Qualities of Primal Beef Cuts from Arsi, Boran, Harar, and Crosses of Holstein Friesian Cattle Breeds

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Abstract: The study was conducted to evaluate the effects of breed, age, and aging duration on instrumental qualities of major primal beef cuts. For this purpose, a total of 24 bulls from Arsi, Boran, Harar, and Holstein Friesian (HF) crossbred cattle breeds slaughtered at the ages of 2-3 and 4-5 years were used. Experimental animals were fattened at the beef farm of Haramaya University based on a feed diet containing 40% concentrate and 60% roughages for 90 days duration. After slaughter, the carcass was fabricated and samples of major primal meat cuts were collected for evaluation of Warner Bratzler Shear Force (WBSF), water holding capacity (WHC), pH, cooking loss (CL), and color (L*, a*, b*) parameters. A total of 96 samples from chuck, loin, rib, and round were evaluated after aging meat samples for 5, 10, 14 and 21 days. The result of the study revealed that breed and age were significant sources of variation ($P<0.05$) for Warner Bratzler Shear Force value of meat cuts. Most beef cuts from Boran bulls exhibited lower Warner Bratzler Shear Force value than Arsi, Harar, and HF crosses. Loin cuts from Boran breeds were tender over other cuts (WBSF, 25.78N) however, round cuts from Arsi breed were the toughest cuts (41.61N). The lowest value of WBSF was obtained from bulls slaughtered at 2-3 compared to 4-5 years of age. WHC of primal cuts was significantly influenced by age at slaughter ($P<0.05$) and aging duration ($P<0.0001$). Breed of cattle was a significant source of variation ($P<0.05$) on pH value of chuck and loin cuts while aging duration was significant source of variation ($P<0.0001$) on pH of most primal cuts. Cooking loss of primal cuts was significantly influenced by breed ($P<0.05$) and aging days ($P<0.0001$). The lightness (L*) and the redness (a*) of the primal cuts were significantly influenced ($P<0.001$) by aging days while breeds of cattle had significant effect ($P<0.05$) the yellowness (b*) of primal cuts. The result of the study suggests the possibilities of using primal beef cuts from Boran, Harar, and HF-crosses for export purposes, particularly, when slaughtered at age 2-3 years.

Keywords: *Age, Aging days, Breed, Primal beef cuts, Quality*

Introduction

Ethiopia has the largest livestock population in Africa, with 65 million cattle, 40 million sheep, 51 million goats, and 8 million camels (CSA, 2018). Cattle fattening systems in Ethiopia are categorized as pastoral/agro-pastoral, mixed-crop livestock, Hararghen cattle fattening system, ranch, and intensive feedlot system (Mummed, 2023).

Beef quality is one of the major factors that affects the competitiveness of East African meat exports on the global market (Eshetie *et al*., 2018). Major categories of meat quality include eating, nutritional, and microbial attributes. These attributes are affected by factors such as nutrition, health status, age, sex, breed, and pre-slaughter handling of cattle. Post-slaughter carcass handling, such as electric stimulation, suspension methods, chilling conditions, and aging of the carcass, also affects the quality of the product. Among these factors, nutrition plays a major role in affecting beef quality (Rodríguez-Vázquez *et al*., 2020). Meat eating quality involves five attributes namely, tenderness, water holding capacity, color, juiciness and flavor (O'Quinn *et al*., 2018).

Few studies were conducted to evaluate instrumental qualities of beef based on longissimus dorsi muscle from cattle breeds in Ethiopia (Birhanu *et al*., 2019; Gadisa *et al*., 2019; Tefera *et al*., 2021; Mummed, 2023). Exporting beef product to the Middle East countries or other parts of the world demands aged primal cuts. Hence, it is important to identify the qualities of primal cuts from cattle breeds at different age. Eating qualities on major primal beef cuts such as round, chuck, loin, and rib cuts from different cattle breeds at different age categories were not evaluated in Ethiopia. The objectives of this study were to evaluate the qualities of major primal beef cuts and to identify the influence of breed, age at slaughter, and aging days on instrumental tenderness, PH, color, and water holding capacity.

Materials and Methods

Samples Collection and Analyzing Design

Primal beef cut samples were collected from twenty-four carcasses of bulls from Arsi, Boran, Harar, and HF crosses. Each breed contain 6 bulls in the age categories of 2-3 and 4-5 years of age which was estimated by dentition (Torrell, 1998). The bulls were slaughtered at ELFORA Export Abattoir in 2020 after fattening for 90

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days at the Beef Farm of Haramaya University based on a diet that contained 60% roughage and 40 concentrate. The bulls were slaughtered following standard procedure of the abattoir. Carcasses were separated into right and left halves and chilled at 4°C ± 1°C for 24 hrs in the chilling room. A total of 96 meat samples (about 250g each) were collected from round, loin, chuck, and rib. Samples were put into a sealed vacuum plastic bag, stored in the icebox, and transported to Oda Bultum University for evaluation of the WBSF (N), pH, WHC %, and color after aging the cuts for 5, 10, 14, and 21 days. All these parameters were evaluated at Oda Bultum University. To analyse the sample, factorial in a completely randomized design was used. Split-split plot with breed and animal age as a factorial in whole plot, cut as a subplot, and aging time as a sub-sub plot and as a repeated measure were used. Compound symmetry was used for the covariance structure for the repeated measure and the Kenward-Roger adjustment was used for determination of the denominator degrees of freedom.

Evaluation of Warner Bratzler Shear Force

Instrumental tenderness of beef was evaluated by Warner-Bratzler shear force device according to the guidelines of AMSA (2016). Chuck, loin, rib, and round beef cuts which were aged for 5, 10, 14, and 21 days were evaluated using WBSF. In order to determine WBSF, steaks or chops were cut 1 inch in (2.5cm^3) in thickness perpendicular to the muscle fibers after removing fat and external heavy connective tissue. The weight of the steaks was recorded before and after cooking. The steaks were put in the pre-heated cooking pan at 204 ^{o}C. In order to cook the steak uniformly, the steak was flipped upside down when the internal temperature reached 45 ^{o}C and removed from the heat source when the temperature reached 70 ^{o}C. The steak was cooled at room temperature for about an hour prior to WBSF analysis. Six 1.27 cm cores were hand-cored in perpendicular to the longitudinal orientation of the muscle fibers with corn borer. The WBSF values of the six cores of each steak were recorded in Newton and the averages were taken as the value of a primal cut.

Evaluation of pH

The pH value of loin, rib, round and chuck samples were measured after 5, 10, 14, and 21 aging days by using a portable digital pH meter with glass electrodes. The pH value of aged beef samples was determined by penetrating the probe in the beef cut to a depth of 3-4 cm and read after about 30 seconds. In doing so, the pH meter probe was inserted into distilled water and a buffer solution (pH7) after each measurement, then the next sample was evaluated by inserting a probe into the meat sample and read the value of pH after about 30 seconds (ESVLDM, 2005).

Evaluation of Cooking Loss

A cooking loss was evaluated based on measuring the weight difference between the weight of raw beef cut before and after cooking. The samples for each major primal beef cuts at 5, 10, 14, and 21 days of aging were evaluated for cooking loss based on the following formula:

$$\text{Cooking loss (\%)} = \frac{(weight\ of\ raw\ meat - weight\ of\ cooked\ meat)}{weight\ of\ raw\ meat} \times 100$$

Evaluation of Water-Holding Capacity

The water-holding capacity (WHC) of each sample was determined by the Whatman filter paper using the press method. The primal cuts were evaluated after aging for 5, 10, 14, and 21 days in triplicate using the method suggested by Whiting and Jenkins (1981). Two Whatman number-1 filter papers were weighed (A) and 0.5 grams of meat sample (C) was once positioned between two filter papers, this in turn, was placed between two glass sheets. Over it, a weight of 2.015 kg was placed, while the glass sheet weighed 0.8278 kg sheet, giving a total compression weight of 2.8428 kg load for 5 min. Then, the weight was once removed and the meat was separated from the filter papers and weighed (D). At the quit, the filter paper was dried and the weight was recorded (B). After that, the quantity of protein attached to the filter paper and the actual weight of meat after stress remedy was determined. The amount of protein connected to the filter paper used to be calculated as (E) = B—A, real weight of meat after pressure cure (F) = E + D and percent drip loss = (C-F)/C*100. WHC was once calculated as the distinction between 75% and the percentage of drip loss.

Evaluation of Meat Color

The color (L*, a*, b*) of major primal beef cuts was measured after aging from chuck, loin, rib, and round for 5, 10, 14, and 21 days. Measurements were made using Mini Scan EZ machine (model wide variety – 4500 L) with a 20 mm diameter size vicinity and illuminant D65-day light after 30-min exposure of samples to air (bloom time). This device was calibrated before taking measurements by use of the black and white shade fashionable samples, provided for this purpose. Three readings have been taken on every sample by means of rotating the color guide 90° between measurements so as to attain the average value for the color. Meat color of the samples was expressed using the CIELAB color area (L* = lightness, a*= redness, and b* = yellowness) according to the CIE machine (Hernández *et al.*, 2016).

Statistical Analysis

The collected data were analyzed using the GLM procedure of SAS 9.4 version software (SAS, 2008). The experimental study of the sample was factorial in a completely randomized design (fact CRD). Split-split plot with breed and animal age as a factorial in whole plot, cut as a subplot, and aging time as a sub-sub plot and as a repeated measure were used. Compound symmetry was used for the covariance structure for the repeated measure and the Kenward-Roger adjustment was used for determination of the denominator degrees of freedom. Tukey was used to determine significant differences among means at a 5% level of significance and p-value of ≤ 0.05. All pairwise comparison tests in multiple comparisons were used to compare means. The Pearson correlations analysis (PROC CORR of SAS) was used to assess the relationship of parameters under evaluation. The following model was used:

$$Y_{ijkl} = \mu + \alpha i + \beta j + \gamma_k + \delta l + (\alpha*\beta*\gamma*\delta)_{il} + e_{ijkl}$$

where, Y_{ijkl} = the response variable.
μ = Overall mean common to all observation
αi = Effects of breed
βj = Effect of age at slaughter
γ_k = Effect of meat cuts
δl= Effect of aging duration
$(\alpha*\beta*\gamma*\delta)_{il}$ = Interaction effect
e_{ijkl} = Random error

Results and Discussion

Effects of Breed, Age at Slaughter, and Aging Days on WBSF of Primal Meat Cuts

The effects of breed, age, and aging days of primal beef cuts are presented in Table 1. Breed had shown significant effect (P<0.01) on WBSF of primal beef cuts. The study shows that WBSF value of chuck, loin, rib, and round cuts from Boran, Harar, and HF cross were similar lower than primal cuts from Arsi breed. All meat cuts from breeds under the study were tender except round cut from Harar cattle breed, chucks and round cuts from Arsi breed which were categorized as intermediate tender based on the criterion set by Calkins and Sullivan (2007), which classified beef as tender for value (< 37.48 N/8.46 lb), intermediate (37.49–48.82 N) and tough (> 48.82 N/10.3 lb). The effects of breed on WBSF of primal meat cuts in the current finding was similarly reported in previous studies. Boran and Harar cattle breeds had relatively lower WBSF values compared to the Arsi breed based on the evaluation of longissimus dorsi (Birhanu *et al.*, 2019). Similarly, Gadisa *et al.* (2019) reported the relative tenderness of longissimus dorsi from Harar cattle breed over Arsi cattle breeds. Strydom *et al.* (2011) reported shear force value ranged from 29.6 - 32.5N for beef from Bonsmara, Brahman, Drakensberger, Nguni, and Tulli cattle breeds in South Africa. The WBSF values of all primal cuts from all breeds under the current study were not higher than the upper limit of intermediate shear force value (48.82N). The result of the present study highlights the possibilities of producing tender primal cuts from cattle breeds in Ethiopia finished under a good feeding condition.

Age of bulls at slaughter was another significant source of variation (P<0.05) for WBSF value. Lower mean WBSF value of primal meat cuts was recorded from bulls slaughtered in 2-3 years of age compared to 4-5 years of age. All primal meat cuts from both age group were tender except chuck from bulls slaughtered 4-5 years of age which was intermediate. Loin cut from Harar cattle breed slaughtered at 2-3 years of age was the most tender (28.35N). The decrease in tenderness of beef as cattle advanced beyond 3 years of age is associated with an increase in the level of connective tissue (Thierry, 2014). The amount and composition of connective tissue, which change as the animal advances in age, highly influence tenderness (Bolumar and Toepfl, 2016).

Table 1. Effects of breed, age, and aging days on instrumental tenderness of major primal beef cuts.

Factors	LSM ± SE (N)				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	37.89 ± 1.22^{Ab}	33.70 ± 1.218^{Acd}	35.55 ± 1.21^{Acb}	41.61 ± 1.22^{Aa}	***
Boran	33.35 ± 1.36^{Bced}	25.78 ± 1.36^{Bg}	31.07 ± 1.36^{Bfed}	37.05 ± 1.36^{Bb}	***
HF crossbred	33.97 ± 1.27^{Bcd}	29.82 ± 1.279^{Bfe}	36.22 ± 1.27^{Bcb}	36.55 ± 1.27^{Bcb}	***
Harar	34.61 ± 1.21^{Bcbd}	28.86 ± 1.21^{Bfg}	34.48 ± 1.21^{Bcbd}	37.86 ± 1.21^{Bb}	***
Age:	**	**	**	**	
2-3	34.12 ± 0.90^{Bbc}	28.35 ± 0.90^{Bd}	33.72 ± 0.90^{Bc}	35.87 ± 0.90^{Bba}	***
4-5	37.64 ± 0.88^{Aa}	33.73 ± 0.86^{Ac}	34.94 ± 0.88^{Abc}	37.31 ± 0.88^{Aa}	***
Sig.	*	*	*	*	
Breed*age					*
Aging days:					
5	42.37 ± 1.02^{Aa}	35.67 ± 1.02^{Acbd}	36.20 ± 1.02^{Acbd}	43.10 ± 1.021^{Aa}	***
10	37.21 ± 1.021^{Bcb}	31.84 ± 1.021^{Be}	35.17 ± 1.021^{Bcd}	37.81 ± 1.021^{Bb}	***
14	34.69 ± 1.021^{Cd}	26.92 ± 1.021^{Cg}	34.59 ± 1.021^{Cd}	35.13 ± 1.021^{Ccd}	***
21	31.69 ± 1.02^{De}	23.73 ± 1.021^{Dh}	30.05 ± 1.021^{Dfe}	30.31 ± 1.021^{Dfe}	***
Sig.	***	***	***	***	
Breed*aging					*
Breed*age*aging					ns

*^{a,b,c} least square mean value in the same row (beef cuts effect) with the same letter are not significantly different; Categories with different letters are significantly different (p<0.05); ^{A,B,C} least square mean value in the same column (breed, age, and aging days effect) with different letters are significantly different; Ns= P > 0.05; ***= P < 0.0001; ** = P < 0.01; * = P < 0.05; SE = Standard error of mean; Sig= Significance level; Ns= Non-significant.*

Aging days was the other significant source of (P<0.0001) variation on WBSF value of primal cuts. The WBSF values of primal beef cuts in general decreased between 5 and 21 days of aging. The increase in the tenderness of meat with increased aging time was reported by some other researchers (Kemp *et al.*, 2010; Jones-Hamlow *et al.*, 2015). The unit difference in instrumental tenderness between 5 and 21 days were 10.68, 11.94, 6.15, and 12.69 for chuck, loin, rib, and round, respectively; meanwhile, less difference in instrumental tenderness (WBSF) were observed between 10 and 14 aging days. The highest differences in shear force were observed between 5 and 10 aging days. Improved tenderness (lower WBSF value) as aging duration increased would be due to an effect of proteolytic enzymes that digest myofibrillar protein structure (Kemp *et al.*, 2010). Proteolytic enzymes, mostly calpains, cause degradation of muscle tissue proteins during aging, leading to changes in micro- and ultrastructure of muscle fibers, which is correlated with a reduction in the hardness of meat (Huff and Lonergan, 2005).

The least square mean values of shear force were related to each other on day 5 to 14 in case of rib cut, while 21 days of aging produced significantly different value compared to aging for 5 days. This suggests the possibility of eating tougher beef by those countries that practice fresh beef eating. The intermediate tender cuts at 5 days of aging chuck and loin changed to tender cuts when aged for 21 days. This indicates the possibility of producing tender cuts from *Bos indicus* and cross of *Bos taurus* by finishing under good feeding conditions.

Effects of Breed, Age, and Aging Days on pH of Major Primal Meat Cuts

The effects of breed, age at slaughter and aging days of primal beef cuts are presented in Table 2. Breed of cattle was a significant source of variation (P<0.05) on pH value of chuck and loin primal cuts.

Aging duration was highly significant source of variation (P<0.0001) on pH of primal cuts. The pH values of major primal cuts gradually decreased during aging for 5, 10, 14, and 21 aging days. Chuck, loin, ribs, and round attained higher pH at 5 days of aging while aging for 10 days significantly decreased the pH of these primal cuts compared to the other days of aging. This indicates the possibly less importance of aging beyond 10 days to attain the minimum pH for normal meat which is 5.4. This could be due to the prevalence of conformational changes associated with the proteolytic degradation of the muscle fibers and the hydrolysis of the meat proteins into amino acids (Lawrie and Ledward, 2006). However, in all days of aging, the pH of least square mean of round, chuck, and loin were in the normal range of 5.4 to 5.8 for all primal cuts except rib cuts.

Table 2. Effects of breed, age, and aging days on pH of major primal meat cuts.

Factors	**LSM± SE**				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	$5.60+0.08^{ABb}$	5.67 ± 0.05^{Ab}	5.76 ± 0.10^{a}	5.51 ± 0.11^{b}	***
Boran	$5.46\pm0.05B^{b}$	5.39 ± 0.07^{Bb}	5.68 ± 0.10^{a}	5.52 ± 0.04^{b}	***
HF crossbred	5.73 ± 0.08^{Ab}	5.69 ± 0.06^{Ab}	5.86 ± 0.07^{a}	5.63 ± 0.06^{b}	***
Harar	5.47 ± 0.07^{Bb}	5.57 ± 0.04^{ABb}	5.79 ± 0.05^{a}	5.56 ± 0.07^{b}	***
Age:	*	*	ns	ns	
2-3	5.53 ± 0.05^{b}	5.63 ± 0.04^{b}	5.77 ± 0.05^{a}	5.57 ± 0.05^{b}	***
4-5	5.60 ± 0.05^{b}	5.53 ± 0.04^{b}	5.78 ± 0.06^{a}	5.54 ± 0.06^{b}	***
Sig.	Ns	Ns	Ns	Ns	
Breed*age					Ns
Aging days:					
5	5.76 ± 0.07^{Ab}	5.70 ± 0.05^{Ab}	5.90 ± 0.09^{Aa}	5.66 ± 0.10^{Ab}	***
10	5.33 ± 0.07^{Cb}	5.43 ± 0.07^{Cb}	5.51 ± 0.10^{Ca}	5.39 ± 0.09^{Cb}	***
14	5.60 ± 0.05^{Bb}	5.60 ± 0.04^{Bb}	$5.86+0.06^{Ba}$	5.53 ± 0.03^{Bb}	***
21	5.57 ± 0.07^{Bb}	5.61 ± 0.06^{Bb}	$5.82+0.03^{Ba}$	5.63 ± 0.04^{Bb}	***
Sig.	***	***	***	***	
Breed*aging					*
Breed*age*aging					ns

*[a,b,c] least square means in the same row (beef cut effect) with the same letter are not significantly different; Categories with different letters are significantly different (p<0.05); [A,B,C] least square means in the same column (breed, age, and aging days effects) with different letters are significantly different; Ns =P > 0.05; *** = P < 0.0001; ** = P < 0.01; * = P < 0.05; SE= Standard error of mean; Sig= Significance level; Ns= Non-significant.*

Effects of Breed, Age at Slaughter, and Aging Days on Water Holding Capacity

Effect of breed, age at slaughter, and aging days on the water-holding capacity of major primal meat cuts are presented in Table 3. Breed was a significant source (P<0.0001) of variation on WHC of major primal cuts. Loin and ribs primal cuts of Boran breed showed WHC of 72.12%, a relatively higher numerically compared to other primal cuts from other breeds. The WHC of primal cuts from the Arsi breeds were relatively low in the range of 67.36 to 69.08.

Water-holding capacity was not significantly affected by age at slaughter of cattle (p<0.05). The lowest numerical mean value of WHC was obtained at age of 4-5 years at 5 aging day from chuck cuts (68.22%) and the highest numerical mean value of water holding capacity was recorded from loin cuts (71.34%) of 2-3 age groups. Gadisa *et al.* (2019) reported relatively lower mean value of WHC from younger compared to the older age group based on the evaluation of the longissimus dorsi muscle. Warner *et al.* (2014) reported that the water-holding capacity of meat influenced by the age of the animal. The interaction of breed and age didn't show significant difference (P>0. 05) on primal cuts.

Aging days were highly significant source of variation (P<0.0001) on water holding capacity of primal meat cuts. In this study WHC of chuck, loin, rib, and round increases at different rate as the aging time increases. Similar to the present study, Cho *et al.* (2016) reported an increase in water holding capacity of tenderloin, top sirloin and bottom round muscles as the aging advanced from 0-21 days. The improvement in water-holding capacity of meat might be related to postmortem proteolysis which is responsible for the improvement of WHC of aged meats. The Degradation of key cytoskeletal proteins by calpain proteases has also a role to play in determining water-holding capacity (Huff and Lonergan, 2005). In the present study, water-holding capacity of all major primal cuts of the current study increased due to postmortem events including rate and extent of pH decline and proteolysis event. Moreover, the highest numerical mean value of water holding capacity was obtained in loin cuts at 21 aging duration (72.74%).

Table 3. Effects of breed, age at slaughter, and aging days on WHC of major primal meat cuts.

Factors	**LSM ± SE (%)**				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	67.36+0.58^{Bc}	69.08±0.52^{Ba}	69.06±0.56^{Ba}	68.15±0.72^{Bb}	***
Boran	69.71±0.56^{Ac}	72.12±0.45^{Aa}	72.05±0.63^{Aa}	70.46±0.63^{Ab}	***
HF crossbred	67.79±0.43^{Bb}	70.54±0.73^{Ca}	70.02±0.43^{Ca}	69.10±0.59^{Cb}	***
Harar	70.15±0.48^{Aa}	71.07±0.53^{Aa}	69.90±0.60^{Aa}	70.02±0.51^{Ab}	***
Age:	***	***	***	***	***
2-3	69.28±0.39^{c}	71.34±0.38^{a}	70.17±0.47^{a}	69.64±0.44^{b}	***
4-5	68.22±0.40^{c}	70.06±0.45^{a}	70.34±0.37^{a}	69.22±0.46^{b}	***
Sig.	Ns	Ns	Ns	Ns	
Breed*age					Ns
Aging days:					
5	66.66±0.67^{Dc}	69.83±0.78^{Da}	67.48±0.64^{Da}	67.50±0.46^{Db}	***
10	68.86±0.33^{Cc}	69.55±0.46^{Ca}	70.09±0.48^{Ca}	68.65±0.68^{Cb}	***
14	68.99±0.62^{Bc}	70.68±0.54^{Ba}	71.02±0.36^{Ba}	69.54±0.59^{Bb}	***
21	70.49±0.22^{Ac}	72.74±0.34^{Aa}	72.44±0.35^{Aa}	72.05±0.39^{Ab}	***
Sig.	***	***	***	***	
Breed*aging					*
Breed*age*aging					ns

*^{a,b,c} least square means in the same row (beef cuts effect) with the same letter are not significantly different; Category with different letters are significantly different (p<0.05); ^{A,B,C} least square means in the same column (breed, age and aging days effect) with different letters are significantly different; Ns =P > 0.05, *** = P < 0.0001, ** = P < 0.01; * = P < 0.05, SE = Standard error of mean; Sig= Significance level; Ns= Non-significant.*

Effects of Breed, Age at Slaughter, and Aging Days on Cooking Loss

The effects of breed, age at slaughter, aging days on cooking loss of primal meat cuts are presented in Table 4. Breed had shown significant difference (P<0.05) in cooking loss across primal cuts. The lowest numerical mean value of cooking loss was obtained from chuck of HF crossbred (15.28%) while the highest mean value of cooking loss was observed for chuck from Boran breed (23.60%). Age at slaughter had not significant effect on cooking loss (P>0.05) of similar primal cuts across age categories.

Aging days were significant (P<0.0001) source of variation on cooking loss. The cooking loss decreased as the aging days increased from 5 to 21 days in general. The cooking loss of the current finding was comparable with Jama *et al.* (2008), who reported a decrease in cooking loss from aging day 2 to day 21 for Angus, Nguni, and Bosmara beef cattle in South Africa. As the aging day increases, the collagenase enzymes may contribute to the break up the myofibrillar proteins and connective tissue thereby improving the water-holding capacity of proteins (Jones-Hamlow *et al.*, 2015).

Effect of Breed, Age at Slaughter, and Aging Days on Color of Major Primal Cuts

Aging days significantly influenced (P<0.001) the lightness (Table 5). The lightness value at 5, 10, and 14 aging days were different from 21 aging day. However, the pattern of change in lightness value was not uniform across the aging days of primal cuts. Interaction of breed with days of aging significantly influenced the lightness of primal cuts. Cho *et al*. (2016) reported higher lightness at 7, 14, and 21 aging day compared to 0 days of aging.

Aging days influenced the redness of primal meat cuts significantly (P<0.0001; Table 6). Moreover, the interaction of breed and aging days significantly influenced (0.0001) the redness (a*) of primal cuts. The increase in redness was reported as aging days increased (Marino *et al*., 2014; Ribeiro *et al*., 2021). The improvement in beef redness as aging day increase might be due to a decrease in oxygen consumption of respiratory enzymes within mitochondria of aged meat. More myoglobin concentration lead to more red color within skeletal muscle of meat (Bekhit and Faustman, 2005). Differences in location of chuck, loin, rib and round might contributed to variation in redness of meat as muscle located in locomotion areas had low in redness due to low in myoglobin concentration.

Table 4. Effects of breed, age at slaughter, and aging days on cooking loss of major primal meat cuts.

Factors	LSM± SE (%)				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	17.34 ± 0.96^{Bb}	18.23 ± 0.89^{Ba}	15.28 ± 0.80^{Bc}	17.94 ± 0.51^{Ba}	***
Boran	23.60 ± 0.88^{Ab}	23.53 ± 0.93^{Aa}	21.11 ± 0.94^{Ac}	23.09 ± 0.85^{Aa}	***
HF crossbred	15.97 ± 0.55^{Bb}	18.84 ± 1.07^{Ba}	17.14 ± 0.78^{Bc}	18.58 ± 1.19^{Ba}	***
Harar	19.44 ± 1.11^{BAb}	$19.97\pm1.21B^{Aa}$	18.42 ± 1.07^{BAc}	$20.41\pm1.15B^{Aa}$	***
Age:	*		*	*	
2-3	19.94 ± 0.80^{b}	21.21 ± 0.88^{a}	18.93 ± 0.77^{c}	21.23 ± 0.84^{a}	***
4-5	18.24 ± 0.68^{b}	19.07 ± 0.63^{a}	17.04 ± 0.60^{c}	18.78 ± 0.56^{a}	***
Sig.	Ns		Ns	Ns	
Breed*age					Ns
Aging days:					
5	21.14 ± 1.16^{Ab}	22.39 ± 1.23^{Aa}	20.15 ± 1.13^{Ac}	22.69 ± 1.17^{Aa}	***
10	20.38 ± 1.10^{Ab}	22.13 ± 1.11^{Aa}	19.12 ± 1.06^{Ac}	21.66 ± 1.00^{Aa}	***
14	18.63 ± 0.92^{Bb}	19.91 ± 0.83^{Ba}	17.20 ± 0.91^{Bc}	19.38 ± 0.79^{Ba}	***
21	16.21 ± 0.81^{Cb}	16.14 ± 0.69^{Ca}	15.46 ± 0.58^{Cc}	16.29 ± 0.61^{Ca}	***
Sig.	***	***	***	***	
Breed*aging					***
Breed*age*aging					Ns

^{a,b,c} *least square means in the same row (beef cuts effect) with the same letter are not significantly different; Category with different letters are significantly different (p<0.05);* $^{A, B, C}$ *least square means in the same column (breed, age and aging days effect) with different letters are significantly different (p<0.05); Ns =P > 0.05; *** = P < 0.0001; ** = P < 0.01; * = P < 0.05; SE = Standard error of mean; Sig= Significance level, Ns= Non-significant.*

Table 5. Effects of breed, age, and aging days on lightness (L*) of major primal beef cuts.

Factors	LSM± SE				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	31.81 ± 0.56^{b}	31.00 ± 0.39^{c}	36.33 ± 0.73^{a}	32.17 ± 0.52^{c}	***
Boran	32.70 ± 0.55^{b}	32.65 ± 0.59^{c}	36.15 ± 0.81^{a}	32.10 ± 0.66^{c}	***
HF crossbred	33.64 ± 0.64^{b}	31.89 ± 0.51^{c}	35.32 ± 0.77^{a}	31.01 ± 0.58^{c}	***
Harar	31.45 ± 0.39^{b}	31.09 ± 0.38^{c}	35.43 ± 0.54^{a}	31.35 ± 0.48^{a}	***
Age:	Ns	Ns	Ns	Ns	
2-3	32.24 ± 0.40^{b}	31.92 ± 0.36^{c}	36.11 ± 0.52^{a}	31.74 ± 0.40^{c}	***
4-5	32.56 ± 0.40^{b}	31.40 ± 0.33^{c}	35.51 ± 0.49^{a}	31.58 ± 0.40^{c}	***
Sig.	Ns	Ns	Ns	Ns	
Breed*age					Ns
Aging days					
5	31.81 ± 0.65^{Ab}	31.76 ± 0.50^{Ac}	36.71 ± 0.68^{Aa}	31.33 ± 0.58^{Ac}	***
10	33.15 ± 0.67^{Ab}	32.27 ± 0.59^{Ac}	37.52 ± 0.60^{Aa}	31.94 ± 0.61^{Ac}	***
14	33.26 ± 0.46^{Ab}	32.04 ± 0.40^{Ac}	36.42 ± 0.68^{Aa}	32.82 ± 0.45^{Ac}	***
21	31.38 ± 0.33^{Bb}	30.57 ± 0.40^{Bc}	32.59 ± 0.44^{Ba}	30.55 ± 0.53^{Bc}	***
Sig.	***	***	***	***	
Breed*aging					***
Breed*age*aging					Ns

^{a,b,c} *least square means in the same row (beef cut effect) with the same letter are not significantly different; Categories with different letters are significantly different (p<0.05);* $^{A, B, C}$ *least square means in the same column (breed, age, and aging days effect) with different letters are significantly different; Ns =P > 0.05; *** = P < 0.0001; ** = P < 0.01; * = P < 0.05; SE = Standard error of mean; sig= Significance level; Ns= Non-significant.*

Table 6. Effects of breed, age, and aging days on redness (a*) of major primal meat cuts.

Factors	LSM± SE				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	12.98±0.32[b]	13.30±0.33[a]	10.61±0.30[d]	12.56±0.34[c]	***
Boran	13.60±0.37[b]	14.82±0.38[a]	11.27±0.47[d]	13.08±0.35[c]	***
HF crossbred	13.67±0.34[b]	14.20±0.34[a]	11.40±0.37[d]	13.10±0.31[c]	***
Harar	13.24±0.24[b]	14.40±0.32[a]	11.00±0.28[d]	12.91±0.31[c]	***
Age:	ns	ns	ns	ns	
2-3	13.19±0.20[b]	14.09±0.24[a]	10.93±0.24[d]	12.77±0.22[c]	***
4-5	13.56±0.25[b]	14.27±0.26[a]	11.21±0.27[d]	13.05±0.24[c]	***
Sig.	ns	ns	ns	ns	***
Breed*age					ns
Aging days:					
5	12.83±0.28[Ab]	13.70±0.40[Aa]	10.58±0.40[Ad]	12.06±0.41[Ac]	***
10	13.18±0.33[CBb]	13.69±0.31[CBa]	10.55±0.34[CBd]	13.14±0.39[CBc]	***
14	13.53±0.32[Bb]	14.36+0.37[Ba]	11.01±0.34[Bd]	13.27±0.11[B c]	***
21	13.94±0.33[Cb]	14.96±0.27[Ca]	12.13±0.27[Cd]	13.19±0.24[Cc]	***
Sig.	***	***	***	***	
Breed*aging					***
Breed*age*aging					ns

*[a,b,c] least square means in the same row (beef cut effect) with the same letter are not significantly different; Categories with different letters are significantly different (p<0.05); [A,B,C] least square means in the same column (breed, age, aging days effect) with different letters are significantly different (p<0.05); Ns =P > 0.05; *** = P < 0.0001; ** = P < 0.01; * = P < 0.05; SE = Standard error of mean; sig= Significance level; Ns= Non-significant.*

Breed had significant effect (P<0.05) on yellowness (b*) of primal cuts (Table 7). The b* values of the Boran and HF crossbred cattle were significantly higher than Harar and Arsi breed (P< 0.05). Numerically minimum yellowness (b*) mean value was recorded from rib cut of HF crossbred (8.76) and the maximum mean value of yellowness of beef was recorded from loin cut of Boran breed (10.89). Similarly, aging days was also significant source of variation (P<0.0001) on yellowness (b*) of primal cuts. The yellowness (b*) values increased with an increase in aging days was in line with reports of Ribeiro *et al*. (2021). According to Oliete *et al*. (2006), the increase in yellowness (b*) of beef cuts as aging duration increased could be due to the meat surface oxidation during aging.

Table 7. Effects of breed, age at slaughter and aging days on yellowness (b*) of major primal beef cuts.

Factors	LSM± SE				
	Chuck	Loin	Rib	Round	Sig.
Breed:					
Arsi	10.84±0.39[CBa]	9.95±0.30[CBb]	9.36±0.31[CBc]	10.15±0.30[CBb]	***
Boran	10.70±0.38[Aa]	10.89±0.50[Ab]	9.61±0.39[Ac]	9.48±0.27[Ab]	***
HF crossbred	10.27±0.15[Aa]	9.49±0.23[Ab]	8.76±0.24[Ac]	9.66±0.22[Ab]	***
Harar	10.35±0.26[BAa]	9.73±0.32B[Ab]	9.14±0.37[BAc]	9.77±0.28[BAb]	***
Age:	****	*	*	*	
2-3	10.45±0.23[a]	10.09±0.29[b]	9.49±0.24[c]	9.88±0.20[b]	***
4-5	10.63±0.21[a]	9.94±0.21[b]	8.95±0.22[c]	9.65±0.18[b]	***
Sig.	ns	ns	ns		
Breed*age					ns
Aging days:					
5	9.84±0.30[Da]	8.85±0.29[Db]	8.593± 0.36[Dc]	8.492± 0.25[Db]	***
10	10.06±0.23[Ca]	9.51±0.21[Cb]	8.737± 0.23[Cc]	9.532±0.18[Cb]	***
14	11.19±0.26[Ba]	11.05±0.32[Bb]	9.095± 0.25[Bc]	10.24±0.14[Bb]	***
21	11.16±0.34[Aa]	10.64±0.41[Ab]	10.47±0.34[Ac]	10.79±0.24[Ab]	***
Sig.	***	***			
Breed*aging					***
Breed*age*aging					**

*[a,b,c,d] least square means in the same row (beef cut effect) with the same letter are not significantly different; Categories with different letters are significantly different (p<0.05). [A, B, C, D] least square means in the same column (breed, age, aging days) effect with different letters are significantly different; Ns =P > 0.05; *** = P < 0.0001; ** = P < 0.01; * = P < 0.05; SE = Standard error of mean; sig= Significance level; Ns= Non-significant.*

Conclusion

From the result of the study it was concluded that tender primal cuts can be produced from Arsi, Boran, Harar and cross of Holstein Friesian cattle breed finished with concentrate supplement. Breeds and age at slaughter of the bulls had influenced the qualities of primal cuts. Aging primal cuts for 14 and 21 days improved its instrumental tenderness and water holding capacity. The qualities of chuck, loin, round, and rib cuts varied considerably. From the conclusion it was recommended that primal meat cuts from Arsi, Boran, Harar, and cross of Holstein Friesian breeds can be used for markets that demand high-quality products provided that they are supplemented concentrate as per their requirements, slaughtered at 2-5 years age and aging 14 to 21 days.

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Conflict of Interests

The authors declare that they have no competing interests.

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