Influence of finishing strategies on carcass composition and meat quality characteristics of Boran crossbred bulls

Ezekiel P. Maro [1,2*], Germana H. Laswai[1], Anthony Z. Sangeda[1] Ismail S. Selemani [1], Martin N. Shem[3]

[1]Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P.O. Box 3004, Morogoro, Tanzania;

[2] Tanzania Livestock Research Institute (TALIRI), P.O. Box 834, Dodoma, Tanzania;

[3]Mgolole Agro-processing Company Ltd, P.O. Box 3136, Morogoro, Tanzania. E-Mail: ezemarro@yahoo.com

Abstract

This study was carried out to evaluate the effects of finishing practices and slaughter periods on carcass composition and quality of meat from Boran crossbred bulls. Fifty-four (2.5 – 3 years old, 205 ± 1.89 kg initial body weight) bulls were assigned/subjected to three different finishing practices; 18 bulls were on sole grazing (P1), 18 bulls were on supplementation after grazing (P2) and 18 bulls were kept on feedlot (P3). After that, 9 bulls (3) from each practice in the same finishing period were slaughtered at 45 days-S1, 60 days-S2, and 75 days-S3. Carcass and non-carcass components and composition were evaluated from slaughtered bulls. Carcass pH was measured at 24 h and 48 h post-slaughter at the LTL muscle and cooking loss and shear force values were evaluated for 4-, 8-, 12-, and 16-days aged meat. The findings showed that finishing practice and the slaughter period significantly (P<0.05) influenced the internal fat, heart-lung-liver, carcass length, and chest depth. The fat thickness, internal fat, Heart-lung-liver, four feet, gastrointestinal tract (GIT) full and empty were affected by finishing practices with bulls on P3 registering the highest fat thickness, internal fat and heart-lung-liver followed by P2 and P1 in that order. Meat pH (5.21-5.49) was similar (P>0.05) in finishing practices and slaughter periods. Carcass length, chest depth, hide, git empty,

tenderness, and a colour significantly ($p<0.05$) interacted by finishing practice and slaughter period. the L* colour intensities were higher in bulls slaughtered at S3 (45.96) than in S2 bulls (41.29) and a* values vary significantly ($p<0.05$) with finishing practices***.** *The Boran crossbred bulls showed improved tenderness with bulls on P3 (41.71N) having the lowest shear force values followed by P1 and P2 (44.41N and 45.4 N) with similar values. overall, bulls on P3 have heavier non-carcass components and better meat quality properties than those on P1 and P2. In conclusion, carcass components and meat quality characteristics were better in feedlot-finished bulls at 75 days of slaughter and aged 12 days. For increased beef quality, livestock farmers are encouraged to finish feedlot bulls for 75 days and age meat for 12 days. The findings of this study need further investigation into the influence of finishing strategies on fatty acid content and consumer health perceptions.*
Keywords: Boran crossbred, meat quality, finishing practice, slaughter period.

1.0 Introduction

Globally, there is a growing demand for quality meat and meat products mainly attributed to, and driven by the change from cereal protein foods to animal protein foods and hasty economic growth due to alarmingly positive population shifts (UN, 2019). According to the Ministry of Livestock and Fisheries 2024 budget in Tanzania, beef production supplied approximately 74 % of red meat to Tanzanians (URT, 2024) with 80%, 14%, and 6% sourced from agro-pastoralists, pastoralists, and formal beef farms respectively (URT, 2015). These producers mainly keep indigenous breeds of cattle solely raised on grazing practices. Finishing cattle in low-input practices delayed the attainment of slaughter weight (275 kg) and consequently produced a low carcass weight (137.5 kg) (URT, 2015) and tough meat. However, practicing improved finishing practices such as supplementation of grazing animals and feedlots could improve the yield and meat quality attributes, thus, meeting the increased prime beef demand.

Animals finished in feedlots and on supplementation with rich-energy diets improve performance, carcass composition, and quality traits by supporting fat deposition and producing more tender meat than grass-finished cattle (Mwilawa, 2012; Mushi, 2020). Tenderness is one of the most essential meat quality properties highlighted by modern markets and is mainly influenced by the quantity and type of fat contained in the meat (Felderhoff et al., 2020). Meat quality characteristics are inherently influenced by animal age, species (*Bos indicus Vs Bos taurus*), breed, sex, muscle fiber type, connective tissue contents, and the type and location of the muscle. Other imperative elements that are external to the animal and influence meat quality traits include the type and quantity of feed, days spent on finishing practice (Sinan et al., 2018), pre-slaughter handling, slaughter method, the post-slaughter pH and temperature, ageing duration, the colour of the meat and fat, and flavour (Wyrwisz et al., 2012)**.**

In order to improve and increase meat quality, it is important to improve the conditions of animals other than indigenous breeds such as Boran and their crossbreds, reared under grass grazing system which is often characterized by low growth rate and production of low-quality products. Feedlot and combination of grazing with concentrate supplementation are the finishing strategies known to improve growth rate, and profitability and shorten the time to attain market weight. Previous studies (Shirima et al., 2013; Neto et al., 2012; Asizua et al., 2017) show that there is a linkage between the animal finishing period, finishing practice, and the quality of meat produced which can be elucidated by a series of biological, biochemical, and biophysical mechanisms. The influence of *ad libitum* supply of high-energy diets during finishing animals in feedlots and supplementation has been reported to result in the production of heavier carcasses and higher levels of subcutaneous and intra-muscular fats (Mwilawa, 2012); (Asimwe et al., 2015)]. Consequently, the meat produced is related to low pH, slow cooling rate and meat tenderness

(Mushi, 2020). Nevertheless, a slow cooling rate leads to a more rapid post-slaughter glycolysis rate, leading to a rapid pH decline (Shirima et al., 2013); (Asimwe et al., 2016). In feedlots and supplementing practices, prolonging the finishing duration results in heavier carcasses, increases water holding capacity, accelerates post-slaughter glycolysis, lowers pH, and increases tenderness in cattle (Mushi, 2020).

Although much has been researched and documented on feeding rich energy diets to finishing cattle, limited information is available on the period of finishing on the carcass composition and attributes of meat quality of finished Boran crossbred cattle. Therefore, the present study aimed at establishing the length of finishing by either feedlot or grazing and supplementation on the carcass composition and meat quality attributes of Boran crossbred cattle.

2.0 Material and methods

2.1 Description of the study area

The feeding study was carried out at Kidago farm and animals were slaughtered at Mgolole Agro-processing Co. LTD. Kidago farm and Mgolole Agro-processing Co. LTD are located in Morogoro district in eastern Tanzania (6.77ºS and 37.68 ºE) and 509 to 600 km above sea level. They receive temperatures ranging between 18.7ºC - 29.2ºC and 972 mm of mean annual rainfall. The meat quality analyses were conducted at the Department of Animal, Aquaculture, and Range Sciences (DAARS) laboratory of the Sokoine University of Agriculture (SUA) situated between 6°- 7°S and 37° - 38°E and lie on the foot of the slopes of Uluguru Mountains.

2.2 Experimental design and treatments

A total of 54 bulls (205 ± 1.89 kg initial body weight, aged 2.5- 3 years) were distributed evenly across three treatment groups in a 3*3 factorial arrangement, comprising grazing alone (P1) as a control group, grazing with concentrate supplementation (P2), and feedlot (P3), with 18 animals per practice. grazing only (P1) The slaughter periods were on 45th day (S1), 60th day (S2), and 75th day (S3) of the experiment.

2.3 Management of experimental animals and sampling

The bulls were ear-tagged for identification, estimated for initial body weight using a measuring band (RONDO® a combined measuring tape for cattle and pigs), and injected with ivermectin (1%) for control of endo and ectoparasites. The bulls had fifteen days of grazing on natural pastures for backgrounding. Bulls were randomly allocated to the different feeding practices with a 10-day adaptation period for experimental animals to be familiarized to experimental settings and diet prior to data collection. A total of 27 bulls were randomly sampled out of 54 and slaughtered at different periods S1, S2, and S3. In each slaughter period 9 bulls, 3 from each practice were slaughtered and carcass composition and meat quality characteristics were evaluated.

2.4 Source of experimental feeds and feeding

The experimental diet (ED) was formulated from 36 % Hominy feeds, 18% cassava meal, 6 % rice polishing, 38% sunflower seed cake, 1.5% mineral, and 0.5% salt and contained 13.53 MJ ME/kg DM and 147g CP kg/DM. Ingredients for ED were all purchased from local Agricultural input suppliers in Morogoro Municipality. The ED was fed *ad libitum* to bulls on P3 and P2, hay and ED were weighed and provided daily in the morning at 0800 hrs and 1600 hrs for P3 (10% refusals) and once for P2 at 1600 hrs after grazing. The adjustment of the amount of feed offered was done every seven days after live weight measurement and this was undertaken till the study ended.

2.5 Slaughter procedure and measurements

Prior to slaughter, live weight of the bulls was estimated using a measuring band (RONDO®) for three days consecutively, where the average value was taken as the final body weight. In each slaughter period, nine bulls were trucked at a speed of 30 km per hours to Mgolole Agro-processing Co. Ltd located 30 km from Kidago farm for slaughter. On arrival, bulls were fasted for 24 hours with free access to fresh drinking water. Thereafter, the bulls were weighed to obtain the slaughter weight. The animals were stunned with a captive bolt pistol to render them unconscious and the neck was humanely severed at the jugular and carotid vessels using a sharp knife following Halal rituals. After that, the slaughtered bulls were suspended by their hind legs on an overhead rail system using a hoisting chain for bleeding, flaying, and evisceration. The head was removed at the atlas joint, while the flaying was done starting from the legs and moving up until the whole animal body was unhide. The fore and hind feet were removed at the carpal and hock joints respectively, then the stomach, intestines and the pluck were removed through the vertical midline incision of the abdominal cavity.

Non-carcass components, which included the head, feet, hide, tail, external organs and small intestines, pluck (the heart, liver, lungs, and trachea), and full and empty digestive tract were weighed in kilograms using a spring weighing scale certified by Weight and Measurement Agency (WMA) (200 kg capacity) and recorded. The gastrointestinal tract (GIT) was weighed while full then emptied, washed off its fillings, and lastly re-weighed to get the weight of the empty GIT within 45 to 60 minutes of slaughter. Gastrointestinal tract (GIT) fill was calculated as the difference between the full and empty GIT weights. The internal fat depots (IFD) were weighed using an electronic weighing scale (10 kg capacity) and recorded.

2.6 Carcass linear measurements

The dressed carcasses were longitudinally sawed into two halves using a hand saw and weighed within 45 minutes post-slaughter and the left half was used for linear measurements. Using a tailor measuring tape the carcass length was measured straight from the anterior edge of the first rib to the caudal end of the pubic symphysis. The hind leg length, chest depth, and hind leg circumference were also measured. The fat thickness was measured by using a ruler on the 10^{th} rib. The 10^{th} rib provides a standard, consistent location across various animals representing a good average of the fat distribution across the body. This uniformity is necessary to draw insightful comparisons between animals. The carcasses were left at room temperature for 12 hours and then transferred to a chilling room at 0^{o} C

Twelve hours post-slaughter, the 6^{th} rib joint from the left side half carcass was extracted by a straight cut perpendicular to the vertebral axis from the middle of each intercostal space to the vertebrae. After that, each excised rib was weighed vacuum-packed in polythene sheets. Similarly, the *Longissimus thoracis et lumborum* (LTL) muscle was excised from rib 7 up to the 10^{th} rib, weighed, vacuum packed in polythene sheets and together with ribs were transported to DAARS-SUA, 12 km away from Slaughter facility, in a cool box for detailed physicochemical analyses (pH, colour, cooking loss, and tenderness). Twenty-four hours post-slaughter all the ribs 6^{th} were re-weighed individually and dissected into muscle, fat, and bone tissues, and each component was weighed and expressed as a percentage of the whole joint weight referred to as the carcass composition.

2.7 Determination of muscle pH

The pH of the meat was measured in the laboratory at 24 hrs and 48 hrs post-slaughter from LTL muscle kept at 4 °C. Briefly, 100 g sampled from each LTL muscle was thoroughly grounded using a food grinder blender machine Europe strong (ES-2L model), and the fined ground meat was then mixed with 150 ml of distilled water, stirred vigorously to obtain the solution. Thereafter, the calibrated pH meter Hanna Instruments HI-98127 was partially immersed into the solution and the pH was read and recorded.

2.8 Determination of cooking losses, meat colour, and Warner-Bratzler Shear Force (WBSF)

Five portions of the LTL muscle were labeled (LTL0, LTL4, LTL8, LTL12, and LTL16) aged for 4, 8, 12, and 16 days were used to determine both cooking loss and shear force following the procedure described in the previous study [16]. The LTL muscle labeled (LTL0) was used to measure meat pH at 24- and 48-hours post-slaughter. Meat color was measured on the same portions a day zero at thaw and at 4, 8, 12, and 16 days of aging on the fresh-cut surface of LTL muscle using Minolta Chroma meter 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. For the CL determination, the samples were weighed (W1), labeled, and vacuum-packed, after each aging time. This happened after overnight thawing of (4 °C) LTL muscle samples. Several samples of LTL muscles of different practices were then heated constantly at 70°C for 1 h in a water bath. Samples were cooled under running tap water for 2 hours. The samples were removed from plastic bags, wiped with clean cotton gauze, and then weighed (W2) and CL was calculated as the difference between W1 and W2. During tenderness analysis, the same LTL muscle samples cooked for CL examination were used. Six rectangular-shaped blocks were cut into 1 cm^3 cubes parallel to the direction of the muscle fibers. Then each block was sheared through two times perpendicular to the muscle fiber direction with a triangular-shaped shear blade attached to the Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany) set with 1 KN load cell, with a crosshead speed of 200 mm/min. The average of 12 shear values per sample of LTL from each treatment was considered the peak WBSF value for that sample.

2.9 Statistical analysis

Data for non-carcass components, carcass composition, and meat quality traits were analyzed using the General Linear Model (GLM) procedures of SAS (Version 9.2; 2004) (SAS, 2004). Meat quality parameters (Colour, pH, CL, and WBSF) on finishing practices and slaughter periods, ageing time, and their interactions were regarded as fixed effects and each slaughtered animal was considered as random effects. The least-square means differed significantly at $p<0.05$ and were separated by the PDIFF option of the GLM model of SAS.

Model: $Yijk = \mu + Ti + Pj + Sk + TPij + TSik + PSjk + eijk$

Where Yijk=Measurement of unit meat sample of an individual animal; μ=Overall mean; Ti= fixed effect of finishing practice (i=grazing alone, concentrate supplementation and feedlot); Pj=fixed effect of slaughter periods (j=45, 60 and 75 days); Sk= Fixed effect of aging time (k=4, 8, 12 and 16 days for CL and WBSF and k=24, 48h for pH); TPij = Interaction effect of finishing practice and slaughter periods; TSik= Interaction effect of finishing practice and aging time; PSjk = Interaction effect of slaughter periods and aging time; eijk= random residual error referring to the experimental animal subjected in the ith finishing practice jth slaughter periods and kth aging time as fixed effects.

3.0 Results

3.1 Carcass measurements and composition

The effects of finishing practice and slaughter period on carcass measurements and composition are summarized in Table 1. Finishing practice and slaughter period significantly ($p<0.05$) affected carcass length and chest depth. Bulls on P3 had the highest ($p<0.05$) fat thickness followed by P2 and the lowest on P1. An interaction effect ($p<0.05$) between finishing practice and slaughter period was observed for the carcass length and chest depth sizes. Bulls on P2 had similar or slightly higher growth rates at an early stage of finishing 45 days (S1) than those on P3, leading them to attain relatively equal carcass length at the last stages of finishing (S3). Bulls on P1 had a slightly high growth rate at the early stages of S1 and consistently low growth from S2 to S3 leading them to produce small carcasses. Bulls on P1 had marked high and consistent chest size at early stages of feeding and moderate growth at late stages leading them to attain slightly higher chest size than those on P2. Bulls on P3 had high and consistently increasing chest size making them attain the widest chest. The weights of dissectible muscle, fat, and bone were neither influenced by finishing practice nor the slaughter period.

Table 1. Lsmeans ± SEM for carcass measurements and tissue composition of Boran crossbred bulls used in the experiment

Parameter	Finishing practices					Slaughter periods					FP*SP
	P1	P2	P3	SEM	P-value	S1	S2	S3	SEM	P-value	P-value
Carcass length (cm)	107.71[c]	147.25[b]	164.01[a]	4.71	<0.0001	133.41[b]	129.65[b]	155.91[a]	4.58	<0.0042	<0.0209
Hind leg length (cm)	75.86	76.61	79.56	1.33	<0.1155	79.25	77.58	75.20	1.3	<0.0916	<0.1725
Hind leg circumference (cm)	101.51	99.11	103.04	3.71	<0.6945	101.74	104.73	97.18	2.94	<0.2917	<0.4516
Chest depth (cm)	35.38[b]	37.07[b]	42.43[a]	1.05	<0.0020	36.77[b]	37.16[b]	40.94[a]	1.02	<0.0203	<0.0206
Fat thickness (cm)	0.59[b]	2.10[a]	2.34[a]	0.17	<0.0002	1.73	1.78	1.52	0.50	<0.4528	<0.5746
Proportions in carcass composition (%)											
Muscle (kg)	46.45	56.05	55.25	6.89	<0.5308	50.34	57.41	49.99	6.70	<0.6350	<0.7126
Fat (kg)	11.31	8.17	10.61	2.60	<0.6417	8.37	9.94	11.78	2.53	<0.5576	<0.3240
Bone (kg)	42.36	35.82	34.28	7.29	<0.6727	41.39	32.88	38.19	7.12	<0.6550	<0.9818

P1- grazing alone, P2–grazing plus supplementation, P3-full feedlot; a-c Means with different superscripts within a row differ significantly (P<0.05). SEM = standard error of the mean, S1- 45 days, S2- 60 days, S3- days FP*SP- interaction effect between finishing practices and slaughter periods

3.2 Non-carcass components measurements

The results of non-carcass components of Boran crossbred bulls finished under various practices and slaughter periods are presented in Table 2. Finishing practices influenced ($p<0.05$) the heart-lung-liver, internal fats, GIT full, GIT empty, and four feet weight of the finished bulls. A quantitative interaction ($p<0.05$) between finishing practice and the slaughter period was observed on the weights of hides and GIT empty. In the early finishing periods bulls on P2 had slightly lower hides weight but consistently increased than those on P3, leading them to attain lighter hide weight at the S3 than P3 bulls. Bulls on P1 had the highest hide weight at the early stages of feeding and gently reduced in the late phases S2 and S3 of slaughter. Bulls on P1 and P2 had similar GIT empty weights at the first phase of finishing and P2 slightly increased the GIT empty at late phases of finishing leading P2 to attain a higher GIT empty weight than those on P3. Bulls on P2 and P3 that were slaughtered 75th day had the comparable ($p>0.05$) weight of GIT empty. Head, hide, internal fats, and heart-lung-liver weights were significantly ($p<0.05$) influenced by slaughter periods.

Table 2. Lsmeans ± SEM for non-carcass components of Boran crossbred bulls used in the experiment

Parameter	Finishing practices					Slaughter periods					FP* SP
	P1	P2	P3	SEM	P-value	S1	S2	S3	SEM	P-value	P-value
Head (kg)	14.37	15.73	15.51	1.48	<0.7647	11.66^{b}	17.36^{b}	16.59^{ab}	1.44	<0.0308	<0.8138
Hide (kg)	20.22	18.94	21.21	0.92	<0.1970	17.48^{b}	22.91^{a}	19.98^{a}	0.90	<0.0062	<0.0240
Internal fat (kg)	0.49^{c}	1.52^{b}	2.26^{a}	0.18	<0.0003	1.10^{b}	1.83^{a}	1.33^{b}	0.17	<0.0341	<0.1013
Heart-lung-liver (kg)	9.87^{b}	10.96^{a}	11.91^{a}	0.44	<0.0210	9.94^{b}	11.69^{b}	11.09^{ab}	0.43	<0.0371	<0.1078
Four feet (kg)	7.98^{b}	8.24^{b}	9.49^{ab}	0.39	<0.0314	8.45	8.97	8.29	0.38	<0.3837	<0.2701
Tail (kg)	0.81	0.89	1.03	0.07	<0.0902	0.87	1.04	0.82	0.07	<0.0858	<0.8207
GIT full (kg)	51.03^{b}	55.51^{b}	61.64^{ab}	2.49	<0.0334	54.27	58.64	54.95	2.42	<0.1432	<0.5393
GIT empty (kg)	16.69^{c}	19.31^{b}	20.78^{ab}	0.81	<0.0142	18.33	20.24	18.21	0.78	<0.1432	<0.0136
GIT content (kg)	34.34	36.20	40.54	2.03	<0.0975	35.94	38.40	36.74	1.99	<0.6359	<0.1425

P1- grazing alone, P2–grazing plus supplementation, P3-full feedlot; a-c Means with different superscripts within a row differ significantly (P<0.05). SEM = standard error of the mean, GIT- gastro-intestinal track, S1- 45 days, S2- 60 days, S3- days FP*SP- interaction effect between finishing practices and slaughter periods

3.3 Carcass pH, cooking losses, meat colour, and Warner Bratzler shear force values

Table 3 illustrates the effect of finishing practices and slaughter periods on carcass pH, cooking losses, meat colour, and shear force of the finished bulls. Finishing practices and slaughter periods did not (p>0.05) influence the pH values and cooking losses. There was an interaction effect between finishing practice and the slaughter period on the tenderness and redness colour of the meat such that the shear force values were improving from P1, P2, and P3 practices and with increasing slaughter periods from S1, S2, and S3. As a result, bulls slaughtered on the 75th day were more tender than the 45 and 60th day slaughtered bulls. Meat from

45th-day slaughtered bulls had a similar redness colour and as finishing days advanced P3 had decreased the redness colour and improved for P1 and P2 bulls. The relative lightness and yellowness of the meat were not affected ($p>0.05$) by the finishing practices but slaughter periods did. The redness colour of the meat was statistically ($p<0.05$) influenced by finishing practices. Finishing practice and slaughter period influenced ($p<0.05$) meat tenderness. The relative redness and yellow colour of the meat were affected by the finishing practice.

Table 3. Lsmeans ± SEM for beef quality characteristics of Boran crossbred bulls used in the experiment

Parameter	**Finishing practices**					**Slaughter periods**					**FP*SP**
	P1	**P2**	**P3**	**SEM**	**P-value**	**S1**	**S2**	**S3**	**SEM**	**P-value**	**P-value**
pH24	5.47	5.44	5.45	0.05	<0.9420	5.44	5.49	5.43	0.05	<0.6633	<0.3109
pH48	5.28	5.21	5.28	0.05	<0.4467	5.24	5.26	5.26	0.05	<0.9249	<0.1392
Cooking Loss (%)	33.31	34.04	34.35	1.08	<0.7814	34.36	32.71	34.63	1.08	<0.4030	<0.0982
Shear Force (N)	44.41^{a}	45.4^{a}	41.71^{b}	1.55	<0.0039	48.19^{a}	48.1^{a}	35.21^{b}	1.55	<0.0001	<0.0002
Lightness	44.15	42.73	42.43	0.70	<0.1824	42.06^{b}	41.29^{b}	45.96^{a}	0.70	<0.0001	<0.0944
Redness	10.47^{a}	9.83^{b}	8.71^{c}	0.36	<0.0034	10.09	9.65	9.27	0.36	<0.2827	<0.0055
Yellowness	8.89	9.00	7.80	0.27	<0.0038	8.59^{b}	8.04^{b}	9.07^{a}	0.27	<0.0298	<0.0712

a-b Means with different superscripts within a row differed significantly ($P<0.05$), FP*SP- interaction effect between finishing practices and slaughter periods

3.4 Effects of aging time on the cooking loss and tenderness of Boran crossbred bulls used in the experiment

The effects of the different aging times on cooking loss and the shear force values are presented in Table 4. Aging time significantly ($p<0.05$) influenced cooking loss and tenderness showing lower values at 12 days reaching the threshold shear force value < 55 N. The meat from bulls from all practices and slaughter periods aged for 16 days had the lowest cooking losses and shear force values compared to those aged for 4 to 12 days as expected.

Table 4. Least square means ± SEM for effects of aging time on cooking loss and tenderness of Boran crossbred bulls used in the experiment

Finishing practices	Slaughter periods	Aging time (days)	Cooking loss (%)	Shear force values (N)	P values
Grazing alone	45-days	4	39.66±3.75	48.41±4.34	<.0001
Grazing alone	45-days	8	41.96±3.75	50.86±4.34	<.0001
Grazing alone	45-days	12	32.83±3.75	47.67±4.34	<.0001
Grazing alone	45-days	16	31.26±3.75	33.15±4.34	<.0001
Grazing alone	60-days	4	30.85±3.75	68.60±4.34	<.0001
Grazing alone	60-days	8	34.25±3.75	47.75±4.34	<.0001
Grazing alone	60-days	12	31.21±3.75	46.50±4.34	<.0001
Grazing alone	60-days	16	26.78±3.75	44.29±4.34	<.0001
Grazing alone	75-days	4	30.18±3.75	50.57±4.34	<.0001
Grazing alone	75-days	8	35.83±3.75	35.51±4.34	<.0001
Grazing alone	75-days	12	34.64±3.75	36.18±4.34	<.0001
Grazing alone	75-days	16	30.22±3.75	21.39±4.34	<.0001
grazing plus supplementation	45-days	4	36.82±3.75	58.85±4.34	<.0001
grazing plus supplementation	45- days	8	37.12±3.75	51.20±4.34	<.0001
grazing plus supplementation	45- days	12	33.53±3.75	51.25±4.34	<.0001
grazing plus supplementation	45- days	16	30.44±3.75	39.03±4.34	<.0001
grazing plus supplementation	60-days	4	38.84±3.75	63.90±4.34	<.0001
grazing plus supplementation	60-days	8	37.63±3.75	50.29±4.34	<.0001
grazing plus supplementation	60-days	12	36.31±3.75	45.97±4.34	<.0001
grazing plus supplementation	60-days	16	24.24±3.75	37.25±4.34	<.0001
grazing plus supplementation	75- days	4	32.46±3.75	47.67±4.34	<.0001
grazing plus	75- days	8	33.33±3.75	31.75±4.34	<.0001

Finishing practices	Slaughter periods	Aging time (days)	Cooking loss (%)	Shear force values (N)	P values
supplementation					
grazing plus supplementation	75- days	12	35.29±3.75	41.61±4.34	<.0001
grazing plus supplementation	75- days	16	32.53±3.75	25.99±4.34	<.0001
Full feedlot	45- days	4	33.71±3.75	52.35±4.34	<.0001
Full feedlot	45- days	8	34.84±3.75	50.61±4.34	<.0001
Full feedlot	45- days	12	34.56±3.75	54.75±4.34	<.0001
Full feedlot	45- days	16	25.60±3.75	40.21±4.34	<.0001
Full feedlot	60-days	4	38.50±3.75	50.76±4.34	<.0001
Full feedlot	60-days	8	33.94±3.75	45.19±4.34	<.0001
Full feedlot	60-days	12	30.69±3.75	39.16±4.34	<.0001
Full feedlot	60-days	16	29.30±3.75	35.54±4.34	<.0001
Full feedlot	75- days	4	43.28±3.75	37.63±4.34	<.0001
Full feedlot	75- days	8	40.15±3.75	26.22±4.34	<.0001
Full feedlot	75- days	12	33.86±3.75	37.77±4.34	<.0001
Full feedlot	75- days	16	33.83±3.75	30.29±4.34	<.0001

SEM = standard error of the mean

4.0 Discussion

The observed higher mean weight of carcass length, chest depth, fat thickness, head, hide, internal fat, and the heart-lung-liver on feedlot (P3) and grazing with concentrate supplementation (P2) bulls were associated with a high-energy diet (13.53 MJ ME/kg DM and 147g CP kg/DM) offered to these bulls. The diet contained slightly higher than recommended in the previous study (NRC, 2000) for beef fattening. The effects of the diet offered are also linked to the observed interaction effects between the finishing practices and slaughter periods on increased carcass length and chest depth sizes. The influences of finishing practice and high-energy diets on growth performance and improved meat quality in the finishing stages reported in this study were also reported in previous studies (Menezes et al., 2010; Asimwe et al., 2016). The findings from the present study concur with results reported in the past (McGee et al., 2007) in feedlot finishing cattle, though the observed fat thickness was relatively higher than those previously reported (Asimwe et al., 2016). The disparities in fat thickness between the two studies could be due to breed differences and nutrient contents of the diets used. Although the previous study (Paula Neto et al., 2018; González-Salazar et al., 2021) have demonstrated slightly shorter carcass lengths on Zebu and crossbred bulls in feedlots and longer on pasture-fed bulls contrary to those obtained from the present study which could be influenced by the age of animals used.

There was an interaction effect between finishing practice and the slaughter period on hide weights with no clear trend. The results from the current study are in line with those reported in the previous studies (Özlütürk et al., 2008), showing the influence of concentrate diet in increasing non-carcass component weights. The heaviest weights of the head, hide, internal fat, and the heart-lung-liver were observed on 60th days than other slaughter periods this implies that 60 days on feed is probably optimal for the growth and development of those parts. In the investigations carried out in the past, (Asizua et al., 2009; Mwilawa et al., 2010) on the effects of feeding practices and slaughter durations on animal performance had values that are in line with those observed in this present study.

The observed higher weights of GIT full and GIT empty in bulls on P2 and P3 are attributed to the nutritional composition of the diet offered, probable variations in diet digestibility owed to slower passage rate through the GIT due to high crude fibre (CF) in the diet. The diet is formulated to contain rice polishing with high CF contents and cassava meal of high fermentable carbohydrates leading to increased water consumption during and prior to the slaughter of the animals. Janssen et al., 2021 have elucidated the effect of feeding rich-energy diets to animals in intensive and semi-intensive systems in increasing the digestive track contents as well as abdominal fats depots which increased both GIT full and empty weights.

Cooking loss is a key meat quality characteristic and is usually used to measure the ability of flesh to hold on to its constituent water (water holding capacity). The observed cooking loss reported in this study ranged between 32-35% and is in line with the values reported in the previous study (Maria et al., 2022) on Braford steers aged for 2,7,14 and 21 days, but are higher than 24.54 to 30.62% which were reported in another study (Fan et al., 2020) on Simmental cattle aged between 1 to 7 days. Meat that results in low cooking loss has both economical and quality merits due to their high-water retaining capacity; hence, more yield and little nutritive value are lost**.** The observed CL in the current study is associated with pH values recorded and probably the intramuscular fat present. The latter was not assessed in the present study, the presence of it can be explained by the observed high b* values (yellowness colour) from the bulls slaughtered under various periods, thus, not influencing the CL values. The influence of ultimate pH and the intramuscular fat on meat cooking loss have been well described in the past study (Mushi et al., 2009). The lowest values for CL and shear force values observed on meat aged for longer days (12 and 16 days) could be attributed to the degree of muscle contraction and the breakdown of the myofibrillar proteins with increasing aging duration. Past studies have revealed that aging time influences the CL and shear force of the meat (Maria et al., 2022).

The post-slaughter aging of meat led to reduced cooking loss and shear force values as it involves biochemical and physical processes that occur during the conditioning of meat. The breakdown of muscle proteins particularly myofibrillar, caused by calpain enzymes weakens the muscle structures leading to a progressive increase in tenderness (Bhat et al., 2018). This process further creates more space within the muscle fibers, allowing them to hold more water, leading to lower cooking loss as more moisture is retained in the meat during cooking. The results of the present study have demonstrated that finishing practice, period to achieve slaughter weight, and aging period are three variables that autonomously influence meat quality attributes. The bulls on P2 and P3 were fed a rich-energy diet which influenced their glycogen reserves leading to a lower muscle pH, and increased intramuscular fat that dilutes the muscle structures, consequently, influencing meat tenderness (Janssen et al., 2021); (Christensen and Purslow, 2016). Tenderness is one of the most valuable meat quality traits, as tough or chewy meats can immediately affect the eating experience. The results of the current study showed that the shear force values were reduced from 44.41 to 41.71N in the meat from bulls finished on pasture only and on feedlot and from 48.19 to 35.21N in the meat from bulls slaughtered on 45 and 75 days respectively. The shear force values observed in this study were in line with (Robbins et al., 2003) established standard scale indicating that less than 55 N shear force values are satisfactorily tender, those ranged from 55-75 N reasonably tender and beyond 75 N is tough. The age of the animal could be linked to the observed similarity in meat tenderness as young animals are known to produce more tender meat due to the plentiful of undeveloped collagen in the muscle with weak crosslinks between them, which dissolves readily when cooked (Archile-Contreras et al., 2010). The tenderness in this study was further influenced by the amount and contents of the intramuscular connective tissues in the meat revealed by the observed high b* values indicating that meat has more yellow colouring probably owing to the presence of higher intramuscular fat content causing the reflection and dispersion of light by fat globules (Table 3). Moreover, this study demonstrates that the production of optimal tender meat is at 75 days of slaughter.

The obtained high redness and yellowness values of the meat from bulls raised on various finishing practices are similar to those reported by (McGee et al., 2024). The redness value (a*) for grazing only (P1) bulls was slightly higher than their contemporaries indicating the presence of a substantial amount of myoglobin in the meat. Atsbha et al., 2021 obtained 10.99, 9.99, and 10.84 values of redness (a*) for LTL muscles from three groups of Begait lambs finished under three dietary treatments. Differences in the level of myoglobin content and the colour of intramuscular fat have been reported to influence redness in beef (Jakobsen and Bertelson, 2000). Bulls slaughtered under various periods had higher lightness and yellowness values which are comparable to those reported by (McGee et al., 2024). The higher L* values indicate that the meat is bright lighter in colour, probably due to the red hue of the meat. The observed finishing practice by slaughter period interaction indicates that meat from P3 bulls became less reddish throughout the entire finishing period where the P1 and P2 have increased bright red colour with increasing finishing days, probably due to the higher myoglobin content oxygenated during exposure to a mixture of gases which contains oxygen (Gašperlin et al., 2000), consistent with the results of (Torrecilhas et al., 2017). These results suggest the differences in diets nutritional values and finishing regimes in responding to meat colour vary significantly causing less reddish meat in bulls on P3 and bright red to those on P1 and P2.

5.0 Conclusions

Finishing strategies and post-slaughter aging of LTL muscles of Boran crossbred bulls had a significant effect on meat quality attributes, specifically in tenderness and meat colour. Bulls on feedlot produced more tender meat as compared to grazing with concentrate supplementation and grazing only. The seventy-five slaughtered bulls also produced tender meat as compared to those slaughtered at forty-five and sixty days on feeding. This implies that feedlot finishing and slaughtering of Boran crossbred bulls on 75 days of feeding is a better option for the production of prime beef as compared to the other finishing practices and slaughter durations. Hence, recommended for adoption by producers and livestock finishers for improved meat quality. Aging times affected the cooking loss and tenderness of the meat from both the finishing practice and slaughter period. The tenderness was improved with increasing aging times; therefore, aging for 12 days is sufficient for all meat from all effects under study. Future research is also necessary to explore the impact of this finishing strategy on fatty acid composition and consumer health perceptions to complement the results gathered in this study.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors would like to give special thanks to the Tanzania Commission for Science and Technology (COSTECH), Mgolole Agro-processing Co. LTD, and Kidago Farm for the financial and material support that enabled the conduct of this study. Appreciation is extended to SUA staff for guiding the first author on data collection and for laboratory analyses.

References

Archile-Contreras, A.C., Mandell, I.B., and Purslow, P.P. (2010). Disparity of dietary effects on collagen characteristics and toughness between two beef muscles. Meat Science, 86(2), 491-497.

Asimwe, L., Kimambo, A.E., Laswai, G.H., Mtenga, L.A., Weisbjerg, M.R., and Madsen, J. (2016). Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum finishing period. Livestock Research for Rural Development 28:11.

Asimwe, L., Kimambo, A.E., Laswai, G.H., Mtenga, L.A., Weisbjerg, M.R., and Madsen, J. (2015). Effect of days in a feedlot on growth performance, carcass and meat quality attributes of Tanzania shorthorn zebu steers. Tropical Animal Health and Production 47: 867- 876.

Asizua, D., Mpairwe, D., Kabi, F., Mutetikka, D., and Madsen, J. (2009). Growth and slaughter characteristics of Ankole cattle and its Boran and Friesian crossbreds. South African Journal Animal Science 39: 81-85.

Asizua, D., Mpairwe, D., Kabi, F., Mutetikka, D., Hvelplund, T., Weisbjerg, M.R., and Madsen, J. (2017). Effects of grazing and feedlot finishing duration on the performance of three

beef cattle genotypes in Uganda. Livestock Science 199: 25-30.
Bhat, Z.F., Morton, J.D., Mason, S.L., and Bekhit, A.E.D.A. (2018). Role of Calpain System in Meat Tenderness: A Review. Food Science and Human Wellness 7: 196-204.
Christensen. S., and Purslow, P.P. (2016). The role of matrix metalloproteinases in muscle and adipose tissue development and meat quality: a review. Meat Sci. 2016.119: 138–146.
Fan, Y., Han, Z., Arbab, A.A.I., Yang, Y., and Yang, Z. (2020). Effect of Aging Time on Meat Quality of Longissimus Dorsi from Yunling Cattle: A New Hybrid Beef Cattle. Animals 10: 1897.
Felderhoff, C,, Lyford, C., Malaga, J., Polkinghorne, R., Brooks, C., Garmyn, A., and Miller, M. (2020). Beef quality preferences: Factors driving consumer satisfaction. Foods 9:3.
Gašperlin, L., Žlender, B. and Abram, V. (2000). Colour of normal and high pH beef heated to different temperatures as related to oxygenation. Meat Science 54: 391-398.
González-Salazar, E., Duarte-Vargas, J.H., Díaz-Avila, V., and Castañeda-Serrano, R.D. (2021). Animal performance and meat quality in feedlot cattle feeding with different levels of agricultural by-products. Rev MVZ Cordoba. 26: e1950.
Özlütürk, A., Esenbuğa, N., Yanar, M., Ünlü, N., Macit, M. and Kopuzlu, S. "The Effect of Duration of Finishing Period on the Performance, Slaughter, Carcass, and Beef Quality Characteristics of Eastern Anatolian Red Bulls," Turkish Journal of Veterinary and Animal Sciences 32: 441-448.
Jakobsen, M., and Bertelson, G. (2000). Colour stability and lipid oxidation of fresh beef. Development of a response surface model for predicting the effects of temperature, storage time, and modified atmosphere composition. Meat Science 54: 49-57.
Janssen. J., Cammack, K., Legako, J., Cox, R., Grubbs, J., Underwood, K., Hansen, J., Kruse, C. and Blair, A.

Influence of Grain and Grass-Finishing Systems on Carcass Characteristics, Meat Quality, Nutritional Composition, and Consumer Sensory Attributes of Bison. Foods 10: 1060.
María, S.C., Dario, P., Gabriela, G. and Gustavo, A.P. (2022). Feeding strategies and ageing time alter calpain system proteins activities and meat quality of Braford steers. Animal Bioscience 35: 272-280.
McGee, M., Keane, M.G., Neilan, R., Moloney, A.P. and Caffrey, P.J. (2007). Body and carcass measurements, carcass conformation and tissue distribution of high dairy genetic merit Holstein, standard dairy genetic merit Friesian and Charolais Holstein-Friesian male cattle. Irish Journal of Agricultural and Food Research 46: 129e147.
McGee, M., Regan, M., Moloney, A.P., O'Riordan, E.G., Lenehan, C., Kelly, A.K., and Crosson, P. (2024). Grass-based finishing of early and late-maturing breed bulls within suckler beef systems: Performance, profitability, greenhouse gas emissions and feed-food competition, Livestock Science 279: 105392
Atsbha, K., Gebremariam, T., and Aregawi, T. (2021). Slaughter performance and meat quality of Begait breed lambs fattened under different diets. Heliyon 7: e06935.
Menezes, L.F.G, de Restle, J., Brondani, I.L., Silveira, M.F., da Freitas, L., da, S., and Pizzuti, L.Â.D. (2010) Carcass and meat characteristics from young Devon steers finished in different feeding systems. Revista Brasileira de Zootecnia 39: 667-676.
Mushi, D. (2020). Feedlot performance of Tanzanian Shorthorn Zebu finished on local feed resources. Tropical Animal Health and Production https://doi.org/10.1007/s11250-020-02346-y
Mushi, D.E., Safari, J., Mtenga, L.A., Kifaro, G.C., and Eik, L.O. (2009). Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African× Norwegian crossbred goats fed low quality grass hay. Livestock Science 124: 148-155.

Mwilawa, A.J. (2012). Effects of Breed and Diet on Performance, Carcass Characteristics and Meat Quality of Beef Cattle. PhD. Dissertation. Sokoine University of Agriculture Morogoro, Tanzania. 244-246 pp.

Mwilawa, A.J., Kimambo, A.E., Mtenga, L.A., Laswai, G.H., Madsen, J., Hvelplund, T., Weisbjerg, M.R., Christensen, M. and Mgheni, D.M. (2010). Carcass and meat quality characteristics of indigenous cattle in Tanzania. In: The 5th Research Week and International Conference. 22 – 24 September 2010, Egerton University, Kenya.

Neto, O.R.M., Ladeira, M.M., Chizzotti, M.L., Jorge, A.M., Mendes de Oliveira, D., de Calvalho, J.R., and do Sacramento Ribeiro, J. (2012). Performance, carcass traits, meat quality and economic analysis of feedlot of young bulls fed oilseeds with and without supplementation of vitamin E. Revista Brasileira de Zootecnia 41: 1756-1763.

NRC (2000). Nutrient requirements of beef cattle: Seventh revised edition, 2000. Washington, DC: The National Academies Press. Available https://doi.org/10.17226/9791.

Paula Neto, J.J., de Alexandrino, E., Costa Junior, W.S., da Rezende, J.M., de Silva, A.A.M., and Melo, J.C. (2018). Performance and carcass characteristics of feedlot-finished Zebu cattle in different feeding systems. Semina: Ciências Agrárias 39: 1725.

Robbins, K., Jensen, J., Ryan, K.J., Homcoryan, C., Mckeith, F.K. and Brewer, M.S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. Meat Science 65: 721-729.

SAS (2004). User's guide, version 9.2. SAS Institute, Inc, Carry 2004.

Shirima, E.J.M., Mtenga, L.A., Kimambo, A.E., Laswai, G.H., Mgheni, D.M., Mushi, D.E., Shija. D.S., Safari, J.G., and Hozza, W.A. (2013). Effects of days in feedlot on physico-chemical properties and meat tenderness from Tanzanian Long Fat-Tailed Sheep. Journal of Animal Production Advances 3: 40-48.

Sinan, K., Nurinisa, E., Alper, O., Muhlis, M., Mete, Y., Sadrettin, Y., Abdulkadir, O., and Necdet, U. (2018). Effects of slaughter age and muscle type on meat quality characteristics of Eastern Anatolian Red bulls. Archives Animal Breeding 61: 497-504.

Torrecilhas, J.A., Neto, O.R.M., Ornaghi, M.G., San Vito, E., Lima, L.O., Simioni, T.A. and Berchielli, T.T. (2017). Effect of breed and finishing system on meat quality from beef cattle. Journal of Animal Science 95: 180-180.

UN (2019). World Population Prospects. Highlights; United Nations Department of Economic and Social Affairs. https://www.un.org/development/desa/publications/world-population-prospects-2019-highlights

URT (2015). Ministry of Livestock and Fisheries Development). Tanzania Livestock Modernisation Initiative. 38 pp

URT (2024). The Ministry of Livestock and Fisheries Hon. Abdallah Ulega (MP) Speech on the Expected Expenditure Financial year 2024/25 of the Ministry of Livestock and Fisheries. Dodoma, Tanzania 121 pp.

Wyrwisz, J., Półtorak, A., Zalewska, M., Zaremba, R., and Wierzbicka, A. (2012). Analysis of Relationship Between Basic Composition, pH, and Physical Properties of Selected Bovine Muscles. Bulletin of the Veterinary Institute in Pulawy 56: 403-409.