

RESEARCH ARTICLE

Variation in Carcass Characteristics and Meat Quality among Ugandan Indigenous and Crossbred Cattle

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ABSTRACT

The limited production of tender beef in Uganda is due to reliance on indigenous cattle raised under extensive systems. Crossbreeding with exotic breeds has created diverse genotypes whose beef quality potential is largely unassessed. This study evaluated the carcass and meat quality attributes of five genotypes slaughtered in Uganda: Ankole (A), Boran (B), Ankole × Friesian (A × F), Ankole × Boran (A × B), and a composite breed (Cross of A × B × Bonsmara). Seventy-five steers (9–13 months old) were raised on pasture for 120 days. Postmortem temperature and pH were monitored, and the *m. longissimus thoracis* muscle samples were analyzed for collagen, myofibrillar fragmentation index (MFI), Warner-Bratzler shear force (WBSF), and sensory attributes. A × B and B steers showed heat shortening and higher pH₂₄ and T₂₄ values than other genotypes. Ankole steers had lower carcass grades but longer hind limbs, while Co and B steers exhibited wider hind limbs and higher blockiness indices. Marbling was highest in Co steers and lowest in A steers. A × B and B steers had lower muscle percentage but higher fat cover. Their beef showed greater thawing and cooking losses, higher MFI and WBSF values, and received lower sensory ratings. Postmortem ageing improved tenderness across all genotypes. Adopting ageing practices could enhance Uganda's ability to deliver consistently tender beef to consumers. These findings demonstrate that postmortem ageing significantly improves tenderness across all genotypes, and adopting this practice could help deliver consistently tender beef to consumers.

Keywords: Beef ageing, Beef sensory ratings, Carcass grading, Meat tenderness.

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1. INTRODUCTION

In beef production, producers prioritize carcasses with a high lean-to-bone ratio and moderate fat content for their economic value [1], [2]. Meanwhile, consumers seek meat that is nutritious [3], tender, and provides a satisfying eating experience [4]. To meet market demands, selecting the right cattle breed is crucial, as it significantly affects both carcass and meat quality attributes [5]. In Uganda, the national slaughter stock consists of genetically diverse cattle, including indigenous breeds, exotic dairy and beef cattle, and their crossbreds. Indigenous breeds like the Ankole and Boran (*Bos taurus africanus*) contribute 89% of the national slaughter stock [6]. Ankole

is part of the Sanga group [7], while Boran is a tropical beef breed classified under East African shorthorn zebu. However, these indigenous breeds and their crosses are often viewed as producing inferior carcasses and meat due to their lower carcass weight, reduced marbling, and lower tenderness compared to exotic breeds. To improve these traits, cattle farmers have engaged in indiscriminate crossbreeding between indigenous cattle and beef breeds [8], while commercial ranchers have introduced Bonsmara crosses with Ankole and Boran to enhance productivity [9]. Additionally, unwanted Friesian bulls and culled dairy cows contribute a substantial portion of the beef supply.



Although crossbreds may yield superior carcass and meat quality, they often lack the unique traits of indigenous breeds, such as heat tolerance, parasite resistance, and survival on poor feed. Moreover, the potential of crossbreds compared to indigenous cattle under extensive production systems remains largely unstudied. As Uganda's population grows, shifting consumer preferences, especially within the middle class, along with demands from hotels, fine dining restaurants, and the tourism sector, are driving the demand for higher-quality beef, particularly tender meat. Oil exploration and tourism expansion bring in new clientele willing to pay premium prices for beef that meets their quality standards [10]. This rising demand for both quantity and quality make it essential to evaluate the beef production potential of the country's major cattle genotypes. Therefore, this study aims to investigate the postmortem physiochemical characteristics, morphological measurements, carcass composition, tenderness, and sensory attributes of different cattle genotypes raised on natural pastures.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

This study was conducted at Betar Ranchers, a private ranch located in Mubende district, within Uganda's cattle corridor in central Uganda. The ranch is situated at 1300 m above sea level, along the coordinates 31° 40' E and 00° 30' N. The region experiences an annual rainfall ranging from 850 mm to 1300 mm, with two distinct rainy seasons occurring between April–May and September–December. The area's annual temperatures range from 15°C to 28°C. The ranch's pastures consist of a variety of natural grass species, including *Sporobolus africanus*, *Panicum maximum*, *Themeda triandra*, *Chloris gayana*, and *Brachiaria brizantha*, with *Acacia nilotica* being the predominant shrub species.

2.2. Experimental Animals and Management

The study involved 15 steers from each of the following genotypes: Ankole (A), Boran (B), Ankole × Friesian (A × F), and Ankole × Boran × Bonsmara (Composite), with an average age range of 9 to 13 months. At the onset of the experiment, all steers were treated for internal parasites, while external parasites were controlled by dipping the cattle every two weeks throughout the experimental period. The animals grazed rotationally in paddocks that were specifically set aside for research purposes. They had free access to water and rock salt. The experiment lasted for 120 days. One day prior to slaughter, the steers were transported by truck to the Uganda Meat Institute's abattoir, where they were fasted overnight with no access to feed, though water was provided ad libitum.

2.3. Slaughter and Sample Extraction

The steers were humanely slaughtered in a commercial abattoir following halal procedures. After slaughter, the carcasses were hung at room temperature until their pH

dropped to 6.2, after which they were transferred to a chilling room at +4°C. Temperature and pH were measured at 45 minutes, 2 hours, 6 hours, 12 hours, and 24 hours postmortem, using a portable pH meter (Knick, Elektronische Messgeräte GmbH & Co.) with a penetrating electrode placed in the Longissimus thoracis muscle on the right side of the carcass.

At 48 hours postmortem, the Longissimus thoracis muscle between the 7th and 12th ribs was excised from the left side of each carcass and divided into four 8 cm samples for Warner-Bratzler shear force and sensory analysis. Samples intended for sensory analysis were immediately stored in a freezer at −18°C, while those for Warner-Bratzler shear force were aged at 4°C for 2, 7, and 14 days. After aging, all samples were transferred to a deep freezer at −18°C until further analysis.

2.4. Carcass Grading, Fat, and Marbling Scoring

Carcasses were graded, and fat was scored by an expert from the Uganda Meat Industries (UMI), following the guidelines described by De Boer *et al.* [11]. Marbling was scored using a hedonic scale from 1 to 5, as adopted from Sami *et al.* [12].

2.5. Morphometric Measurements, Carcass Composition, and Ribeye Area Estimation

Morphological measurements were taken 48 h postmortem on the left-hand side of the carcasses following procedures described by De Boer *et al.* [13]. Carcass blockiness index was computed using formula, blockiness index = Hot carcass weight/carcass length [14]. Carcass composition was estimated using the 6th rib following procedures described by Robelin and Geay [15]. The 6th rib was collected at 48 h postmortem from the right-hand side of each carcass, weighed and dissected into individual components of subcutaneous fat, intramuscular fat, lean muscle, bones and other tissues (e.g., ligaments, tendons). The results were expressed as percentages of the total rib weight. Ribeye area (REA) was estimated using the method described by Johnson and Baker [16].

2.6. Myofibrillar Fragmentation Index Determination

The myofibrillar fragmentation index (MFI) was determined using the procedure developed by Davis *et al.* [17]. Briefly, the epimysial tissue and subcutaneous fat were removed from the frozen samples. Cubes weighing approximately 10 g were placed in 100 ml stainless steel homogenization cups in duplicate. Each cup received 50 ml of a cold solution containing 0.25 M sucrose and 0.02 M KCl, and the cubes were allowed to thaw. After thawing, the cubes were homogenized for 45 seconds at full speed using a Virtis homogenizer (Model 45, 16-2000). The homogenates were filtered through a 250 µm nylon monofilament cloth, and the resulting fraction (muscle fragments larger than 250 µm) was blotted dry on Whatman No. 3 filter paper at 25°C for 40 minutes. The net fraction weights were recorded, and the MFI was calculated as:

$$MFI = \text{Net fraction weight (g)} \times 100$$

where *MFI* values range from 100 (extremely fragmentable) to 600 (extremely unfragmentable).

2.7. Thawing, Cooking Loss, and Warner-Bratzler Shear Force Measurements

For Warner-Bratzler shear force (WBSF) determination, samples were first weighed and then thawed in a refrigerator at +4°C for 18 hours. After thawing, the samples were wiped clean and re-weighed to calculate the percentage of thawing loss (the difference in weight before and after thawing, expressed as a percentage of the weight before thawing). Samples were cooked in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) set at 75°C for 60 minutes. After cooking, they were cooled under running tap water for 10 minutes, wiped clean, and re-weighed to calculate the percentage of cooking loss (the difference in weight before and after cooking, expressed as a percentage of the pre-cooked weight). Muscle cubes measuring 1 cm × 1 cm × 5 cm in the direction of the muscle fibers were prepared from each sample. Warner-Bratzler shear force was measured using a Zwick/Roell (Z2.5, German) instrument equipped with a triangular slot cutting edge (1 mm thick) to shear through the muscle cubes at a right angle to the muscle fibers. Each sample was measured by averaging the peak shear force of five cubes, each sheared twice. Sensory attributes were assessed by a nine-member trained panel, following the guidelines of the American Meat Science Association [18].

2.8. Statistical Analysis

The effects of genotype on carcass characteristics, postmortem physiochemical traits, morphometric measurements, carcass composition, tenderness, and sensory attributes were analyzed using Generalized Linear Procedures in SAS [19]. Significant differences between least square means were compared using the PDIFF test in SAS [19].

3. RESULTS

3.1. Carcass Characteristics and Morphometric Measurements

Except for carcass weight, all measured traits showed significant variation among the genotypes (Table I). Carcass grades ranged from 4.6 for Ankole (A) steers to 5 for the composite (Co) steers. The A × B and Boran (B) steers exhibited significantly higher fat cover scores ($P < 0.001$) compared to the other genotypes. Marbling scores were highest in Co steers, followed by A × B, with the lowest scores observed in A steers. Carcasses from A steers were longer ($P < 0.01$) and had longer hind limbs ($P < 0.001$) than those from the other genotypes. In contrast, Co and B steers had wider hind limbs and chests ($P < 0.05$ and $P < 0.01$, respectively), along with higher blockiness indices ($P < 0.001$) compared to the other genotypes. The total muscle percentage followed a descending order, with Co steers showing the highest percentage, followed by A × Friesian (A × F), A, B, and A × B steers. Subcutaneous fat

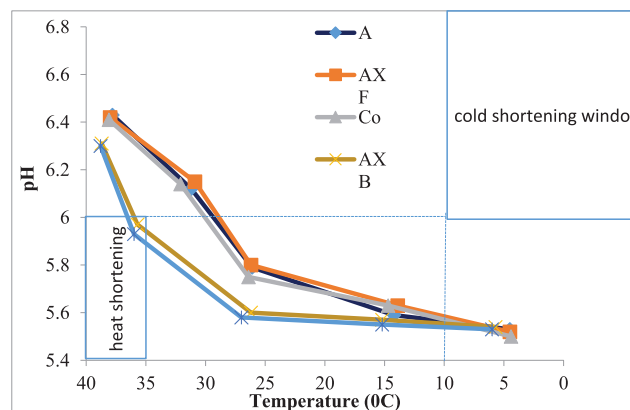


Fig. 1. Genotypic effects on pH/temperature decline profiles of A, A × F, Co, A × B and B steers.

percentage was significantly higher ($P < 0.01$) in A × B and B steers than in A, A × F, and Co steers. Additionally, A × F steers exhibited significantly lower intramuscular fat ($P < 0.001$) compared to A, A × B, B, and Co steers.

3.2. pH and Temperature Decline Profiles

Initial pH and pH24 values were lower ($P < 0.001$) in carcasses from A × B and B steers compared to those from A, A × F, and Co steers (Fig. 1). Carcasses from A × B and B steers also exhibited higher ($P < 0.001$) initial temperatures and temperatures at 24 hours postmortem than those from A, A × F, and Co steers. The pH and temperature decline rates in A × B and B carcasses were similar ($P > 0.05$), but both declined faster ($P < 0.001$) than in A, A × F, and Co carcasses. No differences ($P > 0.05$) in temperature or pH decline rates were observed among carcasses from A, A × F, and Co steers. At pH ≤ 6, mean muscle temperatures significantly differed ($P < 0.001$), with carcass temperatures around 26.1°C, 26.2°C, 26.4°C, 35.7°C, and 36.0°C for A, A × F, Co, A × B, and B steers, respectively. Carcasses from A × B and B steers fell within the heat shortening window (pH < 6 and T > 35°C).

3.3. Genotypic and Aging Effects on Thawing, Cooking Loss, MFI and WBSF

Percent thawing and cooking losses were significantly higher ($P < 0.001$) in A × B and B steers compared to the other genotypes (Table II). As the ageing period increased from 2 to 14 days, both thawing and cooking losses significantly decreased ($P < 0.001$) across all genotypes. A × B and B steers also exhibited higher MFI values, which corresponded to higher ($P < 0.001$) WBSF values than those observed in A, A × F, and Co steers. Genotypes showed a varied response to ageing, with MFI reductions of 13.6%, 12.2%, 12.1%, 7.9%, and 6.1% for Co, A, A × F, A × B, and B steers, respectively, from two to 14 days of ageing. The effects of genotype on WBSF values followed the MFI trend, with A × B and B steers showing higher ($P < 0.001$) WBSF values than the other genotypes. Differential reductions in WBSF due to ageing were also observed, with decreases of 35.3%, 30.4%, 29%, 24.8%, and 23.3% for Co, A, A × F, A × B, and B steers, respectively, over the two to 14 day ageing period.

TABLE I: LEAST SQUARE MEANS OF CARCASS CHARACTERISTICS, MORPHOMETRIC MEASUREMENTS, AND TISSUE COMPOSITION OF ANKOLE, ANKOLE × FRIESIAN, COMPOSITE, ANKOLE × BORAN AND BORAN STEERS

Trait	Genotype					Sig. level
	A	A × B	A × F	Co	B	
<i>Carcass characteristics</i>						
Hot carcass weight (kg)	128.6 ^a	129.3 ^a	130.8 ^a	131.0 ^b	130.0 ^a	0.08
Carcass grade	1.7 ^a	3.0 ^b	2.1 ^a	3.1 ^b	2.9 ^b	0.01
Fat cover score	2.4 ^a	3.1 ^b	2.5 ^a	3.0 ^b	3.2 ^b	0.01
Marbling score	2.1 ^a	2.1 ^a	2.0 ^a	2.7 ^b	2.1 ^a	0.002
<i>Carcass characteristics</i>						
Carcass length	115.4 ^a	97.6 ^b	113.9 ^a	100.8 ^a	97.7 ^b	0.001
Hind limb length (cm)	4.8 ^a	3.9 ^b	3.9 ^b	4.1 ^b	3.8 ^b	0.001
Hind limb width (cm)	2.7 ^a	4.0 ^b	3.3 ^c	3.4 ^c	4.1 ^b	0.01
Blockiness index	1.1 ^a	1.3 ^b	1.2 ^a	1.2 ^a	1.3 ^b	0.001
L.D area	0.20	0.26	0.2	0.31	0.27	0.002
<i>Tissue composition</i>						
Rib weight (g)	1196.9 ^a	1385.2 ^b	1122.2 ^a	14401.2 ^b	1390.1 ^b	0.01
Total muscle (%)	65.7 ^a	62.9 ^b	66.3 ^a	69.0 ^c	63.7 ^b	0.03
Subcutaneous fat (%)	2.3 ^a	4.9 ^b	2.1 ^a	2.1 ^a	4.5 ^b	0.01
Intramuscular fat (%)	5.0 ^a	5.5 ^a	5.1 ^a	5.4 ^a	5.0	0.001
Total bone (%)	19.2 ^a	19.0 ^b	19.0 ^a	16.1 ^c	19.1 ^a	0.03
Other tissues (%)	7.7 ^a	7.7 ^a	7.5 ^a	7.4 ^a	7.7 ^a	0.07

Note: ^{a,b,c}Means within a row with different superscripts are significantly. A (Ankole), A × F (Ankole × Friesian), A × B (Ankole × Boran), B (Boran), Co (Composite).

TABLE II: LEAST SQUARE MEANS OF THAWING LOSS, COOKING LOSS, MFI AND WBSF VALUES OF GRAZED ANKOLE, ANKOLE × FRIESIAN, COMPOSITE, ANKOLE × BORAN AND BORAN STEERS AGED FOR 2, 7 AND 14 DAYS

Trait	Genotype					Sig. level
	A	A × B	A × F	Co	B	
Thawing loss_2 ^a	2.33 ^a	2.42 ^b	2.38 ^c	2.36 ^c	2.58 ^d	0.001
Thawing loss_7 ^b	2.18 ^a	2.28 ^b	2.18 ^a	2.17 ^a	2.43 ^c	0.002
Thawing loss_14 ^c	2.05 ^a	2.15 ^b	2.04 ^a	1.92 ^d	2.39 ^c	0.01
Cooking loss_2 ^d	23.2 ^a	24.8 ^b	24.0 ^c	24.3 ^{bc}	26.7 ^d	0.001
Cooking loss_7 ^e	20.5 ^a	21.2 ^b	20.7 ^a	20.1 ^a	23.5 ^c	0.001
Cooking loss_14 ^f	17.7 ^a	19.3 ^b	17.9 ^a	18.8 ^b	21.1 ^c	0.001
MFI_2 ^g	396.8 ^a	425.9 ^b	394.9 ^a	374.5 ^c	450.6 ^d	0.005
MFI_7 ^h	367.2 ^a	410.6 ^b	365.9 ^a	337.5 ^c	434.5 ^d	0.003
MFI_14 ⁱ	347.2 ^a	392.3 ^b	346.8 ^a	323.5 ^c	422.5 ^d	0.001
WBSF_2 ^j	69.4 ^a	79.9 ^b	68.9 ^a	69.7 ^a	80.4 ^c	0.01
WBSF_7 ^k	54.7 ^a	68.8 ^b	54.6 ^a	54.5 ^a	71.5 ^c	0.002
WBSF_14	48.3 ^a	60.1 ^b	48.9 ^a	47.1 ^a	61.7 ^c	0.001

Note: ^{a,b,c,d}Means within a row with different superscripts are significantly different ($P < 0.05$), A (Ankole), A × F (Ankole × Friesian), A × B (Ankole × Boran), B (Boran), Co (Composite). ^{a, b and c}Thawing loss at 2, 7 and days of ageing, respectively. ^{d, e and f}cooking loss at 2, 7 and 14 days of ageing, respectively. ^{g, h and i}MFI Myofibrillar fragmentation index at 2, 7 and 14 days of ageing, respectively. ^{j, k and l}Warner-Bratzler shear force at 2, 7 and 14 days of ageing.

ratings for all attributes, while A × B and B steers received the lowest ratings.

3.4. Sensory Attributes and Collagen Characteristics

Collagen characteristics varied significantly among the cattle genotypes (Table III). Total collagen content was highest in A × F steers, followed by B, A × B, and lowest in A. Additionally, A × B and B steers had significantly higher ($P < 0.001$) insoluble collagen content compared to the other genotypes. Composite steers exhibited the highest percentage of soluble collagen, followed by A, A × F, and the lowest levels in A × B and B steers. Genotypic effects ($P < 0.001$) were evident in all sensory attributes assessed (Table III). Beef sensory ratings showed a descending order, with Co steers receiving the highest

4. DISCUSSION

Carcass weight is influenced by growth rate, and maturity size of specific cattle genotypes [5], [20]. In this study, we found that indigenous Ankole steers raised on natural pastures can produce carcasses comparable in weight to those from exotic breeds, highlighting the Ankole's ability to perform well under such conditions without crossbreeding. This challenges the assumption that exotic breeds have superior performance under natural pasture conditions, suggesting that their perceived advantage is not fully realized in these settings. However, carcasses from

TABLE III: LEAST SQUARE MEANS OF COLLAGEN CHARACTERISTICS AND SENSORY ATTRIBUTES OF GRAZED ANKOLE, ANKOLE × FRIESIAN, COMPOSITE, ANKOLE × BORAN AND BORAN STEERS

Trait	Genotype					Sig. level
	A	A × B	A × F	Co	B	
<i>Collagen characteristics</i>						
Total collagen (mg/g wet tissue)	2.61 ^a	3.41 ^b	4.01 ^c	2.71 ^a	3.52 ^b	0.07
Insoluble collagen (mg/g wet tissue)	1.95 ^a	2.3 ^b	1.93 ^a	1.92 ^a	2.4 ^b	0.001
Soluble collagen (%)	25.3 ^a	22.3 ^b	25.6 ^a	26.2 ^c	22.7 ^b	0.002
<i>Sensory attributes</i>						
Tenderness	5.6 ^a	4.5 ^b	5.7 ^a	6.5 ^c	4.0 ^b	0.01
Juiciness	5.5 ^a	4.0 ^b	5.4 ^a	7.0 ^b	3.9 ^b	0.001
Flavour	5.5 ^a	4.1 ^b	5.3 ^a	6.2 ^c	4.0 ^b	0.0002
Palatability	6.4 ^a	5.0 ^b	6.3 ^a	6.5 ^a	4.9 ^b	0.0001
Acceptability	6.8 ^a	5.1 ^b	6.5 ^a	6.8 ^a	4.9 ^b	0.001

Note: ^{a,b,c,d}Means within a row with different superscripts are significantly different ($P < 0.05$). A (Ankole), A × F (Ankole × Friesian), A × B (Ankole × Boran), B (Boran), Co (Composite).

Ankole steers had lower grades, fat, and marbling scores compared to Boran, Ankole × Friesian, and Composite steers. This may be due to the Ankole's adaptation to long-distance movement [21], which leads to reduced muscle filling around the hindquarters, longer hind limbs, and less subcutaneous fat—all of which negatively affect carcass grades, fat, and marbling scores [22].

Ankole × Boran and Boran steers exhibited rapid pH declines while their carcass temperatures remained high, placing them within the heat-shortening window (pH < 6 at $T > 35^{\circ}\text{C}$) [23], [24]. This could be due to the heavy deep muscles and high subcutaneous fat around the hindquarters, which hinder heat dissipation while glycolytic potential remains elevated. Despite having carcass weights similar to the other genotypes, Boran and Ankole × Boran steers had lower dissectible muscle percentages and higher subcutaneous fat. A decrease in lean muscle yield percentage is typically observed in carcasses with high subcutaneous fat [25]. In contrast, feedlot-finished Brazilian beef steers showed increased muscle yields with higher subcutaneous fat [26], suggesting that differences in finishing systems, such as feedlot vs. natural pasture grazing, may explain the discrepancies.

Thawing and cooking losses are measures of water-holding capacity, which reflects water attraction to myofibrillar proteins [27]. Water-holding capacity is inversely related to thawing and cooking loss values and directly linked to pH decline during postmortem glycolysis [28], [29]. The higher thawing and cooking losses in Ankole × Boran and Boran steers can be attributed to their more rapid pH decline compared to other genotypes. Huff-Lonergan *et al.* [30] noted that rapid pH decline leads to an ultimate or near-ultimate pH while muscles are still warm, resulting in protein denaturation, including water-binding proteins. Consequently, this leads to low water-holding capacity and elevated thawing and cooking losses. The heat-shortening experienced by carcasses from Ankole × Boran and Boran steers could also contribute to higher water loss, as heat-shortening reduces sarcomere length and myofibrillar lattice space, mobilizing water from intra- to extra-myofibrillar spaces [31]. Over time, water-holding capacity improved with aging, as evidenced by reduced thawing and cooking losses. This may be

due to increased myofibrillar protein degradation during aging, which allows muscle cells to swell and retain more water [29].

The myofibrillar fragmentation index (MFI), which measures myofibril breakdown by calpain enzymes, reflects the extent of meat tenderization [32]. Genotypic effects on MFI suggest differences in postmortem myofibril degradation. The higher MFI values observed in Ankole × Boran and Boran steers, indicative of less fragmented muscle fibers [33], suggest minimal postmortem calpain activity compared to other genotypes. *Bos indicus* breeds, including Borans, have elevated calpastatin levels, which inhibit calpain activity [34], leading to minimal postmortem myofibril degradation [34], [35]. Additionally, heat-shortening experienced by these steers likely reduced proteolytic enzyme activity. In contrast, similar MFI reductions in Ankole, Ankole × Friesian, and Composite steers suggest comparable levels of proteolytic activity. This genetic regulation of proteolysis is tied to calpain and its inhibitor calpastatin, encoded by the CAPN1 and CAST genes [36]. Sanga cattle, including Ankole and Bonsmara, are known to possess favorable CAPN1 and CAST gene combinations [7]. Recent findings revealed that Ankole cattle possess unique genes such as CAPZB, COL9A2, and MAP3K5, which enhance postmortem myofibrillar degradation [7], further demonstrating their potential to produce tender beef comparable to established beef breeds like Bonsmara.

Warner-Bratzler shear force (WBSF) is a key indicator of meat tenderness, where higher WBSF values denote tougher meat [37]. At two days postmortem, WBSF values for the five genotypes classified their meat as “intermediate” in tenderness [38], challenging the general perception that indigenous breeds produce tougher meat. After seven days of aging, beef from Ankole, Ankole × Friesian, and Composite steers reached WBSF values of $\leq 55\text{N}$, considered tender by consumer standards [39]. In Uganda, where beef is typically sold without aging [40], these results suggest a need for change. With growing demand for tender beef from the expanding middle class and foreign clients in oil exploration and tourism, postmortem aging should become a standard practice in slaughterhouses to meet consumer expectations.

Collagen, a key factor influencing meat tenderness, varies across cattle breeds. Bos indicus breeds, including Zebus, have high thermo-stable collagen and lower soluble collagen percentages [33], [41]. This may explain the low soluble collagen in Ankole × Boran and Boran steers, while Composite steers exhibited the highest levels of soluble collagen. High soluble collagen is typical of established beef breeds like Aberdeen Angus [42], and the Bonsmara lineage in the Composite steers likely contributed to this trait.

Sensory attributes such as tenderness and juiciness are inversely related to MFI, shear force, and water-holding capacity [37], [43]. Lower sensory ratings for Ankole × Boran and Boran steaks, compared to Ankole, Ankole × Friesian, and Composite steaks, corresponded with higher MFI, shear force, and cooking losses, likely due to heat-shortening effects. Heat-shortening reduces proteolysis and increases fiber shrinkage, leading to tougher and drier meat [28], [29]. Additionally, the higher insoluble collagen levels in these steers contributed to the lower tenderness ratings [44].

5. CONCLUSION

In conclusion, this study highlights significant variations in beef quality among the different cattle genotypes, driven by factors such as pH, temperature profiles, collagen solubility, and myofibrillar degradation. While Boran and Ankole × Boran steers produced less tender beef with lower sensory ratings, Ankole cattle exhibited desirable tenderness and eating quality comparable to Friesian and Bonsmara crossbreds, attributed to their high collagen solubility and myofibril degradability. Furthermore, the genotypes showed differing responses to a 14-day aging period, emphasizing the importance of postmortem proteolytic enzyme activity in enhancing meat tenderness. These findings underscore the necessity for the Ugandan beef industry to adopt postmortem aging practices to cater to the increasing demand for tender beef, reflecting the evolving preferences of consumers.

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DECLARATION OF COMPETING INTERESTS

Authors have no relevant financial or non-financial interests to disclose.

AUTHOR CONTRIBUTION

Kamatara Kanifa Conceptualization, investigation, data curation, visualization, writing original draft, review and editing. Mpairwe Denis: Supervision, Resources, Project administration, Conceptualization, Writing-review & editing. Mutetika David: Supervision, Writing-review & editing. Asizua Denis Investigation, Writing-

review & editing. Nampijja Zainah Writing-review & editing. Kiggundu Muhammad Writing-review & editing. Nampanzira Dorothy. Lutwama Vincent Writing-review & editing. Nasaka Joweria Writing-review & editing. Nalubwama Sylvia Writing-review & editing. Madsen J: Supervision, Resources, Grant management, Project administration, Conceptualization.

DATA STATEMENT

Data used for this study can be made available by the corresponding author on reasonable request.

ETHICAL APPROVALS

The study was approved by the Higher degrees committee of the School of Agriculture Science, College of Agriculture and Environmental Science.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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