RESEARCH ARTICLE

J Anim Sci Technol 2023;65(4):865-877
https://doi.org/10.5187/jast.2022.e128

JAST
Journal of Animal Science and Technology
pISSN 2672-0191 eISSN 2055-0391

Differences in toughness and aging potential of *longissimus lumborum* muscles between Hanwoo cow, bull and steer

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Received: Nov 6, 2022
Revised: Dec 23, 2022
Accepted: Dec 26, 2022

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Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
It should be acknowledged that this work was supported by the Research Program for The Animal Molecular Genetics & Breeding Center (Project No PJ01316904), Rural Development Administration, Korea.

Acknowledgements
It should be acknowledged that this

Abstract

Thirty Hanwoo cattle including bulls, cows, and steers (n = 10 each) were slaughtered and investigated for carcass traits (weight, meat color, fat color, yield index, maturity, marbling score, back-fat thickness, and firmness) and meat quality. The meat quality such as: pH, color, cooking loss, fatty acid, thiobarbituric acid reactive substance, warner-bratzler shear force, tensile tests, and texture profiles were analyzed on *longissimus lumborum* (LL) muscles of the carcasses at different aging times (3 d and 21 d). The results showed that steers and cows had higher back-fat thickness and marbling score, and a lower firmness ($p < 0.001$) than bulls. Bulls exhibited a lower meat quality indicating by higher cooking loss, thiobarbituric acid reactive substance content, warner-bratzler shear force and tensile test values ($p < 0.01$). Regarding the sensory property, the bull meat also had higher hardness, and lower tenderness, juiciness and flavor scores than the cow or steer meat ($p < 0.01$). Additionally, the bull meat had a higher polyunsaturated fatty acid and a lower monounsaturated fatty acid contents ($p < 0.01$). With increased aging time, the meat tenderness was improved in all the genders. Taken together, the present study demonstrated that the gender and aging time affected the carcass traits, fatty acid and sensory quality of beef. Postmortem aging could improve the meat tenderness of all genders especially bulls.

Keywords: Ageing, Gender, Texture, Tenderness, Sensory, Quality traits

INTRODUCTION

Hanwoo is a native and valuable cattle breed that is very important in the beef industry sector of Korea [1]. Compared to other country's beef (USA, New Zealand, Australia, Canada, and Mexico), Hanwoo beef is characterized by a high intramuscular fat (IMF) and lower content of connective tissues, and unique palatability [2,3]. Hanwoo beef has been regarded as the most expensive and premium meat product in Korea [1].

Several studies have found that animals of different genders and ages how different tenderness with particular muscles [4,5]. Studies on beef indicated that beef from older animals is tougher than

work was supported by the Research Program for The Animal Molecular Genetics & Breeding Center (Project No PJ01316904), Rural Development Administration, Korea. We are grateful to Hoa Van Ba who devote much time to reading this paper and provided many professional writing services, these will benefit me in my later study.

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Hwang I.
Data curation: Song Z.
Formal analysis: Hwang I.
Methodology: Song Z.
Software: Song Z.
Validation: Song Z.
Investigation: Song Z.
Writing - original draft: Song Z.
Writing - review & editing: Song Z, Hwang I.

Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

beef from younger animals [6]. Gender, as a function of sexual hormones, is an important factor influencing the growth pattern, fat, and protein depositions in carcass as a function of sexual hormones [7]. Steer and heifer meat generally have a higher marbling level, so they are tender [8], and better eating quality [9] compared to bull meat. Hence, efforts to improve the eating quality especially tenderness of bull meat is needed.

Post-mortem aging could improve palatability attributes such as flavor, odor, flavor intensity and tenderness [10], this process occurs naturally in carcass after slaughtered. During the conversion of muscle to meat, proteins and lipids are break down into smaller and more flavorful fragments by natural enzymes. Moreover, some of key muscle proteolysis contributes to meat tenderization [11]. Furthermore, during the aging process, oxidative may affect the quality of the meat [12]. Such as: the oxidation of myoglobin turns this pigment into brown metmyoglobin, and lipid oxidation results in formed several products, some of them being associated with the flavor even at low concentrations [13].

Wet aging refers to meat aged in a sealed barrier package at refrigerated temperatures. The process occurs in vacuum bags and increased in popularity [14], due to the method is convenience and higher yields compared with dry aging. The wet aging method is easy and needs a short time. Everyone can do the packed package meat aside in their refrigerators and allow them to age. The beef is usually kept for a period of 14d to 42d in wet aging. During the wet aging process, the enzymes will break down the fibers as the beef ages, resulting in a tender cut of meat [14]. Thus, until now wet age is popular with producers due to it takes less time and it has no moisture loss.

In addition, beef tenderness evaluated is important for the manufacturer due to tenderness is important to the consumer. Till now, different measurements such as; sensory panel [8,15,16], texture profile analysis (TPA), tensile test, and shear force [17] have been used to determine the tenderness of meat. Here, our objective was to evaluate the effects of genders (bull, cow, and steer) on carcass traits, texture and quality characteristics of Hanwoo beef during post-mortem aging (3 d and 21 d).

MATERIALS AND METHODS

Carcass selection

Thirty Hanwoo cattle including bull (n = 10), cow (n = 10), and steer (n = 10) were obtained from the commercial meat processing plant. They were slaughtered at different ages (bull slaughtered average age at 26 months, steer slaughtered average age at 31.2 months, cow slaughtered average age at 46 months). The following day after slaughter, their carcasses were evaluated and graded by an official grader for carcass traits (carcass weight, ribeye area, back fat thickness and yield grade, etc.) according to the beef carcass grading [18].

Sample collection

Longissimus lumborum (LL) muscles were collected from the left sides of carcasses. Muscles were sealed with vacuum-packaged and aged at 4℃ for 3 and 21 days. Each gender contained 10 samples for each aging time. When the aging was completed, they were prepared into sub-sample size depending on analyses. Except for the samples used for the share force, tensile extension, color, and cooking loss, the rests were vacuum-packaged and store at −80℃ until use.

pH and color of meat quality parameters

The pH values of these samples were determined using a Meat pH meter (HI99163, Hanna instrument, Padovana, Veneto, Italy). Each sample was measured 4 times.

https://doi.org/10.5187/jast.2022.e128

The color was determined using a Konica Minolta Spectrophotometer (CM-2500d, Konica Minolta, Tokyo, Japan), the machine contained an 8-mm measuring port AT, D65 illuminant, and 10° observer (Sinodevices, Tokyo, Japan). Each sample was blooming at 4℃ for 30 min, then measured at three different locations on the surface. The samples were measured for L*, a*, and b*. L* means the lightness of meat, a* means the redness of meat, and b* means the yellowness of meat.

Cooking loss and objective of meat quality parameters

Cooking loss, and texture analysis (Warner Bratzler shear force [WBSF], TPA, and tensile tests) were determined on the samples (3 cm thick steak with the weight of 300 g). Particularly, the samples were immediately placed in plastic bags and cooked in a water bath until their core temperature had increased to 70℃. After cooking the samples cooled in circulating water for 30 min. The weight of samples was recorded before and after cooking, then, using the following equation to measure cooking loss:

$$\text{Cook loss}(\%) = \frac{\text{Weight of uncooked sample (g)} - \text{Weight of cooked sample (g)}}{\text{Weight of uncooked sample(g)}} \times 100$$

After cooking loss measurement, the samples were measured for WBSF, TPA, and tensile tests using an Instron Universal Testing Machine (Model 3342, Instron, Norwood, MA, USA). Every sample was cut into more than 6 trips which are parallel to the muscle fiber direction. The WBSF was evaluated with 1.5 cm diameter samples and sheared at a crosshead speed of 400 mm/min, using a 40 kgf load cell. Tensile testing was conducted with 70 × 10 × 10 mm thick per sample. Stretching was performed at 50 mm/min. TPA (hardness) was done on 3 cuts in a rectangular trapezoid shape with 10 × 10 × 40 × 30 mm per sample. Each sample underwent 2 cycles of 60% compression at a constant speed of 50 mm/min.

Sensory of meat quality parameters

The sensory evaluation was followed by our lab's previously established protocols [19]. The panel consisted of eight faculty members. Every sample was cut into 4 cm (length) × 3 cm (height) × 0.5 cm (thick) size to be tested. Three sessions were held for every sample at different times. The panelists evaluated contained tenderness, juiciness, flavor, overall acceptability, and overall rating. Each panelist assessed the cooked beef meat samples in a randomized order, and everyone needs to give a value from 1 to 100 (ie: from denotes unacceptable to extremely acceptable) after the test. Each panelist was asked to use distilled water (DW) to refresh their mouths in between samples.

Fatty acid and oxidative stability (thiobarbituric acid reactive substance)

A procedure developed by Rule [20] was used to detect the composition of fatty acid. The samples were made into thin slices which were then freeze-dried for 48 h. About 500 mg of each dried sample was placed in a 20 mL vial with 2 mL of 14% boron-trifluoride in methanol and 2 mL of high performance liquid chromatography (HPLC) grade methanol. The vials were sealed with a scrimp cap, then they were placed in a heating block set at 80℃, and vortex mixing every 5 min, for maintained 2 h. Thereafter, 3 mL DW and hexane were added, respectively, and followed by centrifuging at 1,000 g force for 5 min. Each sample was infused with about 1 mL of hexane and sealed in a vial. The fatty acids composition was determined using an Agilent Gas Chromatography-Mass Spectrometer system (GC-MS) (GC 7890B, MS 5977B Agilent Technologies, Santa Clara, CA, USA) with an auto-sampler. The injection temperature was set at 250℃, the carrier gas with a speed 45 cm/s with a split ratio of 50:1. Fatty acid methyl esters were separated with a 1.0 mL/min

helium flow which is on a WCOT-fused silica capillary column (30 m × 0.25 mm × 0.25 μm). The oven was programmed as follows: 150℃/2 min, 150℃ to 230℃ at 10℃/min, 230℃/15 min. The fatty acids were identified by comparison with the retention time with those of fatty acid standards (F.A.M.E. Mix., CRM 18918, 47015-U, Sigma-Aldrich Supelco, Bellefonte, PA, USA). The proportion of the fatty acid calculated use the peak area of each identified fatty acid against total identified peak area.

The oxidative stability was determined using the procedure developed by Buege and Aust [21], which was detected the values of TBARS to measure oxidative stability. Briefly, an Ultra Turrax T25 homogenizer (IKA Labortechnik, Selangor, Malaysia) was used 2.5 g meat samples with the solution for 15 s at 11,000 rpm. The solution contained 7.5 mL DW, 25 μL BHA (butyl hydroxyanisole) and 10 mL thiobarbituric acid solution and trichloroacetic acid solution (TBA/TCA). After homogenizing, the sample was immediately placed in ice, and added TBA/TCA solution to homogenate until the volume to 30 mL. The samples were heated at 90℃ in a water bath for 15 min. Then, taken out and placed in ice to cool for 20 min. The absorbance of the sample is determined at 531 nm against a blank that contains all the reagents minus the lipid on an Ultrospec 2000 spectrophotometer (Pharmacia Biotech, Cambridge,UK). Multiply the absorbance reading by 5.88 (mg/kg) to calculate the malondialdehyde (MDA) concentration in the sample.

Statistical analysis

All data were analyzed using the General Linear Model Procedure of the SAS version 9.3 program (SAS Institute, Cary, NC, USA) [22]. The breed and aging were considered as the fixed factors while the carcass traits, quality attributes, etc. were considered as the variables. Means were compared using Duncan's Multiple Range Test. The significance level was set at $p < 0.05$.

RESULTS AND DISCUSSION

Yield and quality grade traits

The carcass traits as affected by gender are presented in Table 1. It was observed that gender affected carcass weight, back fat thickness and, the rib eye area ($p < 0.01$). Cow showed the lowest carcass weight, probably due to the estrous cycle effect and its specific feeding diet. Studies have shown that compared with bulls, steers gain weight at a significantly slower rate and with less efficiency [4,5]. In our study, steers and bulls had no difference in carcass weight, this could be attributed to the slaughter age difference. The back-fat thickness was in the following order: steer > cow > bull. The previous study also reported that castrated animals are easier to deposit fat than non-castrates [23]. Bulls had lower back fat thickness compared with cows, this is due to the influence of testicular hormones that cause a significantly higher proportion of lean and a lower proportion of fat [24]. The yield index was also affected by gender ($p < 0.05$), due to yield index, back fat thickness, ribeye area, and carcass weight has the following relation: Yield index = [68.184 – {0.625 × back fat thickness (mm)}] + {0.130 × rib eye area (cm^2)} – {0.024 × carcass weight (kg)} + 3.23. Steers had the highest marbling and the lowest firmness meanwhile bulls had the lowest marbling and the highest firmness ($p < 0.001$). This is due to testosterone can inhibit fat development in bulls. The marbling and firmness values showed no difference between steers and cows. This can be attributed to the marbling of Hanwoo steers significantly increasing between 12 and 27 months [25], and higher marbling indicating higher softness [26].

Effect of gender and aging on meat quality

Gender showed no influence on color parameters (a* and b*) at 3 d aging (Table 2). However,

https://doi.org/10.5187/jast.2022.e128

Table 1. Yield and quality traits of Hanwoo beef carcasses subjected to different genders

Quality traits	Bull	Steer	Cow	SEM	*F*-value
Back fat (mm)	6.6^{c}	14.6^{a}	11.4^{b}	1.9	8.7***
Rib-eye area (cm^2)	80.6^{b}	93.8^{a}	89^{a}	3.6	5.3**
Carcass weight (kg)	414^{a}	437^{a}	365^{b}	11.7	11***
Maturity[1)]	3^{b}	2^{c}	5^{a}	0.4	23***
Yield index[2)]	68^{a}	64^{b}	67^{a}	1.2	5.8*
Marbling score[3)]	1^{b}	5^{a}	4^{a}	0.6	13***
Meat color[4)]	5.2	4.8	5	0.2	2.4
Fat color[5)]	3	3	3	0	-
Firmness[6)]	2^{a}	1.2^{b}	1.4^{b}	0.2	10***
Month	26^{b}	31.2^{b}	46^{a}	10.09	18.52***

[1)]Maturity: 1 to 9 means the maturity from youthful to mature.

[2)]Yield index = [68.184 − {0.625 × Back fat thickness (mm)}] + {0.130 × Rib eye area (cm^2)} − {0.024 × Carcass weight (kg)} + 3.23.

[3)]Marbling score: the values from 1 to 9 indicate the marbling is from devoid to abundant.

[4)]Meat color: the values from 1 to 7 indicate the color is from bright cherry to dark red.

[5)]Fat color score: the values from 1 to 7 indicate the fat color is from white to dark yellow.

[6)]Firmness score: the values from 1 to 3 indicate the meat is from soft to firm.

[a,b]Indicate significantly different within row with different superscripts.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table 2. Quality traits of LL muscle subjected to different aging time and genders

Quality traits	Aging	Bull	Steer	Cow	SEM	*F*-value
pH	3 d	5.50^{a}	5.43^{b}	5.46^{ab}	0.04	6.72**
	21 d	5.51^{a}	5.49^{ab}	5.42^{b}	0.07	2.93
	F-value	0.1	2.04	2.87		
CIE L*	3 d	33.1^{b}	37.9^{a}	37.2^{aY}	3.32	4.43*
	21 d	36.4	37.9	39.6^{X}	2.64	2.09
	F-value	4.69	0	8.44*		
CIE a*	3 d	16.2^{Y}	17.4^{Y}	17.4^{Y}	1.64	0.83
	21 d	20.0^{X}	20.1^{X}	21.0^{X}	1.66	0.49
	F-value	10.07*	6.16*	14.66**		
CIE b*	3 d	11.5^{Y}	13.4	13.0^{Y}	1.48	2.83
	21 d	14.7^{bX}	15.3^{ab}	17.8^{aX}	2.42	3.03
	F-value	8.67*	5.26	11.59**		
Cooking loss (%)	3 d	19.5	16.8	16.6^{Y}	2.68	2.14
	21 d	22.2	19.0	19.6^{X}	2.93	1.9
	F-value	1.76	1.56	7.61*		
TBARS (mg MA/kg)	3 d	0.21^{aY}	0.17^{abY}	0.13^{bY}	0.09	3.76
	21 d	0.45^{aX}	0.26^{bX}	0.30^{bX}	0.15	11.37**
	F-value	89.42***	5.41*	15.53**		

[a,b]Indicate significantly different within row with different superscripts.

[X,Y]Indicate significantly different within column with different superscripts.

*p < 0.05, **p < 0.01, ***p < 0.001.

significantly lower L* and higher pH values were observed in bull meat compared with steers or cow meat (Table 2). L* values difference can be attributed to the different genders contained different fatness which can influence muscle lightness [27]. Result of the pH values is in agreement with that color values has a negative correlation with muscle pH values [28], meanwhile, Jeremiah et al. [29] found that steers had the lowest ultimate pH values and bulls had the highest compared with steers, bulls and heifers. Regarding aging time, color values increased with increased aging time, especially in bulls and cows ($p < 0.05$). The aging resulted in an increase in lightness, redness, and yellowness values ($p < 0.05$). Previous studies also reported that Bruce et al. [30] and Vitale et al. [31] also showed an increase in L*, a*, and b* values of beef *Longissimus thoracis* after 14d aging. This may be explained due to the higher blooming ability of vacuum-aged meat.

Although, there are no significant differences in cooking loss among genders in Table 2. Bull meat had the highest cooking loss (%) (19.5%) compared with steers (16.8%) and cows (16.6%) in both the aging times (3d or 21d), indicating that the meat of cow and steer had a better water holding capacity. This could be related to the chemical composition differences among the beef breeds. The finding is consistent with those of Pogorzelska-Przybyek et al. [4]. Ozawa et al. [32] reported a lower cooking loss in higher marbling Japanese black steer meat. Cooking loss (%) gradually increased from 3 d to 21 d aging for all genders. Similar results were found in the studies of Boakye and Mittal [33] who showed an increased cooking loss in beef longissimus dorsi (LD) muscle with increased aging time from day 4 to 16. This may be attributed to an increase in protein denaturation which led to the loss of water holding of the muscle tissues.

The TBARS content is often measured and used as an indicator of lipid oxidation levels in foods including meats and meat products [34]. The TBARS concentration is related to the levels of MDA which is the secondary lipid oxidation compound. TBARS values were significantly influenced by aging time ($p < 0.01$) (Table 2). At the initial measurement, the meat of the cow showed a lower TBARS content compared to the bulls and steers. This could be related to the fatty acid composition differences among the cattle genders [35]. At 21 d of aging, the TBARS increased in all the samples. These may be explained by the activity of endogenous or microbiological enzymes. Lipid oxidation produces off-flavors, rancidity, and deterioration in meat and meat products [36]. For example, TBARS of values 2.0 mg MDA/kg were considered to be the lower limit for acceptance of oxidized beef by Campo et al. [37], McKenna et al. [38] adopted 1.0 mg MDA/kg as an arbitrary threshold, and Hughes et al. [39] found that TBARS levels between 2.60 and 3.11 mg MDA/kg were considered acceptable to consumers in long term aged beef striploin. In our study, the highest TBARS value is 0.45 mg MDA/kg which was much lower than the values reported by these authors.

Effects of gender and aging on texture properties

The mean values of TPA, tensile tests, and WBSF are shown in Table 3. The WBSF, tensile tests, and TPA have been recommended as a tenderness standard by the American Meat Science Association [40] As expected, the WBSF, tensile tests, and TPA values decreased as increasing the aging time in all the samples (Table 3). As increasing the aging time from 3 to 21 d, the bulls, cows, and steers reduced shear force from 4.81, 3.97, and 3.67 kgf to 2.29, 2.08, and 2.26 kgf, respectively. In the same aging time, bulls had the highest WBSF values compared to cows or steers. These differences may be attributed to chemical composition differences such as intermuscular fat (IMF) and subcutaneous fat among the genders [41]. With extending aging time, all the meat samples reduced WBSF values, but the bull meat showed the highest percentage (52.39%) of tenderness improvement compared to the cows (47.61%) and steer meat (38.4%).

At the initial measurement, tensile tests values were significantly affected by aging and gender (p

https://doi.org/10.5187/jast.2022.e128

Table 3. Shear force and texture characteristics of LL muscle

Triats	Aging	Bull	Steer	Cow	SEM	*F*-value
WBSF (kgf)	3 d	4.81^{X}	3.67	3.97^{X}	1.23	1.17
	21 d	2.29^{Y}	2.26	2.08^{Y}	0.33	0.53
	F-value	17.37**	5.3	15.67**		
Tensile maximum force (kgf)	3 d	3.34^{aX}	2.25^{bX}	2.85^{abX}	0.62	7.34**
	21 d	1.47^{aY}	1.02^{abY}	0.86^{bY}	0.43	3.67
	F-value	27.1***	26.47***	256.94***		
Tensile strain (%)	3 d	202.3^{aX}	123.7^{bX}	172.2^{aX}	45.42	7.14**
	21 d	60.8^{Y}	82.1^{Y}	83.1^{Y}	23.14	1.6
	F-value	41.86***	8.01*	30.44***		
Tensile extension (mm)	3 d	20.6^{aX}	12.6^{bX}	17.4^{aX}	4.62	6.96**
	21 d	6.13^{Y}	8.3^{Y}	8.34^{Y}	2.33	1.6
	F-value	41.57***	8.99*	29.42**		
Hardness 1 (N)	3 d	5.12^{a}	3.45^{b}	4.54^{ab}	1.14	4.06*
	21 d	4.56^{a}	3.3^{b}	3.73^{b}	0.65	7.3**
	F-value	0.79	0.22	4.8		
Hardness 2 (N)	3 d	0.05^{b}	0.06^{ab}	0.066^{ab}	0.02	0.13
	21 d	0.07	0.05	0.08	0.03	1
	F-value	0.34	1.38	1.16		
Springiness (mm)	3 d	0.97	0.85	0.93	0.17	0.65
	21 d	0.95	0.82	1.14	0.28	1.93
	F-value	0.01	0.05	4.94		
Gumminess (N)	3 d	0.133^{a}	-0.028^{b}	0.032^{ab}	0.09	4.27*
	21 d	0.07	−0.056	0.012	0.11	1.86
	F-value	0.42	0.18	0.19		
Adhesiveness (J)	3 d	0.006^{ab}	-0.002^{aX}	0.005^{ab}	0.002	2.56*
	21 d	−0.006	-0.005^{Y}	0.005	0.002	0.6
	F-value	0.02	8.1*	0.36		
Chewiness (N*mm)	3 d	0.162	0.043	0.062	0.11	1.95
	21 d	0.151	0.059	0.134	0.14	0.56
	F-value	0.01	0.04	1.44		

^{a,b}Indicate significantly different within row with different superscripts.

^{X,Y}Indicate significantly different within column with different superscripts.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

LL, *longissimus lumborum*.

< 0.01). Although all the tensile tests values showed a decrease with aging time from 3 d to 21 d, bulls still had the highest tensile maximum force values in all the aging times. This can be attributed to adipocytes' excessive development caused disorganization of the perimysial connective tissue [42]. Whilst, tensile strain, tensile extension and tensile maximum force values showed no significant difference among the genders ($p > 0.05$) at 21d aging time. Results can be attributed to the increase myofibrillar fragmentation index with increase aging time [43], and myofibrillar fragmentation index could shows the advancement of myofibrillar degradation.

Excepting hardness, all the TPA including, springiness (mm), chewiness (N), hardness (N), and gumminess (N), were not affected by aging. When increasing the aging time up to 21 d, the hardness decreased in all the genders, however, bull meat exhibited the highest hardness values in both aging times. This is consistent with that reported by Lepper-Blilie et al. [44]. Thus, it may be

said that aging could improve the tenderness of meat from all cattle genders.

Effects of gender and aging on sensory properties

The effects of gender and aging on sensory attributes such as tenderness, juiciness, flavor, and acceptability are presented in Table 4. There were no differences in the tenderness, juiciness, flavor, and acceptability scores between steer and cow meat. Compared to the meat of these two genders, bull meat had a significant difference for all the sensory traits at 3d aging time ($p < 0.01$). Although, there was no difference for all the sensory traits among the genders at 21d aging time, bull meat had the lowest scores. These differences can be attributed to the IMF content differences (Table 1). Similarly, previous studies have shown that beef with higher marbling is tender, flavorful, and juicier [4,5,45]. Extending the aging up to 21 d, no differences in the tenderness, juiciness, and flavor scores occurred among the genders. This means that the eating quality of the meat from all genders was improved during aging. The mechanisms underlying this phenomenon could be related to the breakdown of myofibrils into smaller peptides by the endogenous enzymes, which improved the tenderness and flavor characteristics [46].

Fatty acid profiles

The fatty acid profiles of beef from the three gender are presented in Table 5. The fatty acids composition in muscle tissues play an important role in cooked flavor development [47]. A total of 14 fatty acids were identified in which the most predominant fatty acids being oleic acid (C18:1), palmitic acid (C16:0), and stearic acid (C18:0). Our results are consistent with those reported in the

Table 4. Sensorial characteristics of LL muscle as affected by aging and gender

Traits	Aging	Bull	Steer	Cow	SEM	*F*-value
Tenderness[1)]	3 d	26.4^{bY}	50.4^{aY}	50.4^{aY}	15.67	7.59**
	21 d	80.2^{X}	81.8^{X}	86.6^{X}	7.06	1.13
	F-value	273.06***	16.88**	36.18***		
Juiciness[2)]	3 d	32.6^{bY}	47.8^{aY}	54.4^{aY}	12.66	7.55**
	21 d	75.4^{X}	79.4^{X}	81.8^{X}	7.05	1.06
	F-value	174.13***	22.69**	30.4***		
Flavor[3)]	3 d	34.6^{bY}	59.2^{aY}	60^{aY}	13.62	24.43***
	21 d	72.8^{X}	80.6^{X}	79.6^{X}	6.30	2.88
	F-value	165.82***	37.85***	16.38**		
Overall acceptability[4)]	3 d	33.4^{bY}	57.2^{aY}	56.4^{aY}	14.52	9.74***
	21 d	74.6^{X}	81.6^{X}	81.4^{X}	6.25	2.46
	F-value	264.4***	14.96**	21.24**		
Overall rating[5)]	3 d	31.4^{bY}	55.8^{aY}	55.4^{aY}	15.28	8.91**
	21 d	73^{bX}	82.4^{aX}	79.8^{abX}	6.87	3.32
	F-value	305.75***	13.5**	20.53**		

[1)]Tenderness rating: the values from 0 to 100 indicate the tenderness is from not tender to very tender.

[2)]Juiciness rating: the values from 0 to 100 indicate the juiciness is from not juicy to very juicy.

[3)]Flavor rating: the values from 0 to 100 indicate the flavor is from dislike to like extremely.

[4)]Overall acceptability: the values from 0 to 100 indicate overall acceptability is from dislike to like extremely.

[5)]Overall rating: the values from 0 to 100 indicate overall rating is from unsatisfactory to satisfactory extremely.

[a,b]Indicate significantly different within row with different superscripts.

[X,Y]Indicate significantly different within column with different superscripts.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

LL, *longissimus lumborum*.

https://doi.org/10.5187/jast.2022.e128

Table 5. Fatty acid content of LL muscle subjected to different genders

Fatty acid	Bull	Steer	Cow	SEM	*F*-value
C8:0	0.01[b]	0.02[a]	0.013[ab]	0.002	7.2*
C10:0	0.08	0.13	0.11	0.02	2
C12:0	0.17	0.24	0.15	0.03	1.8
C14:0	4.41	5.36	5.4	0.39	1.4
C16:0	19.2	18.4	19.63	0.52	0.98
C16:1	5.91[b]	9.75[a]	10.86[a]	0.68	9.6**
C18:0	19.05[a]	14.99[a]	16.63[b]	0.77	5.1*
C18:1	37.9	42.8	38.95	1.81	1.4
C18:2	11.58[a]	7.31[b]	7.07[b]	0.67	9.6**
C18:3	0.33[b]	0.27[c]	0.27[c]	0.02	7.9**
C20:0	0.29	0.27	0.24	0.03	0.7
C20:0	0.49	0.29	0.3	0.06	2.4
C22:1	0.07		0.03		
C22:4	0.52[a]	0.16[b]	0.38[ab]	0.06	5.5*
SFA	44.24	39.88	42.88	1.39	1.8
MUFA	43.84[b]	52.53[a]	49.81[a]	1.45	6.3**
PUPA	11.91[a]	7.578[b]	7.34[b]	0.68	9.8**

[a,b]Indicate significantly different within row with different superscripts.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

LL, *longissimus lumborum*; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

previous studies on Hanwoo cattle [48], or American Angus [49], and in Japanese Wagyu [50].

Total saturated fatty acids (SFAs) content was similar in all genders. The monounsaturated fatty acids (MUFA) content was lower and the polyunsaturated fatty acids (PUFAs) content was higher in bull meat compared to the other remaining genders ($p < 0.01$). Moreover, bull meat had significantly higher levels of C18:2 and C18:0, and had lower levels of C16:1 and C18:1 than either steers or cows ($p < 0.01$). Our results are in accordance with those of Legako et al. [51] who reported a higher MUFA and lower PUFA content in beef with higher marbling. It has also been reported that the C18:1 and MUFA are positively associated with beef flavor. Thus, the higher flavor score in the steer beef (Table 4) could be due to its higher oleic acid content. Contrastingly, the PUFAs content such as C18:2 has been reported to negatively affect the beef flavor [52]. In our study, we found that the C18:2 and MUFA were the highest in the bull beef ($p < 0.01$).

CONCLUSION

Compared to the cow and steer, bulls had a lower marbling score and back-fat thickness. Regarding meat quality, bull meat had a higher cooking loss, WBSF, and tensile test values compared to those of cows and steers throughout the aging period. Bull meat also exhibited a higher TBARS content during aging. For the sensory quality, the bull meat had lower tenderness, juice, and flavor scores. The meat of steer and cows showed higher C18:1 and MUFA content whereas, the bull meat had higher C18:2 and PUFA content. Aging significantly improved the tenderness of meat from all genders. It may be concluded that gender and aging exhibited a significant effect on carcass and quality of beef, and aging could improve the tenderness of meat from all cattle gender especially bull.

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