Korean Journal for Food Science of Animal Resources

Korean J. Food Sci. An. 2018 October 38(5):970~980
DOI https://doi.org/10.5851/kosfa.2018.e29

pISSN : 1225-8563 eISSN : 2234-246X
www.kosfa.or.kr

ARTICLE

Effects of Pre-cooking Methods on Quality Characteristics of Reheated Marinated Pork Loin

Tae-Kyung Kim[1,†], Ko-Eun Hwang[2,†], Young-Boong Kim[1], Ki-Hong Jeon[1], Kyoung-Hoan Leem[3], and Yun-Sang Choi[1,*]

[1]Research Group of Food Processing, Korean Food Research Institute, Wanju 55365, Korea
[2]Department of Animal Sciences, University of Wisconsin-Madison, WI 53706, USA
[3]R&D Center, Ggulmat to World, Hwasung 18516, Korea

OPEN ACCESS

Received June 27, 2018
Revised August 3, 2018
Accepted August 3, 2018

***Corresponding author** : Yun-Sang Choi
Research Group of Food Processing, Korean Food Research Institute, Wanju 55365, Korea
Tel: +82-63-219-9387
Fax: +82-63-219-9076
E-mail: kcys0517@kfri.re.kr

† Thses authors contributed equally to this work.

Abstract We evaluated the effects of pre-cooking methods on the quality of reheated marinated pork loin. Frozen marinated pork loins cooked using various methods (boiling, grilling, pan frying, infrared cooking, and superheated steam cooking) were reheated in a microwave, and their pH, color, cooking loss, re-heating loss, total loss, thiobarbituric acid reactive substance (TBARS) value, sensory properties, and shear force were determined. Although all parameters varied with different cooking methods, lightness values and TBARS values showed the tendency to decrease and increase, respectively, after reheating. Superheated steam-cooked samples showed the lowest values of cooking loss, total loss, TBARS value, and shear force ($p<0.05$) and the highest lightness, redness, and yellowssness values and juiciness, chewiness, and overall acceptability scores ($p<0.05$). These results show that pre-cooking with superheated steam maintains the quality characteristics of marinated pork loin upon reheating. Therefore, pre-cooking with superheated steam may be beneficial for the commercial distribution of frozen cooked marinated pork loin.

Keywords marinated pork loin, superheated steam, cooking methods, reheating, frozen

Introduction

The method of cooking is a significant factor in the cooking process, owing to the quality changes in meat products as a result of thermal denaturation (Choi, 2009). Meat products may be cooked by boiling, grilling, pan frying, microwaving, infrared cooking, and superheated steam cooking. According to Choi et al. (2016), boiling, grilling, pan frying, and microwave cooking methods are generally used to cook meat. The choice of cooking methods depends on the composition and characteristics of the meat cuts and the effects of cooking time and temperature on the meat product (Lee et al., 2005). Infrared cooking has been recently used and has been shown to be more effective than conventional heating (Suwannakam et al., 2014), owing to some advantages such as high thermal efficiency, fast heating rate, shorter response time, and high degree of process control (Krishnamurthy et al., 2008). The high pressure-induced superheated steam displays higher temperature than the boiling point of water (Choi et al., 2013). In comparison with the traditional cooking systems such as boiling, grilling, pan frying, and microwave cooking, superheated steam is a uniform, rapid, and energy-efficient method of cooking (Chun et al., 2013; Suwannakam et al., 2014). Nathakaranakule et al. (2007) reported that the biggest advantage with superheated steam is that it may extensively reduce nutrient loss. Xiao et al. (2014) indicated that superheated steam cooking reduces the oxidation of food, allows energy recovery, decreases energy consumption and emissions, and minimizes fire hazards.

Meat products prepared by microwave reheating are available in various forms in retail markets (Choi, 2009). Microwave cooking is non-uniform and characterized by edge overheating, absence of browning, and reduction in sensory scores (Risman, 1998). However, microwave is mostly used for reheating meals such as home meal replacer (HMR), as it provides advantages in terms of speed and convenience (Yarmand et al., 2013).

Pre-cooked meat products that are refrigerated and frozen before consumption develop an off-flavor called warmed-over flavor (Tims and Watts, 1958). Rapid lipid oxidation is considered as the primary contributor to warmed-over flavor, resulting in the decline in its acceptability (Choi, 2009). Some researchers have reported the effects of reheating methods on the quality characteristics of meat products (Lyon et al., 1988; Steiner et al., 1985). It is necessary to study preheating methods that may suppress warmed-over flavor of meat products. However, very few studies have focused on the definite reheating condition with various pre-cooked methods.

Here, we evaluated and compared the effects of different pre-cooking methods such as boiling, grilling, infrared cooking, pan cooking, and superheated steaming on marinated pork loin subjected to reheating up to an internal temperature of 75℃. In particular, the effect of each pre-cooking method on reheated marinated pork loin was evaluated with respect to pH, color, cooking loss, reheating loss, total loss, thiobarbituric acid reactive substance (TBARS) value, sensory evaluation, shear force, and correlation between quality characteristics of pork loin.

Materials and Methods

Cooking and reheating marinated pork loin

Pork loin was purchased from a local processor 48 h postmortem. The curing solution comprised soy sauce (15%), sugar (6%), salt (1%), pepper powder (0.5%), onion powder (0.5%), garlic powder (0.5%), isolated soy protein (1%), and ice water (76%). The curing solution was added and the pork loin was tumbled using a tumbler (MKR-150C, Ruhle GmbH., Germany) at 0℃ for 60 min under vacuum pressure (0.75 bar, 25 rpm). The tumbled pork loin samples were aged for 24 h, heat processed using the various cooking methods, and cooled at room temperature (24℃). The pre-cooking methods included boiling (water bath model 10-101, Dae Han Co., Korea), grilling (CG20, Hobart, USA), infrared cooking (ZG-BR377, Zaigle, Korea), pan frying (OES 6.06, Convotherm, Germany), and superheated steaming (DFC-240W, Naomoto, Japan). The pre-cooking treatment was stopped when the temperature at the center of meat samples reached 75℃, which is a generally recommended safe temperature for pork (Kim et al., 2013; Murphy et al., 2001). The treated meat samples were frozen (−15℃) after cooling to 20℃ for 30 min. The frozen pork loin was reheated (after 5 days in frozen storage) using a microwave (NN-S963/S763, Panasonic Inc., Canada) at 720 W and 2,450 MHz. For reheating, each pork loin was placed in the center of the oven on a microwave-safe plastic container with a plastic rack until the targeted center temperature was 75℃. The cooked reheated marinated pork loins were cooled to a temperature of 4℃ and packaged in polyethylene bag. This procedure was performed in triplicates for each marinated pork loin and all analyses were performed at least in triplicates for each batch.

pH

The pH value of the sample was measured in a homogenate prepared with 5 g of sample and distilled water (20 mL) using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH meter was calibrated with standard 4.00, 7.02, and 10.05 pH buffers (VWR Scientific Products) at a temperature of 20±1°C.

Color measurements

The color of the flat surface in the center of each sample was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta Ltd., Japan; illuminate C, calibrated with a white plate, L*=+97.83, a*=−0.43, and b*=+1.98). Lightness (CIE L*-value), redness (CIE a*-value), and yellowness (CIE b*-value) values were recorded.

Cooking loss, reheating loss, and total loss

Cooking loss (%), reheating loss (%), and total loss (%) were determined by calculating the weight difference (g) between marinated pork loin before and after cooking as follows:

$$\text{Cooking loss (\%)} = \frac{\text{Weight of raw pork loin} - \text{Weight of cooked pork loin}}{\text{Weight of raw pork loin}} \times 100$$

$$\text{Reheating loss (\%)} = \frac{\text{Weight of reheated pork loin} - \text{Weight of cooked pork loin}}{\text{Weight of raw pork loin}} \times 100$$

$$\text{Total loss (\%)} = \text{Cooking loss} + \text{Reheating loss}$$

TBARS value

Lipid oxidation was analyzed in triplicates with some modifications in the TBARS method described by Tarladgis et al. (1960). The value was expressed as milligram of malondialdehyde (MD) per kilogram of sample. Briefly, 10 g samples were blended with 50 mL distilled water for 2 min using a homogenizer (AM-7, Nihon Seiki, Kaisha Ltd., Japan) and transferred to a distillation tube. The cup used for mixing was cleaned with 47.5 mL of distilled water, which was added to the same distillation flask along with 2.5 mL 4 N hydrochloric acid (HCl) and antifoaming agent (KMK-73, Shin-Etsu Silicone Co. Ltd., Korea). The mixture was distilled and 5 mL of 0.02 M thiobarbituric acid (TBA) in 90% acetic acid was added to the test tube containing 5 mL of the distillate and mixed. The tubes were closed and heated in boiling water for 30 min for chromogen development, followed by cooling at room temperature. The absorbance of the reaction mixture was measured at 538 nm against a blank using UV/VIS spectrophotometer (Kim et al., 2017).

Sensory evaluation

Sensory evaluations were performed in triplicates on each sample by a panelist. A panel of 12 members including researchers from the Korean Food Research Institute (KFRI), Korea, was used to evaluate the marinated loin samples (Shim et al., 2018). Each marinated loin sample was evaluated in terms of appearance, color, flavor, juiciness, chewiness, and overall acceptability. Marinated pork loins were cooked with different methods until the core temperature reached 75℃. The samples were cooled to 20℃ for 30 min, cut into quarters (width×length: 3×4 cm), and served randomly to the panelists. Each sample was coded with a randomly selected three-digit number. Sensory evaluations were performed under fluorescent lighting. Panelists were instructed to cleanse their palates with water between samples. The cooked samples were evaluated using a 9-point descriptive scale. This analysis was conducted using the hedonic test described by Bergara-Almeida and da Silva (2002).

Warner-Bratzler shear force

Warner-Bratzler shear force was determined using the method of Choi et al. (2016) at room temperature with a texture analyzer (TA-XT2*i*, Stable Micro Systems Ltd., England). The cooked samples were cooled at 20℃ for 30 min. Following equilibration, the samples were cut with a knife into 3×4 cm sections and the sections were sheared at separate locations with Warner-Bratzler blade set attached to a texture analyzer. The Warner-Bratzler shear force condition is head speed 2.0 mm/s, distance 8.0 mm, force 5.0 g, pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, and maximum load 50.0 kg.

Statistical analysis

All tests were performed at least thrice for each experimental condition and mean values reported. One-way analysis of variance (ANOVA) was performed on all variables using the general linear model (GLM) procedure of SAS (Statistical Analysis Systems Institute, 2008) statistical package. Duncan's multiple range test ($p<0.05$) was used to determine the differences between treatment means. The statistical analysis for each parameter combined the data from three batches. Pearson's correlation analysis was used to investigate the relationship between quality indicators and spot intensities (Choi et al., 2015). Correlation coefficients were calculated with CORR procedure of SAS.

Results and Discussion

pH of the marinated pork loin

The pH values of the treated samples are shown in Table 1. The highest pH was reported for samples cooked by boiling ($p<0.05$). Similar results were obtained by Choi et al. (2016), wherein the influence of cooking methods on the pH of

Table 1. The pH of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	pH	
	Cooked	Re-heated
Boiling	6.53 ± 0.03^{a}	6.47 ± 0.03^{a}
Grill	6.34 ± 0.04^{c}	6.12 ± 0.04^{d}
Infrared	6.44 ± 0.08^{b}	6.43 ± 0.04^{b}
Pan-frying	6.26 ± 0.02^{d}	6.25 ± 0.06^{c}
Superheated steam	6.28 ± 0.02^{d}	6.27 ± 0.01^{bc}

All values are mean±SD of three replicates.

$^{a–d}$ Means with different superscripts in the same column are significantly different at $p<0.05$.

chicken steaks was reported. These authors reported higher pH for samples cooked by boiling than those treated with superheated steam. Chun et al. (2013) reported that the pH of meat was affected by superheated steam cooking. Kim et al. (2001) indicated that the pH of the grilled beef was higher than that of the microwaved meat, but no significant difference was observed between grilled, pan-fried, and oven-roasted meats. In general, cooking methods had different effects on the pH of meat products, owing to the differences in the cooking rates. With respect to reheated samples, those treated with boiling showed higher pH as compared with other treatment groups ($p<0.05$). The pH of the samples following reheating treatment was lower than that after first treatment. Choi et al. (2008) reported no significant differences in the pH of the pre-cooked patty reheated by different reheating methods. Choi (2009) reported that higher pH for patties reheated by microwaving as compared with those reheated by convection oven. Thus, reheated meat products may maintain their pH even after reheating, although the cooking methods may influence the pH of meat products.

Color of the marinated pork loin

Table 2 shows the color values reported for the marinated pork loin cooked by various cooking methods and subjected to microwave reheating. We found that the color parameters of the marinated pork loin were influenced by different cooking methods and microwave reheating. The highest lightness value was reported in samples subjected to infrared treatment, whereas the lowest lightness value was observed for grilled marinated pork loin ($p<0.05$). The highest values of redness and yellowness were noted for grilled marinated pork loin, while the lowest redness and yellowness values were reported for infrared-treated marinated pork loin ($p<0.05$). The lightness values of samples following microwave reheating were lower than those reported after first cooking methods ($p<0.05$). In particular, the highest lightness values were observed for reheated samples cooked by superheated steam ($p<0.05$). However, the redness and yellowness values were lower for reheated samples cooked by boiling as compared with other treatment groups ($p<0.05$). Oh et al. (2014) reported higher lightness and lower yellowness values for meat treated with superheated steam as compared with those treated with convection oven. Choi et al. (2016) reported higher lightness, redness, and yellowness values for the steak subjected to superheated treatment as compared with that subjected to other cooking methods. These results are in line with those reported by Jeon et al. (2013), wherein lightness and redness values were lower for beef ribs subjected to grilling than those treated by boiling, pan frying, and steaming. The meat color was closely related to the degree of browning reaction that occurs during cooking. Choi (2009) reported lower lightness for ground pork patties reheated by microwave oven; however, internal color parameters of ground pork patties were unaffected by reheating methods. In general, the color values of meats varied depending on the cooking method employed.

Table 2. The color of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	Cooked			Re-heated		
	L*	a*	b*	L*	a*	b*
Boiling	46.39 ± 0.80^{bc}	7.20 ± 1.11^{ab}	17.48 ± 0.82^{b}	28.50 ± 1.80^{d}	5.29 ± 1.01^{c}	8.64 ± 2.05^{c}
Grill	44.57 ± 1.07^{d}	8.19 ± 1.29^{a}	19.82 ± 1.67^{a}	35.95 ± 3.20^{c}	7.53 ± 1.08^{a}	17.81 ± 1.25^{ab}
Infrared	49.26 ± 1.95^{a}	5.57 ± 0.60^{c}	17.14 ± 1.61^{b}	39.29 ± 1.70^{b}	7.36 ± 0.48^{a}	17.04 ± 0.77^{b}
Pan-frying	$47. 39\pm1.44^{b}$	6.61 ± 0.59^{bc}	18.78 ± 0.92^{ab}	40.22 ± 1.41^{b}	6.44 ± 1.04^{b}	18.21 ± 1.30^{a}
Superheated steam	46.09 ± 1.63^{c}	7.54 ± 0.91^{ab}	18.93 ± 1.34^{ab}	42.98 ± 1.63^{a}	6.38 ± 0.36^{b}	18.13 ± 1.16^{a}

All values are mean±SD of three replicates.
[a–d] Means with different superscripts in the same column are significantly different at $p<0.05$.

Cooking loss, re-heating loss, and total loss of the marinated pork loin

The cooking loss, re-heating loss, and total loss of the marinated pork loins after cooking with various methods and microwave reheating is shown in Table 3. The lowest cooking loss was observed in samples treated with superheated steam as compared to those subjected to other treatments ($p<0.05$), whereas the highest cooking loss was reported for those subjected to boiling and pan frying ($p<0.05$). The reheating loss was lower for frozen marinated pork loin cooked with infrared and pan frying as compared with other treatments ($p<0.05$). The total loss was lower for samples subjected to superheated steam treatment as compared with other treatments ($p<0.05$). Similar results were obtained by Choi et al. (2016), wherein cooking loss was reported for chicken steak cooked by different methods. These authors found that cooking loss was lower for samples cooked with superheated steam as compared with those cooked with other methods and the highest cooking loss was observed for samples cooked by boiling. Kim et al. (2001) reported that the cooking loss with different cooking methods was attributed to the differences in their cooking rates. Jeon et al. (2013) observed no significant difference in the cooking loss of beef loin subjected to boiling, pan frying, grilling, and steaming. In addition, Choi (2009) reported a reheating loss of 7%–8% and 16% for patties reheated using electric grill and microwave oven, respectively. The results observed in our study were in line with the results observed using microwave. Dawson and Sison (1973) reported that cooking and reheating with microwave results in more cooking loss than other cooking and reheating methods. Choi et al. (2008) reported the highest reheating loss with microwave oven cooking and the lowest reheating loss with electric grill reheating cooking methods.

TBARS values of the marinated pork loin

The effects of various cooking methods and microwave reheating on TBARS values of the marinated pork loin are shown in Table 4. The lowest TBARS values were observed for samples treated with superheated steam as compared to those cooked by pan frying ($p<0.05$). On the other hand, the lowest TBARS values were reported for reheated frozen marinated pork loin cooked by infrared cooking ($p<0.05$). TBARS values were higher for reheated samples as compared with those subjected to first cooking step. Similar results were obtained by Choi (2009), wherein TBARS values were affected for microwave-reheated chicken patties. This author showed that meat products reheated in convection oven displayed higher TBARS values than those reheated in microwave oven. In general, TBARS values of meat products increased during cooking and reheating time (Lyon and Ang, 1990). Some researchers reported rapid lipid oxidation as the primary contributor to warmed-over flavor, affecting sensory characteristics (Choi et al., 2008; Penner and Bowers, 1973). Thus, superheated steam cooking may reduce TBARS values.

Table 3. The cooking loss, re-heating loss, and total loss of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	Cooking loss	Re-heating loss	Total loss
Boiling	51.07 ± 1.92^{a}	17.74 ± 1.93^{a}	68.81 ± 1.45^{a}
Grill	47.57 ± 1.97^{b}	16.06 ± 1.26^{ab}	63.63 ± 1.49^{b}
Infrared	47.62 ± 1.45^{b}	13.55 ± 1.97^{c}	61.17 ± 1.63^{c}
Pan-frying	51.33 ± 1.13^{a}	13.29 ± 1.15^{c}	64.62 ± 1.39^{b}
Superheated steam	41.87 ± 2.80^{c}	15.89 ± 1.18^{b}	57.76 ± 1.33^{d}

All values are mean±SD of three replicates.

$^{a-d}$ Means with different superscripts in the same column are significantly different at $p<0.05$.

Table 4. The TBARS of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	TBARS	
	Cooked	Re-heated
Boiling	0.010±0.002^{ab}	0.194±0.014^{a}
Grill	0.010±0.003^{ab}	0.172±0.015^{b}
Infrared	0.011±0.004^{ab}	0.153±0.011^{d}
Pan-frying	0.013±0.004^{a}	0.186±0.014^{ab}
Superheated steam	0.008±0.004^{b}	0.161±0.013^{c}

All values are mean±SD of three replicates.
$^{a–d}$ Means with different superscripts in the same column are significantly different at p<0.05.
TBARS, thiobarbituric acid reactive substance.

Sensory evaluation of the marinated pork loin

Sensory traits of the marinated pork loin after cooking with various methods and microwave reheating are shown in Table 5. No significant difference was observed in the appearance and flavor scores between meat cooked using various methods (p>0.05). The lowest scores for juiciness, chewiness, and overall acceptability were observed for samples cooked by boiling (p<0.05). The overall acceptability score was the highest for grilled and superheated steam-cooked samples (p<0.05). The microwave reheated samples cooked by boiling showed lower juiciness and chewiness scores as compared with those cooked by other methods (p<0.05). The overall acceptability was the highest for microwave-reheated samples cooked by superheated steam (p<0.05). This observation is in agreement with the report of Choi et al. (2016), wherein grilled steaks showed highest scores for color, tenderness, juiciness, and overall acceptability following superheated steam cooking. Similar results were obtained by Seo et al. (2014), wherein superheated steam cooking contributed to higher sensory qualities. Chun et al. (2013) showed that superheated steam cooking of meat results in an increase in the acceptability, tenderness, juiciness, and flavor

Table 5. The sensory evaluation of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	Appearance	Color	Flavor	Juiciness	Chewiness	Overall acceptability
Cooked						
Boiling	7.02±0.71	7.05±1.02^{b}	7.22±0.49	6.63±0.55^{b}	7.06±0.71^{b}	7.22±0.47^{b}
Grill	8.64±0.52	8.02±0.71^{a}	8.64±0.62	8.02±1.01^{a}	8.61±0.54^{a}	8.64±0.59^{a}
Infrared	7.83±0.45	7.63±0.56^{b}	7.43±0.71	7.26±0.84^{ab}	7.84±0.46^{a}	7.82±0.84^{ab}
Pan-frying	8.04±0.71	7.42±0.57^{b}	7.87±0.48	8.03±0.42^{a}	8.02±0.71^{a}	8.04±0.71^{ab}
Superheated steam	6.83±0.63	7.84±0.84^{b}	7.63±0.89	8.04±0.57^{a}	8.83±0.48^{a}	8.46±0.89^{a}
Re-heated						
Boiling	6.44±1.14	6.44±0.55	6.64±0.89	6.42±0.55^{b}	6.44±1.14^{b}	6.63±0.89^{b}
Grill	7.43±0.58	7.63±0.89	7.66±0.51	7.65±0.89^{a}	7.45±0.58^{a}	7.45±0.58^{ab}
Infrared	7.26±0.84	7.25±0.85	7.42±0.58	7.23±0.84^{a}	7.28±0.84^{a}	7.22±0.47^{ab}
Pan-frying	7.86±0.47	8.27±0.84	7.83±0.82	7.26±0.84^{a}	7.52±0.45^{a}	7.34±0.84^{ab}
Superheated steam	7.87±0.82	7.63±1.14	7.89±0.84	7.61±1.14^{a}	7.83±0.84^{a}	7.98±0.55^{a}

All values are mean±SD of three replicates.
^{a,b} Means with different superscripts in the same column are significantly different at p<0.05.

scores as compared with oven-cooked meat. Choi (2009) reported higher flavor scores for patties reheated by microwave oven as compared with those reheated by the convection oven. The reheating of pre-cooked meat was shown to result in undesirable changes in the meat flavor, owing to oxidative reactions. El-Shimi (1992) showed that the flavor of microwave-reheated meat was superior to that of conventionally reheated meat, attributable to the differences in time required for reheating. The sensory characteristics of marinated pork loin were influence by heating method. In addition, the sensory characteristics of marinated pork loin are seen to be even worse, due to the elution of moisture during reheating. Thus, reheated marinated pork loin cooked with superheated steam showed the best overall acceptability among the various cooking methods.

Shear force of the marinated pork loin

Table 6 shows shear force of the marinated pork loin cooked with various cooking methods, followed by microwave reheating. Shear force was lower for samples treated with superheated steam as compared with those cooked by other methods ($p<0.05$). The highest shear force was observed for samples cooked by boiling and pan frying ($p<0.05$). The reheating of frozen marinated pork loin cooked with superheated steam resulted in lower shear force as compared with reheating of samples cooked with other methods ($p<0.05$). The reheating of frozen marinated pork loin resulted in higher shear force as compared with samples subjected to the single cooking step. Choi (2009) reported higher hardness value for patties cooked using a microwave oven as compared with those cooked using an electric grill. Choi et al. (2016) noted the lowest hardness value for samples subjected to superheated steam cooking as compared with those cooked by other methods; the highest hardness value was reported for boiled and grilled samples. Thus, superheated steam cooked steak resulted in decreased values of tenderness. Oh et al. (2014) indicated that superheated steam treatment contributes to decreased hardness. These results are in agreement with those reported by Choi (2009), wherein the hardness of reheated patties increased by about 40% as compared with patties subjected to the single cooking step. Thus, the cooking method employed had a stronger impact on the hardness of the final reheated product as compared with the reheating methods (Miller and Hoseney, 1997).

Correlation between marinated pork loin samples

The correlation between marinated pork loin cooked by various methods and reheating treatment is shown in Table 7. Cooking method affected the pH, lightness value, redness value, yellowness value, TBARS value, cooking loss, re-heating loss, flavor, juiciness, chewiness, overall acceptability, and shear force ($p<0.05$), while reheating affected pH, lightness value, yellowness value, TBARS value, cooking loss, re-heating loss, appearance, color, overall acceptability, and shear force ($p<0.05$). The interaction between cooking method and reheating was shown to affect the pH, lightness value, redness value, yellowness value, TBARS value, cooking loss, re-heating loss, chewiness, and shear force ($p<0.05$). The significant

Table 6. The shear force of marinated pork loin cooked by different cooking methods and microwave re-heating

Cooking method	Shear force	
	Cooked	Re-heated
Boiling	1.87 ± 0.34^{a}	3.49 ± 0.29^{a}
Grill	1.38 ± 0.68^{b}	2.62 ± 1.10^{ab}
Infrared	1.32 ± 0.36^{b}	3.23 ± 0.35^{a}
Pan-frying	2.15 ± 0.34^{a}	3.13 ± 0.95^{a}
Superheated steam	1.28 ± 0.31^{c}	1.79 ± 0.28^{b}

All values are mean±SD of three replicates.

$^{a–c}$ Means with different superscripts in the same column are significantly different at $p<0.05$.

Table 7. The significance of main effects and their interactions of marinated pork loin cooked between different cooking methods and microwave re-heating

Variable	pH	L*	a*	b*	TBARS	Cooking loss	Re-heating loss	Appearance	Color	Flavor	Juiciness	Chewiness	Overall acceptability	Shear force
Cooking method effect (H)	***	**	**	***	***	*	**	NS	NS	**	**	**	**	***
Reheating effect (R)	***	***	NS	***	***	***	***	***	**	NS	NS	NS	*	***
Interaction (H×R)	***	**	**	***	***	**	**	NS	NS	NS	NS	*	NS	*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.
TBARS, thiobarbituric acid reactive substance; NS, not significant.

difference between cooking methods may be associated with the differences in heat conductivity (Choi et al., 2016). The cooking loss and re-heating loss were affected, owing to the variation in heat conductivity. The variation in the cooking loss affected various parameters of the experiment as well as the scores of sensory properties. The reheating process affected the cooking loss and several other parameters.

Conclusion

Although infrared-cooked samples had lower TBARS value than superheated steam-cooked samples, parameters such as cooking loss, overall acceptability, and shear force were improved for samples cooked with superheated steam. Therefore, superheated steam was useful to improve qualities of microwave-reheated marinated pork. In conclusion, superheated steam may be useful for maintaining the quality of marinated pork during the commercial distribution of frozen products.

Acknowledgements

This research was supported by Main Research Program (E0156422-04) of the Korea Food Research Institute (KFRI) funded by the Ministry of Science and ICT (Korea). This research was also partially supported Agri-Bio Industry Technology Development Program (317001-3) by the Ministry of Agriculture, Food and Rural Affairs (Korea).

References

Bergara-Almeida S, da Silva MAAP. 2002. Hedonic scale with reference: Performance in obtaining predictive models. Food Qual Prefer 13:57-64.

Choi JH. 2009. Effects of reheating conditions and various ingredients on the quality characteristics of ground pork patties. Ph.D. dissertation, Konkuk Uinv., Seoul, Korea.

Choi JH, Jeong JY, Kim HY, An KI, Kim CJ. 2008. The effects of electric grill and microwave oven reheating methods on the quality characteristics of precooked ground pork patties with different NaCl and phosphate levels. Korean J Food Sci An 28:535-542.

Choi Y, Oh JH, Bae IY, Cho EK, Kwon DJ, Park HW, Yoon S. 2013. Changes in quality characteristics of seasoned soy sauce treated with superheated steam and high hydrostatic pressure during cold storage. Korean J Food Cook Sci 29:387-398.

Choi YS, Hwang KE, Jeong TJ, Kim YB, Jeon KH, Kim EM, Sung JM, Kim HW, Kim CJ. 2016. Comparative study on the effects of boiling, steaming, grilling, microwaving and superheated steaming on quality characteristics of marinated chicken steak. Korean J Food Sci An 36:1-7.

Choi YS, Kim YB, Kim HW, Hwang KE, Song DH, Jeong TJ, Park J, Kim CJ. 2015. Emulsion mapping in pork meat emulsion systems with various lipid types and brown rice fiber. Korean J Food Sci An 35:258-264.

Chun JY, Kwon BG, Lee SH, Min SG, Hong GP. 2013. Studies on physico-chemical properties of chicken meat cooked in electric oven combined with superheated steam. Korean J Food Sci An 33:103-108.

Dawson LE, Sison EC. 1973. Stability and acceptability of phosphate-treated and precooked chicken pieces reheated with microwave energy. J Food Sci 38:161-164.

El-Shimi NM. 1992. Influence of microwave and conventional cooking and reheating on sensory and chemical characteristics of roast beef. Food Chem 45:11-14.

Jeon KH, Kwon KH, Kim EM, Kim YB, Sohn DI, Choi JY. 2013. Effect of cooking methods with various heating apparatus on the quality characteristics of beef. Korean J Culin Res 19:196-205.

Kim CJ, Chae YC, Lee ES. 2001. Changes of physico-chemical properties of beef tenderloin steak by cooking methods. Korean J Food Sci An 21:314-322.

Kim HW, Hwang KE, Song DH, Lee SY, Choi MS, Lim YB, Choi JH, Choi YS, Kim HY, Kim CJ. 2013. Effects of dietary fiber extracts from brewer's spent grain on quality characteristics of chicken patties cooked in convective oven. Korean J Food Sci An 33:45-52.

Kim TK, Kim YB, Jeon KH, Park JD, Sung JM, Choi HW, Hwang KE, Choi YS. 2017. Effect of fermented spinach as sources of pre-converted nitrite on color development of cured pork loin. Korean J Food Sci An 37:105-113.

Krishnamurthy K, Khurana HK, Jun S, Irudayaraj J, Demirci A. 2008. Infrared heating in food processing: An overview. Compr Rev Food Sci Food Saf 7:2-13.

Lee CH, Ha JS, Jeong JY, Lee ES, Choi JH, Choi YS, Kim JM, Kim CJ. 2005. Effects of cooking method on physicochemical characteristics and qualities of hamburger patties. Korean J Food Sci An 25:149-155.

Lyon BG, Ang CYW. 1990. Effects of reheating method on off-flavor development in precooked, stored chicken patties. Poult Sci 69:320-328.

Lyon BG, Lyon CE, Ang CYW, Young LL. 1988. Sensory analysis and thiobarbituric acid values of precooked chicken patties stored up to three days and reheated by two methods. Poult Sci 67:736-742.

Miller RA, Hoseney RC. 1997. Method to measure microwave-induced toughness of bread. J Food Sci 62:1202-1204.

Murphy RY, Johnson ER, Duncan LK, Clausen EC, Davis MD, March JA. 2001. Heat transfer properties, moisture loss, product yield and soluble proteins in chicken breast patties during air convection cooking. Poult Sci 80:508-514.

Nathakaranakule A, Kraiwanichkul W, Soponronnarit S. 2007. Comparative study of different combined superheated-steam drying techniques for chicken meat. J Food Eng 80:1023-1030.

Oh JH, Yoon S, Choi Y. 2014. The effect of superheated steam cooking condition on physico-chemical and sensory characteristics of chicken breast fillets. Korean J Food Cook Sci 30:317-324.

Penner KK, Bowers JA. 1973. Flavor and chemical characteristics of conventionally and microwave reheated pork. J Food Sci 38:553-555.

Risman PO. 1998. A microwave oven model: Examples of microwave heating computation. Microw World 19:20-23.

SAS. 2008. SAS user's guide: Release 9.2, Basic statistical analysis. SAS Inc., Cary, NC, USA.

Seo SH, Kim EM, Kim YB, Cho EK, Woo HJ. 2014. A study on development of samgyetang using superheated steam and high hydrostatic pressure. Korean J Food Cook Sci 30:183-192.

Shim JY, Kim TK, Kim YB, Jeon KH, Ahn KI, Paik HD, Choi YS. 2018. The ratios of pre-emulsified duck skin for optimized processing of restructured ham. Korean J Food Sci An 38:162-171.

Steiner JB, Johnson RM, Tobin BW. 1985. Effect of microwave and conventional reheating on flavor development in chicken breasts. Microw World 6:10-12.

Suwannakam M, Noomhorm A, Anal AK. 2014. Influence of combined far-infrared and superheated steam for cooking chicken meat patties. J Food Process Eng 37:515-523.

Tarladgis BG, Watts BM, Younathan MT, Dugan L. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J Am Oil Chem Soc 37:44-48.

Tims MJ, Watts BM. 1958. Protection of cooked meats with phosphates. Food Technol 12:240-243.

Xiao HW, Bai JW, Sun DW, Gao ZJ. 2014. The application of superheated steam impingement blanching (SSIB) in agricultural products processing – a review. J Food Eng 132:39-47.

Yarmand MS, Nikmaram P, Emam Djomeh Z, Homayouni A. 2013. Microstructural and mechanical properties of camel *longissimus dorsi* muscle during roasting, braising and microwave heating. Meat Sci 95:419-424.