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ARTICLE

Comparison of Tastes-Related Components and Eating Quality between Hanwoo Steer and Cow *Longissimus thoracis* Muscles

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Abstract The objective of this study was to compare tastes-related components and eating quality properties between Hanwoo steer and cow meats. *Longissimus thoracis* (LT) muscles with same quality grade (1^+ grade) collected from left sides of the steer and cow carcasses were used for analyses of technological quality traits, free amino acids (FAAs), metabolites, nucleotides, fatty acids and sensory attributes. there were no differences occurring in the chemical composition (fat, protein, moisture and collagen) and technological quality traits (cooking loss, water holding capacity, shear force and color) between the two beef types (p>0.05). The cow meat exhibited significantly higher amounts of some FAAs associated with umami (e.g., glutamic acid and lysine), sweetness (e.g., proline and glutamic acid) and saltiness (e.g., histidine and glutamic acid) compared to the steer meat (p<0.05). Regarding the nucleotides, no differences occurred in all the identified nucleotides between the two beef types (p>0.05). A total of 27 metabolites were identified, however, only some compounds (e.g., acetate, creatine, creatinine, glucose and inosine, etc.) showed their significantly higher amounts in the cow meat compared with those in the steer meat (p<0.05). In terms of sensory aspects, the panelists found no differences in scores of all the eating quality traits between the two sex types of beef (p>0.05). Overall, excepts some variations in tastes-active compounds, there were no differences in the quality characteristics in general and eating quality in particular between the cow and steer meats when they were in the same quality grade.

Keywords taste, free amino acid, metabolite, nucleotide, eating quality

Introduction

As Korea's economy has developed quickly, the demand for meats especially palatable beef, has also increased compared to the other countries. This may be evidenced by a larger per capita total meat consumption by 4–16 kg in comparison to

China and Japan (Choi, 2016; Eastwood, 2018). Especially, the demand for beef has increased incessantly from 5.3 kg in 1990 and 7.8 kg in 2003 to approximately 12 kg in 2017 (Olson et al., 2018). Despite the increased demand, the Korean consumers much prefer the domestic beef (e.g., Hanwoo beef) to imported beef regardless of its several times higher price (Jo et al., 2012). Because the consumers assume that the Hanwoo beef is fresher and more palatable mainly due to its high intramuscular fat content or visual marbling (Chung et al., 2018; Hwang and Joo, 2016).

In the Korean beef market, there are three main sex types of Hanwoo beef including steers, cows and bulls. However, the ratio of yearly slaughtered cattle for meat production differs significantly among these sex types. For instance; in 2012, the female cattle accounted for 51.90% (corresponding to 436,977 heads) in total slaughtered cattle (718,256 heads), and this ratio was reduced to be 46.80% and 44.60% in 2015 and 2018, respectively (KAPE, 2019). This is probably due to the increased exploitation of the female Hanwoo cattle for reproduction purpose. Contrastingly, the male Hanwoo cattle (steers) slaughtered for meat consumption increased yearly accounted for 41.40%, 50.4%, and 53.1% in total slaughtered cattle in 2010, 2015 and 2018, respectively (KAPE, 2019). It is well recognized that beef cuts from high quality grades (e.g., 1^{++} and 1^{+} grade) are the most desirable by Korean consumers. Nevertheless, the superior grade (1^{+} grades) has predominantly been found in the Hanwoo steers (41.9%) compared to the rate of 18.2% in the cows (KAPE, 2019).

To date, although no scientifically verified evidence has been published, Korean consumers generally show their more preference for the female (cows and heifers) Hanwoo meat compared to the male (steers and bulls) meat because they assume that the meat of female cattle is tender and tastier. Consequently, the average market price per kg of cow carcass is generally higher compared to that of the steer carcass with same quality grade (KAPE, 2019). Thus, searching the scientific evidences indicating the eating quality (e.g., tenderness) and taste differences between these two sex types of beef is necessary. Additionally, tenderness and tastes are the most important components of beef eating quality taken into account by consumers (Jo et al., 2012; Joo et al., 2017; Warner et al., 2010). The tastes (sweet, salty, bitter, sour and umami) of cooked meat are contributed by water-soluble constituents such as free amino acids (FAAs), sugars, nucleotides and metabolites (Dashdorj et al., 2013; MacLeod, 1994; Spanier et al., 2004). While, the tenderness of meat reflected by instrumental shear force value and/or sensorial evaluation score is mainly affected by the amount of connective tissue and intramuscular fat (IMF) (Warner et al., 2010).

Since taste is one of the important eating quality trait of meats (Ramalingam et al., 2019). However, little attention has been paid to the identification of the tastes-related compounds in Hanwoo beef (Dashdorj et al., 2013; Jayasena et al., 2015), especially almost all of these of studies have only focused on meat muscles from steer or heifer whereas, no study was conducted to identify the tastes-active compounds in the Hanwoo cow meat. Thus, the objective of this study was to identify the tastes-related components in Hanwoo cow meat and comparing with those of steer meat.

Materials and Methods

Sample preparation

The *Longissimus thoracis* (LT) muscles (10^{th}–13^{th} rib) with same quality grade (1^{+} grade) from left carcass sides of Hanwoo steers (31–32 months old, average carcass weight of 391 kg, marbling score of 6.8, n=5) and cows (47–53 months old, average carcass weight of 383 kg, marbling score of 6.0, n=5) collected at 24 h postmortem from commercial abattoirs (Jeonju, Korea) were used in the present investigation. After collecting, the LT muscles were vacuum-packaged and then transported to the meat laboratory of animal product division for analysis. Following trimming of visual fats, the muscle samples were cut into sub-sample sizes starting from the cranial end of the muscles depending on the type of analysis in the following order: proximate composition (10^{th} rib); fatty acids, FAAs, metabolites and nucleotides (11^{th} rib); sensory evaluation (12^{th} rib); pH, color, Warner-Bratzler shear force (WBSF) and water holding capacity (WHC) and cooking loss (13^{th} rib). The analyses of proximate composition, pH, color, WHC, cooking loss and WBSF were performed on fresh samples (48 h postmortem), while the fatty acids, FAAs, metabolites, nucleotides and sensory evaluation samples were vacuum-packed and frozen at −20℃ until use.

pH measurement

The pH values of the beef samples were measured in triplicate by inserting a stainless steel probe of pH*K 21 meter (NWK-Technology GmbH, Kaufering, Germany) deeply into the muscle tissues. Prior to use, the pH meter was calibrated with standard solutions (pH 4.0 and 7.0).

Proximate composition

The protein, moisture, fat and collagen contents were determined using a Food Scan™ Lab 78810 (Foss Tecator, DK) according to the association of official analytical chemists methods (AOAC, 2007).

Meat color measurement

The color of the meat samples was measured using a Minolta Chroma Meter CR-400 with a D65 illuminant*1 and 2° observer (Minolta Camera, Osaka, Japan) as described in our previous study (Cho et al., 2020), and expressed as CIE L* (lightness), CIE a* (redness), CIE b* (yellowness), Chroma and hue angle (h°).

Cooking loss and Warner-Bratzler shear force (WBSF) measurement

The cooking loss and WBSF of the beef samples were measured using the protocols as described in our previous (Cho et al., 2017). Briefly, each sample was made into a 2.5-cm thick steak that was placed into plastic bags and cooked in a pre-heated water bath until their internal temperature reached 80℃. After cooling for 30 min under running water (18℃–20℃), the cooked samples were absorbed with wiping papers to remove the surface water and then their weights were recorded. The cooking loss (%) of each the sample was calculated as the difference between the pre-cooked and post-cooked weights divided by the initial weight. After the cooking loss measurement, the cooked samples were used for the WBSF analysis. Eight cores (1.27 cm in diameter) were prepared parallel to the muscle fiber direction of each the sample using a 0.5-inch metal corer. The WBSF values were obtained by determining the force (kilogram force, kgf) required to cut the cores using a V-shaped shear blade of Instron Universal Testing Machine (Model 4465, Instron, High Wycombe, UK) using a crosshead speed of 400 mm/min and a 40 N load cell.

Water holding capacity (WHC)

The WHC of the samples during storage was determined using centrifugation-based method developed by Kristensen and Purslow (2001). Each sample was analyzed in duplicate and the WHC percentage was calculated as a ratio of moisture to the water loss.

Free amino acids (FAA) and nucleotides analysis

The FAA content in the samples was analyzed following the procedure as described by Dashdorj et al. (2013) with suitable modifications. Briefly, 2.5 g of each sample was homogenized with 5 mL distilled water at 1,200×g for 1 min. After filtering through Whatman filter paper (No. 4, Whatman, Clifton, NJ, USA), 100 µL filtrate taken and mixed with 900 µL methanol containing 0.1% formic acid. After centrifuging at 13,000×g for 10 min at 4℃, the supernatant was collected and then filtered through a 0.45-µm filter membrane (Millipore, Cork, Ireland). The filtrate was derivatized using AccQ-Tag^{TM} (Waters, Milford, MA, USA) according to the manufacturer's instrument. Finally, 5 µL of each derivatized sample was injected into a Waters ACQUITY UPLC (model: Xevo TQ-S, Waters) connected to an Intrada Amino Acid column: 2×50 mm, 3µm (Imtaka, Uphur St, Suite A, Portland). The eluents and conditions used for separation of FAAs were same as those used in the above-cited reference (Dashdorj et al., 2013). For identification and quantification of the FAAs, the external amino acid standards (Sigma-Aldrich, St. Louis, MO, USA) were used, and the detected FAAs were then expressed as milligram per 100 g meat (mg/100 g meat).

Nucleotides were analyzed using the method of Jung et al. (2011) with suitable modifications. For separation, 10 µL of each sample was injected into Waters ACQUITY UPLC connected to a C18-reverse phase column: 4.6×150 mm, 3 µm (Cadenza). The mobile phases used were A: 40% tetrabutylammonium hydroxide solution-TBA-oH (25 mL), 85% H_2PO_4 solution (500 µL) and distilled water (1,000 mL), and B: 40% TBA-oH (25 mL), 85% H_2PO_4 solution (500 µL) and methanol (1,000 mL). The separation of nucleotides was carried out at 40℃, the detection was monitored at a wavelength of 260 nm and flowing rate of 0.8 mL/min. The solvent gradient set was: initial 100% A, linear change to 95% A for 1 min, linear change to 100% B for 11 min and then 95% A for additional 8 min. The nucleotides were identified by comparing their retention times with those of external standards, and then quantified using internal standard (Purine) (Sigma-Aldrich).

Fatty acid profiles

The lipid content in the muscle samples was extracted using a solvent mixture of chloroform: methanol (2:1, v/v) as described by Folch et al. (1957). For the extraction, 10 g of sample was homogenized with 150 mL of the solvent mixture at 300×g for 3 min using a homogenizer (Polytron, PT-MRC 2100, Switzerland). After filtration through Whatman filter paper, the filtrate was added with approximately 20 g of Na_2SO_4, thoroughly mixed for 1 min, and then the upper lipid layer was transferred into an Erlenmeyer flask. After drying at 55℃ using a rotary evaporator, the lipids layer was reconstituted with 1 mL tricosanoic acid and 1 mL of 0.5N NaOH. Finally, the lipid was converted to fatty acid methyl esters following the procedure of Morrison and Smith (1964). The fatty acids were analyzed by a gas chromatography (GC, Model Star 3600, Varian Technologies, Palo Alto, CA, USA) connected with a capillary column (30 m×2 mm×0.25 µm film thickness). The conditions used for separation, and identification of fatty acids were same as those described in our previous study (Cho et al., 2020). The results were expressed as relative percent (%) of total fatty acids based on total peak area.

Sensory evaluation

The sensorial characteristics of both the beef types were evaluated using the procedure as described in our previous study (Cho et al., 2020). The procedure used for the sensory evaluation was approved by the Institutional Review Board of National Institute of Animal Science (No.11-1390744-000007-01). Briefly, the panel consisted of 7 trained members (at 24 to 40 years old) who were the institution's staffs. For evaluation, seven representative strips (50×75×4 mm) were prepared from each sample using a meat slicer. Two sessions per day were carried out, and each session had 7 panelists in which each the panelist evaluated 7 samples. The slices were cooked on an open tin-coated grill at around 160℃–170℃ for approximately 2 min and turned at the start of browning. Immediately after cooking, the cooked samples were placed on individual paper dishes and served to the panelists. The panelists evaluated for tenderness, flavor, roasty flavor, taste (intensity of taste after chewing), juiciness, tenderness and overall acceptability using a 6-point scale. The panelists were asked to refresh their palate with drinking water and unsalted crackers between samples. The sensory evaluation was performed in the sensory panel booth room equipped with white lighting.

Metabolites analysis by NMR spectroscopy

The cooked LT muscle samples (the samples were cooked under the identical conditions as those used in the sensory evaluation) were used for the metabolites analysis. The analysis of metabolites was performed following the protocol as described by Lin et al. (2007). Briefly, after grinding each the sample (20 mg) was extracted with acetonitrile/water (1:1, v/v) mixture on ice for 10 min. After centrifuging at 3,000×g for 10 min at 4℃, the supernatant was transferred to a new tube which was then freeze-dried. The lyophilized samples were dissolved in 700 μL of deuterated water containing 2 mM 3-trimethylsilyl-2,2,3,3-tetradeuteropropionic acid-d4 (TSP-d4, Sigma-Aldrich) as an internal standard, and then was transferred into a 5 mm NMR tube for analysis.

^{1}H-NMR spectra were acquired on a 600 MHz Agilent NMR spectrometer (Agilent Technologies, Palo Alto, CA, USA) equipped with 600 MHz 4-mm gHX NanoProbe (Agilent Technologies, Santa Clara, CA, USA) at a ^{1}H frequency of 599.93 MHz. The ^{1}H-NMR conditions were set as follows: spinning rate at 2,050 Hz and 25℃; number of scans, 126; acquisition time, 3 s; relaxation delay, 3 s; 90° pulse, 6.35 μs; total acquisition time per sample, 13. 9 min. The acquired spectra were phased and then the baseline was corrected and referenced to the TSP-d4 peak using a Vnmrj (version 4.2, Agilent Technologies, Palo Alto, CA, USA).

Metabolites in the ^{1}H-NMR spectra of the cooked beef samples were tentatively identified using Chenomx 600 MHz library database and Chenomx NMR Suite 7.1 professional. Concentration of each the identified metabolite was calculated by its corresponding peak area divided by the internal standard's peak area multiplied by the known concentration of international standard.

Statistical analysis

The Statistical Analysis System (SAS) package (SAS Institute, Cary, NC, USA, 2015) was applied for analysis of the data. The data were analyzed by using the General Linear Model procedure of the SAS, and the beef type (gender) was considered and fixed as the main effect while the quality traits examined were considered random in the model. Means were compared using Duncan's multiple range test. Significance was set at $p<0.05$.

Results and Discussion

Proximate composition

The proximate composition in the LT muscles from the two sex types (cows and steers) is presented in Table 1. The protein, moisture, fat and collagen content were: 18.66% vs 19.49%, 61.30% vs 61.45%, 17.82% vs 16.69% and 2.19% vs 2.12% for the steers and cow meats, respectively. No significant ($p>0.05$) differences occurred in all of these contents between the two beef types. This could be due to the LT samples which were in the same quality grade (1^+ grade). Studies

Table 1. Proximate composition of 1+ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Item	Steer	Cow
Protein (%)	18.66±0.28	19.49±0.36
Moisture (%)	61.30±0.22	61.45±0.88
Fat (%)	17.82±0.55	16.69±1.16
Collagen (%)	2.19±0.15	2.12±0.11

have reported that the proximate composition (e.g., fat and protein) in beef muscles differ depending on the quality grades (Gajaweera et al., 2020; Jung et al., 2013; Kim and Lee, 2003). Compared with our data, those of Gajaweera et al. (2020) found similar protein, fat, moisture and collagen contents in *longissimus thoracis* muscles from Hanwoo steers with same 1+ grade. However, compared with fat content (2.5%–5.5%) and marbling scores (2.3–3.7) reported for Hereford cows slaughtered at 4–12 years old by Galli et al. (2008), or cull Danish Friesian cows (Vestergaard et al., 2007), the cow meat in the present study had several times greater level. This fact could be attributed to the differences in genetics and feeding diet used among the studies.

Technological quality and color traits

Table 2 shows the technological quality and instrument color traits of the LT muscles from both sex types. There were no significant differences occurring in the cooking loss, WBSF, WHC as well as color traits between the two beef types ($p>0.05$). In general, the cooking loss level, shear force values and WHC percent of both the beef types in the present study were almost similar to those reported for Hanwoo steer beef muscles with the same quality grade in literature (Cho et al., 2020; Gajaweera et al., 2020). Interestingly, compared to shear force values (5–6 kg) reported for the same sex type such as Hereford cows slaughtered at 4–12 years (Galli et al., 2008) and cull Danish Friesian cows (Vestergaard et al., 2007), the cow meat in the present study had approximately a half lower value. This could be attributed to the higher IMF content in the Hanwoo cow meat compared with those in the meats from other cattle breeds used in these studies. Regarding this, a lot of studies have found a negative correlation between the IMF and shear force in beef; the higher the fat content the lower the force required to shear and cut the meat (Gajaweera et al., 2018; Park et al., 2000; Wood et al., 2008). The shear force value is considered as an indicator reflecting the tenderness of meats. Compared with WBSF values reported by Obuz et al. (2004)

Table 2. Technological quality and meat color of 1+ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Item	Steer	Cow
Cooking loss (%)	23.79±2.32	24.42±0.93
Warner-Bratzler shear force (kg)	2.81±0.17	2.65±0.18
Water holding capacity (%)	61.24±1.49	63.52±1.34
Meat color		
Lightness (L*)	37.53±0.99	37.10±1.16
Redness (a*)	21.18±0.94	21.23±1.82
Yellowness (b*)	10.19±1.06	10.75±1.47
Chroma (c*)	23.52±1.30	22.49±2.31
Hue (h*)	25.41±1.36	26.35±1.47

for beef muscles from high USDA quality grade (e.g., choice and select), the WBSF values obtained on the both beef types in the present study were lower. Researchers have found that the sex, mainly by hormonal status, is a vital factor affecting the physicochemical quality and color traits of beef muscles (Panjono et al., 2009; Picard et al., 2019; Sauerwein and Meyer, 1989). Furthermore, research conducted to examine the effect of animal age on meat quality traits of Hanwoo female cattle has shown that increasing the slaughter age resulted in increased shear force, and decreased WHC and lightness of beef *longissimus* muscle (Cho et al., 2017). Based on the findings reported in these studies, it may be said that sex and slaughter age both have the important effects on the beef quality. In the present study, though the cows were slaughtered at a mature age (47–53 months), and the steers were slaughtered at younger age (31–32 months), no differences occurred in all the technological quality traits examined between these two beef types. This may be explained due to: (i), the beef samples in both the sex types were in the same quality grade (1^+ grade) group because beef cuts within a same quality grade usually are uniform in quality; (ii), the steers produced after castration (castrated male cattle) usually are changed in their hormonal profiles (Plouzek and Trenkle, 1991) which reduced the action and aggressive behavior whereas, increased the fat deposition in muscle tissues (Destefanis et al., 2003). Other researchers have also shown an increased IMF content and improved meat quality in castrated male cattle (steers) compared to intact male cattle (bulls) (Silva et al., 2019). Till now, no reports comparing the technological quality traits between the steer and cow meats are available. Corresponding to the present findings, however, Choat et al. (2006) and Mueller et al. (2019) also reported no differences in shear force and color traits such as; lightness and redness between steer and female (heifers) meats.

Taste-related compounds (free amino acids, nucleotides and metabolites)

The concentrations of FAAs and nucleotides found in the LT muscles of both sex types are presented in Table 3. FAAs are mainly responsible for the tastes of meats, especially sweetness and umami (Dashdorj et al., 2013; Jayasena et al., 2013; Mateo et al., 1996). Based on their similar taste quality, Kato et al. (1989) and Sforza et al. (2001) categorized the FAAs into several classes for instances; glycine, alanine, serine, proline and glutamic acid are associated with sweet taste; glutamic acid, aspartic acid, alanine, serine, lysine and methionine are associated with umami taste; aspartic acid, glutamic acid and histidine are associated with salty taste; valine, leucine, isoleucine, phenylalanine, arginine, proline, tryptophan and methionine are associated with bitter taste. Results show that the most predominant FAAs found in the both beef types were alanine and glutamine which are responsible for sweet taste. Supporting the present results, Cho et al. (2007) and Jayasena et al. (2015) reported similar trend for these amino acids in Hanwoo *longissimus* muscles. Noticeably, no significant differences occurred in these two major amino acids between the two beef types ($p>0.05$). Other some FAAs associated with umami (e.g., glutamic acid and lysine), sweetness (e.g., proline and glutamic acid) and saltiness (e.g., histidine and glutamic acid), were significantly ($p<0.05$) higher in the cows compared to the steers. Supporting the present findings, Lee et al. (2019) reported higher levels of glutamic acid, leucine, valine and threonine in Hanwoo female *longissimus* muscles compared to the castrated male cattle.

Regarding the nucleotides, inosine-5′-phosphate (IMP) is known as the major breakdown product of adenosine 5-triphosphate (ATP), which is then degraded into hypoxanthine and inosine in meats after slaughter (Nishimura et al., 1988). These breakdown products of 5’-nucelotides are important components contributing and enhancing the taste especially umami of cooked meats (Jayasena et al., 2013; Ichimura et al., 2017; Nishimura et al., 1988). Nucleotides such as IMP is mainly responsible for the tastes of meat, especially sweetness and umami (Dashdorj et al., 2013; Mateo et al., 1996). Results showed that there were no differences in all the detected nucleotides between the cow and steer meats ($p>0.05$), implying a

Table 3. Free amino acid profiles and nucleotides in 1⁺ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Items	Steer	Cow
Free amino acids (mg/100 g)		
Glycine	0.21±0.13	1.08±0.36
Alanine	25.24±1.65	28.73±1.42
Serine	4.45±0.78	6.17±0.53
Proline	2.35±0.09[b]	3.17±0.05[a]
Glutamic acid	3.18±0.60[b]	5.70±0.82[a]
Valine	6.13±0.82[b]	9.22±0.95[a]
Threonine	3.09±0.38[b]	4.71±0.39[a]
Leucine	7.60±1.32[b]	11.90±1.25[a]
Isoleucine	3.77±0.63[b]	6.55±0.72[a]
Aspartic acid	0.37±0.07	0.43±0.07
Lysine	3.80±0.33[b]	5.96±0.75[a]
Methionine	1.91±0.54	3.52±0.51
Histidine	0.93±0.22[b]	2.17±0.26[a]
Phenylalanine	4.75±0.67[b]	7.46±0.75[a]
Arginine	5.43±0.86[b]	9.74±0.66[a]
Tyrosine	4.56±0.81	6.59±0.70
Asparagine	0.53±0.08[b]	1.00±0.10[a]
Glutamine	14.15±3.39	10.17±2.05
Tryptophan	0.25±0.16[b]	0.90±0.15[a]
Nucleotides (μM/g)		
Hypoxanthine	1.99±0.14	2.14±0.12
Uridine	0.58±0.04	0.65±0.07
Guanosine monophosphate (GMP)	0.09±0.04	0.07±0.02
Inosine-5′-phosphate (IMP)	2.77±0.07	2.47±0.23

[a,b] Means within a same row with different superscripts differ significantly p<0.05.

similar conversion rate of ATP to the IMP and others between the two sex types. Compared with our data, those of Dashdorj et al. (2013) found higher amounts of IMP and hypoxanthine in Hanwoo heifer *longissimus* muscles after 7 and 14 days of chiller ageing. These contrasting results could be attributed to the different sampling time between the studies because increasing post-mortem ageing usually results in increased amounts of IMP and hypoxanthine in fresh meats (Tikk et al., 2006).

By using the NMR spectroscopy technique, 27 metabolites were detected and identified in the cooked LT muscles from both the beef types (Table 4). In general, the NMR profiles displayed a broad range of compounds comprising amino acids, peptides, carbohydrates and nucleotides, etc. Among them, alanine, glutamine, glycine, leucine, methionine, tyrosine and valine have also been found in beef *longissimus lumborum* muscles (Frank et al., 2020). All of these amino acids have also found in the raw LT muscle of both the sex types (Table 3). Out of the amino acids, however, only glycine and tyrosine showed a significant (p<0.05) difference between the two sex types. Furthermore, the most predominant amino acid found

Table 4. Concentration of identified metabolites in 1+ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Item (mmol/kg meat)	Steer	Cow
AMP	0.94±0.07	0.98±0.06
Acetate	0.38±0.03[b]	0.54±0.03[a]
Alanine	2.87±0.16	2.79±0.13
Betaine	1.49±0.22	1.40±0.06
Carnosine	7.45±0.54	8.33±0.73
Choline	1.03±0.20	0.90±0.11
Creatine	23.73±0.76[b]	26.32±0.65[a]
Creatinine	0.84±0.10[b]	1.11±0.05[a]
Fumarate	0.29±0.06	0.24±0.03
Glucose	6.24±0.11	6.89±0.15
Glutamine	3.39±0.61	2.80±0.38
Glutathione	0.51±0.04	0.42±0.03
Glycerol	4.53±0.40	4.31±0.22
Glycine	1.22±0.04[b]	1.39±0.05[a]
Inosine	0.62±0.03[b]	0.75±0.02[a]
Isoleucine	0.64±0.12	0.87±0.14
Lactate	32.14±2.01	26.89±1.37
Leucine	0.99±0.19	1.04±0.10
Methionine	0.79±0.03	0.87±0.03
N,N-Dimethylglycine	0.08±0.01	0.08±0.00
N-Nitrosodimethylamine	0.41±0.03	0.37±0.01
O-Acetylcarnitine	0.61±0.06	0.65±0.06
Taurine	2.65±0.28	2.61±0.14
Trimethylamine N-oxide	3.79±0.33[b]	4.95±0.32[a]
Tyrosine	0.27±0.02[b]	0.34±0.03[a]
Valine	0.63±0.04	0.70±0.08
sn-Glycero-3-phosphocholine	1.49±0.26	1.44±0.03

[a,b] Means within a same row with different superscripts differ significantly $p<0.05$.

was alanine whose amount was similar in both the beef types ($p>0.05$). Alanine is associated with sweet taste of cooked meat (Kato et al., 1989). AMP and inosine were two unique nucleotides found in both the beef types. They are known as the products degraded from ATP by endogenous enzymes in muscle tissues after slaughter as mentioned above. The amount of inosine was about 0.13 mmol/kg greater in the cow meat compared to that in the steer meat. The other metabolites identified such as; acetate, betaine, lactate, carnosine, creatine and creatinine have previously been reported in raw beef muscles (Frank et al., 2020; Kim et al., 2016). Of which, carnosine (an antioxidant dipeptide) was found at an abundant level but no differences occurred in its amount between the two beef types ($p>0.05$). Carnosine is a metabolite generated from the proteolysis by muscle enzymes (Frank et al., 2020), and contributes significantly to red meat taste (Cambero et al., 2000). Creatine, a lipid metabolism-derived compound, was found at a high level in both the beef types, which agrees with finding of Frank et al. (2020). While, creatinine is known as a breakdown product of creatine from the muscle protein metabolism. Results show that the concentrations of creatine and creatinine were greater in the cow meat compared to that of the steer meat ($p<0.05$). However, the role of these two metabolites in development of cooked meat taste has not been characterized. In general, the results indicating the variations in levels of some metabolites could be partly related to the sex difference that affects the protein and lipid metabolisms in muscle tissues as well as the proteolysis/breakdown process in meat after slaughter. However, the differences in concentrations of metabolites between the two beef types apparently are negligible.

Fatty acid profiles

The proportion of fatty acids in the LT muscles from both sex types are presented in Table 5. Fatty acids not only reflect the nutritional value but also considerably affect the development of cooked meat flavor (Mottram, 1998). Excepting palmitic acid (C16:0), vaccenic acid (C18:1n-7) and oleic acid (C18:1n-9), all the other remaining fatty acids, total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) did not differ between the two sex types of beef ($p>0.05$). Studies have found that castrated cattle (steers) are usually changed in their hormonal profiles which directly affects body fat deposition (Plouzek and Trenkle, 1991) and distribution of fatty acids in muscle tissues as well

Table 5. Relative percentage of fatty acids in 1⁺ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Item (%)	Steer	Cow
C14:0	2.80±0.30	2.69±0.29
C16:0	31.05±0.88[b]	36.50±0.89[a]
C16:1n7	3.60±0.32	5.01±0.56
C18:0	12.17±1.14	11.19±1.86
C18:1n7	0.35±0.05[b]	0.61±0.06[a]
C18:1n9	47.86±1.56[a]	41.48±1.87[b]
C18:2n6	1.86±0.21	2.00±0.26
C18:3n3	0.07±0.01	0.08±0.01
C18:3n6	0.05±0.00	0.05±0.00
C20:1n9	0.11±0.02	0.29±0.09
C20:4n6	0.05±0.01	0.05±0.01
C20:5n3	0.00±0.00	0.00±0.00
C22:4n6	0.04±0.00	0.04±0.01
C22:6n3	0.00±0.00	0.00±0.00
Saturated fatty acids (SFA)	46.02±1.70	50.38±1.79
Unsaturated fatty acids (UFA)	53.98±1.70	49.62±1.79
Monounsaturated fatty acids (MUFA)	51.92±1.72	47.40±2.01
Polyunsaturated fatty acids (PUFA)	2.06±0.21	2.22±0.27
n3 fatty acids	0.07±0.01	0.08±0.01
n6 fatty acids	2.00±0.20	2.14±0.27
n6/n3 fatty acids	30.31±1.52	27.89±2.95

[a,b] Means within a same row with different superscripts differ significantly $p<0.05$.

(Lee et al., 2009). This may be the main reason explaining why most of the fatty acids in the steer meat were not different from those of the cow meat. The current findings would agree with those of Mueller et al. (2019), who did not find differences in most of fatty acids between steer and heifer meats whereas, the significant differences only were found between bull and heifer or bull and steer meats.

In general, it was observed that both the sex types of beef had the fatty acid profile characteristic of high concentrate-fed animals, being indicated by a high level of MUFAs such as C18:1n9 and n-6/n-3 fatty acids ratio, and a lower level of n-3 PUFAs such as linolenic acid (C18:3n-3) (De Smet et al., 2000). Our results align with those of Jayasena et al. (2015), Lee et al. (2019) who reported similar trends for most of the fatty acids in beef muscles from Hanwoo steers and heifers. Likewise, compared to pastured Australian Angus beef, concentrates-fed Hanwoo beef is lower in C18:3n-3 content and higher in n-6/n-3 fatty acid ratio (Cho et al., 2005). Out of the fatty acids identified, C18:1n-9 was the most abundant fatty acid present in both the beef types, followed by palmitic acid (C16:0), which agrees with those of Jayasena et al. (2015) and Cho et al. (2020). Interestingly, the level of C18:1n-9 was significantly higher in the steer meat (47.86%) compared to that in cow meat (41.48%) ($p<0.05$). Our results are in accordance with those of Lee et al. (2019): C18:1n-9 content was higher in Hanwoo steer meat compared with that in female cattle meat. Previous studies have found that production system (feeding diet and regimes, etc.) significantly affects the fat deposition and fatty acid profiles in beef muscles (Schor et al., 2008; Wood et al., 2008). Therefore, the result indicating the variations in the fatty acids between the two beef types may be mainly attributed to these factor's effects. Unfortunately, the information regarding the diets and feeding regimes for the both sex types of beef in the present study was not recorded.

Eating quality attributes

Sensory evaluation of meat is of utmost important to ascertain the virtual merits in the meat-producing practices as well as the impacts of chemical constituents on the precise sensorial attributes of meat. The results of sensory evaluation for the two beef types are presented in Table 6. On the 6-points scale, the tenderness, juiciness, taste and overall acceptability scores given by the panelists were: 4.22 vs 4.36, 3.78 vs 3.93, 3.56 vs 3.62 and 4.02 vs 4.06 for the steer and cow meat, respectively. There were no statistical differences occurring in all of these sensory traits between the two sex types of beef ($p>0.05$). Similar to our results, those of Choat et al. (2006) showed that cattle sex (steer and heifer) had no effects on juiciness or flavor, tenderness and overall tenderness scores of *longissimus* muscles. Likewise, research conducted to examine the effects of sex on eating properties of Angus cattle beef has found no differences in flavor, aroma, juiciness and overall acceptability between steer and heifer (Mueller et al., 2019). The result indicating no differences in the taste score could be related to the tastes-related components (FAAs and metabolites) whose variations in amount might not be large enough for the consumers to discriminate these two beef types. On the other hand, the results indicating no differences in the other eating quality traits such as tenderness, juiciness and roasty flavor, etc. could be attributed to the IMF content that was similar in both the sex types of beef (Table 1). Supporting the present findings, Mueller et al. (2019) also found no differences in eating quality traits between steer and heifer *longissimus thoracis* muscles that contained a same IMF level. Till now, it is well known that marbling degree or IMF content is the vital factor determining the eating quality of beef since the level of IMF has been found positively correlated to all the eating attributes (Chung et al., 2018; Jo et al., 2012; Joo et al., 2017). In contrast to the current findings, Gajaweera et al. (2018) found higher tenderness, juiciness and overall-liking scores for meat of steers compared to cow meat. These authors also found a positive correlation between the IMF content with the sensory attribute scores in that the significantly higher eating quality scores in the steer meat was due to its double greater IMF level compared

Table 6. Mean scores for sensory traits of 1⁺ grade *longissimus thoracis* muscles from Hanwoo cows and steers

Item (6-points scale)	Steer	Cow
Tenderness	4.22±0.15	4.36±0.25
Juiciness	3.78±0.12	3.93±0.17
Flavor	3.91±0.12	3.98±0.24
Roasty flavor	4.27±0.67	4.20±0.66
Taste	3.56±0.14	3.62±0.30
Overall acceptability	4.02±0.08	4.06±0.22

Score distribution: Juiciness: (1) very dry to extremely juicy (6); Taste: intensity of taste, (1) very weak to very strong (6); Tenderness: (1) very tough to very tender (6); Beef flavor: intensity of beefy flavor, (1) very weak to very strong (6); Roasty flavor: intensity of roasty flavor, (1) very weak to very strong (6) Overall acceptability: (1) extremely dislike to extremely like (6).

to that of cow meat. From the results/observations of our investigation it could be said that the cattle sex apparently had no effects on the eating quality when the quality grade (e.g., marbling or IMF) was adjusted to a common level.

Conclusion

Our results unveil that there were no differences in the chemical composition (e.g., IMF) and technological quality traits such as WHC, cooking loss, shear force and color between cow and steer LT muscles. The marbling score and fat content in the cow meat in the present study were several times greater compared to those reported for other cow breeds (cull dairy and suckling cows) in literature, indicating its better quality and more importance in term of economic value. Out of the fatty acids identified, only C16:0, C18:1n-7, and C18:1n-9 showed significant differences between the two beef types. The cow meat showed greater amounts of some FAAs and metabolites compared to the steer meat. No differences were found in all the eating quality attributes between the two beef types, this is likely related to: (i) the same IMF content, and (ii) the tastes-related components whose variations in amount might not be large enough for the consumers to discriminate. Considering all the parameters examined in the present study, it may be concluded that excepts some tastes-related compounds, the quality characteristics in general and eating quality in particular were similar for the cow and steer meats when their quality grade was same. Further study is needed to compare the quality characteristics and tastes-related compounds between the steer and heifer meats.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

Conceptualization: Cho S. Data curation: Seo H, Van Ba H. Formal analysis: Van Ba H. Methodology: Cho S, Van Ba H.

Software: Kang S, Kim Y. Validation: Cho S, Kim J, Van Ba H. Investigation: Cho S, Kim Y. Writing - original draft: Cho S, Van Ba H. Writing - review & editing: Cho S, Seol K, Kang S, Kim Y, Seo H, Lee W, Kim J, Van Ba H.

Ethics Approval

The procedure used for sensory evaluation was approved by the Institutional Review Board of National Institute of Animal Science (No.11-1390744-000007-01).

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