ASSOCIATION BETWEEN SURFACE TEXTURE FEATURES AND MEAT, SENSORY AND MUSCLE HISTOCHEMICAL CHARACTERISTICS OF HANWOO STEERS

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Abstract – The aim of this study was to compare the meat quality, trained panel sensory scores of cooked beef and histochemical characteristics of *longissimus dorsi* muscle in Hanwoo steer groups that were categorized by surface texture feature (Soft and Tough) at the 24 h post-mortem in order to provide a new indicator or predictor of beef tenderness. There were no significant differences in marbling score and meat quality characteristics between the groups categorized by the surface texture feature ($P > 0.05$). Tenderness attributes, including softness ($P < 0.01$), initial tenderness ($P < 0.01$), chewiness ($P < 0.001$), rate of breakdown ($P < 0.001$), and amount of perceptible residue ($P < 0.05$), were significantly higher in the Soft group compared to the Tough group, even though no significant differences were observed in juiciness, flavor and off-flavor intensities between the groups ($P > 0.05$). These higher scores of tenderness attributes in the Soft group were accompanied by smaller area of muscle bundle (0.29 vs. 0.48 mm^2, $P < 0.001$) compared to the Tough group. Our results suggested that the surface texture feature can be a good indicator or predictor of beef tenderness, and is influenced by the characteristics of muscle bundle in the bovine *longissimus dorsi* muscle.

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

I. INTRODUCTION

Organoleptic characteristics of beef paly important role in determining purchase and repurchase decisions of many consumers. Especially, beef tenderness tend to exhibit a high and uncontrolled variability, since there are many intrinsic and extrinsic factors that influencing tenderness attributes [1]. Texture is one of the tenderness indicators, and used to make the quality assessments [2]. Li et al.[3] reported that texture feature of fresh beef images by computer vision system is a useful indicator to evaluate and predict tenderness of cooked beef. However, there is still limited information about the cause of differences in surface texture features, and its relation to sensory quality characteristics. Therefore, the objectives of this study were to investigate the relationships between surface texture features of bovine *longissimus dorsi* muscle and sensory quality characteristics of cooked beef. In addition, we investigated the effect of muscle histochemical characteristics on muscle surface features to establish the direct cause of differences in surface texture feature.

II. MATERIALS AND METHODS

Animals and muscle samples

A total of 48 Hanwoo steers were used in this study. The treatment conditions for all cattle were similar both before and after slaughter. Within 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. Marbling score and surface texture feature of *longissimus dorsi* muscles at 13th thoracic vertebrae were determined by experienced official graders of the Korean Institute for Animal Products Quality Evaluation. Samples from the Soft group (N =27) exhibited a soft flat surface compared to samples from the Tough groups (N = 19), whereas the Tough group showed a rough surface.

Meat quality measurements

Muscle pH was measured directly on the carcasses at 45 min ($pH_{45\ min}$) and 24 h ($pH_{24\ h}$) post-mortem using a spear type electrode (Testo 260-pH2, Testo Inc., USA). Meat lightness was evaluated, using a Minolta chromameter (CR-400, Minolta Camera Co., Japan). Drip loss and cooking loss was also assessed in accordance with the procedure by Honikel [4]. 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.

Eating quality evaluation

Sensory panel consisting of 12 trained individuals (20 to 40 years of age, 6 females and 6 males) was employed to evaluate the sensory attributes of cooked beef. Panellist training was performed according to published sensory evaluation procedures [5], and lasted over 6 mon. 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 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) [6]. The entire experiment of sensory evaluation was repeated, and the average value of the two replications was used.

Histochemical characteristics

Serial transverse skeletal muscle sections (10 μm) were cut in a cryostat (CM1860, Leica, Germany) at –25 °C. Myofibrillar ATPase activity of the samples was detected following both acidic (pH 4.6) and alkaline (pH 10.7) pre-incubation [7]. Muscle fibers were classified as type I, IIA, or IIB using the nomenclature system of Brooke and Kaiser [7]. 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

Least squares analyses were conducted using the GLM procedure program contained in the SAS statistical package [8].

Table 1 Meat quality characteristics of the bovine *longissimus dorsi* muscle in groups defined by the surface texture features

	Surface texture feature		Level of significance
	Soft	Tough	
Marbling score	5.68 (0.23)[1]	5.21 (0.28)	NS
Muscle $pH_{45\ min}$	6.26 (0.06)	6.26 (0.07)	NS
Muscle $pH_{24\ h}$	5.47 (0.02)	5.43 (0.03)	NS
Lightness (L^*)	29.9 (0.67)	29.6 (0.81)	NS
Drip loss (%)	1.47 (0.21)	1.94 (0.25)	NS
Cooking loss (%)	22.5 (1.22)	23.4 (1.60)	NS
WBS (N)	52.8 (2.29)	56.9 (3.00)	NS

Level of significance: NS = not significant.
[1] Standard error of least square means.
Abbreviation: WBS, Warner-Bratzler shear force.

III. RESULTS AND DISCUSSION

Marbling score by trained official grader was a similar between the Soft and Tough groups (5.68 vs. 5.21, $P > 0.05$) categorized by the surface texture feature (Table 1). There were no significant differences in the muscle $pH_{45\ min}$ and $pH_{24\ h}$ between the groups ($P > 0.05$) suggesting the normal glycolytic rate during the postmortem period without cold shortening.

Table 2 Sensory quality characteristics of the bovine *longissimus dorsi* muscle in groups defined by the surface texture features

	Surface texture feature		Level of
	Soft	Tough	significance
Softness	6.11[a] (0.24)[1]	4.97[b] (0.27)	**
Initial tenderness	6.03[a] (0.25)	4.78[b] (0.29)	**
Chewiness	5.81[a] (0.26)	4.46[b] (0.30)	***
Rate of breakdown	5.52[a] (0.20)	4.41[b] (0.24)	***
Juiciness	5.57 (0.15)	5.25 (0.17)	NS
Flavor intensity	5.90 (0.08)	5.65 (0.10)	NS
Off flavor intensity	6.27 (0.08)	6.03 (0.09)	NS
Mouth coating	5.66[a] (0.18)	5.10[b] (0.21)	*
Amount of perceptible residue	5.64[a] (0.16)	5.15[b] (0.18)	*

Level of significance: NS = not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
[1] Standard error of least square means.
[a-b] Different superscripts in the same row represent significant differences ($P < 0.05$).

The soft group exhibited higher values of tenderness attributes, including softness (6.11 vs. 4.97, $P < 0.01$), initial tenderness (6.03 vs. 4.78, $P < 0.01$), chewiness (5.81 vs. 4.46, $P < 0.001$), rate of breakdown (5.52 vs. 4.41, $P < 0.001$), and amount of perceptible residue (5.64 vs. 5.15, $P < 0.05$) compared to the Tough group, even though there were no significant differences in juiciness, flavor and off-flavor intensities between the groups ($P > 0.05$) (Table 2).

Muscle bundle and perimysium are designed to fit a load and stress bearing function [9], thus the bundle characteristics could associated with the muscle surface tension during postmortem period. In this study, muscles harboring smaller bundle area (0.29 vs. 0.48 mm^2, $P < 0.001$) and greater total number of bundle (36.0 vs. 20.4 ×1000, $P < 0.001$) exhibited soft flat surface and more tender beef compared to muscles harboring larger bundle area and less total number of bundle. On the other hand, no significant differences were observed in the muscle fiber characteristics between the groups ($P > 0.05$).

Table 3 Muscle fiber and bundle characteristics of the bovine *longissimus dorsi* muscle in groups defined by the surface texture features

	Surface texture feature		Level of
	Soft	Tough	significance
Fiber area (μm^2)	3897 (122)[1]	3725 (152)	NS
TFN (×1000)	2623 (93.2)	2613 (116)	NS
Fiber area percentage (%)			
Type I fiber	22.9 (0.86)	22.9 (1.07)	NS
Type IIA fiber	25.3 (1.15)	23.1 (1.44)	NS
Type IIB fiber	51.7 (1.27)	54.0 (1.58)	NS
Muscle bundle characteristics			
Bundle area (mm^2)	0.29[b] (0.01)	0.48[a] (0.02)	***
Fiber no./bundle	75.8[b] (4.16)	131[a] (5.19)	***
TBN (×1000)	36.0[a] (1.41)	20.4[b] (1.75)	***

Level of significance: NS = not significant; *** $P < 0.001$.
[1] Standard error of least square means.
Abbreviations: TFN, total fiber number; TBN, total bundle number.
[a-b] Different superscripts in the same row represent significant differences ($P < 0.05$).

IV. CONCLUSION

Measuring the surface texture feature as determined by experienced official graders could be a good indicator or predictor of beef tenderness, and is influenced by the characteristics of muscle bundle in the bovine *longissimus dorsi* muscle.

ACKNOWLEGEMENT

This work was supported by the Korean Institute for Animal Products Quality Evaluation.

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