Effect of Intramuscular Fat Content on the Meat Quality and Antioxidative Dipeptides of Hanwoo Beef

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근내지방도가 한우육의 품질 및 항산화성 Dipeptide 특성에 미치는 영향

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국문요약

근내지방도(IMF)가 한우육의 품질 및 기능성분에 미치는 영향을 조사하기 위하여, 250두의 한우를 근내지방 함량에 따라 Low(<14%, n=96), Medium(14~17%, n=83), High(>17%; n=71) 세 그룹으로 분류하고, 7일간 숙성 후 등심육의 품질 및 기능성분을 분석하였다. 한우 등심육의 수분 함량은 IMF와 반비례하였으며, High IMF 그룹은 Low IMP 그룹에 비하여 낮은 드립 감량을 나타내었다. 기능성 didpeptide 함량은 IMF에 따라 유의적 차이가 없었으나, High IMF 그룹은 다른 그룹보다 낮은 inosine monophosphate, 높은 hypoxanthine, 낮은 histidine 함량은 나타내었다. 불포화지방산의 비율은 IMF에 따라 유의적 차이가 없었다. 저지방육의 건강지향적 가치를 고려할 때 지나친 IMF를 목표로 하는 육종 및 사양은 지양되어야 할 것으로 판단되었다.

Key words: intramuscular fat, Hanwoo, composition, quality, functional

INTRODUCTION

Hanwoo, Korean native cattle, is well known for its palatable taste and texture as well as high value of nutrients. Compared with other species, Hanwoo beef is characterized by its highly marbled fat, thin muscle fibers, and minimal content of connective tissues (Jo et al. 2012). Intramuscular fat among muscle bundles (marbling) is a prime factor responsible for the palatability of beef and Korean consumers are accustomed to eat highly marbled beef. Hanwoo breeding and feeding strategy has been designed to accumulate more intramuscular fat in beef muscles and the carcass grading system is mainly focused on the marbling score, which are positively related with market price of beef.

It is known that the fatty acids composition from Hanwoo beef is more ideal for human health than the imported ones, as Hanwoo has more contents of unsaturated fatty acids (Jo et al. 2012). Excessive fat present in beef, however, can be regarded as a negative factor for human health (Scollan et al. 2006). Consumers become to seek more healthful meat and meat products

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and some people concerning about obesity began to avoid high fat meats, and the trend will be stronger than before (Arihara 2006). Considering the fat content of high marbled Hanwoo beef, the absolute amounts of saturated fatty acids are greater in Hanwoo beef than imported ones. Thus, it is not easy to say that Hanwoo beef is more healthful than imported one.

There have been many healthful components discovered in meat, such as antioxidative peptides and functional fatty acids. Meat industry also tries to offer the consumer healthful meat products modified by increasing unsaturated fatty acids (Bilek & Turhan 2009). Nevertheless, there is few studies dealing with the quality and functional properties of Hanwoo beef in the view point of high marbling strategy. Therefore, it is imperative to determine the relationship between the fat content of Hanwoo beef and other functional components. The objective of the present study was to elucidate the effects of intramuscular fat content in Hanwoo beef on proximate composition, physicochemical meat quality, micronutrient components, and sensory attributes.

MATERIALS AND METHODS

1. Sample Preparation

A total of 250 Hanwoo steers were randomly selected from a local cattle farm in NongHyup (Anseong), and slaughtered. Carcasses were then immediately cooled at 0℃ for 24 hr in a chilling room. Carcasses were categorized into three groups according to the intramuscular fat (IMF) content: Low IMF (<14%, n=96), Medium IMF (14 to 17%, n=83), and High IMF (>17%; n=71). The left sides of the cold carcasses were then ribbed between the 13th rib and the 1st lumbar vertebrae at 24 hr postmortem and evaluated according to the Korean carcass grading procedure (NLCF, 1998). *Longissimus dorsi* (LD) muscles at the 14th to 18th vertebrae were removed and transferred to the laboratory. After ageing at 4℃ for 7 d, LD muscles were trimmed of all subcutaneous and intermuscular fat, and visible connective tissues. Completely trimmed left LD muscle of each carcass was used to analyze meat composition, quality, and functional parameters of Hanwoo beef whereas the right muscle was used to evaluate sensory qualities.

2. Proximate Composition

The proximate composition of each LD muscle was determined by a slightly modified method of AOAC (1995). Briefly, the moisture content was obtained by drying each sample (3 g) placed in an aluminum dish at 104℃ for 15 hr. The crude protein contents were measured by the Kjeldahl method (VAPO45, Gerhardt Ltd., Idar-Oberstein, Germany). The crude fat contents were measured using the Soxhlet extraction system (TT 12/A, Gerhardt Ltd., Idar-Oberstein, Germany). The crude ash content was measured by igniting 2 g of each sample in a furnace at 600℃ overnight. For measuring pH, meat was homogenated and filtered through a filter paper. The pH value of meat filtrate was determined with a pH meter (Orion 2 Star, Thermo Scientific, Beverly, MA, USA).

3. Physicochemical Properties

The water holding capacity (WHC) was determined by centrifugation method of Kang et al. (2012). Briefly, 5 g of minced meat sample was placed into a centrifugation tube with a filter paper (No. 4, Whatman International Ltd., Maidstone 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 ㎝) meat sample placed in a Petri dish at 4℃ during the storage of 2 day. The cooking loss was determined as the percentage weight loss of a standardized (3×3×3 ㎝) meat sample after cooking in an electric grill with double pans (Nova EMG-533, 1,400 W, Evergreen enterprise, Korea) for 90 sec until the internal temperature of the meat sample reached 72℃.

The color values (CIE L*, a*, and b*) were measured on the surface of meat samples using a colorimeter (CR-410, Minolta Co. Ltd., Japan) which was calibrated against a white reference tile plate (L*=89.2, a*=0.921, b*=0.783). The diameter of aperture was 4 ㎝. The color L* (lightness), a* (redness), and b* (yellowness) values were obtained after blooming the meat samples at room temperature for 30 min. For measuring shear force value, each meat sample was prepared in cubic form (30×30×20 ㎜) and subsequently cut perpendicular to the longitudinal orientation of the muscle fiber using a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2, Stable Micro System Ltd., Surrey, U.K.). The maximum shear force value (kgf) was recorded for each sample. Test and pre-test speeds were set at 2.0 ㎜/sec and post-test speeds were set at 5.0 ㎜/sec.

4. Nucleotide Contents

The meat samples (5 g) were mixed with 25 ㎖ 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 filter paper (No.4, Whatman Inc., Clifton, NJ, USA). The supernatant was then adjusted to pH 7 with 5 N KOH. The pH-adjusted supernatant was placed into a volumetric flask and made up to a volume of 100 ㎖ with 0.7 M perchloric acid (pH 7). After 30 min of cooling, it was centrifuged at 1,130×g (0℃) and the supernatant was filtered through a 0.2 ㎛ polyvinylidine difluoride syringe filter (Whatman, Maidstone, England). The filtrate (5 ㎖) was analyzed using HPLC (ACME 9000, Younglin Instruments Inc, Seoul, Korea). With regard to the analytical conditions for HPLC, a C_{18} reverse phased column (4.6 × 250 ㎜, 5 ㎛ particles, Waters Co., Milford, USA) was utilized, with a mobile phase of 0.1 M triethylamine in 0.15 M acetonitrile (pH 7). The flow rate of the mobile phase was 1.0 ㎖/min and the injection volume was 10 ㎕. The column temperature was maintained at 35℃ 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, St Louis, MO, USA), and the concentration was calculated using the area for each peak.

5. Free Amino Acid Contents

The free amino acid composition was determined by modifying the method described by Hughes et al. (1984). Defatted meat sample (5 g) was mixed with 20 ㎖ of 2% TCA solution and homogenized at 13,500 rpm/min for 1 min. The homogenate was then centrifuged at 17,000×g for 15 min and filtered through 0.45 ㎛ membrane filter. The filtrate was derivatized by the method of Waters AccQ-Tag™ (1993, Millipore Co-Operative, Milford, MA, USA) and 5 ㎕ was injected into a RP-HPLC (AccQ・Tag™ column, 3.9×150 ㎜, Waters). The column tempe-rature was 37℃ and a fluorescent detector (Waters™ 2475, Millipore, USA) was used with 250 nm and 395 nm of excitation and emission wavelengths, respectively. The separation was done by using buffers: A (Waters AccQ・Tag eluent) and B (60%, v/v, acetonitrile). Accuracy and repeatability of this analysis are ensured by the inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

6. Dipeptide Contents

Dipeptides contents of the meat samples were determined according to Mora et al. (2007). Minced meat sample (2.5 g) was homogenized with 7.5 ㎖ of 0.01 N HCl at 13,500 rpm/min for

1 min. The homogenate was then centrifuged at 17,000×g for 15 min, and the supernatant was mixed with 750 ㎕ of acetonitrile. After keeping at 4℃ for 20 min, it was centrifuged at 10,000×g for 10 min and the supernatant was injected into a HPLC with a Waters 1525 pump and a Waters 717 plus auto sampler (Millipore Co-Operative, Milford, MA, USA) with Atlantis HILIC silica column (4.6×150 ㎜, 3 ㎛, Waters). A diode array detector (Waters 2487, Millipore Co-Operative, Milford, MA, USA) was used at 214 nm for the determination of 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 ㎖/min for 16 min with linear gradient (0-100%). Standards (creatine, anserine, carnosine, and creatinine) were used from Sigma (USA).

7. Fatty Acids and Cholesterol

Lipids were extracted from meat samples according to the method of Folch et al. (1957). One milliliter of BF3-methanol (Sigma, USA) was added to 100 ㎕ of lipid extract and incubated at 90℃ for 1 hr. After cooling, 2 ㎖ of hexane (HPLC grade) and 5 ㎖ of distilled water were added, mixed thoroughly, and left overnight for phase separation. The top (hexane) layer containing methylated fatty acids was analyzed using a gas chromatograph (HP 7890, Agilent Technologies, USA). A capillary column (HP-88, 60 m×0.25 ㎜×0.25 ㎛, Agilent Technologies, USA) and a ramped oven temperature condition (180℃ for 1 min, increased to 230℃ at 2.5℃/min, then held at 230℃ for 12 min) were used. The temperatures of both the inlet and detector were 280℃. Helium was the carrier gas at linear flow of 1 ㎖/min. FID detector air, H_2, and make-up gas (He) flows were 350, 35, and 41 ㎖/min, respectively. Relative quantities were expressed as weight percent of total fatty acids identified via comparison of retention times to known standards (37 FAME mix, CLA mix, Sigma-Aldrich, USA).

For the analysis of cholesterol, 10 ㎖ of saponification reagent (33% KOH /ethanol (w/v), 6:94) were added to the lipid extract. The sample was homogenized and then incubated at 50℃ for 1 hr. After cooling, 5 ㎖ of distilled water and 5 ㎖ of hexane were added. The contents were mixed thoroughly and the hexane layer containing unsaponifiable matters was dried using nitrogen gas (99.999%). The dried sample was then mixed with 200 ㎕ of pyridine and 100 ㎕ of Sylon BFT (99% BSTFA+1% TMCS)

and derivatized at 50℃ for 1 hr. Analysis was performed with a gas chromatograph (HP 6890) equipped with an on-column capillary injector and a FID detector. A capillary column (HP-5, 30 m×0.25 ㎜×0.25 ㎛) and a ramped oven temperature were used (increased to 260℃ from 180℃ at 8℃/min, then increased to 280℃ at 2℃/min). The amounts were calculated using an internal standard, 5 α-cholestane.

8. Sensory Evaluation

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℃. The meat samples (2×4×1.5 ㎝) 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^+ as a reference. The sensory parameters tested were color, odor, tenderness, juiciness, and overall acceptance for cooked Hanwoo beef.

9. Statistical Analyses

Analysis of variance was performed on all the variables measured by the procedure of General Linear Model (GLM) using SAS statistical package (SAS, 1999). The Duncan's multiple range test was used to determine differences among the treatment means at $p<0.05$. The mean values and the standard error of the means (SEM) were reported.

RESULTS AND DISCUSSION

1. Proximate Composition

The proximate composition of three Hanwoo LD groups categorized by IMF content is shown in Table 1. The moisture contents were ranked conversely by the IMF content. The Low IMF muscles (average IMF 10.71%) had 67.69% moisture content, while High IMF (average IMF 21.07%) had only 58.45% moisture. The result is accordant to the previous studies where intramuscular fat content was negatively correlated with moisture content (Kim & Lee, 2003; Savell et al. 1986).

The cholesterol contents of Hanwoo LD muscles, ranged 60.59～61.21 ㎎/100 g, were not significantly different by IMF ($p>0.05$). The result is different from the previous study of Bures et al. (2006) that increased IMF contents beef had higher chole-

Table 1. Proximate composition, cholesterol, and pH of Hanwoo beef categorized by different intramuscular fat (IMF) content

	IMF[1]			SEM[2]
	Low	Medium	High	
Proximate composition				
Moisture (%)	67.69[a]	64.47[b]	58.45[c]	0.31
Protein (%)	19.72[a]	19.00[b]	19.29[ab]	0.11
Fat (%)	10.71[c]	14.89[b]	21.07a	0.32
Ash (%)	1.13[a]	1.04[b]	1.03[b]	0.01
Cholesterol (㎎/100 g)	60.67	61.21	60.59	0.37
pH	5.55	5.55	5.52	0.01

[1] Low, <14%; Medium, 14-17 %; High, >17%.
[2] Standard error of the means.
[a-c] Means with different superscript within the same row differ significantly ($p<0.05$).

sterol contents. The pH levels of Hanwoo LD were 5.52 to 5.55, which were not significantly different by the IMF ($p>0.05$). Kim & Lee (2003) also showed that pH values of Hanwoo beef ranged between 5.47 and 5.49 with no differences among the meat quality grades ($p>0.05$).

2. Physicochemical Properties

Beef color is an important factor for consumers to select meat in market as they determine the freshness and organoleptic qualities of meat by its color. The L* values of Hanwoo LD muscles increased with increasing level of IMF content (Table 2). The result can be attributed to the presence of high amounts of fat in beef muscles. The a* values were not significantly different by the IMF level. High IMF muscles had greater b* values than the other groups.

Table 2. Meat color values of Hanwoo beef categorized by different intramuscular fat (IMF) content

	IMF[1]			SEM[2]
	Low	Medium	High	
L*	38.34[c]	39.22[b]	40.29[a]	0.18
a*	21.62	21.46	21.95	0.13
b*	12.93[b]	13.15[b]	13.76[a]	0.10

[1] Low, <14%; Medium, 14-17 %; High, >17%.
[2] Standard error of the means.
[a,b] Means with different superscript within the same row differ significantly ($p<0.05$).

Table 3. Physico-chemical quality parameters of Hanwoo beef categorized by different intramuscular fat (IMF) content

	IMF[1]			SEM[2]
	Low	Medium	High	
WHC (%)	70.33	69.74	71.33	0.30
Drip loss (%)	18.92[a]	18.36[ab]	18.01[b]	0.16
Cooking loss (%)	21.09	21.51	21.81	0.19
Shear force (㎏)	26.18	26.24	26.42	0.49

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

[a,b] Means with different superscript within the same row differ significantly ($p<0.05$).

Meat quality parameters such as WHC, drip loss, cooking loss, and shear force are presented in Table 3. Those quality parameters were not significantly influenced by the IMF level, except drip loss. High IMF group had significantly lower drip loss than Low IMF. The result is accordant with Ozawa et al. (2000) reporting that the cooking loss of Japanese Black steers was significantly lower in the highest IMF content. On the other hand, Kim & Lee (2003) reported no significant differences in WHC, cooking loss, and shear force by meat quality grade. Park et al. (2002) observed no significant differences in WHC and cooking loss by fat content. Contrarily

It is well documented that shear force values are negatively related to IMF content of meat (Seideman et al. 1987). According to Cho et al. (2005), shear values of Hanwoo LD muscles were significantly lower for higher marbling. In contrast, several authors demonstrated that shear force did not show any significant relationship with the IMF content or marbling score (Brooks et al. 2000). In the present study, there was no significant difference of shear force by IMF ($p>0.05$).

3. Nucleotides

Meat components such as soluble amino acids, inosine, IMP, and peptides are mainly responsible for the sensory quality of meat, especially umami taste (Sasaki et al. 2007). Among them, IMP is generally considered as a major nucleotide in meat that imparts flavor to the meat (Jo et al. 2012). Greater amount of IMP contents were found in Low IMF group, whereas hypoxanthine was more found in High IMF group (Table 4). AMP and inosine contents did not differ among the IMF groups ($p>0.05$). Considering that umami taste is attributed by the synergistic effect of inosinic acid and glutamic acid (Cho et al. 2007; Jo et al. 2012) and

Table 4. Nucleic acid (㎎/100 g) of Hanwoo beef categorized by different intramuscular fat (IMF) content

	IMF[1]			SEM[2]
	Low	Medium	High	
IMP	121.73[a]	105.18[b]	94.64[b]	3.16
Hypoxanthine	25.44[b]	27.28[ab]	29.33[a]	0.49
AMP	7.22	6.69	6.69	0.10
Inosine	20.96	21.26	22.14	0.39

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

[a,b] Means with different superscript within the same row differ significantly ($p<0.05$).

bitter taste is done by hypoxanthine, Low IMF group can be regarded more desirable than High IMF group.

4. Soluble Amino Acids

Free amino acids and peptides are responsible for the taste

Table 5. Soluble amino acids (㎎/100 g) of Hanwoo beef categorized by different intramuscular fat (IMF) content

Soluble amino acid	IMF[1]			SEM[2]
	Low	Medium	High	
Ala	49.64	46.09	47.71	0.96
Arg	312.27	287.16	292.07	5.17
Asp	2.19	2.40	2.06	0.10
Cys	5.46	5.69	6.46	0.23
Glu	12.06	11.59	12.99	0.45
Gly	11.54	11.47	11.86	0.29
His	113.39[a]	101.49[b]	98.00[b]	2.44
iLe	5.53	5.50	6.50	0.22
Leu	9.77	9.73	11.17	0.36
Lys	12.08	11.81	13.14	0.35
Met	4.27	4.38	5.15	0.19
Phe	5.91	5.99	6.93	0.23
Pro	5.82	5.54	5.51	0.13
Ser	13.54	12.96	14.03	0.41
Thr	37.17	34.60	33.75	0.94
Tyr	6.70	6.45	7.22	0.22
Val	8.05	8.03	9.18	0.31

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

[a,b] Means with different superscript within the same row differ significantly ($p<0.05$).

and flavour of meat during storage (Jo et al. 2012). Amino acids such as asparagine, threonine, serine, glutamic acid, glycine, and alanine are known to be associated with tasty (sweet) flavor, whereas valine, isoleucine, leucine, phenyalanine, methionine, arginine, histidine and proline are closely associated with bitter taste in meat (Sforza et al. 2001). Furthermore Cho et al. (2007) reported glutamate and alanine were major amino acids in Hanwoo beef responsible for sweet taste. IMF level, however, did not show any significant effect on the profiles of soluble amino acids. Only significantly different amino acid by the IMF level was histidine which is related with bitter taste of meat. Thus IMF content was not a critical factor affecting the soluble amino acids of Hanwoo beef.

5. Dipeptides

Dipeptides including carnosine, anserine, and creatine are considered as functional/ bioactive components in meat (Peiretti et al. 2012). Carnosine and anserine have significant antioxidant properties in tissues (Decker, 1995). Creatine and creatine phosphate are involved in muscle energy metabolism and they provide the necessary energy for vigorous muscle contraction (Mora et al. 2007). Table 6 shows that functional dipeptides present in Hanwoo muscles were not significantly different by the IMF level. Therefore, it can be concluded that fat content of muscle was not related with the antioxidant activities by antioxidative dipeptides.

6. Fatty Acid Composition

The fatty acid compositions of Hanwoo beef as affected by different IMF groups are presented in Table 7. High IMF group had higher proportion of unsaturated fatty acids (USFA), compared with the Medium or the Low IMF group. Thus, the ration of UFA/SFA was also higher in High IMF than Medium or Low IMF group. This is mainly attributed to the higher content of

Table 6. Dipeptides (㎎/100 g) of Hanwoo beef categorized by different intramuscular fat (IMF) content

Dipeptide	IMF[1]			SEM[2]
	Low	Medium	High	
Anserine	124.82	124.99	108.89	3.44
Carnosine	724.08	679.78	723.26	9.66
Creatine	1,524.94	1,493.21	1,507.68	8.80
Creatinine	18.67	19.38	18.18	0.51

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

Table 7. Fatty acid composition (%) of Hanwoo beef categorized by different intramuscular fat (IMF) content

Fatty acid	IMF[1]			SEM[2]
	Low	Medium	High	
C10:0	0.04	0.04	0.04	0.00
C12:0	0.08	0.08	0.07	0.00
C14:0	2.56	2.56	2.45	0.03
C14:1	0.73	0.77	0.79	0.02
C15:0	0.24	0.23	0.21	0.01
C16:0	22.78	23.31	22.69	0.12
C16:1	3.59	3.78	4.00	0.08
C17:0	0.64^a	0.59^b	0.56^b	0.01
C17:1	0.69	0.65	0.65	0.01
C18:0	10.85^a	10.39^{ab}	9.93^b	0.13
C18:1	43.27^b	43.50^b	44.56^a	0.20
C18:1, 11t	2.05	2.05	2.24	0.05
C18:2	3.09	2.93	2.85	0.07
C20:0	0.05	0.05	0.05	0.00
C18:3	0.10	0.10	0.11	0.00
CLA, 9c11t	0.33	0.34	0.34	0.01
C20:1	0.32	0.30	0.34	0.01
CLA 10t12c	0.02	0.02	0.03	0.00
C20:2	0.17^a	0.19^a	0.07^b	0.02
C20:3	0.33	0.30	0.29	0.01
C20:4	0.67^a	0.65^a	0.53^b	0.02
C24:1	0.19^a	0.16^b	0.15^b	0.00
SFA	37.23^a	37.25^a	35.99^b	0.20
UFA	55.56^b	55.74^b	56.94^a	0.22
PUFA	4.72	4.52	4.21	0.09
UFA/SFA	1.51^b	1.51^b	1.60^a	0.01
n-6/n-3	9.35	9.45	8.77	0.16

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

[a-c] Means with different superscript within the same row differ significantly ($p<0.05$).

oleic acid (C18:1) in High IMF group. High IMF is shown more desirable in terms of meat flavor as oleic acid was reported as a main meat flavor component in Hanwoo beef (Cho et al. 2007). Oleic acid was the main fatty acid found in Hanwoo beef followed by palmitic (C16:0) and stearic (C18:0) acid. This is comparable to the findings of Cho et al. (2007). The n-6/n-3 ratio was not significantly different by the IMF level.

Low IMF group had significantly higher heptadecanoic acid

(C17:0) and stearic acid (C18:0) than High IMF group. A few conjugated linoleic acids (CLA, 9c11t and 10t12c) were also analyzed, but the detected amounts were not significantly different by the IMF level. Further, polyunsaturated fatty acids (PUFA) such as C20:2, C20:4, and C24:1 were found at higher amount in Low IMF group than High IMF.

7. Sensory Characteristics

Table 8 shows the results of sensory evaluation of Hanwoo beef from different IMF groups. Color and odor sensory cha-racteristics did not differ ($p>0.05$) among the IMF groups. However, significant differences were found for tenderness, juiciness and overall acceptance scores ($p<0.05$). Significantly higher tenderness and juiciness scores were reported as com-mensurate with the IMF content. These factors results in the higher overall acceptance of High IMF beef. Many authors have proven that tenderness and juiciness are positively related to IMF content/ marbling score in beef (Campion et al. 1975). The dilution of muscle matrix with tender fat can also be a reason for the improved tenderness (Jo et al. 2012).

In conclusion, IMF level had significant effects on meat quality and antioxidative dipeptides of Hanwoo beef. High IMF had less inosine monophosphate, more hypoxanthine, and less histidine, compared with the other groups. Unsaturated fatty acids were more found in High IMF. The functional component such as antioxidant dipeptides was not different by the IMF. If the importance of economic and health benefits of low fat meat is considered, breeding and feeding strategies for excessive IMF could be changed.

Table 8. Sensory evaluation of Hanwoo beef categorized by different intramuscular fat (IMF) content

Sensory attribute	IMF[1]			SEM[2]
	Low	Medium	High	
Colour	5.13	5.13	5.39	0.06
Odour	5.02	4.94	5.37	0.15
Tenderness	4.35[c]	4.93[b]	5.91[a]	0.09
Juiciness	4.60[c]	4.98[b]	5.95[a]	0.08
Overall acceptability	4.32[c]	4.83[b]	5.95[a]	0.08

[1] Low, <14%; Medium, 14-17 %; High, >17%.

[2] Standard error of the means.

[a,b] Means with different superscript within the same row differ signi-ficantly ($p<0.05$).

REFERENCES

AOAC 2007. Official Methods of Analysis. 18th ed, Association of Official Analytical Chemists, Washington, DC

Arihara K. 2006. Strategies for designing novel functional meat products. *Meat Sci* 74:219-229

Bilek AE, Turhan S. 2009. Enhancement of the nutritional status of beef patties by adding flaxseed flour. *Meat Sci* 82:472-477

Brooks JC, Belew JB, Griffin DB, Gwartney BL, Hale DS, Henning WR, Johnson DD, Morgan JB, Parrish FC, Reagan JO, Savell JW. 2000. National beef tenderness survey-1998. *J Anim Sci* 78:1852-1860

Bures D, Barton L, Zahradkova R, Teslik V, Krejcova M. 2006. Chemical composition, sensory characteristics, and fatty acid profile of muscle from Aberdeen Angus, Charolais, Simmental, and Hereford bulls. *Czech J Anim Sci* 51:279-284

Campion DR, Crouse JD, Dikeman ME. 1975. Predictive value of USDA beef quality grade factors for cooked meat pala-tability. *J Food Sci* 40:1225-1228

Cho SH, Kim JH, Seong PN, Choi YH, Park BY, Lee YJ, In TS, Chun SY, Kim YG. 2007. Cholesterol, free amino acid, nucleotide-related compounds, and fatty acid composition of Korean Hanwoo bull beef. *Korean J Food Sci Anim* 27: 440-449

Decker EA. 1995. The role of phenolics, conjugated linoleic acid, carnosine, and pyrroloquinone quinone as nonessential dietary antioxidants. *Nutrition Reviews* 53:49-58

Folch J, Lee M, Sloane-Stanley GH. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *J Biological Chem* 226:497-507

Hughes MC, Kerryb JP, Arendtb EK, Kenneallyc PM., McSweeneya PLH, O'Neilla EE. 2002. Characterization of proteolysis during the ripening of semi-dry fermented sausages. *Meat Sci* 62: 205-216

Jo C, Cho SH, Chang J, Nam KC. 2012. Keys to production and processing of Hanwoo beef: A perspective of tradition and science. *Animal Frontiers* 2:32-38

Kang M, Kim HJ, Jang A, Gam DG, Yun GS, Jo C. 2012. Effect of dietary supplementation of quercetin on antioxidative activity and meat quality of beef cattle. *CNU J Agric Sci* 39:61-68

Kim CJ, Lee ES. 2003. Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. *Meat Sci* 63:397-405

Mora L, Sentandreu MA, Toldrá F. 2007. Hydrophilic chromatographic determination of carnosine, anserine, balenine, creatine, and creatinine. *J Agric Food Chem* 55:4664-4669

Ozawa S, Mitsuhashi T, Mitsumoto M, Matsumoto S, Itoh N, Itagaki K, Kohno Y, Dohgo T. 2000. The characteristics of muscle fiber types of *longissimus thoracis* muscle and their influences on the quantity and quality of meat from Japanese Blacks steers. *Meat Sci* 54:65-70

Park GB, Moon SS, Ko YD, Ha JK, Chang HH, Joo ST. 2002. Influence of slaughter weight and sex on yield and quality grades of Hanwoo (Korean native cattle) carcasses. *J Anim Sci* 80:129-136

Peiretti PG, Medana C, Visentin S, Bello FD, Meineri G. 2012. Effect of cooking method on carnosine and its homologues, pentosidine and thiobarbituric acid-reactive substance contents in beef and turkey meat. *Food Chem* 132:80-85

SAS. 1999. SAS/STAT Software for PC. Release 6.11, SAS Institute, Cary, NC, USA

Sasaki K, Motoyama M, Mitsumoto M. 2007. Changes in the amounts of water-soluble umami-related substances in porcine *longissimus* and *biceps femoris* muscles during moist heat cooking. *Meat Sci* 77:167-172

Savell JW, Cross HR, Smith GC. 1986. Percentage ether extractable fat and moisture content of beef *longissimus* muscle as related to USDA marbling score. *J Food Sci* 51:838-839

Scollan N, Hocquette JF, Nuernberg K, Dannenberger D, Richardson I, Moloney A. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Sci* 74:17-33

Seideman SC, Koohmaraie M, Crouse JD. 1987. Factors associated with tenderness in young beef. *Meat Sci* 20:281-291

Sforza S, Pigazzani A, Motti M, Porta C, Virgili R, Galaverna G. 2001. Oligopeptides and free amino acids in Parma hams of known cathepsin B activity. *Food Chem* 75:267－273

Waters AccQ·Tag amino acid analysis system. 1993. Operator's manual, manual number 154-02TP REV O June, USA