Investigation of instrumental tenderness measurements as indicator of overall meat tenderness

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Abstract— **In this study, the potential correlations among three aspects of meat tenderness and the reliability of instrumental measurements as general indicators of tenderness were investigated. A total of 394 pork loins (Berkshire = 127, Duroc = 128, Landrace = 80, and Yorkshire = 59) were used. In terms of eating quality, sensory hardness at the first bite was positively related to tenderness at initial mastication (r=0.97, P<0.001), chewiness (r=0.94, P<0.001), rate of breakdown (r=0.88, P<0.001), and amount of perceptible residue (r=0.69, P<0.001). Samples evaluated as tender at the first bite were also those easy to chew and breakdown, and with a lower amount of perceptible residue. Two instrumental tenderness measurements, the Warner-Bratzler shear force (WBS) and texture profile analysis (TPA)-hardness, were significantly correlated to these three aspects of tenderness. Therefore, these instrumental parameters, especially TPA-hardness, could be used as general indicators of tenderness in the porcine *longissimus dorsi* muscle.**

Keywords— **Tenderness attributes, instrumental tenderness measurements, pork.**

I. INTRODUCTION

Palatability has been regarded as the primary determinant of the acceptability of a food product, and is generally defined by the integration of several sensory characteristics including tenderness, juiciness, and flavor [1]. Among these, tenderness is the most important characteristic determining eating quality, as it relates to the consumer’s perception of meat.

The overall impression of tenderness to the palate includes texture and involves three aspects: the initial ease of penetration of cooked meat by the teeth, the ease with which the cooked meat breaks into fragments, and the amount of residue remaining after chewing [2].

The most widespread method used as an indicator of sensory tenderness is the Warner-Bratzler shear force (WBS). Texture profile analysis (TPA) is also used for texture assessments of various food items including meat and meat products [3]. Many studies have reported that WBS and TPA-hardness are strongly correlated to initial sensory tenderness [3, 4]. However, there is still limited information about the correlations between these instrumental tenderness parameters and the three aspects of sensory tenderness mentioned. Therefore, the objective of this study was to investigate the correlations among these three aspects of tenderness, and the possibility to use instrumental tenderness parameters, such as WBS and TPA, as general indicators of meat tenderness.

II. MATERIALS AND METHODS

A. Animals and muscle samples

A total of 394 pigs were evaluated (Berkshire = 127, Duroc = 128, Landrace = 80, and Yorkshire = 59). All pigs were raised in the same farm and slaughtered in the winter at the same slaughterhouse using electrical stunning. All pigs had a similar weight (110 ± 5 kg) at the time of slaughtering. Following electrical stunning, pigs were exsanguinated. After chilling for 24 h in a 4 °C cold room, the pork loins (the 10–13th thoracic vertebrae) were taken, and then were immediately stored at –20 °C for instrumental tenderness measurements and eating quality evaluations.

B. Tenderness measurements

B.1. Warner-Bratzler shear force

After 24 h chilling, loin sections were cut into 2 cm thick chops and put into thin-walled polyethylene bags (waterproof and able to withstand 80 °C). Two chops of each sample were cooked in a continuously heated water bath (80 °C) until the internal temperature reached 71 °C, and were then cooled in ice water for 15 min. WBS was determined using an Instron Universal Testing Machine (Model 1011, Instron Cop., USA) equipped with a Warner-Bratzler shearing device. Six cores (1.27 cm diameters), parallel to the longitudinal orientation of the muscle fibers, were taken from each steak. The load capacity was 10 kN with cross-head speed 200 mm min^{-1}. Samples were sheared perpendicular to the long axis of the core.

B.2. Texture profile analysis

Preparation of cooked meat samples for TPA was similar to the procedure described for the measurement of WBS. TPA was performed at room temperature with a texture analyzer (TA-XT Express, Stable Micro System, Surrey, England). Cooked meat samples were cut into 2.0 × 2.0 × 2.0 cm^3 pieces without a cooked surface. Samples were placed under the probe, which moved downward at constant speeds of 3.0 mm s^{-1} (pre-test), 1.0 mm s^{-1} (test) and 3.0 mm s^{-1} (post-test). When the probe first came into contact with the sample, the thickness of the sample was automatically recorded by the software. The probe continued downward to a pre-fixed percentage of the sample thickness (75%), returned to the initial point of contact with the sample, and then stopped for a set period of time (2 s) before the second compression cycle was started [3]. TPA of each sample was measured using more than 10 cubes. The force-by-time data from each test were used to calculate the mean values for the TPA parameters of each steak and were determined as described by Bourne [5].

C. Eating quality evaluations

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. Ten trained panellists were assigned to separate sensory booths at Korea University to evaluate the sensory quality of 394 pork samples. Panellist training was performed according to published sensory evaluation procedures [6], and lasted over 12 weeks. A total of 100 sessions were conducted, with eight samples evaluated per session. Cooked samples were evaluated for sensory hardness (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), juiciness (amount of moisture released after five chews; 1 = extremely juicy, 9 = not juicy), flavor intensity (intensity of pork flavor after eight chews; 1 = no pork flavor, 9 = full pork flavor), off-flavor intensity (intensity of any flavor or after-taste perceived as inappropriate for cooked pork; 1 = very strong, 9 = very weak), 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, mouth coating (amount of oil/fat left on the mouth surface; 1 = very high, 9 = none), and amount of perceptible residue (amount of perceptible residue remaining upon complete disintegration of the meat sample; 1 = abundant, 9 = none) [8]. The entire experiment of sensory evaluation was repeated, and the average value of the two replications was used.

D. Statistical analysis

Descriptive statistical analyses were conducted using the MEANS procedure of the SAS PC software [7] to calculate mean values and standard deviations (SD) for the instrumental tenderness parameters. Partial Pearson correlation coefficients [7] were calculated to determine the correlations among the eating quality parameters, as well as that between the eating quality and instrumental tenderness parameters.

III. RESULTS AND DISCUSSIONS

Table 1 provides the means, standard deviations, and ranges for the instrumental tenderness parameters, including WBS and TPA. The correlation coefficients among the eating quality parameters measured are shown in Table 2. There were significant correlations among the eating quality parameters, especially among the three main determinants of tenderness. Sensory hardness at the first bite was positively related to chewiness (*r*=0.94, *P*<0.001), rate of breakdown (*r*=0.88, *P*<0.001), and amount of perceptible residue (*r*=0.69, *P*<0.001). Moreover, rate of breakdown was positively correlated to amount of perceptible residue (*r*=0.69, *P*<0.001).

Table 1 Instrumental tenderness parameters of the porcine *longissimus dorsi* muscle

	Mean±SD	Minimum	Maximum
WBS (N)	51.91±16.23	22.47	113.79
Texture profile analysis			
Hardness (N)	29.50±5.36	17.25	46.45
Cohesiveness	0.45±0.04	0.26	0.61
Springiness (mm)	0.92±0.09	0.55	1.36
Adhesiveness (N·s)	5.66±2.77	1.45	16.51
Gumminess (N)	13.53±3.36	5.87	24.20
Chewiness (N·mm)	12.44±2.76	5.82	24.34

Abbreviation: WBS, Warner-Bratzler shear force.

The correlation coefficients between instrumental tenderness and eating quality parameters are presented in Table 3. WBS was significantly correlated to sensory tenderness, including sensory hardness (*r*=–0.18, *P*<0.001), initial tenderness (*r*=–0.24, *P*<0.001), chewiness (*r*=–0.27, *P*<0.001), and rate of breakdown (*r*=–0.28, *P*<0.001). However, no correlation was observed between WBS and amount of perceptible residue (*P*>0.05).

As expected based on the design of the experiment, TPA-hardness was correlated to sensory hardness (*r*=–0.40, *P*<0.001) and initial tenderness (*r*=–0.43, *P*<0.001), as well as to the amount of perceptible residue (*r*=–0.28, *P*<0.001). Previous studies have indicated that TPA is a better predictor of sensory texture than is WBS [3, 4]. In this study, TPA-hardness was more closely related to all sensory tenderness attributes (*r*=–0.28 to –0.44) than was WBS.

IV. CONCLSIONS

Firstly, there were significant correlations among the three tenderness attributes. Meat samples judged tender at the first bite were similarly evaluated as easy to chew and breakdown and having a lower amount of perceptible residue. Secondly, instrumental parameters were related to these three tenderness attributes. Therefore, WBS and TPA, in particular, TPA-hardness could be used as general indicators of meat tenderness.

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Table 2 Correlations among eating quality parameters

	Initial tenderness	Juiciness	Flavor intensity	Off flavor intensity	Chewiness	Rate of breakdown	Mouth coating	Amount of perceptible residue
Sensory hardness	0.97***	–0.70***	0.15**	0.40***	0.94***	0.88***	0.67***	0.69***
Initial tenderness		–0.65***	0.14**	0.40***	0.97***	0.91***	0.65***	0.70***
Juiciness			–0.18***	–0.22***	–0.62***	–0.54***	–0.70***	–0.55***
Flavor intensity				–0.02	0.15**	0.16**	0.15**	0.19***
Off flavor intensity					0.39***	0.38***	0.22***	0.35***
Chewiness						0.94***	0.64***	0.69***
Rate of breakdown							0.61***	0.69***
Mouth coating								0.55***

Levels of significance: ** P<0.01, *** P<0.001.
Score distribution: low to high, sensory hardness: hard to soft; initial tenderness: tough to tender; juiciness: extremely juicy to not juicy; flavor intensity: no pork flavor to full pork flavor; off-flavor intensity: very strong to very weak; chewiness: very chewy to very tender; rate of breakdown: very slow to very fast; mouth coating: very high to none; and amount of perceptible residue: abundant to none.

Table 3 Correlations between instrumental tenderness and eating quality parameters

	WBS	Texture profile analysis					
		Hardness	Cohesiveness	Springiness	Adhesiveness	Gumminess	Chewiness
Sensory hardness	–0.18***	–0.40***	–0.19***	0.07	–0.16**	–0.37***	–0.37***
Initial tenderness	–0.24***	–0.43***	–0.20***	0.09	–0.15**	–0.40***	–0.39***
Juiciness	–0.11*	0.14**	–0.02	0.08	0.19***	0.10*	0.13**
Flavor intensity	–0.14**	–0.18***	–0.20***	0.16**	0.01	–0.22***	–0.17***
Off flavor intensity	0.02	–0.06	0.10	–0.07	–0.17**	–0.01	–0.03
Chewiness	–0.27***	–0.44***	–0.21***	0.10*	–0.14**	–0.41***	–0.40***
Rate of breakdown	–0.28***	–0.41***	–0.21***	0.09	–0.08	–0.39***	–0.39***
Mouth coating	–0.01	–0.24***	–0.03	–0.03	–0.13*	–0.18***	–0.22***
Amount of perceptible residue	–0.05	–0.28***	–0.17***	0.10	–0.09	–0.27***	–0.25***

Levels of significance: * P<0.05, ** P<0.01, *** P<0.001.
Abbreviation: WBS, Warner-Bratzler shear force.
Score distribution: low to high, sensory hardness: hard to soft; initial tenderness: tough to tender; juiciness: extremely juicy to not juicy; flavor intensity: no pork flavor to full pork flavor; off-flavor intensity: very strong to very weak; chewiness: very chewy to very tender; rate of breakdown: very slow to very fast; mouth coating: very high to none; and amount of perceptible residue: abundant to none.