Preliminary Study on Slaughter and Meat Quality Characteristics of Selected Strains of Tanzania Shorthorn Zebu

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Abstract

A study was carried out to assess slaughter characteristics and meat quality of five strains of Tanzanian shorthorn zebu (TSZ): Singida white (SW), Gogo (GG), Iringa red (IR), Maasai (MS) and Mbulu (MB). A total of 50 animals (25 entire bulls and 25 castrates) aged 3-4 years were sampled from five slaughter facilities in Tanzania. Slaughter traits, physicochemical properties and the response of beef from the five strains to post-mortem ageing were assessed. IR strain had the highest (P<0.05) values for estimated slaughter weight (ESW), empty body weight (EBW), hot carcass weight (HCW) and linear carcass measurements while MB strain had the lowest values for these parameters. IR strain was 48, 64, 25 kg heavier than MB in terms of ESW, EBW and HCW, respectively. MB strain had the least (P<0.05) proportion of bone in the carcass with about 3% unit less than the rest of the strains. SW strain had the highest (P<0.05) ultimate pH (5.9) while GG had the lowest (5.6). Meat from the GG strain had higher (P<0.05) values for relative redness (15.9) and yellowness (9.8) than that of other strains. Meat from the GG strain had the highest colour stability with only 0.5 units decrease in a value even after 14 days of ageing. Meat from SW and GG strains became sufficiently tender (<55 N) just after 7 days of ageing whereas that from IR and MB became only moderately tender (55 – 75 N) even after 14 days of ageing. It is concluded that beef from GG strain is the most suitable for processing into high quality meat products owing to its high relative redness (a*), colour stability, tenderness and low pHu.*

Keywords: Tanzania Shorthorn Zebu, strains, slaughter traits, meat quality, meat ageing

Introduction

Tanzania has 33.4 million cattle, 98% of which are indigenous breeds broadly categorised as Tanzania Shorthorn Zebu (TSZ). In addition to cattle population, Tanzania has 21.3 million goats, 5.6 million sheep, 2.1 million pigs, 38.7 million local chicken and 44.5 million improved chicken (MLDF, 2020). Despite these resources, Tanzania has remained a net importer of quality beef (Kamugisha *et al.,* 2017). For instance, the amount of beef produced in 2018 was 471,692 tons, with 711 tons (80% of high quality beef consumed in the country) of beef imported mainly to meet demands for the niche market. Although TSZ contributes about 94% of the total production of red meat and meat products in the country (UNIDO, 2012), consumers in niche markets argue that beef from TSZ does not meet the requirements for high quality beef with respect to tenderness and size of standard meat cuts (Kamugisha *et al.,* 2017). These markets, among others, require that a T-bone steak be at least 250g and must be tender, the qualities that beef from TSZ commonly fall short of (Kamugisha *et al.,* 2017). This quality gap drives traders to import beef for the niche market. Supplying high quality beef from the local source has the potential to improve the livelihoods of more than 50% of the country's population that depend on livestock (URT, 2017).

Few studies have been conducted to determine the responsiveness of indigenous cattle breeds to improved feeding (feedlot finishing) in terms of shortening time to slaughter, improving meat yield and quality

(Asimwe *et al.,* 2015; Mwilawa *et al.,* 2010). The TSZ is a diverse group comprised of twelve different strains namely Mkalama, Gogo, Singida white, Chagga, Pare, Fipa, Iringa red, Mbulu, Maasai, Tarime, Sukuma and Zanzibar (Msalya *et al.,* 2017). Attempts have been made to screen some strains of TSZ for the intrinsic difference in milk production and disease resistance but not for beef production (Laisser *et al.,* 2014; Mwambene *et al.,* 2012). Msalya *et al.* (2017) conducted a study to determine genetic structure and signatures of selection in three strains of TSZ and observed genetic relatedness and diversity among the three strains. These strain differences represent a valuable genetic resource for livestock keepers to use in structured breeding and feeding systems to achieve optimal resource utilisation by using the right strain in the right production environment. Knowledge on the intrinsic differences among strains of indigenous breeds could enable producers in different production systems to select and utilize strains that are suitable to a specific management system to produce high quality beef economically (Shabtay, 2015). However, no study has been carried out to systematically characterise different strains of TSZ based on their potential for high quality beef production. There is therefore a need to identify suitable strains of TSZ and promote them as high quality and recognizable brands in the domestic, regional and international market. The present study is a preliminary evaluation of the five most populous strains of TSZ for their intrinsic potential to produce high quality meat.

Materials and methods

Study location

The study was carried out in five districts namely Singida (-4.86775, 34.58375), Bahi (-5.95255, 35.31702), Kilolo (-7.98244, 35.82979), Monduli (-3.31607, 36.44251) and Hanan'g (-4.51616, 35.38961) in Singida, Dodoma, Iringa, Arusha and Manyara regions, respectively. These areas were selected due to the predominance of the targeted strains, which were Singida white (SW), Gogo (GG), Iringa red (IR), Maasai (MS) and Mbulu (MB), respectively. Data were collected in slaughterhouses/slabs from March to July 2019. During data collection the status of rainfall was as shown in Table 1. Overall, the body condition score for experimental animals ranged from average to good.

Table 1: Precipitation status in the study area and body condition scores of experimental animals

Region	Rainy season (2018/2019)	Data collection month (2019)	Body condition score
Singida	November to January	March	Good
Manyara	December to January	April	Good
Arusha	April to June	May	Average
Dodoma	December to March	June	Average
Iringa	November to April	July	Good

Data collection

Sampling framework

During ante mortem inspection, experimental animals were identified and earmarked for inclusion in the sampling framework. Cattle used in the study were pure TSZ originating from the five selected Districts and reared on natural pasture without supplementary feeding. Some of the common and detailed features of the target strains were confirmed from the literature. In addition, the native people were inquired on the origin of the animals so that only those indigenous to the areas could be sampled.

A total of 50 animals (25 entire bulls and 25 castrates), 10 animals (5 entire bulls and 5 castrates) from each strain were sampled. Purposive sampling was used to select animals of target strains in the age category of approximately 3-4 years. The age of the earmarked animal was confirmed by the dentition method whereby 4 permanent incisors (pi) was equated to 2.5 years of age, 6pi to be equivalent to 3 years of age and 8pi (corner teeth replaced) to be equivalent to 4 years of age.

Estimation of slaughter weight

A weigh band was used to measure heart girth (in cm) by placing a tape directly behind the front legs and base of the hump. The regression equation developed by Kashoma *et al.* (2011) using the population of Tanzania Shorthorn Zebu was used to adjust weight estimates by the weigh band: Y = 4.55 X – 409, where Y = live weight (kg), X = heart girth (cm).

Slaughter procedure

Following overnight starvation, animals were slaughtered at the slaughter facilities available. Most of these slaughter facilities were able to slaughter an average of six animals per day except for the one in Singida municipality which could slaughter 30 - 40 animals per day. Using a knife, the head was removed at the antlanto-occipital joint. The forefeet were removed at the carpal-metacarpal joint and hind feet were removed at the tarsal-metatarsal joint. The dressed carcass was divided into two halves and hung on iron bars.

Killing out characteristics

Empty body weight (EBW) was derived from the difference between slaughter weight and gut fill. Gut fill was derived from the difference between the weight of a full and an empty digestive tract recorded within 45 to 60 minutes post-mortem (PM). Dressing percentage was derived from expressing the hot carcass weight as a percentage of slaughter weight.

pH, ribeye area and linear carcass measurements

The right side of a dressed carcass was quartered between the 12th and 13th rib to allow for measurement of pH and the ribeye area (REA), 45 to 60 minutes post-mortem. The pH was measured by inserting a calibrated electrode (Metler Toledo) of a portable pH-meter (Nick Portames 910, Germany) in the geometric centre of the Longissimus thoracis muscle. The area of the Longissimus thoracis muscle between the 12th and 13th rib, also known as rib eye area (REA), was sketched on translucent paper using a permanent marker. By using a Zero Setting Compensating Planimeter the REA in cm^2 was estimated. On the left side of a carcass, linear carcass measurements namely hind leg length, hind leg circumference and carcass length were measured in cm using a tailoring tape.

Carcass composition

Carcass components namely muscle, fat, bone and dissection loss (including fascia) were estimated from dissecting the 6th rib sample joint (Serra *et al.,* 2004) of the left side of each carcass. A total of 50 samples of the 6th rib joint were excised, weighed and dissected into bone, muscle and fat. By using a sensitive weighing balance (Portable electronic weigh-hang), each component was weighed and expressed as a percentage of the whole joint weight.

Physicochemical properties and response to ageing

The Longissimus thoracis (LT) muscle from the right side of each animal was excised from the 5th to 12th rib after 1.5 to 2 hours of slaughter. The LT muscle samples were weighed and packed in Polyvinyl bags and refrigerated at 4°C for 24 hours during which the second pH reading was recorded and considered as ultimate pH (pHu). Thereafter, the samples were deep-frozen until when they were transported to the laboratory at Sokoine University of Agriculture for physicochemical analyses (drip loss - DL, cooking loss - CL, pH, colour, tenderness and chemical composition).

During analysis, the LT muscle samples were removed from the deep freezer, thawed under refrigeration at 1°C - 4°C overnight and cut into seven pieces for DL and CL for day zero, day 7 and day 14 and proximate analysis. The labelling was DL day zero, CL day zero, DL day 7, CL day 7, DL day 14, CL day 14 and proximate analysis. The samples labelled day zero were used for immediate analysis of pH, colour, drip loss, water holding capacity and tenderness. The samples labelled day 7 and 14 were used for assessing the response of beef from different strains to post mortem ageing in terms of pH, colour, DL, CL and Warner-Bratzler shear force (WBSF). Finally, the proximate analysis was carried out once for all samples.

Meat colour was measured at thaw (zero-day), at 7 and 14 days of ageing on the fresh-cut surface of LT muscle using Minolta chromameter CR-400 (Konica Minolta Inc. made in Japan) based on CIE L* a*b* system, where L* – relative lightness; a* – relative redness; b* – relative yellowness.

Cooking loss and Warner-Bratzler shear force

The samples were thawed at 4oC overnight and prepared for cooking loss (CL) and Warner-Bratzler shear force (WBSF) determination. The LT muscle was cut into pieces of approximately 50-160 grams depending on the size of the muscle, labelled and placed in a plastic bag. For immediate determination of CL and WBSF at zero-day, the samples labelled day zero were weighed and vacuum-packed before being cooked.

For the determination of the response to post-mortem ageing, the samples were stored in a refrigerator at 4°C for 7 or 14 days of ageing. After each ageing time, the samples were weighed (W1), labelled and vacuum-packed. The samples were cooked in a thermostatically controlled water bath at 70°C for 1 hour, after which they were removed from the water bath and cooled in running cold water for 2 hours. The samples were then removed from plastic bags, dried with a paper towel and weighed again (W2), the cooking loss was calculated as the difference between W1 and W2.

For determination of tenderness, the same samples cooked for cooking loss assessment were cut into 1 cm x 1 cm x 1 cm cubes parallel to the direction of the muscle fibres. Warner-Bratzler shearing device (Zwick/Roell, Z2.5, Germany) instrument was used to determine the maximum force (N) required to shear 1cm3 meat blocks perpendicular to the grains. The device was set with 1 kN load cell with a crosshead speed of 150 mm/min to determine tenderness.

Drip loss determination

A 21 to 71g sample of LT muscle from each of the experimental animals was weighed (W1), tied in a plastic thread and hung in an inflated plastic bag. After a storage period of 24 hours at 4°C, the sample was weighed again (W2) and the drip loss (DL) was calculated as the difference between W1 and W2.

Determination of chemical composition of the carcasses

Forty-eight samples (one sample for MB and one for SW strain could not be located) of LT muscle designated for proximate analysis were frozen and then minced in a manual mincing machine until a homogeneous mixture was obtained. Determination of dry matter (DM), ash, crude protein (CP) and ether extract (EE) contents was done according to the proximate analysis scheme (AOAC, 2005)

Statistical analysis

Data for slaughter traits as well as meat quality characteristics including pH, colour, drip loss, cooking loss and tenderness were analysed using the General Linear Model procedure in R-software (RStudio Team, 2020). The fixed variables for slaughter traits were strain and sex type whereas strain, sex type, ageing time and their interactions were the fixed variables for meat quality characteristics. Effects of fixed variables on dependent variables were tested using the multcomp" package in R-software. Effects of storage time on meat quality was analysed as repeated measures ANOVA. Multivariate analysis using Principal Component Analysis (PCA) showed no correlation among studied characteristics.

Results

Slaughter traits

The overall means for estimated slaughter weight (ESW), empty body weight (EBW), hot carcass weight (HCW) and dressing percentage (DP) were 201.4kg, 164.5kg, 101.4kg and 50.6%, respectively (Table 2). Iringa red (IR) strain was the heaviest ($P<0.05$) while Mbulu (MB) strain was the lightest. The IR strain was 56 kg, 47 kg, 25 kg heavier than MB in terms of ESW, EBW and HCW but the two strains were similar in DP. Maasai (MS) strain had the least (P<0.05) DP of all the strains. Sex type did not affect (P>0.05) any of the slaughter characteristics.

IR strain had the largest (P<0.05) heart girth circumference (HGC), hindleg length (HLL) and hot carcass length (HCL) whereas MB strain had the smallest hind leg circumference (HLC), HGC and HLL (Table 3). REA tended (P<0.1) to be larger in SW and MS than in other strains. Again, sex had no significant (P>0.01) effects on carcass measurements.

Table 2: Least squares means for heart girth, estimated slaughter weight, empty body weight, hot carcass weight and dressing percentage for different strains of TSZ

Factor	Slaughter traits				
	n	ESW (kg)	EBW (kg)	HCW (kg)	DP (%)
Strain					
GG	10	207.8^{ab}	166.6^{bc}	105.4^{ab}	51.3^{a}
IR	10	230.1^{a}	196.4^{a}	117.1^{a}	51.9^{a}
MB	10	174.6^{b}	149.6^{b}	92.2^{b}	51.9^{a}
MS	10	206.0^{ab}	185.0^{ab}	96.4^{ab}	47.3^{b}
SW	10	188.3^{ab}	159.5^{ab}	95.9^{ab}	51.0^{a}
SE		11.5	10.6	5.8	0.9
P-Value		0.02	0.03	0.03	0.003
Sex					
Entire bulls	25	205.7	175.2	103.7	51.0
Castrates	25	197.0	167.6	99.1	50.5
SE		7.9	7.3	3.9	0.7
P-Value		0.40	0.44	0.37	0.80
Strains*Sex					
P-Value		0.47	0.51	0.36	0.07

[abc]Means with different superscripts along the column are significantly different (P<0.05), SE=Standard error, TSZ=Tanzania shorthorn zebu, HG = Heart girth, ESW = Estimated slaughter weight, EBW = Empty body weight, HCW=Hot carcass weight, DP=Dressing percentage, CV = Coefficient of variation. GG= Gogo, IR =Iringa red, MB=Mbulu, MS =Maasai, SW = Singida White.

Carcass composition

The overall means for the proportion of muscle, fat and bone in carcasses of the five TSZ strains were 63.5, 8.1 and 20.7%, respectively (Table 4). Dissection loss was on average 7.6%. Strains differed (P<0.05) in bone tissue proportion but not in muscle and fat tissue proportions. MB strain had the least proportion of bone in the carcass with about 3% unit less than the rest of the strains, which were comparable in this parameter. On the other hand, entire males had about 2% unit higher (P<0.05) proportion of muscle tissue and a 2% unit lower proportion of fat tissue than castrates.

Meat chemical composition

The SW strain had about 3% unit higher dry matter (DM) content than the rest of the strains, which were comparable in this parameter (Table 5). On the other hand, the MB strain had the highest (P<0.05) crude protein (CP) values. Castrates had about 2% unit higher DM and ether extract (EE) than entire bulls. The interaction between strain and sex was significant (P<0.05) for DM, ash and EE contents. The DM, ash and EE contents for castrated SW strain was higher than that of the entire bull. Castrate and entire bulls of other strains did not differ in these parameters.

Meat pH

Despite the similarity of all strains in pH

Table 3: Least squares means for linear carcass measurements and rib eye area by strain and sex of animals used

Factors		Carcass measurements				
	n	HGC	HLL	HLC	CL	REA
Strain						
GG	10	139.5^{ab}	62.0^{ab}	78.1^{a}	97.2^{b}	46.7
IR	10	144.4^{a}	63.3^{a}	78.3^{a}	111.1^{a}	45.4
MB	10	132.2^{b}	58.3^{b}	71.9^{b}	103.4^{ab}	45.5
MS	10	139.1^{ab}	61.0^{ab}	77.4^{ab}	99.2^{b}	51.0
SW	10	135.2^{ab}	61.6^{ab}	74.1^{ab}	103.7^{ab}	51.1
SE		2.5	1.1	1.4	2.6	1.9
P-Value		0.02	0.048	0.007	0.006	0.071
Sex						
Entire bulls	25	139.0	61.0	75.3	101.4	46.8
Castrates	25	137.1	61.5	76.6	104.5	49.1
SE		1.7	0.8	1.0	1.8	1.2
P-Value		0.403	0.640	0.288	0.187	0.182
Strain*Sex						
P-Value		0.468	0.549	0.296	0.633	0.486

Means with different letter superscripts are significantly different at P<0.05, SE=Standard error, HGC=Heart girth circumference, HLL=Hind leg length, HLC=Hind leg circumference, HCL-Hot carcass length, REA – Rib eye area, GG= Gogo, IR =Iringa red, MB=Mbulu, MS =Maasai, SW = Singida White.

at slaughter, SW strain had the highest (P<0.05) ultimate pH (pHu, recorded 24 hours post-mortem) while GG had the least pHu (Table 6). At thaw, MS strain had the highest value of pH (5.8) whereas IR had the least (5.5). Sex affected only the pH at thaw, which was slightly higher (P<0.01) in entire bulls than in castrates.

Meat colour

Meat from the GG strain had a slightly higher (P<0.05) value for redness (15.9) and yellowness (9.8) than that of other strains (Table 6). Castrates produced meat with higher values for lightness (L*) than intact bulls. Period of ageing affected all colour variables with lightness (L*) increasing, redness (a*) decreasing and yellowness increasing before decreasing slightly. The interaction between strain and ageing time existed for redness (Figure 1). GG strain displayed higher colour stability in redness with the time of ageing, with only 0.5 units decrease in a* value even after 14 days of ageing. On the other hand, beef from SW had very unstable colour, with 6 units decrease in a* value from day 0 to day 14 of ageing (Figure 1A).

Drip loss, cooking loss and Warner-Bratzler shear force

Meat from different strains did not differ in drip loss (DL) and cooking loss (CL) but in Warner-Bratzler shear force (WBSF) (Table 7). IR strain produced the toughest meat (requiring 110 N to shear) while SW strain produced the most tender meat requiring 60 N to shear shortly after slaughter. Similarly, sex type did not differ in DL and CL but in WBSF (Table 7). Castrates had lower WBSF values compared to entire bulls. On the other hand, the period of ageing affected (P<0.001) all three parameters (Table 7). As the ageing period increased, DL, CL and WBSF decreased. Beef aged for 14 days had 3.5 and 3.8 percent unit less DL and CL, respectively, compared to day 0 beef. The average values for WBSF recorded after 7 days was below 60 N while that recorded after 14 days of ageing was below 55 N. Significant interaction between strain and ageing period was observed on DL and WBSF (Fig. 1). MB strain lost less water (about 2% units) as DL from day 0 to day 14 (from 5.4% to 3.3% DL) while other strains lost a slightly higher amount of water (Fig. 1B). The decrease in WBSF value was sharper in the toughest beef from IR (110 to 57 N) than in the most tender beef from SW (60 - 48 N) strain, as the ageing time advanced from day zero to day 14 (Fig. 1C). Meat from SW and GG strains attained WBSF below 55 N just after 7 days of ageing whereas that from IR and MB attained WBSF in the range of 55 - 75 N even after 14 days of ageing.

Discussion

Slaughter traits of five strains of Tanzania shorthorn zebu

The significantly higher values in ESW, EBW and HCW observed in IR strain are indicative of the larger body frame size than in other strains (Wang *et al.,* 2021). The large frame of IR strain is evidenced by the large values for HGC, HLL, HLC and HCL observed in the present study (Table 3). A large body frame can accommodate large quantity of body tissues leading to higher body weight. Considering the present study was the first attempt to compare different strains of the Tanzania Short Horn Zebu for their potential to produce quality meat, no data was available for national-level comparison. These findings point

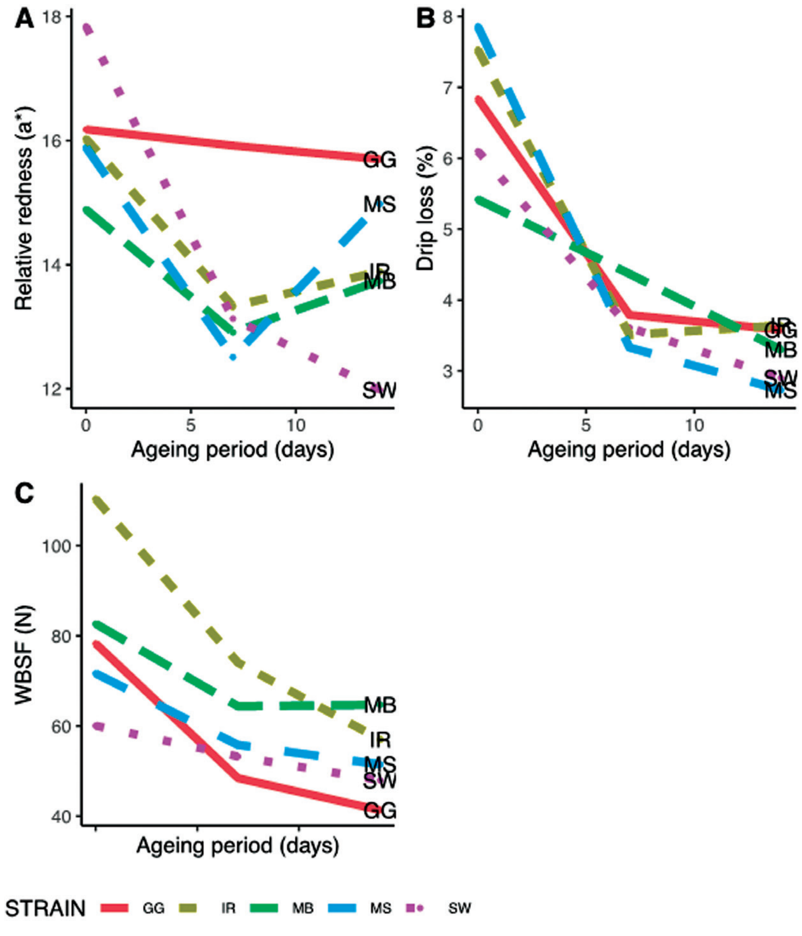

Figure 1: Strain by ageing period interaction on meat relative redness (A), drip loss (B) and Warner-Bratzler shear force (C). GG – Gogo, IR-Iringa red, MB – Mbulu, MS – Masai, SW- Singida white

Table 4: Least squares means for muscle, fat and bone tissues as influenced by strain and sex

Factor		Carcass composition (%)			
	n	Muscle	Fat	Bone	Dissection loss
Strain					
GG	10	62.9	8.1	21.7[a]	7.3 [b]
IR	10	63.7	7.4	21.9[a]	6.9 b
MB	10	64.1	8.1	18.6[b]	9.2 [a]
MS	10	63.2	8.2	20.5[a]	8.1 [a]
SW	10	63.6	8.9	20.6[a]	6.8 [b]
SE		0.6	0.6	0.5	0.5
P-Value		0.551	0.461	0.0001	0.012
Sex					
Entire bulls	25	64.4[a]	7.3[b]	20.7	7.5
Castrates	25	62.6[b]	9.0[a]	20.6	7.8
SE		0.3	0.3	0.4	0.4
P-Value		0.0007	0.001	0.738	0.622
Strain*Sex					
P-Value		0.285	0.967	0.348	0.227

Means with different superscripts along the columns are significantly different (P<0.05), SE=Standard error, GG= Gogo, IR =Iringa red, MB=Mbulu, MS =Maasai, SW = Singida White.

to the existence of intrinsic strain difference and selection potential for improved body frame, muscle mass and edible yield (Bureš and Bartoň, 2018; Piedrafita *et al.,* 2003). However, since there could be other environmental factors affecting the observed phenotypic variations in these strains, a controlled study is needed to validate our findings.

The observed least values for DP in MS strain can only be attributed to its higher proportion of feet as it had the least proportions of the head, FGIT and EGIT (P<0.05; data not shown), which should have contributed to higher DP. DP is affected by many factors including nutrition, carcass fatness, live weight, degree of muscling, gut fill and dressing methods (Asimwe *et al.,* 2015; Wang *et al.,* 2021). Feeding animals with high energy diets reduces gut fill but increases fatness and muscle mass and consequently increases DP of meat producing animals (Bureš and Bartoň, 2018).

Carcass composition

The proportions of muscle, fat and bone in carcasses observed in the present study are within the range (60.5-76.0%, 7.6-18.7% and 14.1- 21.0 %) reported by Piedrafita *et al.* (2003) in seven beef breeds based on the dissection of 6th rib. The least proportion of bone tissue observed in carcasses of MB strain, despite having the least values for HCW, HLL and HLC, may suggest a higher degree of carcass conformation, which is measured by muscle + fat: bone ratio (Bonny *et al.,* 2016; Purchas *et al.,* 2002).

The lower proportion of muscle (62.6 vs. 64.4 %) and a higher proportion of fat (9.0 vs. 7.3 %) observed in castrates than in intact bulls correspond to the early maturing nature of castrates compared to intact bulls (Lage *et al.,* 2012; Nogalski *et al.,* 2018). Castration hastens the passage of bulls from growth to fattening phase (Marti *et al.,* 2017). Results from the present study agree with Nogalski *et al.* (2018) and Prado *et al.* (2015) who observed higher muscle proportions for intact bulls and higher fat proportion for castrates. The higher proportion of muscle in intact bulls is

Table 5: Least squares means (%) for dry matter, crude protein and ether extract for five strains of Tanzania short horn zebu

Factors		Parameter			
	n	DM	Ash	CP	EE
Strain					
GG	10	26.8[b]	4.5	21.6[b]	4.3
IR	10	26.1[b]	4.6	22.9[ab]	4.5
MB	9	26.1[b]	4.7	24.6[a]	4.5
MS	10	27.3[b]	4.3	23.3[ab]	4.2
SW	9	30.8[a]	4.8	22.0[b]	6.4
SE		0.7	0.2	0.6	0.5
P-Value		0.0002	0.55	0.0082	0.134
Sex					
Entire bull	25	26.2[b]	4.4	23.0	4.1[b]
Castrates	23	28.7[a]	4.7	22.7	5.5[a]
SE		0.5	0.2	0.4	0.3
P-Value		0.0033	0.14	0.66	0.015
Strain*Sex					
P-Value		0.001	0.03	0.56	0.0003
CV		8.1	14.57	7.86	39.17

Means with different letter superscripts are significantly different at P<0.05, SE=Standard error, DM= Dry matter, CP= Crude protein, EE= Ether extract, CV= Coefficient of variation, GG= Gogo, IR =Iringa red, MB=Mbulu, MS =Maasai, SW = Singida White.

influenced by androgens, which suppress fat tissue deposition and promote muscle tissue deposition through the proliferation of satellite cells and recruitment of new nuclei into existing muscle fibres leading to muscle hypertrophy (Nian *et al.,* 2018; Nogalski *et al.,* 2018).

Meat chemical composition

The higher DM recorded in the SW strain implies that customers will get more nutrients per unit weight of meat they buy from this strain. Dry matter content is an indicator of the amount of nutrients per unit weight of the meat (Chail *et al.,* 2017). The average CP (22.8%) in the LT muscle recorded in the present study is within the range of 20.5 to 23.1% reported by Alam *et al.* (2017) and Karakök *et al.* (2010). However, the highest CP content in MB strain can neither be attributed to muscle nor DM contents as all strains were statistically similar in carcass muscle composition and also the DM content in meat from MB was not the highest of all strains. As indicated above, MB strain was the lightest of all but had the lowest proportion of bone tissue. We have no plausible explanation for the superior content of CP in MB strain.

The higher proportion of EE observed in castrates in the present study is similar to what has been reported in other studies (Aziz *et al.,* 2014; Marti *et al.,* 2017). This is attributable to the earliness of maturity of castrates, which triggers the deposition of fat tissue earlier than in intact bulls (Marti *et al.,* 2017; Wang *et al.,* 2021). Testicular testosterone found in intact bulls has an inhibitory effect on lipogenic enzyme activity in adipose tissue (Nian *et al.,* 2018). The value of EE recorded in castrates in this study (5.5%) is higher than the value (3.9%) reported by Aziz *et al.* (2014). This discrepancy may reflect breed difference in earliness of maturity and the concomitant effect on fat deposition.

Meat pH

All but SW strain had pHu within the recommended optimum range of 5.5 to 5.8

Table 6: Least squares means for pH and colour change for five strains of Tanzania shorthorn zebu as influenced by strain and ageing time

Factor		Parameters					
	n	pH at Slaughter	pH at 24h PM	pH at thaw	L*	a*	b*
Strain							
GG	10	6.2	5.6^{c}	5.6^{bc}	42.0	15.9^{a}	9.8^{a}
IR	10	6.6	5.6^{bc}	5.5^{c}	39.2	14.4^{b}	8.3^{c}
MB	9	6.2	5.8^{ab}	5.7^{ab}	38.6	13.8^{b}	9.6^{ab}
MS	10	6.3	5.8^{ac}	5.8^{a}	39.3	14.5^{b}	8.3^{bc}
SW	9	6.3	5.9^{a}	5.7^{ab}	40.9	14.3^{b}	9.6^{ac}
SE		0.1	0.1	0.0	1.0	0.5	0.5
P-Value		0.08	0.001	<0.0001	0.06	0.04	0.02
Sex							
Entire bull	25	6.4	5.7	5.7^{a}	39.2^{b}	14.2	9.0
Castrates	23	6.3	5.7	5.6^{b}	40.9^{a}	15.0	9.2
SE		0.1	0.0	0.0	0.6	0.3	0.3
P-Value		0.42	0.948	0.003	0.05	0.07	0.46
Ageing period							
0 day		-	-	5.6	36.1^{b}	16.2^{a}	7.2^{c}
7days		-	-	5.7	41.4^{a}	13.6^{b}	10.6^{a}
14days		-	-	5.6	42.5^{a}	14.1^{b}	9.4^{b}
SE		-	-	0.0	0.7	0.4	0.3
P-Value		-	-	0.5	0.0001	0.0001	0.0001
Strain*Ageing							
P-Value		-	-	0.5	0.22	0.04	0.07

Means with different letter superscripts are significantly different (P<0.05), SE=Standard error, L=lightness, a*=redness, b*=yellowness, CV= Coefficient of variation, GG= Gogo, IR =Iringa red, MB=Mbulu, MS = Maasai, SW = Singida White.*

(Hufflonergan and Lonergan, 2005; Shange *et al.,* 2018). The higher pHu recorded in SW strain is attributable to the slow rate of pH decline post-mortem as pH recorded in meat from this strain at thaw was lower than pHu and was within the optimum range. Time to attain pHu is affected by many factors including variation in nutritional status, preslaughter stress and pre-rigour ambient temperature (Hufflonergan and Lonergan, 2005). Low ambient temperature has been implicated in the slow post-mortem glycolytic activity and the low rate of meat pH decline (Kim *et al.,* 2014; Silva *et al.,* 2019). The selected strains of TSZ were slaughtered in five different localities, which might have involved different pre-slaughter and post-slaughter handling of animals and carcasses, respectively. pHu affects different quality parameters of meat including shelf life, colour, texture and water holding capacity (Cheng and Sun, 2008; Hughes *et al.,* 2014). Meat with optimum pHu has longer shelf life as the pH in the range 5.5 – 5.8 deters the growth of a number spoilage bacteria (Shange *et al.,* 2018).

The lowest pHu observed in beef from GG strain makes it suitable for processing into products that should lose water during fabrication and ripening. Processing of products like cured raw cuts and raw-fermented sausages require meat with pHu in the range of 5.2 - 5.6

Table 7: Least squares means for drip loss, cooking loss and shear force values for five strain of Tanzania short horn zebu as influenced by strains, sex and ageing time

Factors		Parameters		
	n	DL (%)	CL (%)	WBSF (N)
Strain				
GG	10	4.7	22.0	78.3[b]
IR	10	4.9	21.1	110.4[a]
MB	9	4.4	21.8	82.7[b]
MS	10	4.6	21.8	71.7[b]
SW	9	4.2	23.0	60.1[c]
SE		0.4	0.8	1.5
P-Value		0.32	0.37	0.0001
Sex				
Entire bull	25	4.4	22.4	85.8[a]
Castrates	23	4.7	21.5	72.6[b]
SE		0.2	0.4	1.1
P-Value		0.25	0.09	0.0001
Aging				
0 day	48	6.8[a]	24.3[a]	78.4[a]
7 days	48	3.7[b]	20.9[b]	57.5[b]
14 days	48	3.2[b]	20.5[b]	51.9[c]
SE		0.2	0.52	1.1
P-Value		0.0001	0.0001	0.0001
Strain*ageing				
P-value		0.007	0.47	0.0001

Means with different letter superscripts are significantly different at P<0.05, SE=Standard error, DL= Drip loss, CL= Cooking loss, WBSF= Warner-Bratzler shear force, CV= Coefficient of variation, GG= Gogo, IR =Iringa red, MB=Mbulu, MS =Maasai, SW = Singida White.

(Heinz and Hautzinger, 2007; Mitrovic *et al.,* 2019). The lower pH at thaw than pHu recorded in IR strain suggests that post-mortem glycolytic processes in this strain proceed beyond 24 hours PM. The cause of this discrepancy requires further study. On the other hand, the slightly higher pH at thaw for entire bulls than in castrates suggests differences in glycogen reserves. Entire bulls are more aggressive than castrates and they are more likely to deplete their glycogen reserves earlier in response to pre-slaughter handling (Marti *et al.,* 2017).

Meat colour

The overall L*value obtained in the present study (40.0, lighter) was slightly lower than the value (42.1) reported by Cafferky *et al.* (2019) for specialised beef breeds. The higher a* value (a* = 15.9) observed in GG strain suggests higher myoglobin concentration, which is known to increase with live weight and intensity of physical activities (Calnan *et al.,* 2016). In the present study, the GG strain was next to the IR strain in terms of slaughter weight. It is also possible that the GG strain, which is found in the semiarid region of Tanzania exercised more than other strains in search of pasture and water. Colour is usually considered the most important sensory characteristic affecting consumers decision when purchasing meat (Holman *et al.,* 2017). Holman *et al.* (2017) concluded that a* value is an appropriate determinant of consumer acceptance of beef colour and that a value of ≥ 14.5 warrants a 95% confidence that beef colour will be acceptable. In this study, beef from the GG strain was the only one with a*-value above 14.5. From the processing point of view, different myoglobin levels determine the curing capability of meat (Heinz and Hautzinger, 2007). As the red curing colour of meat results from the chemical reaction of myoglobin with the curing substance such as nitrite, the curing colour will be more intense where more muscle myoglobin is available (Waga *et al.,* 2017). In this connection, beef from the GG strain is more suitable for processing into cured meat products.

The higher L* values observed in meat from castrates is consistent with the higher level of fatness than in intact bulls. As expected, castration improves meat fatness and fat increases light reflectance (Mach *et al.,* 2009; Nian *et al.,* 2018). Other studies have reported higher values for lightness, redness and yellowness in castrates than in intact bulls (Marti *et al.,* 2017; Silva *et al.,* 2019). In the present study, meat colour was measured after different durations of ageing to determine the overall colour stability. The observed overall increase in lightness (L*) with increase in the period of ageing suggests an increase in moisture content on the meat surface with the ageing period. Water moves from the core of the meat to the surface through drip channels, which are formed early post-mortem (Farouk *et al.,* 2012). Meat used in the present study was aged after freezing, which might have increased the amount of water moving to the meat surface due to the degradation of muscle microstructure caused by the crystallisation process (Wang *et al.,* 2020). Water on the meat surface reflects light, which increases lightness value (Purslow *et al.,* 2020; Ryu *et al.,* 2008). Water that moves from the meat core to the surface contains water-soluble meat components, including myoglobin (Mancini and Hunt, 2005). This means that aged meat becomes lighter and less red partly because of loss of myoglobin in drip loss (Hughes *et al.,* 2014). In line with this principle, the redness value (a*) in the present study decreased with the ageing period.

The drastic decline in redness value with ageing period observed in SW strain suggests lower colour stability in this strain whereas the subtle change in a*-value observed in GG strain with the time of ageing suggests high colour stability in this strain. The cause for higher colour stability in GG and lower stability in SW requires further study. As indicated above, colour stability is affected by the loss and chemical change of myoglobin during meat storage. In addition, the presence of antioxidants like vitamin E in meat is known to prolong colour stability (Warner *et al.,* 2017).

Water holding capacity and meat tenderness

Strains of TSZ used in the present study were similar in Water holding capacity (WHC). Similar results were observed by Mwilawa *et al.* (2010). WHC determines the suitability of meat for further processing (Cheng and Sun, 2008). Cafferky *et al.* (2019) suggested that early maturing breeds exhibit lower drip loss values in comparison to the larger, late-maturing continental breeds. Low water loss during storage and cooking of meat from early-maturing breeds is attributable to two principles: i) the higher fatness in meat from early-maturing breeds serves as a protection against evaporative water loss, ii) there is less water in meat from early-maturing breeds due to inverse relationship between fat and water contents in meat (Nian *et al.,* 2018; Wang *et al.,* 2021). Despite TSZ being an early maturing breed, the average value obtained for drip loss (4.6%) in the current study was higher than 2.5% reported by Cafferky *et al.* (2019) for other early maturing breeds. This discrepancy in findings from different studies can be attributed to variation in the degree of fatness, level of stress animals were subjected to before slaughter and ultimate pH (Cheng and Sun, 2008).

Meat tenderness is affected both by preslaughter (age, breed, sex, feeding and handling) and post-slaughter (ageing, suspension, cooling and cooking) factors (Warner *et al.,* 2010). The highest WBSF recorded in IR might suggest differences in age at slaughter. However, based on dentition, animals in this study were comparable in age. Therefore, the cause for higher WBSF value in

IR is not apparent and it requires further research involving controlled experiments. Based on the tenderness scale, meat with a WBSF value below 55 N is regarded as sufficiently tender, 55 - 75 N is moderately tender and one above 75 N is tough (Robbins *et al.,* 2003). The tenderness recorded in SW and GG strains before ageing makes them suitable for niche markets that require moderately tender (55 – 75 N) meat shortly after slaughter. The study by Prado *et al.* (2009) considered tenderness as the function of high lipid levels (intramuscular fat - IMF) whereby an animal with high IMF had lower shear force values. In the present study, lipid content (measured as ether extract) in the LT muscle of SW strain was numerically higher (6.4%) than that of other strains and might have contributed to the lower shear force value. The causes for higher tenderness of meat from GG strain even before ageing require further studies.

The observed strain by ageing period interaction indicates that meat from SW and GG strains became sufficiently tender (<55 N) just after 7 days of ageing (Figure 1) whereas that from IR (56. 1 N) and MB (63.9 N) could only become moderately tender (55 – 75 N) even after 14 days of ageing (Robbins *et al.,* 2003). These findings suggest intrinsic differences in strains of TSZ in responding to ageing. While SW and GG strains could be considered most suitable for producing tender meat, further research is required to elucidate causes for the low response of IR and MB meat to post-mortem ageing.

The 9 N lower WBSF value recorded in castrates than in entire bulls agrees with Marti *et al.* (2017) and Cafferky *et al.* (2019). The higher tenderness recorded in castrates can be attributed to both high IMF as measured by ether extract (Table 5) and increased post-mortem proteolytic activity in the skeletal muscle (Silva *et al.,* 2019). On the other hand, the toughness of meat from entire bulls can be attributed to hypertrophy of muscle fibres caused by androgen hormones as well as increased cross-links in collagen fibres within muscles caused by increased intensity of activities, including sexual activity (Morgan *et al.,* 1993; Nian *et al.,* 2018).

Conclusion

The findings from this screening study should be considered preliminary as there could be other environmental factors for the observed phenotypic variations in the studied strains. Controlled experiment is required to validate these findings. However, based on these findings it is concluded that IR strain produces the toughest meat while SW and GG strains produce the most tender meat at the point of slaughter. Meat from SW and GG strains becomes tender just after 7 days of ageing whereas that from IR and MB can only become moderately tender even after 14 days of ageing. Overall, beef from GG strain is the most suitable for processing into quality meat products owing to its high relative redness (a*), colour stability, tenderness and low pHu. The observed strain differences offer opportunities for product differentiation by using specific strain for a specific market segment.

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Declarations

Competing interests

The authors declare that there is no conflict of interest in the content of this article and they have made equal contributions to the manuscript.

Authors' contributions

Daniel Mushi conceptualized and designed the experiment, analysed data and wrote the manuscript. Janeth Baruani did laboratory work, data collection and analysis. Both authors have approved the final article for submission.

Ethical approval

This experiment complies with ethical requirements stipulated by the National Health Ethics Review Committee (NatHREC) of Tanzania.

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