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ARTICLE

The Relationship between Chemical Compositions, Meat Quality, and Palatability of the 10 Primal Cuts from Hanwoo Steer

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Abstract

The relationship between chemical compositions, meat quality traits, and palatability attributes in 10 primal cuts from Hanwoo steer carcasses were assessed. Sensory palatability attributes of Hanwoo beef were more closely related with fat content than to moisture or protein content. Among the chemical compositions, only fat had a significant correlation with juiciness (0.67, p<0.001), tenderness (0.32, p<0.05), and overall palatability (0.56, p<0.001). Oleic acid (%) was not significantly related with overall palatability (p>0.05). Overall palatability was negatively correlated with drip loss (-0.32, p<0.05), cooking loss (-0.36, p<0.05), and shear force (-0.54, p<0.01). The correlation between fat content and overall palatability was increased when higher fat cuts (*Ansim*, *Dungsim*, *Chaekeut*, *Yangjee*, and *Kalbi*) were analyzed, compared to lower fat cuts (*Moksim*, *Abdari*, *Udun*, *Suldo*, and *Satae*). Also, the correlation between shear force and overall palatability was decreased in lower fat cuts compared to higher fat cuts. Our results suggest that the palatability of Hanwoo beef can be improved by increasing fat content in muscles, as increased fat content leads to an increase in sensory tenderness, flavor, and juiciness.

Keywords: Hanwoo, palatability, primal cuts, fat content, beef quality

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Introduction

Although appearance quality traits (AQT) strongly influence a consumer's decision to select meat at the point of purchase, the consumer determines the actual meat quality at the point of consumption with eating quality traits (EQT) such as flavor, juiciness, tenderness, and overall palatability (Joo *et al*., 2013). EQT is not even across all meat cuts, and the lack of consistency in palatability has plagued the Hanwoo beef industry in Korea. For these reasons, the Korean beef industry is showing trends toward marketing individual beef muscle cuts (Hwang *et al*., 2010; Jung *et al*., 2015). However, the palatability characteristics of individual Hanwoo muscles in relation to chemical compositions and meat quality traits are not well known.

For over half a century, efforts have been made to characterize the properties of individual muscles from beef carcasses (Ramsbottom and Strandine, 1948; Ramsbottom *et al*., 1945; Strandine *et al*., 1949). However, the composition and physical properties of beef muscles have changed considerably over the past 70 years, and they are also significantly different between cattle breeds. Needless to say, the chemical compositions and meat quality properties of Hanwoo cattle have also changed significantly during the last several decades. Therefore, it is necessary to assess the palatability attributes of the major muscles or basic cuts of modern Hanwoo beef.

Variations in proximate composition and meat quality traits which are related to palatability arise from a heterogeneous mix of muscles in beef cuts. Most cuts are composed of different muscle fiber types which are affected by various factors, including gender, age, diet, muscle location, amount of exercise, etc. (Joo *et al*., 2013). Because muscle fiber characteristics influence meat quality traits, overall palatability is also affected by individual muscles or primal/retail cuts. In this regard, it is important to understand the relationship between chemical compo-

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sitions, meat quality traits, and palatability attributes of beef cuts. Also, there is a need to characterize the individual primal or retail cuts, so that consumers can make better selections. In addition, understanding the characteristics of individual retail cuts can improve the utilization of many cuts of beef carcasses. The objective of this study was to investigate the relationship of certain chemical compositions and meat quality traits to the palatability attributes of the 10 primal cuts of Hanwoo beef.

Materials and Methods

Carcass selection and primal cut preparation

A total of 25 Hanwoo steer carcasses were separated into 10 primal (wholesale) cuts and 39 sub-primal (retail) cuts. The 10 primal cuts were *Ansim* (tenderloin), *Dungsim* (loin), *Chaekeut* (sirloin), *Moksim* (chuck), *Abdari* (shoulder), *Udun* (outside round), *Suldo* (inside round), *Yangjee* (brisket), *Satae* (shank), and *Kalbi* (rib). The 10 primal beef cuts and sub-primal cuts including the major muscles from Hanwoo carcasses are shown in our previous report (Jung *et al*., 2015). Chemical compositions, meat quality traits, and sensory evaluation were investigated in each sub-primal cut. The mean values of sub-primal cuts in each 10 primal cuts were used for statistical analysis.

Chemical compositions

Moisture content and crude ash content were determined using an oven drying method (AOAC, 1995). Samples (approximately 2 g) were weighed and allowed to dry at 100°C for 24 h in an air oven. Samples were then cooled in a desiccator and weighed. Loss of weight was reported as moisture content. Crude ash concentration was determined in a muffle furnace at 600°C for 8 h. Approximately 1 g of sample was weighed into a crucible. The amount remaining, in weight, is reported as the crude ash content. Crude protein content was determined using the Kjeldahl method (AOAC, 1995, Buchi Kjeldahl Digestion Unit K-424 and Distillation Unit B-324, Buchi Co., Germany). Approximately 0.5 g of dried meat sample was weighed in a combustion boat and the weight was recorded. Crude protein levels were determined by multiplying total nitrogen by a factor of 6.25. Fat content was determined using a method modified from that of Folch *et al*. (1957).

Lipids were extracted to investigate fat content and fatty acid composition from 3 g of homogenized meat sample with 30 mL of Folch solution I (chloroform : methanol = 2 : 1, v/v). The homogenate was filtered with Whatman no.1 filter paper. The filtered solution was stirred with 0.88% NaCl and allowed to separate into two layers. After washing the wall of a measuring cylinder with 10 mL of Folch solution II (chloroform : methanol : H_2O = 3 : 47 : 50), the final volume of the lower layer was recorded. The upper layer (methanol and water) was removed using an aspirator, while 10 mL of the lower layer (chloroform containing lipid extracts) was placed into a dish and allowed to dry at 50°C. The weight of the dish was measured before and after drying. Fat content was computed from the weight difference of the dish.

To investigate fatty acid composition and oleic acid percentage, 100 mg of extracted fat was placed in a screw-capped test tube. 1 mL of 0.5 N NaOH (in methanol) was added, and the solution was hydrolyzed for 10 min at 90°C. Then, it was cooled to room temperature over 5 min. Free fatty acid was methylated for 10 min at 90°C with the addition of 1 mL 14% Boron trifluoride-methanol (BF3 methanol). The solution was cooled at room temperature for 30 min. 3 mL of hexane and 8ml distilled water was added, and 1 mL of supernatant was collected and stored in a -20°C freezer until analysis. To determine total fatty acid content, 10 μL of collected sample was introduced to the split injection port of a Hewlett-Packard 6890 gas chromatograph equipped with a Flame Ionization Detector (FID). A fused Supelcowax 10TM capillary column of 30 m × 0.32 mm × 0.25 μm (Supelco, USA) was used to separate the fatty acid methyl esters. The gas chromatography oven temperature was 180°C, and was increased at a rate of 5°C/min to a final temperature of 200°C. The temperature of the injector port and the detector were 250°C. Fatty acid methyl ester (1 μL) was injected onto the split injection port (10:1 split ratio). The flow rate for N_2 carrier gas was 50 mL/min. Each fatty acid was identified by its retention time, and the weight percentage of C18:1 in all detected fatty acids was computed as an oleic acid %.

Meat quality traits

pH was measured in triplicate in an approximately 3 g sample using a digital pH meter (MP230, Mettler-Toledo, Switzerland). Meat color was measured on the surface of muscles using a Minolta Chromameter CR-300 (Minolta Co., Japan) that was standardized with a white plate (Y= 93.5, X=0.3132, y=0.3198).

Drip loss was measured as the weight loss during suspension of a standardized (2 cm diameter × 2 cm thickness) sample in a plastic box (18 × 15 × 10 cm) at 4°C for

24 h (Joo *et al*., 2002). Drip loss was expressed as a percentage loss based on the initial sample weight. Cooking loss was determined by the weight loss during cooking. Sample (2 cm diameter × 2 cm thickness) in a plastic bag was broiled in a water bath at 90°C for 30 min, and the cooking loss was calculated as the percentage loss based on the initial sample weight.

Warner-Bratzler shear force (WBSF, kg/cm^2) was measured using an Instron Universal Testing Machine (Model 4400, Instron Corp., USA) with a V-shaped shear blade. Samples were 1.3 cm diameter cores obtained from muscles cooked to 70°C internal temperature for 30 min. Sarcomere length was determined according to the method of Cross *et al*. (1981). Samples were placed in vials containing solution A (0.1 M KCl, 0.39 M boric acid, and 5 mM ethylenediaminetetra acetic acid in 2.5% glutaraldehyde) for 2 h. Samples were then transferred to fresh vials containing solution B (0.25 M KCl, 0.29 M boric acid, and 5 mM ethylenediaminetetra acetic acid in 2.5% glutaraldehyde) for 17 to 19 h. On the following day, individual fibers were torn into pieces and placed onto microscope slides with a drop of solution B. The slide was then placed horizontally in the path of a vertically oriented laser beam to give an array of diffraction bands on a screen. These bands were perpendicular to the long axis of the fibers as described by Cross *et al*. (1981). Sarcomere length (μm) was calculated using the following formula: ({632.8 × 103 × D × SQRT [(T/D)2 + 1]} / T)100, where D is the distance (mm) from the specimen-holding device to the screen (D = 98 mm) and T is the separation (mm) between zero and the first maximum band. An average of 10 sarcomere lengths was obtained for each meat sample.

Sensory evaluation

Samples from each treatment were evaluated by an 8-member trained expert descriptive attribute sensory panel in the Meat Science Laboratory at Gyeongsang National University. The panelist were trained according to the procedures of Meilgaard *et al*. (1999). Panelists were given samples representing anchor points for each attribute, and training sessions using 39 sub-primal cuts in the meat lab. Final anchor point ratings were decided upon by training panel after initial evaluation and discussion. They were trained with raw and cooked meat for 2 wk with the characteristics to be evaluated. Cold water was also provided for rinsing their mouths before each sample was tested. For the samples, panelists evaluated the samples for flavor, juiciness, tenderness, and overall palatability using a 9-point hedonic scale as described by Meilgaard *et al*. (1999), where 1 was "extremely dislike" and 9 was "extremely like".

Statistical analysis

Experimental data were analyzed by the analysis of variance procedure using statistical systems software (SAS, 2002), and Duncan's multiple range tests were used to determine significance among means. Also, Pearson correlation coefficients were evaluated to describe the relationship between chemical compositions, meat quality traits, and palatability attributes using partial correlation coefficients (SAS, 2002).

Results

The mean values for the chemical compositions and meat quality traits of 10 primal cuts from Hanwoo carcasses have been previously reported (Jung *et al*., 2015). In this study, correlation coefficients were generated for relationships between sensory panel scores and certain chemical compositions of all 10 primal cuts (Table 1). The results showed that flavor was significantly correlated with fat content (0.45, $p<0.01$) and oleic acid (%) (0.32, $p<0.05$). Of the chemical compositions, only fat had a significant correlation with juiciness (0.67, $p<0.001$), tenderness (0.32, $p<0.05$), and overall palatability (0.56, $p<0.001$).

Correlation coefficients between sensory panel scores and meat quality traits are shown in Table 2. Muscle pH and meat color measurements were not significantly correlated with any sensory trait, including flavor, juiciness, tenderness, and overall palatability ($p>0.05$). However, drip loss (%) and cooking loss (%) were negatively correlated with overall palatability (-0.32 and -0.36, respectively, $p<0.05$). Cooking loss (%) had a significant correlation with juiciness (-0.46, $p<0.01$) and tenderness (-0.34, $p<0.05$), but did not correlate with flavor. Shear force was significantly correlated with tenderness (-0.66, $p<0.001$) and overall palatability (-0.54, $p<0.01$), although there was no significant correlation between sensory panel scores and sarcomere length. These results suggest that shear force is the most important factor for palatability of Hanwoo beef compared to meat color measurements and water-holding capacity.

To investigate the relationship between palatability attributes and fat content by primal cut, separate correlation analyses were run on a primal cut basis (Table 3). Correlation coefficients between fat content and flavor were increased when higher-fat primal cuts (*Ansim*, *Dungsim*,

Table 1. Correlation coefficients between chemical compositions and sensory panel scores of Hanwoo primal cuts[1)]

	Flavor	Juiciness	Tenderness	Overall palatability
Crude moisture (%)	-0.10	-0.18	-0.03	-0.10
Crude protein (%)	0.19	-0.12	-0.06	-0.11
Crude fat (%)	0.45**	0.67***	0.32*	0.56***
Crude ash (%)	0.02	0.03	0.06	0.02
Oleic acid (C18:1, %)	0.32*	0.24	0.15	0.26

*p<0.05, **p<0.01, ***p<0.001.
[1)]10 primal cuts: *Ansim*; *Dungsim*; *Chaekeut*; *Moksim*; *Abdari*; *Udun*; *Suldo*; *Yangjee*; *Satae*; *Kalbi*.

Table 2. Correlation coefficients between meat quality traits and sensory panel scores of Hanwoo primal cuts[1)]

	Flavor	Juiciness	Tenderness	Overall palatability
Muscle pH	0.13	0.08	0.05	0.12
Meat color measurements				
CIE L*	-0.09	-0.12	0.06	0.01
CIE a*	0.18	0.17	-0.22	0.16
CIE b*	-0.12	0.03	0.06	-0.11
Chroma	0.13	0.17	-0.14	0.25
hue	-0.06	0.03	0.09	-0.06
Drip loss (%)	-0.11	-0.22	-0.26	-0.32*
Cooking loss (%)	-0.18	-0.46**	-0.34*	-0.36*
Shear force (kg/cm^2)	0.18	-0.27	-0.66***	-0.54**
Sarcomere length (um)	-0.05	-0.02	0.27	0.22

*p<0.05, **p<0.01, ***p<0.001.
[1)]10 primal cuts: *Ansim*; *Dungsim*; *Chaekeut*; *Moksim*; *Abdari*; *Udun*; *Suldo*; *Yangjee*; *Satae*; *Kalbi*.

Table 3. Correlation coefficients between sensory panel scores and crude fat (%) on primal cut basis

	Flavor	Juiciness	Tenderness	Overall palatability
All cuts	0.45*	0.67***	0.32*	0.56***
Ansim	0.51*	0.72***	0.36*	0.62***
Dungsim	0.53*	0.68***	0.36*	0.68***
Chaekeut	0.57**	0.74***	0.42*	0.72***
Moksim	0.36	0.49*	0.26	0.51*
Abdari	0.31	0.38*	0.24	0.49*
Udun	0.34	0.35	0.18	0.45*
Suldo	0.34	0.37	0.16	0.44*
Yangjee	0.46*	0.58**	0.25	0.57**
Satae	0.23	0.32	0.18	0.32
Kalbi	0.58**	0.72***	0.35	0.74***

*p<0.05, **p<0.01, ***p<0.001.

Chaekeut, *Yangjee* and *Kalbi*) were analyzed, while those of lower-fat primal cuts (*Moksim*, *Abdari*, *Udun*, *Suldo*, and *Satae*) were lower. A similar tendency was observed in juiciness, where the highest correlation coefficient (0.74, p<0.001) was obtained in *Chaekeut*, followed by *Kalbi*, *Ansim*, and *Dungsim*, which have higher fat contents compared to other primal cuts. Consequently, the correlation coefficients between fat content and overall palatability of these high-fat primal cuts increased from 0.56 (all cuts) to 0.62 (*Ansim*), 0.68 (*Dungsim*), 0.72 (*Chaekeut*), and 0.74 (*Kalbi*). These results indicate that overall palatability is closely correlated with fat content in higher-fat cuts, as there is a strong correlation between fat content and flavor or juiciness.

The correlation coefficient between sensory panel score and shear force in each of the 10 primal cuts is given in Table 4. There were no significant differences in correlation coefficients between flavor and shear force for all 10 primal cuts. However, the correlation coefficients between juiciness and shear force for *Dungsim* increased significantly from -0.27 to -0.39 (p<0.05). Also, increased correlation coefficients between tenderness and shear force were observed in *Ansim*, *Dungsim*, and *Chaekeut* (from -0.66 to -0.75, -0.76, and -0.72, respectively). However,

Table 4. Correlation coefficients between sensory panel scores and shear force (kg/cm^2) on primal cut basis

	Flavor	Juiciness	Tenderness	Overall palatability
All cuts	0.18	-0.27	-0.66***	-0.54**
Ansim	0.23	-0.22	-0.75***	-0.72***
Dungsim	0.13	-0.39*	-0.76***	-0.68***
Chaekeut	0.17	-0.34	-0.72***	-0.74***
Moksim	0.06	-0.12	-0.46*	-0.48*
Abdari	0.11	-0.08	-0.34	-0.45*
Udun	0.14	-0.15	-0.48*	-0.52*
Suldo	0.09	-0.07	-0.36	-0.44*
Yangjee	0.16	-0.26	-0.58**	-0.62**
Satae	0.03	-0.12	-0.23	-0.32
Kalbi	0.18	-0.35	-0.55**	-0.58**

*p<0.05, **p<0.01, ***p<0.001.

the correlation coefficients decreased in *Moksim*, *Udun*, *Yangjee*, and *Kalbi* (from -0.66 to -0.46, -0.48, -0.58, and -0.55, respectively). Moreover, no significant correlations between tenderness and shear force were observed in *Abdari*, *Suldo*, and *Satae*, which are lower-fat primal cuts. Consequently, correlation coefficients between shear force and overall palatability were less in the primal cuts with lower fat content than in other primal cuts. The correlation coefficients decreased from -0.54 (all cuts) to -0.48 (*Moksim*), -0.45 (*Abdari*), -0.52 (*Udun*), -0.44 (*Suldo*), and -0.32 (*Satae*), although increased correlations were observed in *Ansim*, *Dungsim*, *Chaekeut*, *Yangjee*, and *Kalbi*. These results indicate that overall palatability is more closely correlated with shear force within higher-fat cuts than in lower-fat cuts, as shown by the strong correlation between shear force and tenderness panel score.

Discussion

The correlation between chemical compositions and sensory panel scores can provide insight into the most influential compositions of palatability of Hanwoo beef cuts. In this study, the correlations between fat content and sensory palatability attributes were consistent with previous findings. Earlier research clearly showed that intramuscular fat content affects juiciness and flavor directly and affects tenderness indirectly, and accounts for 12-14% of the variation in all palatability traits (Jeremiah *et al*., 1970). Nishimura *et al*. (1999) reported that intramuscular fat increases meat tenderness because it is deposited between fasiculi, disrupting the honeycomb structure of the endomysium and separating and thinning perimysial fibers. Parrish (1981) and Jost *et al*. (1983) observed that the correlation between marbling and palatability was usually positive, and the relationship of marbling to flavor was variable, with marbling being more strongly related to juiciness than to tenderness. Park *et al*. (2000) reported that beef loins with high intramuscular fat had high tenderness, juiciness, and flavor scores. Our present results also confirmed that, of the chemical compositions of meat, fat content was the most strongly related with palatability traits.

In this study, no significant correlation between oleic acid and overall palatability was observed, although oleic acid was significantly related with panel flavor score. This is not in agreement with earlier reports that the concentration of oleic acid in beef is positively correlated with overall palatability (Waldman *et al*., 1968; Westerling & Hedrick, 1979). According to Smith *et al*. (2006) and Chung *et al*. (2006), beef palatability may be related to fat softness, because beef lipids enriched with oleic acid have lower melting points. As oleic acid is believed to be an umami element in beef, the Korean beef industry has made efforts to produce highly marbled Hanwoo cattle. It has been reported that Korean Hanwoo cattle consistently produce highly palatable, well-marbled beef with a high oleic acid content (Jung and Choi, 2003), and Korean consumers prefer it because of its high intramuscular fat content (Kim *et al*., 1999). However, according to Oliver *et al*. (2006), the meat preferences of taste panelists depend on their previous cultural experiences and eating habits. Our data clearly show that fat content is a more influential factor in the taste of Hanwoo beef than is oleic acid (%).

Negative correlations between fat content and the water-holding capacity of meat have been reported (Joo *et al*., 2000, 2002), in agreement with the results of this study. Jeremiah *et al*. (2003) reported that fattier cuts have lower drip and cooking loss. Also, Ozawa *et al*. (2000) reported that the cooking loss of Japanese black steer meat was significantly lower for samples with the highest marbling scores. A previous study by our group confirmed that highly marbled meat has less drip loss and cooking loss (Jung *et al*., 2015). Furthermore, the present results show that shear force is closely correlated with tenderness and overall palatability, and suggest that shear force is the most influential factor of all meat quality traits for the palatability of Hanwoo beef. In the present study, shear force was found to be strongly related to overall palatability, as was fat content. These results suggest that the overall palatability of Hanwoo beef is affected mainly by fat content and shear force.

On the other hand, previous research clearly demonstrated that tenderness varied between beef muscles and occasionally within muscles (Ramsbottom *et al*., 1945; Ramsbottom & Strandine, 1948; Strandine *et al*., 1949). Other reports have indicated that beef muscles responded differently to postmortem aging and tenderness (Koohmaraie *et al*., 1988; Olson *et al*., 1976). Differences have also been reported between beef muscles in flavor intensity (Carmack *et al*., 1993) and juiciness (Crouse *et al*., 1984; Ritchey & Hostetler, 1964). In agreement with the previous findings, we saw differences in correlation coefficients between sensory panel scores and fat content or shear force among the 10 primal cuts.

When the 10 primal cuts were divided into high-fat cuts (*Ansim*, *Dungsim*, *Chaekeut*, *Yangjee*, and *Kalbi*) and low-fat cuts (*Moksim*, *Abdari*, *Udun*, *Suldo*, and *Satae*), the correlation coefficients between fat content and sensory panel traits were greater in the high-fat cuts. These results suggest that the palatability of Hanwoo beef can be increased by increasing the fat content of the meat, as that will increase sensory flavor and/or juiciness scores. Furthermore, the present study also showed that correlation coefficients between shear force and sensory panel traits were greater in higher-fat cuts than in lower-fat cuts. This result supports previous findings that beef loins with high intramuscular fat content had high tenderness, juiciness, and flavor scores (Park *et al*., 2000; Smith *et al*., 1985). Miller *et al*. (1997) reported that steaks from US Choice grade carcasses had higher tenderness than steaks from carcasses graded as US select. In general, tenderness is slightly positively associated with intramuscular fat content in most studies (Dikeman *et al*., 1986; Hwang *et al*., 2010; Jones & Tatum, 1994; Wheeler *et al*., 1996). In this regard, our results suggest that the overall palatability score can be improved by increasing the fat content of beef cuts as doing so will increase tenderness as well as flavor and/or juiciness.

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