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Abstract

The objective of this study was to investigate the effects of quality grade (QG) on the physicochemical composition and eating quality attributes of pork belly and shoulder butt. Seventy-two growing-finishing crossbred pigs were slaughtered and their carcasses were graded according to the Korean pork carcass grading system. Based on the grading criteria, the carcasses were classified into: QG1+ (n=23), QG1 (n=23) and QG2 (n=26) groups. At 24 h postmortem, belly and shoulder butt cuts were collected from the QG groups and used for analysis of meat quality, flavor compounds and eating quality attributes. Results showed that the variation in fat content among QG was approximately 2% in the both cut types. The QG showed no effects on all the quality traits: cooking loss, pH and color of the belly or shoulder butt ($p>0.05$). Thirty-five flavor compounds comprising mainly fatty acids oxidation/degradation-derived products (e.g., aldehydes) and only few Maillard reaction-derived products (e.g., sulfur-and nitrogen-containing compounds) were identified. However, the QG showed a minor effect on the flavor profiles in both the belly and shoulder butt. Regarding the sensory quality, no effects of the QG were found on all the eating quality attributes (color, flavor, juiciness, tenderness and acceptability) for both the belly and shoulder butt cuts ($p>0.05$). Thus, it may be concluded that the current pork carcass grading standards do not reflect the real quality and value of the belly and shoulder butt cuts.

Keywords: Quality grade; pork; belly; shoulder butt; eating quality

Introduction

Together with the economic growth, demand for meats has remarkably increased in recent decades in Korea (Ban and Olson, 2018). Like other Asian countries, pork meat is a staple in Korean traditional cuisine, with per capita consumption is ranked seventh in the world and third in Asia (Choe et al., 2015). Currently, each pork carcass is fabricated into 7 standard primal cuts (loin, belly, hind and fore legs, shoulder butt, tenderloin and shoulder rib) which are then made into 25 sub-primal cuts (eye-loin, tenderloin, top round, outside round, shanks, belly etc.) according to the Korean Pork Cutting Specification (2018). Out of them, belly (called Samgyeopsal) is considered as the most preferable part, followed by shoulder butt and rib (Oh and See, 2012). The belly and shoulder butt are usually used to make the grilled pork (Samgyeopsal-gui) that is the most popular pork dish in Korean cuisine. Consequently, there is a distinct difference among the cuts in market prices; the retail price per kilogram of belly generally costs 17,810 won while, the other remaining low-fat cuts are worth about 3,003 to 4,111 won per kilogram depending on point in time (Ban and Olson, 2018; Kang, 2019). Although the belly cut only accounts for approximately 14-18 % by weight of each pork carcass, it represents a significant value (approximately 15–17%) (Choe et al., 2015; Pulkrabek et al., 2006). Because of high demand and insufficient supply, a huge amount of belly and shoulder butt must be imported from other markets yearly (Clay, 2018). In 2017, Korea imported approximately 496,442 tons of pork (mainly belly and shoulder cuts) that valued about 1.570,613 US$ from foreign countries (Ban and Olson, 2018).

In Korea, after slaughter, the quality of pork carcasses is graded into different quality grades (QG) by the Korea Institute for Animal Products Quality Evaluation (KAPE). The current Korean pork quality grades consist of three main QGs (1^+, 1 and 2) in which the $QG1^+$ and QG2 are considered as the most desirable and undesirable grades, respectively. Based on the grading criteria by the KAPE (2017), the QGs of pork are determined by warm carcass weight, back-fat thickness, and appearance and meat quality parameters. Of which, the meat quality (marbling, meat and fat color, and texture) is measured on exposed *longissimus dorsi* muscle at the last rib (13^{th}) and the 1^{st} lumbar vertebrae. Particularly, pigs with warm carcass weight of 83-93 kg, back-fat thickness of 17-25 mm, good marbling, meat color values of 3-5 and fat color values of 2-3 etc. belong to the QG1+; pigs with warm carcass weight of 80-98 kg, back-fat thickness of 15-28 mm, fine marbling, meat color values of 3-5 and fat color values of 1-3 etc. belong to the QG1; pigs with rest of warm carcass weight and back-fat thickness (excluded in the QG1+ and 1), poor marbling, meat color values of 2 and 6, fat color values of 4-5 belong to the QG2. It should be noted that a pork carcass with good quality loin doesn't mean to yield a high quality belly or other cuts, and thus withdrawing conclusion on bellies quality based on the loin quality is inappropriate and misleading [16,17].

It should be noted that the final market price of each pork carcass is mainly determined by its QG. According to the report of KAPE (2019), the price per kilogram of pork carcass was 4,222, 4,134 and 3,960 won for the QG1+, 1 and 2, respectively. The carcass grading, therefore, is an important step and is the basis to determine the final market price for each finishing pig. Till now, there have been several studies assessing the effects of QG on the pork meat quality (Ba et al., 2019), however, these authors usually used the *longissimus dorsi* (LD) muscles as the representative samples in their studies. Though the belly and shoulder butt are considered as the most economically important and preferable pork cuts, no studies were conducted to investigate whether the QG affects their technological and eating qualities. This study was undertaken to evaluate the quality parameters, flavor compounds and eating quality of high-fat pork cuts (belly and shoulder butt) and, their associations with the Korean pork grading standards.

Materials and Methods

Samples preparation

Belly and shoulder butt cuts collected from crossbred ([Landrace × Yorkshire] ♀ × Duroc ♂) (LYD) with body weights of 100 to 120 kg were used in the present investigation. The pigs were reared in commercial farms and finished around 180 days old. The day before slaughter, the animals were loaded onto a lorry, shipped to a slaughterhouse (Jeonju, Korea) with a transporting time of about 1 to 2 h and kept in lairage. All the pigs were fasted off feed but with full access to water. The next day, the pigs were humanely slaughtered according to Korean rules and regulations for animal care and standard procedures (Korea Institute of Animal Products Quality Evaluation, KAPE, 2013). During our investigation period, eight slaughter batches (10 pigs per batch and at 1-week intervals) were conducted at a same slaughterhouse. Just after slaughter, the warm carcass weight was recorded and the split carcasses were then chilled at 2°C. On the following day, the left sides of chilled carcasses were ribbed at the last rib (13th) and the 1st lumbar vertebrae to expose the *longissimus dorsi* (LD) muscle. The carcass QGs were evaluated by an official meat grader according to the Korean pork carcass grading system (KAPE, 2013) as described in our previous study (Ba et al., 2019). Based on the grading criteria obtained from the pre-chilling (e.g., warm carcass weight) and post-chilling measurements such as back-fat thickness (at the 11th – and 12th –rib, and between the last rib and first lumber vertebra), and marbling score, meat color and texture, fat color, and fat quality degrees etc. of the exposed LD muscle, the carcasses were categorized into three QG groups: QG 1+ (n=23), QG 1 (n=23) and QG 2 (n=26). The information regarding the live weight and carcass traits of the used pigs are summarized in Table 1. After grading and classification, the carcasses were transferred to a cutting room where the belly and shoulder butt were collected from the left sides and used for the meat quality analysis. The cuts were then skinned, deboned and relatively trimmed of external fats according the instruction of Korean Pork Cutting Specification (2018). Thereafter, each the cut was prepared into sub-sample sizes (Fig. 1) depending on the type of analysis. Analysis of proximate composition, color and pH, were performed on fresh samples on the sampling day, while vacuum packed and storage frozen (−20°C) samples were used for analysis of flavor compounds and sensory attributes.

Chemical composition

The moisture, protein and fat contents were determined using a Food Scan™ Lab 78810 (Foss Tecator Co., Ltd, Hillerod, Denmark), as described in our previous study (Seong et al., 2016). Each sample was determined in triplicates.

pH measurement

The pH of the meat samples was measured in triplicate by inserting a calibrated stainless steel pH probe of a pH*K 21 meter (NWK-Technology GmbH, Kaufering, Germany) deeply into the meat. Three readings were carried out at random locations for each the sample.

Instrumental color measurement

Transversal sections of belly or shoulder butt were taken consecutively and bloomed for 30 min before color measurement using a Minolta Chroma Meter CR-400 with a D65 illuminant*1 and 2^{o} observer (Minolta Camera Co, Osaka, Japan). Care was taken to avoid scanning of intermuscular fat areas in the samples. The color was expressed according to the Commission International de l'Eclairage (CIE) system and reported as CIE L*(lightness), CIE a*(redness) and CIE b*(yellowness). The color values were measured at three random locations on each the sample.

Cooking loss determination

The cooking loss was determined by subjecting approximately 150 g meat steak (2.54-cm in thickness) of each sample to heat treatment by cooking in a pre-heated water bath (72°C) until the temperature reached 70℃ as described by Ba et al. (2019). Following the cooking process, the cooked samples were immediately cooled for 30 min under running water and then re-weight to determine cooking loss. The cooking loss was calculated as the ratio of the cooked to the raw meat sample weight.

Sensory evaluation

The sensorial characteristics of both the pork samples were evaluated using a six-member well trained panels selected from the institution's staffs as described in our previous study (Ba et al., 2019). The sensory evaluation procedure was approved by the Institutional Review Board of National Institute of Animal Science (No.11-1390744-000007-01). To minimize the variation in eating quality caused by the sampling location, for each the belly, three fixed sub-samples (Fig. 1) were collected, separately evaluated and the mean score for each sensorial trait was the average of scores obtained from these three sub-samples. Prior to use, the frozen vacuum-packed sub-samples were defrosted at 4°C for approximately 2 h, and they were then manually sliced into 7 representative slices (50 × 50 × 4 mm: W × L × D). Of which 1 strip was used for general sensorial color evaluation after 30 min cutting (blooming). The rests of strips (6 per sample) were cooked at approximately 180ºC on an open tin-coated grill for about 2 min. Immediately after cooking, the samples were placed on individual dishes and served to the panelists. The panelists then handled the cooked samples with an approved odorless plastic fork and ranked on 7-point hedonic scale (7=extremely like; 6=like very much; 5=like moderately; 4=neither like nor dislike; 3=dislike moderately; 2=dislike very much and 1=dislike extremely) for flavor, juiciness, tenderness and overall acceptability as described by Meilgaard et al. (1991). Between the samples, the panelists were asked to refresh their palate with drinking water and unsalted crackers.

Volatile flavor compounds

The volatile flavor compounds in cooked pork samples were determined using the method standardized by Ba et al. (2010) with minor modifications. Briefly, immediately after cooking, 2.0 g of each the cooked sample was taken and placed into a 20-mL headspace vial (Part No. 5188-2753, Agilent, Santa Clara, CA, USA) and 1.0 µL of 2-methyl-3-heptanone (816mg /mL in methanol) as an internal standard (ISD) was also added. The vial containing sample was sealed with PTFE-faced silicone septum and was then extracted for volatile flavor compounds at 65ºC for 60 min using the solid-phase micro-extraction technique. The extracted volatiles were then separated into a DB-5MS capillary column, 30 m×0.25 mm i.d.×0.25 µm film thickness (Agilent J & W Scientific, Folsom, CA, USA) connected to a Gas Chromatography (Model: 7890B GC) and Mass Spectrophotometry (Model: 5977B MSD, Agilent Technologies, USA). Conditions used for the separation and analysis of the volatiles were same as those described in the above-cited reference (Ba et al., 2010). The volatiles were identified by (i) comparing their mass spectra with those already present in the Wiley registry of mass spectral data (Agilent Technologies, USA) and (ii) by comparing their retention times with those of external standards. The final concentration (µg/g meat) of each identified was calculated by comparing its peak area with the peak area of known-concentration internal standard.

Statistical analysis.

The obtained data was statistically analyzed using a Statistic Analysis System (SAS) package (SAS Institute, Cary, NC, USA, 2007). Means and standard errors were calculated for the variables (meat quality traits etc.). The data were analyzed by using the ANOVA procedure considering QG as the main effect. Means were compared using Duncan's multiple range test. Significance was defined at $p<0.05$. Pearson correlation coefficients between the QG with meat quality traits were also determined using the same statistical analysis software.

Results and Discussion

Effect of QG on the chemical composition and technological quality

The proximate composition and technological quality traits of the belly and shoulder butt cuts as affected by the QG are presented in Table 2. It was observed that the QG significantly affected the chemical composition such as; moisture, fat and protein contents in the both cuts. The moisture content among the QG groups ranged from 52% to 54% and from 61% to 63% in the belly and shoulder butt, respectively. We observed that the bellies in the higher QG group contained lower moisture whereas, the shoulder butt in the higher QG group contained higher moisture content ($p<0.05$). For the fat content (subcutaneous and intermuscular fat), a same trend was observed for the both cuts; increasing the QG increased the fat content. In general, both of cut types contained a relatively high fat level (27-31% and 17-20% for belly and shoulder butt, respectively). Our results align with those of Ba et al. (2019) and Lee et al. (2019), who reported similar trends for the fat content in pork and beef LD muscles from different QG groups. Compared with our data, those of Lowell et al. (2019) and Soladoye et al. (2017) found higher fat content (33-46%) and lower moisture (41-49%) in belly cut of Duroc and Peitrain breeds finished at heavier weight (130-135 kg). These contrasting results are probably due to the differences in the sampling position, slaughter weight and breed used between the studies. Additionally, the fat and moisture results obtained on the belly cut agree with the general rule that fat content is inversely related to moisture content in meat (Kim and Lee, 2003). The protein content among the QG groups ranged from 16.0 to 16.95% and from 17% to 18% in the belly and shoulder butt, respectively. A higher protein content was found in the bellies from the lower QG group ($p<0.05$).

Previous studies have indicated that the color, cooking loss, pH and water holding capacity could be considered as the main technological quality parameters using for segregation of raw meat (Knecht et al., 2018). In both the cut types, all of the technological quality traits (cooking loss, pH and color) were not affected by the QG ($p>0.05$). The cooking loss level among the QG groups ranged from 17.29% to 17.25% and from 24% to 25% in the belly and shoulder butt, respectively. Similar to our results, those of Ba et al. (19) showed that cooking loss of pork LD muscles was not affected by the QG. Compared with our data, however, those of Knecht et al. (2018) found higher cooking loss (22-30%) for pork belly finished at older age (210 days). In fact, the fat content has been proven to strongly affect technological quality traits such as; cooking loss and instrumental color etc. of pork and beef (Lee et al., 2019; Skubina et al., 2010). In the present study, however, this effect was not observed in both the cut types, probably because: (i), the fat levels were relatively higher in all the QG groups and (ii), a small variation in fat content (approximately 2% among the QG groups) that might not cause some effects on the quality traits examined.

Effects of QG on the volatile flavor compounds

The concentrations of the identified volatile flavor compounds in the cooked belly and shoulder butt cuts as affected by the QG are presented in Table 3. The outcome of our analysis displayed a broad range of flavor compounds (over forty compounds) comprising of 17 aldehydes, 6 alcohols, 2 ketones, 6 hydrocarbons, 2 furans and 4 nitrogen-and sulfur-containing compounds. Based on the formation pathways of flavor compounds in cooked meats (Ba et al., 2013; Mottram,1998), it appears likely that most of the identified compounds were derived from the lipid oxidation/degradation, and only few were formed via the Maillard reaction between amino acids with reducing sugars. In general, both cut types had the volatile flavor profile characteristic of high fat content meats, being indicated by a greatly predominant number and amount of the fatty acids-derived compounds such as aldehydes, alcohols and hydrocarbons (Elmore et al., 2005).

Regarding aldehydes, which were the most predominant flavor class found in the both cut types with a total of 15 and 17 compounds in the belly and shoulder butt, respectively. Each of the identified aldehydes was present at a level of at least 0.01 μg per 1.0 g of sample in each the QG group. Of these compounds, however, only few were influenced by the QG when examined by analysis of variance. For the belly, only 3 compounds namely 3-methyl-butanal, 2-methyl-butanal and hexanal showed statistical difference among the QGs. The 3-methyl-butanal and 2-methyl-butanal possessing cheese, nutty and salty notes in cooked pork (Dos Santos et al., 2015), were significantly higher in the QG2 compared to the other remaining QG groups. These two compounds are originated from the degradation of isoleucine and leucine, respectively (Aaslyng and Meinert, 2017). Hexanal is known to arise from the degradation/oxidation of linoleic acid (Hoa et al., 2013; Martın et al., 2001), our results depict that its amount was greater in the QG1+ than in the QG2. Hexanal has been reported to contribute positively to the cooked meat flavor (e.g., fatty odor), but may produce undesirable flavors at higher concentrations (Calkins and Hodgen, 2007). For the shoulder butt, three aldehydes showing the statistical difference ($p<0.05$) among the QGs were 2-ethylhexanal, benzaldehyde and nonanal. Of them, 2-ethylhexanal appears likely to be formed from the Strecker degradation of amino acid, and its concentration was significantly higher in the QG1+ than those in the QG1 and QG2 ($p<0.05$). While, benzaldehyde and nonanal are the products derived from the oxidation/degradation process of linolenic and oleic acid, respectively (Ba et al., 2013; Elmore et al., 2002). The concentrations of these compounds also were higher in the QG1+ than those in the QG1 and QG2 ($p<0.05$). The benzaldehyde has been reported to possess unpleasant flavors (e.g., almond oil, bitter almond and fishy odors) whereas, the nonanal was reported to possess pleasant flavors (e.g., roasted, sweet and fatty odors) in cooked meat (Aaslyng and Schäfer, 2008; Calkins and Hodgen, 2007). Thus, the results indicating the differences in amounts of these aldehydes is likely related to the variations in levels of precursors (e.g., amino acids and fatty acids) among the QGs studied because the content and nature of the precursors determine the flavors generated during cooking (Aaslyng and Meinert, 2017).

Regarding the alcohols, they partly contribute to the cooked meat flavors due to their low odor-detection threshold (Sabio et al., 1998). However, except 1-pentanol, all of the identified alcohols showed no significant differences among the QG groups for both the belly and shoulder butt cuts ($p>0.05$). The 1-pentanol associated with fruity and oily odors (Calkins and Hodgen, 2007), is known as the linoleic acid oxidation-derived product in meat during cooking (Ba et al., 2013; Elmore et al., 2002). Our result depicts that the amount of this compound was higher in the QG1+ bellies (0.16 μg/g) compared to those in the other remaining QG groups. Similarly, a research conducted to examine the effect of QG on volatile flavor profiles in pork LD muscles has also shown that the QG had a minor effect on the quality and quantity of alcohol class (Ba et al., 2019).

Out of the identified hydrocarbons, toluene, and 1,3-dimethylbenzene and xylene were the compounds showing significant ($p<0.05$) differences among the QG groups in the belly and shoulder butt, respectively. Of which, toluene and 1,3-dimethylbenzene were likely derived from the Strecker degradation of amino acids (Olivares et al., 2011). In general, hydrocarbons are known as the lipid oxidation/or amino acids Strecker degradation-derived products which apparently have a minor contribution to the cooked meat flavors because of their high odor-detection thresholds (Mottram 1998). No differences occurred in the identified furans among the QG groups for the bellies ($p>0.05$). For the shoulder butt, both of the furans (2-pentylfuran and 2-octylfuran) showed differences among the QG groups, with significantly higher amounts in the QG2 ($p<0.05$). The 2-pentylfuran and 2-octylfuran are the products derived from the oxidation of C18:2n-6 and C18:1n-6, respectively (Ba et al., 2013). The furan class seems to little contribute to the flavor of cooked meat due to their high odor-detection thresholds.

Nitrogen-and sulfur-containing compounds are produced in the Maillard reaction between amino acids and a reducing carbohydrate in meat during cooking/heating (Mottram, 1998; Thomas et al., 2014). In which, the sulfur-containing amino acids such as cysteine are the main precursors for the formation of the sulfur-containing compounds which are associated with pleasant odors such as meaty and onion of cooked meats (Mottram, 1998). The other amino acids are such as; glycine and valine favor the formation of nitrogen-containing flavor compounds such as pyrazines and thiazoles which are associated with roasted and grilled flavors of cooked meats (Mottram, 1998). With respect to these Maillard compounds, the QG only affected the 2,5-dimethylpyrazine whose amount was significantly higher in the QG2 bellies compared to those in the other QG groups ($p<0.05$). For the shoulder butt, the QG also did affect two compounds (4-methylpyrazole and 2-ethyl-3,5-dimethyl-pyrazine) whose amounts also were higher in the QG2 than those in the QG1+ or the QG1 ($p<0.05$). Almost all of these compounds have also been reported in cooked pork and beef in literatures (Ba et al., 2020; Cho et al., 2020). It appears that both the belly and shoulder butt cuts in the lower QG group (e.g., QG2) presented higher amounts of the Maillard reaction-derived flavor compounds which are associated with meaty, roasted and grilled flavors whereas, those from the higher QG groups (e.g., $QG1^{+}$) presented higher amounts of the fatty acids-derived compounds which are associated with the fatty and oily flavors. This could be related to the differences among the QG groups in the content and nature of precursors present in the cuts.

Effect of QG on the eating quality traits

Mean scores for the eating quality traits of the belly and shoulder butt among the quality grade groups are shown in Table 4. On a 7-point hedonic scale, the panelists gave relatively high scores approximately 5.0~5.7 for all the eating quality traits such as fresh meat color, flavor, juiciness, tenderness and overall acceptability for the both cut types. Thus, it may be said that the bellies and shoulder butts were rated as flavorful, juicy, tender and highly acceptable cuts. In both the cut types, however, no differences occurred in all the eating quality traits among the QG groups ($p>0.05$). In fact, a positive effect of fat level on the eating quality attributes of pork LD muscles has been shown in a large number of studies (Brewer et al., 2001; Fernandez et al., 1999; Wood et al., 2004). Increasing fat level (intramuscular fat) in pork LD muscles resulted in improved flavor, juiciness and tenderness (Fortin et al., 2005; Fernandez et al., 1999; Ngapo and Gariepy, 2008). This study for the first time, evaluated the eating quality of high-fat cuts like belly and shoulder butt as affected by the Korean pork carcass grading system. And the results indicating no statistical differences among the QG groups in all the sensory attributes is likely due to the fact that the panelist could not visually detect the variations in the fat levels among the QG groups because all the cuts in all the QG groups owned a quite high fat level (27-31% and 17-20% for belly and shoulder butt, respectively). Supporting the present findings, Fernandez et al. (1999) showed that an increase in fat level (intramuscular fat) in pork LD muscles resulted in increased flavor and taste but further increases did not intensify the flavor. On the other hand, researches conducted to examine the effect of fat content on consumer's acceptability of pork LD muscles has also shown that increasing fat level could increase the acceptability, but this increase may be associated with a high risk of meat rejection due to visible fat (Fernandez et al., 1999; Fortin et al., 2005). This implies that increasing QG did not result in improved eating quality of belly and shoulder butt cuts. In other words, the current pork carcass grading system does not reflect the real eating quality as well as economic value of these two cuts. Moreover, it is well known that the belly and shoulder butt are the most preferable cuts by consumers worldwide (Oh and See, 2012), and they account for the most important economic value in a pork carcass. By using the criterial parameters (e.g., marbling degree and color etc.) measured on the LD muscle when carcass grading, it is not possible to discriminate the real eating quality of these two cut types among the QG groups accurately. Regarding this, Arkfeld et al. (2016) also stated that a pork carcass with good quality loin doesn't mean to yield a high quality belly or other cuts, and thus withdrawing conclusion on bellies quality based on the loin quality is inappropriate and misleading. Contrastingly, the current carcass grading system is partly based on the marbling score (fat content), therefore, attempts (e.g., through feeding diet) made to increase pork carcass QG may result in excessively deposited fat tissues (e.g., subcutaneous and intermuscular) which may be associated with a high trimmed loss or high risk of meat rejection by consumers in some markets (Fernandez et al., 1999).

Furthermore, the relationships between QG and chemical composition, technological quality and eating quality attributes in the belly and shoulder butt were also determined as shown in Table 5. It was observed that in both the cut types studied there was no ($p>0.05$) correlations between the QG and all the quality traits examined except for the fat and moisture content.

Conclusion

Summing up, the QG only affected the chemical composition such as moisture, fat and protein whereas, did not affect all the technological quality traits examined such as cooking loss, pH and color of the belly and shoulder butt. A large number of volatile flavor compounds comprising mainly fatty acids oxidation/degradation-derived products such as aldehydes and only few Maillard reaction products such as sulfur-and nitrogen-containing compounds at trace quantities was identified. Both cut types from all the QG groups exhibited the volatile flavor profile characteristic of high fat content meats. However, the QG apparently showed a minor effect on the volatile flavor profiles of the belly and shoulder butt. Noticeably, no effects of QG were found on all the eating quality attributes in the both cut types. Considering all the technological quality and eating quality traits examined in the present study, it may be said that the current pork carcass grading system does not reflect the real quality as well as value of the belly and shoulder butt. Therefore, it is necessary to develop a novel pork carcass grading system or the currently-used grading system should be at least modified to guarantee the real quality and value for each pork carcass in each the grade. Additionally, further study is necessary to determine whether the QG affect the nutritional constituents such as fatty acid profile, vitamins and minerals etc. of these two cuts.

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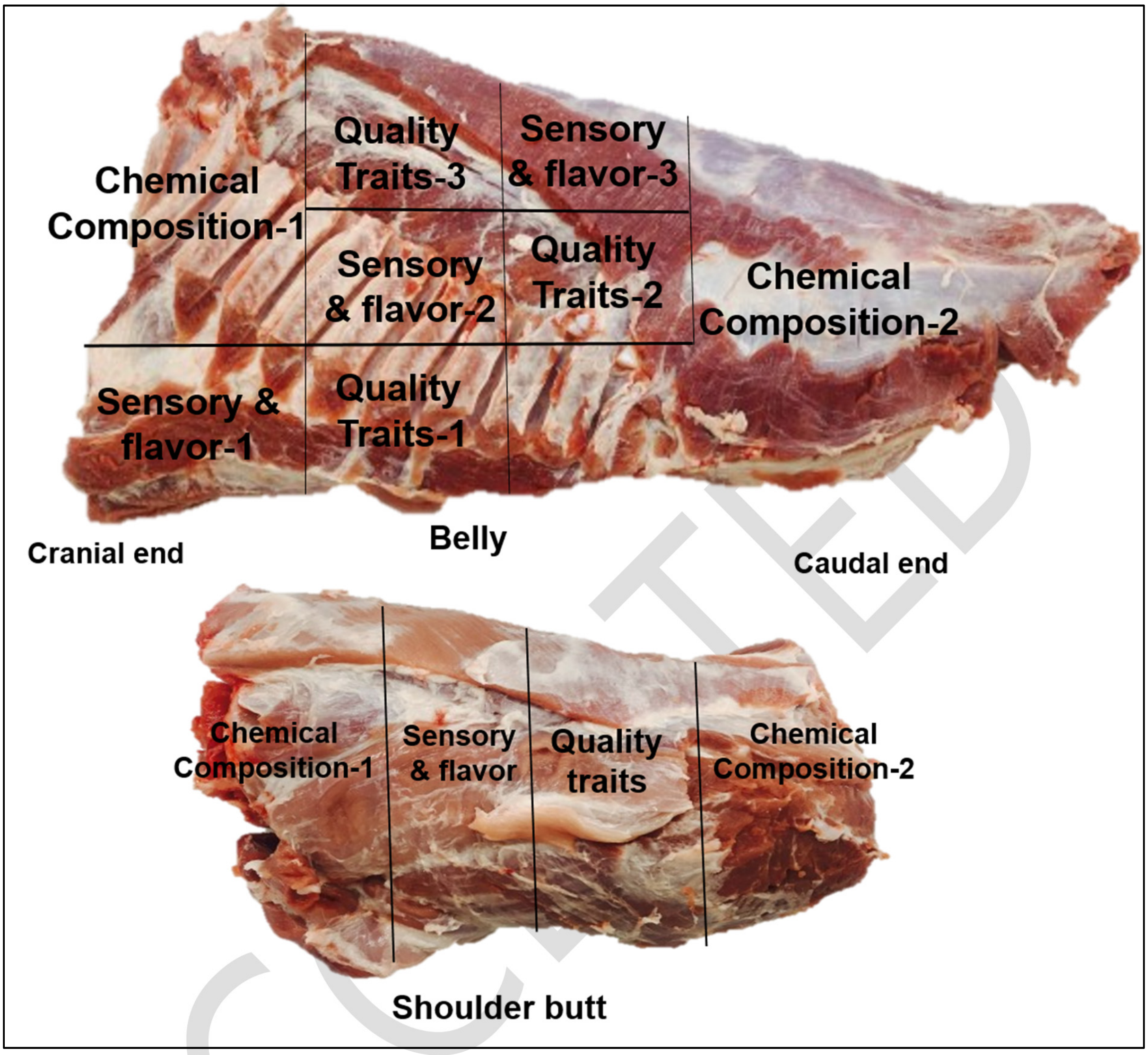

Fig 1: The representative diagram showing the sampling locations on the belly and shoulder butt for the analyses.

Table 1. Live weight, carcass traits and yields of belly and shoulder butt among the three quality grade groups

Grade group	Live weight (kg)	Warm carcass weight (kg)	Cold carcass weight (kg)	Back-fat thickness (mm)	Shoulder butt weight (kg)	Belly weight (kg)
1+	114.48±3.71	92.23±3.69	89.39±2.77	20.50±1.66	2.50±0.20	7.04±0.39
1	115.61±5.90	92.68±4.41	90.17±4.50	21.64±4.15	2.46±0.24	7.10±0.55
2	116.26±13.82	92.86±11.06	90.71±10.81	22.86±6.09	2.58±0.37	7.03±0.94

Table 2. The proximate composition and technological quality traits of belly and shoulder butt among the quality grades

Items	Belly			Shoulder butt		
	QG1+	QG1	QG2	QG1+	QG1	QG2
Proximate composition						
Moisture (%)	52.20±8.81[b]	55.50±8.65[a]	54.47±8.29[a]	63.78±3.90[a]	63.16±5.58[b]	61.47±5.27[b]
Fat (%)	31.95±11.46[a]	27.72±11.29[b]	28.96±11.14[b]	20.47±7.47[a]	18.04±8.47[ab]	17.13±6.20[b]
Protein (%)	16.00±3.04[b]	16.95±3.04[a]	16.77±3.22[a]	18.86±3.19	18.54±3.95	17.95±2.74
Collagen (%)	2.80±1.65	2.82±1.86	2.65±1.57	2.50±1.43	2.61±1.54	2.54±1.52
Technological quality traits						
Cooking loss (%)	17.50±4.05	17.47±3.83	17.29±3.56	25.33±4.16	24.40±3.14	24.82±3.33
pH	5.83±0.16	5.81±0.45	5.79±0.18	5.92±0.43	5.87±0.28	5.81±0.19
CIE L* (lightness)	59.81±9.38	60.31±9.78	58.58±9.89	50.78±4.29	51.99±4.86	50.82±4.12
CIE a* (redness)	11.21±4.45	11.24±4.19	11.22±5.39	14.72±2.19	14.43±2.26	14.38±2.64
CIE b* (yellowness)	7.27±1.74	7.19±1.66	7.39±3.86	7.53±1.59	7.52±1.63	7.46±1.74

Means within a row in each cut with different superscripts (a,b) are different at $p<0.05$

QG: Quality grade.

Table 3. Volatile aroma profiles in cooked belly and shoulder butt among the quality grades

		Belly			Shoulder butt			Identification method[1)]
	Retention Time (min)	QG1+	QG1	QG2	QG1+	QG1	QG2	
Aldehydes								
Propanal	1.723	0.03±0.01	0.04±0.01	0.05±0.02	0.03±0.01	0.03±0.01	0.03±0.01	MS+STD
2-ethylhexanal	2.167	0.01±0.01	0.02±0.01	0.03±0.01	0.02±0.01^{a}	0.01±0.01^{b}	0.01±0.01^{b}	MS+STD
3-methylbutanal	2.72	0.02±0.01^{b}	0.02±0.01^{b}	0.04±0.02^{a}	0.02±0.02	0.01±0.01	0.02±0.01	MS+STD
2-methylbutanal	2.829	0.02±0.02^{b}	0.03±0.02^{b}	0.08±0.04^{a}	0.04±0.03	0.02±0.02	0.03±0.02	MS+STD
Hexanal	6.121	3.06±0.19^{a}	2.82±0.14^{ab}	2.72±0.26^{b}	2.50±0.46	2.56±0.33	2.95±0.23	MS+STD
2-methyl-4-pentenal	7.815	0.00±0.01	ND	ND	ND	0.01±0.01	0.01±0.01	MS
Heptanal	9.261	0.17±0.05	0.16±0.05	0.16±0.03	0.23±0.05	0.25±0.05	0.27±0.04	MS+STD
E, 2-heptenal	10.755	0.04±0.02	0.04±0.02	0.04±0.02	0.07±0.02	0.06±0.02	0.06±0.02	MS+STD
Benzaldehyde	10.873	0.04±0.01	0.04±0.01	0.06±0.02	0.08±0.01^{a}	0.05±0.01^{b}	0.05±0.02^{b}	MS+STD
Octanal	11.915	0.18±0.11	0.21±0.03	0.21±0.09	0.24±0.06	0.26±0.04	0.27±0.06	MS+STD
Benzenacetaldehyde	12.874	0.01±0.01	0.01±0.01	0.02±0.01	0.02±0.02	0.01±0.01	0.01±0.00	MS+STD
E,2-octenal	13.19	0.02±0.02	0.03±0.01	0.02±0.01	0.03±0.02	0.03±0.01	0.02±0.00	MS+STD
Nonanal	14.198	0.21±0.08	0.20±0.05	0.18±0.05	0.53±0.14^{a}	0.26±0.05^{b}	0.25±0.04^{b}	MS+STD
E,2-nonenal	15.33	0.10±0.06	0.06±0.03	0.14±0.13	0.05±0.04	0.10±0.06	0.10±0.07	MS+STD
E,E-2,4-decadienal	16.229	ND	ND	ND	0.01±0.00	0.01±0.00	0.01±0.01	MS+STD
2-undecenal	17.277	ND	ND	ND	0.01±0.00	0.01±0.00	0.00±0.00	MS+STD
2-methylundecanal	17.471	ND	ND	ND	0.02±0.01	0.01±0.00	0.01±0.00	MS
Alcohols								

1-penten-3-ol	3.067	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	MS+STD
4-amino-1-hexanol	3.302	0.15±0.09	0.20±0.05	0.20±0.05	0.22±0.04	0.14±0.08	0.17±0.02	MS
1-pentanol	5.026	0.16±0.02^{a}	0.13±0.02^{b}	0.12±0.02^{b}	0.12±0.01	0.12±0.02	0.14±0.02	MS+STD
1-Heptanol	11.112	0.02±0.01	0.01±0.01	0.01±0.01	0.04±0.01	0.02±0.01	0.03±0.01	MS+STD
1-Octen-3-ol	11.356	0.11±0.06	0.08±0.06	0.09±0.04	0.12±0.04	0.12±0.05	0.07±0.03	MS+STD
2-ethyl-1-hexanol	12.588	0.03±0.01	0.03±0.00	0.03±0.00	0.08±0.08	0.03±0.02	0.03±0.01	MS
Hydrocarbons								
Toluene	4.929	0.01±0.00	0.01±0.00	0.01±0.00	0.02±0.00^{a}	0.01±0.00^{b}	0.01±0.00^{b}	MS+STD
1,3-dimethyl benzene	7.982	0.01±0.01^{b}	0.01±0.01^{b}	0.02±0.00^{a}	0.00±0.00	0.01±0.01	0.01±0.00	MS
Xylene	8.915	0.08±0.02	0.07±0.03	0.07±0.04	0.03±0.00^{b}	0.06±0.03^{b}	0.06±0.02^{a}	MS
2,4-dimethylhexane	13.029	0.03±0.01	0.02±0.01	0.03±0.01	0.03±0.01	0.03±0.00	0.03±0.01	MS
Benzoic acid	15.433	0.06±0.01	0.05±0.01	0.05±0.04	ND	ND	ND	MS+STD
Tridecane	16.101	ND	ND	ND	0.03±0.01	0.01±0.01	0.01±0.00	MS
Furans								
2-pentylfuran	11.581	0.27±0.08	0.27±0.03	0.21±0.08	0.14±0.05^{b}	0.19±0.05^{ab}	0.25±0.05^{a}	MS+STD
2-octylfuran	15.965	0.04±0.01	0.03±0.00	0.02±0.01	0.02±0.01^{b}	0.03±0.01^{a}	0.03±0.01^{a}	MS+STD
Nitrogen and sulfur containing compounds								
4-methylthiazole	11.475	0.19±0.09	0.20±0.01	0.17±0.03	0.11±0.03^{b}	0.15±0.04^{ab}	0.16±0.03^{a}	MS+STD
2,5-dimethyl-pyrazine	9.558	0.01±0.01^{b}	0.01±0.01^{b}	0.04±0.03^{a}	0.02±0.02	0.02±0.01	0.01±0.01	MS+STD
Carbon disulfide	1.862	ND	0.01±0.00	0.01±0.01	0.01±0.00	0.01±0.00	0.01±0.00	MS+STD
2-ethyl-3,5-dimethyl-pyrazine	13.575	0.02±0.01	0.02±0.00	0.02±0.01	0.04±0.02^{a}	0.02±0.00^{b}	0.02±0.00^{b}	MS

Means within a row in each cut with different superscripts (a,b) are different at $p<0.05$; QG: Quality grade; ND: Not detectable.

[1)]Identification method: the compounds were identified by mass spectra (MS) from library or external standard (STD).

Table 4. Mean scores (7-point scale) of sensory traits of belly and shoulder butt among the quality grades

Items	Belly			Shoulder butt		
	QG1+	QG1	QG2	QG1+	QG1	QG2
Sensorial fresh color	5.16±0.83	5.14±0.77	5.10±0.81	5.00±0.76	4.95±0.77	4.92±0.79
Flavor	5.63±0.82	5.59±0.84	5.58±0.92	5.24±1.00	5.30±0.96	5.22±1.05
Juiciness	5.59±0.75	5.59±0.78	5.55±0.80	5.29±0.83	5.27±0.87	5.29±0.77
Tenderness	5.34±0.88	5.35±0.87	5.23±0.91	5.18±0.85	5.23±0.83	5.31±0.80
Overall Acceptance	5.71±0.73	5.72±0.78	5.66±0.87	5.38±0.79	5.53±0.79	5.44±0.82

Means within a row in each cut with different superscripts (a,b) are different at $p<0.05$; QG: Quality grade.

The mean values were calculated using 7-point scale (7=extremely like; 6=like very much; 5=like moderately; 4=neither like nor dislike; 3=dislike moderately; 2=dislike very much and 1=dislike extremely).

Table 5. Correlation coefficients (*r*) between quality grade and meat quality traits in belly and shoulder butt

Items	Quality grade	
	Belly	Shoulder butt
Moisture	-0.467*	0.35*
Fat	0.678*	0.522*
Protein	0.267	0.215
Collagen	0.251	0.254
Cooking loss (%)	0.225	0.251
pH	0.125	0.254
CIE L* (lightness)	0.205	0.215
CIE a* (redness)	0.244	0.125
CIE b* (yellowness)	0.295	0.255
Sensorial fresh color	0.214	0.229
Flavor	0.256	0.257
Juiciness	0.264	0.253
Tenderness	0.214	0.244
Overall Acceptance	0.251	0.252

*, $p<0.05$.