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ARTICLE

Effects of Various Salts on Physicochemical Properties and Sensory Characteristics of Cured Meat

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Abstract

This study was carried out to investigate the effects of refined, solar, and bamboo salt on the physico-chemical properties and sensory characteristics of cured pork loin. Moisture, protein, fat, and ash content, lightness, yellowness, cooking yield, and color, juiciness, and tenderness of sensory properties on curing pork loin exhibited no significant differences regardless of the nature of salts. The pH of raw and cooked cured pork loin with added bamboo salt was higher that of other salt treatments. However, the cooking loss, and Warner-Bratzler shear force of cured pork loin with added refined salt was lower than those of solar and bamboo salt pork loins cured. The flavor and overall acceptability scores of treatments with refined salt was higher than those of solar and bamboo salt treatments. The unique flavor of bamboo salt can render it as a functional material for marinating meat products. In addition, the results of this study reveal potential use of bamboo salt in meat curing.

Keywords: pork loin, curing meat, refined salt, solar salt, bamboo salt

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Introduction

Meat product is one of the main sources of salt in human diet (Ruusunes and Puolanne, 2005), and salt contributes to the flavor of processed meats and adds functional benefits such as preservation, emulsification, tenderness and juiciness to meat products (O'Flynn *et al.*, 2014). Accordingly, it is necessary to ensure an adequate salt content in cured meat products to maintain microbiological stability and circumvent excessive softness (Choi *et al.*, 2006b). Generally, three types of salt are used in food processing such as refined salt, solar salt, and processed salt (Lee *et al.*, 2007; Lee and Lee, 2014). Solar salt is made from seawater, but relies on natural sun- and wind-mediated evaporation of salt brine held in open ponds (Seo *et al.*, 2012), solar salt contains 92.4-94.4% sodium chloride, and various minerals such as calcium, potassium, magnesium, and sulfur (Ha and Park, 1998). Refined salt contains 99.8% sodium chloride and is made from seawater by electrodialysis using ion-exchange membranes with subsequent evaporation in an evaporator tube (Lee *et al.*, 2003). Currently, refined salt is commonly employed in processing of meat products. Bamboo salt is a form of processed salt, which is made from roasting, burning, and melting, and it is processing referred to as a salt deformation processing (Zhao *et al.*, 2012). Bamboo salt is formed by eliminating the harmful ingredients through firing salt at a minimum of 800°C for eight times and melting at minimum of 1500°C. According to Kim *et al.* (2010), bamboo salt is beneficial for health as it is produced using processes that lead to decreased toxicity and strong alkalinity. Zhao *et al.* (2012) reported that bamboo salt at a concentration of 25%, showed higher anti-oxidative activity than solar and refined salts. Moreover, it is known to have therapeutic effects for diseases such as viral diseases, dental plaque, gastropathy, diabetes, circulatory organ disorders, cancer, and anti-inflammatory disorders (Kim *et al.*, 2012; Yang *et al.*, 1999; Yoo *et al.*, 2000). However, utilization of bamboo salt in commercial products has so far been limited.

Therefore, the objective of this study was to compare

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the quality characteristics of pork loin cured with three different types of salts.

Materials and Methods

Preparation and processing of pork loins

Fresh pork loin (*M. longissimus dorsi*) with 70.51% moisture, 4.78% fat, and 16.38% protein content from 5 months old castrated boars [Landrace × Yorkshire × Duroc] was purchased from a local processor 48 h post-mortem. All subcutaneous, intramuscular fat, and visible connective tissue were removed by utilizing a knife from the fresh loin muscle. Three different modes of treatments were prepared. The treatment sample was prepared using different curing solutions; salt (8%), phosphate (1%), and ice water (91%); and refined salt, solar salt, and bamboo salt, were employed respectively. Table 1 shows the proximate composition, pH, color, and salinity of various salt. Typically, 40% curing solution was added in proportion to the pork loin, and the meat was tumbled using a tumbler (MKR-150C, Ruhle GmbH., Germany). The tumbling conditions were set to 0°C for 60 min under vacuum pressure (0.75 bar, 25 rpm). The tumbled pork loin samples were aged overnight (24 h), heat processed using the steam cooking methods until core temperature reached 75°C, and with subsequent cooling at room temperature (24°C) for 30 min. This procedure was performed in triplicate for each treatment, and all the analyses were carried out at least in triplicate for each treatment.

Proximate composition

Compositional properties of the cured pork loins were performed according to AOAC (2000). Moisture content (950.46B) was determined by measuring the weight loss of samples 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scienctific Co., Korea). Fat content (960.69) was determined by the Soxhlet method using a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Sweden) and protein content (981.10) was determined by Kjeldahl method using an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Sweden). Ash content was determined according to AOAC method 920.153 (muffle furnace).

Salinity

Mohr's titration was carried out according to the method described by Chen *et al*. (2005). The salinity of the sample was calculated according to the amount of titrated chloride ion. Means with standard deviations of triplicate determinations were reported.

pH

The pH values of samples 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) (Choi *et al*., 2006a).

Color measurements

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

Curing yield

The curing yield (%) was determined using the weight differences between raw pork loin before and after curing as mentioned below (Choi *et al*., 2006b):

Curing yield (%) = [(weight of cured pork loin (g)) / weight of raw pork loin (g)] × 100

Table 1. Chemical and physical properties of various salts

Parameters	Refined salt	Solar salt	Bamboo salt
pH	6.54±0.02^C	7.93±0.03^B	10.71±0.02^A
Moisture content (%)	0.07±0.02^B	4.56±0.14^A	0.09±0.04^B
Ash content (%)	99.92±1.21^A	95.72±1.31^B	99.77±0.89^A
CIE L^*-value	91.10±0.94^C	83.11±0.85^B	98.25±1.08^A
CIE a^*-value	-0.07±0.34	-0.10±0.25	-0.03±0.39
CIE b^*-value	0.09±0.25^B	-0.01±0.19^B	0.80±0.19^A
Salinity (%)	89.20±0.45^A	84.73±0.78^B	88.92±0.83^A

All values are mean±standard deviation of triplicates.

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

Cooking loss

The cooking loss (%) was determined using the weight differences between cured pork loin before and after cooking (steam cooking methods until core temperature reached 75°C) as mentioned below (Choi *et al*., 2009):

Cooking loss (%) = [(weight of raw cured pork loin (g) – weight of cooked cured pork loin (g)) / weight of raw cured pork loin (g)] × 100

TBA values

Lipid oxidation was assessed in triplicate by the 2-thiobarbituric acid (TBA) method of Tarladgis *et al*. (1960) with minor modifications. A 10 g sample was blended with 50 mL distilled water for 2 min and transferred to a distillation tube. The cup used for blending was washed with an additional 47.5 mL of distilled water, and it was added to the same distillation flask with 2.5 mL of 4 N HCl and a few drops of an antifoam agent, silicone o/w (KMK-73, Shin-Etsu Silicone Co., Ltd., Korea). The mixture was distilled and 50 mL distillate was collected. Five mL of 0.02 M TBA in 90% acetic acid (TBA reagent) was added to a vial containing 5 mL of the distillate and mixed well. The vials were capped and heated in a boiling water bath (100°C) for 30 min to develop the chromogen and cooled to room temperature. The absorbance was measured at 538 nm, against a blank prepared with 5 mL distilled water and 5 mL TBA-reagent, using a UV/VIS spectrophotometer (Optizen 2120 UV plus, Mecasys Co. Ltd., Korea). Thiobarbituric acid-reactive substances (TBARS) content was calculated from a standard curve (8-50 nmol) of malondialdehyde (MA), freshly prepared by acidification of TEP (1,1,3,3-tetraethoxy poppane). Reagents were obtained from Sigma (UK). The TBARS levels were expressed as mg MA/kg sample.

Warner-Bratzler shear force (WBSF)

The WBSF values were measured at room temperature using a texture analyzer (TA-XT2*i*, Stable Micro Systems Ltd., England). The cooked samples (steam cooking methods until core temperature reached 75°C) were cooled at room temperature (24°C) for 30 min, and were allowed to equilibrate to room temperature. Each sample was cut with a knife into length × width: 3 × 4 cm sections and the sections were sheared in separate locations with Warner-Bratzler blade set attached to the texture analyzer. The Warner-Bratzler head moved at a crosshead speed of 200 mm/min. Data were collected and analyzed from Warner-Bratzler shear force values to obtain the maximum force required to shear through each sample which was then converted into kg (Combes *et al*., 2003).

Sensory evaluation

The sensory evaluations were performed in triplicate on each sample by sensory panelist. A trained 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 cured pork loin. Selection of trained panelists was performed according to sensory evaluation procedure (Lawless and Heymann, 1999). Each cured pork loin sample was evaluated for color, flavor, juiciness, tenderness, and overall acceptability. Cured pork loin samples were cooked until the core temperature reached 75°C, cooled to 24°C, cut into cubes (width × length × depth: 3 × 4 × 1.5 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 before tasting the next 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 were reported. One way analysis of variance was performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package (2008). Duncan's multiple range test ($p<0.05$) was used to determine the differences among treatments.

Results and Discussion

Proximate composition and salinity

The proximate composition and salinity of cured pork loin formulated with various salts are given in Table 2. Moisture, protein, fat, and ash contents of cured pork loin did not show significant differences regardless of the addition of various salts. These results are in agreement with the results reported by Lee and Lee (2014), which

Table 2. Effect of various salts on proximate composition and salinity of cured pork loin

Parameters	Refined salt	Solar salt	Bamboo salt
Moisture (%)	70.24±1.69	69.27±1.25	69.65±1.19
Protein (%)	21.21±0.79	21.31±1.04	21.19±1.11
Fat (%)	5.39±0.52	5.33±0.31	5.28±0.38
Ash (%)	2.53±0.14	2.69±0.15	2.81±0.19
Salinity (%)	3.25±0.21^{A}	2.89±0.18^{B}	3.00±0.21^{B}

All values are mean±standard deviation of triplicates.
^{A,B}Means within a row with different letters are significantly different (p<0.05).

state similar proximate composition of *tteokgalbi* in the presence of various salts types. They suggested that any differences in proximate analysis did not track differences in formulation with added refined or solar salt. Kang *et al*. (2009) reported preblending effects of cured agents on the characteristics of mechanically deboned chicken meat. Preblending with different curing agents was found to have significant effect on protein, fat, and ash contents.

The differences in salinity of cured pork loins were observed to be significant (Table 2). The salinity of treatment with refined salt was higher than that of other treatment samples, due to the influence by salinity of salt. Lee *et al*. (2011) reported content of sodium chloride in refined salt as 99.8% and that in solar and processed salts as 92.4-94.4%.

pH and color

Table 3 provides the pH, L*-value (lightness), a*-value (redness), and b*-value (yellowness) for raw and cooked cured pork loin formulated with various salts. The pH of raw and cooked cured pork loin with added bamboo salt was higher than that of other salt treatment samples, due to higher pH of bamboo salt (Zhao *et al*., 2012). Kim *et al*. (2010) reported similar results for added effects of bamboo salt in meat emulsion systems. Their study demonstrated higher pH of the meat batter with added bamboo salt compared to batter with added refined salt. It is already proven that bamboo salt contains high levels of K, Ca, and alkali or alkaline minerals (Zhao *et al*., 2012), which contributes to high pH value of the meat batter. Lee and Lee (2014) reported that addition of refined salt and solar salt to *tteokgalbi* produced no changes in the pH value of meat products.

The differences in redness and yellowness values of cured pork loin were found to be significant (Table 3). No significant difference in the lightness value for the raw and cooked cured pork loin between various salt types was observed; however redness values of raw and cooked cured pork loin with solar salt was the lowest (p<0.05). The yellowness of raw treatment with bamboo salt was the highest (p<0.05), and the yellowness of cooked treatments with refined and bamboo salt were the highest (p<0.05). Kim *et al*. (2007) reported that the lightness of the food in the presence of bamboo salt was lower when compared to Korean solar salt, and redness of meat on treatment with Korean solar salt was lower when compared to bamboo salt. Cho and Kim (2010) reported no significant differences in the color values of salt-fermented shrimp prepared with various salts.

Curing yield, cooking loss, TBA value, and Warner-Bratzler shear force (WBSF)

The curing yields of cured pork loin formulated with different kinds of salts are shown in Table 4. Curing yield

Table 3. Effect of various salts on pH and color values of cured pork loin

Parameters		Refined salt	Solar salt	Bamboo salt
Raw	pH	5.95±0.02^{B}	5.94±0.03^{B}	6.01±0.02^{A}
	CIE L*-value	57.27±1.35	58.90±1.66	56.97±1.08
	CIE a*-value	4.14±0.51^{AB}	3.96±0.87^{B}	4.98±0.54^{A}
	CIE b*-value	3.26±0.93^{B}	3.64±0.93^{B}	4.05±0.37^{A}
Cooked	pH	6.25±0.03^{B}	6.17±0.21^{C}	6.43±0.02^{A}
	CIE L*-value	78.79±0.53	78.75±0.26	78.24±1.14
	CIE a*-value	1.14±0.35^{A}	0.60±0.24^{B}	0.96±0.48^{AB}
	CIE b*-value	5.24±0.57^{AB}	4.97±0.65^{B}	5.88±0.49^{A}

All values are mean±standard deviation of triplicates.
$^{A-C}$Means within a row with different letters are significantly different (p<0.05).

of cured pork loin did not show significant differences regardless of the addition of various salts ($p>0.05$). Some studies have provided insights on the effects of salt contents, curing periods, curing temperature, and additives on curing yield (Choi *et al*., 2006a). However, in this study, ever slightly different salt concentrations produced no statistically significant differences in the curing yield.

The effects of various salts on the cooking loss of the cured pork loins are shown in Table 4. The cooking loss of cured pork loin with refined salt was lower than treatments with solar salt and bamboo salt ($p<0.05$); however, no significant difference was observed between the treatments with solar salt and bamboo salt ($p>0.05$). According to Lee and Lee (2014), no significant difference in cooking loss of *tteokgabli* prepared with refined salt and solar salt was observed. In contrast to results of the present study, Kim *et al*. (2010) reported lower cooking loss of meat batter prepared with bamboo salt when compared to meat batter prepared with refined salt, which could probably be due to significantly higher pH of bamboo salt when compared to other samples. The myofibrils with a high pH had more effect on water content, and it can be attributed to the effect of pH on the net charge on the myofibrillar proteins (Hamm, 1986). In general, cooking loss of meat products is known to be affected by size and shape of chopped meat, meat composition, fat type and content, salt content, and presence of various additives (Choi *et al*., 2009).

The highest TBA value was the cured pork loins with refined salt ($p<0.05$)(Table 4). Generally, TBA value is affected by salt concentration. In the present study, it appears that refined salt promotes lipid oxidation faster than bamboo salts. The bamboo salt well be known to antioxidant properties (Zhao *et al*., 2012), and bamboo salt treatment is shown to be the lowest TBA values. Lee and Lee (2014) reported a significantly lower TBA value in solar salt treated *tteokgalbi* when compared to refined salt treatment. In general, sodium chloride affects lipid oxidation due to the release of iron ions from heme pigments (Buckely *et al*., 1989). TBA is widely used as indicator of lipid oxidation in meat products. Typically, malonaldehyde concentrations higher than 0.5 mg/kg are considered as threshold value for rancidity perception by consumers (Kang *et al*., 2009).

The effects of various salts on the WBSF values of cured pork loins are presented in Table 4. The WBSF values of the treatment with refined salt was lower when compared to other salt treatments ($p<0.05$). Lee and Lee (2014) reported similar results in hardness of meat products which treatment with refined salt was the lowest. According to Na and Ha (2009), myofibrillar proteins in muscle become solubilized when salt is added to meat, which enhances binding strength texture. Normally, sodium chloride increases the shear force, and shear force is affected by composition of meat products and various additives. The present results are in agreement with those reported by Lim and Yang (2014), which stated that preblending of marinade solutions decreased shear force when compared to control without salt.

Sensory evaluation

The sensory properties of cured pork loin in the presence of various salts are shown in Table 5. The color, juiciness, and tenderness scores were not significantly different between the different treatments with various salts ($p>0.05$). The flavor and overall acceptability of cured pork loin treated with refined salt scored the highest score ($p<0.05$). These results are in agreement with Lee and Lee (2014), who reported that various kinds of salt had no effect on the quality of *tteokgalbi* with respect to color and juiciness scores as per sensory evaluation. Moreover, overall acceptability of *tteokgalbi* with solar salt was significantly higher than the control with refined salt. However, Kim *et al*. (2010) reported absence of significant differences in color, flavor, tenderness, juiciness, and overall acceptance in meat batters treated with refined, solar and two times baked bamboo salt. In the present study, treatments with solar and bamboo salts had lower overall acceptability scores and lower flavor scores due to changes in flavor, and presence of mineral impuri-

Table 4. Effect of various salts on curing yield, cooking loss, TBA value, and Warner-Bratzler shear force of cured pork loin

Parameters	Refined salt	Solar salt	Bamboo salt
Curing yield (%)	103.89±0.89	102.31±1.15	102.78±0.91
Cooking loss (%)	7.71±0.95^{B}	8.41±0.68^{A}	8.26±0.52^{A}
TBA (mg/ kg)	0.09±0.04^{A}	0.07±0.03^{AB}	0.04±0.06^{B}
Warner-Bratzler shear force (kg)	4.46±0.78^{B}	5.95±0.15^{A}	5.67±0.73^{A}

All values are mean±standard deviation of triplicates.
^{A,B}Means within a row with different letters are significantly different ($p<0.05$).

Table 5. Effect of various salts on sensory characteristics of cured pork loin

Parameters	Refined salt	Solar salt	Bamboo salt
Color	7.70±0.67	7.72±0.55	7.71±0.76
Flavor	7.44±0.73^{A}	7.01±0.60^{AB}	6.50±0.52^{B}
Juiciness	7.56±0.72	6.89±0.85	7.02±0.78
Tenderness	7.22±0.24	6.44±0.24	6.78±0.39
Overall acceptability	7.67±0.50^{A}	6.78±0.83^{B}	6.89±0.33^{B}

All values are mean±standard deviation of triplicates.
^{A,B}Means within a row with different letters are significantly different (p<0.05).

ties and sulfur content, respectively (Kim *et al*., 2007; Zhao *et al*., 2012).

Conclusion

In the present study, we have compared the quality characteristics of cured pork loin in the presence of various salt types. The obtained results suggest that the salt types used in cured pork loin affect the quality of the meat products. Especially, flavor of cured pork loin was negatively affected by solar and bamboo salt, due to presence of mineral impurities and sulfur content, respectively. Hence, it is proposed that the unique flavor of bamboo salt can render it as a functional material for marinating meat products. In addition, the results of this study reveal potential use of bamboo salt in curing of meat products.

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