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Research Article

Effect of cattle age on the physio-chemical properties of beef

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Abstract

This study, conducted at Bangladesh Agricultural University, examined how the age of indigenous cattle affects beef quality, focusing on the Longissimus dorsi muscle. The cattle were divided into three age groups: 1.5 years, 2 years, and 2.5 years. Various physical and chemical properties of the meat were analyzed, including pH levels, drip loss, tenderness, cooking loss, water holding capacity (WHC), and chemical composition. The study found that pH levels measured at both 0- and 24-hours post-slaughter showed no significant differences between age groups, and all values were within the normal range, indicating that pH did not impact meat quality. However, drip loss was significantly higher in the 2.5-year-old cattle (3.15%), suggesting that older cattle lose more water from their muscle fibers, which could affect meat texture and juiciness. In terms of tenderness, measured by shear force, the 2.5-year-old cattle were the toughest (52.5 N), while the 1.5-year-olds were the most tender (38.86 N). The 2-year-old cattle were in between. The tenderness improved for the 1.5-year-olds after 24 hours, while the 2.5-year-olds maintained their tougher texture. The 2.5-year-old cattle also had higher cooking loss, meaning they lost more moisture during cooking, which could result in less juicy meat. In contrast, the 1.5-year-old cattle had lower cooking loss, aligning with consumer preferences for more tender and juicy beef. The 1.5-year-olds also exhibited higher WHC (5.64%), which likely contributed to their superior tenderness and juiciness. Chemical analysis revealed that the 1.5-year-olds had the highest moisture content (75.89%), while the 2.5-year-olds had higher protein (22.37%) and ash content, reflecting a more developed muscle structure.

Introduction

Livestock being one of the four components of agriculture (crops, livestock, fisheries and forestry) contributing 16.33% of agricultural GDP (DLS, 2023). The average per capita meat consumption is 42.1 kg/year in the world. Per capita meat consumption of developed and developing world is 82.9 and 31.1 kg/year, respectively (FAO, 2009). Meat consumption of people of Bangladesh is 44gm/person on daily basis (DLS, Economic Review-2023-2024). Meat has the appeal for being nutritious and it is highly attractive in appearance (Akter et al., 2009; Akhter et al., 2009; Azad et al., 2021; Hossain et al., 2022a, 2022b, 2023). There are different kinds of meat depending on the source from which they are obtained, for example, mutton from sheep, chevon from goat, beef from cattle, and chicken from birds. The majority population in Bangladesh is Muslim. Beef has the highest priority for preferential meat consumption. Besides safety and nutritional content, beef consumers expect a satisfying eating experience. This means that beef and especially premium beef cuts must embrace a series of characteristics in flavor, texture, tenderness, juiciness and appearance in order to meet consumer expectations (Chakrabartty et al., 2024; Sagar et al., 2024; Torun et al., 2023; Tushar et al., 2023; Troy and Kerry, 2010). These characteristics, which together determine the overall eating quality of beef, are affected by several factors, typically classified as: intrinsic and extrinsic (Gagaoua et al., 2018; Mobin et al., 2022; Rahman et al., 2023; Sadakuzzaman et al., 2024; Sagar et al., 2024; Sarkar et al., 2008; Sarker et al., 2021). Thus, variations in these factors may cause unpredictable eating experiences that can lead to consumer disappointment, and even dissatisfaction (McCarthy et al., 2017). In Bangladesh, beef usually comes from the non- reproductive cows, unproductive aged bullocks and culled animals from our country or partly from the neighboring country, India. Beef is considered as a high source of animal protein. Chemically meat composed of water, protein, fat, ash and carbohydrate. The nutritional feature of meat, which provide consumer demand for protein, some vitamins and certain minerals. However, as most of the cattle in Bangladesh slaughtered at later stage of their life therefore it is important to know how age of the cattle. Numerous factors influence beef quality, including genetics, feeding practices, environmental conditions, and management strategies (Begum et al., 2007; Mia et al., 2023; Hasan et al., 2022). However, one of the most significant determinants is the age of the cattle at slaughter. Age not only affects the growth and development of the animal but also has profound implications for the quality of the meat produced (Chakrabartty et al., 2024). As cattle mature, physiological and biochemical changes occur that can impact several qualities parameters, including drip loss, pH, and shear force. lower pH range of about 5.3 to 5.6, which is associated with better water retention and tenderness (Huff-Lonergan and Lonergan, 2005). As cattle age to around 1.5 years, the pH can rise slightly to approximately 5.6 to 5.8, which may begin to affect the meat's texture and juiciness (Campo et al., 2006).

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In older cattle, pH levels often increase further, reaching between 5.8 to 6.2 or higher, resulting in tougher meat with reduced quality due to higher ultimate pH levels often linked to physiological stress and delayed rigor mortis. These pH variations highlight the importance of age as a critical factor in determining beef quality. Drip loss, a measure of moisture lost during storage and processing, significantly impacts the juiciness and flavor of meat. Studies indicate that older cattle exhibit higher drip loss due to increased muscle fiber diameter and altered protein structures. The pH level of meat post- mortem is another critical factor, with lower pH typically indicating better water retention and quality. However, older cattle often have a higher ultimate pH due to physiological stress, negatively affecting water-holding capacity. Shear force value, a measure of tenderness, is largely influenced by muscle fiber characteristics and connective tissue composition. Research shows that older animals tend to have higher shear force values due to increased collagen cross- linking, making the meat tougher (Maltin et al., 2003). In contrast, younger cattle generally exhibit lower shear force values, indicating greater tenderness, which is more desirable in the marketplace (Wheeler et al., 1994). The cooking loss of meat is significantly influenced by the age of cattle, primarily due to variations in muscle composition and water-holding capacity. Younger cattle generally exhibit lower cooking loss, resulting in juicier and more tender meat, as their muscle fibers have a higher moisture content and less connective tissue (Rhee et al., 2004).In contrast, as cattle age, the increased collagen content and thicker muscle fibers contribute to higher cooking losses, making the meat drier and tougher after cooking (Hwang et al., 2010). Studies indicate that older beef cuts tend to shrink more during cooking, largely due to their lower water-holding capacity and greater fat content, which can render out during the cooking process (Miller et al., 2017). The age of cattle significantly affects the water-holding capacity and proximate composition of meat, which are critical determinants of meat quality. Younger cattle typically produce meat with higher moisture content and improved tenderness, largely due to lower levels of connective tissue and a more favorable muscle fiber composition. As cattle age, there is an increase in collagen and intramuscular fat, which can enhance flavor but may decrease water-holding capacity, leading to a drier product (Dutson et al., 1986). Proximate analysis often shows that meat from younger animals has a higher percentage of protein and moisture, while older animals tend to yield meat with more fat and less water, affecting its juiciness and overall palatability. Based on the decision above, we can outline the following objectives for the experiments: This present study aims to explore the impact of cattle age on key quality parameters: drip loss, pH, shear force values, cooking loss, water holding capacity and proximate analysis of meat and a comprehensive analysis of how these parameters change with age, offering insights into the underlying biochemical and structural mechanisms.

Materials and Methods

Place of Experiment:

The experiment was conducted in the laboratory of the Department of Animal Science at Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

Collection of Sample

Longissimus Dorsi (LD) muscle was taken as samples. I purchased only healthy animal. It looked good for the experiment. We made sure its health condition.

Experimental Layout

The meat samples were used to examine physical properties. Drip loss, pH, share force, cooking loss, water holding capacity and proximate analysis of meat were examined as physical properties. Determining drip loss, pH, and shear force values in beef at different ages involves specific methodologies. Nine samples of longissimus dorsi muscle of nine indigenous beef cattle were obtained from 1.5, 2- and 2.5-years age beef cattle (age evaluated through dentition stage) with three replications of each age group. The experiment conducted on August 15, 2024.

Analysis of Different Characteristics of raw chicken meat Samples in the Laboratory

Physical Properties

The pH of beef was measured using a HANNA Meat pH Meter, following a detailed process to ensure accurate and reliable results. First, the pH meter was calibrated by immersing the probe in pH 4.0 and pH 7.0 buffer solutions, adjusting the meter accordingly. Prior to the first measurement, the probe was soaked in HI 70300 storage solution for about an hour to reactivate it. After calibration, the probe was rinsed with distilled water and then immersed in the homogenized meat sample, ensuring it did not touch the sides of the container. The pH meter displayed the pH value on the primary LCD, with the secondary LCD showing the temperature of the sample, which was automatically compensated for. The pH measurement was recorded once the reading stabilized. The beef sample was carefully prepared by selecting a representative cut, trimming excess fat and connective tissue, and weighing approximately 10 grams of the trimmed meat. The sample was then homogenized by blending it with 90 mL of distilled water to create a slurry. The mixture was blended thoroughly to ensure uniformity. Temperature was measured to account for any effects on the pH reading. After each measurement, the probe was cleaned with distilled water to avoid contamination between samples. The process was repeated for multiple samples (at least 3-5) from different areas of the cut to obtain an average pH value. This ensured a comprehensive analysis of the beef's pH, which is important for assessing meat quality and freshness. The results from different regions of the sample were averaged to minimize any inconsistencies and provide a reliable pH value for the beef.

Drip loss refers to the moisture released from meat during storage and is an important measure of meat quality. To assess drip loss in beef, samples of fresh beef cuts, such as the longissimus dorsi muscle, were prepared and stored under controlled conditions. The meat was first trimmed to remove excess fat and connective tissue, ensuring that only muscle tissue was analyzed. Each trimmed meat sample was weighed (Weight 1) using a digital scale to obtain an initial weight. The meat samples were then placed in inflated polythene bags, which were sealed tightly to prevent moisture escape and air entry. The inflated bags helped to minimize direct contact between the meat and the bag, allowing the moisture released from the meat to drip into the container below. The bags were suspended in a refrigerator set to 4°C (39°F) for a 24-hour period to allow for moisture loss. During this time, the meat samples rested while any dripping moisture was collected in the container. After the designated 24 hours, the bags were carefully removed from the refrigerator. The collected drip loss was noted, and the meat was weighed again (Weight 2) to determine the final weight. Drip loss was calculated as the percentage of weight lost due to moisture release. This procedure provided a detailed and accurate measure of drip loss, which is critical for understanding the moisture retention properties of beef and its overall quality after storage.

The Warner-Bratzler shear test is a method used to measure the tenderness of beef muscle by determining the shear force required to cut through a sample. To perform the test, freshly obtained beef cuts, such as loin, rib, or round, are prepared by trimming excess fat and connective tissue to ensure only muscle fibers are tested. The meat is then cut into standardized portions with a typical size of about 2.5 cm (1 inch) thick and 3 cm (1.2 inches) wide, with the muscle fibers aligned perpendicular to the cut to ensure accurate shear force measurement. The samples are allowed to reach room temperature (20-25°C) before testing to maintain consistency. The next step involves setting up a texture analyzer equipped with a Warner-Bratzler shear blade, which is calibrated according to the manufacturer's instructions. The software controlling the device is configured to set the pre-test, test, and post-test speeds, as well as the distance to be cut based on the sample thickness. The beef sample is placed on the base of the texture analyzer, and the shear blade is lowered to measure the force required to cut through the meat. The data generated is a force vs. distance curve, and the peak force represents the maximum shear force required to cut the sample. For accurate results, it is recommended to test multiple samples from each cut, typically 5-10, to obtain a reliable average shear force value. Regular maintenance of the Warner-Bratzler blade, consistent sample dimensions, and control of the testing environment's temperature are important factors to ensure precise and reproducible results. This method provides valuable insights into meat tenderness, which is crucial for assessing meat quality and consumer preference.

The cooking loss for treated chilled and frozen meat was determined as the percentage weight loss after cooking in an electric grill with double pans (Nova EMG-533, 1,400W, Evergreen Enterprise, Yongin, Korea) for 60 s until it reached the internal temperature of the meat sample at 72℃ with the standardized of cuts sample (30×50×10 mm). Shortly, for cooking loss, samples with an average weight of 100±5 g covered with polypropylene bags were heated for 30 min in a water bath at 95℃ and cooled for 30 min with ice-cool water. Recorded the weight before and after heating and cooling and calculated the yield percentage.

The Water Holding Capacity (WHC) of meat, particularly cooked beef, is a critical indicator of its ability to retain moisture, which directly affects texture and juiciness. The procedure for measuring WHC, following the method described by Uttaro et al. (1993) with minor modifications, involves several steps. First, a 5-gram sample of beef is cooked using the desired method, ensuring it is not overcooked. Once the beef is cooked, it is allowed to cool for a few minutes before being weighed to record its initial weight. The cooked beef is then placed on a paper towel or clean cloth, where gentle pressure is applied to remove any excess surface moisture. The sample is weighed again after draining to obtain the initial weight after draining. Next, the drained sample is submerged in water and left to soak for a period of 1 to 2 hours. After the soaking period, the sample is removed, drained, and weighed again to determine the final weight after rehydration. The WHC is calculated by finding the difference between the final weight after rehydration and the initial weight after draining, then expressing this difference as a percentage of the initial draining weight. In addition to these steps, to assess WHC under chilled and frozen conditions, a 5-gram sample is subjected to centrifugation at 4°C for 10 minutes at 123×g. The weight of the meat is measured after centrifugation to evaluate moisture retention under different storage conditions. Overall, this method provides valuable insights into how much water meat retains during cooking and rehydration, offering a reliable measure of meat quality and its potential for delivering juiciness and tenderness to consumers.

Chemical Properties

Proximate analysis is used to determine the chemical composition of meat samples, specifically focusing on moisture, protein, ether extract (lipids), and ash content. To measure moisture**,** a 5-gram sample is placed in a porcelain crucible, heated at 105°C for 24 hours, and the loss in weight is calculated as the percentage of moisture. Protein content is determined using the Micro-Kjeldahl method, where nitrogen is released from the meat sample through digestion with sulfuric acid and other reagents, then distilled and titrated to calculate crude protein by multiplying the nitrogen content by a factor of 6.25. For ash content, the sample is heated at 550°C for 6 hours in a muffle furnace, and the remaining material is weighed to determine the percentage of ash. Ether extract, representing lipid content, is measured by extracting the fat from a 2-gram sample using a Soxhlet apparatus with ether. The sample is dried, and the lipid content is calculated as a percentage. These analyses provide essential insights into the nutritional composition and quality of the meat.

Moisture content was determined by placing an accurately weighed known amount sample (5g) in a pre-weighed porcelain crucible in an electric oven at 105°C for about 24 hours until constant weight was obtained. The loss of moisture was calculated as percent moisture. The micro-Kjeldahl method was used to calculate crude protein. Using the Kjeldahl equipment, the total nitrogen content of each sample was calculated in triplicate. The samples were digested with 20 ml of concentrated sulfuric acid (H_2SO_4) in the presence of K_2SO_4, $CuSO_4$, and selenium powder to estimate the total nitrogen in this example. Ammonia released by the alkali (NaOH) was then distilled into boric acid and titrated with standard HCl. The nitrogen values thus obtained were converted to total crude protein by multiply with a factor of 6.25. Ether extract content was determined by Soxhlet apparatus using diethyl ether. At first flask weight was taken. Then 5 gm sample was taken in a thimble and added 200 ml acetone in a Soxhlet. Extraction was done at 40-45°C which took about 7-8 hours. After extraction the flask were taken out and dried in oven for30 minutes at 100°C. The flask containing ether extract was cooled in a desiccator and weighed. The calculated value for ether extract content was obtained as percent of the sample. Weighed samples were taken in porcelain crucibles and heated at 100°C in an electric oven. The crucibles were then placed in a muffle furnace and heated at 550°C for 6 hours. The crucibles were then cooled in desiccators. The average weight in percentage of each sample of the remaining material was taken as ash.

Statistical Analysis

All data from the experiments were subjected to one-way ANOVA followed by Duncan's test (IBM SPSS Statistics 20). Values of $P < 0.05$ were considered significant. Duncan’s multiple range tests were performed to calculate significant differences between means s ($p<0.05$). The means values and the SEM were noted.

Results and Discussion

Meat pH

The results presented in Table 1 demonstrate the effect of cattle age on meat pH at two key time points post-slaughter: 0 hours and 24 hours. At 0 hours, the pH values were 5.6 for 1.5-year-old cattle, 5.71 for 2-year-olds, and 5.8 for 2.5-year-olds, showing an increasing trend of pH with age. However, after 24 hours, the pH values decreased across all age groups, with measurements of 5.44 for the 1.5-year-old, 5.4 for the 2-year-old, and 5.35 for the 2.5-year-old cattle. Despite this decline, no significant differences in pH were observed between the different age groups at either 0- or 24-hours post-slaughter. This aligns with findings from Mach et al. (2008), who also reported minimal differences in carcass pH between age groups 24 hours after slaughter. Additionally, previous studies have indicated that pH values ranging from 5.35 to 5.60 do not pose a risk to meat quality, as pH values above 5.8 are generally considered detrimental to quality, particularly affecting tenderness. The study also found no significant pH differences between muscle types (biceps femoris and longissimus dorsi), with pH values ranging from 6.31 to 6.44, which is consistent with findings from Rosalina et al. (2008). According to Liu and Ge (1997), pH values above 5.45 indicate high-quality beef. The study's findings are consistent with prior research, including Li et al. (2018), who observed no significant differences in meat pH across various age groups of buffalo. Overall, the results suggest that age does not significantly affect meat pH or quality, with values remaining within an acceptable range that does not negatively impact tenderness or other quality parameters.

Table 1. Effect of age of cattle on meat pH

pH **Time after slaughter**	**1.5 years**	**2 years**	**2.5 years**	**p-value**
0 hours	5.60 ± 0.05	5.71 ± 0.07	5.80 ± 0.05	0.056
24 hours	5.44 ± 0.07	5.4 ± 0.04	5.35 ± 0.05	0.061

5% level of significant ($p<0.05$);

Drip loss

The analysis of drip loss in beef cattle of varying ages (1.5, 2, and 2.5 years old) reveals in table 2 drip loss increases over time after slaughter and is higher in older cattle. At 12 hours post-slaughter, the 2.5-year-old cattle exhibited the highest drip loss, while the 1.5-year-old cattle had the lowest (Table 2). A similar trend was observed at 24 hours, with drip loss continuing to increase, particularly in the 2.5-year-old cattle, reaching 4.25%. This suggests that older cattle may experience more water loss due to changes in muscle composition, including increased intramuscular fat and connective tissue, which can affect moisture retention. Additionally, post-mortem muscle metabolism and enzymatic activity contribute to the breakdown of muscle proteins, leading to greater fluid loss (Dikeman, 2007). Factors like stress, diet, and management practices also play a role in drip loss (Wheeler et al., 1994). Sargentini et al. (2010) similarly reported an increase in drip loss with advancing age in bulls. Overall, the study indicates that older cattle tend to have higher drip loss, possibly due to structural changes in muscle fibers and differences in muscle composition.

Table 2. Time course changes in drip loss (%) of meat sample from different ages of cattle

Drip loss **Time after slaughter**	**1.5 years**	**2 years**	**2.5 years**	**p-value**
12 hours	2.47± 0.02	2.61± 0.02	3.15± 0.023	0.072
24 hours	3.77± 0.021	3.56± 0.014	4.24± 0.015	0.053

5% level of significant ($p<0.05$);

Shear Force

The shear force measurements from Table. 3 highlight that beef tenderness varies significantly with the age of cattle and time post-slaughter. At 0 hours post-slaughter, 1.5-year-old cattle showed the lowest shear force (38.87 ± 4.88), indicating greater tenderness, while 2.5-year-old cattle had the highest shear force (52.5 ± 1.51), suggesting tougher meat. By 24 hours post-slaughter, the shear force for 1.5-year-old cattle decreased, becoming even more tender (29.23 ± 2.17), while the 2-year-old group showed increased tenderness (35.4 ± 2.28). In contrast, the shear force for 2.5-year-old cattle remained relatively high (48.4 ± 3.22), indicating that meat from older cattle retains its toughness longer. These findings align with previous studies (Hossain et al., 2021; Dikeman, 2007; Troy and Kerry, 2010; Wheeler et al., 1994), suggesting that younger cattle produce more tender meat due to less connective tissue and smaller muscle fibers, and that post-mortem aging has a more significant tenderizing effect on younger cattle. The results underscore the influence of age and post-mortem time on meat quality and the challenges of achieving desirable tenderness in beef from older cattle.

Table 3. Time course changes in shear force of meat sample from different ages of cattle

Shear force **Time after slaughter**	**1.5 year**	**2 years**	**2.5 years**	**p-value**
0 hours	38.86^{c} ± 4.88	48.96^{b} ± 4.12	52.5^{a}± 1.51	0.032
24 hours	29.23^{c} ± 2.17	35.41^{b}± 2.28	48.4^{a}± 3.22	0.022

a,b,c means on the same column with different superscripts differ significantly ($p<0.05$);

Cooking Loss

The cooking loss of meat from cattle of different ages increased with both age and time post-slaughter (Table.4) . At 0 hours post-slaughter, the cooking loss percentages were 20.42% for 1.5-year-old cattle, 22.16% for 2-year-old cattle, and 24.91% for 2.5-year-old cattle, with significant differences ($p < 0.05$). This trend continued at 24 hours, with cooking losses rising for all groups: 1.5-year-olds (22.06%), 2-year-olds (24.19%), and 2.5-year-olds (27.20%). The increase in cooking loss is attributed to biochemical changes such as protein denaturation and moisture loss, which are more pronounced in older cattle due to higher connective tissue and collagen content (Huff-Lonergan and Lonergan, 2005; Marsh and Leech, 1986). Older cattle experience greater moisture loss during cooking due to structural changes in muscle fibers (Pohlman et al., 2004; Savell et al., 1986). The results indicate that younger cattle (1.5 years) retain more moisture and have lower cooking losses, which is associated with greater juiciness and tenderness, making younger cattle more desirable in terms of culinary quality (Pérez et al., 2016).

Table 4. Time course changes in cooking loss of meat sample from different ages of cattle

Cooking Loss Time after slaughter	1.5 years	2 years	2.5 years	p-value
0 hour	20.42^{c}±0.83	22.16^{b}±0.12	24.91^{a}±0.33	0.041
24 hours	22.06^{c}±.086	24.19^{b}±0.37	27.2^{a}±0.58	0.036

a,b,c means on the same column with different superscripts differ significantly (p<0.05);

Water holding capacity

The water holding capacity (WHC) of meat from cattle of different ages showed significant differences over time post-slaughter. At 0 hours, the WHC was highest in 1.5-year-old cattle (5.64 ± 0.44%), followed by 2-year-olds (4.54 ± 1.4%), and lowest in 2.5-year-olds (4.08 ± 0.72%), with significant differences ($p < 0.05$) (Table.5). After 24 hours, WHC increased in the younger groups (1.5-year-olds: 8.27 ± 0.25%, 2-year-olds: 7.68 ± 0.18%), but decreased in the 2.5-year-olds (5.99 ± 1.4%). Younger cattle retain more water due to differences in muscle fiber composition and lower connective tissue, which enhances water retention. In contrast, older cattle have more connective tissue, which reduces water retention. The decrease in WHC for older cattle after 24 hours reflects moisture loss and muscle fiber changes (Pérez et al., 2016). Lower WHC can negatively affect meat quality by reducing juiciness and tenderness, key factors for consumer preference.

Table 5. Time course changes in water holding capacity of meat sample from different ages of cattle

Water Holding Capacity Time after slaughter	1.5 year	2 years	2.5 years	p-value
0 hours	5.64^{a}±0.44	4.54^{b}±1.4	4.08^{c}±0.72	0.041
24 hours	8.27^{a}±0.25	7.68^{b}±0.18	5.99^{c}±1.4	0.032

a,b,c means on the same column with different superscripts differ significantly (p<0.05);

Proximate composition of beef

Table 6 shows the moisture content of the beef samples was highest in the 1.5-year-old cattle (75.89%), followed by the 2.5-year-olds (74.00%), and lowest in the 2-year-olds (72.62%). This trend may suggest that younger cattle retain more moisture in their muscle tissue, potentially affecting the juiciness and tenderness of the meat. As cattle age, the decrease in moisture content could be attributed to the development of connective tissues and fat deposition (Kauffman et al., 2002).

Crude protein levels showed (Table.6) a significant variation with age. The highest protein content was found in the 2.5-year-old cattle (22.37%), while the 1.5-year- old group had the lowest (20.15%). The reduction in protein content in older cattle could reflect changes in muscle composition, where fat replaces lean tissue as animals mature (Lorenzo et al., 2014). The statistical significance (indicated by different letters) suggests that the protein content in the 2.5-year group is markedly higher than in the 1.5-year group, which could be advantageous for certain nutritional applications.

Ash content, which is indicative of the mineral content in the meat, also decreased with age, with the 1.5-year-olds having the highest ash percentage (1.5%) (Table.6).The decline in ash content in older cattle (1.39% for 2 years and 1.1% for 2.5 years) may point to changes in mineral deposition as the animal ages (Tudor et al., 2015). The observed statistical significance in ash content indicates a noteworthy difference between the 1.5-year and older age groups.

Ether extract values, which reflect fat content, remained relatively stable across the different age groups, ranging from 2.38% to 4.32% (Table.6). This consistency suggests that the fat content may vary significantly until later ages or different feeding regimens are implemented. However, the slight variations could be related to diet and environmental factors, which often influence fat deposition in cattle (Coffey et al., 2002).

Table 6. Proximate composition of meat sample from different ages of cattle

Proximate component Age of Beef cattle	1.5 years	2 years	2.5 years	p-value
Moisture (%)	75.89±0.54	72.62±1.59	74.00±0.96	0.065
CP (%)	20.15^{b}±0.73	21..49^{a}±0.46	22.37^{a}±2.32	0.012
Ash (%)	1.5^{a}±0.10	1.39^{b}±0.02	1.1^{b}±0.02	0.041
EE (%)	2.38^{c}±0.02	3.36^{b}±0.02	4.32^{a}±0.06	0.046

a,b,c means on the same column with different superscripts differ significantly (p<0.05);

Conclusion

The findings from this study demonstrate that age significantly influences key quality parameters of beef, with younger cattle (1.5 year) generally producing higher-quality meat in terms of tenderness, moisture retention, and overall eating quality. Specifically, younger cattle exhibited better water holding capacity, lower cooking loss, and more tender meat, making them more desirable for consumers seeking juicy and tender beef. Conversely, older cattle (2.5 years) showed higher drip loss, tougher meat, and lower water retention, which can negatively impact meat quality. While older cattle may have higher nutritional value in terms of protein and mineral content, their meat tends to be tougher and less desirable for consumers preferring tender cuts.

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