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ARTICLE

Meat Quality of Loin and Top Round Muscles from the Hanwoo and Holstein Veal Calves

Dong-Gyun Yim, Eui-Gang Chung[1], and Ku-Young Chung[1]*
Department of Health Administration and Food Hygiene, Jinju Health College, Jinju 52655, Korea
[1]Department of Animal Science and Resources, Sangji University, Wonju 26339, Korea

Abstract

This study was conducted to compare the meat qualities of loin (*m. longissimus dorsi*) and top round (*m. semimembranosus*) from Hanwoo and Holstein veal. Ten Hanwoo and Holstein calves were randomly selected from a local cattle farm and raised. They were slaughtered when they were 8 mon old and weighed. Weight and percentage in primal cuts and slaughter performance of Hanwoo and Holstein veal calves are obtained. Immediately after weighting, slices of loin and top round muscles were sampled. After vacuum packaging, the samples were subjected to proximate composition, physicochemical and microbiological analyses. Dressing weight and percentage were heavier and greater ($p<0.05$) in the Holstein than in the Hanwoo. Water contents of the top round muscle was higher in the Holstein than in the Hanwoo ($p<0.05$). Water-holding capacity, protein content and CIE L^* (lightness) of both muscles were higher in the Holstein than in the Hanwoo veal, whereas fat content, pH, cooking loss, a^* (redness), and b^* (yellowness) were higher in the Hanwoo than in the Holstein veal ($p<0.05$). Thiobarbituric acid and volatile basic nitrogen values of both the muscles were lower in the Hanwoo than in the Holstein veal during the first 10 d of storage ($p<0.05$).

Keywords: Holstein veal, Hanwoo veal, loin; top round, meat quality

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Introduction

Hanwoo may be originated from crossbreeding between *Bos indicus* in India and *Bos primigenius* in Europe and they have been reared for at least 2000 years in Korean peninsula (Han, 1996). Korean consumers prefer Hanwoo beef to imported beef, because they strongly believe Hanwoo beef have superior palatability characteristics (Hwang *et al*., 2010). This kind of stereotype may not be easily broken, thereby Hanwoo have been maintained in superior position in meat quality in Korea (Hur *et al*., 2008).

Holstein cattle are the premier dairy breed with a high potential for milk production (Jurie *et al*., 2007). Therefore, Holstein breed have been introduced and raised as a domestic stock since 1903 in Korea (Cho *et al*., 2013). In Korea, the statistics indicate that 64,107 Holstein beef were slaughtered and the frequencies of quality grading above grade 1 for Holstein steers were only 8.4% in 2013 (Korea Institute for Animal Products Quality Evaluation, 2015). Holstein beef have been not so popular and utilized limitedly because not only they have inferior palatability characteristics as compared to Hanwoo beef, but also their poor eating quality does not make it a viable choice for retail for Korean consumers. Some Holstein dairy farmers tried to produce the highly marbled Holstein steer by using a longer feeding period, but this was not financially advantageous for them, due to the expensive feeding cost and low feeding efficiency.

Traditionally, many European (Nederland, France, Switzerland, Italy, Belgium etc.) consumers demand veal because it has been regarded as the highest quality associated with a healthy product, low fat content, and a good smooth flavor (Vieira *et al*., 2005). According to Council Regulation (EC) No 361/2008 of April 14^{th} (EU, 2008), veal is described as the meat from unweaned calves that are slaughtered when they are no more than 8 mon old. The European Commission differentiates veal meat derived from calves of 16-19 wk of age (Ngapo and Gariépy, 2006). Presently, Korean consumes imported veal from Australia about 200 tons annually and have limitedly because of high price at the hotel restaurant and in-flight

*Corresponding author: Ku-Young Chung, Department of Animal Science and Resources, Sangji University, Wonju 26339, Korea. Tel: +82-33-730-0534, Fax: +82-33-744-6118, E-mail: kychung @sj.ac.kr

meals.

In Korea, Holstein cattle are slaughtered at an average age of 20-22 mon. Recently, young Holstein bulls have been problem for a livestock raiser in Korea. The farmers encounter serious challenges when they have new-born, male veal, given the unstable market price and low valuation of this product in the domestic beef market (Cho *et al.*, 2014). Most of the studies have focused on meat quality of Hanwoo. However, little research has been carried out on the meat quality of Holstein calves which was born and raised in Korea. Especially, the difference in meat quality of loin and top round of Hanwoo and Holstein veal has rarely been investigated. Therefore, the objective of the present work was to compare the physicochemical and microbial quality characteristics of loin (*m. longissimus dorsi*) and top round (*m. semimembranosus*) from the Hanwoo and Holstein veal.

Materials and Methods

Animals and slaughter procedure

A total of 5 young Hanwoo and 5 Holstein bull calves were reared at selected local cattle farm, where they were kept in individual boxes on slatted floors with individual bucket feeding. They were fed with breast milk during the first 8 wk. Calves remained with their mothers on natural pastures until weaning. After that, they were confined and fed with roughage and straw during 4-8 mon. Both calves were slaughtered at an average age of 8 mon and they were dressed in an officially approved slaughterhouse, according to standard methods, using a captive bolt stunner, followed by sticking and bleeding. The carcasses were immediately cooled at 0°C for 24 h in a chilling room. Then, commercial fabrication procedures according to the guidelines of the notification of the Ministry of agriculture, food and rural affairs, the right side of each carcass was fabricated into bone-in primal cuts. Weight and percentage in primal cuts and slaughter performance of Hanwoo and Holstein veal calves are obtained. Immediately after weighting, slices of loin (*m. longissimus dorsi*) and top round (*m. semimembranosus*) muscles were taken. After vacuum packaged, the samples were transported to laboratory at university, South Korea. Immediately the samples were removed from vacuum packages. All subcutaneous fat and visible connective tissue of muscles were trimmed and re-vacuum packaged using vacuum package system (Vc999, K4N, Switzerland). Packaged samples were stored in refrigerator (CA-D17DC, LG, Korea) in which temperatures were controlled within 0±1°C of designated storage temperature. These samples were analyzed at the 1, 3, 7, 10, 20 and 30 d for TBA, VBN and microbiological analyses.

Proximate composition

Immediately after keeping in a chilling room, samples from each treatment were analyzed for proximate composition. All determinations were carried out on the homogenized samples, in triplicate. Moisture, fat, protein and ash were determined on samples using with a slightly modified method of AOAC (2000).

Physico-chemical analyses

The pH values of samples were measured by blending a 10 g sample with 90 ml distilled water for 1 min in a homogenizer (Ultra-turrax, T25-S1, Germany). This analysis was determined by using a pH meter (PHM201, Radiometer, France). The water holding capacity (WHC) was conducted by a modification of the procedure of Grau and Hamm (1953). Three hundred mg sample of muscle was placed in a filter-press machine and compressed for 2 min. WHC was calculated from duplicate samples as a ratio of the meat film area to the total area; hence, a larger value suggests a higher WHC. WHC (%) was calculated as follows: WHC (%) = 100 − [total meat area/meat film area × 100]. For cooking loss, after the samples were thawed at 4°C overnight before analyses and sliced with a thickness of 2 cm. The samples were weighed and cooked in an electric grill (EMG-533, AIJIA electric appliance, China) until they reached a final internal temperature of 70°C. Cooking loss was determined by the ratio of the difference between raw weight and final cooked weight as follows: Cooking loss (%) = 100 × (raw weight − final cooked weight) / raw weight. Shear force values were measured by the method described by the procedure of Bourne (1978). The samples were prepared a cubic form (30 × 30 × 20 mm) and six cores of 1.27 cm in diameter, were drilled parallel to the muscle fiber from each sample. Each core was sheared once with a Warner-Bratzler shear attachment using a texture analyzer (TA-XT2, Stable Micro System Ltd., U.K.). The maximum shear force value (kg) was recorded for each sample. Test and post-test speeds were set at 1.0 mm/s. Color measurements were taken using a Minolta chromameter (CR-410, Minolta Co. Ltd., Japan). CIE L^*, a^* and b^* values were determined with measurements standardized with respect to a white calibration plate (L^* = 94.4, a^* = 0.313, b^* = 0.319) at room temperature. Color measurements for each of three replicates, always trying to avoid area with excess fat were taken and the value was recorded. The TBARS of samples were analyzed by the modification method described by the procedure of Witte (1970). Readings were made on a spectrophotometer (X-MA 3000, Human Ltd., Korea) at 530 nm. A micro-diffusion method described by Conway (1950) was modified for the determination of volatile basic nitrogen (VBN) values in samples. Each sample (10 g) was homogenized (Ultra-turrax, T25-S1, IKA, Germany) for 1 min with 90 mL of distilled water. The supernatant solution was filtered using a filter paper (No. 4, Whatman). A 0.01 N of boric acid was placed in the inner section of a Conway micro-diffusion cell (Sibata Ltd., Japan). One ml sample solution and 1 mL of saturated K_2CO_3 were also placed into the outer section of the same cell, and the lid was immediately closed. The cell was incubated at 25°C for 60 min, and it was then titrated against 0.02 N H_2SO_4. The VBN value was reported as mg/100g.

Microbiological analysis

Meats were subjected to microbiological analysis to monitor the dynamic changes in the populations responsible for the aging of the veal samples and their hygienic quality. The samples (10 g) were homogenized with 90 mL of 0.85% sterile peptone water using a Stomacher Lab blender (Interscience BagMixers, USA) for 2 min and serially diluted with saline solution by 10-fold. Total aerobic plate counts were enumerated on plate count agar (Difco^{TM}, Laboratories, USA) at 37°C for 48 h. Bacterial counts were expressed as colony forming units per gram of sample (CFU/g).

Statistical methods

The experiment had three replications. Variance analysis (ANOVA) were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS, 2002). Duncan's multiple range tests and *t*-test were used to determine differences among the treatment means. Mean values and deviations were reported. A probability level (p) of 0.05 was chosen as the limit for statistical significance in all tests.

Results and Discussion

Weight and percentage in primal cuts

Weight and percentage in primal cuts of Hanwoo and Holstein veal calves are presented in Table 1. Loin, strip loin, neck, and rib in primal cuts of the Hanwoo had higher weights and percentages than those of the Holstein. Ttenderloin, blade, topside, butt, brisket, and shank weights of the Holstein were higher than those of the

Table 1. Weight and percentage in primal cuts of Hanwoo and Holstein veal calves

	Hanwoo		Holstein	
	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)
Tenderloin	2.46±0.01	2.76±0.01	2.76±0.02	2.92±0.02
Loin	12.70±0.10	14.22±0.19	10.14±0.07	10.72±0.89
Strip loin	3.50±0.10	3.92±0.20	2.88±0.09	3.05±0.05
Neck	7.02±0.20	7.86±0.42	6.60±0.20	6.98±0.11
Blade	8.87±0.11	9.33±0.22	10.14±0.10	10.72±0.95
Topside	9.88±0.10	11.07±0.23	10.32±0.09	10.91±0.93
Butt & rump	13.79±0.17	15.44±0.40	15.50±0.01	16.39±1.13
Brisket	10.51±0.31	11.77±0.71	17.60±4.47	18.14±7.31
Shank	6.76±0.01	7.57±0.04	7.88±0.01	8.33±0.59
Rib	13.80±0.73	15.45±1.60	11.20±0.51	11.84±1.03

Values are Mean±standard deviation (n=5).

Table 2. Slaughter performance of Hanwoo and Holstein veal calves

	Hanwoo		Holstein	
	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)
Live weight at slaughter	280±10.50		270±11.43	
Cold carcass weight	140±7.43		141±6.43	
Dressing weight	76.8±0.63^{B}		83.4±1.48^{A}	
Dressing percentage		54.9±0.1^{B}		59.1±0.2^{A}

^{A,B}Means with different superscripts in the same row are significantly different (p<0.05).
Values are Mean±standard deviation (n=5).

Hanwoo. These results showed the presence of differences in the weight and percentage in primal cuts between Hanwoo and Holstein veal calves.

Slaughter performance and proximate composition

As shown in Table 2, the Hanwoo calves were heavier (live weight of 280 kg) than the Holstein calves (live weight of 270 kg), but no difference was noted between the breeds. The carcass weights of the Hanwoo and Holstein veal calves were similar in this study. Dressing weight was higher and percentage was greater (p<0.05) in the Holstein than in the Hanwoo. Our results are supported by those of Gregory *et al*. (1994) who showed that the breed of beef cattle could affect the dressing percentage.

Comparison of the proximate compositions of loin (*m. longissimus dorsi*) and top round (*m. semimembranosus*) of Hanwoo and Holstein veal calves is shown in Table 3. Water content of the top round muscle was higher in the Holstein veal than in the Hanwoo sample (p<0.05). Fat and protein contents of both muscles differed significantly between the two breed groups (p<0.05). Hanwoo veal had higher fat content of both muscles, while Holstein veal had higher protein content. Ash contents were higher in the Holstein sample compared with Hanwoo; however, no significant differences were observed. A previous study (Hur *et al*., 2008) found that water and protein contents were higher in the Holstein than in the Hanwoo. Our values are also similar to those for the loin and top round muscles of Holstein calves shown by Cho *et al.* (2014). Tuma *et al*. (1963) showed that the *m. longissimus dorsi* from 6 mon-old calves contained 72.63% moisture, 21.24% protein, and 1.1% ash content. Generally, increase in the intramuscular fat content of the meat causes decrease in the water content (Varela, 2002), and these reports are consistent with our findings. High protein and low fat content of the loin and top round of Holstein veal calves were confirmed in our study.

Physicochemical traits

Some physicochemical properties of loin (*m. longissimus dorsi*) and top round (*m. semimembranosus*) in the Hanwoo and Holstein veal are presented in Table 4. Muscle pH values were higher in the Hanwoo than in the Holstein veal (p<0.05). Water-holding capacity (WHC) of both the muscles was significantly higher in the Holstein than in the Hanwoo veal, whereas cooking loss was higher in the Hanwoo veal (p<0.05). Sanudo *et al*. (1998) also showed differences in the WHC among breeds. An inverse relationship is noted between moisture content and cooking loss (Jeremiah *et al*., 2003). Futther, an inverse relationship is noted between WHC and fat content (Jeremiah *et al*., 2003). As shown in Table 4, the shear force values of the loin muscle were lower in the Holstein than in the Hanwoo veal, which is similar to the results by Hur *et al*., (2008). Monteiro *et al*. (2013) suggested that shear force in veal was more affected by cooking losses than by other physicochemical characteristics. Many studies have shown that shear force values are correlated with intramuscular fat content (Fiems *et al*., 2000; Park *et al*., 2000).

Consumers typically assess veal quality based on the lean color (Ngapo and Gariépy, 2006). CIE L^* (lightness) of both the muscles was significantly higher in the Holstein than in the Hanwoo veal. However, a^* (redness) and b^* (yellowness) of both the muscles were higher in the Hanwoo than in the Holstein veal (p<0.05), similar to the results of Hur *et al*. (2008), who reported higher a^* and b^* for Hanwoo than for Holstein veal. The veal industry depends strongly on lean color for carcass grading and determination of carcass value, as whiter graded carcasses command greater value (Cho *et al*., 2014). The Holstein veal in this study showed a very light color, characterized by high L^* values (45.54 for the loin and 44.27 for the

Table 3. Proximate composition of *M. longissimus dorsi* and *semimembranosus* in Hanwoo and Holstein veal

	Breed	Cut	
		Longissimus dorsi	*Semimembranosus*
Water (%)	Hanwoo	73.49±0.30	73.76±0.50^b
	Holstein	74.90±0.06	76.09±0.05^a
Fat (%)	Hanwoo	1.92±0.39^a	2.49±0.43^a
	Holstein	0.65±0.16^b	0.24±0.13^b
Protein (%)	Hanwoo	21.77±0.12^b	21.85±0.06^b
	Holstein	24.21±0.20^a	22.86±0.23^a
Ash (%)	Hanwoo	1.10±0.05	1.15±0.09
	Holstein	1.17±0.06	1.37±0.03

^{a,b}Means with different superscripts in the same column are significantly different (p<0.05).
All values are mean±standard deviation (n=5).

Table 4. Physicochemical traits of *M. longissimus dorsi* and *semimembranosus* in Hanwoo and Holstein veal

	Breed	Cut	
		Longissimus dorsi	*Semimembranosus*
pH	Hanwoo	6.05±0.01^{a}	5.58±0.01^{a}
	Holstein	4.72±0.01^{b}	4.90±0.01^{b}
WHC	Hanwoo	41.50±3.39^{b}	39.26±9.81^{b}
	Holstein	60.93±2.39^{a}	58.72±4.44^{a}
Cooking loss	Hanwoo	32.28±3.59^{a}	35.85±6.35^{a}
	Holstein	16.83±2.35^{b}	20.83±4.12^{b}
Shear force (kg)	Hanwoo	7.89±0.37^{a}	10.63±0.60
	Holstein	4.39±0.29^{b}	9.64±5.41
CIE L*	Hanwoo	39.65±2.19^{b}	34.93±0.85^{b}
	Holstein	45.54±0.11^{a}	44.27±0.16^{a}
CIE a*	Hanwoo	16.99±2.45^{a}	18.68±3.14^{a}
	Holstein	9.06±0.03^{b}	8.67±0.05^{b}
CIE b*	Hanwoo	8.45±1.56^{a}	8.82±1.92^{a}
	Holstein	2.41±0.03^{b}	1.59±0.02^{b}

^{a,b}Means with different superscripts in the same column are significantly different (p<0.05).
All values are mean±standard deviation (n=5).

Table 5. Change of TBA, VBN and total plate counts of *M. longissimus dorsi* and *semimembranosus* in Hanwoo and Holstein veal during storage

	Breed	Cut	Days					
			1	3	7	10	20	30
TBA (mg malonal-dehyde/kg)	Hanwoo	*Longissimus dorsi*	0.34^{bB}	0.39^{bB}	0.34^{bB}	0.38^{bB}	0.79^{aA}	0.81^{aA}
		Semimembranosus	0.31^{bC}	0.39^{bB}	0.37^{bB}	0.35^{bB}	0.44^{bA}	0.45^{bA}
	Holstein	*Longissimus dorsi*	0.49^{a}	0.44^{a}	0.48^{a}	0.42^{a}	0.44^{b}	0.44^{b}
		Semimembranosus	0.38^{b}	0.38^{b}	0.47^{a}	0.42^{a}	0.43^{b}	0.43^{b}
VBN	Hanwoo	*Longissimus dorsi*	10.28^{Cc}	11.71^{cC}	11.46^{cC}	17.96^{bB}	25.84^{aA}	22.50$^{b A}$
		Semimembranosus	12.55^{bB}	13.85^{bB}	14.01^{bB}	18.64^{bB}	17.35^{cB}	25.61^{aA}
	Holstein	*Longissimus dorsi*	14.89^{aB}	16.57^{aB}	17.62^{aB}	22.02^{aA}	23.30^{bA}	22.48^{bA}
		Semimembranosus	15.38^{aB}	16.29^{aB}	18.39^{aB}	23.25^{aA}	24.97^{aA}	23.08^{bA}
Total plate counts (Log CFU/g)	Hanwoo	*Longissimus dorsi*	2.44^{D}	2.26^{D}	4.07^{C}	4.85^{B}	6.06^{A}	6.16^{A}
		Semimembranosus	2.89^{C}	2.56^{C}	4.67^{B}	6.08^{A}	5.69^{A}	6.30^{A}
	Holstein	*Longissimus dorsi*	2.70^{C}	2.56^{C}	6.17^{B}	6.17^{B}	6.52^{B}	6.92^{A}
		Semimembranosus	2.91 ^{C}	2.50 ^{C}	5.47^{B}	5.90^{A}	6.13^{A}	6.51^{A}

[1)]Means of three replicate experiments with three samples analyzed per replicate (n=9).
$^{a\text{-}c}$Figures with different letters within a same column differ significantly (p<0.05).
$^{A\text{-}D}$Figures with different letters within a same row differ significantly (p<0.05).

top round) and low a^* and b^* values. Meat color depends on the concentration and oxidation state of myoglobin. Color changes are because of the formation of metamyoglobin, characteristic of the maturation process (Renerre, 1982). Color is also correlated with the pH, as lightness decreased with an increase in the pH (Guignot *et al*., 1993). In addition, meat lightness (L^*) could be affected by beef breed (Muchenje *et al*., 2008).

Comparison of the changes in TBA, VBN, and total plate counts of *m. longissimus dorsi* and *m. semimembranosus* of the Hanwoo and Holstein veal during storage are shown in Table 5. TBA values of both the muscles were lower in the Hanwoo than in the Holstein veal during the first 10 d of storage (p<0.05). The initial value of the lipid oxidation in Holstein veal was about 0.3-0.4 mg/kg and remained unchanged for up to 30 d. On the other hands, oxidation levels in Hanwoo veal increased to approximately 0.8 mg/kg after 20 d. TBA values of all muscles were less than 1 mg malondialdehyde/kg, which is considered the limit of acceptability for rancidity for fresh meat (Ockerman, 1976). The VBN values of both muscles were lower in the Hanwoo than in the Holstein veal during the first 10 d of storage (p<0.05). Higher VBN values in the Holstein veal samples are due to the high protein content in this study. The VBN in Holstein meat can be explained by bacterial or enzymatic degradation of protein (Egan *et al*., 1981). The VBN values of both breeds continuously increased during storage ($p<0.05$).

The total aerobic counts of both breeds and all cuts tended to increase slowly during storage. The samples remained below the microbiological guidelines maximum limit (below 7 Log CFU/g) for meat as recommended by Korean Food Standards Codex (MFDS, 2015) for 30 d. Vacuum packaging retards microbiological growth, and delays the development of spoilage due to slow proliferation of bacteria capable of tolerating anaerobic conditions (Gill, 1992). Therefore, the shelf life of Holstein veal samples stored at 0°C under vacuum conditions would be at least 30 d. Bacteria counts of veal appeared to be irrelevant in this study; breed and cut did not have an effect on bacteria counts of veal ($p>0.05$). This leads to the conclusion that veal shelf life could exceed 30 d under vacuum conditions.

Conclusions

Breed can affect the proximate composition and physicochemical traits of the Hanwoo and Holstein veal. In this study, Holstein veal had higher water, and protein contents, WHC, and L*, whereas Hanwoo veal had higher fat content, pH, cooking loss, shear force, a*, and b*. The results of this study provide objective information to consumers on relative meat quality of the Hanwoo and Holstein veal. Further, consumer preference toward Holstein veal could contribute to less demand for Hanwoo veal in the domestic beef market.

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References

1. AOAC (2000) *Official methods of analysis* (17th ed.). Gaithersburg, MD: Association of Official Analytical Chemists.
2. Bourne, M. C. (1978) Texture profile analysis. *Food Technol.* **32**, 72.
3. Cho, S. H., Kang, S. M., Seong, P. N., Kang, G. H., Choi, S. H., Kwon, E., Moon, S. S., Kim, D. H., and Park, B. Y. (2014) Physico-chemical Meat qualities of loin and top round beef-from Holstein calves with different slaughtering ages. *Korean J. Food. Sci. An.* **34**, 674-682.
4. Cho, S. H., Seong, P. N., Kang, G. H., Choi, S. H., Kang, S. M., Park, K. M., Kim, Y. C., Kwon, E. G., and Park, B. Y. (2013) Physicochemical meat quality and fatty acid compositions of striploin, chuck tender, eye of round muscles from Holstein steer beef slaughtered at different fattening periods. *Korean J. Food. Sci. An.* **33**, 633-639.
5. Conway, E. J. (1950) Microdiffusion Analysis and Volumetric Error, 3rd ed. Crosby Lockwood and Son Ltd, London.
6. Egan, H., Kirk, R. S., and Sawyer, R. (1981) Pearson's chemical analysis of foods. 8th ed, Essex, Longman scientific and Technical. UK, pp. 185-185.
7. EU (2008) Council Regulation (EC) No 361/2008 of 14 April 2008 amending Regulation (EC) No 1234/2007 establishing a common organization of agricultural markets and on specific provisions for certain agricultural products (Single CMO Regulation). Official J. European Communities (pp. L 121/121-L 121/131).
8. Fiems, L. O., De Campeneere, S., De Smet, D., Van de Voorde, G., Vanacker, J. M., and Boucque, C. V. (2000) Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. *Meat Sci.* **56**, 41-47.
9. Gill, C. O. (1992) Application of preservative packagings to chilled raw meats. Canadian Meat Science Association Symposium, **7**, 1-8.
10. Grau, R. and Hamm, R. (1953) Eine einfache methode zur bestimmung der wasserbindung in muskel. *Naturwissenschaften,* **40***,* 29.
11. Gregory, K. E., Cundiff, L. V., Koch, R. M., Dikeman, M. E., and Koohmaraie, M. (1994) Breed effects and retained heterosis for growth, carcass, and meat traits in advanced generations of composite populations of beef cattle. *J. Anim. Sci.* **72**, 833-850.
12. Guignot, F., Touraille, C., Ouali, M., and Monin, G. (1993) Relationships between post-mortem pH changes and some traits of sensory quality in veal. *Meat Sci.* **37**, 3133-3139.
13. Han, S. Y. (1996) Animal breeds. Breeds of cattle. In S. Y. Han (Ed.), Animal breeds (pp. 53-55). Seoul: Sunjin Publishing Company.
14. Hur, S. J., Park, K. B., and Joo, S. T. (2008) A comparison of the meat qualities from the Hanwoo and Holstein steer. *Food Bioprocess Technol*. **1**, 196-200.
15. Hwang, Y. H., Kim, G. D., Jeong, J. Y., Hur, S. J., and Joo, S. T. (2010) The relationship between muscle fiber characteristics and meat quality traits of highly marbled Hanwoo (Korean native cattle) steers. *Meat Sci.* **86**, 456-461.
16. Jeremiah, L. E., Dugan, M. E. R., Aalhus, J. L., and Gibson, L. L. (2003) Assessment of the chemical and cooking properties of the major beef muscle and muscle groups*. Meat Sci.* **65**, 985-992.
17. Jurie, C., Picard, B., Hocquette, J. F., Dransfield, E., Micol, D., and Listrat, A. (2007) Muscle and meat quality characteristics of Holstein and Salers cull cows. *Meat Sci.* **77**, 459-466.
18. Korea Institute for Animal Products Quality Evaluation (2015) Report of business for animal products grading. Korea.
19. MFDS (2015) Korean Food Standards Codex (No. 2011-76) No. 10. General method, 10-3-35.
20. Monteiro, A. C., Gomes, E., Barreto, A. S., Silva, M. F., Fontes, M. A., Bessa, R. J., and Lemos, J. P. (2013) Eating quality of "Vitela Tradicional do Montado"-PGI veal and Merto-

lenga-PDO veal and beef. *Meat Sci.* **94**, 63-68.

21. Muchenje, V., Dzama, K., Chimonyo, M., Raats, J. G., and Strydom, P. E. (2008) Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on natural pasture in the Eastern Cape, South Africa. *Meat Sci.* **79**, 20-28.
22. Ngapo, T. M. and Gariépy, C. (2006) Factors affecting the meat quality of veal. *J. Sci. Food Agr.* **86**, 1412-1431.
23. Ockerman, H. W. (1976) Quality control of post-mortem muscle and tissue. Ohio State University, Columbus, OH, USA: Department of Animal Science.
24. Park, B. Y., Cho, S. H., Yoo, Y. M., Kim, J. H., Lee, J. M., Joung, S. K., and Kim, Y. K. (2000) Effect of intramuscular fat contents on the physicochemical properties of beef *longissimus dorsi* from Hanwoo. *Korean J. Anim. Sci. Technol.* **42**, 189-194.
25. Renerre, M. (1982) La couleur de la viande et sa mesure. *Bulletin Technologique C.R.Z., V. Theix. I.N.R.A.* **65**, 41-45.
26. Sanudo, C., Albertý, P., Campo, M. M., Olleta, J. L., and Panea, B. (1998) Instrumental quality of beef meat from seven Spanish breeds. *Archivos de Zootecnia* **168**, 397-402.
27. SAS (2002) SAS/STAT Software for PC. Release 6.11, SAS Institute, Cary, NC, USA.
28. Tuma, H. J., Henrickson, R. L., Odell, G. V., and Stephens, D. F. (1963) Variation in the physical and chemical characteristics of the *longissimus dorsi* muscle from animals differing in age. *J. Anim. Sci.* **22**, 354-357.
29. Varela, A. (2002) Estudio de las variables que afectan a la produccion del tipo 'Cebon'. Doctoral Thesis. University of Santiago de Compostela, Spain.
30. Vieira, C., Garcia, M. D., Cerdeno, A., and Mantecon, A. R. (2005) Effect of diet composition and slaughter weight on animal performance, carcass and meat quality, and fatty acid composition in veal calves. *Livest. Sci.* **93**, 263-275.
31. Witte, V. C. (1970) A new extraction method for determining 2-thiobarbituric acid values of pork. *Food Technol.* **8**, 326-326.