*Original Research Article*

An assessment of the carcass composition and meat quality of Boran crossbred cattle finished using different strategies

ABSTRACT

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| A study was performed to evaluate the effects of finishing practices and slaughter periods on carcass composition and quality of meat from Boran crossbred bulls. Fifty-four (54) bulls aged 2.5 - 3 years with initial body weight of 205 ± 1.89 kg were allocated to three finishing practices: sole grazing (P1), grazing with supplementation (P2) and feedlot finishing (P3). Three (3) bulls from each practice were slaughtered at 45 (S1), 60 (S2) and 75 (S3) days of finishing period, when the non-carcass components and carcass composition were assessed. The carcass pH was measured at 24- and 48-hours post-slaughter in the *Longissimus thoracis et lumborum* (LTL) muscle. The meat colour, cooking loss and shear force were determined after ageing portions of LTL muscle for 4, 8, 12, and 16 days. The feedlot finished bulls (P3) produced higher (P<0.05) internal fat (2.26 kg), heart-lung-liver weight (11.91 kg), carcass length (164 cm), and chest depth (42.43 cm) than those on P2 compared to their counterparts. The late slaughter period (S3) resulted in the highest (P<0.05) carcass length (155.97 cm) and chest depth (40.94 cm) compared to slaughter periods S2 (129.65 and 37.16) and S1 (133.41 and 36.77), respectively. Significant interactions between finishing practice and slaughter period were observed for carcass length, chest depth, hide weight, GIT weight (empty), tenderness, and redness colour. Lightness ~~\*~~ colour intensity was highest in S3 (45.96), while redness were significantly higher in P1 (10.47) than in P2 (9.83) and P3 (8.71). Bulls on P3 exhibited significantly more tender meat (shear force of 41.71 N/kg) compared to P1 (44.41 N/kg) and P2 (45.4 N/kg). In conclusion, 75 days of feedlot finishing and 12-day ageing produced acceptable tender meat and colour. Further research is needed on the influence of the current finishing strategies on consumer preferences. |

***Keywords*:** *Boran crossbred, finishing practice, slaughter period, pH, tenderness, cooking loss*

1. 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 positive population shifts [1]. According to the budget for the Tanzanian Ministry of Livestock and Fisheries for the year 2024, beef production locally supplied approximately 74 % of red meat [2]sourced from agro-pastoralists (80%), pastoralists (14%) and formal beef farms (6%) [3]. Agro-pastoralists and pastoralists mainly keep indigenous cattle breeds, which are solely raised on traditional grazing systems. Finishing cattle in low-input practices delayed the attainment of slaughter weight (275 kg) and consequently produced a low carcass weight (137.5 kg) [3] and tough meat. However, improved finishing practices, such as feedlots and supplementing concentrate on grazing animals could improve the yield of beef and meat quality attributes, thus, meeting the increased demand for prime beef.

Animals finished in feedlots and those on grazing plus supplementation with energy-rich diets were shown to have improved growth performance, carcass composition and meat quality traits by supporting fat deposition and producing more tender meat than sole grass-finished cattle [4-5]. Tenderness is one of the most essential meat quality properties influencing meat palatability is highlighted by modern markets and is mainly influenced by the quantity and type of fat contained in the meat [6]. The characteristics of meat quality are inherently influenced by animal age, species (*Bos indicus Vs Bos taurus*), breed, sex, type and location of muscle fibre and contents of connective tissues. Other imperative elements, which are external to the animal and may influence meat quality traits include the type and quantity of feed, days spent on finishing practice [7], pre-slaughter handling and slaughter method. Others are post-slaughter pH and temperature, ageing duration, the colour of the meat and fat content [8]**.** The characteristics of meat quality, especially colour and tenderness are influenced by finishing practices and slaughter durations [9]. Moreover, animals raised in low-production systems have produced meat lighter in colour than animals raised in feedlots and supplements [10]. Similarly, the breakdown of cytoskeletal myofibrillar proteins by endogenous proteases during meat ageing after slaughter notably enhances the flavour, tenderness and overall quality [11].

Feedlot and a combination of grazing with concentrate supplementation are the finishing strategies known to improve the growth performance and quality of the meat. Previous studies by several researchers [12-14]showed a linkage between the animal finishing practice, the finishing period and the quality of meat produced, which elucidate series of biological, biochemical and biophysical mechanisms. In the practice of feedlot and grazing plus supplementation, prolonging the finishing time results in heavy and fatty carcasses, increases water holding capacity, accelerates post-slaughter glycolysis, lowers pH and increases tenderness in cattle [5]. The influence of *ad libitum* supply of high-energy diets during finishing animals in feedlots has been reported to result in the production of big carcasses and relatively high levels of subcutaneous and intramuscular fats [4]; [15]. These attributes are related to low pH, slow cooling rate and meat tenderness [5]. Nevertheless, a slow cooling rate leads to a rapid rate of post-slaughter glycolysis, which leads to rapid pH decline [12]; [16].

A narrow window of opportunity exists for achieving acceptable meat quality attributes on finished Boran crossbred cattle through optimal finishing and ageing duration, despite the fact that extensive research and documentation have been done on feeding finishing cattle-rich energy diets. Therefore, the present study aimed at establishing the length of finishing Boran crossbred cattle using different finishing practices and meat ageing on the carcass composition and attributes of the meat quality of Boran crossbred cattle.

2. materialS 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 as detailed in the previous publication [17].

**2.2 Experimental design, feeds, feeding and management of experimental animals**

A total of 54 bulls were distributed evenly across three treatment groups in a 3\*3 factorial arrangement, comprising of grazing only (P1) as a control group, grazing with concentrate supplementation (P2) and feedlot finishing (P3). A compounded diet constituting hominy feed (36%), cassava meal (18%), rice polishing (6%), sunflower seed cake (38%), minerals (1.5%) and salt (0.5) was provided to bulls in groups P2 and P3.The concentrate was fed *ad libitum* (10% refusals) to bulls on P3 and once for P2 after grazing. The adjustment of the amount of feed offered was done weekly after weighing the bulls. The details on the diets, feeding and management of the experimental animals are presented by Maro *et al.* [17]. Twenty-seven (27) out of the 54 bulls, that is 9 bulls from each practice were randomly selected and slaughtered at 45 (S1), 60 (S2) and 75 (S3) days of the finishing period.

**2.3 Slaughter procedure and measurements**

Before slaughter, the 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 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, they 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 unhiding. The fore and hind feet were removed at the carpal and hock joints respectively. Then evisceration was done, whereby the stomach, intestines and the pluck were removed through the vertical midline incision of the abdominal cavity.

The non-carcass components, head, feet, hide, tail, external organs and small intestines were weighed in kilograms, using a spring weighing scale (200 kg capacity). Other non-carcass components, such as full and empty digestive tract and pluck, which included the heart, liver, lungs and trachea were also weighed. The gastrointestinal or digestive tract (GIT) was weighed while full, emptied within 45 to 60 minutes of slaughter, washed off its fillings and lastly re-weighed to get the weight of the empty GIT. The GIT fill or contents was derived as the difference between the weight of full and empty GIT. The internal fat depots (IFD) were extracted and weighed using an electronic weighing scale (10 kg capacity).

The dressed carcasses were longitudinally sawed into two halves using a hand saw. The left half carcass was used for carcass linear measurements. The carcass length was measured straight from the anterior edge of the first rib to the caudal end of the pubic symphysis using a tailor measuring tape. The hind leg length, chest depth and hind leg circumference were also measured. The back fat thickness was measured using a ruler on the 10th rib. The carcasses were left at room temperature for 12 hours and then transferred to a chilling room set at 0 ͦC. Twenty hours post-slaughter, the 6th rib joint from the left side of the half carcass was extracted by a straight cut perpendicular to the vertebral axis from the middle of each intercostal space to the vertebrae, then weighed and vacuum packed in polythene sheets. Similarly, the *Longissimus thoracis et lumborum* (LTL) muscle was excised from the 7th to the 10th rib, weighed and vacuum packed in a polythene sheet. The cuts were placed in a cool box and transported to the laboratory, where they were stored in a deep freezer, set at -4°C.

**2.4 Determination of carcass composition**

The physical composition of the carcass was estimated from the samples of the 6th rib joint, whereby the samples were thawed, weighed and dissected into muscle, fat and bone tissues. Each tissue component was weighed using a digital weighing scale (10 kg capacity). The weight of each tissue was then expressed as the percent of the joint weight.

**2.5 Determination of the meat quality attributes**

The pH of the meat was taken at 24- and 48 hours post-slaughter on each LTL muscle. This was done by taking 100 g of the thawed LTL muscle and thoroughly grounded using a food grinder blender machine (Europe strong; ES-2L model). The finely ground meat was then mixed with 150 ml of distilled water and 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.

The influence of ageing meat from bulls finished at different practices and slaughter periods on cooking loss and tenderness was determined using the *Longissimus thoracis et lumborum* (LTL) muscle. The LTL muscle from each slaughtered bull was apportioned into five portions weighed between 150 to 180g with labels LTL0, LTL4, LTL8, LTL12 and LTL16 and kept in a deep freezer, set at 0°C for ageing periods 0, 4, 8, 12 and 16 days, respectively. The samples were then assessed for cooking loss, meat colour and tenderness after each ageing time.

In the determination of the cooking loss (CL), the samples were thawed in a refrigerator at 4°C overnight, weighed (W1), labelled and vacuum-packed. They were then heated constantly at 70°C for 1 h in a water bath. The samples were cooled under running tap water for 2 hours. Thereafter, they were removed from the plastic bags, wiped with clean cotton gauze and then weighed (W2). The CL was calculated as the difference between W1 and W2. Assessment of meat colour was performed on LTL muscle before cooking, whereby a fresh cut was done on the surface of each portion of the LTL muscle. The Minolta Chroma meter CR-400 (Konica Minolta Inc. made in Japan) aperture was perpendicularly placed to the LTL muscle surface and colours of the meat were examined based on Commission Internationale de l’Eclairage (CIE) L\*a\*b\* system, where L\* implies relative lightness, a\*, relative redness and b\* is relative yellowness [18].

In the determination of meat tenderness, the cooked portions of LTL muscle were used. For each portion, six rectangular-shaped blocks were cut into 1 cm3 parallel to the direction of the muscle fibre. Then each block was sheared through twice perpendicular to the muscle fibre 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. An average of 12 shear values per sample were considered the peak WBSF value for that sample.

**2.6 Statistical analysis**

The collected data were analyzed using the General Linear Model (GLM) procedures of SAS (Version 9.2; 2004) [19]. The influence of finishing practices, slaughter periods, ageing time and their interaction effects on the parameters of meat quality which are colour, pH, CL, and WBSF, were regarded as fixed effects. The least-square means were considered significantly different at (P<0.05) and were separated by the PDIFF option of the GLM model of SAS.

3. results

**3.1. Effects of finishing practices and slaughter periods on the yields of non-carcass components of the finished bulls**

The effects of the finishing practices and slaughter periods on theweights of non-carcass components of the bulls are presented in Table 1. The lsmean weights of heads and hides were not affected (P>0.05) by the finishing practices, however, they were higher (P<0.05) in bulls slaughtered at 60 (S2) and 75 (S3) days of finishing compared with those slaughtered at 45 (S1) days of finishing. Bulls on P3 had the highest (P<0.05) internal fat accretion, followed by those on P2 and the least for those on P1. Bulls slaughtered at S2 had largest (P<0.05) internal fat accumulation than those at S1 and S3 periods of finishing. Bulls on P2 and P3 had higher (P<0.05) mean weights of heart-lung-liver and four feet than those on P1. On the other hand, bulls slaughtered at S2 and S3 had higher (P<0.05) weights of heart-lung-liver than those slaughtered at S1. The lsmeans of the GIT full and GIT empty were higher (P<0.05) for the bulls finished using practices P3 and P2 than those on P1. The slaughter periods did not (P˃0.05) influence the weights of neither full nor empty GIT of the slaughtered bulls. Bulls finished under various practices and slaughter periods had similar (P˃0.05) weights of the GIT contents. Quantitative interaction (P<0.05) effects between finishing practices and slaughter periods were observed on the lsmeans of hide and empty GIT. During the early finishing periods (S1) bulls on P2 had a lower mean weight of hide than their counterparts (Figure 1a). Consistently with increased slaughter periods at S2, they had the higher weight of hide than other groups and later decreased, leading them to attain a lighter mean weight of hide at S3 than those of P3. On the other hand, bulls on P1 had the highest mean weight of hide at the early stages of finishing (S1), and gently reduced at the slaughter periods S2 and S3. At the early stages of finishing (S1), all bulls had more or less similar mean weights of empty GIT (Figure 1b). However, the mean weight of empty GIT for the feedlot (P3) group increased drastically, while for the other groups the weights decreased. This trend led the bulls in P3 to attain the highest mean weight of empty GIT at S2. This weight dropped thereafter, leading to bulls on P2 and P3 having comparable weights of empty GIT at slaughter period S3.

Table 1. Lsmeans ± SEM of the weights of non-carcass components as influenced by finishing practices and slaughter periods

| **Parameter (kg)** | **Finishing practices** | | |  |  | **Slaughter periods** | | |  |  | **FP\*SP** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **P1** | **P2** | **P3** | **SEM** | **P-value** | **S1** | **S2** | **S3** | **SEM** | **P-value** | **P-value** |
| Head | 14.37 | 15.73 | 15.51 | 1.48 | 0.7647 | 11.66b | 17.36a | 16.59a | 1.44 | 0.0308 | 0.8138 |
| Hide | 20.22 | 18.94 | 21.21 | 0.92 | 0.1970 | 17.48b | 22.91a | 19.98a | 0.90 | 0.0062 | 0.0240 |
| Internal fat | 0.49c | 1.52b | 2.26a | 0.18 | 0.0003 | 1.10b | 1.83a | 1.33b | 0.17 | 0.0341 | 0.1013 |
| Heart-lung-liver | 9.87b | 10.96a | 11.91a | 0.44 | 0.0210 | 9.94b | 11.69a | 11. 09a | 0.43 | <0.0371 | 0.1078 |
| Four feet | 7.98b | 8.24ab | 9.49a | 0.39 | 0.0314 | 8.45 | 8.97 | 8.29 | 0.38 | 0.3837 | 0.2701 |
| Tail | 0.81 | 0.89 | 1.03 | 0.07 | 0.0902 | 0.87 | 1.04 | 0.82 | 0.07 | 0.0858 | 0.8207 |
| GIT full | 51.03b | 55.51ab | 61.64a | 2.49 | 0.0334 | 54.27 | 58.64 | 54.95 | 2.42 | 0.1432 | 0.5393 |
| GIT empty | 16.69c | 19.31b | 20.78a | 0.81 | 0.0142 | 18.33 | 20.24 | 18.21 | 0.78 | 0.1432 | 0.0136 |
| GIT content | 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- 75 days FP\*SP- interaction effect between finishing practices and slaughter periods*

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| Figure 1. Trends of the mean weights of hides “a” and empty gastrointestinal tract “b” of Boran crossbred bulls as influenced by finishing practices and slaughter periods | |

**3.2. Effects of finishing practices and slaughter periods on the carcass measurements and composition**

The effects of finishing practices and slaughter periods on the carcass measurements and composition are summarized in Table 2. The longest (P<0.05) carcass length was shown in bulls on P3, followed by those on P2, and the shortest (P<0.05) in those on P1. Similarly, bulls slaughtered on the 75th day of finishing (S3) had the longest (P<0.05) carcass length than their counterparts. Bulls slaughtered at periods S1 and S2 had similar (P>0.05) values of carcass length. A significant interaction effect between finishing practices and slaughter periods was observed on the carcass length. Bulls on P2 had slightly higher carcass lengths than those on P3 at the early stages of finishing (S1), however, the opposite trend was observed at the later stage of finishing (S3) (Figure 2a). The lsmeans for the hind leg length and hind leg circumference were neither influenced (P>0.05) by finishing practices nor the slaughter periods. The bulls on P1 and P2 had similar (P<0.05) values of chest depths, however lower than that of bulls on P3. On the other hand, chest depth size increased (P<0.05) with slaughter periods, leading to bulls slaughtered at S3 having the largest chest depth followed by those at S2 and least in those slaughtered at S1. The interaction effect of finishing practices and slaughter periods on chest depth size was significant (P<0.05). Bulls on P2 had relatively higher values of chest depth size at the early stages of finishing (S1) than those on P1. However, the chest size for P2 decreased, while that of P1 increased with finishing time, making those on P2 have lower chest size than those on P2 at S2 (Figure 2b). Towards the late slaughter period (S3), the mean chest size for bulls on P2 increased and attained a similar mean value to that of P1. Bulls on P3 had consistently higher (P<0.05) mean values of chest size than their counterparts throughout the finishing period. The lsmeans of fat thickness were highest (P<0.05) in bulls on P3 followed by those on P2 and lowest (P<0.05) in those on P1. The periods in which the bulls were slaughtered did not influence (P>0.05) the thickness of fat in the body. The percentages of dissectible muscle, fat, and bone were neither influenced by finishing practice nor the slaughter period.

Table 2. Lsmeans ± SEM of carcass measurements (cm) and carcass composition of the bulls as influenced by finishing practices and slaughter periods

| **Parameter** | **Finishing practices** | | |  |  | **Slaughter periods** | | |  |  | **FP\*SP** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **P1** | **P2** | **P3** | **SEM** | **P-value** | **S1** | **S2** | **S3** | **SEM** | **P-value** | **P-value** |
| Carcass length | 107.7c | 147.3b | 164.0a | 4.71 | 0.0001 | 133.41b | 129.65b | 155.91a | 4.58 | 0.0042 | 0.0209 |
| Hind leg length | 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 | 101.51 | 99.11 | 103.04 | 3.71 | 0.6945 | 101.74 | 104.73 | 97.18 | 2.94 | 0.2917 | 0.4516 |
| Chest depth | 35.38b | 37.07b | 42.43a | 1.05 | 0.0020 | 36.77b | 37.16b | 40.94a | 1.02 | 0.0203 | 0.0206 |
| Fat thickness | 0.59b | 2.10a | 2.34a | 0.17 | 0.0002 | 1.73 | 1.78 | 1.52 | 0.50 | 0.4528 | 0.5746 |
| % in the 6th rib joint | | | |  |  |  |  |  |  |  |  |
| Muscle | 59.41 | 62.5 | 60.11 | 7.89 | 0.5308 | 60.24 | 61.36 | 60.5 | 7.89 | 0.6350 | 0.7126 |
| Fat | 17.72 | 18.88 | 20.5 | 3.60 | 0.6417 | 18.55 | 19 | 20.49 | 3.60 | 0.5576 | 0.3240 |
| Bone | 22.87 | 18.62 | 19.39 | 4.21 | 0.6727 | 21.21 | 19.64 | 19.01 | 4.21 | 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- 75days FP\*SP- interaction effect between finishing practices and slaughter periods*

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| Figure 2. Trends of the carcass length “a” and depth of chest “b” of the bulls as influenced by finishing practices and slaughter periods | |

**3.3. Effects of finishing practices and slaughter periods on the meat quality attributes**

Table 3 illustrates the effects of finishing practices, slaughter periods and their interaction effects on the pH, cooking losses, colour, and shear force of the meat from the finished bulls. Finishing practices and slaughter periods did not (P˃0.05) influence the average pH of the meat and cooking losses. The meat from bulls on the feedlot practice (P3) became more tender with the lowest (P<0.05) Warner-Bratzler Shear Force (WBSF) values, compared to that of bulls on P2 and P1, which produced meat with similar (P<0.05) values of shear force. Similarly, bulls slaughtered at period S3 had lower (P<0.05) mean shear force values than those slaughtered at S1 and S2, which had similar (P˃0.05) shear force values. There was a significant (P<0.05) interaction effect between finishing practice and the slaughter period on the tenderness of the meat from the bulls (Table 3). At the early stage of finishing (S1), the mean values of shear force were relatively high for all finishing practices (Figure 3a). However, with increased finishing time to S2, the values of shear force for meat from bulls on P1 increased and started to decrease thereafter. On the other hand, the values for the meat from bulls in practices P2 and P3 decreased slightly from periods S1 to S2 and drastically from periods S2 to S3. During the late slaughter period S3, the mean values of the shear force of the meat from bulls in practices P1 and P2 were similar (P>0.05), while that from bulls on practice P3 was lowest (P<0.05). This means relative lightness and yellowness of the meat were not affected (P˃0.05) by the finishing practices (Table 3). However, the meat from the bulls slaughtered at period S3 was lighter in colour (P<0.05) than the meat from those slaughtered at S1 and S2 periods. The redness colour of the meat was stronger (P<0.05) in the meat from the bulls on P1, followed by those on P2 and least in those on P3. The periods of slaughter did not influence the redness of the meat, however, there was a significant (P<0.05) interaction effect between the feeding practices and slaughter periods on the redness of the meat. Meat from bulls in all practices slaughtered at period S1 had similar levels of meat redness colour (Figure 3b). However, as finishing days advanced, the redness colour of the meat from bulls on P3 faded out but became more intense for the meat from bulls on P1 and P2 (Figure (3 b). The finishing practices had no effect (P<0.05) on the yellowish colour of the meat, but bulls slaughtered at S3 had more (P<0.05) yellowish meat than those slaughtered in other periods.

Table 3. Lsmeans ± SEM for the attributes of meat quality of bulls as influenced by finishing practices and slaughter periods

| **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/kg) | 44.41a | 45.4a | 41.71b | 1.55 | 0.0039 | 48.19a | 48.1a | 35.21b | 1.55 | 0.0001 | 0.0002 |
| Lightness | 44.15 | 42.73 | 42.43 | 0.70 | 0.1824 | 42.06b | 41.29b | 45.96a | 0.70 | 0.0001 | 0.0944 |
| Redness | 10.47a | 9.83b | 8.71c | 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 | 8.59b | 8.04b | 9.07a | 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*

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| Figure 3. Trends of the mean values of shear force “a” and redness “b” of the meat from the bulls as influenced by finishing practices and slaughter periods | |

**3.4 Effects of finishing practices, slaughter periods and meat ageing on the attributes of meat quality of the finished bulls**

The mean effects of the ageing of meat from the bulls under different finishing practices and slaughter periods on the mean values of cooking losses and shear force values are presented in Figures 4 (a and b). Bulls finished under P1 and slaughtered early (S1) had significantly higher cooking losses after 4-8 days of ageing compared to 12-16 days. This indicates a possible interaction between ageing time and initial meat quality, which is affected by finishing and slaughter timing. Cooking loss generally decreased with longer ageing, with 4- and 12-day aged meat having similar, slightly higher cooking loss and shear force values than 16-day aged meat. However, cooking loss increased from 8 to 12 days before levelling off at 16 days. At S3 (late finishing), 4- and 16-day aged meat had the lowest cooking loss, slightly lower than 8- and 12-day aged meat, resulting in lower shear force values.

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| Figure 4. Demonstrates the trends in mean cooking loss ‘a’ and shear force ‘b’ of bull meat as influenced by finishing practices | |

The effects of the various ageing times on the mean values of cooking losses and the shear force are presented in Figure 4 (c and d). At the early finishing stage (S1), P1 and P2 bulls showed similar, slightly lower cooking losses for 4- and 8-day aged meat than 12- and 16-day aged meat, resulting in marginally lower shear force values (more tender meat). In the S2 finishing period, P2 bulls exhibited similar cooking loss for 4, 8, and 12-day aged meat, with a slight decrease for 16-day aged meat. Meat tenderness improved (lower shear force) as ageing time increased from 4 to 16 days, across both S1 and S2 finishing periods. P2 bulls slaughtered at S3 showed consistently low cooking loss across all ageing times (4, 8, 12, and 16 days) and progressively lower shear force values (increasing tenderness) with longer ageing. The meat from bulls on P3 showed slightly higher cooking loss for 4, 8, and 12-day aged meat at the early finishing stage (S1), with this loss increasing at later stages (S2 and S3). Interestingly, 4, 12, and 16-day-aged meat showed similar low shear force values, with the lowest value observed at 8 days of ageing in the S3 period.

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| Figure 4. Presents the trends in mean cooking loss ‘c’ and shear force ‘d’ for Boran crossbred bull meat as influenced by slaughter periods | |

**4. DISCUSSION**

**4.1 Yield of non-carcass components**

The enhanced non-carcass components (hide, internal fat depots, heart-lung-liver, four feet, tail, GIT full, GIT empty and GIT content), and carcass composition observed in bulls under feedlot finishing (P3) and supplemented grazing (P2) are directly attributable to the high-energy diet provided (13.53 MJ ME/kg DM and 147g CP kg/DM), exceeding the 12 MJ ME/kg DM and 140g CP kg/DM recommended in previous research [20]. This aligns with existing literature [21] demonstrating the positive impact of concentrate diets on non-carcass weight. The peak weights of the head, hide, internal fat, and heart-lung-liver at 60 days (S2) suggest that this may represent an optimal period for their development. The obtained findings regarding non-carcass components are consistent with previous studies [22-23]. The increased full and empty GIT weights in the P2 and P3 groups are likely due to the dietary composition [17], specifically the high crude fibre (CF) content of rice polishing and the high fermentable carbohydrates in cassava meal. This combination likely resulted in slower GIT passage rates and increased water consumption pre- and post-slaughter. This observation is supported by research [24] showing that high-energy diets in intensive systems increase the contents of the digestive tract and abdominal fat, consequently increasing both full and empty GIT weights.

**4.2 Carcass measurements and composition**

The observed significant interaction effect between finishing practice and slaughter period on carcass length and chest depth is directly linked to the impact of the high-energy diet. This interplay between diet and time highlights the importance of both nutritional management and slaughter timing in optimizing carcass characteristics. The obtained findings on the positive effects of finishing practices and high-energy diets on backfat thickness and meat quality attributes such as tenderness and meat colour aligned with previous research [25, 15]. While this study's results on the same parameters align with those reported in feedlot-finished cattle [26], however, there was a relatively higher fat thickness than previously reported [15] was observed. This discrepancy might be attributed to breed differences and variations in dietary nutrient composition, a factor also highlighted by [27]. In contrast to our findings, other studies [28, 29] reported shorter carcass lengths in feedlot-finished Zebu and crossbred bulls than in pasture-fed animals. However, this difference could be explained by variations in the age of the bulls used in each study. Therefore, breed, age, and specific dietary components appear to be crucial factors influencing the final carcass measurements.

**4.3 Attributes of meat quality of the bulls**

The values of cooking losses (CL) observed in the present study (32-35%) aligned with values (33.8-35%) reported for Braford steers [30]. However, the values are slightly higher than the cooking losses ranging from 24.54-30.62% reported for Simmental cattle [31] for the meat aged for 1-7 days and 15.2 -25.45% for Red Sokoto goats [43]. Lower CL is economically and qualitatively advantageous due to higher water retention, minimizing yield loss and preserving nutritional value. The slightly elevated CL in the current study may be linked to the higher pH values recorded and potentially higher intramuscular fat content, although the latter was not directly measured. The observed high b\* values (yellowness) in bulls across different slaughter periods hint at a possible higher intramuscular fat content, as supported by previous research [32] establishing the relationship between ultimate pH, intramuscular fat, and meat CL.The lower cooking loss (CL) and shear force values observed in meat aged 12 and 16 days are consistent with the increased breakdown of myofibrillar proteins and reduced muscle contraction associated with longer ageing periods. This tenderization process is driven by the action of naturally occurring calpain enzymes, which break down proteins and connective tissues [33]. Ageing is a widely accepted method for improving meat quality, particularly tenderness and flavour, involving a post-slaughter resting period of at least twelve hours. Despite the emergence of numerous innovative tenderization techniques, ageing remains a globally preferred method. The enhancement of tenderness with increased ageing time reflects the intracellular proteolytic mechanisms gradually breaking down the muscle structure. The observed improvement in tenderness in bulls from finishing practices P2 and P3 as ageing time increases is a direct consequence of these sequential physical and enzymatic processes that enhance the sensory qualities of the meat.

The obtained findings on the effects of ageing time on the attributes of meat quality aligned with previous research [15] which observed similar trends in meat aged for 3, 6, 9, and 12 days. This consistency across studies underscores the established influence of ageing time on both cooking loss (CL) and shear force, as reported in the literature [30]. This current study investigated the effects of post-slaughter ageing (4, 8, 12, and 16 days) on meat quality, observing reduced cooking loss (CL) and shear force values. These improvements are attributed to biochemical and physical changes during meat conditioning, specifically the calpain enzyme-mediated breakdown of myofibrillar proteins [34]. This protein breakdown weakens muscle structure, enhancing tenderness and water retention, thus lowering CL. The study demonstrated that finishing practice, slaughter weight attainment period, and ageing duration independently influence meat quality. The high-energy diet fed to bulls on practices P2 and P3 could have impacted glycogen reserves, resulting in lower muscle pH and potentially increased intramuscular fat, which further contributed to tenderness [25, 35]. Tenderness is a critical quality attribute significantly influencing consumer purchasing decisions. The obtained results showed a reduction in shear force values of 44.41 N for pasture-only to 41.71 N for feedlot-finished bulls, and from 48.19 N to 35.21 N for bulls slaughtered at 45 and 75 days of finishing, respectively. These values fall within the acceptable tenderness range (<55 N) established by [36]. The observed similarity in tenderness for grazing only, grazing plus supplementation and feedlot finished bulls might be related to the age of the animals, as young animals generally possess more tender meat than adults due to less developed collagen [37]. The high b\* values (yellowness), suggesting higher intramuscular fat content, further influenced tenderness by affecting light reflection and dispersion [37]. Thus, the data reveals that optimal meat tenderness is achieved when bulls are slaughtered at 75 days of finishing (Figure 3(a)).

Additionally, meat colour significantly has an impact on consumer perception and purchasing decisions, primarily determined by myoglobin concentration. However, consumers generally prefer bright red meat. In the current study, the redness and yellowness values observed across different finishing practices aligned with those reported by [38]. Interestingly, the redness (a\*) value was slightly higher in bulls finished on grazing (P1), suggesting higher myoglobin content. This aligns with findings in Begait lambs [39], where dietary treatments influenced redness values. Variations in myoglobin content and intramuscular fat colour are known to affect beef redness [40]. Bulls slaughtered at different times exhibited higher lightness (L\*) and yellowness (b\*) values, comparable to [38]. Higher L\* values suggest brighter meat colour, possibly due to the red hue. The interaction between finishing practice and the slaughter period on redness colour revealed that bulls finished on practice P3 showed decreased redness in meat over time, while those on practice P1 and P2s exhibited increased meat redness. This is likely due to higher myoglobin oxygenation during exposure to oxygenated gases [41, 42]. The present results highlight the significant impact of dietary composition and finishing regimes on meat colour, with bulls finished on practice P3 exhibiting lesser red meat compared to the brighter red meat of those on practices P1 and P2.

**Conclusions and recommendations**

It is concluded that a 75-day feedlot finishing strategy optimizes beef quality compared to other finishing practices and slaughter durations, representing a valuable approach for beef cattle producers. Furthermore, post-slaughter ageing of meat for 12 days is sufficient to optimize the meat quality attributes across the finishing practices and slaughter periods. Future research is recommended on the assessment of the effects of the tested finishing strategies on the meat fatty acid profiles and consumer health.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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