CORRELATIONS OF SENSORY QUALITY CHARACTERISTICS WITH MEAT QUALITY, MUSCLE FIBER AND MUSCLE BUNDLE CHARACTERISTICS IN BOVINE *LONGISSIMUS DORSI* MUSCLE

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Abstract – The objective of this study was to investigate the relationships of sensory quality characteristics of cooked beef with meat quality, muscle fiber and bundle characteristics in the *longissimus dorsi* muscle from Hanwoo steers. Drip loss and Warner-Bratzler shear force were negatively correlated with tenderness attributes, including softness, initial tenderness, chewiness and rate of break down, whereas lightness showed a positive correlation with softness (r = 0.33) and initial tenderness (r = 0.26). Marbling score was more closely associated with sensory attributes with the exception of flavor and off-flavor intensities. Even though, no or few correlations were observed between the sensory scores and muscle fiber characteristics, the characteristics of muscle bundle including bundle area, fiber number per bundle and total bundle number were significantly correlated with tenderness attributes. Therefore, sensory quality characteristics of cooked Hanwoo beef, especially tenderness, were somewhat influenced by the extent of marbling and meat quality as well as the morphological characteristics of muscle bundle.

Keywords – Sensory quality, tenderness, meat quality, muscle fiber, muscle bundle, Hanwoo.

I. INTRODUCTION

Sensory quality is significantly influenced by the major components of muscle and postmortem meat quality state [1]. Intramuscular fat content or marbling is an important factor that contribute to sensory quality, including tenderness, juiciness and flavor, and is positively correlated with the eating quality of cooked meat [1, 2]. On the other hand, the characteristics of muscle fiber is also associated with tenderness of cooked beef, since muscle fiber is the main component of skeletal muscle [3]. However, there are no clear conclusions between the sensory quality and muscle fiber characteristics [1, 3]. Moreover, the effects of the muscle bundle characteristics on sensory quality characteristics are not yet fully understood. Therefore, the objective of this study was to investigate the relationships of trained panel sensory characteristics of cooked beef with meat quality, muscle fiber and bundle characteristics in the *longissimus dorsi* muscle from Hanwoo steers.

II. MATERIALS AND METHODS

Animals and muscle samples

A total of 64 Hanwoo steers were used in this study. The treatment conditions for all cattle were similar both before and after slaughter, and all treatment conditions were approved by the Ministry for Food, Agriculture, Forestry, and Fisheries of South Korea. At 45 min postmortem, muscle samples were taken from the *longissimus dorsi* muscles at the 13th thoracic vertebra, and frozen in isopentane cooled by liquid nitrogen, and then stored at –80 °C until subsequent analysis. After 24 h in a 4 °C cold room, the beef loins were removed and evaluated for marbling score and meat quality, and then were immediately stored at –20 °C for the measurement of sensory quality.

Sensory quality evaluation

Ten trained panellists were assigned to separate sensory booths at Kyungpook National University to evaluate the sensory quality. Panellist training was performed according to published sensory evaluation procedures [4], and lasted over 12 weeks. Samples were cut into 2 cm thick steaks. Steaks were roasted in an oven set at 180 °C and turned every 3 min until cooked to an internal temperature of 71 °C. Cooked steaks were cut into 1.3 cm^3 pieces that were given randomly to panellists to minimize bias. Cooked samples were evaluated for sensory softness (force required to compress the meat sample between molar teeth; 1 = very hard, 9 = very soft), initial tenderness (force required to chew three times after the initial compression; 1 = very tough, 9 = very tender), chewiness (energy required at the ninth chew to swallow at a constant rate; 1 = very chewy, 9 = very tender), rate of breakdown (number of chews required for the sample to disintegrate during the mastication process in preparation for swallowing; 1 = very slow, 9 = very fast), juiciness (amount of moisture released after five chews; 1 = not juicy, 9 = extremely juicy), flavor intensity (flavour intensity after eight chews; 1 = no flavor, 9 = full flavor), off-flavor intensity (intensity of any flavor or after-taste perceived as inappropriate for cooked beef; 1 = very strong, 9 = very weak), mouth coating (amount of oil/fat left on the mouth surface; 1 = none, 9 = very high) and amount of perceptible residue (amount of perceptible residue remaining upon complete disintegration of the meat sample; 1 = abundant, 9 = none) [1, 4]. The entire experiment of sensory evaluation was repeated, and the average value of the two replications was used.

Meat quality characteristics

After 24 h post-mortem, Muscle pH was measured directly on the carcasses using a spear type electrode (IQ Scientific Instruments Inc., USA). Meat lightness (L^*) was measured by a Minolta chromameter (CR-400, Minolta Camera Co., Japan) after exposing its surface to the air for 30 min at 4 °C. Water holding capacity including drip loss and cooking loss was also measured [1]. Warner-Bratzler shear force (WBS) was determined using an Instron Universal Testing Machine (Model 1011, Instron Cop., USA) equipped with a Warner-Bratzler shearing device.

Histochemical characteristics

Serial transverse skeletal muscle sections (10 μm) were cut in a cryostat (CM1860, Leica, Germany) at –25 °C and mounted onto glass slides. Myosin ATPase activity of the samples was detected following both acidic (pH 4.6) and alkaline (pH 10.7) pre-incubation [5]. Muscle fibers were classified as type I, IIA, or IIB using the nomenclature system of Brooke and Kaiser [5]. Average area and total number of muscle fibers were calculated. The percent area of each fiber type was calculated as the proportion of the total cross-sectional area of each fiber type divided by the total area of the fibers × 100. Muscle bundle characteristics, including bundle area, fiber number per bundle and total bundle number were also measured.

Statistical analysis

The data for the histochemical characteristics of muscle were analysed using the SAS [6] to calculate mean values, standard deviations, and overall ranges. Pearson correlation coefficients were evaluated using the partial correlation coefficients in order to determine the relationships of sensory quality characteristics with meat quality, muscle fiber and bundle characteristics.

III. RESULTS AND DISCUSSION

The means, standard deviations, and overall ranges for the histochemical characteristics in the bovine *longissimus dorsi* muscle are shown in Table 1. Drip loss was negatively correlated with tenderness attributes with the exception of amount of perceptible residue (Table 2). As expected, marbling score by experienced quality grader was positively correlated with softness (r = 0.55) and mouth coating scores (r = 0.59), whereas WBS was negatively related to softness (r = –0.44) and initial tenderness (r = –0.40).

Even though many studies have reported the effects of muscle fiber characteristics on sensory tenderness, opinions among scientists on this point remain divided [3]. In this study, no or few correlations were observed between the sensory scores and muscle fiber characteristics (Table 3). On the other hand, bundle structure is fixed before birth as like total muscle fiber number, and beef breed showing higher tenderness exhibited a smaller area of primary bundle compared to extreme breed for muscle growth [7]. This results supported this notion. In this study, the characteristics of muscle bundle were significantly correlated with tenderness attributes. For example, muscles harboring a smaller bundle area were more closely softer (r = –0.30), more tender (r = –0.29) and a lower number of chews (r = –0.33) compared to muscles harboring a larger bundle area.

Table 1 Muscle fiber and bundle characteristics of *longissimus dorsi* muscle from Hanwoo steers

	Mean±SD	Minimum	Maximum
Muscle fiber area (μm²)	3974±739	2131	5989
TFN (×1000)	2481±517	1577	4083
Muscle fiber area percentage (%)			
Type I	22.4±4.71	12.6	36.3
Type IIA	25.3±6.55	13.0	40.6
Type IIB	52.3±7.15	33.3	66.6
Muscle bundle characteristics			
Bundle area (mm^2)	0.389±0.128	0.181	0.792
Fiber number per bundle	101±36.0	44.3	128
TBN (×1000)	27.3±9.72	12.0	58.0

Abbreviations: TFN, total fiber number; TBN, total bundle number.

IV. CONCLUSION

Sensory quality characteristics of cooked Hanwoo beef, especially tenderness, were associated with the extent of marbling and meat quality as well as the morphological characteristics of muscle bundle.

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Table 2 Correlation between sensory quality characteristics of cooked beef and meat quality characteristics in *longissimus dorsi* muscle of Hanwoo steers

	$pH_{24\,h}$	L^*	Drip loss	Cooking loss	WBS	Marbling score
Softness	0.09	0.33**	–0.33**	–0.18	–0.44***	0.55***
Initial tenderness	0.13	0.26*	–0.32*	–0.11	–0.40**	0.45***
Chewiness	0.12	0.23	–0.30*	–0.07	–0.41**	0.43***
Rate of breakdown	0.05	0.28*	–0.35**	–0.05	–0.38**	0.36**
Juiciness	0.13	0.14	0.03	–0.20	–0.29*	0.49***
Flavor intensity	0.08	–0.03	0.18	–0.06	–0.15	0.15
Off-flavor intensity	0.09	0.05	–0.10	–0.23	–0.04	0.21
Mouth coating	0.12	0.24*	0.15	–0.25*	–0.42***	0.59***
Amount of perceptible residue	0.14	0.22	–0.22	–0.03	–0.28*	0.45***

Levels of significance: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
Abbreviation: WBS, Warner-Bratzler shear force.

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Table 3 Correlation between sensory quality characteristics and histochemical characteristics in *longissimus dorsi* muscle of Hanwoo steer

	Fiber area	TFN	Muscle fiber area percentage			Muscle bundle characteristics		
			Type I	Type IIA	Type IIB	Bundle area	Fiber no. per bundle	TBN
Softness	0.09	0.13	0.10	0.17	–0.21	–0.30*	–0.29*	0.38**
Initial tenderness	0.11	0.11	0.15	0.10	–0.19	–0.29*	–0.30*	0.36**
Chewiness	0.08	0.14	0.14	0.10	–0.17	–0.29*	–0.29*	0.36**
Rate of breakdown	0.07	0.15	0.11	0.08	–0.13	–0.33**	–0.32*	0.41**
Juiciness	0.08	0.01	0.28*	0.10	–0.26*	–0.05	–0.07	0.15
Flavor intensity	–0.01	–0.03	0.24*	0.01	–0.15	–0.15	–0.16	0.11
Off-flavor	–0.03	0.13	0.08	0.09	–0.13	–0.03	–0.03	0.11
Mouth coating	–0.05	0.16	0.26*	0.02	–0.17	–0.16	–0.11	0.23
Amount of perceptible residue	0.12	0.17	0.23	0.09	–0.22	–0.12	–0.16	0.26*

Levels of significance: * $P < 0.05$; ** $P < 0.01$.
Abbreviations: TFN, total fiber number; TBN, total bundle number.