

## Comparison of Physicochemical and Functional Traits of Hanwoo Steer Beef by the Quality Grade

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### Abstract

The physicochemical and functional traits for loin muscles of Hanwoo steers were compared by quality grade (QG). A total of 500 Hanwoo steers were slaughtered, their carcasses were categorized into four groups (QG 1++, 1+, 1, and 2), and the *longissimus dorsi* muscles were analyzed. QG 1++ group had the highest fat and lowest moisture content ( $p < 0.05$ ). QG 1++ showed higher  $L^*$  and  $b^*$  color values, higher cooking loss, and lower shear force values, compared with the other groups ( $p < 0.05$ ). The flavor, tenderness, juiciness, and preference scores by sensory evaluation were highly ranked for premium QG groups (1++ and 1+). Regarding the micro compounds, QG 1 and QG 2 had greater amounts of inosine monophosphate, and QG 2 had greater amounts of anserine, carnosine, and creatine, than QG 1++ ( $p < 0.05$ ). QG 1++ and 1+ had higher percentages of oleic acid (C18:1) than QG 2 ( $p < 0.05$ ). Within premium QG 1++ and 1+, the results of the nucleotides, free amino acids, dipeptides, and fatty acids did not show any distinctive differences. Hanwoo beef as determined by the current grading system was not significantly different in terms of functional components; the only significant difference was in intramuscular fat content.

**Keywords:** Hanwoo steers, quality grade, functional components, sensory evaluation

### Introduction

The native beef cattle in Korea are known as Hanwoo; it is a hybrid of *Bos taurus* × *Bos zebu*, which was migrated and settled in the Korean peninsula in BC 4000 (Rhee and Kim 2001). However, commercialized production of Hanwoo as meat-type cattle was started only in 1960s with the commencing of rapid economic growth in Korea (Jo *et al.*, 2012). Korean consumers prefer beef from Korean native cattle to imported beef because they believe that juiciness and flavor of Hanwoo beef is better than imported beef (Kim *et al.*, 1993). Therefore, Hanwoo beef has been regarded as the most expensive and high quality beef in South Korea. Presently, the prime Hanwoo strip loin received a more than twelve US dollar

premium per kilogram compared to that for an average quality (Hwang *et al.*, 2010).

Consumers are using quality grades as a reference when purchasing beef products. Under the Korean meat market circumstance, carcass quality is largely determined by marbling score (Park *et al.*, 2002), and consequently breeders and producers have forced on the improvement of marbling. Marbling is a prime theme in Korean beef industry, as consumer judge meat quality on the basis of the degree of marbling, and they are willing to pay premium for highly marbled product (Moon *et al.*, 2003; Neely *et al.*, 1998; Savell *et al.*, 1989). Better quality grades have a heavier carcass weight with a higher marbling score, redder meat color and whiter fat color (Moon *et al.*, 2003).

Korean government introduced beef carcass grading specifications in 1992 to be evaluated by beef quality. The quality grade (QG) has five possible values (1++, 1+, 1, 2, 3), and the yield grade (YG) has three possible values (A, B, C) for the evaluation of beef quality in Korean beef carcass grade system (KAPE, 2013). The quality of beef

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is primarily based upon marbling score and additionally determined by lean color, fat color, texture and maturity of the exposed *longissimus dorsi* (LD) muscle at the 13th rib interface (Moon *et al.*, 2006; NLCF, 1998). Quality grade 1++ is the highest or most desirable grade and grade 3 is the lowest degree of quality (Kim and Lee, 2003). Typically, 54% of slaughtered Hanwoo cattle are at or above quality grade 1 compared with 10.7% for Holstein bulls and 0.6% for Holstein cows. Of Hanwoo cattle slaughtered in 2008, 7.5% were grade 1++, 18.1% grade 1+, and 31.7% grade 1. Of 220,355 Hanwoo steers carcasses, 12.3% were grade 1++, 30.3% were grade 1+, and 33.1% were grade 1. Of 263,189 Hanwoo cow carcasses, 6.4% were grade 1++, 18.1% were grade 1+, and 31.7% were grade 1 (KAPE, 2013).

Korean consumers preferred the high quality graded beef, but there is little information concerning both meat quality and functional components of Hanwoo beef according to Korean carcass quality grade system. The objective of this study was to investigate the effect of quality grade on the physicochemical, functional, and sensory traits of *M. longissimus dorsi* of Hanwoo steers.

## Materials and Methods

### Animals and sample preparation

A total of 500 Hanwoo steer (27-30 mon old) were randomly selected from a local cattle farm by Nong-Hyup (Anseong, Korea), slaughtered without electrical stimulation, and then immediately cooled at 0°C for 24 h in a chilling room. The carcass weight was ranged 213 to 477 kg (average 409 kg). The cold carcasses were graded by an official meat grader at 24 h postmortem with the loin surface ribbed between the 13th rib and the 1st lumbar vertebrae according to the Korean carcass grading procedure (NLCF, 1998). The *Longissimus dorsi* (LD) muscles at the 14th to 18th vertebrate were removed and transferred to laboratories. After ageing during 7 d at 4°C, the subcutaneous and intermuscular fat and visible connective tissue of LD muscles were trimmed and used to analyze meat composition, quality, and functional parameters of Hanwoo beef.

### Proximate composition

The proximate composition of each LD muscles was obtained with a slightly modified method of AOAC (2000). Briefly, moisture content was measured by drying 3 g of samples place in aluminum dishes at 104°C for 15 h. The crude protein contents were measured by the Kjeldahl me-

thod (VAPO45, Gerhardt Ltd., Idar-Oberstein, Germany). The crude fat contents were extracted according to the method described by Folch *et al.* (1957). The crude ash contents were measured by burning in a furnace at 600°C overnight.

### Instrument color values

The surface color value were measured by the CIE L\*, a\* and b\* system using a Minolta colorimeter (Model CR-410, Minolta Co. Ltd., Japan). The colorimeter was calibrated against a white reference tile plate (L\*=89.2, a\*=0.921, b\*=0.783), and the diameter size of aperture was 4 cm. The color L\* (lightness), a\* (redness), and b\* (yellowness) values were obtained after 30 min blooming at room temperature. The average value of five random measurements taken from different locations was used for the statistical analysis.

### Physicochemical quality parameters

The pH value of each filtrate was determined with a pH meter (Orion 2 Star, Thermo scientific, USA). Water holding capacity (WHC) was determined by the centrifugation. Briefly, 5 g of minced meat sample was placed into a centrifugation tube with a filter paper (No. 4, Whatman International Ltd., England), and centrifuged at 3,000×g for 10 min. WHC was calculated as the remaining moisture in the meat sample on the basis of the moisture content of the original meat sample. The drip loss was measured as the percentage weight loss of a standardized (3×3×3 cm) meat sample placed in a sealed petri-dish at 4°C during the storage of 2 d. The cooking loss was determined as the percentage weight loss of a standardized (3×3×3 cm) meat sample after cooking in an electric grill with double pans (Nova EMG-533, 1,400 W, Evergreen enterprise, Korea) for 90 s until the internal temperature of the meat sample reached 72°C.

### Shear force measurement

The samples were prepared a cubic form (30×30×20 mm), heated until internal temperature of the samples reached 72±2°C, and then cooled for 30 min at room temperature. Each sample was cut perpendicular to the longitudinal orientation of the muscle fiber with a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2, Stable Micro System Ltd., U.K.). The maximum shear force value (kg) was recorded for each sample. Test and pre-test speeds were set at 2.0 mm/s. Post-test speeds were set at 5.0 mm/s.

### Sensory evaluations

For the sensory evaluation, meat samples were cooked in an electric grill with double pans (Nova EMG-533, 1,400 W, Evergreen, Korea) to an internal temperature of 75°C. The meat samples (2×4×1.5 cm) were placed into randomly coded white dishes and served with drinking water. Ten trained panelists recorded their preferences using a 9-point hedonic scales (1=profoundly dislike, 5=like moderately, 9=profoundly like) after training the panelists using the Hanwoo beef with quality grade 1<sup>+</sup> as a reference. The sensory parameters tested were color, odor, tenderness, juiciness, and overall acceptance for cooked Hanwoo beef.

### Nucleotide-related compounds

The meat samples (5 g) were mixed with 25 mL of 0.7 M perchloric acid and centrifuged at 1,130 g for 1 min to extract nucleic acids. The extracted nucleic acids were then centrifuged at 2,090 g for 15 min and filtered through a Whatman No.4 filter paper (Whatman Inc., USA). The supernatant was then adjusted to pH 7 with 5 N KOH. The pH-adjusted supernatant was placed in a volumetric flask and made up to a volume of 100 mL with 0.7 M perchloric acid (pH 7.0). After 30 min of cooling, it was centrifuged at 1,130 g (0°C) and the supernatant was filtered through a 0.2 µm PVDF syringe filter (Whatman, England). The filtrate (5 mL) was analyzed using HPLC (ACME 9000, Younglin Instruments Inc, Korea). With regard to the analytical conditions for HPLC, a Waters-Atlantis dC18 RP column (4.6×250 mm, 5 µm particles, Waters Co., USA) was utilized, with a mobile phase of 0.1 M triethylamine in 0.15 M acetonitrile (pH 7.0). The flow rate of the mobile phase was 1.0 mL/min and the injection volume was 10 µL. The column temperature was maintained at 35°C and the detection was monitored at a wavelength of 260 nm. The peaks of the individual nucleotides were identified using the retention times for standards: hypoxanthine, inosine, inosine-5'-phosphate (IMP), adenosine-5'-phosphate (AMP) (Sigma, USA), and the concentration was calculated using the area for each peak.

### Free amino acids

The soluble amino acid composition was determined by using a modification of the method described by Hughes *et al.* (2002). The meat was defatted by solvent extraction, according to the method of Lee *et al.* (1996). Defatted meat sample (5 g) was mixed with 20 mL of 2% TCA solution and homogenized at 13,500 rpm/min for 1 min. The homogenate was centrifuged at 17,000 g for 15 min

and filtered through 0.45 µm membrane filter. The filtrate was derivatized by the method of Waters AccQ-Tag<sup>TM</sup> (1993, Millipore Co-Operative, USA) and 5 mL was injected into a RP-HPLC (AccQ-Tag<sup>TM</sup> column, 3.9×150 mm, Waters). The column temperature was 37°C and a fluorescent detector (Waters<sup>TM</sup> 2475, Millipore, USA) was used with 250 nm and 395 nm of excitation and emission wavelength, respectively. Accuracy and repeatability of this analysis is ensured by the inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

### Dipeptides

Dipeptides contents of the meat samples were determined by the method of Mora *et al.* (2007). Minced meat sample (2.5 g) was homogenized with 7.5 mL of 0.01 N HCl at 13,500 rpm/min for 1 min. The homogenate was centrifuged at 17,000 g for 15 min, and the supernatant was mixed with 750 mL acetonitrile. After stored at 4°C for 20 min and then centrifuged at 10,000 rpm for 10 min, it was injected into a HPLC with a Waters 1525 pump and a Waters 717 plus auto sampler (Millipore Co-Operative, USA). Atlantis HILIC silica column (4.6×150 mm, 3 µm, Waters) was used. A diode array detector (Waters 2487, Millipore Co-Operative, USA) was used at 214 nm for determining creatine, carnosine, and anserine, and at 236 nm for creatinine. Mobile A phase was 0.65 mM ammonium acetate in water/acetonitrile (25:75, v/v, pH 5.5) and B phase was 0.55 mM ammonium acetate in water/acetonitrile (70:30, v/v, pH 5.5). B phase was supplied at 1.2 mL/min for 16 min with linear gradient (0-100%). Standards (creatine, anserine, carnosine, and creatinine) were used from Sigma (USA).

### Fatty acids and cholesterol

Lipids for fatty acid analysis were extracted from meat samples according to the method of Folch *et al.* (1957). Meat sample (5 g) were homogenized with 30 mL Folch solution (chloroform:methanol=2:1) and the homogenate was filtered through a filter paper. After adding 0.88% KOH solution, the filtrate was thoroughly mixed. After phase separation, the upper layer was removed and the remaining organic layer was dried under nitrogen flow (99.99%). The dried lipid was dissolved with an aliquot of hexane (at 100 mg lipid/mL hexane) and used for the fatty acid and cholesterol analysis.

One mL BF<sub>3</sub>-methanol (Sigma, USA) was added to 100 mL of lipid extract and incubated in a 90°C for 1 h. After cooling, 2 mL hexane and 5 mL distilled water were added,

mixed thoroughly, and left overnight for phase separation. The top (hexane) layer containing methylated fatty acids was analyzed using a GC (HP 7890, Agilent Technologies, USA). A capillary column (HP-88, 60 m × 0.25 mm × 0.25 mm, Agilent Technologies, USA) was used. A ramped oven temperature condition (180°C for 1 min, increased to 230°C at 2.5°C/min, then held at 230°C for 12 min) was used. Temperatures of both the inlet and detector were 280°C. Helium was the carrier gas at linear flow of 1 mL/min. FID detector air, H<sub>2</sub>, and make-up gas (He) flows were 350, 35, and 41 mL/min, respectively. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma-Aldrich Inc., USA). The fatty acid methyl esters (FAME) in the total lipids were identified by comparison of the retention times with those of a standard FAME mixture (Supleco™ 37 Component FAME Mix, Catalogue number 47885-UP, Lot number, LB-85684, Sigma-Aldrich Inc., USA). Fatty acids were expressed as a percentage of total fatty acids identified, saturated fatty acid (SFA), mono-unsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA). PUFA/SFA and n-6/n-3 ratios were calculated.

For analysis of cholesterol, 10 mL of saponification reagent (33% KOH (w/v)/ethanol, 6:94) were added to lipid extract. The sample was homogenized and then incubated at 50°C for 1 h. After cooling, 5 mL of distilled water and 5 mL of hexane were added. The contents were mixed thoroughly and the hexane layer containing unsaponifiable matters was dried under nitrogen gas (99.99%). The dried sample was then mixed with 200 mL of pyridine and 100 mL of Sylon BFT (99% BSTFA+1% TMCS) and derivatized at 50°C for 1 h. Analysis was performed with a HP 6890 GC equipped with an on-column capillary injector and a FID detector. A capillary column (HP-5, 30 m × 0.25 mm × 0.25 mm) and a ramped oven temperature were used (increased to 260°C from 180°C at 8°C/min, then increased to 280°C at 2°C/min). The amounts were calculated using an internal standard, 5 $\alpha$ -cholestane. The content of cholesterol was expressed as mg/

100 g of meat.

### Statistical methods

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS, 1999). Data given in the tables are means and standard error of the means. Differences in the mean values were tested by Student-Newman-Keul method. A probability level (P) of 0.05 was used to determine differences among the treatment means ( $p < 0.05$ ). The mean values and the standard errors of the means (SEM) were reported.

## Results and Discussion

### Carcass characteristics, nutritive composition, and meat color

The carcass weight of quality grade (QG) 2 was significantly lower than the other group, and the back fat depth of quality grade 1++ were higher than the others (Table 1). Proximate composition and cholesterol of LD muscles from Hanwoo by quality grade are also presented in Table 1. Moisture and crude protein contents significantly decreased with increasing quality grade from grade 2 to grade 1++ ( $p < 0.05$ ). However, crude fat content for LD muscles was 24.25% in QG 1++, followed by QG 1+ (17.44%), QG 1 (14.05%), and QG 2 (7.09%), which is understandable because the most predominating parameter to determine the QG is intramuscular fat content (marbling) in Korean beef carcass grade system (KAPE, 2013). QG 2 contained the highest moisture (70.92%) and crude protein (20.18%) and crude ash (1.83%) when compared with the other three groups, while QG 1++ muscles contained the lowest ( $p < 0.05$ ).

This result agreed to the previous studies (Cho *et al.*, 2010; Lee *et al.*, 2010) that reported that the protein and moisture contents were higher in QG 2, and the fat contents were higher in QG 1++ compared to the other grades. This is also confirmed an earlier report by Kim and

**Table 1. Carcass characteristics and nutritive composition of loins from Hanwoo with different quality grade**

	1++	1+	1	2	SEM <sup>1</sup>
Carcass weight (kg)	421.3 <sup>a</sup>	420.2 <sup>a</sup>	412.1 <sup>a</sup>	400.8 <sup>b</sup>	3.5
Back fat depth (mm)	14.6 <sup>a</sup>	13.3 <sup>b</sup>	12.9 <sup>b</sup>	12.7 <sup>b</sup>	0.1
Moisture (%)	55.79 <sup>d</sup>	62.06 <sup>c</sup>	64.84 <sup>b</sup>	70.92 <sup>a</sup>	0.31
Crude protein (%)	18.98 <sup>b</sup>	19.19 <sup>b</sup>	19.26 <sup>b</sup>	20.18 <sup>a</sup>	0.11
Crude fat (%)	24.25 <sup>a</sup>	17.44 <sup>b</sup>	14.05 <sup>c</sup>	7.09 <sup>d</sup>	0.32
Crude ash (%)	0.96 <sup>c</sup>	1.03 <sup>bc</sup>	1.17 <sup>ab</sup>	1.83 <sup>a</sup>	0.01
Cholesterol (mg%)	61.78	59.79	58.08	59.80	0.27

<sup>1</sup>Standard error of the means (n=500).

<sup>a-d</sup>Means with different letters within the same row differ significantly ( $p < 0.05$ ).

Lee (2003) who the QG 1 meat had significantly more crude fat content and less moisture than other grades. Moon *et al.* (2006) reported that the crude fat content was closely related to marbling score as evaluated by the meat graders. Previous studies have also reported an inverse relationship between intramuscular fat and moisture content in bovine muscle (Park *et al.*, 2000; Savell *et al.*, 1986). Cholesterol for LD muscles did not differ among the four quality grade groups. In the present study, cholesterol LD muscles among quality grade ranged from 60.33 to 61.67 mg/100 g. Bures *et al.* (2006) noted similar findings among the quality grade which ranged from 59 to 68 mg/100 g, which is similar to our results. A slight tendency towards higher cholesterol contents in beef having increased IMF contents was found by Bures *et al.* (2006), but not in the present study.

Comparisons of meat color of LD muscles among quality grade are shown in Table 2. CIE L\* (lightness) and b\* (yellow) value significantly increased with increasing quality grade from QG 2 to QG 1++ ( $p < 0.05$ ). QG 1++ showed a higher CIE L\* (lightness) and b\* (yellow) value when compared to the other grades. Similar findings were obtained by Kim and Lee (2003) who observed high quality grade LD muscles had higher b\* value than low quality grade. Lee *et al.* (2010) showed that L\* values were significantly higher in QG 1++ compared to the other grades. Also, distinctive differences observed between 1++ and 1+ QG groups in moisture and crude fat contents.

### Physicochemical traits and sensory evaluation

Quality grade significantly ( $p < 0.05$ ) affected the drip loss and cook loss of LD muscles although it gave similar values among the four groups (Table 3). The pH, WHC

and drip loss were not significantly different among the groups. The pH values were similar in all quality groups (all mean values were between 5.52 and 5.57). Previous study (Kim and Lee, 2003) showed that pH values among the quality grade groups from Hanwoo LD muscles were not statistically different. Water holding capacity (WHC) was expressed as a ratio of the meat film area to the total expressible juice area; therefore large values indicate a higher actual WHC (Kim and Lee, 2003). The WHC increased with increase of the quality grade, but the WHC among the four grade groups did not differ. This is in agreement with the previous research (Kim and Lee, 2003; Lee *et al.*, 2010), which reported there were no significant differences in WHC among the groups. Drip loss was also significantly different by quality grade, and the similar finding was obtained by Kim and Lee (2003).

Cooking loss was significantly different by quality grade. The cooking loss of QG 1++ was the worst, and the values were decreased as the quality grade was lower. This result can be attributed to the loss of fat during the cooking process. However, the results disagree with previous studies (Kim and Lee, 2003; Park *et al.*, 2000), which cooking loss among steaks samples from the three grades did not differ. Ozawa *et al.* (2000) reported that cooking loss of Japanese black steer meat was significantly lower for samples with the highest marbling score. This might be due to the difference resulted from the method for cooking loss. The shear force values of 1++ were lower than the others, and the values of quality QG 2 were the greatest. The higher intramuscular fat in 1++ can be a factor for the lower shear force values. Cho *et al.* (2010) also evaluated WBSF values of LD muscles were significantly lower for QG 1++ compared with QG 2. Marbling often

**Table 2. CIE color values of loins from Hanwoo with different quality grade**

	1++	1+	1	2	SEM <sup>1</sup>
L*	40.70 <sup>a</sup>	39.84 <sup>b</sup>	38.52 <sup>c</sup>	37.46 <sup>d</sup>	0.15
a*	22.06	21.87	21.46	21.63	0.13
b*	13.94 <sup>a</sup>	13.63 <sup>ab</sup>	13.05 <sup>bc</sup>	12.66 <sup>c</sup>	0.10

<sup>1</sup>Standard error of the means (n=500).

<sup>a-d</sup>Means with different letters within the same row differ significantly ( $p < 0.05$ ).

**Table 3. Physicochemical traits of loins from Hanwoo with different quality grade**

	1++	1+	1	2	SEM <sup>1</sup>
pH	5.52	5.52	5.54	5.57	0.01
WHC (%)	71.14	70.76	69.82	69.97	0.30
Drip loss (%)	17.92 <sup>b</sup>	18.00 <sup>b</sup>	18.60 <sup>ab</sup>	19.22 <sup>a</sup>	0.16
Cooking loss (%)	20.69 <sup>a</sup>	19.34 <sup>b</sup>	18.02 <sup>c</sup>	17.04 <sup>d</sup>	0.14
Shear force (kg)	48.91 <sup>c</sup>	53.93 <sup>b</sup>	56.11 <sup>ab</sup>	58.37 <sup>a</sup>	0.49

<sup>1</sup>Standard error of the means (n=500).

<sup>a-d</sup>Means with different letters within the same row differ significantly ( $p < 0.05$ ).

**Table 4. Sensory evaluation of loins from Hanwoo with different quality grade**

	1++	1+	1	2	SEM <sup>2</sup>
Color <sup>1</sup>	5.25	5.45	5.14	5.04	0.06
Flavor	6.07 <sup>a</sup>	5.90 <sup>a</sup>	5.13 <sup>b</sup>	4.10 <sup>c</sup>	0.10
Tenderness	5.92 <sup>a</sup>	5.86 <sup>a</sup>	4.67 <sup>b</sup>	3.98 <sup>c</sup>	0.09
Juiciness	5.99 <sup>a</sup>	5.84 <sup>a</sup>	4.89 <sup>b</sup>	4.06 <sup>c</sup>	0.08
Preference	6.15 <sup>a</sup>	5.70 <sup>b</sup>	4.61 <sup>c</sup>	3.93 <sup>d</sup>	0.08

<sup>1</sup>1: extremely bad~9: extremely good.

<sup>2</sup>Standard error of the means (n=500).

<sup>a-d</sup>Means with different letters within the same column differ significantly ( $p<0.05$ ).

**Table 5. Nucleotide-related compounds of loins from Hanwoo with different quality grade (unit: mg%)**

	1++	1+	1	2	SEM <sup>1</sup>
IMP	100.22 <sup>b</sup>	110.80 <sup>b</sup>	126.35 <sup>a</sup>	129.83 <sup>a</sup>	3.24
Inosine	29.77	26.66	26.58	25.55	0.52
AMP	6.64	6.57	7.06	6.93	0.10
Hypoxanthine	20.98	19.93	21.51	20.29	0.41

<sup>1</sup>Standard error of the means (n=500).

<sup>a,b</sup>Means with different letters within the same row differ significantly ( $p<0.05$ ).

has been regarded as a contributing factor to beef palatability and is used as the most important factor in evaluating the beef quality (Tatum *et al.*, 1982).

Sensory evaluation of loins from Hanwoo by quality grade is presented in Table 4. Color did not differ significantly among the four groups. Quality QG 1++ and 1+ had significantly higher flavor, tenderness, and juiciness scores than the others ( $p<0.05$ ). QG 1++ LD muscles contained the highest flavor (6.07), tenderness (5.92), and juiciness (5.99) compared with the other three groups. Flavor, tenderness, and juiciness significantly increased with increasing quality grade ( $p<0.05$ ). Therefore, the overall preference was clearly ranked by the quality grade.

These results are consisted with those of the previous research (Kim and Lee, 2003) that the QG 1 steaks had higher tenderness and juiciness score than QG 3 steaks. These findings also suggested that meat quality grade for Hanwoo affect the sensory characteristics of meat, mainly juiciness and tenderness. Many authors have proven tenderness and juiciness are positively related to intramuscular fat content in most studies (Fiems *et al.*, 2000; Renand *et al.*, 2001; Wheeler *et al.*, 1996). Park *et al.* (2000) reported beef loin with high intramuscular fat had high scores in juiciness and tenderness. A decrease in marbling level had resulted in a reduction in juiciness, tenderness, and flavor intensity scores (Savell *et al.*, 1989). The overall acceptance is the sum of all sensory parameters. Cho *et al.* (2010) found that Korean consumers decided their overall acceptability of Hanwoo beef in following proportions: weights of tenderness 55%, juiciness 18%, and flavor-likeness 27%. Therefore the higher overall acceptability

scores of beef with increasing quality grade might be associated to the synergistic effect of higher tenderness and juiciness scores of those quality grade groups (Table 4). In addition, higher IMF content (marbling) played a vital role in determining overall acceptance scores (Okumura *et al.*, 2007). As a result of the physicochemical traits and sensory evaluation, a clear difference of Hanwoo LD muscles was observed by the quality grade. Distinctive differences were also observed between 1++ and 1+ QG in preference score.

#### Nucleotide-related compounds, amino acids, and dipeptides

Nucleotide-related compounds result from the decomposition of adenosine triphosphate (ATP) (Flores *et al.*, 1999). ATP is the major compound in muscle before slaughter, whereas muscle after slaughter contains large amounts of inosine monophosphate (IMP) and small amounts of ATP, AMP, and ADP (Lee and Lee, 2001). ATP becomes AMP by dephosphorylation and is then converted to IMP, which provides good taste to meat. And IMP changes to inosine, and then to hypoxanthine, which has a bitter taste (Tikk *et al.*, 2006). There was only significant difference in IMP among the nucleotide-related compounds (Table 5). QG 1++ and 1+ LD muscles contained higher IMP compared with the other two groups ( $p<0.05$ ). AMP, inosine, and hypoxanthine were not significantly different. Cho *et al.* (2008) investigated that 1++ QG Hanwoo steer beef had higher IMP in eye of round and top round. It is well documented that nucleotide-related compounds, free amino acids, and peptides are

**Table 6. Free amino acids of loins from Hanwoo with different quality grade (unit: mg%)**

	1++	1+	1	2	SEM <sup>1</sup>
Ala	48.43 <sup>b</sup>	48.69 <sup>b</sup>	44.39 <sup>b</sup>	56.46 <sup>a</sup>	0.96
Asp	2.10	2.23	2.17	2.50	0.10
Cys	6.64	6.63	6.32	5.03	0.23
Glu	13.38	13.83	10.41	14.01	0.45
Gly	12.35 <sup>ab</sup>	12.28 <sup>ab</sup>	10.42 <sup>b</sup>	13.52 <sup>a</sup>	0.29
His	95.12 <sup>b</sup>	101.91 <sup>b</sup>	102.39 <sup>b</sup>	125.00 <sup>a</sup>	2.43
Ile	6.71 <sup>a</sup>	6.62 <sup>a</sup>	4.82 <sup>b</sup>	6.72 <sup>a</sup>	0.22
Leu	11.48 <sup>a</sup>	11.48 <sup>a</sup>	8.61 <sup>b</sup>	11.74 <sup>a</sup>	0.36
Lys	13.12	13.70	10.94	13.62	0.35
Met	5.29 <sup>a</sup>	5.31 <sup>a</sup>	3.75 <sup>b</sup>	5.27 <sup>a</sup>	0.19
Phe	7.12 <sup>a</sup>	7.10 <sup>a</sup>	5.26 <sup>b</sup>	7.07 <sup>a</sup>	0.23
Pro	5.59 <sup>b</sup>	5.70 <sup>b</sup>	5.28 <sup>b</sup>	6.63 <sup>a</sup>	0.13
Ser	14.32 <sup>ab</sup>	14.7 <sup>ab</sup>	11.88 <sup>b</sup>	15.78 <sup>a</sup>	0.41
Thr	33.97 <sup>b</sup>	34.86 <sup>b</sup>	32.81 <sup>b</sup>	44.30 <sup>a</sup>	0.94
Tyr	7.57 <sup>a</sup>	7.32 <sup>a</sup>	5.77 <sup>b</sup>	8.18 <sup>a</sup>	0.22
Val	9.44 <sup>a</sup>	9.44 <sup>a</sup>	7.07 <sup>b</sup>	9.76 <sup>a</sup>	0.31

<sup>1</sup>Standard error of the means (n=500).

<sup>a,b</sup>Means with different letters within the same row differ significantly ( $p<0.05$ ).

responsible for improving the taste, flavour and aroma of meat during storage (Jo *et al.*, 2012; Rikimaru and Takahashi, 2010). However, IMP is generally considered as the major nucleotide in muscle that imparts flavor to the meat (Jo *et al.*, 2012).

Free amino acids of loins from Hanwoo by quality grade are given in Table 6. Tseng *et al.* (2005) classified free amino acid in food to umami (aspartic acid, glutamic acid), sweet (serine, glycine, threonine, alanine), bitter (valine, methionine, isoleucine, leucine, phenylalanine, histidine, arginine), and other taste (glutamine, tyrosine, lysine and proline). QG 1 had significantly lower glycine, isoleucine, leucine, methionine, phenylalanine, serine, tyrosine, and valine than others ( $p<0.05$ ). QG 2 had significantly more alanine, histidine, proline and threonine than QG 1 ( $p<0.05$ ). The results showed that the high amino acid in QG 2 corresponded well with a high crude protein contents. However, any characteristic differences of free amino acids by quality grade were not found in the present study.

Dipeptides of loins from Hanwoo by quality grade are given in Table 7. QG 2 had more anserine, carnosine, and

creatinine content than 1++ group ( $p<0.05$ ). Dipeptides including carnosine, anserine and creatine are considered as bioactive components in meat because they provide antioxidant or energy-providing including prevention and treatment of a disease (Peiretti *et al.*, 2012). Peiretti *et al.* (2012) recently found 1,680-1,720 mg of carnosine and 160-270 mg of anserine in 100 g of freeze-dried beef. Additionally, they reported a reduction in carnosine content in cooked beef which was attributed to the high water solubility of carnosine and related compounds. The results of this study concerning the nucleotide, amino acid and dipeptide have showed that no distinctive differences found between QG 1++ and 1+.

### Fatty acids composition

Fatty acid compositions of LD muscles from Hanwoo by quality grade are presented in Table 8. The major fatty acids were oleic (C18:1), palmitic (C16:0), stearic (C18:0), palmitoleic (C16:1), linoleic (C18:2) and myristic (C14:0) acid. These fatty acids accounted for over 88% of the total fatty acids in the intramuscular fat (IMF). The difference by quality grade was shown in some fatty acids. QG 2 had significantly more C15:0, C17:0, C17:1, C20:3, C20:4 and C24:1 than others ( $p<0.05$ ). Oleic acid (C18:1) makes up the largest proportion of the monounsaturated fatty acid (MUFA). QG 1++ and 1+ had higher percentage of oleic acid (C18:1) and unsaturated fatty acid (UFA) contents than QG 2 ( $p<0.05$ ). Similar findings were obtained by Lee *et al.* (2010) who found out UFA were higher in loin of QG 1++.

There was no significant difference by quality grade on total saturated fatty acids (SFA), the ratio of unsaturated fatty acids to saturated fatty acids (UFA/SFA), and the ratio of n-6/n-3 unsaturated fatty acids related with a risk of coronary heart disease (Enser, 2001). Therefore, WHO (2003) recommends reducing the intake of SFA and increasing the intake of n-3 fatty acids. Meats from ruminant animals had a more favorable n-6/n-3 ratio due to the less C18:2 high C18:3 than pork (Wood *et al.*, 2004). Hanwoo beef had significantly higher n6/n3 ratio than Angus which had high contents of n-3 PUFA (C18:3n3, C20:5n3, C22:

**Table 7. Dipeptides of loins from Hanwoo with different quality grade (unit: mg%)**

	1++	1+	1	2	SEM <sup>1</sup>
Anserine	107.11 <sup>b</sup>	114.90 <sup>ab</sup>	120.56 <sup>ab</sup>	137.81 <sup>a</sup>	3.44
Carnosine	697.19 <sup>c</sup>	778.39 <sup>ab</sup>	762.39 <sup>b</sup>	817.60 <sup>a</sup>	8.97
Creatine	1444.27 <sup>c</sup>	1564.80 <sup>b</sup>	1633.70 <sup>a</sup>	1663.40 <sup>a</sup>	8.76
Creatinine	18.06	19.49	19.13	17.39	0.51

<sup>1</sup>Standard error of the means (n=500).

<sup>a-c</sup>Means with different letters within the same row differ significantly ( $p<0.05$ ).

**Table 8. Fatty acid composition of loins from Hanwoo with different quality grade (unit: %)**

	1++	1+	1	2	SEM <sup>1</sup>
C10:0	0.04	0.04	0.04	0.04	0.00
C12:0	0.07 <sup>b</sup>	0.08 <sup>ab</sup>	0.08 <sup>a</sup>	0.09 <sup>a</sup>	0.00
C14:0	2.38	2.52	2.54	2.61	0.03
C14:1	0.74 <sup>a</sup>	0.81 <sup>a</sup>	0.76 <sup>a</sup>	0.68 <sup>b</sup>	0.02
C15:0	0.2 <sup>b</sup>	0.21 <sup>b</sup>	0.23 <sup>ab</sup>	0.26 <sup>a</sup>	0.01
C16:0	22.69	22.87	23.07	22.80	0.12
C16:1	4.01	4.03	3.63	3.66	0.08
C17:0	0.55 <sup>b</sup>	0.58 <sup>b</sup>	0.59 <sup>b</sup>	0.68 <sup>a</sup>	0.01
C17:1	0.65	0.66	0.64	0.66	0.01
C18:0	10.05 <sup>b</sup>	9.92 <sup>b</sup>	10.64 <sup>b</sup>	10.99 <sup>a</sup>	0.13
C18:1	44.59 <sup>a</sup>	44.58 <sup>a</sup>	43.39 <sup>ab</sup>	42.77 <sup>b</sup>	0.20
C18:1, 11t	2.09	2.25	2.10	1.95	0.05
C18:2	2.85	2.86	3.00	3.12	0.07
C20:0	0.05	0.05	0.05	0.05	0.00
C18:3	0.12	0.11	0.10	0.10	0.00
CLA, 9c11t	0.35	0.34	0.33	0.33	0.01
C20:1	0.36 <sup>a</sup>	0.32 <sup>ab</sup>	0.32 <sup>ab</sup>	0.28 <sup>b</sup>	0.01
CLA 10t12c	0.02	0.03	0.02	0.02	0.00
C20:2	0.04 <sup>b</sup>	0.11 <sup>ab</sup>	0.19 <sup>a</sup>	0.17 <sup>a</sup>	0.02
C20:3	0.30 <sup>b</sup>	0.27 <sup>b</sup>	0.31 <sup>b</sup>	0.37 <sup>a</sup>	0.01
C20:4	0.53 <sup>bc</sup>	0.50 <sup>c</sup>	0.66 <sup>ab</sup>	0.74 <sup>a</sup>	0.02
C24:1	0.16 <sup>b</sup>	0.14 <sup>b</sup>	0.17 <sup>b</sup>	0.22 <sup>a</sup>	0.00
SFA	36.01	36.27	37.24	37.39	0.20
UFA	56.8 <sup>a</sup>	56.99 <sup>a</sup>	55.62 <sup>ab</sup>	55.2 <sup>b</sup>	0.22
PUFA	3.41	3.49	3.88	4.32	0.09
UFA/SFA	1.59	1.58	1.51	1.49	0.01
n-6/n3	8.42	9.43	9.55	8.67	0.16

<sup>1</sup>Standard error of the means (n=500).

<sup>a-c</sup>Means with different letters within the same row differ significantly ( $p < 0.05$ ).

5n3) and lower contents of n-6 PUFA (C18:2n6, C18:3n6 and C22:4n6) (Cho *et al.*, 2005).

Korean consumers tend to purchase beef with high quality grade, since marbling is one of the key factors determining carcass grade. Within quality grades of Hanwoo beef, the present study did not show any negative points in the fatty acids compositions of premium QG beef. The unsaturated fatty acids including oleic acid were higher in QG 1++ than the others. A few functional fatty acids, conjugated linoleic acids such as CLA 9c11t and CLA 10t12c, were not significantly different among different QG groups, notwithstanding remarkable differences in fat content and the sensory preference. In conclusion, Hanwoo beef determined by current grading system did not show any distinctive difference of the compositions of functional components but did in only intramuscular fat content. However, further research will be given to develop a better beef quality grade system in the aspects of meat quality, functional, and sensory traits, because consumers are getting interested in the health benefits of what they eat.

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