finding that sheep meat (study III) was more tender than goat meat (study IV) is in line with Sen et al. (2004) who reported less tender meat (74.2 N) from yearling goats compared with sheep meat (37.4 N). Gaili and Ali (1985) also reported a similar tendency and suggested that goat muscle fibers are thicker and the fiber bundles larger than those in sheep muscles. It has been shown that fiber type composition and meat quality also differ between muscles within the body (Lefaucheur, 2010). Differences in WBSF values between muscles (Paper V, Table 5) might be explained by the fact that muscles differ in the amount and proportions of red and white fiber types which are themselves different in contractile properties and energy metabolism both ante- and post- mortem (Maltin et al., 2003; Kadim et al., 2004). For example, it has been shown that according to their composition in fibre types, muscles have different abilities to release and sequester Ca^{2+}, activate ATPase activities, stimulate glycolysis, produce lactic acid and decrease post-mortem pH depending on their buffering capacity (Bowker et al., 2004). All these factors would influence meat tenderization.

Meat tenderness is also a function of collagen content, heat stability and the myofibrillar structure of muscle, though these appear to be affected mainly by the rate of growth of the animal rather than genotype *per se* (Muchenje et al., 2008). The overall differences in tenderness between muscles may be a reflection of differences in their functions which is affected by the size of fiber. The myofibrillar component of tenderness can also be influenced by the calpain proteolytic enzyme system during ageing of the carcass post-moterm. Since animals used in the present work were young especially those in studies III and IV, it can be expected that the muscles produced contained low amount of connective tissues. Thus, myofibrillar component might have been a more important factor influencing meat tenderness than the characteristics of connective tissue as suggested by Wheeler and Koohmaraie (1991).

In the present work, pHu was not significantly associated with shear force (Papers III, IV and V). Other studies have suggested a curvilinear relationship between pHu and shear force, such that meat toughness is greater between pHu 5.8 and 6.0 than below or above this range (Okeudo and Moss, 2005). Explanation for this discrepancy may lie in the narrow range of pHu values observed in the current studies. Related to this argument is the fact that studies involving feeds with a much wider range of energy densities show large differences in growth rate of the animals, slaughter weight, level of fat deposition, pHu and water holding capacity which ultimately lead to differences in meat tenderness (Andersen et al., 2005a).

The Warmer-Bratzler shear force values for goat and sheep meat in literature vary considerably depending on factors such as handling prior and at slaughter, age, breed and pH, muscle used, cooking temperature and time (Thompson, 2002; Ferguson and Warner, 2008; Behrends et al., 2009; Miranda-de la Lama et al., 2009). Age for example is linked with differences in total collagen content and collagen solubility which account for part of the variation found in tenderness (e.g. $r = 0.48$ for correlation between collagen content and WBSF in cooked sheep meat, Tschirhart-Hoelscher et al., 2006, and $0.66<r<0.82$ in beef, Riley et al., 2005). Similarly, Schönfeldt et al. (1993) found that an increase in age of the animal resulted in increase of the collagen content of the specific muscle and decrease in collagen solubility with concomitant decrease in tenderness of the muscle. The authors also showed that the quantity of connective tissue changed very little after maturity but a decrease in tenderness with respect to connective tissue and advanced age of the animals was largely due to increased number of cross links in the collagen fibrils resulting in increased resistance to shearing and chewing. Consistent with this note, Purslow (2005) showed that muscles of older animals were characterized with increased mechanical and thermal stability. On the other hand, the amplitude of cold shortening toughening was long shown to depend on collagen content (Dutson et al., 1976). In the present work, older goats in study V (Table 5) produced less tender meat than goats in study IV (Table 10). The above noted reasons may explain for such differences in tenderness.

6.0 Conclusions

Forage species found to have potential for feeding small ruminants were *A. xanthophloea, O. kirkii, B. stepia, L. capensis, Sorghum spp* and *C. nlemfuensis*. This is because they have relatively low fibre content, high CP levels and high organic matter digestibility. And in the case of browses and forbs, there are less seasonal variations in quality compared to grasses. Meanwhile, supplementation of nitrogen and some minerals e.g. phosphorous is essential to grass based diets since grasses alone cannot provide adequate levels of these nutrients especially in dry months. With respect to investigations made on feeding behaviour, goats expressed high degree of selective feeding under the changing conditions of grazing environment. This implies that plant communities need to be preserved for a more diversified botanical structure in order to increase animal productivity and other benefits associated with rich plant diversity.

In reference to Paper II, results based on flushing suggest that dietary supplementation may not be necessary for local goats to conceive when they are kept on a lightly grazed rangeland. Results also show that flock productivity could be increased if goats are bred in January-March for kidding to take place during early dry season (June-August). Additional supply of upgraded poor quality crop residues Papers (III and IV) and/or supplementation with concentrates (Paper V) would increase weight gain or reduce loss in body weight featuring late in the dry season (Paper I). Improvement of feeding value of cereal straws through chemical treatment would, however, depend upon local conditions, especially the economics involving inputs and value addition in meat yield as a result of this technology, and this aspect is subject to further investigations. From Paper V, it is concluded that an intermediate level of concentrate supplementation (66 % of the *ad libitum* equivalent to 244 g/day as fed) is sufficient to improve weight gains and carcass fatness. This feeding strategy would also reduce the negative impacts of feed shortages on growth, carcass yield and quality for goats under grazing. Potential benefits of shortening time for raising meat animals also exist although cost benefit analysis would be required taking into account local conditions and prevailing market forces.

7.0 Future perspectives

In the present study, researchers were involved in assessing the native feed resources. There is, however, evidence that livestock keepers are conversant in assessing the nutritive value of forages for animals within their vicinity. Thus, the information generated in the present study would have been more useful if it was integrated with indigenous knowledge on local grasses, forbs and browses. In this way, the principle underlying the various systems in the use of feeds will be explored more correctly. Further, an understanding of local knowledge of native plant species can guide researchers in the identification of research priorities and management of feed resources including advocating correct plant conservation measures in the study area.

In the present study, effect of supplementation on reproductive performance of goats was carried out using relatively small number of animals for only two years. Future studies in pre-mating dietary supplementation should include more animals per treatment over a longer period of observation. This will increase the probability of detecting differences due to dietary supplementation and therefore creating more confidence in advocating feeding and mating strategies in the areas for improving the production efficiency of the local goats under free ranging grazing conditions.

The current study shows clearly that the improved nutrition increases growth rate and carcass yield from sheep and goats but detailed study should be carried out to assess the economics of such fattening interventions. In addition, farmers have kept goats for years and have well established reasons for keeping animals. The acceptability and adaptability of the tested intervention need to be studied. It is even of more interest to find out whether farmers are willing to specialize in producing kids and lambs for sale to feedlot enterprises or undertake specialized feeding and finishing themselves. The present study shows the yield and quality of meat are superior in sheep compared to goats but in Tanzania goat meat is more preferred and popular. It is of interest to assess reasons for the differences in preferences between sheep and goat meat.

One may, at glance of the present findings, recommend fattening of sheep and goats. However, an array of stakeholders will be affected (farmers, traders, consumers etc) if such entrepreneurship is recommended. At the moment no data are available on how the various actors will react to such intervention. It is certain that the cost of producing carcases under fattening scheme will be higher than the cost of producing meat under grazing conditions but the quality of carcasses will also be higher. Consumer must therefore be willing to pay more for such products. Overall, a chain of stakeholders has to have positive response to small ruminant fattening enterprise. In general, the implication of feedlot feeding in Tanzania and in many parts of Africa in the whole chain value addition has not been carried out, and this is therefore an area of further research. A study on a value chain analysis involving the production stages including marketing is therefore needed.

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Paper I

Seasonal variation in chemical composition of native forages, grazing behaviour and some blood metabolites of Small East African goats in a semi - arid area of Tanzania

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Abstract

A study was conducted to evaluate the chemical composition and digestibility of twelve most preferred forage species by goats in a semi-arid area of Tanzania. The forages representing grasses, forbs and browses were collected during three seasons (rainy: February-May, mid dry: July-August and late dry: October-November) in 2008. In the same periods, sixteen Small East African does (25±1.2 kg body weight) under free ranging grazing conditions were observed for their grazing behaviour, body weight changes, worm counts and blood metabolites. There was a wide variability in chemical composition between species and seasons. Crude protein (CP) content ranged from 24.4 to 191.0, 45.7 to 241.6 and 97.5 to 228.4 g/kg DM for grasses, forbs and browses, respectively. Unlike forbs and browses, the mean CP of grasses declined below the critical maintenance level for goats during mid and late dry seasons. *In vitro* organic matter digestibility (IVOMD) coefficients and predicted metabolizable energy (ME) density were in the range of 0.21 to 0.61 and 3.5 to 8.1 MJ/kg DM for grasses, 0.47 to 0.76 and 6.2 to 10.2 MJ/kg DM for forbs and 0.23 to 0.69 and 3.8 to 10.7 MJ/kg DM for browses, respectively. Mineral concentrations varied among forage species and were all low in phosphorous concentration. Most plants were rich in Ca. Except for forbs and to some extent grass species, browses were deficient in Zn while Cu was only deficient in grasses. Goats showed high flexibility in feeding behaviour with shifts in diets and grazing/non grazing activities in different seasons. In the rainy season, goat diets were largely composed of herbaceous vegetation. As the season advanced from rainy to dry, more browses and forbs were consumed while grasses contributed much less to the diets of goats. The proportion of feeding time increased from rainy (0.57) to late dry (0.68) but that of idling in the same seasons decreased from 0.048 to 0.009. Highest (35 g/d) and lowest (15 g/d) mean weight gains were recorded during mid and late dry seasons, respectively. On the other hand, serum urea concentrations and faecal egg counts decreased from rainy to late dry season. The concentrations of minerals and biochemical indicators determined in the blood showed seasonal cycles but generally within the physiological limits. It is concluded that seasonal changes in the quality of forages elicited shifts in dietary preference and the time spent for grazing by goats and that supplementation of nitrogen and essential minerals is crucial to grass based diets since grasses cannot provide enough of these nutrients especially in the dry months.

Key words: Season; goats, feeding behaviour; weight gains; blood metabolites

Abbreviations: ADF, acid detergent fibre; ADL, acid detergent lignin; BW, body weight; BCS, body condition scores; CP, crude protein; DM, dry matter; DOMD, digestible organic matter per kg dry matter; EPG, eggs per gram; FEC, faecal egg counts; IVOMD, *In vitro* organic matter digestibility; ME, metabolizable energy; NDF, neutral detergent fibre; S, season; Spp, species; SEA, Small East African; TP, total protein; WC, worm count.

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1. Introduction

Natural pastures in many tropical countries represent the main source of animal feed. The forages are characterized by seasonal variation in availability and quality which affect preference and growth performance of grazing animals (Burns and Sollenberger, 2002; Mellado et al., 2006). Research has also shown close correspondence between seasonal changes in the quality of feeds, goat activity patterns and their productivity (Aldezabal and Garin, 2000; El Aich et al., 2007; Sanon et al., 2007). This is because the environment determines the quality and quantity of forage, and the animal must integrate these factors by evolving suitable behavioural pattern to meet its nutritional requirements (Kassilly, 2002). Accordingly, evaluation of the nutritional characteristics of diets consumed gives insights on their capacity to support diverse kinds and levels of production (France et al., 2000). There are, however, differences in the magnitude of these changes emanating from variations in local climate, soil fertility, plant species and animal management factors (Odo et al., 2001; Van et al., 2005; Celaya et al., 2007). Besides, knowledge on good grazing management presupposes knowledge of how goats interact with the vegetation (Papachristou et al., 2005). Equally important, are the genetic differences among breeds which result from morphological and physiological characteristics (Provenza, 2003; Aharon et al., 2007). On the other hand, blood metabolite concentrations, which reflect the balance between environmental supply and animal requirements for nutrients, are less understood for the Small East African (SEA) goats in the grazing situation. Blood metabolite profiles as animal response indicators can serve as the basis for diagnosis, treatment, and prognosis of diseases (Otto et al., 2000, Ndlovu et al., 2007). There is limited information on the impacts of seasonal variations on nutritional values of forages and grazing behaviour of indigenous goats in Tanzania. A study was therefore carried out to evaluate the effects of season on nutritive value of key native forages, grazing behaviour and body weight changes in SEA goats under free-ranging grazing conditions. Seasonal variations on worm counts and blood metabolites were also monitored.

2.0 Materials and Methods

2.1 Study area

This study was carried out in a 40 ha plot within Malbadaw farm (35º 12' E, 04º 25' S), in Hanang district, Manyara region in Tanzania. The climate in this area is semi-arid with annual rainfall varying between 408 and 802 mm nearly all of which falls between December and May. The period from June until late October is dry. Usually, temperatures do not exceed 29 ^{o}C and the minimum mean monthly temperature is above 10 ^{o}C. The relative humidity ranges from 55 to 75 %. The vegetation type is mainly wooded grassland with *Cynodon nlemfuensis, Chloris* *pycnohrix, Cenchrus centgrus, Sorghum spp, Cynoglossum lanceolutum, Lactuca capensis, Sesbania sp, Bidens stepia, Solanum arundo, Acacia seyal, Acacia xanthophloea* and *Ormocarpum kirkii* as the most preferred grasses, forbs and browses (shrubs and tree foliage) by goats.The soils are characterized by clay loam, silt clay to clay textures. The Barabaig people, who are primarily pastoralists, inhabit the area with cattle and goats as the most common livestock species.

2.2 Forage sampling, grazing behaviour and body weight changes

Forage preference of goats was first established by observing the frequency of a total of eight goats in feeding various plant species. The average scores of the selected plant species from each goat were then computed and used to rank forage preference. The first twelve most selected plant species i.e. four from each forage class (grasses, forbs and browses) were hand plucked for a one year period represented in three seasons based on rainfall pattern: rainy (February- May), mid dry (July-August) and late dry (October-November). In each season, three replicates of representative leaves were randomly collected from each of the studied forage species along a 1.5 km line transect for the analysis of chemical composition. During each sampling period, browse leaves and apices of less than 4 mm were hand plucked and mixed together before taking a sub-sample while grasses were cut at approximately 6 cm. In parallel with feed sampling, sixteen SEA goats (25±1.2 kg body weight, aged 3-4 years) were monitored for their grazing behaviour while grazing natural pasture. Various grazing activities were recorded after every five minutes for five grazing hours (9:00-12:00 and 14.00-16.00 h) in two consecutive days of every month within each season. Between 12:00 and 14:00 h, goats rested in their house where they could also have access to water. The activities recorded during grazing hours were: consumption of forage (grasses, forbs or browses), idling, walking, standing + ruminating, lying + ruminating, playing and scratching/self grooming. Eight trained persons were involved in monitoring these activities. One person followed one goat in all observation hours in a particular day. To avoid personal biases to a specific goat, each goat was monitored by a different person during the second day of study. In each season, time spent in various grazing or non grazing activities (e.g. eating, idling and walking) was expressed as a proportion (0 to 1) of the total time spent in all activities while time recorded for the type of forage consumed (grass, forb or browse) was expressed as a proportion of the total time spent grazing. Body weights (BW) and body condition scores (BCS) were also recorded. These measurements were taken a day before the grazing study commenced during each month under study. The Weight gains (g/d) of goats in each season were obtained as (final BW (g) - initial BW (g)) /number of days in a given season. A five point-scale 1 = very thin, 5 = very fat (Russel et al., 1969) was used for the BCS by averaging the scores of a panel of three trained technicians. In the evenings, all goats were confined in pens where water and mineral licks were availed. Herd management during the study generally followed the usual routine management practices.

2.3 Faecal/ blood sampling and analysis

Rectal faecal samples were collected to investigate the pattern of naturally acquired gastrointestinal helminth infections in the three seasons of one year of study. The animals used were not given anthelmintics except when individuals harboured 1000 or more eggs per gram (EPG) of faeces. The analysis of faecal egg counts (FEC) was performed using the modified McMaster method (MAFF, 1986). To assess blood metabolites which serve as indicators of nutritional and health status of an animal, about 10 ml of blood samples were taken by venipuncture of the jugular vein into vacutainers for full blood in each season. Blood was collected in the morning before the animals were allowed to graze. The samples were deposited in anticoagulant free glass tube and allowed to clot at room temperature within 3 hours of collection, and thereafter centrifuged using Hettich universal centrifuge EBA 3S (3000 rpm for 15 min). Sera was separated and stored at -20^{o}C for biochemical parameters (total protein, urea nitrogen and serum minerals). A COBAS MIRA$^{®}$ Plus photometer (ABX Diagnostics, Montpellier, France) was used to measure serum total protein and urea concentrations. Serum Ca, P, Cu and Zn were analysed using analyst 100/300 atomic absorption spectrophotometer according to operator’s manual (Analyst 100 and Analyst 300 Atomic Absorption Spectrometer – Hardware Guide).

2.4 Chemical analysis of feed samples

Feed samples were weighed, dried at 70°C for 48 hours and ground to pass through a 1 mm sieve. While dry matter (DM), CP and ash contents were analyzed according to Association of Official Analytical Chemists (AOAC, 2000), aNeutral detergent fibre (NDF) was determined according to Mertens (2002) and both heat stable alpha amylase and sodium sulphite were added during extraction. Acid detergent fibre (ADF) was determined according to method 973.18 of AOAC (1990) while Sulphuric acid solubilized lignin (sa) was determined according to Robertson and Van Soest (1981). All extractions were performed on ANKOM220 Fibre Analyzer (ANKOM Technology 05/03, Macedon, NY, USA) using F57 filter bags (25 µm porosity). The aNDF, ADF and Acid detergent lignin (ADL) values were expressed inclusive of residual ash. The *in vitro* digestibility analyses were carried out as described by Tilley and Terry (1963). The feed samples were analysed in duplicates and values reported on DM basis. The prediction of metabolizable energy value from digestible organic matter content of forages was calculated as ME (MJ/kg DM) = 0.016 DOMD (McDonald et al., 2002). Where; DOMD is g digestible organic matter per kg dry matter. Mineral concentration was determined by digesting samples in $HNO_3/HClO_4$ (final acid concentration approximately 5 %). The atomic absorption spectrophotometer (UNICAM 919 spectrometer) was used to estimate Ca, P, Zn and Cu contents according to Okalebo et al. (1993).

2.5 Statistical analysis

Proximate and mineral concentration data from108 forage samples (i.e. four plant species per forage class x three replicates x three forage classes x three seasons) were analyzed using the GLM procedures of SAS (2001) with forage species, season (rainy, mid dry and late dry), forage class (grass, forb and browse), and forage species by season interaction as fixed effects. For the grazing behaviour data, a mixed model procedure for repeated measures analysis of variance was used according to Littell et al. (1996) where grazing or non grazing activities were the dependent variables while season of observation and animal identification number were the independent and random effects. Worm count (WC) data were log transformed [ln (WC+100)] and the resulting values were subjected to the analysis of variance using mixed model procedures for repeated measures, including in the model the effect of season. Means presented are based on the back-transformed values from the analyses of the log transformed data. The effect of season on BW, BCS and blood metabolites was also assessed. Least squares means were separated by PDIFF option of SAS when the respective *F*-test was significant ($P<0.05$). A tendency to significance was accepted at $0.05<P<0.10$.

3.0 Results

3.1 Chemical composition and in vitro organic matter digestibility

3.1.1 Grass species

The CP content of grass species was significantly influenced by species (P = 0.01), season (P = 0.004) and their interaction (P = 0.04). Crude protein content varied from 24.4 g/kg DM for *C. pycnohrix* in the late dry season to 191.2 g/kg DM for *Sorghum spp* in the rainy season with *C. centgrus* also having relatively lower value of 33 g/kg DM in mid and late dry seasons (Table 1). The mean CP content was higher in the rainy season (116 g/kgDM) than in mid and late dry seasons (<40 g/kg DM). Species, season and their interaction affected significantly the NDF and ADF contents. *Sorghum spp* had low NDF and ADF contents while high levels of NDF and ADF were generally recorded in *C. pycnohrix* and *C. centgrus* in the three seasons. There were low NDF and ADF concentrations in the rainy and mid dry seasons compared to the late dry season. Both IVOMD and ME were significantly influenced by species (P = 0.01) and season (P = 0.03). ME contents for most species generally declined from rainy to late dry seasons but the opposite tendency was noted for IVOMD. Mean Ca, P, Zn and Cu contents in grass ranged from 3 to 23 g/kgDM, 0.2 to 0.5 g/kgDM, 11.9 to 44.5 mg/kg DM and 2.5 to 8.7 mg/kg DM, respectively. Except for Zn, which showed marked variations among forage species (P = 0.002), forage species and season had no significant influence ($P>0.05$) on concentration of the minerals studied.

3.1.2 Forbs

The chemical composition of forbs in the three seasons is presented in Table 2. The CP content was significantly influenced by species (P = 0.05), season (P = 0.003) and species by season interaction (P = 0.02) ranging from 45.7 g/kg DM in *Sesbania sp* (late dry season) to 241.6 g/kg DM in *L. capensis* (rainy season). Mean CP content was highest in the rainy season and lowest during mid dry season. The amount of CP began to rise toward the end of the dry season. The NDF, ADF and ADL contents were lowest in *B. stepia* and highest in *C. lanceolutum* compared to other species. However, species caused no significant variation in fiber parameters except for NDF levels. These parameters increased from rainy to mid dry seasons, and the levels began to decline in the late dry season.

Digestibility values were not affected by species (P = 0.47) but the influence of season (P = 0.002) was significant where the lowest and the highest coefficients were recorded in the late dry and rainy seasons, respectively. Whereas species had significant effect (P = 0.003) on energy density, season did not (P = 0.47). Mean Ca concentration (g/kgDM) ranged from 12 in *C. lanceolutum* to 45 in *L. capensis* (late dry season). Species and season did not affect (P>0.05) Ca concentration significantly. Phosphorous concentration (g/kgDM) was as low as 0.1 in *L. capensis* and Sesbania spp. in mid and late dry seasons and as high as 1.1 in *B. stepia* (rainy season). Both season and species had significant influence on P concentration being higher in the rainy season than in the mid dry and late dry seasons. There was a tendency (P<0.1) for species to affect Cu concentration. The lowest (5.6 mg/kg DM) and highest (30.5 mg/kg DM) levels of Cu concentrations occurred in *B. stepia* (late dry season) and *L. capensis* (rainy season), respectively. The concentration of Cu between seasons was highly variable (P = 0.003), and declined from rainy to late dry seasons. Species by season interaction also tended to affect the amount of Cu.

3.1.2 Browse species

Season and species effects on chemical composition and digestibility of browse species are shown in Table 3. Species affected (P = 0.003) crude protein content whose levels ranged from 97.5 g/kg DM in *O. kirkii* (mid dry season*)* to 228.4 g/kg DM in *S. arundo* (rainy season) with seasonal mean values declining (P = 0.01) from 178.4 g/kg DM in the rainy season to 143.8 g/kg DM in the mid dry season. Species tended (P = 0.07) to affect NDF levels but the ranking order of the four browse species based on NDF values varied from one season to the other. The ADF and ADL levels were, however, not affected by species (P>0.05). As with grasses and forbs the NDF, ADF and ADL values increased from rainy to mid dry seasons, after which they decreased.

Digestibility coefficients were lowest for *A. seyal* and *S. arundo* and highest for *O. kirkii* and *A. xanthophloea.* There were large differences (P = 0.001) in digestibility coefficients between browse species but the influence of season on this parameter was not significant (P = 0.76). Values for the ME density (MJ/kg DM) were as low as 3.8 in *A. seyal* (rainy season) and as high as 10.7 in *Acacia xanthophloea* (rainy and mid dry seasons). Lowest (5.6 MJ/kg DM) and highest (8.3 MJ/kg DM) mean values for ME were recorded in the late dry and rainy seasons, respectively. Among browse species, Ca concentration (g/kgDM) varied (P = 0.05) from 19 in *A. xanthophloea* (rainy season) to 42 in *O. kirkii* (mid dry season). Conversely, season caused no significant influence (P = 0.38) on Ca concentration. Phosphorous concentration (g/kgDM) remained low and similar (P = 0.82) in all seasons. Neither season nor species effected concentrations of P, Zn and Cu.

3.2 Forage selection and grazing behaviour of goats

Goats exhibited marked flexibility in feeding behaviour with shifts in diets and grazing or non grazing activities in different seasons (Table 4). In the rainy season, goat diets were largely composed of herbaceous vegetation. As the dry season advanced, more browses and forbs were consumed so that grasses represented the least component of the three forage classes late in the dry season. The activity pattern of goats was variable (P = 0.03) with increasingly long periods being devoted to feeding as the season changed from rainy (0.57) to late dry (0.68). Conversely, the proportion of time spent idling decreased with advancing dryness. The highest (0.048) and the lowest (0.009) indices for idling were recorded in the rainy and late dry seasons, respectively. Similarly, the proportion of time allocated for standing while ruminating decreased (P = 0.003) with progressive dryness, being 0.068, 0.036 and 0.014 for the rainy, mid and late dry seasons, respectively. However, goats spent similar amounts of time walking (P = 0.68) and lying while ruminating (P = 0.25) in the three seasons. Other activities including fighting, scratching, playing, and self grooming were also similar in the three seasons (P = 0.89).

3.3 Body weight, feacal egg counts and blood metabolites

The mean values for the seasonal changes in body weight, total serum protein (TP), urea and serum minerals of goats over the study period are presented in Table 5. Season affected (P = 0.04) weight gains with some animals losing weight. The largest loss of weight was recorded in the rainy (- 400g/d) followed by late dry (-150 g/d) and mid dry (-16 g/d) seasons. Highest (35 g/d) and lowest (15 g/d) mean weight gains were recorded during mid and late dry seasons, respectively. A similar pattern was observed for the body condition scores. Serum urea concentration was lowest in the late dry season when mean weight gain was lowest. Season had significant effects on all serum minerals studied. Serum Ca and P concentrations were lowest in the rainy season while the opposite was true for serum Zn and Cu concentrations. Serum total protein concentration was similar in rainy and mid dry seasons and higher than in the late dry season. On the other hand, serum urea concentrations and faecal egg counts decreased from rainy to late dry season. There was a dispersed distribution of worms with a few individuals repeatedly harbouring relatively high worm counts.

4.0 Discussion

The decrease in protein content and feed digestibility with advancing dry season for grass species is consistent with previous studies conducted in areas with distinct wet and dry seasons (Hassen et al., 2007; Fulkerson et al., 2007). This decline in nutrient contents is related to the stage of physiological maturity (Rawnsley et al., 2002). The levels of protein are usually high at young stages of plant growth, achieve maximum values at the end of vegetative stage and decline as plants mature (Mero and Udén, 1998). When averaged across seasons and species, only CP (g/kg DM) in forbs (132) and browses (165) exceeded 80, the minimum threshold level which would limit intake of tropical forages (Minson, 1980). These findings suggest that forbs and browses can support maintenance requirements and certain level of production in ruminants (Whitman, 1980; Van Soest, 1994). However, the CP levels (24.4 to 49.1 g/kg DM) in grasses during mid and late dry seasons imply that grasses alone may not provide adequate concentrations of crude protein particularly for the young, pregnant and lactating goats whose nutrient requirements are high.

The wide variation in NDF, ADF, ADL contents and IVOMD of forages between seasons is in accordance with other reports in tropical and sub-tropical regions (Mero and Udén, 1998; Ramírez et al., 2004) and might be attributed to the differences in cell wall lignifications which increase with plant maturity (Kozloski, 2005). Lignin is a principal factor limiting digestibility (Van Soest, 1994). In addition, low protein and high fiber contents have negative effects on digestibility (Minson, 1982). Low fiber content and higher energy density and IVOMD in forbs and browses compared to grasses is in agreement with the findings in other studies (Mellado et al., 2006; Yayneshet et al., 2009). Forages containing digestible organic matter coefficients of less than 0.45, 0.45 to 0.55 and above 0.55 to 0.70 are of poor, low and medium nutritional quality, respectively (Tainton, 1999). Thus, grasses in the present study were of poor digestibility especially during late dry season while forbs and browses largely showed low to medium nutritional values for most of the year.

Large differences of mineral contents between grass, forb and browse species were recorded in Ca, Zn and Cu. For example, mean Ca concentration of less than 10 g/kgDM in grasses was lower than 27 g/kgDM or above recorded in forbs and browses. Compared to results from semi arid areas of Ethiopia, mean Ca and Zn concentrations in the present work were slightly higher than 5 to 13 g/kgDM for Ca and 9.2 to 11.1 ppm for Zn reported by Yayneshet et al. (2008). Cu concentration in forage species in the present study is, however, comparable to the range of 10.5 to 15.9 ppm reported by the same authors. Except for forbs and to some extent grass species, browses were deficient in Zn with less than the optimum level of 30 mg/kg DM. On the other hand, grasses were short of 9 mg/kg DM of the required Cu concentration for goats (Kessler, 1991), and may be among the limiting factors of goat production under grass based diets in the study area.

The changes in the quality of diet may have had elicited shifts in dietary preference and the time allocated for grazing and non grazing activities by goats. The prolonged grazing time in the late dry season compared to the rainy season could be associated with the decline in proteins and digestible nutrients after the rains such that more selective feeding by animals was necessary to meet their intake requirements. The higher decline in nutritive value of grasses relative to forbs and browses notably the CP (<50g/kg DM) and energy contents (<8 MJ/kg DM) may have caused limited utilization of grasses during late dry season. The decline in nutritive values of browse species occurs with less variation over time, while herbaceous species with their short cycles of development have their nutritive values declining rapidly after the rainy season (Sanon et al., 2007). In the dry season, only browses may still be green making it ideal forage when grasses have senesced. There is evidence that animals select diet of higher quality. For example, Papachristou et al. (2005) reported that goats and sheep grazing in shrub lands selected diets with higher CP content, more digestible and lower NDF and lignin levels. Although seasonal changes in amount of forage were not quantified in the present study, the amount of grasses and forbs in the dry season is usually more subject to decline than that of browses (Ahmed and El Hag, 2003). This may also explain the shift toward browse species and appears to be an adaptation to the changing grazing conditions. Lamoot et al. (2004) described such dietary shifts as a strategy necessary for the animal to meet its nutrient requirements. Grazing lands having greater diversity of forage types would, therefore, allow more dietary selection and sustain the animals better.

Goats seem to have better body condition and higher weight gains at the middle of the dry season. Increase in weight gain in this season is partly due to changes in grazing behaviour (e.g. spending more time on forages of high nutritive value) and reduction in worm population. Low egg counts can be associated with low worm infestation in this season as well as increased intake of high quality feeds, possibly with antihemintic activities of condensed taninnis (CT) contained in browses such as *Acacia species* (Kahiya et al., 2003). The effect of CT on mucous secretion and possible binding to larvae or adult nematodes has been suggested as a possible mechanism that reduces establishment or viability of gastro-intestinal nematodes (Niezen et al., 1998). The marked decrease in susceptibility of goats to gastrointestinal nematodes as manifested by low faecal egg counts in mid dry season indicates a decline in development and maturation of hypobiotic larvae in the mid dry season as reported by Tembely (1998). However, the loss in body weights (of up to 57 %) and condition in late dry season shows that the beneficial effects of lowered worm counts could not compensate for the drastic fall in nutritive value of forages.

The differences in total serum protein and urea concentration in the present work is partly due to the variations in quality of pasture as suggested by Ndlovu et al. (2009) in a study of cattle raised on sweetveld. Overall, serum urea concentrations in the present study were below the normal reference values of 3.57 to 7.14 mmol/l (Kaneko, 1997). Blood urea concentration is a useful indicator of nitrogen intake in grazing animals and complements information from the analysis of total protein (Jia et al., 1995; Chimonyo et al., 2002). These results should, however, be interpreted with caution as other factors such as internal parasites and intake of glucose precursors are known to affect urea concentrations (Kumagai and Ngampongsai, 2006; Mellado et al., 2009). Although the mechanism for which Ca and P levels are maintained in the body is a result of high levels of homeostasis (Musalia et al., 1989; Fujihara et al., 1992), seasonal variations in these minerals were evident. Season-related factors that might influence serum concentrations of minerals including temperature, stress, feed restriction and parasitism have been reviewed (Doornenbal et al., 1988; Kincaid, 1999; Grunwaldt et al., 2005). In the present study, a relatively lower serum phosphorous concentration, for example, was recorded during the rainy season when faecal egg counts were high. There is evidence that intestinal nematode infections impair absorption of phosphorous (Grunner, 2001) and deficiency of P is often associated with reduction in feed consumption, live weight gains and conception rates (Coop and Field, 1983; Tainton, 1999). In general, monitoring metabolite concentrations across the seasons may assist in designing appropriate interventions such as the need for dietary supplementation.

Conclusion

On the basis of chemical composition (relatively low fibre and high CP levels) and high organic matter digestibility, *A. xanthophloea, O. kirkii, B. stepia, L. capensis, Sorghum spp* and *C. nlemfuensis* showed high potential as feedstuffs that would sustain goats during critical months of the year. Supplementation of nitrogen and essential minerals is crucial to grass based diets since grasses cannot provide enough of these nutrients especially in the dry months. Browses on the other hand, are an important feed resource during deficits in feed quality as they are less subject to seasonal variations compared to grasses. Results in the present study indicate that seasonal changes in the quality of forages elicited shifts in dietary preference and the time spent for grazing by goats. This shift in dietary preference underlines the importance of plant diversity of a sward in sustaining grazing animals especially during the dry season.

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Table 1. Seasonal variation for DM (g/kg), CP, NDF, ADF, ADL (g/kg DM), IVOMD (coefficient) estimated ME (MJ/kg DM), Ca and P (g/kg DM) and Zn and Cu (mg/kg DM) in most selected grasses by grazing goats as sampled from three individuals of each plant species

Season/species	DM	CP	NDF	ADF	ADL	IVOMD	ME	Ca	P	Zn	Cu
Rainy											
Cynodon nlemfuensis	953	145.5	701	367	80	0.54	7.3	7.2	0.5	16.1	6.0
Chloris pycnohrix	950	53.9	821	499	86	0.49	7.0	4.1	0.2	24.2	5.6
Cenchrus centgrus	949	71.4	787	471	81	0.34	4.3	12.9	0.3	37.6	7.2
Sorghum spp	927	191.2	576	344	59	0.61	8.1	7.4	0.5	29.9	6.1
SEM	12	1.8	4.9	0.6	2.8	0.04	5.3	2.8	0.2	3.1	2.5
Mid dry											
Cynodon nlemfuensis	964	38.2	791	458	95	0.38	4.6	23	0.4	15.5	8.7
Chloris pycnohrix	967	31.1	741	451	78	0.38	4.5	5	0.5	31.1	4.4
Cenchrus centgrus	960	32.9	828	524	140	0.32	3.8	4	0.4	44.5	2.5
Sorghum spp	950	42.8	529	338	64	0.46	5.9	5	0.4	30.4	4.9
SEM	11	1.8	4.7	6.6	2.7	0.04	0.9	2.8	0.2	0.3	2.6
Late dry											
Cynodon nlemfuensis	973	48.5	787	343	98	0.39	5.1	8	0.4	11.9	7.5
Chloris pycnohrix	967	24.4	811	487	89	0.44	5.5	3	0.3	12.9	3.8
Cenchrus centgrus	963	33.2	811	502	94	0.28	3.5	5	0.2	31.3	3.5
Sorghum spp	958	49.1	765	595	93	0.40	5.1	4	0.3	33.0	5.0
SEM	12	1.7	4.4	6.6	3.5	0.05	0.8	3.2	0.3	2.9	2.5
Significance (P)											
Season(s)	0.66	0.004	0.04	0.03	0.04	0.03	0.03	0.52	0.35	0.05	0.17
Species (spp)	0.25	0.01	0.001	0.27	0.01	0.01	0.01	0.14	0.70	0.002	0.19
S*spp	0.48	0.04	0.05	0.23	0.04	0.07	0.78	0.18	0.47	0.64	0.33

ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; IVOMD, *In vitro* organic matter digestibility; ME, metabolizable energy; (ME MJ/kg DM = 0.016 DOD, McDonald et al., 2002); NDF, neutral detergent fibre; S, season; Spp, species.

Table 2. Seasonal variation for DM (g/kg), CP, NDF, ADF, ADL (g/kg DM), IVOMD (coefficient), estimated ME (MJ/kg DM), Ca and P (g/kg DM) and Zn and Cu (mg/kg DM) in most selected forbs by grazing goats as sampled from three individuals of each plant species

Season/species	DM	CP	NDF	ADF	ADL	IVOMD	ME	Ca	P	Zn	Cu
Rainy											
Cynoglossum lanceolutum	945	214.0	500	274	191	0.65	8.9	34	0.6	62.5	17.9
Lactuca capensis	936	241.6	342	393	159	0.76	10.2	31	0.5	54.6	30.5
Sesbania sp	940	138.1	455	324	170	0.59	8.0	30	0.2	61.2	17.3
Bidens stepia	931	161.9	316	208	139	0.65	8.8	32	1.1	47.6	18.6
SEM	17	2.3	5.7	5.3	4.9	0.05	0.8	3.9	0.3	19.5	3.5
Mid dry											
Cynoglossum lanceolutum	954	64.4	419	458	179	0.63	8.4	32	0.3	27.7	8.1
Lactuca capensis	948	85.2	561	211	252	0.59	7.9	32	0.4	50.9	6.9
Sesbania sp	953	54.4	633	323	295	0.47	6.2	29	0.1	61.5	26.5
Bidens stepia	942	159.6	263	265	103	0.62	8.2	25	0.7	10.2	14.7
SEM	14	2.8	4.9	5.7	4.8	0.04	0.7	3.2	0.2	19.5	3.5
Late dry											
Cynoglossum lanceolutum	956	87.2	443	294	217	0.63	8.6	12	0.5	33.7	11.5
Lactuca capensis	950	223.9	309	212	120	0.50	6.6	45	0.1	59.5	24.5
Sesbania sp	958	45.7	407	286	188	0.49	6.4	27	0.1	60.3	9.9
Bidens stepia	951	109.5	351	295	149	0.60	7.9	26	0.6	37.2	5.6
SEM	17	2.3	4.7	5.9	4.5	0.05	0.8	3.9	0.3	16.0	3.4
Significance (P)											
Season(s)	0.78	0.003	0.01	0.08	0.08	0.002	0.45	0.69	0.004	0.74	0.003
Species (spp)	0.88	0.05	0.02	0.12	0.17	0.47	0.003	0.25	0.001	0.27	0.08
S*Spp	0.99	0.02	0.05	0.27	0.31	0.06	0.05	0.81	0.13	0.61	0.09

ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; IVOMD, *In vitro* organic matter digestibility; ME, metabolizable energy (ME MJ/kg DM = 0.016 DOD, McDonald et al., 2002); NDF, neutral detergent fibre; S, season; Spp, species.

Table 3. Seasonal variation for DM (g/kg), CP, NDF, ADF, ADL (g/kg DM), IVOMD (coefficient), estimated ME (MJ/kg DM), Ca and P (g/kg DM) and Zn and Cu (mg/kg DM) in most selected browses by grazing goats as sampled from three individuals of each plant species

Season/species	DM	CP	NDF	ADF	ADL	IVOMD	ME	Ca	P	Zn	Cu
Rainy											
Solanum arundo	928	228.4	598	354	316	0.56	7.1	34.1	0.2	16.2	22.8
Acacia seyal	899	177.7	455	281	127	0.31	5.7	22.2	0.2	22.3	7.5
Acacia xanthophloea	893	138.4	466	338	171	0.59	10.7	18.8	0.1	16.4	6.8
Ormocarpum kirkii	951	168.9	436	266	144	0.69	9.6	36.0	0.2	25.6	12.2
SEM	16	1.5	9.1	8.7	3.1	0.06	1.0	2.9	0.2	5.4	15.6
Mid dry											
Solanum arundo	945	224.3	574	450	244	0.48	6.5	26.1	1.5	12.3	42.6
Acacia seyal	931	127.1	594	438	195	0.31	4.3	34.4	0.2	14.9	5.1
Acacia xanthophloea	937	126.3	526	162	165	0.59	10.7	22.6	0.1	21.1	12.4
Ormocarpum kirkii	952	97.5	450	323	224	0.54	7.2	42.3	0.3	24.9	12.1
SEM	14	1.2	10.4	5.4	2.6	0.04	1.1	3.2	0.2	4.3	14.8
Late dry											
Solanum arundo	974	219.2	620	366	242	0.43	5.8	25.9	0.2	14.6	22.9
Acacia seyal	949	144.1	606	371	190	0.23	3.8	36.4	0.1	18.5	6.8
Acacia xanthophloea	964	159.3	288	309	77	0.51	6.4	25.4	0.3	16.1	7.3
Ormocarpum kirkii	972	170.4	553	246	204	0.49	6.2	22.5	0.2	25.7	12.4
SEM	13	1.5	9.5	5.8	2.4	0.05	0.9	2.9	0.2	4.9	16.9
Significance (P)											
Season (s)	0.71	0.01	0.20	0.09	0.07	0.76	0.004	0.38	0.82	0.85	0.83
Species (spp)	0.84	0.003	0.07	0.75	0.81	0.001	0.76	0.05	0.86	0.09	0.31
S*spp	0.95	0.20	0.62	0.38	0.41	0.60	0.60	0.11	0.94	0.87	0.97

ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; IVOMD, *In vitro* organic matter digestibility; ME, metabolizable energy (ME MJ/kg DM = 0.016 DOD, McDonald et al., 2002); NDF, neutral detergent fibre; S, season; Spp, species.

Table 4. Grazing behaviour index of Small East African goats based on observation time of various activities expressed while grazing natural forages in three seasons

	Season			
Activity	Rainy	Mid dry	Late dry	*P* -value
Eating				
Browse	0.174^{b}±0.04	0.259^{ab}±0.03	0.291^{a}±0.05	0.04
Grass	0.213^{a}±0.04	0.186^{ab}±0.04	0.124^{c}±0.03	0.05
Forbs	0.183^{b}±0.03	0.177^{b}±0.03	0.262^{a}±0.03	0.04
Total	0.570^{c}±0.03	0.622^{b}±0.03	0.677^{a}±0.29	0.03
Idling	0.048^{a} ±0.01	0.038^{b}±0.01	0.009^{c}±0.01	0.001
Walking	0.272±0.01	0.263±0.02	0.286±0.02	0.68
Standing+ ruminating	0.068^{a}±0.02	0.036^{b}±0.01	0.014^{c}±0.01	0.003
Lying+ ruminating	0.021±0.008	0.018±0.008	0.01±0.00	0.25
Other*	0.021±0.01	0.023±0.005	0.013±0.009	0.89

Means with a common superscript in the same row are not significantly different (P>0.05).
*includes fighting, scratching, playing and self grooming.

Paper II

Influence of flushing and season of kidding on reproductive characteristics of Small East African does and growth performance of their progeny in a semi arid area of Tanzania

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Abstract

A study was carried out to assess the effects of nutritional supplementation (flushing) and season of kidding (early dry = season 1 or late dry = season 2) on reproductive performance of SEA does and growth performance of their progeny. A total of 90 grazing does were divided into three groups of 30 does each and monitored for two years. In each observational year, one group (control goats) received no concentrate supplementation while the remaining groups were subjected to 200 or 400 g of concentrate diet/doe/day for a period of 60 days (November-January) before mating. Does were then exposed to sexually active bucks in the months of January through June 2008 and 2009. Nutritional flushing did not improve ($P>0.05$) fertility, fecundity, prolificacy or twinning rate. The relative weight increases during gestation was higher ($P<0.01$) in season 1 (35.8 %) than that in season 2 (12.6 %) whilst the proportion of weight loss of does kidding in season 1 was lower than that in season 2 (6.1 vs. 8.9 %, $P<0.05$). Kids born in season 1 grew at a faster rate than their counterparts born in season 2 (80 vs. 57 g/day). Consequently, the average weight of kids weaned per doe kidding was 2 kg in favour of season 1. It is concluded that nutritional flushing during peak-dry season may not be necessary for goats to conceive especially when raised on lightly grazed rangeland and that breeding activities of goats should preferably be restricted to January-March for kidding to take place during early dry season (June-August)

Key Words: Goats, nutrition, seasonality, reproductive performance, body weight development

Introduction

The seasonality in feed availability and quality of feeds is an important constraint to biological productivity of small ruminants in the tropics (Berhane and Eik, 2006; Ben Salem and Smith, 2008). In Tanzania, as in most of the tropical countries, small ruminants breed throughout the year and this can result in overall poor survival of dams and kids, reduced reproductive and productive performances especially when late pregnancy and resulting kidding fall into periods with insufficient forage availability (Harry, 2004, Karikari and Blasu, 2009). However, tropical breeds of goats are known to be aseasonally polyoestrus and therefore it is possible to manipulate their breeding activity to coincide with periods of adequate feed supply and low disease challenges (Amoah et al., 1996). Such a breeding strategy is potentially advantageous both in terms of improved reproductive activity of the parents and the growth performance of kids. Since nutritional requirements vary throughout the reproductive cycle, strategic feed supplementation can also be an important tool to improve reproductive efficiency. Nutrition is generally recognized as a significant regulator of reproduction (Smith and Akinbamijo, 2000) and that improvement in the nutritional status of the does particularly preceding mating (flushing), is known to increase fertility in small ruminants due to dynamic effects of nutrition on ovulation rate (Kusina et al., 2001). Flushing has also been reported to increase the body condition and weights of does not only at mating (static effects) but also during their post-partum period and thus resulting in improved milk of dams and growth rates of young ones (Robinson et al., 2006; Titi et al., 2008). The effects of flushing on fertility and performance are pronounced when the dams are in poor body condition at the time of flushing. Flushing can be accomplished either by allowing animals to graze nutritious pasture which is rare in the dry season in the tropics or by feeding energy and protein-rich supplements. But responses to flushing are often variable and inconsistent depending on factors such as genotypes (Henniawati and Fletcher, 1986; Sormunen-Cristian and Jauhiainen, 2002; Chemineau et al., 2004), body conditions of the animals (O'Callaghan et al., 2000), timing and duration of flushing (Venter and Greyling, 1994; Sabra and Hassan, 2008; Karikari and Blasu, 2009), the amount and quality of dietary supplements e.g. energy and protein levels (Acero-Camelo et al., 2008) and the grazing background (Molle, 1995). There is, however, scanty information on effects of nutrition and seasonal influences on productivity and reproduction of goats under grazing conditions of semi arid areas in Tanzania. The objective of this study was to test the hypothesis that supplementary feeding during peak-dry season is needed if goats are to attain high conception rate and that kidding towards the end of the long-rains will improve performance of SEA goats and their progeny.

2. Materials and Methods

2.1 Site

This study was conducted at Mulbadaw farm (35º 12' E, 04º 25' S), in Hanang district of Manyara region in Tanzania. The area receives on average 408-802 mm of rainfall most of which falls between December and May. Mean annual minimum and maximum temperatures at the site are 10 ^{o}C and 29 ^{o}C, respectively. The vegetation type is mainly wooded grassland. The area is inhabited by the Barabaig people whose main occupation is pastrolism with cattle and goats as the most predominant livestock species. The experimental site was only lightly grazed as no livestock species other than the experimental goats were allowed to graze in the area. More details of feed resources in the study area are given in (Safari et al., unpublished).

2.2 Animals, treatments and management

Ninety SEA does of 2-6 years of age and of parity 2-5 with mean weight of 27.9±0.7 kg were used in a two year study commencing in November, 2007 and ending in October, 2009. All does were injected ivermectin (Kelamectin 1 %) subcutaneously at a dose of 0.2 mg/kg body weight for treatment and control of gastrointestinal and ecto-parasites. The does were then randomly assigned to three dietary treatment groups which were balanced according to weight, parity and age. The dietary treatment groups were control goats (T0) where goats received no dietary supplementation and represent the traditional management system while T200 and T400 groups were supplemented with 200 g and 400 g of concentrate diet per doe per day, respectively. The concentrate diet was composed of maize bran (70 %), sunflower seedcake (28 %) and mineral mix (2 %). The mineral mix (Tanfeed Co. Ltd) consisted of (in %, manufacturer's specifications) Ca (25.8), S (0.3), Mg (0.5), Fe (0.1), Na (29.05), P (12.9), Cl (31.08), Zn (0.02), B-cr (0.02) and K (0.05). The flushing period was 60 days after which, does were exposed to sexually active Norwegian bucks (buck to doe ratio of 1:15) for the period between January and June in 2008 and in 2009. All goats grazed during the day and in the evening, the animals were confined in separate pens with access to water and mineral licks.

2.3 Measurements

Body weights (BW) and body condition scores (BCS) of does were recorded monthly for the period between flushing and three months post-kidding. A five point-scale 1 = very thin, 5 = very fat (Russel et al., 1969) was used for the assessment of BCS. Birth type (single or twins), birth weight and sex of kids were recorded. Kids were weighed within 24 hours after birth and thereafter weekly for 12 weeks. Weight gains (g/day) of both does and kids were derived as (final BW (g) - initial BW (g)) /number of days involved.

2.4 Statistical analyses

Data from doe live-weight, BCS and birth weight and weight gain of kids were analysed using the General Linear Models procedure of SAS (2001). For does, fixed effects included in the model were season of birth of kids (season 1, June-August and season 2, September-November), flushing (0, 200 or 400 g of concentrate/doe/day), type of birth (single or twin), parity of the doe (<3, 3-5 and >5) and the birth type x doe parity interactions. Least squares means were generated for body weights of does e.g. pre-mating live weight changes and relative weight increases during gestation. The independent variables used to assess response variables in does were also used to study their effects on birth weights of kids, growth rate of kids from kidding to weaning and the average weight of kids weaned per kg doe kidding. Where means were generated for variables studied in does and kids, the PDIFF option was used to separate them and when means were significant by ANOVA at $P<0.05$, they were separated by Least Significance Difference test. If $0.10 > P > 0.05$, then differences were considered to suggest a trend, or tendency, to significance. Reproductive characteristics data were derived as follows: Fertility rate as the number of does kidding (live or dead offspring)/number of does exposed for breeding x100; prolificacy as number of offspring born (alive or dead)/number of does kidding (live or dead offspring) x100 and fecundity as number of offspring born (alive or dead)/number of does exposed for breeding x 100. Values obtained were then subjected to Chi-square test to assess the association between the reproductive characteristics and nutritional treatments. Yearly difference was not significant for any of the traits studied. Thus, data for the two years were pooled to increase precision. Kiddings were separated into season 1 (June-August) vs. season 2 (September -November) as this categorization showed the largest variations for most of the traits studied.

3.0 Results

3.1 Effects of concentrate supplementation on body weight and condition of does

Concentrate supplementation affected ($P<0.05$) body weight gains of does. At the end of the supplementation period, T400 goats performed better than other groups (Table 1). On average T400 goats were heavier (2.8 kg) and in better condition (0.42 points) than the control does. Changes in body weight among supplemented goats relative to the control group corresponded to 5.8 % and 1 % increase for T400 and T200 does, respectively. During the same period, control goats lost 5.7 % of their body weight. Live weights of T400 does at the time of kidding and at one month post-kidding were still higher ($P<0.05$) than the weights for T200 and control does. Twelve weeks post-kidding, however, the corresponding weights for these groups did not differ substantially. The average reduction in live weight of does from kidding to weaning was similar in the three groups. Generally, body condition scores followed the same trend as body weight changes. There were no significant effects of concentrate supplementation on fertility, fecundity, prolificacy and twinning rates (Table 2) as were for the litter size, birth weight, growth rate from birth to weaning or weight loss of does from kidding to weaning (Table 3). Litter size averaged 1.34, 1.28 and 1.23 in T400, T200 and control goats, respectively. Differences in these means, however, were small and insignificant. Similarly, concentrate supplementation had no significant effect on birth weight and pre-weaning growth rates of kids.

3.2 Effects of season on live weight changes of does and growth rates of kids

Period of mating as reflected by the season of kidding affected gestational weight increases of does and growth rates of kids (Table 4). Increase in relative weight during gestation period for does carrying singles for season 2 kidding was lower ($P<0.01$) by 21.2 % compared to the weight increase of their counterparts in season 1. Corresponding value for does carrying twins was 18 % higher ($P<0.05$) in season 1 compared to that in season 2. The average birth weights of kids born in season 1 and season 2 were similar (2.5 vs. 2.4 kg, respectively; $P>0.05$) and a steady increase in body weights was observed for kids born in the two kidding seasons. However, the rate of growth was different between seasons. Kids born in season 1 grew at faster rates compared with their counterparts in season 2 that a difference of 2.2 kg (29 %) was reached at 12 weeks post-kidding ($P<0.01$). The average weight of kids weaned per kg doe kidding was higher in season 1 than in season 2 (2.6 vs. 1.8 kg; $P<0.05$) and the weight of kids weaned per doe kidding was about 27 % lighter (7.5 vs. 9.5 kg; $P<0.001$) in season 2 than that in season 1. Pre-weaning mortality was similar for seasons 1 and 2. However, percentage weight loss of does from kidding up to 12 weeks post-kidding was lower for season 1 compared to that in season 2 (6.1vs. 8.9, $P<0.01$)

3.3 Effects of sex, type of birth and parity of dam on growth rates of kids

Male and female kids had similar ($P>0.05$) weights at birth but male kids were consistently heavier ($P<0.05$) than female kids thereafter (Table 5). Differences of 0.55, 0.94 and 0.48 kg in favour of male kids were recorded at the fourth, eighth and twelfth week, respectively. Type of birth also affected weight gain in kids. Between week 0 and week 12, kids born as singles gained weight at a faster rate than twins. As a result, the weights of singletons were higher ($P<0.01$) by 1.1 kg at 12 weeks. In contrast, parity of does had no effect ($P>0.05$) on birth weight and pre-weaning growth rate of kids. Sex of kids, type of birth and parity of dams did not influence ($P>0.05$) the survival rates of kids significantly. Birth type-parity interaction affected ($P<0.05$)

birth weight of kids where single kids from all parity classes were similar (P>0.05) in birth weights and heavier (P<0.05) compared with those of twins from parity five and below. However, the difference narrowed at the fourth week and disappeared at the eighth week of age. Differences between weights of kids born singles and those born twins also narrowed with increasing parity stage. These differences were 0.8, 0.3 and 0.2 kg for kids born of does in <3, 3-5 and >5 parity categories, respectively.

3.4 Effects of season of kidding, type of birth and parity stage on live weight changes of does from birth to weaning

Results summarizing live weight changes of does (kg) from kidding to weaning are presented in Table 6. Kidding season influenced live body weight of does up to weaning period. Higher live weights of does were recorded in season 1 than in season 2 with an average of +1.1 (29.6 kg vs. 28.5 kg; P<0.05) at kidding and +1.8 (27.9 kg vs. 26.1 kg; P<0.05) at weaning. Type of birth had significant influence on weight of dams up to eight weeks post-kidding with does nursing singles exhibiting heavier weights compared with those nursing twins. Twelve weeks post-kidding, however, weights of these two groups of does were similar (P>0.05). Between week 0 and week 8, does in parity 3 and those in >5 parity category had similar (P>0.05) body weights and heavier (P<0.05) than those under parity stage lower than three. However, no differences of live weights of does due to parity were found 12 weeks post-kidding. Interaction between parity and litter size indicated lightest live weights for does with less than parity three nursing singles whilst the heaviest does were those with greater than parity five nursing twins. Significant differences in these weights were detected during week 0, 4 and 8 but not in week 12.

Discussion

The effect of the nutritional flushing on reproductive performance was insignificant and the results are in agreement with previous investigations (Sormunen-Cristian and Jauhiainen, 2002; Zarazaga et al., 2005). This could be explained by the fact that does used in the present study were already in good condition at the time of flushing. Similarly, Hart (2008) concluded that flushing practice in Spanish goats is unlikely to show clear effects on kidding or conception rates when the goats are in reasonable body condition score (2.5-3.5, in a five point-scale). Thus, there appears no justification for flushing does except when they are in poor body condition.

A sufficiently higher live weight of does is essential in maintaining good reproductive performance as well as growth performance and survival rates of kids. In the present study, the gestational live weight increases of does that kidded in season 1 were well above the range of 20 and 22 % required during pregnancy in order to prevent mobilisation of fat reserves by the dam (Teacher, 1970). However, the corresponding gestational weight increases of does kidding in season 2 were below this range. Weight changes of does during pregnancy often indicate pre-natal development of the fetus as evidenced by significant correlations between birth weight of the off spring and the body weight of the dam (Wallace et al., 2005; Bosso et al., 2007). Overall, reproduction is energetically demanding especially for gestational development and production of milk and therefore the growth performance of kids (Brand and Frank, 2000; Blache et al., 2008). The observed differences in weight changes between the two seasons in the present study are most likely a result of the fluctuating nature of nutrient supply in semi-arid areas. Nutrient availability during late dry season was probably insufficient to cover the requirement of dams as both herbage availability and quality are usually low. Results of the assessment of important forages relished by goats in the same area (Safari et al., unpublished) showed a drastic decline in energy and protein levels in this period.

The low growth performance of kids born in season 2 was presumably a result of reduced ability of dams to produce sufficient milk for the kids in this season. It is likely that weaning stress of such kids would be severe as pointed out by Hary (2002) and Berhane and Eik (2006) following observations made during long dry seasons. The present study also shows that it is potentially advantageous if goats are bred in January-March so that late pregnancy and lactation, stages with high nutritional demands will coincide with the season of adequate supply of feeds (season 1). Goats kidding in this season are also likely to have a short post-partum anoestrus and hence shorter kidding intervals (Hary and Schwartz, 2002). The growth rates of cross bred kids in the present study were higher than values reported elsewhere with pure SEA growers under the same environment (Kyomo, 1978; Ntakwendela et al., 2002) and could be attributed to the genetic differences of goats involved. Increased growth performance of SEA x Norwegian goats has also been reported in earlier studies (Kiango, 1996; Safari et al., 2005)

Kidding in the wet season is normally discouraged as this season is associated typically with adverse weather condition which is also exacerbated by high intestinal parasitism (Hary, 2002; Hoste et al., 2005). Thus, kidding taking place soon after rains as illustrated in the present study will confer the best results in terms of weight development of the dams and the production efficiency. Higher production efficiency in season 1 implies low investments in self-maintenance among animals and this is an important aspect in animal production as drastic losses of weight and condition during lactation may influence negatively the resumption of oestrous and ovarian activity (Mbayahagaab et al., 1998; Butler, 2000).

Kids born in season 1 were heavier at different stages of growth and this has implications in future reproductive performance of animals. Greyling (2000) and Papachristoforou et al. (2000) found that such kids achieve better reproductive performance when they attain sexual maturity and thus increase efficiency of goat enterprises. Overall, results from the present study also concur with the conclusion arrived from an experimental study conducted in Kenya that seasonal breeding could reduce the impact of fluctuations in nutrient supply necessary for growth and survival of young stock through improvements in birth weights and maternal lactation ability (Hary and Schwartz, 2002).

Conclusion

There were significant differences in body weight of does and growth rates of kids due to season of kidding whereby early dry season (June-August) was found to be the favourable kidding period. Thus, under semi-arid areas of Tanzania mating activity of goats should preferably be restricted to January-March. The number of does used in this study, however, was small. It would be of interest if more animals were involved with more years covered in order to increase the probability of detecting differences on reproductive and productive performance of goats due to dietary treatments.

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Table 1. Effect of flushing on body weight and condition of Small East African does (lsmeans ± SE)

Variable	Supplementation			S.E.M	Sign.
	T0	T200	T400		
Body weight					
Start of flushing (kg)	28.2	27.85	27.8	0.67	NS
End of flushing (kg)	26.6^{c}	28.1^{b}	29.4^{a}	0.39	*
ADG, flushing to mating	-27.8^{c}	3.3^{b}	26.2^{a}	6.61	***
At kidding (kg)	33.5^{b}	33.3^{b}	34.1^{a}	0.48	*
One month post-kidding (kg)	31.2^{b}	30.8^{b}	32.2^{a}	0.47	*
Three months post-kidding (kg)	28.5	27.9	28.6	0.47	NS
ADG, kidding to weaning	-53.9	-57.0	-53.2	6.40	NS
Body condition scores	2.81^{b}	2.87^{b}	3.07^{a}	0.03	***
Start of flushing	2.69	2.69	2.71	0.09	NS
End of flushing	2.96^{c}	3.19^{b}	3.38^{a}	0.07	*
At kidding	2.87^{c}	3.18^{b}	3.34^{a}	0.07	*
One month post-kidding	3.03	3.21	3.30	0.11	****
Three months post-kidding	2.75	2.62	2.78	0.07	NS

^{abc}Within rows, least squares means with different superscripts are significantly different $P<0.05$.
*, P <.05; ***, P <.001; ****, .05<P <0.1; NS, not significant.

Table 2. Reproductive traits of Small East African does and their kids (NxSEA) as influenced by flushing in two successive years

Variable	Supplementation			Sign.
	T0	T200	T400	χ^2
Number of does exposed to bucks	60	60	60	
Number of does kidded	44	48	50	NS
Number of kids born				
Season 1	36	46	56	NS
Season 2	16	14	6	NS
Total	52	60	62	NS
Rate (%) reproductive performance (seasons 1 and 2)				
Fertility	73.3	80.0	83.3	NS
Fecundity	0.86	1.00	1.03	NS
Prolificacy	1.18	1.25	1.24	NS
Twinning rate	9.0	12.5	12.0	NS

NS, not significant.

Table 3. Lsmeans ± SE for the litter size, birth weight and body weight changes of Small East African does and their kids (NxSEA) as influenced by flushing and season of kidding in two successive years

	Supplementation			Sig.
Variable	T0	T200	T400	
Litter size	1.23±0.07	1.28±0.07	1.34±0.05	NS
Birth weight, kg				
Season 1	2.33±0.06	2.33±0.06	2.46±0.06	NS
Season 2	2.00±0.25	2.33±0.22	2.50±0.15	NS
Growth rate of kids (g/day), birth to weaning				
Season 1	57.91±5.05	59.42 ±5.05	66.69 ±5.12	NS
Season 2	17.85±7.15	19.87±6.92	22.95±7.00	NS
Weight loss of does (%), birth to weaning				
Season 1	7.81±5.76	7.34±1.59	5.60±1.74	NS
Season 2	9.55±1.92	9.15±4.07	8.19±4.70	NS

NS, not significant.

Table 4. Lsmeans ± SE for the body weight changes of SEA does and their kids (NXSEA) in two seasons of kidding in two years of study

Variable	Season 1	Season 2	Sig.
Relative weight increases during gestation (%)			
Does carrying singles	33.9±2.35	12.6±7.57	**
Does carrying twins	35.8±5.57	17.8±5.50	*
Live weight of kids, kg			
Wk0	2.5±0.23	2.4±0.07	NS
Wk4	5.5±0.14	4.4±0.25	***
Wk8	7.5±0.24	6.4±0.47	*
Wk12	9.8±0.26	7.6±0.55	**
Growth rate of kids, g/day			
Wk 0- 4	102.2±6.22	68.0±5.62	*
Wk 4-8	68.1±5.96	65.3±6.05	NS
Wk 8-12	76.6±7.57	41.2±8.97	*
Weight of kid weaned, kg/kg doe kidding	2.6±0.24	1.80±0.30	*
Weight of kid weaned, kg/doe kidding	9.5 ±0.20	7.5 ±0.33	***
Pre-weaning mortality (%)	13	17	NS
Weight change of does (%), kidding to weaning	-6.1±0.47	-8.9±0.45	*

*, *P* <.05; **, *P* <.01; ***, *P* <.001; NS, not significant.

Table 5. Effect of birth type, parity of dam, and sex on growth performance (0-12 weeks) and survival rates of NXSEA kids in two years of study

	Time (weeks)				
Fixed effects	0	4	8	12	Survival rate χ^2
Sex of kid					
Male	2.38±0.06	5.23±0.14	7.37±0.22	9.25±0.18	72/82 (87.8 %)
Female	2.37±0.07	4.68±0.14	6.43±0.23	8.77±0.17	78/92 (84.7 %)
Significance	NS	*	**	*	NS
Type of birth					
Single	2.4±0.06	5.3 ±0.11	7.31 ±0.20	9.4±0.24	124/142(87.3%)
Twin	2.2±0.07	4.3 ±0.15	6.18 ±0.27	8.3±0.31	26/32 (81.3 %)
Significance	*	***	***	**	NS
Parity					
<3	2.3±0.26	4.96±0.58	7.08±0.93	9.1 ±1.06	44/50 (88.0 %)
3-5	2.4±0.07	5.19±0.16	7.19±0.93	9.3 ±0.34	58/64 (90.6 %)
>5	2.4±0.12	5.10±0.22	7.27±0.93	9.3 ±0.46	48/60 (80.0 %)
Significance	NS	NS	NS	NS	NS
Birth type-parity interaction					
Single x parity <3	2.4^{a}±0.19	4.96±0.55	7.08±0.91	9.3±1.03	
Single x parity 3-5	2.4^{a}±0.06	5.49±0.19	7.49±0.32	9.8±0.42	
Single x parity >5	2.5^{a}±0.08	5.19±0.23	7.42±0.39	9.9±0.46	
Twin x parity <3	1.6^{b}±0.03	-	-	-	
Twin x parity 3-5	2.1^{b}±0.09	4.52±0.28	6.52±0.48	8.4±0.58	
Twin x parity >5	2.3^{ab}±0.21	4.58±0.55	6.12±1.12	8.6±1.03	
Significance	*	****	NS	NS	

^{ab}Least squares means with a common superscript in the same column are not significantly different (P>0.05), *, *P* <.05; **, *P* <.01; ***, *P* <.001; ****, .05<*P* <0.1; NS, not significant

Table 6. Least-squares means and SE of live weight of fertile SEA does (kg) from birth to weaning (wk 0-12) as affected by season, litter size and parity at kidding in two years of study

	Time (weeks)			
Fixed effects	0	4	8	12
Kidding season				
Season 1	29.6 ±0.43	29.3±0.41	28.8±0.44	27.9±0.5
Season 2	28.5 ±0.40	28.0±0.40	27.5±0.50	26.1±0.3
Significance	*	*	*	*
Type of birth				
Does nursing singles	31.8±0.35	30.3±0.7	30.3±1.1	29.0±1.2
Does nursing twins	29.7±0.47	28.3±0.5	28.2±0.4	27.9±0.5
Significance	*	*	*	NS
Parity				
<3	25.8^{b} ±2.24	24.0^{b}±1.93	24.7^{b}±1.82	25.0±1.86
3-5	30.6^{a} ±0.69	28.5^{a}±0.60	28.7^{a}±0.57	28.0±0.58
>5	31.9^{a} ±0.89	29.5^{a}±0.78	29.3^{a}±0.76	28.9±0.80
Significance	*	*	*	NS
Birth type-parity interaction				
Single x parity <3	25.8^{c}±2.21	24.0^{c}±1.90	24.7^{c}±1.78	25.0±1.18
Single x parity 3-5	30.6^{b}±0.76	28.4^{b}±0.65	28.3^{b}±0.63	27.7±0.66
Single x parity >5	31.5^{ab}±0.93	29.1^{ab}±0.82	28.9^{ab}±0.79	28.9±0.84
Twin x parity <3				
Twin x parity 3-5	31.9^{ab}±1.56	29.3^{ab}±1.34	30.2^{ab}±1.26	29.1±1.33
Twin x parity >5	35.7^{a}±2.71	33.4^{a}±2.33	32.5^{a}±2.18	28.5±3.26
Significance	*	*	*	NS

^{abc}Least squares means with a common superscript in the same column are not significantly different (P>0.05), *, *P* <.05; NS, not significant.

Table 5. Seasonal changes in body weight, total serum protein (TP), urea and serum minerals of Small East African goats

	Season			
Variable	Rainy	Mid dry	Late dry	*P* -value
Weight				
Range (g/d)	-400 to 150	-83 to 16	-150 to 116	
Mean (g/d)	24.4^{b}±5.5	35.0^{a}±5.1	15.0^{c}±4.0	0.04
BCS	2.9^{b}	3.2^{a}	2.8^{b}	0.03
Mean EPG	390^{a} ± 117	227^{b} ± 72	100^{c} ± 91	0.04
TP (mmol/l)	80.8^{a}±1.7	82.9^{a}±1.1	74.6^{b}±1.1	<0.0001
Urea (mmol/l)	3.4^{a}±0.19	3.0^{ab}±0.12	2.6^{b}±0.12	0.001
Serum mineral				
Ca (mg/100l)	0.20^{c} ±0.02	0.23^{b} ±0.02	0.28^{a} ±0.02	0.04
P (mg/100l)	0.13^{c} ±0.01	0.17^{b} ±0.02	0.22^{a} ±0.01	0.04
Zn (µg/100l)	99^{a} ±7.0	56^{b} ± 8.0	54^{b} ± 11.1	<0.0001
Cu (µg/100l)	93^{a} ± 2.3	87^{a} ± 2.1	79^{b} ± 3.2	0.0028

Means with a common superscript in the same row are not significantly different (P<0.05). BCS, body condition scores; EPG, eggs per gram; TP, total protein

Paper III

Growth, carcass yield and meat quality attributes of Red Maasai sheep fed wheat straw-based diets

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Abstract

Thirty-two castrated Red Maasai sheep (12.7 kg initial body weight, aged 12-18 months), were used in an 84-day experiment to evaluate diets based on treated straw upon growth performance, carcass yield and meat quality. The animals were blocked by weight into four similar groups and randomly allotted into four dietary treatments, with eight individually fed animals per treatment. The dietary treatments were *ad libitum* untreated wheat straw (UTS), wheat straw treated with urea and lime (TS), straw and *ad libitum* hay (UTSH), and TS and *ad libitum* hay (TSH). In addition, each experimental animal received 220 g/d (on as fed basis) of a concentrate diet. Treatment of straw increased ($P<0.05$) dry matter intake (42.3 vs. 33.7 g/kgW$^{.75}$/d), energy intake (4.6 vs. 3.7 MJ ME/d) and the average daily gain (40.7 vs. 23.1 g). Animals on TS produced heavier ($P<0.05$) carcasses (6.6 vs. 5.4 kg) with superior conformation than animals on UTS. Percentage cooking loss was higher in carcasses from animals fed TS compared to those from other diets. Except M. *longissimus dorsi* and M. *semitendinosus*, tenderness of muscles was not affected by diet but ageing of meat improved ($P<0.001$) tenderness. Overall, straw treatment increased carcass yields with limited effects on meat quality attributes.

Key words crop residues, sheep, productivity, meat quality

Introduction

During dry season, sheep in the tropical countries are largely dependent on crop residues and low-quality roughages. These diets, however, are low in protein and high in fiber contents which limit intake and digestibility (Buranov and Mazza, 2008). High content of lignin and low accessibility of cell wall polysaccharides by both cell-free and microbial enzymes impede the utilization of gross energy contained in fibrous roughages. Nonetheless, the nutritive value of crop residues can be improved by supplementation with other feedstuffs or by treatment with chemicals which increase digestibility and/or feed intake by partial solubilization of cell-wall components hemi-cellulose and lignin as reviewed by Sundstøl and Owen (1984). Various techniques to improve utilisation of low quality forages have been tested but the techniques have to a large extent not been adopted by farmers in tropical countries for various reasons including economic constraints (Ben Salem and Smith 2008). However, earlier studies (Trach, 2000) reported that a combination of urea ($CO (NH_2)_2$) and lime ($CaO/Ca (OH)_2$) for chemical treatment of straw is more economically feasible although the effects of forage alkali treatments on animal performance are often variable due to the variation in the type/genotype of crop used and treatment conditions (Nurfeta et al., 2009). In addition, the efficiency at which low-quality roughages are digested depends on species of the animal (Li et al., 2008) and breed of animal within species (Habib et al., 2008). There is limited information on performance of the indigenous sheep in Tanzania in terms of growth rate, carcass characteristics and meat quality when raised on upgraded crop residues. This study was therefore designed to evaluate the effects of using treated wheat straw alone or in combination with grass hay on growth performance, carcass characteristics and meat quality attributes of Red Maasai sheep.

Materials and Methods

Animals and management

Thirty-two castrated sheep (12.7 ± 0.29 kg initial body weight, aged 12-18 months), were used in the 84 days experiment which was preceded by an adaptation period of 14 days. The animals were purchased from farmers and transported to Magadu Research Farm, Sokoine University of

Agriculture. On arrival at the farm, initial weights were recorded. The animals were distributed into four groups based on their initial body weight. Each group consisted of eight comparable animals which were then randomly assigned to one of the four dietary treatments in a completely randomized block design. All animals were injected with ivermectin (Kelamectin 1 %) for treatment and control of gastro-intestinal and ecto-parasites. The animals were housed in individual pens.

Feeds and feeding

Wheat straws were chopped into about 5 cm long using a straw chopper and weighed in 10 kg lots. Using a digital weighing balance, 200 g of fertilizer grade urea were weighed and dissolved in 10 litres of water to make a 2 % solution which was sprayed over the 10 kg straws with a watering can. The straws were then mixed with 300 g of unslaked lime and placed in sealed plastic bags and stored for about three weeks before use. Hay was also chopped, and provided in separate troughs to animals receiving it. Each animal was offered experimental diets in two lots daily; at 8.00 and 14.00 h. Feeding was done on individual basis. The dietary treatments were *ad libitum* untreated wheat straw (UTS), wheat straw treated with urea and lime (TS), straw and *ad libitum* hay (UTSH), and TS and *ad libitum* hay (TSH). In addition, each experimental animal was offered 220 g of concentrate once daily. The concentrate was composed of maize bran (70 %), sunflower seedcake (28 %) and mineral mix (2 %). The mineral mix consisted of (in %, manufacturer's specifications) Ca (25.8), S (0.3), Mg (0.5), Fe (0.1), Na (29.05), P (12.9), Cl (31.08), Zn (0.02), B-cr (0.02) and K (0.05). Grass hay consisting of *Bracharia and Bothriocloa* species and wheat straws were offered on *ad libitum* basis (20 % refusal rate). Daily weights of feed offered and daily feed refusals were recorded to derive daily feed intake.

Body weight measurements and slaughter procedures

All animals were weighed weekly during the adaptation and experimental periods. At the end of the growth trial, the final weight of each animal was obtained by averaging live weights recorded for two consecutive days. Growth rate (g/d) was calculated as the (final body weight (BW) (g) - initial BW (g)) /number of days on trial. Feed conversion ratio was calculated as the amount of feed consumed (kg DM) per body weight gain (kg).

At the end of the 12 weeks of feeding trial, feed was withheld overnight and the animals were weighed to record the shrunk body weight (SBW). The animals were then slaughtered following standard procedures described by Colomer-Rocher et al. (1987). After slaughter, 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). Hot carcass weights (HCW) were recorded immediately after slaughter then the carcasses were split into two halves through the median plane using a hand saw. Non-carcass components which included skin, head, feet, heart, lungs, trachea, liver and kidney were weighed and recorded. Digestive tract was weighed while full and when empty. The weight of digestive contents was computed as the difference between full and empty digestive tract. Empty body weight (EBW) was computed as the difference between SBW and the weight of digestive content. Commercial dressing percentage was expressed as hot carcass weight (HCW) x 100) /SBW and true dressing percentage as cold carcass weight (CCW) x100/EBW. Internal carcass length (CL), measured from lumbo-sacral joint to the cervico-thoracic joint was used to determine carcass compactness (CCW / CL).

Assessment of carcass conformation and fatness scores was based on EUROP classification system (Johansen et al., 2006). Carcasses were classified for conformation (scale from E = excellent (5) to P = poor (1) and fatness (scale from 1 = none or low fat cover to 5 = entire carcass covered with fat) based on visual scores. 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 and 1- for fatness. Grade 15 is E+ for conformation class and 5+ for fat class.

Temperature and pH measurements

Temperature and pH of the carcasses were measured 45 min and 6 h post-mortem (PM), at the same point on the M. *gluteobiceps* of the right half-carcasses. An electrode (Mettler Toledo) of a portable pH-meter (Knick-portamess 910, Germany) was inserted at the geometrical centre of the muscle. The carcasses were then chilled at 0 ^{o}C overnight. The ultimate pH (pHu) and temperature were recorded on the same muscle 24 h PM. Both the right and left chilled carcasses were reweighed to obtain cold carcass weights (CCW).

Muscle sampling and tissue separation

For determination of cooking losses and Warner-Bratzler shear force (WBSF), 10 muscles were sampled from the left half of the carcass of each animal, 24 h PM. The muscles were *Longissimus dorsi, Gluteobiceps, Infraspinatus, Supraspinatus, Psoas major, Rectus abdominis, Semimembranosus, Semitendinosus, Triceps brachii* and *Vastus lateralis.* The muscles were weighed to obtain initial weight (W1) and vacuum packed in PVC bags using a vacuum packing machine (Komet plus Vac 20, Germany). Three samples of LD muscle each measuring approx. 7 cm long were prepared from each animal to study effects of conditioning on meat tenderness. One LD sample was immediately frozen at -25^{o}C while the other LD muscle samples were conditioned in a fridge set at 4 ^{o}C for 6 or 9 days before also being frozen at -25^{o}C. These conditioning treatments are referred to as LD (0d), LD (6d) and LD (9d) in this paper. The remaining parts of the left half-carcasses were dissected into muscle, fat and bone for estimation of carcass composition. Total weight of muscles included weights of the 10 individual muscles sampled at 24 h PM. Thereafter, muscle and fat tissues from the left half-carcasses were homogenized, mixed and three sub-samples taken for chemical analysis.

Cooking loss determination

The ten muscles were thawed at 4 ^{o}C overnight before analyses. The muscles in the water-tight PVC bags were then boiled in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) set at 70.5 ^{o}C for a total of 50 min. The boiled muscles were left to equilibrate with the room temperature for 2 h, and then transferred to a refrigerator set at 4 ^{o}C for 12 h. The muscles were removed from the PVC bags and blotted dry by paper towel and weighed (W2). Cooking loss was computed as ((W1 – W2)/ W1) x 100.

Determination of shear force values

The samples for the determination of cooking loss were also used to determine meat tenderness. The muscles were cut into 1 x 1 x 1 cm cubes. Muscle toughness (shear force) was measured as the maximum force (N/cm^2) required for shearing through the cubes perpendicular to the muscle grain, at a crosshead speed of 100 mm/min using a Warner- Bratzler shear force blade, fitted to Zwick/Roell (Z2.5, Germany) instrument. The average peak shear force for 6 cubes per muscle sample was considered as a force needed to shear through a particular muscle.

Chemical analyses of feed samples

Samples of feeds used in dietary treatments were dried (70 ^{o}C), ground (1mm screen) and stored for subsequent analyses of dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), crude fibre (CF), i*n vitro* dry matter and organic matter digestibility. DM, N and total ash were determined according to the official methods of AOAC (2000) and NDF and ADF according to Van Soest et al. (1991). Ash content was determined by ashing at 600 ^{o}C for 6h. Nitrogen was determined by Kjeldahl method (CP = N x 6.25). *In vitro* dry matter digestibility and *In vitro* organic matter digestibility were determined according to Tilley and Terry (1963). Metabolisable energy content of concentrate diet was estimated using the equation of MAFF (1975): ME (MJ/ kg DM) = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE. For other diets, the equations of AFRC (1993) were used to estimate the ME contents as follows: Hay ME = 2.67 + 0.0110 DOMD; untreated wheat straws ME = 0.53 + 0.0142 DOMD and treated wheat straws ME = 2.24 + 0.0098 DOMD.

For the meat samples, water content was determined by the weight loss of 3 g minced meat and LD samples dried for 48 h in 104 ^{o}C oven according to AOAC (2000). Similarly, ash content was determined by ashing the dried samples in a 600 ^{o}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 1 g sample following the Kjeldahl method as described in the AOAC (2000).

Statistical analysis

Data were analyzed using the GLM procedures of SAS (2001). Dietary treatments were considered as fixed effects whilst residuals were considered as random effects. Each individual animal served as an experimental unit for all the parameters assessed. Covariance analysis, with initial live weight as a covariate, was used to correct for the various traits studied. In all analyses, when Least Squares Means were different at $P < 0.05$, they were separated by the PDIFF option of SAS.

Results

Growth, feed intake and yield of carcasses and non carcass components

Urea and CaO treatment increased the CP content of wheat straw from 40 to 55 g/ kg DM (Table 1). There was a slight decrease in NDF content from 756 to 732 g/kg DM while ADF increased from 448 to 484 g/kg DM. Metabolisable energy in wheat straws increased by 39 % as a result of chemical treatment. Higher growth rates were recorded in animals on treated wheat straw (TS, TSH) compared with those on untreated wheat straw (UTS, UTSH) based diets (Table 2). Diet caused significant differences on mean final body weight (FBW), shrunk body weight (SBW), empty body weight (EBW) and carcass weight (Table 3). These were heavier for animals fed TS than those fed UTS based diets. The gut fill of animals fed UTS tended ($P<0.1$) to be larger than that of animals on TS whilst the commercial dressing percentage was higher ($P<0.05$) for TS than UTS fed animals. Results in Table 4 show that diets affected ($P<0.05$) hot carcass weight (HCW). The lowest values were recorded for animals fed UTS. Furthermore, carcasses from TS had higher ($P<0.05$) conformation and fatness scores than those from UTS. Mean conformation score was O^- based on 15-point scale. Neither straw treatment nor hay inclusion influenced the linear carcass measurements.

Carcass composition and meat quality attributes

The weight of muscles from animals on treated straw-based diets was higher ($P<0.05$) compared with those fed untreated straw-based diets (Table 5). Diets, however, had no ($P> 0.05$) effect on dissectible muscle contents in sheep when expressed as percentage of carcass weight. The percentage of fat tissue in the carcasses from sheep fed TS, TSH and UTSH were similar ($P>0.05$) but higher ($P<0.05$) than that recorded in the carcasses from UTS. The dietary treatments did not ($P>0.05$) affect pH values for M. g*luteobiceps* (Table 6). However, minced meat from animals on UTS contained higher ($P<0.05$) proportions of moisture, protein and ash compared to other diets. The variations in proximate composition were nonetheless not clearly associated with the effect of straw treatment. Except for M. g*luteobiceps* and M. *triceps brachii*, diet had no effect on the cooking loss of most of the individual muscles studied but wide variations were observed in cooking losses between muscles (Table 7). The cooking loss for *M. semimembranosus* was about twice as great as that of M. *rectus abdominis.* With exception of M. *longissimus dorsi* (0 d) and M. *semitendinosus,* WBSF values were not affected by diet (Table 8). There were differences ($P<0.01$) on pooled values for cooking loss with higher losses from animals fed treated straw based diets (Table 9). The losses decreased ($P<0.05$) with increasing ageing time with day 6 and 9 having significantly lower loss than 0d ageing. Post-mortem ageing of sheep meat improved ($P<0.001$) tenderness especially after 9 days of ageing. The WBSF value of LD 9d was 20 % lower than that of LD 0d.

Discussion

Feed intake, yield of carcasses and non carcass components

The improvement in CP content by chemical treatment of wheat straw in the present study is similar to an increase of 37.5 % (26 vs. 42 g/kg DM) reported by Nurfeta et al. (2009) but lower than that of Sharma et al. (2004) who recorded more than a two fold increase (39 vs. 85 g/kg DM). Probable reasons for these variations include differences in treatment conditions and the initial straw quality. Higher DMI in sheep fed TS based diets is presumably attributed to the increase in dietary protein which might have caused increased rate and extent of fibre digestion in the rumen. In addition, the increase in ME of straws as a result of chemical treatment may explain the observed higher weight gains recorded in sheep fed treated wheat straw based diets.

Based on the EUROP grading system for conformation and fatness estimates, the findings indicate that besides sustaining sheep in the dry season, straw treatment has a potential to produce carcasses of fair conformation and fatness. The observed variation in fat content in the carcasses may have resulted from differences in dietary energy intake which were 4.61, 4.65, 3.48 and 4.00 MJ, ME/d for the animals on TS, TSH, UTS and UTSH, respectively. Feeding regimen affects carcass composition of farm animals particularly the fat content when there is variation in energy concentration and intake of diets (Mushi et al., 2009).

Meat quality attributes

The average ultimate pH (pHu) of 5.7 for sheep after completion of glycolysis (24 h PM) in the present study is within the quality range of pHu < 6.0 (Miranda-de la Lama et al., 2009). The rate of pH fall and the ultimate pH (pHu) are important determinants of meat quality and are related to the rate of glycogen breakdown (Abdullah and Qudsieh 2009). Elevated pH affects several meat characteristics including modifications of membranes and extracellular fluids, which affect the meat's electrical properties (Damez and Clerjon, 2008). The lack of dietary effect on pH values in the present study agrees with the observation made on Assaf lambs fed *ad libitum* commercial concentrates and barley straw or whole grain and protein supplement (Rodríguez et al., 2008) but contrasts those of Olfaz et al. (2005) where differences in pH were recorded due to greater glycogen concentrations in Karayaka growing rams fed high energy diets compared with lambs on low energy diet. In the present study, however, it could be argued that differences in energy content between diets were not large enough to elicit significant differences in pH values.

The rate of temperature fall post-mortem affects tenderisation since this process is dependent on postmortem proteolysis mediated by proteolytic enzymes such as calpains and lysosomal proteases (Kemp et al., 2010). Muscle temperature falling below 15 ^{o}C with pH higher than 6.0 – 6.4 during early post-mortem, causes shortening of muscle to occur thereby limiting tenderness through reduction of calpain activity and ageing potential (Kannan et al., 2006). The temperature and pH decline in the present study suggest that conditions were unfavourable for muscle shortening to occur. The observed variation in cooking loss with ageing time could be attributed to increased volume of myofibrils in aged meat, which leads to higher water holding capacity (Kolczak et al., 2007). Ageing increases tenderisation by weakening the structural integrity of the myofibrilar proteins (Han et al., 2009), and the rate of tenderisation varies with ageing time. Findings from 9 days of ageing in the present study are comparable with those of Abdullah and Qudsieh (2009) where ageing meat from Awassi ram lambs for 7 days reduced the shear force by 26 % (from 28.3 N in day 1 to 20.7 N in day 7). A review by Warriss (2004) indicated that up to 80 % of 'maximum' tenderness of sheep meat could be reached in 7.7 days of ageing. Generally, muscles studied in the present study were tender as the values were below 52.7 N above which meat is considered tough (Destefanis et al., 2008).

Conclusion

Treatment of wheat straw with urea/ lime solution increased dry matter and energy intake in sheep which resulted in improved live weight gain and carcass conformation. Straw treatment, however, had limited effects on meat quality attributes. Investigation on the economics and practical aspects of this technology at farmers' level is recommended.

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Table 1 Chemical composition of the experimental feeds

Chemical composition	Feedstuff			
	Concentrate	TS	UTS	Hay
Dry matter (g/kg)	910	580	890	900
Crude protein (g/kg DM)	173	55	40	39
Ether extract (g/kg DM)	134	12	16	12
Ash (g/kg DM)	52	98	106	87
Neutral detergent fibre (g/kg DM)	391	732	756	737
Acid detergent fibre (g/kg DM)	223	484	448	429
Crude fibre (g/kg DM)	146	334	340	353
In vitro dry matter digestibility (g/kg DM)	546	590	360	396
In vitro organic matter digestibility(g/kg DM)	546	570	360	310
Nitrogen free extract	405	81	388	409
Metabolisable energy (MJ/kg DM)	12.6	7.83	5.64	6.08

Table 2 Least squares means ±SE for intake and growth performance of castrated Red Maasai sheep fed different diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Sign.
Intake (g DM /d)						
Straw	146^{bc}	243^{a}	77^{d}	124.5^{c}	12.3	***
Hay	-	-	138^{b}	159.5^{a}	4.1	***
Conc.	211	219	211	211	0.7	-
Total	358^{d}	463.9^{b}	427^{c}	495.9^{a}	13.5	***
Intake (% BW)	2.36^{c}	2.81^{ab}	2.66^{b}	2.89^{a}	0.1	***
Intake g/kgW$^{.75}$/d	33.7^{c}	42.3^{a}	39.4^{b}	44.7^{a}	0.9	***
Energy intake (MJ, ME/d)	3.48^{c}	4.61^{a}	4.00^{b}	4.65^{a}	2.4	***
Daily gain (g/d)	23.1^{c}	40.7^{ab}	34.1^{bc}	47.8^{a}	2.6	***
Total gain (kg)	1.96^{c}	3.51^{ab}	2.89^{bc}	4.08^{a}	0.3	***
FCR (kg DMI/kg gain)	15.6	11.2	13.1	10.4	2.4	†
BCS (1-5)	2.5	2.9	2.9	3.4	1.5	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05) Significance: NS, not significant; *****, *P* <0.05; ******, *P* <0.01; *******, *P* <0.001; †**,** 0.05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay; FCR feed consumed (kg) for 1kg body weight gain; BCS, body condition score.

Table 3 Least squares means ±SE for final body weight (FBW), slaughter weight (SBW), fasting loss, empty BW, gut fill, dressing percentage and individual organs as the proportion (%) of shrunk weight of castrated Red Maasai sheep fed different diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Sign.
FBW (kg)	14.9^{c}	15.9^{ab}	15.8^{bc}	16.7^{a}	0.2	**
SBW (kg)	14.5^{c}	15.7^{a}	15.1^{b}	16.3^{a}	0.2	**
Empty BW (kg)	11.4^{b}	12.6^{a}	12.1^{b}	13.7^{a}	0.3	*
Gut fill % Live weight	20.4	18.9	19.7	18.8	1.9	NS
Gut fill % Empty BW	28.1	25.3	25.2	26.6	2.4	NS
Commercial dressing %	33.25^{b}	43.97^{a}	41.90^{a}	41.58^{a}	1.2	**
True dressing %	42.50^{c}	52.77^{a}	49.35^{ab}	47.27^{b}	1.1	***
Individual organs % of shrunk weight						
Blood	4.21	4.41	4.13	3.41	0.3	NS
Spleen	0.20	0.21	0.23	0.21	0.0	NS
Liver	1.33	1.26	1.38	1.30	0.1	NS
Heart	0.52	0.57	0.58	0.51	0.0	NS
Kidneys	0.30	0.33	0.28	0.27	0.0	NS
GI tract (empty)	6.94	9.54	7.53	6.84	1.4	NS
GI tract (full)	26.9	25.4	29.0	26.9	1.9	†
Lung, trachea and diaphram	1.26	1.47	1.53	1.56	0.1	NS
Head, skin and feet	18.31	16.76	15.88	20.18	1.4	NS
Total non carcass yield	33.13	34.56	31.50	34.29	2.4	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <0.05; **, *P* <0.01;***, *P* <0.001; †**,** 0.05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay. Shrunk weight, live weight of animals after 16 hours of fasting.

Table 4 Least squares means ±SE of hot carcass weight (HCW), EUROP classification and linear carcass measurements of castrated Red Maasai sheep fed different diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Sign.
HCW (kg)	5.4^{b}	6.6^{a}	6.3^{a}	6.7^{a}	0.3	*
Score (l-15) conformation	2.5^{c}	4.1^{ab}	4.1^{ab}	4.8^{a}	0.5	**
Score (1-15) Fatness	1.5^{b}	2.0^{b}	1.8^{b}	4.0^{a}	0.8	*
Carcass measurements (cm)						
Carcass length	44.9	46.8	39.6	47.0	2.2	NS
Chest depth	20.7	21.7	20.8	20.9	1.3	NS
Hind- limb length	31.6	32.4	31.5	31.7	0.6	NS
Hind-limb width	54.0^{b}	56.3^{a}	54.0^{b}	56.0^{a}	0.6	*
Compactness index (g/cm)	133	154	135	159	35	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <0.05; **, *P* <0.01;***, *P* <0.001; †**,** 0.05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay.

Table 5 Least-squares means ± SE for weights, percentage and ratios of carcass tissues from castrated Red Maasai sheep fed different diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Sign.
Muscle (kg)	3.00^{b}	3.66^{a}	3.40^{b}	3.78^{a}	0.1	***
% carcass wt	64.60	64.71	64.17	64.61	1.3	NS
% SLW	6.47	7.32	7.18	6.31	0.5	†
Fat (kg)	0.40^{c}	0.70^{ab}	0.62^{bc}	0.56^{c}	0.1	**
% carcass wt	8.9^{b}	12.3^{a}	11.5^{ab}	$11,8.0^{a}$	1.3	*
% SLW	1.41^{b}	2.59^{a}	2.09^{ab}	1.54^{b}	0.3	***
Bone (kg)	1.2	1.3	1.28	1.36	0.0	NS
% carcass wt	26.3^{a}	22.96^{b}	24.03^{ab}	23.5^{b}	1.1	**
% SLW	4.26	4.51	4.28	4.09	0.3	NS
Muscle: fat	8.44	5.64	5.88	6.10	0.9	NS
Muscle: bone	2.46	2.81	2.67	3.15	0.3	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <.05; **, *P* <.01;***, *P* <.001; †, .05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay.

Table 6 Least-squares means ± SE for pH and temperature of *M.gluteobiceps* and chemical composition of minced meat from castrated Red Maasai Sheep fed different diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Sign.
pH 45 min	6.41	6.12	6.49	6.44	0.1	NS
pH 24h	5.75	5.72	5.72	5.76	0.3	NS
Temp, ^{o}C (45min)	32.1^{ab}	32.1^{ab}	32.2^{b}	32.9^{a}	0.8	*
Temp, ^{o}C (24h)	5.0	5.0	4.9	4.3	0.6	NS
Moisture (%)	68.5^{a}	63.4^{b}	64.1^{b}	63.4^{b}	1.0	*
Protein (%)	19.9^{a}	17.6^{b}	18.2^{b}	18.7^{ab}	0.4	*
Fat (%)	5.4^{c}	11.8^{a}	8.6^{b}	9.7^{ab}	2.0	*
Ash (%)	5.8^{a}	4.5^{b}	4.7^{b}	4.9^{ab}	0.3	*

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <.05; **, *P* <.01;***, *P* <.001; †, .05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay.

Table 7 Least Squares means ± SE for the cooking loss (%) of muscles from castrated Red Maasai Sheep fed different diets

	Diets					
Muscle	UTS	TS	UTSH	TSH	SE	Sign.
LD(0d)	29.8	32.7	33.4	34.7	1.2	NS
LD(6d)	22.8	30.3	25.9	29.8	1.3	NS
LD(9d)	26.9	29.8	25.8	32.0	1.2	NS
Gluteobiceps	30.6^{c}	41.9^{a}	31.7^{bc}	29.8^{c}	1.3	*
Infraspinatus	20.6	28.8	26.8	26.5	1.3	NS
Psoas major	27.9	29.6	32.9	27.2	1.2	NS
Rectus abdominis	21.6	18.4	13.3	18.8	1.4	NS
Semimembranosus	32.4	39.0	35.8	38.7	1.3	NS
Semitendinosus	23.6	30.1	30.2	27.3	1.3	NS
Supraspinatus	34.4	37.4	37.2	40.7	1.3	NS
Triceps brachii	26.6^{b}	36.1^{a}	26.1^{b}	31.8^{ab}	1.2	*
Vastus lateralis	30.3	35.1	32.3	33.4	1.3	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *****, *P* <.05; ******, *P* <.01; *******, *P* <.001 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay. LD (0d), LD (6d) and LD (9d); M. *longissimus dorsi* aged for 0, 6 and 9 days respectively.

Table 8 Least Squares means ± SE for Warner–Bratzler shear force values (N) of muscles from castrated Red Maasai Sheep fed different diets

	Diets					
Muscle	UTS	TS	UTSH	TSH	SE	Sign.
LD(0 d)	17.2	24.6	16.9	19.5	1.1	†
LD(6 d)	14.7	15.0	15.7	16.9	1.2	NS
LD(9 d)	13.3	14.6	15.1	14.0	1.2	NS
Gluteobiceps	23.7	29.6	25.4	24.7	1.2	NS
Infraspinatus	17.6	15.8	16.2	17.1	1.2	NS
Psoas major	18.0	15.5	15.3	20.5	1.1	NS
Semimembranosus	28.7	29.5	22.0	28.4	1.2	NS
Semitendinosus	21.7	22.9	15.3	20.9	1.1	†
Supraspinatus	26.8	23.1	23.5	23.6	1.2	NS
Triceps brachii	20.6	18.0	19.6	18.2	1.2	NS
Vastus lateralis	20.3	22.0	18.3	19.1	1.1	NS

Significance: NS, not significant; *****, P <.05; ******, P <.01; *******, P <.001; †**,** .05<P <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay. LD (0d), LD (6d) and LD (9d); M. *longissimus dorsi* aged for 0, 6 and 9 days respectively.

Table 9 Least Squares means ± SE for pooled cooking loss (%) and Warner–Bratzler shear force values (N) for castrated Red Maasai Sheep by dietary treatments and duration of ageing

Variable	Cooking loss (%)	Shear force (N)
Treatment		
TS	32.3 ^{a}±0.9	20.9±0.8
TSH	30.9 ^{ab} ±0.9	20.5±0.8
UTS	27.9^{c}±0.9	20.5±0.9
UTSH	29.3^{bc}±0.9	18.1±0.9
Significance	**	†
Ageing		
LD(0 d)	32.6^{a}±1.3	19.6 ^{a} ±0.8
LD(6 d)	27.7^{b}±1.4	15.7 ^{ab} ±0.9
LD(9 d)	28.4^{b}±1.4	14.4 ^{c} ±0.9
Significance	*	***

^{abc}Least squares means with different superscripts in the same column are significantly different. NS, not significant; *****, *P* <.05; ******, *P* <.01; *******, *P* <.001; †**,** .05<*P* <0.1, and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay. LD (0d), LD (6d) and LD (9d); M. *longissimus dorsi* aged for 0, 6 and 9 days, respectively.

Paper IV

Growth, carcass and meat quality characteristics of Small East African goats fed straw based diets

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Abstract

Thirty-two castrated male goats of Small East African breed (13.8 kg BW, 12-18 months of age) were used to evaluate the potential of using treated-wheat straw alone or in combination with grass hay as dry season feeds. Animals were allotted into four dietary treatments with eight animals per treatment for 84 days. The dietary treatments were either *ad libitum* amount of untreated wheat straw (UTS), wheat straw treated with urea and lime (TS), untreated wheat straw with hay (UTSH) or treated wheat straw with hay (TSH). In addition, each animal received 220 g/d (on as fed basis) of a concentrate diet. Dry matter intake from wheat straws was highest (438.1 g/d, $P<0.05$) for goats on TS. Daily body weight gain for goats fed TS was nearly two-fold higher than for those fed UTS. Meanwhile, goats fed TSH were more ($P<0.05$) efficient in converting feeds to body tissue as they required 9 kg less feed for one kg body weight gain compared to those fed TS. Goats on TS had the highest commercial dressing percentage (DP), which was about 5 % higher than the DP of the other dietary groups. Compared to goats fed UTS, those fed TS had 0.70 and 0.32 kg heavier muscles and fat, respectively. Goats on diets including hay (TSH and UTSH) produced carcasses with higher proportion of fat than those without access to hay (TS and UTS). There was muscle-specific response to straw treatment with respect to cooking loss notably for *M. gluteobiceps* and *M. triceps brachii.* Chemical treatment of straws improved potentials for crop residues to sustain goats in the dry season with a minimum level of fattening. However, straw treatment had limited effect on the quality of goat meat. Grass hay complemented the effects of chemical treatment in increased intake and growth performance of goats.

Key words: crop residues; goats; productivity; meat quality

1.0 Introduction

Seasonal availability of forages is a major factor influencing livestock productivity in the tropics, and remains the major technical constraint in meeting future demands for animal products. During the long dry periods of the year, ruminants are mainly dependent on crop residues such as straw although these feeds contain low amounts of protein and high levels of indigestible or slowly degradable fiber which result in low voluntary intake and digestibility. Meanwhile, human population growth, increasing urbanisation and rising incomes are causing increasing demands for food of animal origin (Gilland, 2002; Reddy et al., 2003). The increase in population also leads to increased cereal and straw production. Crop residues will therefore assume even greater importance as animal feed as the available land for grazing diminishes because of human pressure for more cropping (Thomas and Rangnekar, 2004).

Tanzania produces an estimated 139 metric tons of wheat straw annually (Magingo et al., 2004) but a large proportion of this resource is wasted. However, various studies show that supplementing crop residues with other feedstuffs or upgrading with chemicals increases digestibility and/or feed intake by solubilization of crusting substance (cellulose, hemicellulose and lignin) with subsequent improvement in the performance of ruminants (Silva and Ørskov, 1988; Abebe et al., 2004). But reports show limited success in the adoption of such technologies in tropical countries for various reasons including in adequate technical support and economic constraints (Trach, 2004; Roy and Rangnekar, 2006). It is, however, imperative that effective strategies are designed to improve the efficiency with which crop residues are utilised if productivity in livestock sector is to increase.

A combination of urea (CO (NH2)2) and lime (CaO/Ca (OH)2) for chemical treatment of straw has been shown to be technically effective in improving the nutritive value of straw and economically feasible (Trach, 2000; Animut et al., 2002). While ammonia acts to increase hemicellulose digestibility, lime appears to increase ADF and cellulose digestibility (Trach, 2000). Nonetheless, the effects of forage alkali treatments on animal production performance are often variable. The variations are a result of the influence of many factors including the type/genotype of crop used and treatment conditions (Habib et al., 1998; Sirohi and Rai, 1998). In addition, the efficiency to digest poor-quality roughages has been shown to depend on species of the animal (Hadjipanayiotou et al., 1993) and breed of animal within species (Ørskov, 1998; Habib, 2009).

In Tanzania, goats are next to cattle in terms of population size which is estimated at 13.1 million (MAFS, 2002). There is limited information on the use of crop residues and performance of the indigenous goats in East Africa in terms of growth rate, carcass characteristics and particularly in meat quality attributes. Information on non-carcass yield is also limiting although the contribution of edible offals to the supply of dietary animal protein and economic gains is substantial (Riley et al; 1989; Aduku et al., 1991; Mushi et al., 2009b). The objective of this study was to evaluate the effects of using treated wheat straw alone or in combination with grass hay on growth performance, carcass characteristics, non-carcass yield and meat quality attributes of Small East African (SEA) goats.

2. Materials and Methods

2.1 Animals and management

Thirty-two castrated male goats of SEA breed (12.7 ± 0.29 kg BW, aged 12-18 months), were used in an 84- day experiment which was preceded by an adaptation period of 14 days. The animals were purchased from farmers and transported to Magadu Research Farm, Sokoine University of Agriculture. On arrival at the farm, initial weights were recorded. The animals were distributed into four groups based on their initial BW. Each group consisted of eight comparable animals which were then randomly assigned to one of the four dietary treatments in a completely randomized block design. All animals were injected with ivermectin (Kelamectin 1 %) for treatment and control of gastro-intestinal and ecto-parasites. The animals were housed in individual pens.

2.2 Feeds and feeding

Wheat straws were chopped into about 5 cm long and weighed in 10 kg lots. Using a digital weighing balance, 200 g of urea were weighed and dissolved in 10 litres of water to make a 2 % solution which was sprayed over the 10 kg straws with a watering can. The straws were then mixed with 300 g of unslaked lime and stored in sealed plastic bags for about three weeks before use. Each animal was offered experimental diets in two lots daily; at 8.00 and 14.00 h. Feeding was done on individual basis. The dietary treatments were either *ad libitum* amount of untreated wheat straw (UTS), treated wheat straw (TS), untreated wheat straw with hay (UTSH) or treated wheat straw with hay (TSH). Each experimental animal was in addition offered 220 g of concentrate daily. The concentrate was composed of maize bran (70 %), sunflower seedcake (28 %) and mineral mix (2 %). The mineral mix (Tanfeed co. Ltd) consisted of (in %, manufacturer's specifications) Ca (25.8), S (0.3), Mg (0.5), Fe (0.1), Na (29.05), P (12.9), Cl (31.08), Zn (0.02), B-cr (0.02) and K (0.05). Grass hay consisting of *Bracharia and Bothriocloa* species and wheat straws were offered on *ad libitum* basis (20 % refusal rate). Daily weights of feed offered and daily feed refusals were recorded to derive daily feed intake.

2.3 Body weight measurements

All animals were weighed weekly during the adaptation and experimental periods. At the end of the growth trial, the final weight of each animal was obtained by averaging live weights recorded for two consecutive days. Growth rate (g/d) was calculated as the (final BW (g) - initial BW (g)) /number of days on trial. Body condition scores (BCS) were also recorded using a five point-scale; 1 = very thin, 5 = very fat (Russel et al., 1969). Feed conversion ratio was calculated as the amount of feed consumed (kg DM) per body weight gain (kg).

2.4 Slaughter procedures

At the end of the 12 weeks of the feeding trial, feed was withheld overnight and the animals were weighed to record the shrunk body weight (SBW). The animals were then slaughtered following standard procedures described by Colomer-Rocher et al. (1987). After slaughter, 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). Hot carcass weights (HCW) were recorded immediately after slaughter then the carcasses were split into two halves through the median plane using a hand saw. Non-carcass components which included skin, head, feet, heart, lungs, trachea, liver and kidney were weighed and recorded. Digestive tract was weighed while full and when empty. The weight of digestive contents was computed as the difference between full and empty digestive tract. Empty body weight (EBW) was computed as the difference between SBW and the weight of the digestive content. Commercial dressing percentage was expressed as hot carcass weight (HCW) x 100) /SBW and true dressing percentage as cold carcass weight (CCW) x100/EBW. Internal carcass length (CL), measured from lumbo-sacral joint to the cervico-thoracic joint was used to determine carcass compactness (CCW / CL).

Assessment of carcass conformation and fatness scores was based on EUROP classification system (Kosum et al., 2003; Johansen et al., 2006). Thus, carcass conformation was scored as E = excellent (5), P = poor (1) while carcass fatness was classified as 1 = none or low fat cover, 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 and 1- for fatness. Grade 15 is E+ for conformation class and 5+ for fat class.

2.5 Temperature and pH measurements

Temperature and pH of the carcasses were measured 45 min and 6 h post-mortem (PM), at the same point on the *M. gluteobiceps* of the right half-carcasses. An electrode (Mettler Toledo) of a portable pH-meter (Knick-portamess 910, Germany) was inserted at the geometrical centre of the muscle. The carcasses were then chilled at 0 ^{o}C overnight. The ultimate pH (pHu) and temperature were recorded on the same muscle 24 h PM. Both the right and left chilled carcasses were reweighed to obtain cold carcass weights (CCW).

2.6 Muscle sampling and tissue separation

For determination of cooking losses and Warner-Bratzler shear force (WBSF), 10 muscles were sampled from the left half of the carcass of each animal, 24 h PM. The muscles were *Longissimus dorsi, Gluteobiceps, Infraspinatus, Supraspinatus, Psoas major, Rectus abdominis, Semimembranosus, Semitendinosus, Triceps brachii* and *Vastus lateralis.* The muscles were weighed to obtain initial weight (W1) and vacuum packed in PVC bags using a vacuum packing machine (Komet plus Vac 20, Germany). Three samples of LD muscle each measuring approx. 7 cm long were prepared from each animal to study the effects of conditioning on meat tenderness. One LD sample was immediately frozen at -25°C while the other LD muscle samples were conditioned in a fridge set at 4 °C for 6 or 9 days before also being frozen at -25°C. In this paper, these conditioning treatments are referred to as LD (0d), LD (6d) and LD (9d). The remaining parts of the left half-carcasses were dissected into muscle, fat and bone for estimation of carcass composition. Total weight of muscles included weights of the 10 individual muscles sampled at 24 h PM. Thereafter, muscle and fat tissues from the left half-carcasses were homogenized, mixed and three sub-samples taken for chemical analysis.

2.7 Determination of cooking loss

The ten muscles were thawed at 4 °C overnight before analyses. The muscles in the water-tight PVC bags were then boiled in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) set at 70.5 °C for a total of 50 min. The recorded temperature at the geometrical centre of muscles after cooking was 70.5 °C. The boiled muscles were left to equilibrate with the room temperature for 2 h, and then transferred to a refrigerator set at 4 °C for 12 h. The muscles were removed from the PVC bags and blotted dry by paper towels and weighed (W2). Cooking loss was computed as ((W1 – W2)/ W1) x 100.

2.8 Determination of meat tenderness

The samples for the determination of cooking loss were also used to determine meat tenderness. The muscles were cut into 1 x 1 x 1 cm cubes. Muscle toughness (shear force) was measured as the maximum force (N/cm^2) required for shearing through the cubes perpendicular to the muscle fibre, at a crosshead speed of 100 mm/min using a Warner- Bratzler shear force blade (angle, 60^o), fitted to Zwick/Roell (Z2.5, Germany) instrument. The average peak shear force for 6 cubes per muscle sample was considered as the force needed to shear through a particular muscle. A higher reading indicates greater shear force and therefore tougher meat.

2.9 Chemical analyses of feed samples

Samples of feeds used in dietary treatments were dried (70 ^{o}C), ground (1mm screen) and stored for subsequent analyses of dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), crude fibre (CF), *in vitro* dry matter (IVDMD) and organic matter (IVOMD) digestibility. DM, N and total ash were determined according to the official methods of AOAC (2000) and NDF and ADF according to Van Soest et al. (1991). Ash content was determined by ashing samples at 600 ^{o}C for 6 h in a muffle furnace. Nitrogen was determined by Kjeldahl method (CP = N x 6.25). Both *in vitro* dry matter digestibility and *in vitro* organic matter digestibility were determined according to Tilley and Terry (1963). Metabolisable energy content of concentrate feed was estimated using the equation of MAFF (1975): ME (MJ/ kg DM) = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE. The equations of AFRC (1993) were used to estimate the ME contents of other feeds as follows: Hay ME = 2.67 + 0.0110 DOMD; untreated straw ME = 0.53 + 0.0142 DOMD and treated straw ME = 2.24 + 0.0098 DOMD. The composition of diets is presented in Table 1.

For the meat samples, moisture content was determined by the weight loss of 3 g minced meat and LD samples oven dried for 48 h in 104 ^{o}C according to AOAC (2000). Similarly, the ash content was determined by ashing the dried samples at 600 ^{o}C 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 1 g sample following the Kjeldahl method also according to the procedures of AOAC (2000).

3. Results

3.1. Growth and feed intake

Dry matter intake (DMI) from wheat straw was highest ($P<0.05$) for goats receiving treated straw alone (TS) followed by those fed treated straw with hay (TSH) (Table 2). The least ($P<0.05$) straw DMI was recorded in goats fed untreated straws with hay (UTSH). Overall, total DMI and energy intake were higher ($P<0.05$) for goats fed treated straws than for those fed untreated straw. Goats on TSH, however, were more ($P<0.05$) efficient in converting feeds to body tissue as they required 9 kg less feed for one kg body weight gain compared to those on TS (Table 2). Consequently, relatively higher growth rate (10 g/d) and total weight gain (0.8 kg) were recorded in TSH compared to TS dietary groups. On the other hand, daily body weight gain for goats fed TS was nearly two-fold higher than for those fed UTS.

3.2. Killing out characteristics

At slaughter, goats on TS and TSH had comparable empty body weight (EBW) which was about 1.5 kg higher ($P<0.05$) than that of goats in other diets (Table 3). The commercial DP of goats fed TS (48.3) was about 5 % higher compared to those from the rest of the diets. Similarly, goats fed on TS had the highest true DP. Comparable ($P>0.05$) values of commercial and true dressing percentages were recorded in goats fed TSH and UTSH. The proportions of both internal and external offals in the shrunk body weight did not differ with dietary treatments, except for the full gastrointestinal tract (GIT) which tended ($P<0.1$) to differ significantly (Table 4). The proportion of pelvic fat in the EBW varied ($P<0.05$) with dietary treatments (Table 5). Goats fed on TS had 0.4 % more pelvic fat in the EBW compared to those on UTS

Similarly, the proportion of the omental fat in EBW tended ($P<0.1$) to differ with dietary treatments, being higher for goats fed TS than for those offered other diets. The proportion of carcass fat in EBW was higher ($P<0.05$) in goats on treated straw-based diets (TS and TSH) compared to values obtained in other dietary groups (Table 5). The proportion of carcass fat in

EBW for goats fed on TS was 1 % higher than those fed on UTS. When weights of various fat depots were expressed as the percentage of total body fat, only limited variation was noted among animals in different dietary treatments (Table 5).

Goats on treated straw-based diets (TS and TSH) had similar scores for carcass conformation. These scores were two-fold higher compared to those obtained from goats fed UTS (Table 6). The magnitude of conformation scores for carcases from goats on UTSH was between those for goats fed TS and UTS. Fatness scores of goat carcasses from treated straw-based diets were similar and higher than those from other diets (Table 6). Dietary treatment affected ($P<0.05$) hind-limb width but this variation could not be clearly associated with the effect of chemical treatment of straws.

3.3. Carcass composition

Goat carcasses from treated straw-based diets (TS and TSH) had similar weight of muscles which were higher ($P<0.05$) compared to those recorded from other diets (Table 7). Goats fed TS had 0.7 kg (muscles) and 0.32 kg (fat) heavier ($P<0.05$) than the respective tissues from goats fed UTS. The weight of fat as a percentage of carcass weight in goats fed TS, TSH and UTSH were comparable and tended ($0.05<P<0.1$) to be higher than that of goats fed on UTS. The weight of fat as a percentage of carcass weight in goats fed TS, TSH and UTSH were comparable and higher ($P<0.05$) than that of goats fed UTS. Percentages of bone in carcasses, on the other hand, were higher for goats on untreated straw-based diets than for those on treated straw-based diets.

3.4. Physico-chemical properties of carcasses and selected muscles

Temperature measured in carcasses 45 min post-mortem (PM) was similar ($P>0.05$) for goats on TS, TSH and UTS and higher ($P<0.05$) than that of goats fed UTSH (Table 8). Carcasses from goats on UTS contained higher ($P<0.05$) percentage of moisture than those of goats on other dietary groups. Carcasses from goats fed UTS had about 3 % higher moisture content compared to those from TS. Goats on UTS, UTSH and TSH produced carcases with similar but higher ($P<0.05$) percentage of protein than those on TS. On the other hand, goats with access to hay

(TSH and UTSH) produced carcasses with higher proportion of fat than those on diets without hay (TS and UTS). Goats on TSH produced carcasses with 2 % higher fat than those on TS. The proportion of ash in carcasses also differed significantly and was found to be the lowest in carcass of TS fed goats.

Of the muscles sampled, only the *M. gluteobiceps* and *Triceps brachii* varied significantly in cooking loss with dietary treatments (Table 9). *M. gluteobiceps* from goats fed TS produced the least ($P<0.05$) cooking loss. *M. gluteobiceps* from goats fed UTS, on the other hand, had 7 % more ($P<0.05$) cooking loss compared to values obtained from goats fed TS while *M. triceps brachii* from goats on TS produced the highest ($P<0.05$) cooking loss. Warner–Bratzler shear force for the selected muscles did not differ ($P>0.05$) with dietary treatments, except for *M. semitendinosus* and LD (0D) which tended ($P<0.1$) to differ with dietary treatments (Table 10).

4. Discussion

4.1. Feed intake and growth performance

Higher dry matter intake (DMI) for treated straws may be associated with increased rate and extent of fibre digestion in the rumen. The intake in the present study is comparable with that of 42 g per kg $BW^{0.75}$ previously recorded in goats fed sorghum straw treated with 2 % urea solution or wheat straw as a sole diet (Nianogo et al., 1999; El-Meccawi et al., 2009). When expressed as the percentage of body weight, the average daily DMI for goats in the present study is within the range of 2.3 to 2.6 % reported for goats fed untreated wheat straw plus concentrate mixture or sodium hydroxide (5%, w/w) treated straw plus concentrate mixture (Rai and Mudgal, 1996), but below 3.0 to 3.2 % reported by Kabir et al. (2004). Finishing goats are expected to consume DM equivalent to 2 to 5 % of their body weight per day (NRC, 1985).

The two-fold higher gain in body weight for goats on TS compared to those fed UTS can be attributed to increased availability of energy and protein from wheat straws as a result of chemical treatment. This observation indicates the effectiveness of urea and CaO in improving nutritive value of low quality fibrous feeds. Ammoniation of wheat straw has been reported to have positive effects on performance of yearling castrated Spanish goats (Abebe et al., 2004). Grass hay in this study complemented the effects of feeding treated straws.

Dry matter conversion to body weight gain is a useful indicator of quality of feed and the ability of an animal to convert feeds to body tissues (Hoque et al., 2005). Dietary treatments used in the present study affected the feed conversion ratio (FCR). The improved FCR for goats on treated straw-based diets could be a result of the elevated crude protein (CP) and increased digestibility from solubilization of crusting substance as illustrated in other studies (Kitalyi, 1982., Browne et al., 2004). CP content is positively correlated with voluntary feed intake (Fisher, 2002). In the present study, treatment of wheat straw with urea and CaO increased CP by 38 % and the *in vitro* digestibility of DM by 16 %. High FCR observed in goats fed UTS suggest that UTS may not sustain goats in the dry season. Simultaneous feeding of hay with treated straws improved FCR but not for goats fed untreated straws. The FCR values for goats in the present study are similar to those obtained for Sahelian goats (13.5 to 37.8) raised on browses (Sanon et al., 2007)

4.2. Killing out characteristics

Information on yield of non-carcass components of animals is important especially in developing countries as the components are consumed and/or sold and thereby contributing immensely to the consumed dietary protein and increased household income (Moron-Fuenmayor and Clavero, 1999; Sebsibe et al., 2007; Mushi et al 2009b). The weights of individual organs and sub-products, as a proportion of shrunk weight in the present study, however, were not affected by dietary treatments.

The higher EBW recorded for goats fed treated straw-based diets compared to the weights of goats on UTS reflects a relatively lower proportion of the GIT content in the slaughter body weight of goats on TS as reported in other studies (Diaz et al., 2002; Caneque et al., 2003). These results are consistent with increased digestibility and reduced retention time expected in treated compared to untreated straw, which also agrees with the findings of Chowdhury and Khan (2003) who reported that ammonia-treated straw in the rumen disappears faster than untreated straw. The higher commercial and true dressing percentages observed in goats fed TS compared to those on UTS indicates straw treatment increased carcass yield. Increase in carcass yield may result from protein and/or fat deposition. Higher proportion of pelvic and carcass fat in the EBW for goats fed TS compared to those on UTS implies that higher DP in goats fed TS was due to increased fat deposition. In this experiment, urea and lime application resulted in increased potentials of low quality feeds in sustaining goats in the dry season with at least a minimum level of fattening.

Higher values for conformation score values recorded in goats fed treated straw-based diets (TS and TSH) compared to those on other diets reflects higher amount of flesh (meat) relative to bone (Johansen et al., 2006; Mushi et al., 2009a). Similarly, higher scores for carcass fatness observed in goats fed treated straw-based diets is indicative of a higher amount of subcutaneous fat on the carcass (Bohuslavek, 2002). Higher scores for conformation and fatness in goats fed treated straw-based diets relative to those fed other diets can be associated with the higher intakes of energy and protein, which are expected to increase muscle and fat mass.

4.3. Carcass composition

The higher weight of muscles in favour of goats fed treated straw-based diets coincides with higher carcass conformation scores for goats on the same diets. These results show that the EUROP system for carcass conformation scoring provides a good index of the carcass muscle mass. Similarly, the higher weight of carcass fat for goats fed TS versus those fed UTS conforms to the EUROP scores for carcass fatness. Feeding regimen is known to affect carcass composition of farm animals particularly the fat content when there is variation in dietary energy concentration and intake (Gruszecki et al., 2001; Mahgoub et al., 2005; Attah et al., 2006). In the present study, the dietary energy intakes were 4.5, 4.7, 3.6 and 4.2 MJ, ME/d for goats on TS, TSH, UTS and UTSH, respectively. The observed higher percentages of bone in carcasses of goats fed untreated straw-based diets against those on treated straw-based diets is attributable to the thinness of carcasses of the former group. The contribution of bones in carcass weight is likely to become significantly high in thinner carcasses. This tendency is often a result of loss in weights of fat and muscle tissues as bones are least affected by dietary treatments (Kamalzadeh et al., 1998; Hango et al., 2007; Mushi et al., 2009a).

4.4. Physico-chemical properties of carcasses and selected muscles

The higher moisture content recorded in carcasses from goats fed UTS could be associated with their lower fat content. On the other hand, the higher proportion of fat in goats with access to grass hay compared to those without, reflects a higher supply of energy obtained from hay that superseded the effects of straw treatment. Despite the variation in carcass fatness with dietary treatment, there was no difference in pH decline among animals in different diets. These results suggest that the difference in energy intake has to be large enough to affect the rate and extent of pH decline. High energy diets are known to protect animals from potentially glycogen-depleting stressors (Immonen et al., 2000; Lanza et al., 2003). However, many other factors including genotype, sex of an animal, pre-slaughter stress and chilling regimen affect post-mortem pH decline (Scerra et al., 2001; Dhanda et al., 2003; Botha et al., 2007). Overall, the higher ultimate pH recorded in goat carcasses in the present study in spite of the less stressful slaughter condition, is subject to further investigations that include testing for effects of breed and /or straw-based diets on ultimate pH of goat carcasses.

Low cooking loss for *M. glueobiceps* from goats fed TS may be related to high ultimate pH recorded in goat muscles under the same dietary treatment. High pH results in increased water binding capacity (low drip loss and cooking loss) due to higher net charges and greater space between myofilaments (Gregory, 2003; Huff-Lonergan and Lonergan, 2005). In reference to the role of chemical treatment in increasing energy availability in roughages, these results are unexpected. Increased energy intake leads to increase glycogen storage, which serves as the raw material for glycolysis (Maltin et al., 2003; Kadim et al., 2006), and glycolysis is responsible for the lowered ultimate pH. The observation that some muscles showed specific response to straw treatment with respect to cooking loss is not clearly understood, and is subject to further investigation. However, differences in cooking loss could be attributed to the differences in intramuscular fat and the activity of glycolytic enzymes, which determine the rate of lactic acid production. Lack of significant effect of diet on Warner–Bratzler shear force for the selected muscles observed in the present study indicates lack of significant difference in intramuscular fat (marbling) attributable to diets. Increased intramuscular fat dilutes the amount of muscle fibres contained per unit area of muscle, consequently making highly marbled muscles more tender

(Wood et al., 1999; Priolo et al., 2002). These results indicate that the difference in energy intake for goats in different diets was not large enough to cause significant differences in marbling.

Conclusion

Chemical treatment of straws increased dry matter intake, daily body weight gain, dressing percentage, carcass weight as well as carcass muscle and fat weight. Simultaneous feeding of treated wheat straw with grass hay complemented the effects of feeding treated straw in promoting the production performance of goats. Straw treatment, however, had limited effect on the quality of goat meat. Results under this experiment indicate that not only does the use of low quality roughage with chemical treatment sustain goat production in the dry season, but also supports at least a minimum level of fattening.

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Table 1

Chemical composition of the experimental feeds

Chemical composition	Feedstuff			
	Concentrate	TS	UTS	Hay
Dry matter (g/kg)	910	580	890	900
Crude protein (g/kg DM)	173	55	40	39
Ether extract (g/kg DM)	134	12	16	12
Ash (g/kg DM)	52	98	106	87
Neutral detergent fibre (g/kg DM)	391	732	756	737
Acid detergent fibre (g/kg DM)	223	484	448	429
Crude fibre (g/kg DM)	146	334	340	353
In vitro dry matter digestibility (g/kg DM)	546	590	360	396
In vitro organic matter digestibility(g/kg DM)	546	570	360	310
Nitrogen free extract	405	81	388	409
Metabolisable energy (MJ/kg DM)	12.6	7.83	5.64	6.08

Table 2

Least squares means ±SE for intake and growth performance of castrated Small East African goats fed straw-based diets

Variable	Diets				SE	Significance
	UTS	TS	UTSH	TSH		
Intake (g DM /d)						
Straw	105.2^{c}	220.1^{a}	75.2^{d}	112.9^{bc}	8.6	***
Hay	-	-	102^{b}	118.4^{a}	3.6	***
Conc.	210	219.0	210.3	211	1.2	-
Total	314.6^{b}	438.1^{a}	389.2^{c}	442.6^{a}	9.9	***
Intake (% BW)	2.33^{c}	2.98^{a}	2.71^{b}	2.87^{ab}	0.1	***
Intake g/kgW$^{.75}$/d	30.9^{b}	41.7^{a}	37.4^{c}	41.4^{a}	0.9	***
Energy intake (MJ, ME/d)	3.30^{c}	4.55^{a}	3.81^{b}	4.33^{a}	0.0	***
Daily gain (g/d)	8.1^{c}	16.9^{b}	13.6^{b}	26.8^{a}	2.5	***
Total gain (kg)	0.68^{d}	1.42^{bc}	1.14^{cd}	2.25^{a}	0.2	***
FCR (kg DMI/kg gain)	38.2^{a}	25.4^{c}	29.5^{ab}	16.3^{d}	11.2	*
BCS (1-5)	2.7	3.0	2.8	3.2	1.5	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05) Significance: NS, not significant; *****, *P* <0.05; ******, *P* <0.01; *******, *P* <0.001; SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay; FCR feed consumed (kg) for 1 kg body weight gain; BCS, body condition score.

Table 3

Least squares means ±SE for final body weight (FBW), slaughter weight (SBW), fasting loss, empty BW, gut fill and dressing percentage of castrated Small East African goats fed straw-based diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Significance
FBW (kg)	14.3^{b}	15.2^{a}	14.9^{ab}	15.5^{a}	0.2	**
SBW (kg)	12.9^{b}	13.8^{b}	13.6^{b}	14.8^{a}	0.2	**
EBW (kg)	10.5^{b}	12.1^{a}	11.1^{b}	12.5^{a}	0.3	*
Fasting loss (%)	5.5	5.7	5.6	4.5	0.5	NS
Gut fill % LW	18.6	14.4	17.3	15.3	1.9	NS
Gut fill % EBW	24.8	18.9	22.6	19.1	1.9	NS
Commercial dressing %	42.03^{c}	48.33^{a}	43.33^{bc}	43.30^{c}	1.2	**
True dressing %	47.78^{bc}	49.90^{a}	47.28^{c}	46.88^{c}	1.2	***

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <0.05; **, *P* <0.01;***, *P* <0.001; and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay.

Table 4

Least squares means ±SE for individual organs as the proportion (%) of shrunk weight of castrated Small East African goats fed straw-based diets

	Diets					
Item	UTS	TS	UTSH	TSH	SE	Significance
Blood	4.02	4.12	4.05	4.18	0.2	NS
Spleen	0.14	0.15	0.45	0.16	0.0	NS
Liver	1.60	1.56	1.65	1.78	0.1	NS
Heart	0.51	0.49	0.56	0.50	0.0	NS
Kidneys	0.32	0.34	0.28	0.32	0.0	NS
GI tract (empty)	7.97	7.62	8.40	7.77	0.4	NS
GI tract (full)	26.3	23.6	28.0	20.2	1.9	†
Lung, trachea and diaphram	1.43	1.39	1.43	1.4	0.1	NS
Head, skin and feet	16.08	16.81	17.40	17.53	0.7	NS
Total non carcass yield	33.08	32.49	33.87	33.66	1.1	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <0.05; **, *P* <0.01;***, *P* <0.001; †**,** 0.05<*P* <0.1 and SE, standard error of mean. Shrunk weight, live weight of animals after 16 hours of fasting; UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay.

Table 5

Least squares means ± standard error for fat distribution as proportion of empty body weight of castrated Small East African goats fed straw-based diets

	Diets					
Item	UTS	TS	UTSH	TSH	SE	Significance
% Empty BW						
Omental fat	1.41	2.05	1.55	1.38	0.2	†
Mesenteric fat	0.52	0.63	0.45	1.56	0.5	NS
Pelvic fat	0.52^{c}	0.91^{a}	0.77^{ab}	0.61^{bc}	0.1	***
Heart fat	0.19	0.19	0.18	0.21	0.0	NS
Kidney fat	0.56	0.73	0.61	0.57	0.0	NS
Total non-carcass fat	3.19	4.52	3.56	4.33	0.6	NS
Carcass fat	2.66^{b}	3.65^{a}	2.95^{b}	3.14^{ab}	0.2	*
% Total body fat						
Omental fat	22.23	25.07	23.27	20.21	2.5	NS
Mesenteric fat	8.44	7.54	7.25	7.84	1.4	NS
Pelvic fat	9.03	11.06	12.14	8.76	1.2	NS
Heart fat	3.52^{a}	2.32^{c}	2.80^{b}	2.79^{bc}	0.4	***
Kidney fat	9.47	8.93	9.44	8.01	0.8	NS
Total non-carcass fat	52.69	54.95	54.92	55.69	3.1	NS
Carcass fat	47.30	45.05	45.07	44.31	3.2	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *****, *P* <0.05; ******, *P* <0.01; *******, *P* <0.001; **†,** 0.05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay.

Table 6

Least squares means ±SE of hot carcass weight (HCW), EUROP classification and linear carcass measurements of castrated Small East African goats fed straw-based diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Significance
HCW (kg)	5.4^{b}	6.2^{a}	5.8^{ab}	6.6^{a}	0.3	*
Score (l-15) conformation	3.3^{c}	5.9^{a}	5.0^{ab}	6.3^{a}	0.5	**
Score (1-15) Fatness	3.3^{c}	5.1^{ab}	3.9^{bc}	6.9^{a}	0.9	*
Carcass measurements (cm)						
Carcass length	45.4	46.0	44.6	46.5	3.1	NS
Chest depth	20.5	21.1	18.7	20.8	0.9	NS
Hind- limb length	31.4	32.7	32.7	32.3	0.5	NS
Hind-limb width	55.4^{a}	54.1^{b}	54.3^{b}	56.0^{a}	0.6	*
Compactness index (g/cm)	108	124	133	128	34	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <0.05; **, *P* <0.01;***, *P* <0.001; †, 0.05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay.

Table 7

Least-squares means ± SE for percentage and ratios of carcass tissues from castrated Small East African goats fed straw-based diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Significance
Muscle (kg)	3.14^{b}	3.84^{a}	3.48^{ab}	3.78^{a}	0.2	*
% carcass wt	58.14	61.13	60.61	54.78	1.9	NS
% SLW	24.34	27.77	25.56	24.44	0.6	†
Fat (kg)	0.58^{bc}	0.90^{a}	0.68^{ab}	0.80^{ab}	0.0	**
% carcass wt	11.51^{b}	14.73^{a}	12.38^{ab}	13.47^{ab}	0.8	†
% SLW	4.14^{b}	6.19^{a}	5.01^{b}	5.27^{ab}	0.4	**
Bone (kg)	1.30	1.36	1.30	1.35	0.0	NS
% carcass wt	26.13^{a}	21.17^{b}	22.01^{ab}	21.16^{b}	1.6	**
% SLW	10.85	9.80	9.55	9.05	0.4	NS
Muscle: fat	5.64	4.25	5.12	4.70	1.4	NS
Muscle: bone	2.40	2.85	2.68	2.69	0.2	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <.05; **, *P* <.01;***, *P* <.001; †, .05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay; SLW, slaughter weight.

Table 8

Least-squares means ± SE for pH, temperature and chemical composition of minced meat from castrated Small East African goats fed straw-based diets

	Diets					
Variable	UTS	TS	UTSH	TSH	SE	Significance
pH 45 min	6.49	6.45	6.57	6.53	0.1	NS
pH 24 h	6.41	6.16	5.59	6.46	0.3	NS
Temp, ^{o}C (45 min)	33.4^{a}	33.2^{a}	31.1^{b}	34.4^{a}	0.7	*
Temp, ^{o}C (24 h)	3.6	3.9	3.9	4.1	0.6	NS
Moisture (%)	67.15^{a}	63.9^{b}	64.1^{b}	62.8^{b}	1.0	*
Protein (%)	20.1^{a}	18.2^{b}	19.4^{a}	18.9^{a}	0.4	*
Fat (%)	5.7^{c}	8.1^{b}	8.5^{ab}	10.2^{a}	0.5	*
Ash (%)	5.7^{a}	4.4^{b}	4.6^{b}	4.9^{ab}	0.3	*

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *, *P* <.05; **, *P* <.01;***, *P* <.001; †, .05<*P* <0.1 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay and TSH, treated straw with hay

Table 9

Least Squares means ± SE for the cooking loss (%) of muscles from castrated Small East African goats fed straw-based diets

Muscle	Diets				SE	Significance
	UTS	TS	UTSH	TSH		
LD (0d)	26.3	27.3	27.5	28.3	1.3	NS
LD (6d)	24.6	25.4	25.9	24.2	1.6	NS
LD (9d)	23.6	26.2	21.9	24.3	1.5	NS
Gluteobiceps	30.2 ^{a}	23.7 ^{c}	28.3 ^{ab}	28.0 ^{ab}	1.3	*
Infraspinatus	29.1	28.2	25.9	27.8	1.4	NS
Psoas major	25.4	28.1	21.4	23.8	1.3	NS
Rectus abdominis	15.4	15.0	11.1	16.0	1.4	NS
Semimembranosus	33.7	33.2	30.2	28.6	1.3	NS
Semitendinosus	26.1	27.7	26.4	23.4	1.4	NS
Supraspinatus	39.4	33.0	32.1	35.5	1.3	NS
Triceps brachii	28.7^{c}	36.8^{a}	28.9^{bc}	26.6^{c}	1.3	*
Vastus lateralis	28.3	30.2	29.3	29.2	1.3	NS

^{abc}Least squares means with a common superscript in the same row are not significantly different (P>0.05). Significance: NS, not significant; *****, *P* <.05; ******, *P* <.01; *******, *P* <.001 and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay. LD (0d), LD (6d) and LD (9d); *M. longissimus dorsi* aged for 0, 6 and 9 days, respectively.

Table 10

Least Squares means ± SE for Warner–Bratzler shear force values (N) of muscles from castrated Small East African goats fed straw-based diets

	Diets					
Muscle	UTS	TS	UTSH	TSH	SE	Significance
LD (0 d)	20.7	23.8	16.5	24.4	1.6	†
LD (6 d)	22.9	20.4	20.0	32.6	2.2	NS
LD (9 d)	20.8	19.5	19.9	18.6	1.9	NS
Gluteobiceps	31.1	34.6	27.4	46.1	1.7	NS
Infraspinatus	21.2	25.0	20.1	24.1	1.8	NS
Psoas major	17.5	16.1	16.4	16.5	1.7	NS
Semimembranosus	28.8	28.3	29.7	49.2	1.8	NS
Semitendinosus	27.1	21.3	24.0	22.1	1.8	†
Supraspinatus	35.8	29.9	28.6	32.8	1.7	NS
Triceps brachii	29.1	25.2	25.1	27.9	1.7	NS
Vastus lateralis	29.5	25.8	22.8	36.4	1.8	NS

Significance: NS, not significant; *****, $P < .05$; ******, $P < .01$; *******, $P < .001$; †, $.05 < P < 0.1$ and SE, standard error of mean. UTS, untreated straw; TS, treated straw; UTSH, untreated straw with hay; TSH, treated straw with hay. LD (0d), LD (6d) and LD (9d); *M. longissimus dorsi* aged for 0, 6 and 9 days, respectively.

Paper V

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 month 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.

Key words: feedlot; goats; carcass characteristics; chevon quality

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).

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 x 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 meat, 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 tones/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 month 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, 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 ^{o}C for 24 h before ultimate pH (pHu) and temperature were recorded.

After 24 h of refrigeration at 0 ^{o}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^{o}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 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 d 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 ^{o}C overnight before being frozen at -25 ^{o}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 ^{o}C.

The remaining part of the left half-carcasses were chilled at 0 ^{o}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 ten muscles were thawed at 4 ^{o}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 ^{o}C for a total of 50 minutes. The muscles were then kept at room temperature for 2 h and stored in a refrigerator at 4 ^{o}C for 12 h. Muscles were then blotted dry with paper towel and weighed (W2). Cooking loss was calculated as ((W1 – W2)/ W1) x 100. Six to ten cubes measuring 1 x 1 x 1 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 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 six to ten 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 ^{o}C oven according to AOAC (2000). Ash content was determined by ashing the dried samples in a 600 ^{o}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 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 x muscle type interaction was not significant ($P>0.05$); hence only 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/d, which was 230 g and 90 g higher than that of goats with 33% (T33) and 66% (T66) access to *ad libitum* concentrate allowance, 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).

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 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 minutes post-mortem (PM) was not significantly affected by concentrate supplementation (Fig. 1). After 45 minutes, 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 minutes PM did not differ between treatments (Fig. 2), while at 6 h PM, carcass temperature for non-supplemented goats was 3 ^{o}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 nine 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.

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 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 & 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 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 x Norwegian Dairy Breed) under similar feeding regime (Mushi *et al.*, 2009). Small East African goats normally put on weights 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 two year or more before slaughter. Feedlot finishing of goats, when properly undertaken, should reduce this period to less than two 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 un-supplemented 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 life time 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 un-supplemented goats. Fat content in minced meat for concentrate-supplemented goats was above the threshold (10-15%) below which consumers find 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 ^{o}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 ^{o}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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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

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

	Treatment			
Variable	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/ d)	-	150.0 ± 11.0^{c}	300.0 ± 11.0^{b}	396.7 ± 11.0^{a}
Hay, as fed (g/ d)	405.0 ± 25^{a}	306.0 ± 27.0^{b}	193.3 ± 20.0^{c}	120.0 ± 25.0^{d}
Total dry matter (TDMI, g/d)	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/d)	3.1 ± 0.2^{c}	4.4 ± 0.2^{b}	5.0 ± 0.2^{ab}	5.6 ± 0.2^{a}
Total crude protein (g/ d)	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.

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

	Treatment			
Variable	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 x 100/ EBW); AD is abattoir dressing (CCW x 100/ SLW); CD is commercial dressing (HCW x 100/ SLW).

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

	Treatment			
Variable	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.

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, six and 9 days respectively. [a,b,c,d,e,f,g]Lsmeans 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.