



Effects of Various Kinds of Salt on the Quality and Storage Characteristics of Tteokgalbi

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Abstract

This study was carried out to evaluate the effects of various kinds of salt on the quality and storage characteristics of tteokgalbi. The tteokgalbi was prepared using four types of salt: 1.5% purified salt (control, C), 1.5% five-year-old solar salt (FS), 1.5% Topan solar salt (TS), and 1.5% French Guérande solar salt (GS). The moisture, crude lipid, crude ash, crude protein and calorie contents, water holding capacity, and cooking loss were not significantly different between control and all other treatments. As for the textural characteristics, the use of GS increased the hardness of the tteokgalbi. According to the sensory evaluation, the use of TS had the best score in springiness. Tteokgalbi made with TS and GS had the two highest scores in flavor and total acceptability. During 15 d of storage, the contents of 2-thiobarbituric acid (TBA) value, volatile basic nitrogen (VBN) and the total microbial counts increased, while the pH decreased. The TBA values of the tteokgalbi containing TS and GS were lower than that of C. Lightness (*L*) and yellowness (*b*) values decreased during storage, but redness (*a*) displayed no significant difference during storage. Overall, the best results, in terms of TBA value and sensory attributes, were obtained for the tteokgalbi containing TS and GS.

Keywords: solar salt, tteokgalbi, thiobarbituric acid value, quality

Introduction

Modern society has brought many changes to the structure and style of dietary habits along with a qualitative improvement of life in Korea, as the technology and information industries have developed. Particularly, westernization of the Korean diet has resulted in a decrease in grain consumption and an increase in meat consumption (Kim *et al.*, 2007). Furthermore, development of the food service industry has facilitated an annual increase in minced beef or pork consumption through hamburger patties, sausage, meatballs, and tteokgalbi (Hansley and Hand, 1995). Tteokgalbi is a type of Korean native local food from galbi, or short ribs which is a good representative of Korean food flavor. Tteok means sticky rice cakes and galbi is a marinated Korean meat dish. Tteokgalbi is grilled short rib meat patties and hand-chopped beef short ribs mixed with vegetables, aromatics, sometimes even

pork into a rectangular appearance, then grilled over a hot charcoal fire. The reason pork and beef are mixed is that beef alone is too dry, so pork is added to make it more fatty. It is loved by people of all ages since its texture is soft and tasty, and available all year round (Choi *et al.*, 2011). Among seasonings used in tteokgalbi, salt improves the taste and flavor of the meat, and melds the proteins in the meat into a gelatinous form to enhance binding quality, chewiness and texture of the meat. It also prevents spoiling of the meat by inhibiting bacterial propagation (Na and Ha, 2009). Therefore, taste, flavor and quality of tteokgalbi may differ according to the kind and composition of the salt used in producing it.

Salt, also commonly referred to as table salt, is a crystalline substance composed primarily of sodium chloride that has been widely used as a food seasoning for thousands of years (Na and Ha, 2009). Salt is one of the major sources of sodium; human blood and cells contain ~0.9% salt, which is involved in many homeostatic mechanisms. Salt helps maintain the electrochemical potential difference across cell membranes, is involved in material transport, helps control body fluid osmotic pressure, helps maintain acid-base equilibrium, and is involved in the

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transmission of information in our nerves and stimuli in muscles. It also aids in heart function, the digestion and absorption of many nutrients, and in the secretion of the hydrochloric acid component of gastric acid (Chang *et al.*, 2010; Kang, 2006).

As of now, there are three types of salt used in food processing such as solar salt, purified salt, and processed salt (Lee *et al.*, 2007). Purified salt is made from sea water by electrodialysis using ion-exchange membranes and then evaporated in an evaporator tube (Na and Ha, 2009). Solar salt is also made from sea water but relies on natural sun- and wind-mediated evaporation of salt brine held in open ponds (Hwang, 1988). Solar salt is classified into Topan solar salt (gray salt) and Jangpan solar salt (white salt) depending on the manufacturing method. Topan solar salt is harvested from the bottom of salt pans covered with soil from tidal fields or yellow soil. Jangpan solar salt is also harvested from the bottom of salt pans, but which have been covered instead with PVC or tiles (Joo *et al.*, 2009). Purified salt contains 99.8% sodium chloride, while solar salt contains diverse minerals such as calcium, potassium, magnesium, and sulfur, in addition to 92.4-94.4% sodium chloride (Ha and Park, 1998). Salt produced on the west coast of Korea and the Guérande salt produced in France are solar salts harvested from tidal mudflats. While Korean solar salt contains lower levels of sodium chloride than the world-famous French Guérande salt, it contains more minerals such as potassium and magnesium (Jin *et al.*, 2011). The use of Korean solar salt has been limited as it has been classified as a mineral pursuant under the 1962 Salt Management Act. However, in March 2008 it was reclassified as food by the revised Salt Management Act, allowing the use of solar salt by the food industry (Jeon, 2009). Moreover, similarities in the manufacturing processes of Korean TS and GS have become known to the public, thus drawing attention to Korean TS in both domestic and international salt markets and triggering many studies on Korean solar salt (Jin *et al.*, 2011). However, these studies have focused mostly on mineral content of Korean solar salt (Ha and Park, 1998; Jin *et al.*, 2011), characteristics of salt-fermented food (Cho and Kim, 2010; Lee *et al.*, 2011), and the safety of salt (Kim *et al.*, 2012; Na and Ha, 2009).

Therefore, the purpose of this study was to compare the quality and characteristics of tteokgalbi, a local dish in South Jeolla Province, seasoned with different types of salt during its storage period in order to promote the use of Korean solar salt and develop recipes that use the salt.

Materials and Methods

Preparation of tteokgalbi

Tteokgalbi was produced using a traditional method (Lee *et al.* 2008, 2013). Boneless beef rib muscle and pork meat from shoulder were obtained fresh from a local meat market. The beef and pork meat were prepared by first removing the connective tissue and excess fat and ground using a meat processor (M-12S, Hankook Fugee Industries Co., Korea) and a grinding plate with 8 mm diameter holes. The ground beef and pork meat mixed with 3.0% sugar, 2.8% scallion, 2.0% chopped garlic, 0.2% ground black pepper, 3.0% sesame oil, 0.5% ginger juice, 1.2% chopped onion, 0.5% rice wine, 1.0% honey, 0.3% sesame, 2.0% starch syrup, 1.0% flour and 1.5% purified salt was used as the control (C), and the experimental samples contained one of the solar salts: 1.5% FS, 1.5% TS, or 1.5% GS (Table 1). The meat and ingredients were mixed for 15 min at 4°C by hand. After mixing, the mixtures were stored in a cold room for 1 d. Each mixture was molded to a diameter of 10.0 cm, thickness of 1.2 cm and a weight of 100 g using a patty molding machine, and this experiment was performed by opening the package of each experimental group on days 0, 5, 10 and 15 while keeping for 15 d at 5°C after vacuum packing in nylon/polyethylene film.

Table 1. Formula of tteokgalbi prepared with various kinds of salts

Ingredients	C ¹⁾	FS	TS	GS
Beef	70.00	70.00	70.0	70.0
Pork	10.00	10.0	10.0	10.0
Sugar	3.00	3.00	3.00	3.00
Scallion	2.80	2.80	2.80	2.80
Chopped garlic	2.00	2.00	2.00	2.00
Ground black pepper	0.20	0.20	0.20	0.20
Sesame oil	3.0	3.0	3.0	3.0
Ginger	0.50	0.50	0.50	0.50
Onion	1.20	1.20	1.20	1.20
Rice wine	0.50	0.50	0.50	0.50
Honey	1.00	1.00	1.00	1.00
Sesame	0.30	0.30	0.30	0.30
Starch syrup	2.00	2.00	2.00	2.00
Flour	1.00	1.00	1.00	1.00
Purified salt	1.50	0.00	0.00	0.00
Five-year-old solar salt	0.00	1.50	0.00	0.00
Topan solar salt	0.00	0.00	1.50	0.00
Guérande solar salt	0.00	0.00	0.00	1.50

¹⁾C (Control: Purified salt 1.5%), FS (Five-year-old solar salt 1.5%), TS (Topan solar salt 1.5%), GS (Guérande solar salt 1.5%).

Proximate composition

The analysis of the proximate composition of samples was conducted in accordance with the method described by the Association of Official Analytical Chemists (AOAC, 1990). Moisture was analyzed using a drying method by heating under atmospheric pressure at 105°C, crude protein was analyzed by the micro-Kjeldahl method, whereas the crude lipid was analyzed by the Soxhlet extraction method, crude ash was analyzed by the ashing method, and calories were analyzed using a calorimeter (PARR 1351 Bomb Calorimeter, USA).

Measurement of water holding capacity (WHC)

The measurement of WHC was performed in accordance with the method of Laakkonen *et al.* (1970). Briefly, 0.5±0.05 g of sample was heated at 80°C for 20 min in a water bath (HB-205SW, Hanbaek Scientific Co., Incheon, Korea), allowed to cool to room temperature for 10 min, centrifuged at 6,710 g at 4°C for 10 min and measured the volume of meat juices in the lower part of the tube, after which is calculated using the equation.

$$\text{WHO (\%)} = \frac{\text{extracted meat juice (mL)} \times 0.951}{\text{total moisture in the sample (g)}} \times 100$$

0.951: pure water amount for meat moisture which is separated under 70°C

Measurement of cooking loss

For cooking loss, the cooking pan was preheated on an open flame for 30 s, and then each tteokgalbi sample was placed on the pan and heated until the center temperature reached at 72°C and then cooked for another 15 min. The samples were then transferred to a wire net and allowed to cool for 30 min and their weights were measured. Cooking loss was calculated as the percentage change in weight before and after cooking.

Texture profile analysis

The texture profile analysis of the cooked tteokgalbi was measured by the Rheometer (Compac-100, Sun Scientific Co., Japan) and analyzed using Rheology Data System version 2.01. Table speed was 110 mm/min, graph interval was 20 m/sec, and load cell (max) was 10 kg. Hardness (g), cohesiveness, springiness, and chewiness (g) were determined by Bourne (1978).

Sensory evaluation

Sensory evaluation was conducted after explaining in

advance the evaluation content to the evaluation group, which consisted of ten food-related-major students and graduate students who were already knowledgeable about the sensory test. The color, sweetness, saltiness, springiness, flavor, juiciness, and overall acceptability were evaluated on a 5 point scale, where 'extremely good' = 5 points, 'moderately like' = 3 points, and 'extremely unlike' = 1 point with respect to each evaluation item. The sample was heated and cooked as described above and then tested by placing it on a white dish after cutting into 2 cm × 2 cm × 1.5 cm pieces; drinking water was provided between each sample.

Determination of pH

The pH values of tteokgalbi were measured according to the method of Khalil (2000). Ten g of sample was taken and then homogenized for 30 s by using a Stomacher 400 Lab blender (Seward Ltd., England) in 100 mL distilled water, and then the pH of sample was measured with a pH-meter (WTW pH 720, Germany).

2-Thiobarbituric acid value

Thiobarbituric acid (TBA) value was measured using a modified version of the extraction method by Witte *et al.* (1970). To 10 g of each sample was added 15 mL cold 10% perchloric acid and 25 mL triple-distilled water. Samples were homogenized at 10,000 rpm for 10 s in an AM-Series homogenizer, and the homogenate was followed by filtration through qualitative Whatman filter paper (No. 2, GE Healthcare, UK). Five mL of 0.02 M TBA was added to 5 mL of sample filtrate and its absorbance was measured at 529 nm using a DU-650 spectrophotometer (Beckman, USA) after allowing it to stand for 16 h in a cool and dark place. 1,1,3,3,-Tetraethoxypropane (Sigma-Aldrich, USA) was used as standard for TBA assay. The triple-distilled water served as the blank. TBA values were expressed as mg malonaldehyde (MA) per 1 kg sample based on a TBA standard curve.

Volatile basic nitrogen (VBN) value

The content of volatile basic nitrogen (VBN) was measured by microdiffusion analysis (Short, 1954) using a Conway unit. Distilled water (90 mL) was added to 10 g of each sample followed by homogenization at 10,000 rpm for 30 s in an AM-Series homogenizer and filtration using qualitative filter paper No. 2. The filtrate (1 mL) was placed in the outer chamber of the Conway unit, and 1 mL 0.01 N boric acid and 3 drops of indicator dye (0.066% methyl red + 0.066% bromocresol green) were

added to the inner chamber. Glycerine was applied to the contact surface of the lid, and the lid was closed and 1 mL 50% K_2CO_3 was injected into the outer chamber. After sealing the chamber and horizontally stirring, the unit was incubated at 37°C for 120 min followed by titrating the boric acid in the inner chamber with 0.02 N H_2SO_4 . The value of VBN was expressed by converting to mg per 100 g sample (mg%).

$$\text{VBN (mg\%)} = \{(a - b) \times F \times 28.014 \times 100\} / \text{sample weight (g)}$$

a: Amount of injected sulfuric acid (mL)

b: Amount of sulfuric acid injected in blank (mL)

F: Standardized index of 0.02 N H_2SO_4

28.014: Amount required to consume 1 mL 0.02 N H_2SO_4

Microbiological analysis

Ten-gram samples were taken aseptically from each treatment, transferred to sterile plastic pouches and homogenized with 90 mL 0.1% peptone solution in a Stomacher 400 Lab Blender (Seward Ltd., England) for 1.5 min. Serial 10-fold dilutions in liquid culture broth were prepared from each sample and then inoculated on plate count agar (PCA) medium and incubated for 48 h at 37°C (Harrigan and MaCane, 1976). The results were expressed as log colony forming units (CFU)/g.

Instrumental color evaluation

The meat color was measured by a spectrophotometer (Model JX-777, Color Techno System Co., Japan) that was standardized to the white plate (L, 94.04; a, 0.13; b, -0.51). A white fluorescent lamp (D65) was used as the light source, and the meat color was indicated by the lightness (L), redness (a), and yellowness (b) values of Hunter lab color coordinates.

Statistical analysis

Three replications of this study were performed and measured of all parameters were made in duplicate. Statistical analysis was performed by computing analysis of variance using the SAS program (2002) and significance was verified at the level of 5% using Duncan's multiple range test.

Results and Discussion

Proximate composition and calorie content of tteokgalbi added with various kinds of salts

The proximate composition and calorie content of tteokgalbi prepared with various kinds of salts are shown in Table 2. Moisture and crude ash contents of tteokgalbi did not show significant differences regardless of the addition of various kinds of salts. The crude lipid and crude protein contents were also not significantly different between control and all other treatments. According to a study by Jang *et al.* (2011), the moisture contents of purified salt and solar salt are 0.01% and 10.76-12.51%, respectively. A study by Kim *et al.* (2005) reported that the quantities of microelements in these two salts are 1.3% and 3.3%, respectively. Na *et al.* (2012) found that the iron and zinc contents of gray salt (Topan salt) were higher than those of white salt (Jangpan salt) while the calcium, potassium, and magnesium contents were lower than those of white salt. Jin *et al.* (2011) reported that the sodium chloride contents of white salt, gray salt and French Guérande salt (gray salt) were 85.1, 89.3, and 91.3%, respectively. The sodium content of the white salt was found to be slightly lower than that of Guérande salt while magnesium and potassium contents of the white salt were found to be higher than those of Guérande salt. Little difference in this study was detected in the moisture and crude ash contents of tteokgalbi, probably because only slight amounts of salt were added. Total calories content of tteokgalbi ranged between ~2,248.00-2,314.00 kcal/g with no statis-

Table 2. Proximate compositions of tteokgalbi prepared with various kinds of salts

Items	Treatments ¹⁾			
	C	FS	TS	GS
Moisture (%)	66.10±0.32 ^{2)NS3)}	65.32±0.41	66.06±0.43	65.54±0.36
Crude lipid (%)	7.58±0.46 ^{NS}	8.02±0.14	7.62±0.29	7.68±0.16
Crude ash (%)	2.80±0.13 ^{NS}	2.74±0.08	2.80±0.08	2.65±0.05
Crude protein (%)	23.52±0.52 ^{NS}	23.91±0.12	23.53±0.38	24.13±0.13
Calorie (kcal/g)	2305.00±48.50 ^{NS}	2248.00±58.89	2314.00±55.43	2313.00±60.04

¹⁾Treatment: See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

³⁾NS: Not significant.

Table 3. Water holding capacity (WHC) and cooking loss of tteokgalbi prepared with various kinds of salts

Items	Treatments ¹⁾			
	C	FS	TS	GS
WHC (%)	71.69±0.78 ^{2)NS3)}	71.60±1.00	72.46±3.88	72.44±0.79
Cooking loss (%)	19.94±0.10 ^{NS}	19.60±0.39	19.73±0.71	19.69±1.56

¹⁾Treatment: See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

³⁾NS: not significant.

Table 4. Textural properties of tteokgalbi prepared with various kinds of salts

Items	Treatments ¹⁾			
	C	FS	TS	GS
Hardness (g)	1664.00±92.23 ^{2)NS3)}	2054.00±97.86 ^{ab}	1958.00±179.68 ^{ab}	2502.00±233.46 ^a
Cohesiveness (%)	33.69±1.47 ^{NS4)}	35.14±1.41	34.63±2.58	33.18±4.04
Springiness (%)	48.13±0.94 ^{NS}	53.84±3.98	47.35±1.54	53.91±2.87
Chewiness (g)	269.50±18.82 ^{NS}	397.21±49.49	332.53±55.89	461.57±91.86

¹⁾Treatment: See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

³⁾Means in the same row not sharing a common letter are significantly different ($p<0.05$) by Duncan's multiple range test.

⁴⁾NS: Not significant.

tically significant differences. These results suggest that the addition of these solar salts does not significantly affect the proximate composition and calorie content of tteokgalbi compared to control.

Water holding capacity (WHC) and cooking loss of tteokgalbi added with various kinds of salts

The WHC and cooking loss results of tteokgalbi prepared with various kinds of salts are shown in Table 3. The WHC value and cooking loss were not significantly different among the tteokgalbi preparations. WHC is defined as the ability of food to hold all or part of its own water without losing water to the spaces between original fibers (Huff-Lonergan and Lonergan, 2005). When meat is heated, fat and moisture tend to be discharged from the meat, decreasing the weight and size of the meat. Palatability tends to decrease if there is too much loss due to heating (Berry and Leddy, 1989). Cooking loss is known to be affected by many factors such as size and shape of the minced meat, type and content of fat, salt content, amount of additives, composition of the meat, etc. (Ruusunen *et al.*, 2005; Tarrant *et al.*, 1985). Ruusunen *et al.* (2005) reported that increase sodium content could reduce cooking loss. These results suggest the addition of the solar salts does not significantly affect the WHC or cooking loss of tteokgalbi compared to control salt.

Texture properties of tteokgalbi added with various kinds of salts

Results from the texture properties analysis of tteok-

galbi added with various kinds of salts are shown in Table 4. In terms of hardness, the lowest value was found in the control group, while the highest value was found in the GS. However, the cohesiveness, springiness and chewiness of tteokgalbi were not significantly different among the groups. In general, sodium chloride increased the hardness. The hardness and chewiness are affected by various factors such as the moisture and fat contents of meat products, and the kinds of additives (Song *et al.*, 2000). When salt is added to meat, myofibrillar proteins in muscle become solubilized, which enhances binding strength and creates a unique chewiness and texture (Na and Ha, 2009). In this study, there was slightly increased hardness score of tteokgalbi added with GS compared to the other samples. But moisture and fat contents were not significantly different among the tteokgalbi added with various kinds of salts. Thus, further research will be required to evaluate the differences in hardness depending on the different types of salt.

Sensory evaluation of tteokgalbi added with various kinds of salts

The sensory properties of tteokgalbi added with the various kinds of salts are shown in Table 5. The color, sweetness, and saltiness were not significantly different among the groups. The juiciness of tteokgalbi added with the solar salts (FS, TS and GS) received overall higher scores than the control group, but there were no statistically significant differences. Springiness of tteokgalbi added with TS was judged significantly better than the control (C). For

Table 5. Sensory evaluation of tteokgalbi prepared with various kinds of salts

Sensory Characteristics ²⁾	Treatments ¹⁾			
	C	FS	TS	GS
Color	3.94±0.23 ^{3)NS4)}	3.43±0.20	3.88±0.24	3.58±0.28
Sweetness	2.95±0.21 ^{NS}	2.93±0.17	3.24±0.27	3.16±0.24
Saltiness	3.81±0.36 ^{NS}	3.57±0.32	3.19±0.37	3.17±0.33
Juiciness	3.61±0.26 ^{NS}	4.18±0.28	4.41±0.36	4.19±0.38
Springiness	3.50±0.19 ^{b5)}	4.09±0.18 ^{ab}	4.61±0.25 ^a	4.24±0.40 ^{ab}
Flavor	3.57±0.20 ^b	4.03±0.24 ^b	4.77±0.23 ^a	4.83±0.16 ^a
Total acceptability	3.11±0.20 ^b	4.06±0.24 ^a	4.44±0.26 ^a	4.93±0.28 ^a

¹⁾Treatment: See the Table 1 legend.

²⁾1: dislike extremely, 3: neither like nor dislike, 5: like extremely.

³⁾All values are expressed as mean±SEM of triplicate determinations.

⁴⁾NS: Not significant.

⁵⁾Means in the same row not sharing a common letter are significantly different ($p<0.05$) as determined by Duncan's multiple range test.

Table 6. pH changes of total aerobic counts for raw tteokgalbi prepared with various kinds of salts during 15 d of storage at 5°C

storage time (d)	Treatments ¹⁾			
	C	FS	TS	GS
0	5.91±0.01 ^{2) b3)A4)}	5.98±0.01 ^{aA}	5.93±0.01 ^{bA}	5.94±0.01 ^{bA}
5	5.21±0.02 ^{cB}	5.31±0.03 ^{bB}	5.47±0.03 ^{aB}	5.43±0.01 ^{aB}
10	4.66±0.01 ^{aC}	4.60±0.01 ^{bC}	4.61±0.01 ^{bC}	4.64±0.01 ^{abC}
15	4.49±0.01 ^{bD}	4.56±0.01 ^{aC}	4.55±0.01 ^{aD}	4.55±0.01 ^{aD}

¹⁾Treatment : See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

^{3)a-d}Means with different superscripts within a row differ significantly ($p<0.05$).

^{4)A-D}Means with different superscripts within a column differ significantly ($p<0.05$).

flavor and overall acceptability, teokgalbi added with TS and GS were considered significantly better than the control (C). When meat products are heated, their palatability depends on ATP-related chemicals, sugars, organic acids, fatty acids, content of free amino acids and peptides and the type of muscle (Watanabe and Sato, 1974). The types and amounts of supplementary materials added to the meat product also greatly affect its palatability. As opposed to purified salt, which contains relatively high levels of sodium chloride, solar salt with its greater variety of minerals tends to enhance the palatability of meat products (Kim and Kim 2013). Therefore, tteokgalbi added with TS that contains many minerals and that added with GS produced positive results in terms of flavor and overall palatability.

Changes in pH of raw tteokgalbi added with various kinds of salts

Table 6 shows the pH changes in raw tteokgalbi added by refrigeration at 5°C with various kinds of salts over 15 days. The pHs immediately after preparing the raw tteokgalbi with the four kinds of salts (C, FS, TS and GS) were 5.91, 5.98, 5.93 and 5.94, respectively, while after storage 15 d the pH values dropped to 4.49, 4.56, 4.55 and 4.55, respectively. Tteokgalbi added with TS and GS showed

the highest pH values in comparison with the control group (C) after storage 5 d. Tteokgalbi added with FS and TS showed the lowest pH values in comparison with the control group after storage 10 d. Tteokgalbi added with solar salts (FS, TS and GS) showed significantly higher pH values in comparison with the control group (C) after storage 15 d. The different kinds of salt added to raw tteokgalbi seemed to have produced no changes in the pH value of meat products.

Changes in TBA value of raw tteokgalbi added with various kinds of salts

The TBA values in raw tteokgalbi added with various kinds of salts during refrigerated storage over 15 d are shown in Table 7. Initial TBA values for the control tteokgalbi added with purified salt and tteokgalbi added with various solar salts were significantly different. Moreover, the TBA value of tteokgalbi added with GS was significantly lower than the other treatment groups. However, TBA values in the meat products increased significantly over time; from the 10 d of the storage period, TBA values in tteokgalbi added with TS and GS were significantly lower than that of the control group (C). TBA is widely used as indicator of lipid oxidation in meat stud-

Table 7. Changes of TBA values for raw tteokgalbi prepared with various kinds of salts during 15 d of storage at 5°C

	storage time (d)	Treatments ¹⁾			
		C	FS	TS	GS
TBA (mg MA/kg)	0	0.29±0.01 ^{2)3)D4)}	0.26±0.01 ^{BD}	0.24±0.01 ^{CD}	0.22±0.01 ^{BD}
	5	0.40±0.01 ^{AC}	0.37±0.01 ^{BC}	0.32±0.01 ^{CC}	0.28±0.01 ^{DC}
	10	0.50±0.01 ^{AB}	0.42±0.01 ^{BB}	0.37±0.01 ^{CB}	0.36±0.01 ^{CB}
	15	0.65±0.02 ^{AA}	0.50±0.01 ^{BA}	0.46±0.01 ^{CA}	0.45±0.01 ^{CA}

¹⁾Treatment : See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

^{3)a-d}Means with different superscripts within a row differ significantly ($p<0.05$).

^{4)A-D}Means with different superscripts within a column differ significantly ($p<0.05$).

Table 8. Changes of VBN values for raw tteokgalbi prepared with various kinds of salts during 15 d of storage at 5°C

	storage time (d)	Treatments ¹⁾			
		C	FS	TS	GS
VBN (mg%)	0	7.78±0.46 ^{2)3)C4)}	6.95±0.24 ^{ABD}	6.59±0.16 ^{BD}	5.95±0.09 ^{BD}
	5	10.57±0.32 ^{NS5)B}	9.75±0.01 ^C	9.20±0.16 ^C	9.29±0.56 ^C
	10	11.67±0.16 ^{AB}	11.58±0.09 ^{AB}	10.39±0.16 ^{BB}	10.75±0.24 ^{BB}
	15	15.88±0.33 ^{NSA}	15.98±0.18 ^A	15.79±0.27 ^A	15.88±0.18 ^A

¹⁾Treatment: See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

^{3)a-d}Means with different superscripts within a row differ significantly ($p<0.05$).

^{4)A-D}Means with different superscripts within a column differ significantly ($p<0.05$).

^{5)NS}: Not significant.

ies. Sheard *et al.* (2000) indicate MA concentrations higher than 0.5 mg/kg as threshold values for rancidity perception by consumers. In the present study, the purified salt samples would be perceived as rancid after 10 d of storage whereas in the solar salts treatments MA concentrations did not exceed 0.5 mg/kg at the end of the storage period. Buckley *et al.* (1989) reported that sodium chloride affected lipid oxidation due to the release of iron ions from heme pigments. According to this result, it seems that purified salt (C) promoted lipid oxidation faster than Topan solar salt (TS) and Guérande solar salt (GS). TS and GS were still prooxidative, but it was weaker than purified salt. Different composition and amounts of minerals in salt affect the production of peroxides; it has been reported that solar salt is more effective than purified salt in inhibiting production of peroxides (Ha and Park, 1999). Therefore, our results suggest that the composition and amounts of minerals in Korean TS and French GS inhibited the lipid oxidation of the tteokgalbis seasoned with these two salts.

Changes in VBN values of raw tteokgalbi added with various kinds of salts

The VBN contents in raw tteokgalbi added refrigerated with various kinds of salts over 15 d are shown in Table 8. VBN content is considered an important index of meat product freshness. Proteins are decomposed into low molec-

ular weight substances such as albumose, peptone, peptides and amino acids, and then undergo reduction by bacteria to produce VBN (Crespo *et al.*, 1978); thus, an increase in bacteria and enzyme activity lead to an increase in VBN content. Foods with VBN content below 20 mg% are considered safe to eat (Korean Food & Drug Administration, 2002). In this study, VBN contents, as well as the microbial counts, increased significantly during storage. At 10 d, the control and FS samples had significantly higher VBN value of 11.7 and 11.6 mg%, compared with those of the samples with TS and GS added (10.4 and 10.8 mg%, respectively). These results suggest that the shelf-life of the tteokgalbi may be improved slightly by TS and GS. However, all of them remained fresh, with VBN content below 20 mg%. Na and Ha (2009) have reported that salts in food generally prevent decomposition by inhibiting the growth of harmful foodborn microorganisms. Therefore, these data suggest that salt delayed the decomposition of protein in our tteokgalbi preparations by inhibiting the growth of harmful foodborn microorganism.

Changes in total aerobic bacteria of raw tteokgalbi added with various kinds of salts

The total bacteria counts in raw tteokgalbi added refrigerated with various kinds of salt over 15 d are shown in Table 9. On the day of production, total plate counts in tteokgalbi ranged between 3.63-4.13 Log CFU/g and tteok-

galbi with TS had the smallest count. Over time, however, these counts increased significantly. On the 5 and 10 d of storage, the counts in tteokgalbi with TS and GS were significantly lower than that of the control (C). On the 15 d, the total plate counts in all tteokgalbis ranged between 7.30-7.72 Log CFU/g, and showed no significant differences. Jang *et al.* (1995) have reported that the growth of putrefactive bacteria at 5°C was inhibited in 2% salt steep liquid, while the preservability of the meat products was lengthened by 40-50 h in 3-4% salt steep liquid. In the current study, tteokgalbi was seasoned with 1.5% of the various salts, but only tteokgalbi seasoned with TS showed inhibition in the growth of microbial counts. These differences probably derived from the different composition of minerals in each salt. However, further investigation is needed as the inhibiting effects of the salts were not robust.

Instrumental color surface of raw tteokgalbi added with various kinds of salts

Table 10 shows the results for instrumental surface color

values of tteokgalbi added with various kinds of salts. *L* values represent lightness, while *b* values represent yellow color range. The two values were significantly low in tteokgalbi added with TS immediately following preparation, but differences between the control group (C) and solar salt groups (FS, FS and GS) decreased with time. While lightness of tteokgalbis added with C and FS decreased with time, lightness of tteokgalbis added with GS remained virtually constant during the storage period except on the day of preparation. However, lightness of tteokgalbis added with TS remained virtually constant during the whole period. The *a* values, which represent red color range, of tteokgalbi during the entire storage period, was not affected by the addition of salts. These results coincide with the report of Farouk and Swan (1998) that the changes in ionic strength due to the addition of salts did not influence the redness value of meat. On the other hand, Anderson *et al.* (1990) showed that the addition of 0.1% sodium chloride to minced meat tended to increase discoloration. It suggests that the red-

Table 9. Changes of total aerobic counts for raw tteokgalbi prepared with various kinds of salts during 15 d of storage at 5°C

storage time (d)	Treatments ¹⁾			
	C	FS	TS	GS
0	4.13±0.01 ^{2)a3)(C4)}	3.93±0.09 ^{abD)}	3.63±0.01 ^{bc)}	3.97±0.01 ^{ac)}
5	6.39±0.01 ^{ab)}	5.95±0.02 ^{bc)}	6.04±0.03 ^{bb)}	5.95±0.03 ^{bb)}
10	6.66±0.02 ^{ab)}	6.40±0.12 ^{abB)}	6.20±0.08 ^{bb)}	6.09±0.05 ^{bb)}
15	7.72±0.12 ^{NSA)}	7.60±0.01 ^{A)}	7.39±0.09 ^{A)}	7.30±0.30 ^{A)}

¹⁾Treatment : See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

^{3)a-d)}Means with different superscripts within a row differ significantly ($p < 0.05$).

^{4)A-D)}Means with different superscripts within a column differ significantly ($p < 0.05$).

Table 10. Color properties (*L*, *a*, and *b*) of raw tteokgalbi prepared with various kinds of salts during 15 d of storage at 5°C

storage time (d)	Treatments ¹⁾				
	C	FS	TS	GS	
<i>L</i>	0	47.79±1.43 ^{2)a3)A4)}	46.30±1.05 ^{aA)}	40.58±0.88 ^{bNS)}	50.60±1.33 ^{aA)}
	5	43.22±0.31 ^{NS5)AB)}	43.86±1.59 ^{AB)}	41.94±0.63	41.72±1.09 ^{B)}
	10	43.37±0.55 ^{NSAB)}	41.72±1.05 ^{AB)}	42.24±1.07	42.06±1.92 ^{B)}
	15	42.07±0.74 ^{NSB)}	40.84±0.41 ^{B)}	43.73±1.14	42.84±1.56 ^{B)}
<i>a</i>	0	12.03±0.78 ^{NS)}	10.45±0.58 ^{NS)}	12.04±1.09 ^{NS)}	10.16±0.90 ^{NS)}
	5	11.31±0.41 ^{NS)}	11.87±0.23	11.08±0.85	10.43±0.68
	10	11.51±0.23 ^{NS)}	10.53±0.06	10.86±0.29	10.43±0.34
	15	10.50±0.28 ^{NS)}	11.65±0.14	9.39±1.16	10.05±0.61
<i>b</i>	0	17.23±0.25 ^{aA)}	17.19±0.21 ^{aA)}	15.08±0.60 ^{bNS)}	18.30±0.22 ^{aA)}
	5	15.00±0.07 ^{NSB)}	15.24±0.87 ^{A)}	13.88±0.33	14.70±0.59 ^{B)}
	10	15.46±0.22 ^{NSB)}	15.61±0.80 ^{A)}	14.42±0.40	13.94±1.32 ^{B)}
	15	11.75±0.35 ^{NSC)}	12.87±0.43 ^{B)}	13.93±1.55	13.76±0.83 ^{B)}

¹⁾Treatment: See the Table 1 legend.

²⁾All values are expressed as mean±SEM of triplicate determinations.

^{3)a-d)}Means with different superscripts within a row differ significantly ($p < 0.05$).

^{4)A-D)}Means with different superscripts within a column differ significantly ($p < 0.05$).

^{5)NS:} Not significant.

ness value due to treatment did not change with the addition of different salts. Cheng *et al.* (2007) reported that raw pork patties showed lower yellowness or redness when higher lipid oxidation happened. Lipid oxidation contributes to the deterioration of redness (Faustman *et al.*, 2010). In this study, the addition of purified salt (C) of sample had slightly higher TBA value compared to tteokgalbi added with TS and GS. However, *a* value of tteokgalbi did not significantly change among the treatments. Badr (2007) reported that the addition of salt slowed down the accumulation of metmyoglobin in raw beef patties.

Conclusion

The purpose of this study was to compare the quality and characteristics of tteokgalbi added with different types of salt during refrigerated storage. Taken together, our results suggest that the type of salt used in tteokgalbi affects the quality and preservability of the meat products. In particular, lipid oxidation in tteokgalbi added with Topan solar salt and Guérande solar salt was effectively inhibited. Tteokgalbi added with Topan solar salt scored highly in sensory attributes, demonstrating an outstanding quality that is as competitive as that of French guérande solar salt.

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