

Comparative Study on the Effects of Boiling, Steaming, Grilling, Microwaving and Superheated Steaming on Quality Characteristics of Marinated Chicken Steak

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Abstract

The effects of five different cooking methods (boiling, steaming, grilling, microwaving, and superheated steaming) on proximate composition, pH, color, cooking loss, textural properties, and sensory characteristics of chicken steak were studied. Moisture content and lightness value (L^* -value) were higher in superheated steam cooked chicken steak than that of the other cooking treatments such as boiling, steaming, grilling and microwaving cooking ($p < 0.05$), whereas protein content, redness value (a^* -value), hardness, gumminess, and chewiness of superheated steam cooked chicken steak was lower than that in the other cooking treatments ($p < 0.05$). Fat content and ash content, springiness, and cohesiveness were not significantly different among the chicken steak cooked using various methods ($p > 0.05$). Among the sensory characteristics, tenderness score, juiciness score and overall acceptability score were the highest for the superheated steam samples ($p < 0.05$), whereas no difference in flavor scores were observed among the other treatments ($p > 0.05$). These results show that marinated chicken steak treated with superheated steam in a preheated 250°C oven and 380°C steam for 5 min until core temperature reached 75°C improved the quality characteristics and sensory properties the best. Therefore, superheated steam was useful to improve cooked chicken steak.

Keywords: chicken steak, superheated steam, cooking methods, textural properties, sensory characteristics

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Introduction

Chicken meat and products are generally a very popular food commodity worldwide, as chicken meat is characterized by low fat, low cholesterol content and high nutritional value (Choi *et al.*, 2011). Consumption of chicken meat has increased steadily over the last few decades in many countries. However, chicken meat is limited to frying methods and various processing methods have not yet been developed in Korea. Thus, the variety of cooking methods for chicken products needs to be researched.

The purpose of cooking is to make meat palatable, digestible and microbiologically safe. Meat products undergo many changes during cooking, such as weight loss, water

holding capacity, texture, and color and aroma development (Mora *et al.*, 2011). These changes are dependent on protein denaturation and water loss. Additionally, the quality characteristics of meat products are affected by the composition and characteristics of the muscle, cooking method, and cooking time and temperature (Kim *et al.*, 2001; Lee *et al.*, 2005).

Boiling, steaming, grilling, and microwave cooking are the most commonly used methods to cook meat and are widely used during commercial processing and foodservice operations (Dominguez *et al.*, 2014; Jeon *et al.*, 2013; Mora *et al.*, 2011).

Superheated steam is steam that has been given additional heat to raise its temperature above the saturation point at a given pressure (Cenkowski *et al.*, 2007; Choi *et al.*, 2013; Kim *et al.*, 2008). Superheated steam technology results in a uniform, rapid, energy-efficient cooking process (Chun *et al.*, 2013; Suwannakam *et al.*, 2014). Compared with a traditional cooking system, the biggest

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advantage is that superheated steam can extensively reduce nutrient loss, as the materials are superheated by steam (Nathakaranakule *et al.*, 2007). Furthermore, a superheated steam cooking system is cleaner, oxidizes food less, minimizes energy consumption and emissions, provides for easy energy recovery due to steam compression, and minimizes fire and explosion hazards (Moreira, 2001; Saadchom *et al.*, 2011; Xiao *et al.*, 2014). Nevertheless, many researchers have reported that utilizing superheated steam drying of food is an active area of research, but a limited number of studies have reported superheated steam cooking to prepare quality meat products. The use of superheated steam cooking of chicken steak and its effects on the properties of the cooked product were investigated in this study.

Therefore, the objective of this study was to evaluate the effect of different cooking methods on marinated chicken steak by comparing boiling, steaming, grilling, microwaving, and superheated steaming until core temperature reached 75°C. In particular, the effect of each cooking method was evaluated in relation to cooking loss, pH, color, textural properties, and sensory characteristics of chicken steak.

Materials and Methods

Chicken steak preparation and processing

Fresh chicken breast meat (*M. pectoralis major*) was purchased from a local processor 48 h postmortem. The curing solution was soy sauce (13%), sugar (7%), salt (1%), pepper powder (0.3%), onion powder (0.3%), garlic powder (0.4%), isolated soy protein (1%), dietary fiber (1%), and ice water (76%). A curing solution was added, and the meat was tumbled using a tumbler (MKR-150C, Ruhle GmbH., Germany). The tumbling conditions were 0°C for 60 min under vacuum pressure (0.75 bar, 25 rpm). The tumbled chicken steak samples were aged overnight (24 h), heat processed using the various cooking methods, and then the cooked chicken steak was cooled at room temperature (24°C). The cooking methods were boiling, a convective oven, grilling, microwave, and superheated steam. The cooking treatment ended when the meat samples reached 75°C at their thermal center, which is a generally recommended safe temperature for chicken (Murphy *et al.*, 2001; Kim *et al.*, 2013). Changes in core temperature of each sample were monitored with digital thermometer (Tes-1305, TES Electrical Corp., Taiwan) equipped with a data logger (RS 232, TES Electrical Corp., Taiwan), and the required cooking times to reach

the target core temperature were as follow: the boiled chicken steak was heat processed in a 100°C water bath (model 10-101, Dae Han Co, Korea) until core temperature reached 75°C for about 22 min. Convective oven (OES 6.06, Convotherm, Germany) cooking was conducted at 120°C in a preheated oven until core temperature reached 75°C for about 20 min. Grilled cooking included a preheated electric grill (CG20, Hobart, USA) at a grill surface temperature of 150°C. The grilled chicken steaks were cooked for 3 min on each side and thereafter flipped over every 2 min until the targeted core temperature reached 75°C for about 14 min. Microwave cooking used a 720 W and 2,450 MHz house-type microwave oven (NN-S963/S763, Panasonic Inc., Canada). The chicken steak center temperature reached 75°C for about 10 min. The microwave cooked sample could be overheated, and the surface of the chicken steak was occasionally burned. Superheated steamed cooking used superheated steam (DFC-240W, Naomoto, Japan). The superheated steam conditions were a preheated 250°C oven and 380°C steam. The superheated steam-treated chicken steaks were cooked for about 5 min until core temperature reached 75°C. This procedure was performed in triplicate for each chicken steak, and all analyses were carried out at least in triplicate for each formulation.

Proximate composition

Composition properties of the chicken steak were determined using AOAC methods (2007). Moisture content (950.46B) was calculated by weight loss after 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Korea). Fat content (960.69) was determined by the Soxhlet method with a solvent extraction system (Soxtec Avanti 2050 Auto System, Foss Tecator AB, Sweden), and protein content (981.10) was determined by the Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec 2300 Analyzer Unit, Foss Tecator AB). Ash content was determined according to the AOAC method 923.93 (muffle furnace).

Cooking loss

The cooking loss (%) was determined by calculation the weight differences of chicken steak before and after cooking as follow:

$$\text{Cooking loss (\%)} = \left[\frac{\text{weight of raw chicken steak (g)} - \text{weight of cooked chicken steak (g)}}{\text{weight of raw chicken steak (g)}} \right] \times 100$$

pH measurements

The pH values of sample were 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 calibrated with standard 4.00, 7.02, and 10.05 pH buffers (VWR Scientific Products) at a temperature of $20 \pm 1^\circ\text{C}$. All determinations were performed in triplicate.

Color measurements

The color of the flat surface in the center for 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 $b^*=+1.98$). Seven measurements for each of five replicates were obtained. Lightness (CIE L^* - value), redness (CIE a^* - value), and yellowness (CIE b^* - value) values were recorded.

Texture profile analysis

The texture profile analysis (TPA) was conducted using the method of Choi *et al.* (2010) at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., England). The chicken steaks followed by various heating until the core temperature reached 75°C , and the cooked steak samples were cooled to room temperature (24°C) for 30 h. The samples were allowed to equilibrate to room temperature. Samples were taken from the central portion of each chicken steak. The texture analysis conditions were as follows: pre-test speed, 2.0 mm/s; post-test speed, 5.0 mm/s; maximum load, 2.0 kg; head speed, 2.0 mm/s; distance, 8.0 mm; force, 5.0 g. TPA values were calculated by graphing force and time plots. Values for hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described by Bourne (1978).

Sensory evaluation

The sensory evaluations were performed in triplicate on each sample by sensory panelist. A selected twelve-member panel consisting of researchers from the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea was used to evaluate the chicken steak samples. Selection of trained panelists was performed according to sensory evaluation procedure (Lawless & Heymann, 1999). Each chicken steak sample was evaluated in terms of color, flavor, juiciness, tenderness, and overall acceptability. Chicken steaks were variously cooked until the core temperature reached 75°C ,

cooled to 20°C , cut into quarters (width \times length: 3.0×4.0 cm), and served randomly to the panelists. Each sample was coded with a randomly selected 3-digit number. Sensory evaluations were performed under fluorescent lighting. Panelists were instructed to cleanse their palates with water between 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. This analysis was conducted using the hedonic test described by Bergara-Almeida and da Silva (2002).

Statistical analysis

All tests were done at least three times for each experimental condition and mean values are reported. One-way ANOVA was performed on all the variables using the general linear model (GLM) procedure of the SAS (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 combines the data from three batches.

Results and Discussion

Proximate composition of the chicken steak

The proximate composition of the chicken steak using various cooking methods is shown in Table 1. The highest moisture content was in the superheated steam cooked treatment compared to that of the other treatments ($p < 0.05$). This result could be affected by the formation of a coating on the surface of the chicken stake during high temperature steaming contribution, which contributed to the reduction in water loss during thermal processing. These results agree with those reported by Seo *et al.* (2014), who found that superheated steam-treated *samgyetang* had higher moisture content. Lee *et al.* (2005) reported that the cooking method resulted in different moisture contents of hamburger patties. Our results showed that cooking time, temperature, and the cooking rates are greatly related to the proximate composition (or quality) of meat products. In a previous study, cooking with various heating apparatus considerably affected the quality characteristics of beef. The protein content of the chicken steak was lower for the superheated steam treatment than that of the other treatments ($p < 0.05$). According to Seo *et*

Table 1. Effect of different cooking methods on proximate composition of chicken steaks

Parameters	BC	CO	GC	MC	SSC
Moisture content (%)	64.21±0.34 ^C	64.11±0.32 ^C	65.79±0.38 ^B	65.75±0.45 ^B	68.07±0.42 ^A
Protein content (%)	27.02±0.58 ^A	26.82±0.63 ^A	25.92±0.52 ^B	25.47±0.62 ^B	23.85±0.68 ^C
Fat content (%)	2.13±0.12	2.14±0.13	2.14±0.10	2.13±0.14	2.12±0.12
Ash content (%)	1.42±0.13	1.60±0.11	1.60±0.07	1.54±0.09	1.47±0.13

All values are mean±standard deviation of three replicates (n=9).

^{A-C}Means within a row with different letters are significantly different ($p<0.05$).

¹⁾BC, chicken steak cooked with boiled; CO, chicken steak cooked with convective oven; GC, chicken steak cooked with grilling; MC, chicken steak cooked with microwave oven; SSC, chicken steak cooked with superheated steam.

al. (2014), superheated steam treatment contributes to the decrease in protein content of meat products. These results suggest that the protein content was lower relative to the increase in moisture content of the meat products (Lee *et al.*, 2005). Fat and ash contents were not significantly different among the meat cooked using various methods ($p>0.05$).

Cooking loss of the chicken steak

Fig. 1 shows cooking loss of chicken steaks heated with various cooking methods. Cooking loss was lower for the superheated steam treatment than that for the other treatments ($p<0.05$), whereas the highest cooking loss was observed in the boiled and convective oven-treated chicken steaks ($p<0.05$). Generally, cooking loss of meat products increases as cooking temperature and time increase (Lee *et al.*, 2005). Chun *et al.* (2013) reported that meat products cooked with superheated steam were lower cooking

loss than that of oven-cooked meat products. According to Kim *et al.* (2001), meat products show significant differences in cooking loss based on the heating method, and this difference affects the quality characteristics of the meat product. Dominguez *et al.* (2014) reported that cooking loss depends on mass transfer during thermal treatment; thus, different cooking methodologies lead to different losses. Additionally, the distance between proteins becomes smaller with increased cooking rate, and more water is expelled from the meat product. Cooking loss of superheated steam-treated meat was lower, which was affected by the surface proteins of the chicken steak that formed a coating during high temperature heating; thus, the moisture was prevented from escaping.

pH and color of the chicken steak

The pH and color of the chicken steaks after cooking with various methods are shown in Table 2. The highest pH was observed in the grilled cooking treatments when compared to those of the other treatments ($p<0.05$), whereas the lowest pH was found in the microwave and superheated steam-treated samples ($p<0.05$). Similar results were obtained by Chun *et al.* (2013) who noted that influence of superheated steam cooking on pH of chicken meat. They reported that superheated steam lowers pH more than that of oven cooking. Kim *et al.* (2001) reported that the pH of grilled beef tenderloin steak was higher than that of pan-fried, oven-roasted, or microwaved steak, but no significant difference was observed among the treatments. The cooking methods differently influence the changes in pH values of meat products, which might be associated with the heating rate.

The statistical results indicated that the color parameters of the chicken steak were affected by the different cooking methods (Table 2). The highest lightness value was observed in chicken steaks cooked with superheated steam, whereas the lowest lightness was detected in grilled chicken steak. The redness and yellowness values of the chicken steaks were higher for the grilled treatment

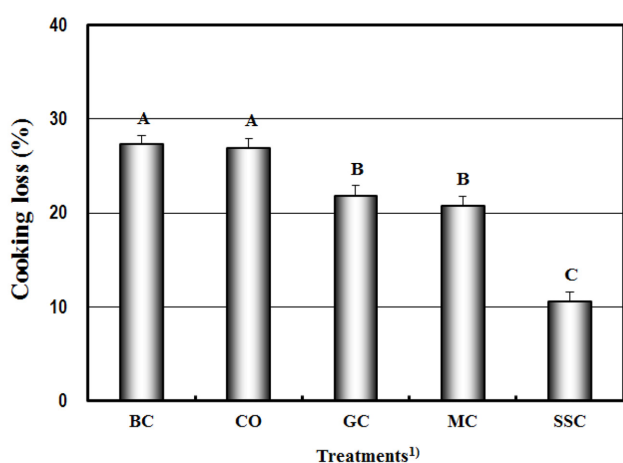


Fig. 1. Effect of different cooking methods on cooking loss of chicken steaks. ^{A-C}Means between treatments with different letters are significantly different ($p<0.05$) (n=9). ¹⁾BC, chicken steak cooked with boiled; CO, chicken steak cooked with convective oven; GC, chicken steak cooked with grilling; MC, chicken steak cooked with microwave oven; SSC, chicken steak cooked with superheated steam.

Table 2. Effect of different cooking methods on pH and color characteristics of chicken steaks

Parameters	BC	CO	GC	MC	SSC
pH	5.98±0.07 ^B	5.94±0.08 ^B	6.09±0.04 ^A	5.85±0.08 ^C	5.86±0.06 ^C
CIE L*-value	93.43±0.87 ^B	90.90±0.64 ^C	82.21±2.35 ^D	91.38±0.61 ^C	95.15±0.64 ^A
CIE a*-value	-0.05±0.57 ^B	0.39±0.62 ^C	4.59±0.77 ^A	1.95±0.24 ^B	-1.01±0.26 ^E
CIE b*-value	3.39±0.63 ^{CD}	4.84±0.34 ^C	11.98±0.27 ^A	7.36±0.89 ^B	2.24±0.87 ^D

All values are mean±standard deviation of three replicates (n=9).

^{A-E}Means within a column with different letters are significantly different ($p<0.05$).

¹⁾BC, chicken steak cooked with boiled; CO, chicken steak cooked with convective oven; GC, chicken steak cooked with grilling; MC, chicken steak cooked with microwave oven; SSC, chicken steak cooked with superheated steam.

than that of the other cooking methods, and the lowest values were observed with superheated steam. These results agree with those reported by Oh *et al.* (2014), who found that the lightness of chicken fillets treated with superheated steam was higher than those treated with a convection oven. They also found that the yellowness of chicken fillets treated with superheated steam was a lower than that of convection oven-cooked chicken fillets. According to Jeon *et al.* (2013) and Kim *et al.* (2001), color of meat products after cooking varies according to cooking method.

Textural profile analysis of the chicken steak

The effects of various cooking methods on the textural properties of chicken steak are shown in Table 3. The lowest hardness, gumminess, and chewiness occurred in the superheated steam treatment compared with that in the

other treatments ($p<0.05$), whereas the highest was in samples that were boiled or grilled ($p<0.05$). Springiness and cohesiveness were not significantly different among all treatments ($p>0.05$). According to Oh *et al.* (2014), the superheated steam treatment contributes to decrease hardness, cohesiveness, and chewiness. Seo *et al.* (2014) reported that *samgyetang* prepared using superheated steam has lower hardness, cohesiveness, gumminess, and chewiness than that of boiled *samgyetang*. Jeon *et al.* (2013) observed that grilling or oven heating beef results in a higher shear force among cooking methods. Tenderness is normally a major quality attribute of steak (Callahan *et al.*, 2013). Thus, superheated steam cooked steak had the best tenderness.

Sensory properties of the chicken steak

The sensory traits of the chicken steak after cooking

Table 3. Effect of different cooking methods on textural attributes of chicken steaks

Parameters	BC	CO	GC	MC	SSC
Hardness (kg)	1.93±0.18 ^A	1.13±0.06 ^B	1.89±0.13 ^A	1.23±0.18 ^B	0.76±0.04 ^C
Springiness	0.73±0.04	0.75±0.05	0.76±0.03	0.79±0.04	0.71±0.06
Cohesiveness	0.49±0.03	0.48±0.04	0.48±0.03	0.47±0.03	0.45±0.05
Gumminess (kg)	1.41±0.11 ^A	0.84±0.08 ^B	1.45±0.11 ^A	0.97±0.19 ^B	0.54±0.07 ^C
Chewiness (kg)	1.03±0.06 ^A	0.64±0.06 ^B	1.11±0.10 ^A	0.76±0.18 ^B	0.39±0.08 ^C

All values are mean±standard deviation of three replicates (n=9).

^{A-C}Means within a row with different letters are significantly different ($p<0.05$).

¹⁾BC, chicken steak cooked with boiled; CO, chicken steak cooked with convective oven; GC, chicken steak cooked with grilling; MC, chicken steak cooked with microwave oven; SSC, chicken steak cooked with superheated steam.

Table 4. Effect of different cooking methods on sensory properties of chicken steaks

Parameters	BC	CO	GC	MC	SSC
Color	7.22±0.57 ^B	7.00±0.70 ^B	8.18±0.61 ^A	7.09±0.64 ^B	7.18±0.82 ^B
Flavor	7.18±0.75	7.23±0.81	7.82±0.67	7.73±0.68	7.27±0.85
Tenderness	6.73±0.81 ^C	7.27±0.75 ^B	6.64±0.72 ^C	7.73±0.71 ^B	8.36±0.71 ^A
Juiciness	6.55±0.82 ^C	7.00±0.74 ^B	6.54±0.75 ^C	7.42±0.77 ^B	8.18±0.72 ^A
Overall acceptability	6.82±0.48 ^C	7.36±0.45 ^B	7.55±0.71 ^B	7.45±0.72 ^B	8.09±0.65 ^A

All values are mean±standard deviation of three replicates (n=9).

^{A-C}Means within a row with different letters are significantly different ($p<0.05$).

Sensory scores were evaluated using a 10-point descriptive scale.

¹⁾BC, chicken steak cooked with boiled; CO, chicken steak cooked with convective oven; GC, chicken steak cooked with grilling; MC, chicken steak cooked with microwave oven; SSC, chicken steak cooked with superheated steam.

with various methods are given in Table 4. The chicken steak was evaluated for color, flavor, tenderness, juiciness, and overall acceptability. The grilled samples had the highest color scores ($p < 0.05$), compared to those of the other samples ($p < 0.05$). Tenderness, juiciness, and overall acceptability scores were highest for the superheated steam samples ($p < 0.05$), whereas no difference in flavor scores was observed among the other treatments ($p > 0.05$). These results agree with those reported by Seo *et al.* (2014) who found that superheated steam cooking contributes to increase the satisfaction scores for taste, texture, juiciness, and overall preference. Similar results were obtained by Oh *et al.* (2010) for the influence of superheated steam cooking on the sensory qualities of chicken fillets. They reported that the superheated steam cooking conditions showing the best sensory characteristics in filets were 300°C oven temperature, 330°C steam temperature, and an 8 min cooking time. Chun *et al.* (2013) reported that superheated steam cooked meat has better acceptability, tenderness, juiciness, and flavor scores compared to those of oven-cooked. Thus, superheated steam-cooked chicken steak showed the best sensory characteristics among the various cooking methods. As superheated steam is of high temperature for a short time, the bound water in the steak is not expelled, and the protein denatures and solidifies in a short time. Thus, it was possible to prepare chicken steak with excellent water holding capacity. Therefore, a relationship was observed between heating rate and the quality of the chicken steak in accordance with cooking method.

Conclusion

Chicken steak cooked with superheated steam had improved cooking loss and textural properties. Chicken steak treated with superheated steam had higher overall acceptability than that of other cooking methods. Therefore, superheated steam was useful to improve chicken steak. The optimal superheated steam conditions were 250°C oven and 380°C steam for about 5 min until core temperature reached 75°C.

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