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ARTICLE

Effects of Doneness on the Microbial, Nutritional, and Quality Properties of Pork Steak of Different Thicknesses

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Abstract This study aimed to evaluate the effect of doneness on the microbial, nutritional, and quality characteristics of 1.5 cm- and 2.0 cm-thick pork neck steaks. Pork neck meat was obtained within 24 h after slaughtering, cut into 1.5 cm- and 2.0 cm-thick slices (n=5), packed in LLD-PE wrap, and stored at 4±2°C for 7–10 days until aerobic plate counts (APC) reach 5.51–6.50 Log CFU/g. Then, the pork meat was cooked on a frying pan till it was medium-rare, medium, or well-done. The microbial inhibition rates of the 1.5 cm- and 2.0 cm-thick steak in medium-rare state were 58.26% and 51.70%, respectively, whereas it was 100% for medium-done pork steak of either thickness. The total calories of the 1.5 cm- and 2.0 cm-thick well-done pork steaks were 643.61 kcal/100 g and 675.00 kcal/100 g, respectively, which was higher than that in medium-rare and medium-done steaks. The retention ratios for Fe and K in the well-done steak were significantly lower than those in the medium and medium-rare steak of either thickness ($p<0.05$). The shear force of the medium-rare and medium steak did not differ, whereas that of the well-done steak was significantly higher than that of the medium-rare steak of either thickness ($p<0.05$). We observed that the well-done pork steak had tough texture, low mineral content, and high calories. Therefore, consumption of medium and medium-rare pork is more beneficial than that of well-done pork.

Keywords pork steak, doneness, calorie, minerals, microbial property

Introduction

Pork is one of the most widely consumed types of meat, and the OECD predicted that global pork meat consumption in 2025 will be 12.54 kg carcass weight equivalent/capita/year (OECD/FAO, 2016). Pork is nutritious and contains high-quality protein and various bioactive compounds. Regular supplementation of small amount of pork improves body growth, physical activity, cognitive function, and immunity (Iannotti et al., 2017; Kim et al., 2017; Neumann et al., 2003).

Currently, concerns regarding the safety of fresh meat and meat products are increasing. Food safety, but not food tenderness or freshness, is the most important aspect guiding consumers' decision of purchasing meat (Loureiro and Umberger, 2007). Pork is vulnerable to microbial contamination and is easily perishable as it is a nutrient-dense medium ideal for colonization by various pathogens and spoilage microbes (Kim and Jang, 2018). Furthermore, pork can be contaminated at many steps during processing such as bleeding, evisceration, skinning, and washing. Improper storage and distribution during meat processing may result in contamination with spoilage microorganisms and foodborne pathogens, which constitute the highest meat safety risks (Domenech et al., 2015). Previously, trichinosis was a health hazard associated with consumption of undercooked pork, which prompted overcooking of pork to avoid the risk. However, incidences of trichinosis have not been reported in commercial pork since 2010 owing to evolution of strict hygiene systems. Scientists have attempted to ensure pork meat safety by applying the HACCP system and enforcing nationwide biosecurity measures. Ministry of Food and Drug Safety (MFDS) in Korea reported that the hygiene of pork meat distributed in Korea was managed well during the monitoring period, as the percentage of pork samples exceeding the aerobic plate count (APC) guidelines was less than 1% between 2010 and 2014 (Kim and Jang, 2018).

Most consumers prefer to eat pork meat well-done or even overcooked to the point of appearing burnt, rather than medium-rare or medium with slight pink color in the inside. This is because of reports of pork contamination by the parasitic worm *Trichinella* and food poisoning-related pathogens in the last few decades. Several decades ago, the Korean government had promoted the consumption of well-done pork to eliminate cases of infection by *Trichinella* and similar pathogens. However, the incidence of *Trichinella* contamination in pork is no longer reported and it has been eradicated in Korea (Jang et al., 2018). In addition, most pork meat in Korea is produced under strict hygiene conditions according to the HACCP system. Therefore, pork meat does not have to be cooked till it is well-done or overcooked to avoid the risk of *Trichinella* infection. The United States Department of Agriculture (USDA) listed guidelines and recommendations for safe pork cooking in 2011, which suggests 62.7℃ as the safe temperature for cooking pork cuts; however, ground pork should be cooked at 71℃ for safety. Owing to persisting concerns regarding pork safety, pork meat is still overcooked to avoid microbial poisoning. This results in the consumption of dry, burned, and unsafe pork steak, as exposure of pork meat to high temperature and long cooking time induces the formation of several carcinogens such as polycyclic aromatic hydrocarbon and heterocyclic amines. Pork meat thickness is also an important factor determining the doneness as most Korean people eat 1.5 cm-thick pork rather than 2.0 cm-thick pieces, while most western people consume 2.0–2.5 cm-thick pork as steaks. However, there is a lack of information to show microbial safety and quality characteristics of pork meat of various doneness of different thickness in Korea.

Therefore, the present study aimed to evaluate the effect of doneness on the microbial and nutritional property, and quality changes of pork steak of different thicknesses (1.5 cm and 2.0 cm, as these are the common thicknesses of pork steak consumed in Korea) for elucidating the safety and wholesomeness of pork steak of different doneness.

Materials and Methods

Pork neck meat cooking conditions and doneness

A loaf of pork neck meat was obtained from the local meat packing center within 24 h after slaughtering and was cut into 1.5 cm and 2.0 cm thicknesses and packed in LLD-PE wrap. The wrapped pork meats were stored at 4±2℃ for 7–10 d until APCs reached 5.51–6.50 Log CFU/g, after which it was cooked on a frying pan with surface temperature of 200℃ for different doneness under the conditions mentioned in Table 1. Also inside meat color of pork steaks with doneness was shown in Fig. 1.

Table 1. Cooking temperature and times with different doneness

Thickness	Doneness	Internal temperature (°C)	Cooking time (front/back)
1.5 cm	Medium-rare	62.8	5 min / 3 min
	Medium	71.1	7 min / 6 min
	Well-done	76.7	14 min / 13 min
2.0 cm	Medium-rare	62.8	5 min / 4 min
	Medium	71.1	8 min / 7 min
	Well-done	76.7	15 min / 14 min

* Medium rare was done cooking pork neck meat at 62.8℃ for 5 min in front and for 4 min, respectively, followed by 3 min rest.

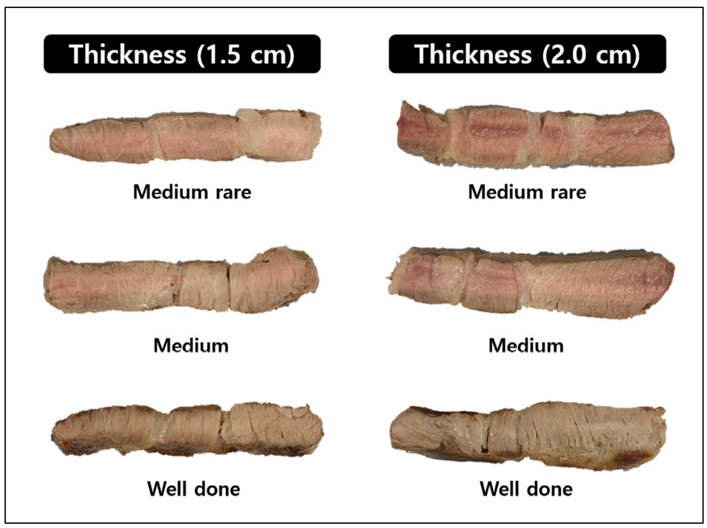

Fig. 1. Effect of doneness on the inside color of pork neck steak with different thicknesses.

Microorganisms

For APCs and *Escherichia coli*/coliform counts, 10 g pork neck was added to a sterile stomacher bag filled with 90 mL sterile water. The contents were homogenized for 2 min using a stomacher (Bag Mixer 400, Interscience, St. Nom, France). A serial dilution was prepared with sterile water, and 1 mL of the diluent was seeded onto Petrifilms for APC and *E. coli*/coliform count plate (3M Microbiology, St. Paul, MN, USA). The films were incubated at 37°C for 48 h and APCs and *E. coli* counts were determined according to the manufacturer's instructions.

Proximate composition and total calorie

The proximate compositions of pork neck were evaluated according to the methods of Association of Official Agricultural Chemists (AOAC, 1997). Moisture content was analyzed using oven drying at 105℃, and crude protein content was analyzed using the Kjeldahl method. Crude fat content was determined using solvent extraction, and crude ash was analyzed via ashing using a furnace at 550℃. The total calories of pork steak were determined by multiplying the protein and fat contents per gram of pork by 4 kcal/g and 9 kcal/g, respectively (Rhee et al., 1993).

Minerals

To analyze the mineral contents (K, Fe, and Zn) of pork of different doneness, 2 g minced pork neck meat was placed in the furnace at 550°C–600°C for 12 h. After cooling, the sample was digested with 10 mL of 50% HCl solution overnight and filtered using a filter paper (Whatman No.6). The solution was analyzed using an inductively coupled plasma emission spectrophotometer (OPTIMA 7300 DV, PerkinElmer, Shelton, CT, USA).

True retention of minerals

The changes in the weight of meat before and after cooking were recorded to compensate for the weight of drippings, cooking water, or other discard. The true retentions (TR) of minerals with cooking were determined using the method of Murphy et al. (1975) as mentioned below.

$$\text{TR (\%)} = (\text{Nc} \times \text{Gc}) / (\text{Nr} \times \text{Gr}) \times 100$$

Nc: Nutrient content per gram of cooked meat (g)

Gc: Weight of cooked meat (g)

Nr: Nutrients content per gram of raw meat

Gr: Weight of raw meat (g)

Cooking loss

Pork neck steak of 1.5 cm and 2.0 cm thicknesses were placed in a polyethylene bag. The packages were heated in a water bath at constant temperature until the core temperature reached 75℃, after which it was cooled for 20 min to 23℃. The cooking loss percentage was determined using steak weights taken before and after cooking.

$$\text{Cooking loss (\%)} = [\text{Initial raw meat weight (g)} - \text{Final cooked meat weight (g)}] / \text{Initial raw meat weight (g)} \times 100$$

Meat color

The color of the pork neck on the surface and inside was determined using a Minolta colorimeter (CR-400 Minolta Co., Osaka, Japan), and the Commission Internationale de l'Eclairage (CIE) color values of L* (lightness), a* (redness), and b* (yellowness) were determined in triplicate. The instrument was calibrated using a white standard plate before analysis with Y=93.60, x=0.3134, and y=0.3194.

Warner-Bratzler shear force

The core temperature of pork neck steak reached 62.8℃, 71.1℃, and 76.7℃ according to the doneness for medium-rare, medium, and well-done pork, respectively. The pork steaks were cut into 1×2×1.5 cm or 1×2×2 cm pieces and used for measurement of shear force using a texture analyzer (TA 1; Lloyd Instruments, Berwyn, PA, USA). The texture analyzer was set to a 50 kg load cell, 50 mm/min trigger speed, 50 mm/min test speed, and 10 gf trigger force.

Texture analysis

Pork neck meat was cut into 1×1×1.5 cm or 1×1×2 cm pieces and texture profile analysis was performed thrice using Texture Analyzer TA 1 (LLOYD instruments, Berwyn, PA, USA). The test conditions were as follows: compression speed, 20 mm/min; wait time, 5 s; trigger force, 10 gf; 50 mm, diameter probe; sample compressed, 70%.

Statistical analysis

All analyses were performed at least thrice. One way analysis of variance (ANOVA) was performed using the general linear model procedure of the SAS software (SAS Institute Inc., Cary, NC, USA), followed by Tukey's test to analyze significant differences among mean values at $p<0.05$. Data were expressed as means and SEM.

Results and Discussion

Microbial change

Changes in APC and coliform content of pork steak of different doneness are shown in Table 2. The APC decreased significantly from medium-rare and medium to well-done steak, showing 4.58 CFU/g APC, 2.36 CFU/g APC, and not detected, respectively, all of which were lower than the APC of 1.5 cm-thick raw pork. The microbial inhibition rates of medium-rare steak of 1.5 cm and 2.0 cm thickness were 58.26% and 51.70%, respectively. Interestingly, the inhibition rate of medium pork steak of either thickness was 100%, which was significantly higher than that of the medium-rare steak ($p<0.05$). The inhibition rates of medium and well-done steaks did not differ significantly irrespective of the thickness. *E. coli* was not detected in raw or cooked pork steak (data not shown). After cooking, the coliforms were not detected in steak irrespective of thickness. According to the MFDS in Korea, the APC level of pork meat should be below the 5.0×10^6 CFU/g (6.70 Log CFU/g). This indicated that medium and well-done pork steak of 1.5 and 2.0 cm thickness met the APC standards. Several groups have investigated the relationship between cooking and microbial safety of meat. Shao et al. (1999) showed that compared to 3.14 Log CFU/g APC in original raw meat, the APC in 2.0 cm-thick raw emu steaks was reduced to 1.55, 1.79, and 3.14 Log CFU/g by cooking when the internal temperature reached 60℃, 66℃, and 75℃, respectively. McKinley and Avens (1981) observed that 3.4 Log CFU/g APC in raw ground turkey was reduced to 2.18 Log CFU/g after cooking for 7 min in an electric frying pan, when the internal temperature reached 71℃–77℃, and microorganisms were not detected in 46% of the samples. When mutton chops cooked at different end point temperature (51℃–79℃), APC levels of them was

Table 2. Effect of doneness on the microbes in pork steak with different initial microbial numbers

Microbes (Log CFU/g)	Doneness	Pork steak thickness (cm)		SEM
		1.5	2.0	
Aerobic plate count	Raw	5.51^a	6.50^a	0.127
	Medium-rare	2.30^b	3.14^b	0.027
	Medium	ND^c	ND^c	0.000
	Well-done	ND^c	ND^c	0.000
	SEM	0.020	0.089	0.000
Coliforms	Raw	1.00^a	0.77^a	0.028
	Medium rare	ND^b	ND^b	0.000
	Medium	ND^b	ND^b	0.000
	Well done	ND^b	ND^b	0.000
	SEM	0.000	0.196	0.000

$^{a–c}$ Means within a doneness with different superscript differ significantly at $p<0.05$.
ND, not detected.

decreased from 3.73 Log CFU/g up to 1.75 Log CFU/g (Sen et al., 2014).

Nutritional property

The proximate composition and total calories of pork steak of different doneness, from raw to well-done, are shown in Table 3. The water content of raw pork steak was significantly higher than those of medium and well-done pork steak of either thickness ($p<0.05$). Compared to that of raw pork, the water content of medium and well-done pork steak was reduced to 22.04% and 28.50%, respectively. In contrast, the crude protein, crude fat, and crude ash contents of well-done pork steak were significantly higher than those of raw pork of either thickness ($p<0.05$). Crude protein, crude fat, and crude ash were condensed due to reduction in the water content with pork doneness. The total calories of 1.5 cm and 2.0 cm-thick raw pork

Table 3. Proximate composition and total calories of pork steak with doneness

Traits	Doneness	Pork steak thickness (cm)		SEM
		1.5	2.0	
Moisture (%)	Raw	72.86^{Aa}	72.38^{Aa}	0.399
	Medium-rare	62.54^{Ab}	62.17^{Ab}	0.179
	Medium	59.53^{Ac}	56.43^{Bc}	0.209
	Well-done	53.78^{Ad}	51.75^{Bd}	0.254
	SEM	0.343	0.179	
Crude protein (%)	Raw	18.80^{Ac}	19.86^{Ac}	0.378
	Medium-rare	20.41^{Ac}	20.18^{Abc}	0.506
	Medium	23.20^{Ab}	21.52^{Bb}	0.113
	Well-done	27.37^{Aa}	27.26^{Aa}	0.434
	SEM	0.439	0.328	
Crude fat (%)	Raw	6.57^{Ac}	7.92^{Ac}	0.382
	Medium-rare	15.79^{Bb}	18.09^{Ab}	0.186
	Medium	15.64^{Bb}	21.42^{Aa}	0.215
	Well-done	17.04^{Ba}	20.75^{Aa}	0.362
	SEM	0.243	0.346	
Crude ash (%)	Raw	1.02^{Bb}	1.17^{Ab}	0.024
	Medium-rare	1.02^{Ab}	1.10^{Ab}	0.024
	Medium	1.05^{Ab}	1.07^{Ab}	0.046
	Well-done	1.35^{Aa}	1.36^{Aa}	0.020
	SEM	0.034	0.026	
Total calorie (kcal/100 g)	Raw	139.50^{Bc}	162.82^{Ad}	3.867
	Medium-rare	229.54^{Bb}	249.39^{Ac}	1.490
	Medium	240.14^{Bb}	285.12^{Ab}	1.810
	Well-done	643.61^{Ba}	675.00^{Aa}	7.060
	SEM	4.844	3.418	

^{A,B} Means within a pork steak thickness with different superscript differ significantly at $p<0.05$.
$^{a–d}$ Means within a doneness with different superscript differ significantly at $p<0.05$.

steak were 139.50 and 162.82 kcal/100 g, respectively. However, the total calories of well-done pork steak of 1.5 cm and 2.0 cm thickness were 643.61 kcal/100 g and 675.00 kcal/100 g, respectively, which were significantly higher than those of medium-rare and medium pork steak. This increase was also due to elevation in the content of crude protein and crude fat, and decrease in water content with doneness. Similar to our results, as the increase in endpoint temperature of beef steaks, percent of fat and protein increased and the calories consequently increase (Smith et al., 2011). Rhee et al. (1993) reported that the total energy of cooked ground pork meat containing 10%–20% fat was higher (210–270 kcal/100 g) than that of raw ground pork meat (150–190 kcal/100 g). This indicated that higher calories were obtained from consumption of well-done pork steak than from raw, medium-rare, and medium pork steak.

The mineral content and mineral retention ratio of pork steak changed with doneness as shown in Table 4. Pork is an abundant source of minerals, which can change during cooking. Cooking is essential to make meat palatable and safe. However, heat treatment can decrease the nutritional value, mainly due to loss of minerals and vitamins (Gerber et al. 2009). Potassium (K) and zinc (Zn) are major two minerals in pork meat. Also, iron (Fe) plays essential minerals to human because when its deficiency causes several hindrances, particularly disturbs normal development of child (Williams, 2007). K helps the human body to maintain the acid-base balance, metabolism, and muscle building, and Zn required for the immune system, helping in cell growth and wound healing, as part of many enzymes (Williams, 2007). The Fe, Zn, and K contents of medium-done pork steak of 1.5 cm and 2.0 cm thickness were significantly higher than those of raw and medium-rare pork. In addition, the mineral content of well-done pork steak was significantly higher than that of 1.5-cm thick steak of other doneness. Interestingly, the Fe and K contents of medium-done pork steak were higher than those of well-done 2.0-cm thick steak ($p<0.05$), while the Zn of medium-done and well-done steak did not differ significantly. This indicated that the Fe and K

Table 4. Mineral content of pork steaks of different doneness

Minerals (mg/100 g)	Doneness	Pork steak thickness (cm)		SEM
		1.5	2.0	
Fe	Raw	0.99^{Ac}	0.83^{Bd}	0.005
	Medium-rare	0.96^{Ac}	0.88^{Bc}	0.003
	Medium	1.07^{Ab}	1.04^{Ba}	0.005
	Well-done	1.46^{Aa}	1.00^{Bb}	0.007
	SEM	0.006	0.004	
Zn	Raw	2.94^{Ad}	2.89^{Ab}	0.015
	Medium-rare	3.06^{Ac}	2.85^{Bb}	0.003
	Medium	3.52^{Ab}	3.11^{Ba}	0.051
	Well-done	4.79^{Aa}	3.11^{Ba}	0.019
	SEM	0.019	0.035	
K	Raw	291.38^{Bb}	306.20^{Ac}	0.748
	Medium-rare	287.84^{Bb}	307.90^{Ac}	1.295
	Medium	279.18^{Bc}	343.11^{Aa}	2.350
	Well-done	351.44^{Aa}	328.23^{Bb}	0.593
	SEM	1.455	1.391	

^{A,B} Means within a pork steak thickness with different superscript differ significantly at $p<0.05$.
$^{a–d}$ Means within a doneness with different superscript differ significantly at $p<0.05$.

contents of 2.0-cm thick pork steak increased with doneness from raw to medium, whereas they were low in well-done steak. The increase in mineral content with doneness were in agreement with the results reported by Tomvic et al. (2015) who showed that cooking pork loin (1.5-cm thick) at endpoint temperatures of 51℃, 61℃, 71℃, 81℃, and 91℃ significantly increased mineral content (magnesium, calcium, zinc, iron, copper, and manganese) compared to that of raw meat. This increase in mineral content of meat can be explained as a consequence of moisture loss due to cooking (Lawrie and Ledward, 2006), as we observed that the nutrient contents in cooked pork did not increase but rather decreased after calculating the retention ratio of nutrients. The mineral retention ratio in pork steak was also affected by doneness as shown in Fig. 2. When the mineral content of raw pork steak was 100%, the retention ratio for Fe and K in well-done steak was significantly lower than those of medium and medium-rare steak of either thickness ($p<0.05$). The Zn content of 2.0-cm thick well-done pork steak was also lower than that of raw and medium-rare pork steak. This indicated that the mineral content of meat decreased and the total calories increased upon overcooking.

Meat quality

The colors of both the surface and inside of pork steak of different doneness are shown in Table 5. In the meat surface and inside, the CIE L* and CIE b* values of medium-done steak were higher than those of medium-rare pork of 1.5 cm thickness ($p<0.05$). However, the CIE L* values of medium and medium-rare steaks of 2.0 cm thickness were not significantly different. The CIE a* values of steak decreased significantly with doneness for both thicknesses and ranged from 6.91 to 8.36 for surface color, and from 7.66 to 13.93 for internal color. Most consumers consider the color of cooked meat as a reliable indicator of safety and doneness (Suman and Joseph, 2013). A brown pigment of denatured metmyoglobin is formed when pork meat is cooked, resulting in higher b* value. Meat cooked at different end point temperatures show reddish color as all

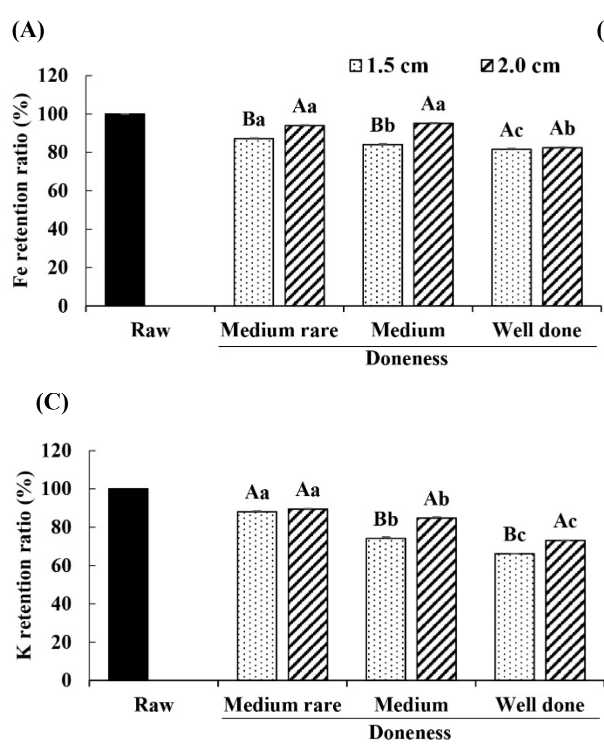

Fig. 2. Mineral retention ratio of pork steaks of different doneness. ^{A,B} Means within a pork steak thickness with different superscript differ significantly at $p<0.05$. $^{a–c}$ Means within a doneness with different superscript differ significantly at $p<0.05$.

Table 5. Surface and internal color of pork steaks of different doneness

Traits		Doneness	Pork steak thickness (cm)		SEM
			1.5	2.0	
CIE L*	Surface	Raw	49.15^{Ac}	49.72^{Ab}	0.240
		Medium-rare	55.55^{Ab}	56.04^{Aa}	0.350
		Medium	57.29^{Aa}	57.74^{Aa}	0.410
		Well-done	49.94^{Ac}	50.83^{Ab}	0.543
		SEM	0.313	0.473	
	Inside	Raw	47.77^{Ad}	47.62^{Ad}	0.176
		Medium-rare	61.81^{Ab}	60.82^{Ab}	0.503
		Medium	66.42^{Aa}	66.25^{Aa}	0.172
		Well-done	57.39^{Ac}	57.60^{Ac}	0.307
		SEM	0.394	0.220	
CIE a*	Surface	Raw	13.63^{Aa}	13.52^{Aa}	0.142
		Medium-rare	8.36^{Ab}	8.24^{Ab}	0.085
		Medium	8.29^{Ab}	8.15^{Ac}	0.167
		Well-done	6.91^{Bc}	7.39^{Ad}	0.083
		SEM	0.064	0.164	
	Inside	Raw	14.93^{Aa}	14.54^{Aa}	0.124
		Medium-rare	12.34^{Bb}	13.93^{Ab}	0.307
		Medium	10.96^{Bc}	13.10^{Ac}	0.233
		Well-done	7.66^{Ad}	7.84^{Ad}	0.119
		SEM	0.271	0.125	
CIE b*	Surface	Raw	7.64^{Ad}	7.18^{Ad}	0.163
		Medium-rare	11.44^{Ac}	11.49^{Ac}	0.133
		Medium	12.52^{Ab}	12.38^{Ab}	0.094
		Well-done	15.07^{Ba}	15.45^{Aa}	0.045
		SEM	0.120	0.114	
	Inside	Raw	4.58^{Bd}	4.84^{Ad}	0.066
		Medium-rare	10.40^{Ac}	10.38^{Ac}	0.229
		Medium	11.54^{Ab}	11.66^{Ab}	0.039
		Well-done	12.57^{Aa}	12.75^{Aa}	0.062
		SEM	0.128	0.121	

^{A,B} Means within a pork steak thickness with different superscript differ significantly at $p<0.05$.
$^{a–d}$ Means within a doneness with different superscript differ significantly at $p<0.05$.

the pigment is not affected at the same time or to the same extent (Boles and Pegg, 2010). In this study, we observed that the b* value of both surface and internal pork steak increased significantly with doneness irrespective of thickness ($p<0.05$). In medium-done pork steak, the b* value ranged from 12.38 to 12.52 in the surface and from 11.54 to 11.66 in the inside.

Cooking loss, Warner-Bratzler shear force (WBSF), and texture analysis such as springiness and chewiness of pork steak can change with doneness (Table 6). Cooking loss is highly related to juiciness of meat and depends on cooking time and temperature (Winger and Fennema, 1976). Cooking loss of the well-done steak was significantly higher than that of medium-rare and medium-done steaks of either thickness ($p<0.05$), which corresponded to the water content loss of the steak (Table 1). Cooking time and temperature can strongly affect the tenderness of pork meat (Bouton and Harris, 1972). The WBSF of medium-rare and medium-done steak did not vary, while that of the well-done steak was significantly higher than that of medium-rare steak of either thickness ($p<0.05$). The springiness of steaks of different doneness did not vary significantly when the thickness was 1.5 cm. However, the springiness of well-done steak was lower than that of medium-rare and medium-done steaks of 2.0-cm thickness ($p<0.05$). The chewiness of the well-done and medium-done steaks was significantly higher than that of medium-rare steak of either thickness ($p<0.05$). This indicates that well-done cooking makes meat dry, tough, and unpalatable. This observation is in agreement with the sensory evaluation by 85 panelists (data not shown). The panelists opined that the juiciness and tenderness of well-done pork steak was significantly lower than that of medium-rare and medium-done steaks ($p<0.05$). In agreement with these results, medium-rare or medium-done steaks were found to be preferred by consumers (Lorenzen et al., 1999); in addition, these steaks were more tender and showed low cooking loss than well-done steak (Aaslyng et al., 2003; Chiavaro et al., 2009). This indicated that the panelists found the well-done pork steak dry and tough. Interestingly, however, some of the panelists preferred the tough and chewy well-done pork steak. Therefore, we observed that the well-done pork steak of 1.5 and 2.0-cm thickness was tough and contained high calories and low mineral content.

Table 6. Cooking loss, shear force, springiness, and chewiness of pork steaks of different doneness

Traits	Doneness	Pork steak thickness (cm)		SEM
		1.5	2.0	
Cooking loss (%)	Medium-rare	15.09^{Ac}	13.13^{Ac}	0.589
	Medium	22.60^{Ab}	23.20^{Ab}	1.497
	Well-done	36.04^{Aa}	35.18^{Aa}	1.775
	SEM	1.003	1.679	
Shear force (kgf)	Medium-rare	4.88^{Ab}	5.42^{Ab}	0.184
	Medium	4.86^{Bb}	5.81^{Aab}	0.172
	Well-done	6.05^{Ba}	6.42^{Aa}	0.059
	SEM	0.090	0.192	
Springiness	Medium-rare	0.87^{Aa}	0.89^{Aa}	0.027
	Medium	0.79^{Aa}	0.80^{Ab}	0.019
	Well-done	0.75^{Aa}	0.69^{Ac}	0.016
	SEM	0.028	0.010	
Chewiness (kgf)	Medium-rare	2.66^{Ab}	2.26^{Ab}	0.118
	Medium	4.44^{Aa}	3.29^{Ba}	0.200
	Well-done	5.11^{Aa}	3.75^{Ba}	0.141
	SEM	0.181	0.129	

^{A,B} Means within a pork steak thickness with different superscript differ significantly at $p<0.05$.
$^{a–c}$ Means within a doneness with different superscript differ significantly at $p<0.05$.

Conclusion

Some Korean consumers prefer consuming overcooked pork with Maillard reaction flavors. However, consumption of overcooked pork meat adversely affects health. Therefore, meat consumption habits have to be changed and medium or medium-rare pork should be preferred to well-done or overcooked meat, as the former provides more benefits to consumers without compromising the microbial safety of meat. This is the first study to show microbial safety and nutritional benefits of medium - done pork meat of 1.5 and 2.0 cm thickness compare to those of well-done pork meat in Korea.

Conflicts of Interest

The authors declare no potential conflict of interest.

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Author Contributions

Conceptualization: Kim HJ, Kim D, Jang A. Data curation: Kim HJ, Kim D. Formal analysis: Kim HJ, Kim D. Methodology: Kim HJ, Kim D. Software: Kim HJ, Kim J. Validation: Jang A, Lee SK. Investigation: Kim HJ, Kim D, Jang A. Writing - original draft: Jang A, Kim D. Writing - review & editing: Jang A, Kim HJ, Kim D, Kim J, Lee SK.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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