Effects of Season and Age on Eating Quality of Beef from Guraghe Cattle Breed Slaughtered in Public Abattoirs of Hadiya Zone, Ethiopia

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Abstract: Eating quality of beef from Guraghe cattle breeds slaughtered in public abattoirs at Hadiya Zone of Ethiopia under different age and season were evaluated in this study. For this purpose, a total of 48 meat samples which were stratified into three age groups (4-5, 5-7, and 7-9 years) and two seasons (wet and dry) were collected from *longissimus-dorsi* (LD) muscle between 12th and 13th ribs. Quality parameters such as initial pH (pHi) and ultimate pH (pHu), instrumental tenderness using Warner Bratzler Shear Force Device (WBSF), eating quality of meat using sensory panel, water holding capacity (WHC), and cooking loss (CL) were evaluated after aging the meat samples for 14 days. The overall mean values of WBSF, sensory tenderness, juiciness, flavor, pHi, pHu, WHC, and CL were 31.46±1.37, 7.08±0.08, 7.07±0.07, 7.34±0.10, 6.73±0.02, 5.63±0.02,70.83±0.15, and 17.55±0.68, respectively. Age at slaughter and season had significantly influenced ($P<0.05$) Warner Bratzler Shear Force value. The interaction of age and season significantly influenced juiciness ($P< 0.001$) and the water holding capacity ($P <0.05$). The percentages of dark firm dry (DFD) meat in the wet and dry seasons were 25% and 8.33%, respectively. Instrumental tenderness (WBSF) showed high significant negative correlation with sensory tenderness and high significant positive correlation with flavor and Juiciness. Cooking loss showed high significant positive correlation with pHi in the wet season. From the study, it was concluded that eating quality of beef from Guraghe cattle breed was tender. The younger the cattle the better the quality of beef. The better quality of beef in the dry compared to the wet season justifies the need to identify and minimize the degree of stress due to draft service that possibly affected quality of the beef in the latter season. From the study, it was recommended that beef quality improvement strategy in the region should consider mechanisms that minimize multi-stress factors in the wet season and encourage slaughter of the cattle at a young age.

Keywords: *Beef, WBSF, Sensory panel testing*

Introduction

Ethiopia has 65 million cattle population (CSA, 2020). Pastoral, agro-pastoral, mixed-crop, Hararghen cattle fattening system commonly practiced in Ethiopia with few practice of fattening in ranch and intensive feedlot system (Mummed, 2023).

The share of East African countries in the global animal product market was estimated about 4% the global market share (Tekeba *et al.,* 2018). Poor quality of meat was indicated as one of the major reasons for the lower share of the market (Mummed, 2023). The major determinants of meat quality are eating, nutritional, and microbial quality (Warris, 2010). The same author indicated tenderness, juiciness, flavor, appearance, and color are function of eating quality. Eating quality is affected by a number of factors such as pre-slaughter animal handling from farm to abattoir and post-slaughter carcass handling methods. Consumers give tenderness, juiciness, flavor, color, and appearance primarily importance (Lee *et al.,* 2012).

In Ethiopia, despite the availability of some documented information on quality of beef reported using sensory evaluation, few studies were conducted using instrumental tenderness (Addis *et al*., 2019; Gadisa *et al*., 2019; Tefera *et al*., 2021). These researchers evaluated qualities of beef from Borana, Arsi, Hararghe, and Bale cattle breeds managed in Oromia Regional State of Ethiopia. Few studies on instrumental tenderness of beef was conducted from cattle breeds in Southern Nation Nationalities and Peoples Regional State (SNNPRS) of Ethiopia (Lijalem *et al*., 2015). In Hadiya Zone of SNNPRS, Guraghe cattle breed is among the major cattle breeds used for beef purposes. Hence, assessing the quality of beef objectively using instrumental methods helps to generate information that will be used as feedback to producers thereby make them improve production practices that ensure consumers demand. This study was conducted with the aim to evaluate eating qualities of beef produced from Guraghe cattle breed slaughtered at Hosanna municipal abattoir of Hadiya Zone.

Materials and Methods

Study Area

The study was conducted in Hadiya Zone of Southern Nation Nationalities and Peoples Regional State, Ethiopia. The Zone has a latitude and longitude of

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7.6472°N and 37.7238°E (Fig 1). The Zone is 232 km southeast of Addis Ababa. *Enset* based mixed livestock and crop production farming system is widely practiced in the Zone (HZSA, 2010).

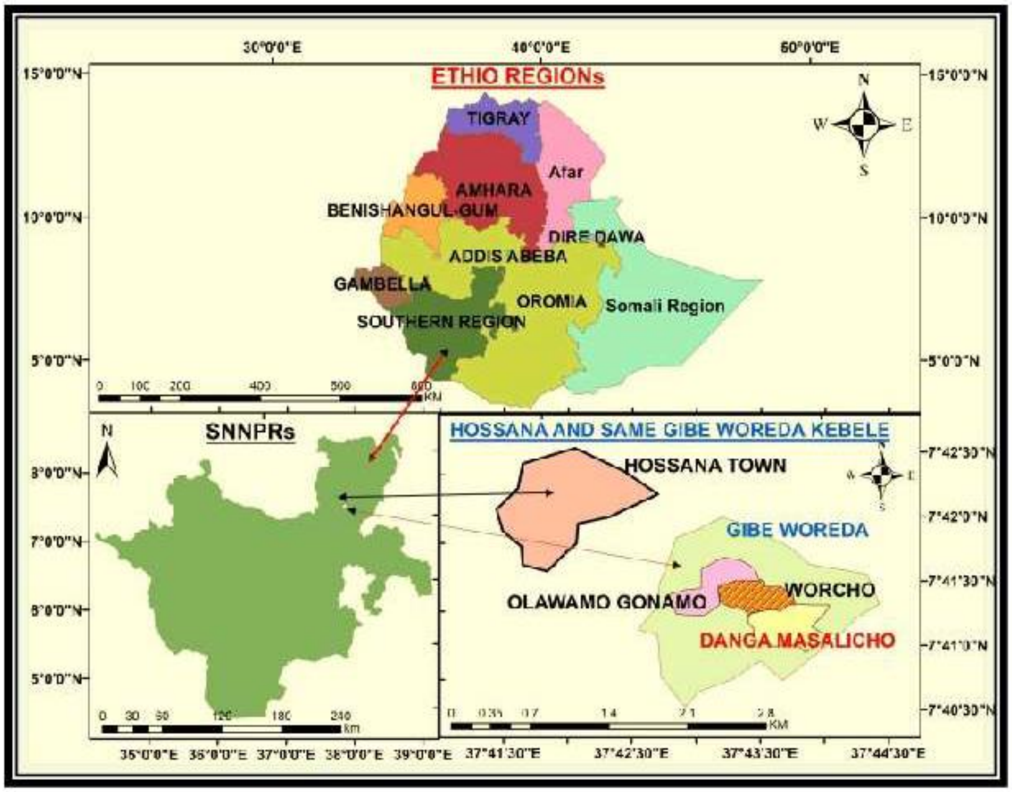

Figure 1. Map of the study areas.

Data Collection

Meat samples were collected from cattle slaughtered at Hosana municipal abattoir. The cattle were given identification numbers for proper recording of ante-mortem and post-mortem examination during the entrance period to the abattoir from 2:00 pm to 4:00 pm of the day. Purposive selection of slaughtered animals was made based on the population each day in that only Guraghe breed was selected and stratified into three age groups (i.e., 4-5, 5-7, 7-9 years). The breed was selected based on its phenotypic characteristics (Lombebo and Zeleke, 2018). Age of cattle at slaughter was estimated using dentition method (Torell *et al.,* 2003).

Meat samples (n=48) were collected at wet season (24 samples; August 2020) and dry season (24 samples; January 2021). Number of samples collected were stratified across three age groups with 16 meat samples from each age category. Meat samples were collected from *longissimus dorsi* muscle between 12th and 13th ribs. About 250g meat sample was collected from carcass of each animal. Sensory and instrumental tenderness of the meat samples were evaluated at Oda Bultum University after being transported in packed plastic bag.

Measuring of pH in Meat

The pH was measured by using portable microprocessor-based pH meter (model number-pH-013). The initial pH (pH_i) was measured at 45min post-slaughter by directly inserting the probe into the *LD* of carcasses between 12th and 13th ribs and the ultimate pH (pH_u) was evaluated at 24-hour postmortem on meat sample. The pH meter was calibrated after each sample measurement by inserting the probe into distilled water and a buffer solution (pH=7). Reading of the value of pH was made after about 30 seconds (ESVLDM, 2005).

The pale soft exudate (PSE) and dark firm dry (DFD) beef was determined based on the pH_u following the standard procedure by Warris (2010). Meat samples whose pH_u <5.4 were considered PSE meat while those pH_u > 5.8 were considered as DFD meat.

Measuring of Water Holding Capacity

The water-holding capacity of meat samples were determined in triplicate 24 h post-slaughter following the standard procedure of Whiting and Jenkins (1981).

Steak Preparation for Instrumental and Sensory Evaluation

The samples were aged for 14 days in a deep freeze at negative 20°C. To prepare steaks for instrumental tenderness evaluation, meat samples were thawed at room temperature (24–25°C) for 24h. The instrumental tenderness of the steaks of meat samples were evaluated using Warner Bratzler Shear Force device following the procedure by AMSA (2016). The steaks were placed in the pre-heated 204^{o}C pan after removing external heavy connective tissue and taking the initial weight. When the internal temperature reaches 45°C, the steak was flipped so that the upper and lower parts of the steaks exposed for similar heat. At 70°C, the steak was removed from pan and re-weighted to determine final weight of the steak. External temperature of the steak was measured using digital infrared thermometer (model-cen-tech, 60725) while the internal temperature of the steak was measured using thermocouple thermometer type T (450 ATT).

Measuring of Instrumental Tenderness

The instrumental tenderness of the sample was evaluated after cooling the steak, removing heavy connective tissue and cutting 1 inch (2.5cm) thickness steak long the direction of fiber perpendicular to the long axis of the *LD*. From each sample, 6 cores were extracted and evaluated to determine a single average instrumental tenderness value of a steak expressed by Newton (N).

Sensory Panel Testing

Ten individuals were selected from faculty and students at Oda Bultum University based on their interest and meat eating experience and trained on the procedures of sensory panel testing described by AMSA (2016). The steaks for sensory panel testing was prepared using similar procedure followed to prepare steaks for Warner-Bratzler Shear Force evaluation. The samples were served to panelists at room temperature (23-25°C). Each panelist received two to three cubes from different locations within the piece steaks. The steaks were cut uniformly to reduce any bias related to serving position and presented in a random fashion. Each assessor evaluated the three most important eating quality such as tenderness, juiciness, and flavor based on nine-hedonic scale (AMSA, 2016).

Cooking Loss

The difference between the weight of the steak before and after cooking served to calculate the cooking loss as shown below.

$$Cooking\ loss\ calculate\ (CL) = \frac{(Initial\ weight - final\ weight) * 100}{Initial\ weight}$$

Data Analysis

The data was analyzed using the GLM procedure of SAS 9.1 version (SAS, 2008). Age of cattle and seasons were considered as the fixed effects. Correlation between parameters were determined using Pearson correlation coefficient. Duncan multiple range test was used to separate means when the F-test was significant ($P \leq 0.05$). The model $Y_{ijk} = \mu + \alpha i + \beta j + k\gamma + e_{ij\gamma}$ was used, where, Y_{ijk}= the response variables; μ= the overall mean; αi = the effect of age; βj = the effect of season; $k\gamma$ = interaction effect, and $e_{ij\gamma}$= random error.

Results and Discussion

Instrumental and Sensory Tenderness of Beef Samples

The instrumental and sensory tenderness of beef samples are presented in Table 1. The overall mean WBSF (N) values of beef in the present study was 31.46±9.56. The overall mean values of sensory panel testing for tenderness, juiciness and flavor were scores 7.08, 7.07 and 7.34. The mean WBSF value in the present finding was comparable with the finding by Gadisa *et al.* (2019) who reported mean values of 33.12±11.30, 7.21, 7.2 and 7.24 for WBSF (N), sensory tenderness, juiciness and flavor of beef, respectively, for Arsi, Bale and Harar cattle breed in Eastern Oromia Region of Ethiopia. The overall mean value of WBSF value of beef in the current study can be considered as tender based on the criteria set by Calkins and Sullivan (2006). According to these criteria, value of instrumental tenderness less than 37.31 N (8.46 lb) is considered tender, value from 37.49 to 44.54 N is considered intermediate and value greater than 44.98N is considered as tough meat. Similarly, Addis *et al.* (2019) reported that tender beef from bulls of Arsi, Boran, and Harar cattle breeds in Ethiopia.

Table 1. The instrumental and sensory tenderness of beef samples

Factors		Instrumental tenderness	Sensory panel testing		
		WBSF(N)	Tenderness	Juiciness	Flavor
		Mean±SE	Mean±SE	Mean±SE	Mean±SE
Overall mean		31.46±1.37	7.08±0.08	7.07±0.07	7.34±0.10
Season		***	NS	NS	NS
	Wet	36.31^{a}±2.26	6.99±0.14	6.97±0.09	7.37±0.15
	Dry	26.62^{b}±0.75	7.17±0.09	7.18±0.11	7.32±0.14
Age		*	***	*	***
	4-5 years	27.23^{b}±1.87	7.69^{a}±0.08	7.34^{a}±0.14	6.65^{c}±0.10
	5-7 years	31.5^{ab}±3.02	6.94^{b}±0.07	6.84^{b}±0.10	7.51^{b}±0.13
	7-9 years	35.67^{a}±1.66	6.61^{c}±0.47	7.03^{b}±0.12	7.88^{a}±0.12
A*S		NS	NS	***	NS

*WBSF (N) = Warner Bratzler Shear Force in Newton; SE = Standard error; NS=Not significant; A*S= Age and season interaction; * indicates p<0.05; *** indicates P<0.001.*

The season of slaughter was one of the significant (P<0.001) source of variation for instrumental tenderness. The mean value of instrumental tenderness scores value was lower to shear force values of 26.62N at dry season and while higher shear force values 36.31N at wet season. This result was due to effect of seasons based on body conformation variation of beef cattle at wet and dry seasons. During wet season farmers used oxen for draft purpose which may lower body condition. However, beginning of dry season cattle are exposed to less physical work and may supplemented with cereal and grain left over. Gadisa *et al.* (2019) reported good body condition of beef cattle at end of wet season and beginning of dry season due to availability of grain to be supplemented as the period coincide with the harvesting season. Yesihak and Webb (2014) reported that most of the local cattle used for beef purpose in Ethiopia were supplied to market after the plowing season was over, usually in poor body condition and at old in age. Chimonyo *et al.* (2002) reported the possibility of draft service in inducing chronic stress on the oxen. Similarly, some other studies reported the possible effect of physical exercise in inducing stress on cattle (Bendall and Swatland, 1988; Yucca and Muchenje, 2013; Alam *et al.*, 2018).

Age at slaughter had significantly influenced (P<0.05) WBSF (N) value. This can be associated with the variation in the cross-link of collagen in the muscle at different age of the animals. The relatively higher value of WBSF for beef from oxen slaughtered at 7-9years of age might be explained by the presence of more cross-link of collagen in the muscle of older animals compared to the younger once. Similar to the present finding, the effects of age at slaughter on WBSF value of beef for Arsi, Harar and Boran cattle breeds were reported by Addis *et al.* (2019). The increase in the quantity of connective tissue and degree of cross-linking in the muscle as the cattle advanced in age might increase the toughness of the meat. This change in connective tissue that can be attributed to a change in muscle collagen solubility was reported as the major contributor to meat quality (Thierry, 2014). The same explanation can be given to the variation in sensory tenderness between ages oxen slaughtered at different age.

The flavor of beef increases as the age at slaughter of oxen increased in this study. This might be explained by the increase in the development of fat as the animal advance in age. The higher amount of fat in older cattle might be implicated for better flavor (Nhat Thu, 2006). The juiciness of the beef was significantly influenced (P< 0.001) by the interaction of age and season at slaughter. The effect of interaction can be explained by the difference in body condition there by juiciness of the beef.

Beef Samples pH, Water Holding Capacity and Cooking Loss

The pH, water holding capacity and cooking loss of beef samples in the present study is shown in Table 2. The overall mean value of initial and ultimate pH was 6.73 and 5.63, respectively. The values indicated that the meat can be considered normal (Warris, 2010) as the ultimate pH range between 5.4 and 5.8. The WHC was relatively higher in wet compared to the dry season in the present study. The interaction of age at slaughter and season was the significant source of variation (P<0.05) on water holding capacity. This implies that different age groups are affected differently by seasons as younger oxen are more susceptible to feed and draft stress which varied between season. The findings obtained in the present study is similar to the report of Gadisa *et al.* (2019).

Seasons of slaughter was one of the significant sources of variation (P <0.001) on cooking loss. The higher numerical mean value 19.61of cooking loss recorded at wet season compared to the value (15.49) recorded at dry season might be associated to the more access to direct water (drinking) and indirect (through feed) in the former season compared to the latter one. The effect of age on cooking loss didn't follow a uniform pattern. On the other hand, Gadisa *et al.* (2019) reported a linearly influenced by age of at slaughter on cooking loss. The interaction of age and season were the other source of variation (P<0.001) for cooking loss in the present study.

Table 2. pH, water holding capacity and cooking loss of beef samples.

Factors		Initial pH	Ultimate pH	WHC	Cooking loss
		Mean±SE	Mean±SE	Mean±SE	Mean±SE
Overall mean		6.73±0.02	5.63±0.02	70.83±0.15	17.55±0.68
Season		NS	NS	*	**
	Wet	6.69±0.04	5.64±0.04	$71.22^{a}\pm0.2$	$19.61^{a}\pm0.97$
	Dry	6.76±0.02	5.63±0.03	$70.45^{b}\pm0.2$	$15.49^{b}\pm0.78$
Age		NS	NS	NS	*
	4-5 years	6.73±0.05	5.59±0.05	70.9±0.25	$18.02^{ab}\pm0.90$
	5-7 years	6.72±0.05	5.70±0.04	71.0±0.22	$19.11^{a}\pm1.47$
	7-9 years	6.74±0.02	5.60±0.04	70.58±0.32	$15.54^{b}\pm1.01$
Age* season		NS	NS	*	**

*SE= Standard error; NS= Not significant; WHC= Water holding capacity; A*S= Age and season interaction; * indicates p<0.05; ** indicates P<0.01.*

The Percentage of PSE and DFD Beef in Wet and Dry Seasons

The percentage of PSE and DFD in the present study is shown in Table 3. Meat samples in the normal range of pH (5.4-5.8) were higher in dry season (91.6%) compared to the wet season (66.67%). No PSE was observed in dry season compared to the wet (8.33%). The rate of DFD was higher in the wet season (25%) compared to the dry season (8.33%). This indicates the exposure of slaughter cattle to different kind of stress from the pre-slaughter phase from farm to abattoir. The cattle might have exposed to physical stress due to draft service at farm, stress at market places and during transport to abattoirs. The trekking by foot in the wet season might exposed cattle for more physical strain as they walk in the muddy road which is common in most rural town in Ethiopia. The vehicle which is commonly used for transport of cattle can expose the animal to the rain and sun stimuli during transport. The cumulative effect of stress due to draft service, trekking and vehicle might reflect on more PSE and DFD in wet season compared to the dry one. The prevalence of DFD in wet season in the present study is compared with the report by Gadisa *et al.* (2019) which was reported for Arsi, Bale and Harar cattle breeds. The levels of DFD should not exceed 10% to produce good quality beef products (BC Cook Articulation Committee, 2015).

Table 3. Percentages of PSE, normal, and DFD meat.

Variable	PSE meat (pH<5.4)		Normal meat (pH 5.4-5.8)		DFD meat (pH>5.8)	
	№ of	%	№ of	%	№ of	%
Wet season	2	8.33	16	66.67	6	25
Dry season	0	0	22	91.6	2	8.33

PSE=Pale Soft Exudative; DFD= Dry firm dark.

Correlation Between Sensory and Instrumental Qualities of Beef in Wet and Dry Season

The Pearson correlation between sensory and instrumental qualities of beef in the present study is shown in Table 4. The current analysis of correlation between instrumental tenderness and sensory evaluation of tenderness shows the significant (negative) high relationship (r= -0.51; P <0.001) at the wet and (r= -0.47; P <0.05) at the dry seasons. Similarly, Gadisa *et al.* (2019) reported negative high correlation between instrumental and sensory tenderness Significant correlation coefficient of -0.72 and −0.69 were reported between WBSF and sensory tenderness in another studies (Destefanis *et al.,* 2008; Ishihara *et al.*, 2013). The negative sign in the correlation value is due to the opposite direction followed by sensory and instrumental tenderness evaluation to indicate better quality of meat. The significant positive correlation (r= 0.46, 0.47; P <0.05) detected between WBSF and flavor (wet and dry seasons) shows the increase in the value of WBSF with increase in flavor. This can be justified by the lower the WBSF of beef from older animals, the better the flavor. As the animal get older, they accumulate more fat in their body. Flavor is the function of triglyceride and phosphoglycerate which interact with amino acid (Warris, 2010). Similarly, Gadisa *et al.* (2019) reported a strong positive correlation between flavor and WBSF value (r= 0.6) for beef from Arsi, Harar, and Bale cattle breeds.

Table 4. The Pearson correlation between sensory evaluations with instrumental tenderness.

Variable	WBSF	Tenderness	Juiciness	Flavor	WHC	pHi	pHu	CL
WBSF	A	-0.51***	0.12	0.46*	0.001	-0.30	0.03	-0.14
Tenderness	-0.47*	A	-0.23	-0.81***	0.21	-0.12	0.01	-0.06
Juiciness	-0.31	0.50*	A	0.27	-0.12	0.14	-0.08	-0.18
Flavor	0.47*	-0.53**	-0.57**	A	-0.31	0.07	-0.04	-0.03
WHC	-0.20	0.02	-0.09	-0.07	A	-0.11	-0.09	-0.11
Initial pH	0.20	0.46*	0.11	-0.20	0.17	A	0.12	0.33
Ultimate pH	0.18	-0.36	-0.21	-0.09	0.29	0.06	A	0.54**
Cooking loss	-0.31	0.37	0.33	-0.51**	0.19	0.17	0.16	A

*Diagonal above a letter a is wet season while below a letter is dry season; pHi = Initial pH; pHu= Ultimate pH; CL= Cooking loss; * indicates p<0.05; ** indicates P<0.01; *** indicates P<0.001.*

The correlation coefficient between tenderness and juiciness of beef has moderate positive correlation of (r= 0.50; P < 0.05) at dry season. The significant positive relationship between tenderness and juiciness is also in line with the finding by Arse *et al.* (2013) who reported moderate positive correlation of 0.40 value (P < 0.05) between juiciness and tenderness of beef. The significant positive correlation between tenderness and flavor were also reported by Wheeler *et al.* (2005). Tenderness and flavor has highly negatively correlation (r = -0.81, P < 0.001) at wet season and at dry season (r = -0.53, P < 0.01) in the present study. A significantly negative correlation was observed between juiciness and flavor in wet season (r = -0.57, P < 0.001) in the present study. This is because the tender beef produced from young compared to the old while the better flavor produced by older animals than young animals. A highly significant correlation between flavor and juiciness (r = 0.12; P < 0.001) for top-loin steaks was reported by Lorenzen *et al.* (2003). This can be explained by the fact that the older the animal, the better the flavor and the lower the juiciness of the meat.

Cooking loss was positively correlated with ultimate pH value at wet season (r = 0.54; P < 0.001) in the present study. This might be due to the lower water holding capacity due to higher ultimate pH that might implicated to the higher the CL.

Conclusion

Eating quality of beef from Guraghe cattle breed based on instrumental and sensory evaluation was comparable to eating quality of other cattle breeds reported in Ethiopia. The better qualities of beef in the dry compared to the wet season further suggested the possible exposure of cattle for more stress in the latter season. The younger the cattle, the better the quality of beef. From the study, it was recommended that beef quality improvement strategy in the region should consider mechanism that minimize stress factors in the wet season and encourage slaughter of cattle at young age.

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Conflict of Interests

The authors declare that they have no competing interests.

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