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ARTICLE

Effects of Various Cooking Methods on Quality Characteristics of Korean Boiled Pork (*Soo-yuk*)

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Abstract

This research was conducted to evaluate the effects of cooking conditions on quality characteristics of *Soo-Yuk*, a traditional Korean food. The cooking conditions were as follows: boiled until the core temperature of a sample in 20°C cold water reached at 75°C (T1); boiled until the core temperature of a sample in 90°C boiling water reached at 75°C (T2); and boiled with sample from 20°C to 100°C and kept at 98°C for 25 min (T3, Korean traditional method). The sample cooked at 90°C water (T2) had the fast cooking time, and the highest cooking yield and moisture content. *Soo-yuk* boiled in 100°C water (T3) showed the longest cooking time, the lowest cooking yield and moisture content, and the highest shear force. The instrumental color showed a significant difference among the cooking conditions. The sarcomere length of *soo-yuk* boiled in 100°C water (T3) was the shortest, but the myofibrillar fragmentation index and thiamine content of the sample cooked at 90°C (T2) were the highest. In sensory evaluation, the evaluation of *soo-yuk* boiled in 98°C water (T3) was of superior flavor and overall acceptability.

Key words: *soo-yuk*, boiled pork loin, cooking method, eating quality

Introduction

Korean boiled pork, *soo-yuk*, is one of the popular foods in Korea. This cooking method tenderizes the texture of meat by dissociating connective tissue such as collagen and decrease a nutrient loss, especially vitamin B_1. Over the past few years, several studies have been made on boiled pork in Korea. Moon *et al*. (2001) reported that as the internal temperature of pork increased, cooking loss and hardness increased. Oh (1994) found that cooking loss increased in the studies of both conventional and microwave methods as heating temperature and power increased. Choi *et al*. (2006) improved quality properties of boiled pork loin using tumbling methods. Also, Park and Kwon (1998), and Jung *et al*. (2004) conducted the studies about the quality change of *soo-yuk* such as Korean boiled pork using bark (*Morus alba* Linne) and mugwort powder.

Abroad, there have conducted many researches on cooking conditions of meat. Many researchers conducted the studies about the effect of heating period to meat quality (Dube *et al*., 1972; Laakkonen *et al*., 1970; Machlik and Draudt, 1963). Forrest *et al*. (1975) recommended the appropriate temperatures: 77°C for end point for most fresh pork, 77 to 82°C for poultry, 58 to 60°C for rare beef, 66 to 68°C for medium rare, 73 to 75°C for medium and 80 to 82°C for well done. Steak and chop like tender cut are well matched with dry heat cooking methods for a short time. In case of meat cut with many connective tissue, the moist cooking method is suitable for braising for a long time at low temperature. Especially, Buck *et al*. (1979) found that pork roast had the best quality at internal temperature between 71.1°C and 76.7°C in the treatment that the oven at 21°C was roasted right after setting to 163°C. Additionally, the research of Moss *et al*. (1983) on terms of heating methods for nutrient composition and Bower *et al*. (1987) on terms of heating temperature at 55 to 85°C for broiling at 290°C and roasting at 149°C said that the heating method was one of main factors that affect meat quality. Obuz *et al.* (2003) emphasized that we needs to monitor the temperature of all the cooking process to satisfy eating quality for consumers.

However, the food service industry still uses color or other visual observation methods to diagnose meat doneness and there has been no study about the cooking meth-

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ods of Korean boiled pork, *soo-yuk*. It is only the method that boils for a long time at 100°C with pork and cold water. Therefore, this study was conducted to improve the textural and sensorial quality of *soo-yuk* using various different cooking methods.

Materials and Methods

Sample preparation

Pork loin (*M. longissimus dorsi*) was purchased from a local processor at 48 h postmortem. All subcutaneous and intermuscular fat and visible connective tissue were removed from the fresh muscles, and then the pork loin was sliced at thickness of 2.5 cm and in the weight of 100±10 g and packed in Nylon/Polyethylene film at the temperature of 8±1°C. The cooking conditions of samples are as follows (Fig. 1): boiled until reached to 75°C at core temperature with sample in 20°C cold water and immediately cooled for 30 min (T1); boiled until reached to 75°C at core temperature with sample in setting 90°C hot water and immediately cooled for 30 min (T2); and boiled with sample from 20°C to 100°C and held at 98°C for 25 min (T3, Korean traditional method). The change of internal temperature was measured, using a digital thermocouple (KM330, Kane-May, Germany). After cooking, the samples were taken from the water and cooled for 30 min at room temperature.

Cooking yield

The raw samples sliced in 2.5 cm thickness were boiled in three cooking conditions. After each cooked, samples were cooled for 30 min in the room temperature. The yield was calculated by the Eq. (1).

$$\text{Cooking yield (\%)} = \text{Weight after cooking/Weight before cooking} \times 100 \quad (1)$$

Moisture content

The moisture content (%) was determined by weight loss after 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Bucheon, South Korea), using AOAC (2000) method.

Shear force

For the determination of shear force, samples were cooked individually in plastic bags immersed in a 75°C water bath for 30 min. The cooked meats were cooled and sampled at room temperature using a 12.7 mm circular core to determine shear force. Four sample cores were sheared from each sample across the length of the core with a Warner-Bratzler shear attachment (V-type blade set) on the texture analyzer (TA-XT2*i*, Stable Micro Systems, England) under cross head speed of 2 mm/sec. Texture Expert for the WINDOWS™ operation system was used to analyze the data. The shear force value was the

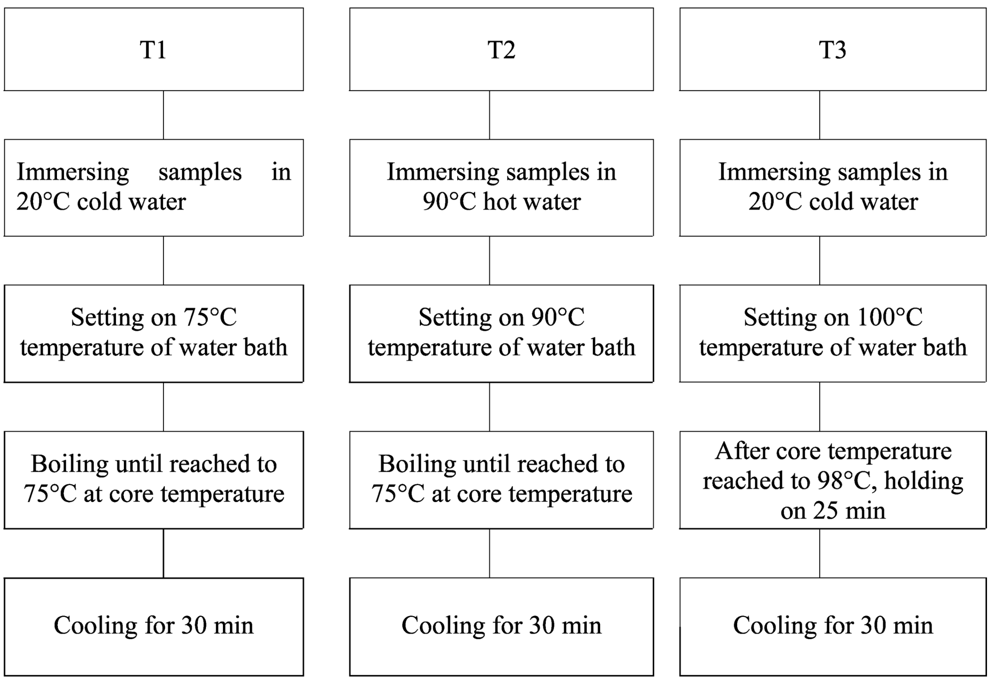

Fig. 1. Experimental design using various cooking conditions.

mean of the maximum forces required to shear each set of core samples and the units used for shear force were kilograms (kg).

Instrumental color

Color measurement were taken with color meter (Chroma meter, CR210, Minolta, Japan; illuminate C, calibrated with white standard palate L=97.83, a=-0.43 and b=+1.98). Color value were determined as indicator of lightness (CIE L*), redness (CIE a*), and yellowness (CIE b*) of sample.

Sarcomere length

Sarcomere length was determined by the method (Voyle, 1971) with Helium-Neon-Laser diffraction (Model No. 212-2, Spectra-physics, USA). At different time postmortem, 1-2 g of muscle samples were carefully cut with a knife and immersed in 2% glutaraldehyde solution with 2% glucose in a 0.1 M phosphate buffer, pH 7.0, at temperature similar to that at which the muscles were incubated, and sarcomere length was measured.

Myofibrillar fragmentation index (MFI)

Myofibrils were obtained according to the method of Olson *et al*. (1976a) using the MFI buffer (20 mM K_2HPO_4/KH_2PO_4, pH 7, 100 mM KCl, 1 mM EDTA, 1 mM NaN_3). The myofibrils were suspended in MFI buffer. An aliquot of myofibril suspension was diluted with the MFI buffer to 0.5 mg/mL protein concentration and the absorbance of this suspension was measured at 540 nm. MFI values were recorded as absorbance units per 0.5 mg/mL myofibril protein concentration multiplied by 200.

Thiamin content

Five g of sample and 0.1 N 50 mL of HCl was boiled in hot plate at 70-80°C for 1 h and cooled. Subsequently, the samples were cooled to ambient temperature, and the sample volume was brought up to 50 mL with water before centrifugation at 3000 rpm for 5 min. The 5 mL supernatant was mixed with 2.5 mL potassium ferricyanide in 15% sodium hydroxide, and mixed for 10 s to ensure derivatisation of thiamine to thiochrome. Subsequently, the derivatisation solution was brought up to 10 mL with 3.75 M HCl before sample clean-up with C18 solid phase extraction columns and analysis of thiochrome. HPLC used Waters 486 Tunable Absorbance Detector, Waters M510 Pump for Waters 717Plus Autosampler (USA). The condition of separation was mobile phase (5 mmol/L sodium hexanesulfonate, 20 mmol/L $H_2PO)/CH_2CN$ = 91/9, column (Waters Atlantis C_{18}, 5UM, id 4.6 mm×150 mm) with 1 mL/min of flow rate, absorbance (210 nm) and 10 μL of input.

Sensory evaluation

Uniformed dimensions of sample (1 cm×1 cm×0.2 cm) were used for the sample for sensory evaluation. Cooked samples were served to 12 experienced panel members with previous experience. Panelists were presented with three randomly coded samples. The color (1 = extremely undesirable, 10=extremely desirable), flavor (1=extremely undesirable, 10=extremely desirable), tenderness (1=extremely tough, 10=extremely tender), juiciness (1=extremely dry, 10=extremely juicy), and overall acceptability (1=extremely undesirable, 10=extremely desirable) of the cooked samples were evaluated using a 10-point descriptive scale. Sliced samples served at a temperature of approximately room temperature to each panelist. Warm water (30°C) was given to panelists to consume between samples.

Statistical analyses

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (1996). The Duncan's multiple range test (p<0.05) was used to determine differences between treatment means.

Results and Discussion

Time-temperature profile and cooking yield

The time-temperature profile and cooking yield of boiled pork loins (*soo-yuk*) cooked with various cooking

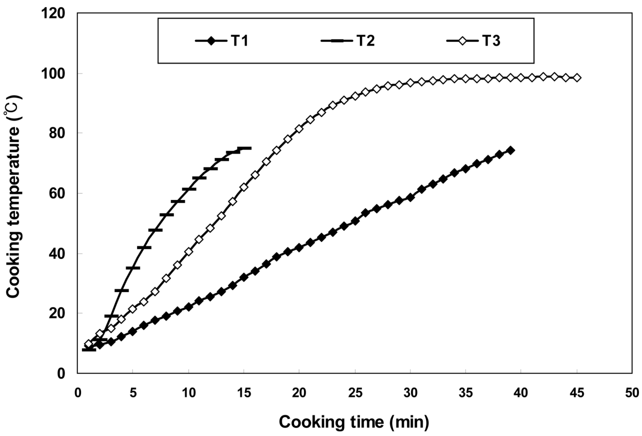

Fig. 2. The time-temperature profile of boiled pork loins (*soo-yuk*) cooked with various cooking conditions.

Table 1. Comparison on cooking yield, moisture content, and instrumental color of boiled pork loins (*soo-yuk*) cooked with different cooking conditions

Traits		Cooking condition[1)]		
		T1	T2	T3
Cooking yield (%)		66.13±2.93[b2)]	67.88±3.54[a]	56.03±3.10[c]
Moisture content (%)		62.68±1.28[b]	64.34±1.86[a]	58.79±1.38[c]
Color	CIE L*	67.03±2.02[b]	69.42±1.76[a]	66.99±2.04[b]
	CIE a*	4.70±0.84[a]	4.17±0.81[b]	3.24±0.80[c]
	CIE b*	8.38±0.93[b]	7.38±0.52[c]	9.56±0.53[a]

[1)]Cooking conditions are presented in Fig. 1.
[2)]All values are mean ± SD.
[a-c]Means values with different superscripts within a same row are significantly different ($p<0.05$).

conditions are shown in Fig. 2 and Table 1, respectively. T2 treatment that started heating from hot water (4.46°C/min) showed a faster cooking rate than T1 treatment that started heating from cold water (1.7°C/min) and T3 treatment by the conventional method (3.72°C/min). T2 treatment reached internal temperature of 75°C in the shortest time due to boiling at 90°C water and its cooking yield was significantly higher than other treatments due to the short cooking time. T1 treatment took 40 min to reach 75°C, showing the longest cooking time. The cooking yield of T3 treatment was the lowest because of its high temperature and long cooking time ($p<0.05$). T2 treatment took 15 min to reach at 75°C in internal temperature and resulted in a cooking yield of 67%. The result was similar to the study of Choi *et al*. (2006), in which the core temperature reached at 75°C in 14 min and the cooking yield was about 65%. Also, Pan and Singh (2001) reported that cooking loss increased and the cooking yield decreased as cooking temperature increased, and Barbanti and Pasquini (2005) indicated that the cooking yield increased as cooking time decreased.

Moisture content and instrumental color

Table 1 shows the moisture content of boiled pork loins (*soo-yuk*) cooked with different cooking conditions. T3 treatment had a lower moisture content than other treatments due to its high temperature and long cooking time ($p<0.05$). On the contrary, T2 treatment had the highest moisture content because of short cooking time ($p<0.05$). This result agrees with the report of Lawrie (1988) that increasing heating velocity leads to less cooking loss and more juiciness, and are consistent with the results of a study on the moisture content by Bengtsson *et al.* (1976). Godsalve (1977) indicated that, in the process of various heating temperature and time, heating temperature influenced more in moisture content than time. On the other hand, Pietrasik and Shand (2003) found that cooking loss affected the moisture content of the meat as well as its tenderness. The result of this study is similar with their result.

The instrumental color of *soo-yuk* cooked with different cooking conditions was shown in Table 1. T2 treatment with high heating temperature indicated the highest value of CIE-L (lightness) and no significant difference was observed between T1 and T3 ($p>0.05$). T1 treatment with a fast cooking rate had the highest CIE a* (redness) and T3 treatment boiled at high temperature and for a long time showed the lowest. In CIE b* (yellowness) value, T3 treatment was the highest and T2 treatment was lowest.

Shear force, sarcomere length, and MFI

The shear force and sarcomere length of boiled pork loin cooked with different cooking conditions are shown in Table 2. T3 treatment showed the highest shear force with the lowest cooking yield, but there was not a significant difference between T1 and T2 treatments. This result is similar with the report of Choi *et al*. (2008) that cooking yield was negatively correlated with shear force. Also, Abugroun *et al*. (1985) found that fast heating (2°C/2 min) showed a lower shear force than slow heating (2°C/12 min) as indicated by the results of this experiment. With respect to Warner-Bratzer shear force (WBS), Belew *et al*. (2003) divided into most tender (WBS=2.03 kg), very tender (WBS<3.2 kg), tender (3.2 kg<WBS<3.9 kg), intermediate (3.9 kg<WBS<4.6 kg), tough (WBS>4.6 kg) and toughest (WBS=7.7 kg). According to that standard, the shear force of the treated samples observed in this study were evaluated tender (T1, T2) and intermediate (T3), respectively.

In the changes of sarcomere length (Table 2), T3 treat-

Table 2. Comparison on shear force, sarcomere length, MFI, and thiamine content of boiled pork loins (*soo-yuk*) cooked with different cooking conditions

Traits	Cooking condition		
	T1	T2	T3
Shear force (kg)	35.68±6.47[b2)]	34.58±6.37[b]	40.80±7.45[a]
Sarcomere length (μm)	1.53±0.08[a]	1.45±0.06[b]	1.30±0.09[c]
MFI	57.96±4.70[b]	66.35±4.82[a]	57.04±3.81[b]
Thiamine content (mg/kg)	4.35±0.70[ab]	5.04±0.83[a]	3.60±0.86[b]

[1)]Cooking conditions are presented in Fig. 1.
[2)]All values are mean ± SD.
[a-c]Means values with different superscripts within a same row are significantly different ($p<0.05$).

ment heated for a long time and high temperature had the shortest sarcomere length, and T1 treatment that cooked slowly from low temperature showed a longer sarcomere length than other treatments (p<0.05). Herring *et al.* (1965) found that the relationship between sarcomere length and meat tenderness was highly significant. In the present study, likewise, T3 treatment showed the highest shear force and the shortest sarcomere length. Dube *et al*. (1972) reported that the sarcomere shortening rate increased when heated the meat in a water bath at 60, 70, 80 and 90°C for 30 min. Bouton *et al.* (1975) observed the same result that the sarcomere length of calf decreased as temperature increased. Lewis and Purslow (1989) observed that sarcomere shrinkage did not happen until 60°C, but M-lines and I-bands of collagen fibers were disrupted and changed at the shrinkage temperature of 79°C.

Generally, MFI is positively correlated with sensory and Warner-Bratzler measures of tenderness (Kim and Lee, 2003). MFI increases with longer postmortem aging times (Olson *et al*., 1976b) and is higher for younger maturity animals than for older maturities (Parrish *et al*., 1979). The MFI of boiled pork loin cooked with various cooking conditions is shown in Table 2. The pork loin (T2) cooked with the shortest cooking time in hot water showed higher MFI than those cooked in other conditions (p<0.05). However, there was no significant difference in MFI between T1 and T3 treatments (p>0.05). Tenderness of meat is in close connection with the MFI of sarcomere (Moller *et al*., 1973), and especially, the sample was considered very soft when the value of MFI was 60, and the sample with MFI below 50 was tough (Culler *et al*., 1978). In the present study, T2 treatment with lower shear force showed higher MFI than other treatments (p<0.05).

Thiamine contents

Meat is a food source of vitamin B group like thiamine and riboflavin. Because thiamine is unstable at high temperature, cooking causes a much loss of thiamine (Leonhardt and Wenk, 1997). The thiamine content of boiled pork loin cooked with various cooking conditions is shown in Table 2. T1 and T2 treatments with low internal temperature (75°C) did not show significant differences in thiamine contents, but T3 treatment cooked in 100°C water and heated at 98°C for 25 min had lower thiamine contents than T2 treatment (p<0.05). In this result, the thiamine content of all the treatments ranged from 0.3 to 0.5 mg/100 g. Pearson and Dutson (1988) reported that pork had a thiamine content of 0.904 mg/100 g in lean tissue and 0.693 mg/100 g for roasted. Also, the thiamine content of raw pork loin changed from 0.60 mg/100 g to 0.15 mg/100 g when heated in a 180°C oven for 30 min (Boccia *et al*., 2005). The thiamine content of 0.86 mg/100 g in pork loin was reduced to 40% by braising, 65% by broiling and 56% by roasting according to heating method (Moss *et al*., 1983). It is impossible to identify nutrient composition for all the prepared foods, but analytical and calculated data are fundamentally important to customers according to cooking method like boiling, steaming, braising, stewing, frying, roasting in oven and deep frying (Bognár and Piekarski, 2000).

Sensory properties

The results about the sensory characteristics of *soo-yuk* according to cooking condition were shown in Table 3. Color, tenderness, and juiciness were not significantly different among the treatments. However, T3 treatment cooked by the Korean traditional method obtained the highest score in flavor and overall acceptability. These results agreed with the report of Tajima *et al*. (2001) that flavor of beef heated for 3 h at 95°C was improved. Deethardt and Tuma (1971) reported that cooked pork loin using several different heating methods did not show significant differences in texture and flavor. Marsh *et al*. (1966) reported that tenderness decreased as shear force increased. However in the present study, tenderness was not significantly different among the treatments (p>0.05). Also, Montgomery *et al.* (1977) reported that the panel score for juiciness, tenderness and overall acceptability did not show any difference when pork loin was heated in a microwave and a conventional oven at 63°C of internal temperature.

In conclusion, boiled pork loin (*soo-yuk*) cooked at

Table 3. Comparison on sensory characteristics of boiled pork loins (*Soo-Yuk*) cooked with different cooking conditions

Traits	Cooking condition[1)]		
	T1	T2	T3
Color	7.33±0.82	7.33±0.92	7.50±1.40
Flavor[3)]	7.02±1.03^{b}	7.40±0.89^{b}	8.21±1.07^{a}
Tenderness	7.25±1.11	7.61±0.96	7.65±1.30
Juiciness	7.46±1.14	7.46±0.88	7.61±1.42
Overall acceptability	7.07±1.11^{c}	7.59±1.09^{b}	8.07±0.86^{a}

[1)]Cooking conditions are presented in Fig. 1.
[2)]All values are mean ± SD.
[3)]Sensory scores were assessed on 10 point scale where 1 = extremely bad or slight, 10 = extremely good or much.
[a-c]Means values with different superscripts within a same row are significantly different (p<0.05).

90°C hot water (T2) had excellent physicochemical properties such as cooking yields, moisture contents, and shear force. On the other hand, *soo-yuk* cooked at 98°C (T3) had better sensory properties such as flavor and overall acceptability. Because the quality characteristics of boiled pork loin change according to cooking conditions, more studies, therefore, are needed for establishing the cooking conditions of *soo-yuk*.

References

1. Abugroun, H. A., Forrest, J. C., Aberle, E. D., and Judge, M. D. (1985) Shortening and tenderness of prerigor heated beef. I. Effect of heating rate on muscle of youthful and mature carcasses. *Meat Sci*. **14**, 1-13.
2. AOAC. (2000) Official Methods of Analysis. 17th ed, Association of Official Analytical Chemists, Washington, DC, chapter 39. pp. 1-8.
3. Barbanti, D. and Pasquini, M. (2005) Influence of cooking conditions on cooking loss and tenderness of raw and marinated chicken breast meat. *J. Food Sci. Technol*. **38**, 895-901.
4. Belew, J. B., Brooks, J. C., Mckenna, D. R., and Savell, J. W. (2003) Warner-Bratzer shear evaluations of 40 bovine muscles. *Meat Sci*. **64**, 507-512.
5. Bengtsson, N. E., Jakobsson, B., and Dagerskog, M. (1976) Cooking of beef oven roasting a study of heat and mass transfer. *J. Food Sci*. **41**, 1047-1053.
6. Boccia, G. L., Lanzi, S., and Aguzzi, A. (2005) Aspects of meat quality: trace elements and B vitamins in raw and cooked meats. *J. Food Compos. Anal*. **18**, 39-46.
7. Bognár, A. and Piekarski, J. (2000) Guidelines for recipe information and calculation of nutrient composition of prepared foods (dishes). *J. Food Compos. Anal*. **13**, 391-410.
8. Bouton, P. E., Harris, P. V., and Shorthose, W. R. (1975) Change in shear parameters of meat associated with structural change produced by aging, cooking and myofibrillar contraction. *J. Food Sci*. **40**, 1122-1126.
9. Bower, J. A., Craig, J. A., Kropf, D. H., and Tucker, T. J. (1987) Flavor, color, and other characteristics of beef *Longissimus* muscle heated to seven internal temperatures between 55°C and 85°C. *J. Food Sci.* **55**, 533-536.
10. Buck, E. M., Hickey, A. M., and Rosenau, J. (1979) Low-temperature air oven VS a water bath for the preparation of rare beef. *J. Food Sci*. **44**, 1602-1605.
11. Choi, Y. S., Jeong, J. Y., Choi, J. H., Lee, M. A., Lee, E. S., Kim, H. Y., Han, D. J., Kim, J. M., and Kim, C. J. (2006) Effects of immersion period after tumbling processing on the quality properties of boiled pork loin with soy sauce. *Korean J. Food Cookery Sci*. **22**, 379-385.
12. Choi, J. H., Jeong, J. Y., Choi, Y. S., Lee, E. S., and Kim, C. J. (2008) The relationship between fat level and quality properties of ground pork patties cooked by microwave energy. *Korean J. Food Sci. Ani. Resour.* **28**, 295-300.
13. Culler, R. D., Parrish, Jr. F. C., Smith, G. C., and Cross, H. R. (1978) Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine. *J. Food Sci*. **43**, 1177-1180.
14. Deethardt, D. and Tuma, H. J. (1971) Effect of cooking methods on various qualities of pork loin. *J. Food Sci.* **36**, 626-628.
15. Dube, G., Bramblett, V. D., Judge, M. D., and Harrington, R. B. (1972) Physical properties and sulfhydryl content of bovine muscles. *J. Food Sci*. **37**, 23-26.
16. Forrest, J. C., Aberle, E. D., Hedrick, H. B., Judge, M. D., and Merkel, R. A. (1975) Principle of meat science. W.H Freeman and company, San Francisco, pp. 298-305.
17. Godsalve, E. W. (1977) Effect of oven conditions and sample treatment on water loss of dry cooked bovine muscle. *J. Food Sci.* **42**, 1325-1330.
18. Herring, H. K., Cassens, R. G., and Briskey, E. J. (1965) Further studies on bovine muscle tenderness as influenced by carcass position, sarcomere length, and fiber diameter. *J. Food Sci*. **30**, 1049-1054.
19. Jung, I. C., Moon, Y. H., and Kang, S. J. (2004) Effect of addition of mugwort powder on the physico-chemical and sensory characteristics of boiled pork. *Korean J. Food Sci. Ani. Resour.* **24**, 15-22.
20. Kim, C. J. and Lee, E. S. (2003) Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. *Meat Sci*. **63**, 397-405.
21. Laakkonen, E., Whllington, G. H., Sherbon, J. W. (1970) Low-temperature, long-time heating of bovine muscle. I. Changes in tenderness, water-binding capacity, pH and amount of water-soluble components. *J. Food Sci.* **35**, 175-177.
22. Lawrie, R. A. (1988) Lawrie's meat science. 6th ed, Woodhead Publishing LTD., Cambridge, pp. 226-228.
23. Leonhardt, M. and Wenk, C. (1997) Animal species and muscle related differences in thiamine and riboflavin contents of Swiss meat. *Food Chem*. **59**, 449-452.
24. Lewis, G. J. and Purslow, P. P. (1989) The strength and stiffness of perimysial connective tissue isolated from cooked beef muscle. *Meat Sci.* **26**, 255-269.
25. Machlik, S. M. and Draudt, H. N. (1963) The effect of heating time and temperature on the shear of beef *semitendimosus* muscle. *J. Food Sci*. **28**, 711-718.
26. Marsh, B. B., Woodhams, P. R., and Leet, N. G. (1966) Studies in meat tenderness. I. Sensory and objective assessments of tenderness. *J. Food Sci.* **31**, 262-267.
27. Moller, A. J., Vestergaard, T., and Perdersen, W. (1973) Myofibril fragmentation in bovine *longissimus dorsi* as an index of tenderness. *J. Food Sci*. **38**, 824-825.
28. Montgomery, T. M., Ramsey, C. B., and Lee, R. W. (1977) Microwave and conventional precooking of hot and cold processed pork loins. *J. Food Sci*. **42**, 310-315.
29. Moon, Y. H., Kim, Y. K., Koh, C. W., Hyon, J. S., and Jung, I. C. (2001) Effect of aging period, cooking time and temperature on the textural and sensory characteristics of boiled pork loin. *J. Korean Soc. Food Sci. Nutr.* **30**, 471-476.
30. Moss, M., Holden, J. M., Ono, K., Cross, R., Slover, H.,

Berry, B., Lanza, E., Thompson, R., Wolf, W., Vanderslice, J., Johnson, H., and Stewart, K. (1983) Nutrient composition of fresh retail pork. *J. Food Sci.* **48**, 1767-1771.
31. Obuz, E., Dikeman, M. E., Erickson, L. E., Hunt, M. C., and Herald, T. J. (2003) Predicting temperature profiles to determine degree of doneness for beef *biceps femoris* and *longissimus lumborum* steak. *Meat Sci.* **67**, 101-105.
32. Oh, H. S. and Myoung, C. O. (1994) Application of microwave heating to the convenient preparation of moist-heated meats. *J. Korean Soc. Food Sci*. **10**, 357-362.
33. Olson, D. G., Parrish, F. C. Jr., and Stromer, M. H. (1976a) Relationship of myofibril fragmentation index to measures of beef steak tenderness. *J. Food Sci.* **42**, 506-509.
34. Olson, D. G., Parrish, F. C. Jr., and Stromer, M. H. (1976b). Myofibril fragmentation and shear resistance of three bovine muscles during postmortem storage. *J. Food Sci*. **41**, 1036-1041.
35. Pan, Z. and Singh, P. (2001) Physical and thermal properties of ground beef during cooking. *Lebensm-Wiss. U. Technol.* **34**, 437-444.
36. Park, S. W. and Kwon, S. K. (1998) Sensory characteristics and tenderness of boiled beef by addition of the barks (*Morus alba* Linne). *J. Korean Soc. Food Sci. Nutr.* **11**, 580-584.
37. Parrish, F. C. Jr., Vandell, C. J., and Culler, R. D. (1979) Effect of maturity and marbling on the myofibril fragmentation index of bovine *longissimus* muscle. *J. Food Sci.* **44**, 1668-1671.
38. Pearson, A. M. and Dutson, T. R. (1988) Edible meat byproducts. Advances in meat research. Elsevier Science Publishers LTD, NY, Vol. 5, pp.15-45.
39. Pietrasik, Z. and Shand, P. J. (2003) The effect of quantity and timing of brine addition on water binding and textural characteristics of cooked beef rolls. *Meat Sci.* **65**, 771-778.
40. SAS. (1996) SAS/STAT Software for PC. Release 6.11, SAS Institute Inc., Cary, NC, USA.
41. Tajima, M., Ito, T., Arakawa, N., and Parrish, Jr. F. C. (2001) Heat-induced changes of myosin and sarcoplasmic proteins in beef during simmering. *Food Chem. Toxicol.* **66**, 233-237.
42. Voyle, C. A. (1971) Sarcomere length and meat quality. Proceedings 17th European meeting of meat research workers, Bristol, England, pp. 95-97.

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